Vetenskapsrådet

THE SWEDISH RESEARCH COUNCIL'S GUIDE TO INFRASTRUCTURES 2012

VETENSKAPSRÅDETS RAPPORTSERIE 3:2012

THE SWEDISH RESEARCH COUNCIL'S GUIDE TO INFRASTRUCTURES 2012

Recommendations on long-term research infrastructures by the research councils and VINNOVA

THE SWEDISH RESEARCH COUNCIL'S GUIDE TO INFRASTRUCTURES 2012

This report can be ordered at www.vr.se

VETENSKAPSRÅDET
Swedish Research Council
Box 1035
101 38 Stockholm
Sweden

ISSN 1651-7350
ISBN 978-91-73072-203-8

Cover Photo: SXC
Graphic Design: Erik Hagbard Couchér, Swedish Research Council
Printed By: CM-Gruppen AB, Bromma, Sweden 2012
Translation: Ron Gustafson, MedText International AB, Hörby, Sweden

FOREWORD

The primary mission of the Council for Research Infrastructures (RFI) of the Swedish Research Council is to support the formation and utilisation of infrastructures that serve the national interest and promote Swedish research of the highest scientific quality in all subject areas. The Board of the Swedish Research Council established RFI in 2005 (initially referred to by the acronym KFI).

An important aspect of RFI's work is to collaborate with other research financers to develop a long-term strategic plan to give Swedish researchers in the academic, public, and industrial sectors access to the most qualified research infrastructures in Sweden and other countries. The Guide addresses proposals for new infrastructures that have reached a level of scientific, technical, and organisational maturity that it is time to decide whether or not they can be implemented. Furthermore, it recommends new infrastructure projects or areas where Swedish research could benefit substantially from greater national and/or international coordination. The Guide also presents an overview of the infrastructures currently financed by the Swedish Research Council. The recommendations do not represent commitments for new initiatives; decisions on new infrastructures are made following calls for proposals and expert evaluation in a competitive process.

The Swedish Research Council's Guide to Infrastructures serves as a roadmap for FAS, Formas, VINNOVA, and the Swedish Research Council regarding Sweden's long-term need for national and international research infrastructures. The first edition was published in 2006, and an updated version was released at the end of 2007. This is the third edition of the Guide, produced by the Council for Research Infrastructures and its evaluation panels through extensive consultation with the scientific councils of the Swedish Research Council, other research funding bodies, universities and institutions of higher education, and other research groups.

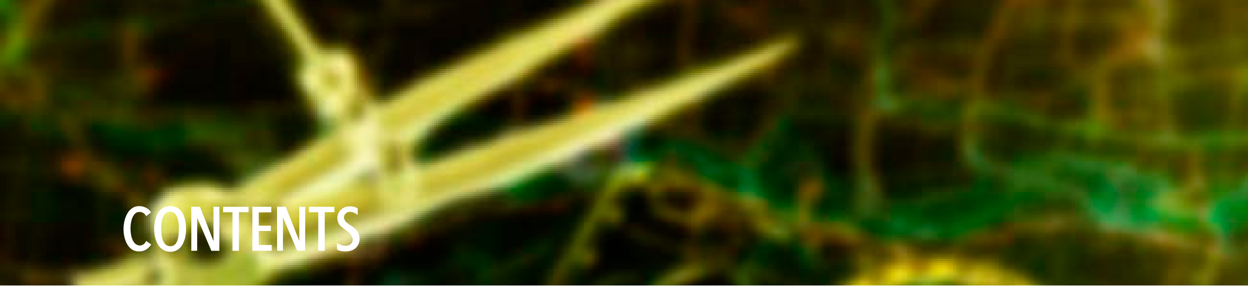
The third edition incorporates government directives, previous infrastructure decisions by Swedish Research Council, and recommendations from investigations and assessments. The European Roadmap for Research Infrastructures from the European Strategy Forum on Research Infrastructures (ESFRI) has also provided an important basis for the positions taken in this guide.

The Guide emphasises the importance of viewing research infrastructures as an integrated component of the research system, where the infrastructures collaborate with research, education, technical advancements, and innovation. Given the growing importance of research infrastructures in all research areas in Sweden and internationally, and also because of their often large-scale and long-term character, the needs for defined assessment and prioritisation processes are also discussed.

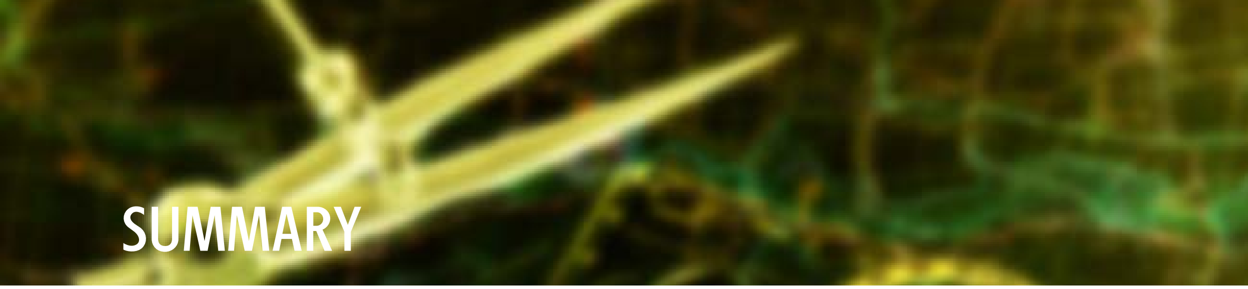
The Swedish Research Council's Guide to Infrastructures serves as part of the background information that the Swedish Research Council is submitting to the Swedish Government prior to the next Government Bill on Research Policy.

Juni Palmgren
Secretary General
Council for Research Infrastructures

Kerstin Eliasson
Chair
Council for Research Infrastructures



CONTENTS



SUMMARY

The term *research infrastructure* refers to central or distributed research facilities, databases or large-scale computing, analysis and modelling resources. These resources often fully determine the opportunities to conduct cutting-edge research in most areas, and as they become ever more extensive and costly, it is necessary to develop infrastructures jointly in large cooperative ventures, regionally, nationally and internationally.

The Swedish Research Council is tasked with financing the national research infrastructures, and Swedish cooperation in international infrastructures, whilst the universities are responsible for local infrastructure and equipment. Common features of national infrastructures are that they require an independent board and open access to researchers in the field.

In order to enhance Swedish research long-term, the Swedish Research Council recommends the following:

- Sweden should participate in *international infrastructures that are of greatest value to Swedish research:* the biobank infrastructure BBMRI.eu, the Council of European Social Science Data Archives (CESSDA) the European Social Survey (ESS), bioinformatics infrastructure ELIXIR, the next generation telescope (ELT), the Integrated Carbon Observation System (ICOS) measuring greenhouse gases, the integrated structural biology infrastructure (INSTRUCT), the Lifewatch biodiversity infrastructure, and the Survey of Health, Ageing and Retirement in Europe (SHARE), as well as offering Sweden as a host country for facilities such as the European Spallation Source (ESS) and the EISCAT-3D radar facility.
- Sweden should be a driving force behind the *development of e-infrastructure* (i.e. tools for electronic communication, storage, process and visualization of research data that is key for almost all research).
- Sweden should be a driving force behind the *co-ordination of infrastructure and data in the area of climate and the environment* for cutting-edge research in fields such as marine environment, ecology, and studies of cycles in the atmosphere and the seas on issues such as the exchange of greenhouse gases and development of environmental engineering.
- Sweden should *develop and co-ordinate biomedical infrastructures* by developing existing national infrastructures, constructing new ones, and promoting co-ordination and data integration between them.

- Sweden should take advantage of the opportunities that *MAX IV and ESS* are opening for cutting-edge research in materials science, structural biology, other life sciences, and energy and environmental research.
- Sweden should take advantage of its position in *research involving personal registers* for studies of urgent issues regarding the correlation between social conditions, economics, health and education, as well as the molecular and lifestyle mechanisms behind common diseases in our population.
- Sweden should take advantage of the opportunities offered by research infrastructures for *cooperation between the private and public sectors* in connection with the construction and use of research infrastructure.

Along with the new investments corresponding to the above recommendations, Swedish investments in research infrastructures must be co-ordinated in order to achieve efficiency in management and utilization. The processes for monitoring, evaluation and prioritization should be improved for both existing and new infrastructures.

Preparations are in progress for a powerful pan-European neutron source, the European Spallation Source (ESS) planned for construction in Lund. The decision to start construction is expected in 2013. Research fields and industries that will be able to utilise ESS include material- and nanotechnology, chemistry, molecular biology, biomedicine, pharmaceuticals, energy technology, and information technology. The Öresund region, with the MAX IV facility and the XFEL and Petra III facilities in northern Germany, has a strong potential to develop into a world-class centre for research in materials science, structural biology, and life sciences.

PHOTO: ESS

SAMMANFATTNING

Med forskningsinfrastruktur menas till exempel centrala eller distribuerade forskningsanläggningar, databaser eller storskaliga beräknings-, analys och modelleringsresurser. Dessa resurser är många gånger helt avgörande för möjligheten att bedriva högklassig forskning inom de flesta områden och i takt med att de blir allt mer omfattande och kostnadskrävande är det nödvändigt att utveckla infrastrukturerna gemensamt i större samarbeten regionalt, nationellt eller internationellt.

Vetenskapsrådet har i uppdrag att finansiera nationell forskningsinfrastruktur och Sveriges medverkan i internationell infrastruktur medan universiteten har ett ansvar för lokal infrastruktur och utrustning. Gemensamt för de nationella infrastrukturerna är bland annat att de ska ha en oberoende styrelse och vara öppet tillgängliga för forskare inom området.

För att stärka svensk forskning på lång sikt rekommenderar Vetenskapsrådet att:

- Sverige bör delta i *internationella infrastrukturer av stort värde för svensk forskning*; biobanksinfrastrukturen BBMRI.eu, dataarkivet för socialvetenskap CESSDA, socialundersökningen ESS, bioinformatikinfrastrukturen ELIXIR, nästa generations jätteteleskop ELT, infrastrukturen för växthusgasmätningar ICOS, strukturbiologiinfrastrukturen INSTRUCT, biodiversitetsinfrastrukturen Lifewatch och undersökningen om hälsa, åldrande och pensionering SHARE, och i några fall även positionera sig som värdland, i nuläget gäller det spallationskällan ESS och radaranläggningen EISCAT-3D.
- Sverige bör driva *utvecklingen av e-infrastruktur*, d.v.s. verktyg för elektronisk kommunikation, lagring, bearbetning och visualisering av forskningsdata som är centrala för de flesta forskningsområden.
- Sverige bör driva *samordning av infrastruktur och data inom klimat- och miljöområdet* för framstående forskning inom bl.a. marin miljö, ekologi och studier av förlopp i atmosfär och hav som t.ex. utbytet av växthusgaser och utveckling av miljöteknik.
- Sverige bör *utveckla och samordna biomedicinska teknikplattformar* i form av utveckling av befintliga och uppbyggnad av nya nationella infrastrukturer, och samordning och dataintegrering mellan infrastrukturerna.
- Sverige bör värna om de möjligheter *MAX IV och ESS* öppnar för toppforskning inom materialvetenskap, strukturbiologi, övriga livsvetenskaper och energi- och miljöforskning.

- Sverige bör utnyttja sin position inom *personnummerbaserad registerforskning* för studier av angelägna frågor kring sambandet mellan samhällsförhållanden, ekonomi, hälsa och utbildning samt molekylära och livsstilsmekanismer bakom våra vanliga folksjukdomar.
- Sverige bör utnyttja de möjligheter forskningsinfrastrukturer erbjuder till *samverkan med näringsliv och samhälle* i samband med konstruktion och användning av forskningsinfrastruktur.

Vid sidan av de nysatsningar som ingår i rekommendationerna behöver svenska investeringar i forskningsinfrastruktur samordnas för att uppnå effektivitet i styrning och nyttjande. Processerna för uppföljning, utvärdering och prioritering bör utvecklas för befintliga och nya infrastrukturer.

Nya behov per område under en fyraårsperiod (uppskattning Mkr)

Samhällsvetenskap och humaniora	101
Miljövetenskaper – planeten jorden	228*
Biologi och medicin	298
Materialvetenskap	240**
Fysik- och teknikvetenskaper	110
e-vetenskap	230
Summa	**1207**
Summa per år 2012–2015	302

* *Exkl ev. svenskt värdskap för kolportal och biodiversitetsportal för ICOS respektive Lifewatch.*

** *Vetenskapsrådets beräknade kostnad för 3 strålrör till MAX IV*

RESEARCH INFRASTRUCTURES AS PART OF THE RESEARCH SYSTEM

Importance of research infrastructures in research and society

Prominent research is important for the advancement of society. It provides the foundation for understanding our place in the universe, the nature of matter, the development of life, and the advancement of society. It also serves as the basis for developing countless technical and medical innovations of socioeconomic interest. Greater knowledge can create better conditions for a sustainable society in terms of environment, health, and the economy.

Much of the most innovative and highest quality research takes place where the conditions are favourable, i.e. where an intellectual and creative environment offers opportunities for research careers and access to the most advanced methods, the best equipment, and relevant expertise. When these environments, e.g. near leading research infrastructures, generate ideas and create conditions for growth, then innovative companies also find it attractive to establish themselves in close proximity. Often a win-win situation arises where the research, business and public sectors reinforce each other and help turn new ideas into reality.

The term *research infrastructures* encompasses, e.g. centralised or distributed research facilities, databases, or large-scale computing resources.

Global challenges

In recent years, major political focus has been placed on the global challenges facing the world and the potential of the research community to address them. This perspective became clear during Sweden's EU chairmanship and the conference New Worlds – New Solutions that resulted in the *Lund Declaration* [1] and the report, *A Vision For Strengthening World-class Research Infrastructures in the ERA* [2] from the EU Commission's expert panel on infrastructures. During the conference, *Global challenges – regional opportuni-*

---

1 http://www.se2009.eu/polopoly_fs/1.8460!menu/standard/file/lund_declaration_final_version_9_july.pdf

2 http://ec.europa.eu/research/infrastructures/pdf/era_100216.pdf

ties. How can research infrastructure and e-Science support Nordic competitiveness, arranged in Stockholm during Sweden's chairmanship of the Nordic Council of Ministers in 2008, climate-environment and welfare-health were highlighted as areas of strength where Nordic research has a strong potential to contribute greater knowledge.

Although the challenges differ in their formulation, they all relate in some way to the consequences of climate change, future energy supply, health, and the challenges associated with the world's aging population. Often mentioned in parallel with these political and socioeconomic issues is also the importance of studying great questions that capture our curiosity, e.g. regarding the largest and the smallest entities in sub-atomic physics and astronomy or questions about the nature of life.

Although most people agree that high-quality research infrastructures are necessary to meet these global challenges and questions, it is less apparent how to best pursue this and which infrastructures are of greatest interest. Major research breakthroughs often occur in contexts other than those expected, and therefore the need for curiosity-driven research should be the primary motive for developing new infrastructures. Curiosity-driven basic research is not in conflict with targeted or innovation-driven research or industrial development. New infrastructures should be developed to enable new ideas and create access to cutting-edge technology.

High-quality research infrastructures are often essential to address global challenges and issues. Since research breakthroughs often occur in contexts far from those expected, the need for curiosity-driven research should be the primary motive in developing new infrastructures.

PHOTO: SCANPIX

Significance for business sector, community development, and economic growth

Swedish industry can be engaged in building national and international research infrastructures and, when appropriate, should be given the opportunity to utilise research infrastructures for their own projects or collaborative research. Initiatives may be needed to promote the involvement of industry in procurement of research infrastructures, not least because in recent years Sweden has been among the European countries with the lowest success in participating in and winning contracts on construction of joint research infrastructures. Here, research funding bodies such as the Swedish Research Council and VINNOVA, along with universities and higher education institutions, play an important role.

One of the requirements that the Swedish Research Council places on national research infrastructures is that they must be open and easily accessible for researchers, industry, and others, and must have a plan for accessibility. Hence, major benefits accrue from involving industry or other community interests already during the planning of research infrastructures, e.g. to influence the development of equipment and user support and thereby enhance the utility and utilisation of the infrastructures among these parties. Some aspects of accessibility may need to be adapted.

The Swedish Research Council intends to join with VINNOVA and others to investigate the extent to which national research infrastructures can be developed to encompass and support more applied research areas, e.g. transportation, construction, manufacturing, or biotechnology.

Mobility and careers

World-class infrastructures contribute to researcher mobility since they attract researchers from many nations and may be the single most important factor in researchers' decisions to locate all or part of their research in other countries.

When researchers become involved in building joint national and international infrastructures this is important for the research community at large. However, a structural problem is that researchers who are involved for long periods in building or operating research infrastructures are at risk of falling behind in their academic career. The same applies to researchers involved in industry for a period and then want to return to the academic community and to researchers who spend much of their time engaged in collaboration or communication. It is essential to raise the CV-related value of participating in constructing infrastructures and engaging in activities that promote research, but do not result in publications.

Development of joint international research infrastructures

Increasingly, European countries recognise that competing with the United States and emerging powers such as China and India will require collaboration on the most advanced research resources.

In 2010, the EU Commission's expert panel on research infrastructures published a report, *A Vision for Strengthening World Class Research Infrastructures in the ERA*, which reviews the role of the research infrastructures in the European research area (ERA). The panel asserts that infrastructures can play a decisive role in addressing global challenges and recommends strengthening ERA by increasing collaboration within and outside of Europe.

The European Strategy Forum on Research Infrastructures (ESFRI) is a forum of Member States for planning and coordinating pan-European infrastructures. The European Roadmap for Research Infrastructures, produced by ESFRI, addresses common European infrastructures in social sciences and humanities, environment, energy, biology and medicine, materials science, physics and engineering sciences, and e-Infrastructure. The first roadmap was published in 2006, the second edition in 2008, and the third edition was released in May 2011. [3] The latter focuses on greater coordination and structural initiatives in organisation, priority setting, evaluation, and financing with the objective of better utilising joint resources and achieving higher quality. Concurrently, one of ESFRI's most important goals is to implement as many of the roadmap's recommended infrastructures as possible. The infrastructure projects presented in the roadmap have been assessed and found to be of high scientific value and sufficiently mature to be built. Implementation of these infrastructures is then subject to bilateral and multilateral negotiations among the Member States.

ESFRI's roadmap and the implementation of the proposed infrastructures have generated, and will continue to generate, major structural changes in European research. Parallel with the joint European report, most countries have published their own roadmaps for research infrastructures.

ERIC – Legal framework for European infrastructures

The European Research Infrastructure Consortium (ERIC) is an initiative by the EU Commission to facilitate the construction of joint European infrastructures. The framework regulates, e.g. financing, taxes, and procure-

3 http://ec.europa.eu/research/infrastructures/index_en.cfm?pg=esfri-roadmap

ment to assist participating countries and the researchers working in the infrastructures. The principles for ERIC were established in August 2009, and in 2011 the statutes were endorsed for the first infrastructure to apply the framework (Survey for studies of health, ageing, and retirement, SHARE). Several of the European infrastructures under construction aim to implement ERIC.

The International Thermonuclear Experimental Reactor (ITER) in France will be the bridge between today's studies in plasma physics at research facilities and tomorrow's energy-producing fusion power stations. The facility is estimated to become operational in 2016. Sweden contributes to the construction of ITER mainly through the EU Framework Programme, Euratom.

PHOTO: ITER

Global infrastructures

European countries also participate in building and operating global research infrastructures, e.g. the ITER fusion reactor under construction in France, the planned Square Kilometre Array (SKA) radiotelescope, and the next generation of linear colliders in particle physics. The globalisation aspect is noticeable in part because infrastructures that were previously a European concern have become so expensive and specialised that global collaboration offers the only possibility for engaging in pioneering research. Hence, CERN's particle accelerator LHC, ESO's radiotelescope ALMA, and the planned E-ELT giant telescope have attracted participant countries from around the world. This trend will probably become stronger as infrastructures become large scale and require development through global collaboration. There will be a need, as found in Sweden and Europe, to review regulations and legislation so they do not hinder research, but do not forego safety and integrity – not least with regard to infrastructures that handle personal data. Another trend towards global infrastructure collaboration involves more of a business approach, i.e. scientists turn to entities that can provide what they need quickly, cheaply, and with high quality. This is becoming noticeable, e.g. in molecular sequencing where large-scale equipment is constructed in China.

Swedish participation in international research infrastructures

For a relatively small country like Sweden, participating in international infrastructure projects is necessary to give Swedish scientists access to the most advanced research tools. Establishment of national or Nordic nodes is often a good way to channel participation into broader European collaboration. In addition to national nodes, local resources at universities are necessary to build knowledge by developing technology and methods that can be used in national and international infrastructures. Several of the proposed infrastructures in the ESFRI roadmap affect research areas where Sweden currently holds a leading position. In addition to the two European infrastructures proposed for construction in Sweden, i.e. ESS and EISCAT-3D, several of the recently allocated national infrastructures are expected to serve as Swedish nodes in the formation of their European counterparts.

In some cases it is important for Sweden to position itself as the host nation since high-end infrastructures serve as magnets for researchers, attracting expertise to our country. In turn, this has positive effects by stimulating the quality of research within the country. It also has other positive long-term effects for society because of the inflow of new expertise and new ideas. For instance, the construction of a large research facility such as ESS in Lund can potentially generate socioeconomic gains for Sweden and the Öresund region in terms of, e.g. business sector development, innovation-related opportunities, and tax revenues. [4]

Swedish participation in European infrastructures

As a result of processes to clarify Swedish researchers' interest in European infrastructures from the ESFRI roadmap, several research groups serve as Swedish partners in planning joint European infrastructures. To set priorities among new proposals, Sweden uses a process whereby representatives of the different ESFRI groups are encouraged to submit applications for Swedish participation in the various European infrastructures. Hence, the Swedish Research Council's decisions are reached in a competitive context and based mainly on scientific quality, national interest, and relevance for Swedish

[4] Neutrons and Innovations, Copenhagen Business School, and Locating ESS in Lund, ITPS

research. Other aspects such as industrial interests and the procurement of expertise, as well as investment and operational costs, may also be considered in setting priorities.

Status of Swedish participation in ESFRI projects from 2006, 2008, and 2010 roadmaps:
Infrastructures under construction where Sweden participates as a Member State (after bilateral negotiations):

- FAIR, nuclear physics facility (2006)
- PRACE, high-performance computer system (2006)
- XFEL, x-ray free electron laser (2006)

Swedish researchers participate in the planning of the following infrastructures following notification of interest to the Swedish Research Council:

- ANAEE, infrastructure for experimental ecology (2010)
- BBMRI, biobank infrastructure (2006)
- CESSDA, infrastructure for data in social sciences (2006)
- CLARIN, language technology infrastructure (2006)
- CTA, Cherenkov telescope (2008)
- EATRIS, infrastructure for translational research (2006)
- EISCAT-3D, radar system (2008)
- ELIXIR, bioinformatics infrastructure (2006)
- EMBRC, marine biology resource centre (2008)
- EMSO, deep-sea-based observation system (2006)
- EPOS, observation system for tectonic plates (2008)
- ERINHA, previously BSL4, high-security laboratories (2008)
- ESS, European social survey (2006)
- ESS, spallation source (2006)
- Euro-Bioimaging, bioimaging network (2008)
- EURO-FEL, network for infrared to soft x-ray free-electron lasers (previously IRUVX-FEL) (2006)
- EU-openscreen, open screening platforms in chemical biology (2008)
- ICOS, observation system for measuring carbon dioxide exchange (2006)
- INFRAFRONTIER, phenotyping facility (2006)
- ISBE, system biology infrastructure (2010)
- LifeWatch, biodiversity infrastructure (2006)
- MYRRHA, research reactor (2010)
- SIOS, Svalbard observatory (2008)

In addition to the list above, Swedish researchers participate in planning infrastructures that are operated within the framework of organisations where Sweden is already a member, e.g. the planned E-ELT (ESO) giant telescope, the SKA (Onsala) radioastronomy infrastructure, and the TIARA (CERN) accelerator infrastructure.

Financing of joint European infrastructures

Planning grants from EU's seventh framework programme have financed the preparatory work for most of the new pan-European infrastructures, ranging from design studies to producing documents for multilateral contracts. Given the EU Commission's nearly non-existent budget for construction of new infrastructures, financing must come from the Member States. For the infrastructures to be joint in the true sense of the word, however, European funds should be earmarked for the construction and operation of the infrastructures with the highest priority according to the ESFRI roadmap, either through the eighth framework programme, Horizon 20/20, loans financed through the European Investment Bank (EIB), or via structural funding sources. Otherwise, imbalance could easily arise between large and small countries, and the largest countries might have disproportionately strong influence on design and priorities and possibly even on access to the infrastructure.

Collaboration among Baltic countries, including Scandinavia

Collaboration with neighbouring countries (e.g. Nordic, Baltic, and other countries in the Baltic area) could yield substantial benefits regarding the establishment of infrastructures in the region and for becoming a stronger partner in international projects. To date, this type of collaboration has taken place mainly within the Nordic countries. There are several examples of successful collaboration in research infrastructures, including the Nordsync consortium for participation in the European Synchrotron Radiation Facility (ESRF), the Nordic Data Grid Facility (NDGF), and the EISCAT radar facility.

Future Nordic collaboration may involve continued cooperation within the framework of larger international infrastructures in the Nordic countries and possibly infrastructures for special Nordic research needs or areas of strength in research, e.g. climate, energy, health, welfare, and e-Science.

A clear trend can be seen in e-Infrastructures, where the Nordic countries are jointly strengthening their role in Europe through collaboration, e.g. in the European Grid Initiative (EGI) and the PRACE computing infrastructure (see section on e-Science). In parallel with Nordforsk, the Nordic Council of Ministers is promoting a Nordic globalisation initiative in e-Science that is expected to utilise and promote further development of Nordic e-Infrastructures. [5] Nordforsk also promotes coordination of Nordic biobank infrastructures, e.g. to strengthen their position in Europe and facilitate coordination of registry data.

5 http://www.nordforsk.org/no/programs/programmer/escience-globaliseringsinitiativ

Collaboration is under way in the Baltic region through the Baltic Science Link, where the Swedish Government has assigned the Swedish Research Council to build a network between universities, research institutes, and the business sector in the region. The goal is to strengthen the area's scientific capacity and attractiveness through collaboration in research, expertise development, and infrastructures, mainly in materials science and life sciences. The objective is one of the Government's ambitions in a comprehensive Baltic strategy.

Development of research infrastructures in Sweden

In recent years, researchers' needs for large-scale infrastructures have increased considerably, and the growing scope and cost of infrastructures has consequently increased the need for national coordination. In its bill on research and innovation in 2008, the Government focuses on the importance of research infrastructures, earmarking large sums for investing in infrastructures. The government bill specifically gives the Swedish Research Council the responsibility for national coordination, whilst mandating that the Committee for Research Infrastructures should become permanent and serve as an advisory body for research infrastructures.

Before the Committee for Research Infrastructures (KFI) was formed in 2005, the Swedish Research Council financed infrastructures primarily through membership in several international organisations, operation of a few national facilities, and calls for funding proposals for expensive research equipment and longitudinal databases. However, the focus has gradually shifted towards infrastructures of national interest, grants for operation and planning have been added, and in 2009 the Council issued its first call for grant applications to build and operate new national research infrastructures. Eleven new infrastructures were allocated funding and are under construction at the respective host universities and other participating universities. These include infrastructures for biobanks, biodiversity, bioinformatics, biological imaging, DNA sequencing, high-performance computing, chemical biology, carbon dioxide measurement, clean rooms, a neutron reflectometer, and the MAX IV synchrotron radiation facility. Several of the new infrastructures were developed as part of the strategic research initiatives in the latest government bill on research and innovation. Characteristics that these new infrastructures have in common include: they are intended to promote world-class research, they are openly accessible to researchers nationally, and they have independent boards. The infrastructures are evaluated every 3 to 5 years.

Swedish Research Council's responsibility for research infrastructures

In 2009, the Swedish Research Council started allocating grants only to research infrastructures that are openly accessible to Swedish researchers and have the potential for world-class research. The most recent Government Bill on Research Policy (2008) addresses the Swedish Research Council's responsibility for national infrastructures, followed by an appeal to universities to take greater responsibility for local infrastructures and equipment. A study of investment in research equipment over a 10-year period [6] shows a sharp decline in the level of investment at universities and higher education institutions. These investments have steadily declined since the peak period of 1999-2001, whilst costs have increased for research and teaching staff. Since 2010, several universities started their own processes for prioritising and financing equipment and local infrastructures, a trend that is expected to continue.

It is also important to note that research and innovation depend on infrastructures that are administered and/or financed by agencies and organisations other than the Swedish Research Council. For instance, the Swedish Research Council does not deal with library and museum collections or resources such as university hospitals, greenhouses, and various types of animal housing, even though these are important research resources and in some cases could be classified as research infrastructures according to the Swedish Research Council's definitions. An expansion of the Swedish Research Council's sphere of responsibility is conceivable, but it must be followed by a corresponding expansion in opportunities for financing. Other alternatives, particularly concerning infrastructures used only in part for research purposes, might include greater collaboration among those involved and opportunities for research interests, including the Swedish Research Council, to influence the design or use of the infrastructures.

Other Swedish financers of research infrastructures

Research finances other than the Swedish Research Council also contribute to research infrastructures. Among state financing sources, FAS partially finances several national and international databases. Formas does not directly invest in infrastructures, but calls for proposals for research projects and moderately expensive equipment that can generate ideas and concepts. The same applies to VINNOVA's programme. VINNOVA is also contributing towards the construction of MAX IV, as are other bodies, e.g. the Swedish Research Council, Region Skåne, and the Knut and Alice Wallenberg Foundation. The Swedish

6 A study of investments in research equipment at Swedish universities and HEIs, 1997-2007.

National Space Board finances various satellite projects used in astronomy, environmental and climate monitoring, etc. The Bank of Sweden Tercentenary Foundation finances, e.g. the cataloguing, digitising, and accessibility of collections at archives and libraries and the establishment of databases within and outside of the country. Many infrastructures that are used partially or totally for research are financed by other agencies, research institutes, county councils, and within universities and higher education institutions (HEIs). Often, resources for research and other activities are jointly utilised, e.g. research at university hospitals and aspects of climate- and environment-related research.

Over the years, the Knut and Alice Wallenberg Foundation (KAW) has been the dominant financer of advanced equipment and infrastructure, but like the Swedish Research Council, it has recently given notice that the foundation will no longer finance basic equipment at universities, or give equipment grants to individual researchers. Until 2015, however, KAW intends to finance national infrastructures where a specific technology plays a decisive role in the development of a field. Other private foundations also contribute to different types of research infrastructures.

Definition of research infrastructure

The research infrastructure concept varies widely and may have different definitions in different contexts. The Swedish Research Council uses the following, which is based on ESFRI's definition:

"... tools that provide essential services to the research community for basic or applied research. They cover the entire range of scientific and technological fields, from social sciences to astronomy, genomics, or nanotechnology. They may be single-sited, distributed, or virtual. Research infrastructures comprise the necessary tools for future research of the highest quality in many areas."

The research infrastructures that receive funding from the Swedish Research Council must partially or fully meet the following general criteria. They must:

- be of broad national interest
- provide the potential for world-class research
- be used by several research groups/users with highly advanced research projects
- be so extensive that individual groups cannot manage them on their own
- have a long-term plan addressing scientific goals, financing, and utilisation
- be open and easily accessible for researchers, industry, and other actors, and have a plan for accessibility (concerning infrastructure use, access to collected data, and presentation of results)
- in relevant cases, introduce new cutting-edge technology.

Research infrastructures have different characteristics. They can be categorised in different ways, e.g. by subject area, geographical distribution (centralised or distributed), or how they function for the users. The Swedish Research Council supports infrastructures that are openly accessible to Swedish researchers and that are operated under international conventions, through other international collaboration, or by society at the national level. The Swedish Research Council does not, however, finance local infrastructures and equipment where accessibility is limited to individual researchers or research groups.

Similar infrastructures can be categorised differently depending on how they are used. For instance, a biomedical core facility used primarily by research groups at a university is categorised differently than an identical facility that is nationally accessible and where scientific priorities based on peer review determine its use.

The difference between a distributed research infrastructure and a network for collaboration may be difficult to distinguish. However, an infrastructure, in contrast to a network, always has joint management, and the nodes are part of the same overarching organisation. To create a national infrastructure from a network, it must be shown that the more consolidated form will provide added value for research, or will be more cost effective.

Evaluation criteria

In evaluating research infrastructures, scientific quality is the primary criterion. The Swedish Research Council also considers the impact on development of society (e.g. knowledge formation, internationalisation, and technical development), feasibility (e.g. costs, technology, and organisational maturity), and strategic research considerations where relevant.

Open access to infrastructures and to the data they produce is a key issue when it comes to assuring the best research quality and the best exchange of shared resources financed by public funds.

The formation of new national and European infrastructures, as a rule, requires open calls for grant applications where proposals compete based on quality review. Experience shows that development of infrastructures, and the research projects using them, benefit when the best projects take over. Commercial users that fully cover the cost of utilising infrastructures may, in relevant cases, have access based on other conditions. A certain waiting time for open accessibility to data and results, or limitations based on relevant laws and regulations, are also possible. The Swedish Research Council aims to improve the opportunities for more effective utilisation of research data from agencies and individual researchers.

Financing research infrastructures

The development of research infrastructures involves several phases, from ideas, concept development, and planning to construction and operation, to occasionally upgrading, and eventually to phasing out.

These phases have different financing needs. To assure that the long-term infrastructure needs of Swedish researchers are met, different types of support and financing are necessary. From an infrastructure perspective, relevant types of funding include:

- ***Project grants*** to generate ideas and concepts
- ***Planning grants*** for design studies and planning of construction or collaboration
- ***Grants for investing in equipment or databases*** can be used to construct national or international infrastructures or a single infrastructure that is nationally accessible
- ***Operational grants*** to operate joint research infrastructures.

The construction phase, mainly for centralised infrastructures involving facilities and instrumentation, requires major investment costs for a limited time. The cost balance between construction and operation may be the opposite for distributed infrastructures, where the greatest expense is seldom the investment cost, but rather the cost of ongoing work in standardisation, harmonisation, and quality assurance of procedures and data.

Usually infrastructures must be upgraded to maintain their competitive strength, necessitating financing of new investments. Eventually, most infrastructures will be phased out, which is associated with substantial costs for disassembling technical equipment and phasing out staff, etc. Hence, a phase-out plan should also be established prior to a decision to build an infrastructure.

In addition to providing grants for national infrastructures, the Swedish Research Council finances memberships in several international infrastructure organisations that give Swedish researchers access to facilities. Contributions can take the form of membership fees, but also in-kind grants where Swedish universities and other research institutions develop components for infrastructures or create nodes in Sweden for international infrastructures.

Long-term planning in a changing economy

The membership fees of several infrastructures linked to conventions and infrastructures that apply ERIC are tied to a country's GNP. Hence, if the Swedish economy trends upward, and the membership fees increase automatically without a corresponding increase in state funds for the Swedish

Research Council, this would necessitate a reduction in other, nonconvention-related grants. This is an inappropriate way to finance infrastructures and leads to problems in long-range budgetary planning. Therefore it would be desirable if the level of state funding for the Swedish Research Council followed the fluctuations in expenses related to international memberships, or that the Council is given the options of using credit or increasing the amount it can save for this purpose.

Grants for using infrastructures

New infrastructures involve large strategic investments that enable pioneering research. Concurrently, it may be difficult for large segments of the research community to recognise the potential of new infrastructures. A large investment in new infrastructures should therefore be combined with targeted project grants for a limited time in conjunction with operationalising the infrastructure. This can stimulate broad utilisation by research groups, increasing the profitability of the investment.

Education on the use of infrastructures is essential for effective utilisation of research infrastructures. Organising education and training linked to national infrastructures is primarily the responsibility of the host university, but also a concern for all universities with researchers that could benefit from the infrastructure. Increased coordination and exchange of experience between different types of research infrastructures can generate considerable added value.

In conjunction with the planning to build the European Spallation Source (ESS) in Lund, research collaboration contracts have been signed with Germany and France. This enables Swedish researchers to participate so they can broaden and deepen their expertise, e.g. in instrumentation development, neutron research, structural biology, materials research, climate and environmental research, and nuclear technology.

Follow-up and evaluation

To continually meet the needs for research infrastructures, it is necessary to regularly monitor current infrastructures to determine whether they serve their purpose, or if they should be upgraded or phased out in favour of other initiatives. Since 2010, the Swedish Research Council has included a stipulation in the terms and conditions for national research infrastructures that activities must be evaluated every 3 to 5 years.

ESFRI is discussing the prerequisites for and the advantages of European countries applying the same criteria in evaluating new infrastructure pro-

PHOTO: SCANPIX

Through a collaborative agreement with Germany and France, Swedish researchers have the possibility to further their expertise, e.g. in instrumentation development, neutron research, structural biology, materials research, climate and environmental research, and nuclear technology. The photo shows a tool used in Chadwick's neutron experiment, which led to the discovery of the neutron in 1932.

posals and evaluating national and joint-European infrastructures. [7] The Swedish Research Council is monitoring developments in this area.

During 2010-2011 the Nordic countries have used a NORIAnet to implement a pilot evaluation of researcher utilisation of a pan-European infrastructure for the purpose of guiding future evaluations of Nordic participation in international infrastructures. The conclusions will be presented in early 2012.

Recommendations on infrastructure projects in the near future

In addition to the new investments included in the recommendations below, the level of coordination needs to increase among research infrastructures. The goal is to achieve greater efficiency in management and utilisation. Processes for follow-up, evaluation, and prioritisation need to be developed and tested for current infrastructures and for those being constructed. As part of this work, the Swedish Research Council has, since 2010, indicated times for evaluation or follow-up as part of the terms and conditions for financing infrastructures. Swedish participation in international initiatives tied to conventions must also be reviewed. The NORIAnet collaboration within infrastructures offers a forum for Nordic discussions concerning evaluation instruments. The Swedish Research Council is also discussing the principles for evaluation, prioritisation, and financing presented in the ESFRI roadmap from 2010.

The infrastructures or actions included in the recommendations below are described in greater detail in the area and infrastructure descriptions and in Table 1.

To strengthen Swedish research in the long term, the Swedish Research Council recommends the following actions (not necessarily in the following order):

International participation

Sweden should participate in the international infrastructures of greatest value for Swedish research.

Research infrastructures comprise a key component of the European Research Area (ERA), and Sweden should participate in construction of the projects from the ESFRI roadmap that are of highest priority to Swedish research.

7 ESFRI WGR on evaluation of RIs, 2011

After the call for proposals and the prioritisation process in 2011, the Swedish Research Council emphasised the following infrastructures as being the most relevant for Swedish research and development: Biobanking and Biomolecular Resources Infrastructure (BBMRI.eu), the Council of European Social Science Data Archives (CESSDA), the European Social Survey (ESS), the European Life Science Infrastructure for Biological Information (ELIXIR), the next generation Extremely Large Telescope (ELT), the Integrated Carbon Observation System (ICOS), the Structural Biology Infrastructure (INSTRUCT), the Biodiversity Infrastructure (LifeWatch), and the Survey of Health, Ageing and Retirement in Europe (SHARE). The Swedish Research Council advocates initiating discussions as soon as possible concerning the conditions for Swedish participation in the above infrastructures and has decided on conditions and a maximum sum regarding Swedish participation. The Council for Research Infrastructures has also decided, in principle, to recommend the construction of the European Extremely Large Telescope (ELT).

In some cases, Sweden needs to position itself as the host country. Currently this applies to the European Spallation Source (ESS) and the MAX IV synchrotron in Lund and the European Incoherent Scatter Facility (EISCAT-3D) with a site in Kiruna.

Nordic collaboration often provides a good base for European collaboration and should be strengthened and developed in cases where it offers added value.

Sweden should promote the development of e-Infrastructure

Perhaps one of the most important success factors for Swedish research in all areas for the foreseeable future will be Sweden's ability to maintain and advance its leading position in e-Infrastructure and e-Science in Europe and internationally. The rapid development in technology provides new opportunities for electronic communication, storage, processing, and visualisation of research data. Construction of e-Infrastructures affects, in turn, the organisation of other infrastructures and their accessibility to researchers. Basic e-Infrastructures can be viewed as horizontal functions that are necessary for most vertical or subject-related research areas and other infrastructures, e.g. accelerators, telescopes, sensors, digitised archive data, and analytical equipment.

In Sweden, the Swedish University Computer Network (SUNET) and the Swedish National Infrastructure for Computing (SNIC) form a structure for communication, storage, processing, analysis, and modelling. Sweden has also positioned itself amongst the most powerful computing resources in Europe and in the Nordic and European grid collaboration. E-tools for research are rapidly developing and continued upgrading of Swedish e-Infrastructures will be a decisive success factor for Swedish research.

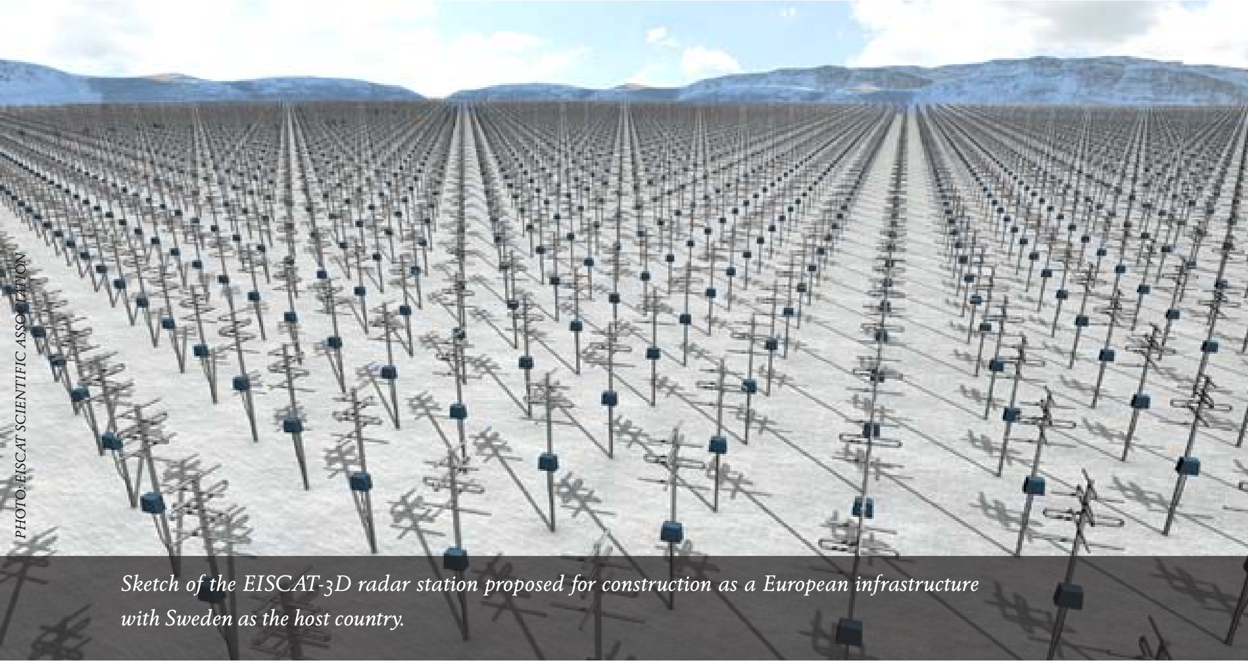


PHOTO: EISCAT SCIENTIFIC ASSOCIATION

Sketch of the EISCAT-3D radar station proposed for construction as a European infrastructure with Sweden as the host country.

To improve researcher accessibility to data for research through more efficient and secure integration of data from different sources, major challenges remain, including routines for quality assurance, documentation, and archiving. This applies to researchers' own data and to agency data primarily collected for administrative purposes. General solutions for federated database systems and principles for data integration – including procedures for authentication and authorisation – need to be developed in several areas.

With the work of the European e-Infrastructure group (eIRG) and the strategic investment in e-Science by the Swedish government, a wider mission has become apparent where e-Infrastructures clearly need to be integrated with scientific, discipline-specific solutions. In several cases, the focus needs to be shifted from physical resources to advanced, long-term user support.

Sweden should promote coordination of infrastructure and data in the climate and environmental arena

The on-going changes in climate place a focus on research concerning planet earth. Sweden has prominent research in areas such as marine environment, ecology, and studies of processes in the atmosphere and oceans, e.g. exchange of greenhouse gases and development of environmental technology. What distinguishes this research is that it usually requires long observation series at multiple sites, often through international collaboration.

This requires coordinated infrastructures for measurement and data management. A current example would be ICOS, an ESFRI project to measure greenhouse gas, and LifeWatch for data on biodiversity where the Swedish

The Swedish Research Council is the main financer of LifeWatch, a national electronic infrastructure that will make biodiversity data searchable and more accessible for research and environmental monitoring. LifeWatch is part of a European vision to link research resources across Europe.

PHOTO: SVENSKA LIFEWATCH

Research Council finances Swedish infrastructures, and will start negotiations in 2012 for Swedish participation in the construction of the European counterparts. The Swedish Research Council intends to join with other actors to prioritise long-term financing for construction of e-Infrastructures for climate and environmental research, and views Sweden as a forerunner in international coordination of measurements and data management. Furthermore, specialised equipment is needed to collect and analyse samples of different types, e.g. drilling cores that reflect the earth's development. In land-based and marine research there is great potential to improve quality through efficiency and national coordination of research stations that provide an important base for much of the research in this area. Development in this area should be coordinated with FORMAS and possibly VINNOVA.

Sweden should develop and coordinate biomedical technology platforms

The Swedish Research Council finances national infrastructures for biobanks, bioinformatics, large-scale sequencing, bioimaging, and chemical biology. Continued development of national technology platforms is a prerequisite for Swedish biomedical research. Coordination and data integration are needed among existing platforms, and collaboration needs to be developed with their Nordic, European, and international counterparts. Here, there should be ongoing collaboration to achieve maximum synergy effects along with, e.g. the Government's strategic initiative in the molecular biology laboratory, Science for Life Laboratory (SciLifeLab). The Council for Research Infrastructures has initiated a study on the organisation of facilities for mouse phenotyping and foresees major opportunities for coordination in a national infrastructure. A national facility for determining protein structures is essential, as is expanded instrumentation for biological imaging and the development of technical platforms for proteomics, metabolomics, and systems biology.

Sweden as a magnet

Sweden should utilise the opportunities for world-class research presented by MAX IV and ESS

The investments in the most advanced facilities of their type for synchrotron radiation, neutron scattering, and free electron lasers in Sweden and northern Germany present new research opportunities, with Sweden in a central position. The facilities in Lund, i.e. MAX IV for synchrotron radiation and ESS for neutron scattering, and the free electron laser XFEL and

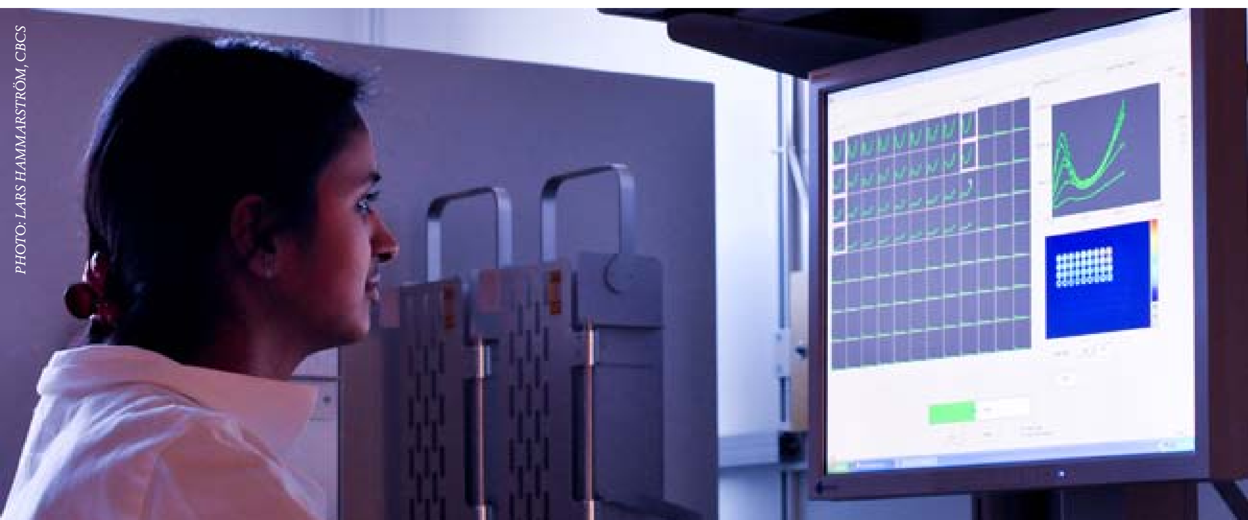


PHOTO: LARS HAMMARSTRÖM, CBCS

The Swedish Research Council finances national infrastructures for biobanks, bioinformatics, large-scale sequencing, bioimaging, and chemical biology. Continued development of national technical platforms is a prerequisite for Swedish biomedical research.

the Petra III synchrotron in Hamburg, form a framework for a world-class centre for broad research activities in materials science, structural biology, and other life sciences.

Financing of the accelerator and the first set of beamlines for the synchrotron radiation facility MAX IV is assured, but further expansion of MAX IV is needed in coming years to take full advantage of the facility's potential. The Council for Research Infrastructures emphasises the importance of establishing new collaboration in, e.g. the Baltic region, to attract the best researchers, broaden the financial base, and contribute towards technical development.

The construction of ESS is expected to give Swedish research new opportunities. The large added value that ESS is expected to give Sweden includes regional growth, business sector development, and other socioeconomic benefits. Hence, it is important not to burden other research with the increased costs associated with building the facility in Sweden.

It is essential to take a comprehensive approach with calls for targeted grant applications for research, doctoral programmes, and industrial collaboration to achieve the greatest possible long-term effects in the areas that can use the MAX IV, ESS, and free electron lasers. These areas include materials science, structural biology, other life sciences, and energy and environmental research. Expansion of collaboration with Swedish industry also requires coordination with VINNOVA.

Sweden should pursue registry research based on its system of personal ID numbers

Sweden's administrative registers, e.g. at Statistics Sweden and the National Board of Health and Welfare, constitute a resource for the research community that is unparalleled outside of Scandinavia. Registries covering the entire population and the system of personal identification numbers give Sweden unique resources for studying several important issues involving associations between social conditions, the economy, health, and education. Although the Swedish registers and databases are underutilised in research, their value has contributed to Sweden's leading international position in certain aspects of social sciences, public health, and epidemiology.

By connecting the registers to large-scale molecular technology and standardised clinical and population-based biobanks and associated information, new opportunities arise to study the molecular and lifestyle mechanisms behind our most common public health diseases. Such a structure also enables Sweden to contribute to translational research by transferring the findings from basic research into developing new tools for early diagnostics, prevention, and individualised treatment. The Swedish Research Council recognises the great benefits of coordination through national, Nordic, or European infrastructures that promote opportunities to utilise databases and registers for research.

PHOTO: MAX IV

Sketch of the next generation synchrotron radiation source, MAX IV, currently under construction near the MAX-lab national laboratory in Lund. The facility will include over 20 large instruments (beamlines) for measurements based on different methods and will enable studies of very small specimens within a broad field, e.g. nanostructured material or smaller protein crystals than heretofore possible.

By guaranteeing the longevity of the most valuable databases, and by avoiding duplication through greater coordination of publicly financed survey databases and longitudinal databases in social sciences and medicine, major opportunities exist for greater clarity and, over time, lower costs. The Swedish Research Council has initiated a study on this in collaboration with FAS and the Bank of Sweden Tercentenary Foundation.

Further initiatives are needed for: coordination of agencies; development of legal, technical, and organisational conditions; routines for documentation, accessibility, and standardisation; and efficient and secure routines for linking data from different sources. Coordinated technical solutions need to be developed within the framework of e-Science.

Technical development and collaboration with the business sector and society

Sweden should utilise the opportunities for collaboration offered by research infrastructures

Sweden has fallen behind other comparable European nations in securing industrial contracts associated with procuring technology or innovations via infrastructure initiatives. It is essential for Sweden to develop a strategy to better utilise the opportunities that construction and research infrastructures offer Swedish industry. An initiative to strengthen this over time is being started in 2012 as a pilot project where Swedish engineering students will be offered the opportunity to work on their degree at CERN. Examples of areas where Sweden has the possibility to strengthen its position regarding research and technological development are in accelerator and antenna development and more generally in components and instruments for large research facilities and distributed facilities.

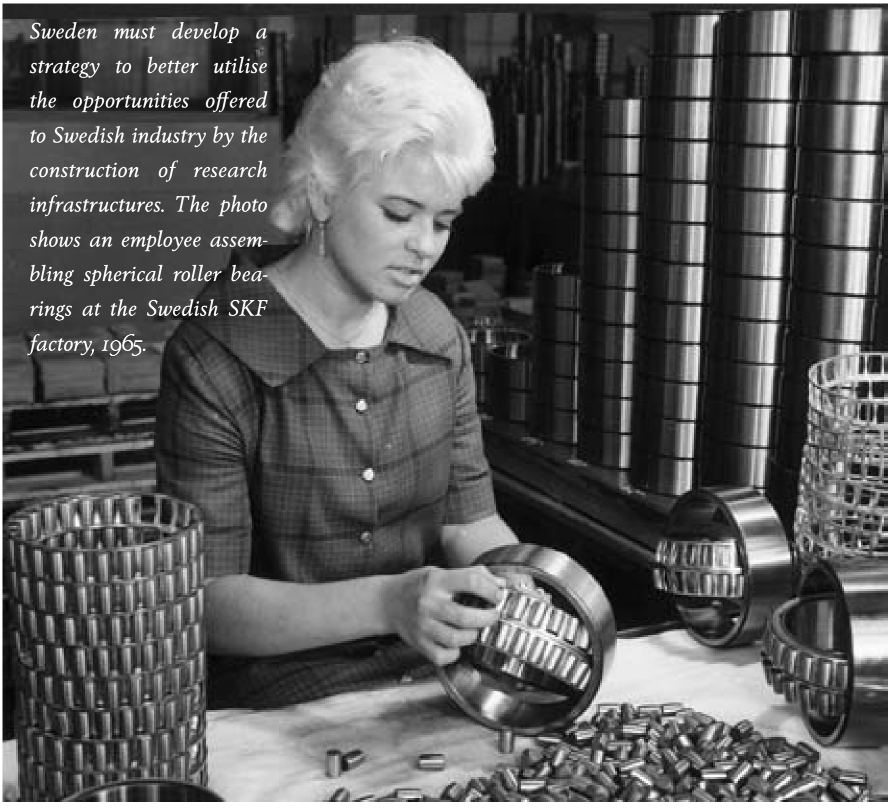
Scientific motivation must drive the development of infrastructures, but collaboration with the business and public sectors both in development projects and as infrastructure users is important for Swedish research and the development of society. A national action plan for industrial collaboration should be developed in relation to on-going EU initiatives that are a continuation of the ERAnet project (ERID-watch). [8] To a large extent, Sweden's welfare depends on innovative and research-initiated industries such as pharmaceuticals, metal, forestry, and electronics. Even small and mid-sized knowledge-based companies benefit from access to advanced infrastructures. Investing in research infrastructures is essential for continuing this positive trend. Broadening the collaboration with the business sector requires coordination with VINNOVA. Social advancement also encompasses the need for increased knowledge as a base for development of the welfare

Sweden should utilise its potential for register research based on personal ID numbers to study important questions concerning the associations between social conditions, economics, health and education, and molecular and lifestyle mechanisms behind our most common public health diseases.

PHOTO: SCANPIX

8 http://www.eridwatch.eu/

sector, and research infrastructures supporting research in social sciences, humanities, medicine, and health contribute new knowledge about the human condition in a changing society.



Sweden must develop a strategy to better utilise the opportunities offered to Swedish industry by the construction of research infrastructures. The photo shows an employee assembling spherical roller bearings at the Swedish SKF factory, 1965.

PHOTO: PRESSENS BILD, SCANPIX

Tables

Table 1 presents several new infrastructure initiatives or actions judged to be of major national interest. In addition to recommendations for investment or operation, these actions could include studies or increased coordination deemed to provide added value to research and/or improve joint utilisation of shared resources. Table 2 presents infrastructure initiatives deemed to have potential for future research, but where the uncertainty factor is relatively high and more detailed review is needed. Table 3 presents existing infrastructures that receive grants from the Swedish Research Council. Those that were recently decided, or are under construction, are assumed to have new or greater needs during the upcoming 4-year period.

The tables do *not* indicate any commitment by the Swedish Research Council to finance the new infrastructures mentioned. Decisions on financing are preceded by calls for proposals, evaluation, and prioritisation.

The infrastructure projects shown in the tables have been grouped into larger areas to provide a better overview. Note that many of the infrastructures are used in several different research areas, e.g. the computing, analytical, and modelling resources presented under e-Science are used in all areas. Registers and personal databases and the Swedish National Data Service (SND) are used in social sciences and medicine. Synchrotron and neutron facilities, in addition to being used in materials science, are of use in medicine, life sciences, and other areas.

The infrastructure projects are described both in the area overviews where they are placed in context, and in the section on infrastructure descriptions where the respective infrastructures are described in greater detail.

Need for new funds for investments and operation

Table 1 presents the proposed new joint research infrastructures viewed to be most important for assuring the highest quality of Swedish research. The table presents the estimated total cost of construction and operation of the respective infrastructures and the probable timeframe for decision making. Several of the projects involve international infrastructures where Swedish participation is considered essential, or construction of Swedish nodes in internationally distributed infrastructures.

Increased investments in joint national or international infrastructures are also followed by an increased need for operational grants when the respective infrastructures come into service. Since construction takes place successively, and most individual projects take several years to construct, the total funding for operations should increase progressively.

The need for operational grants and investments in research infrastructures is estimated to be just over 300 million Swedish kronor (SEK) higher per year in 2016 compared to the current level.

Table 1. New high-priority infrastructure needs.

Presented below are infrastructures not currently financed by the Swedish Research Council, but considered to be of major national interest – or are areas or infrastructure in need of further investigation or coordination. The description of the infrastructures, the reasons they are needed, and relevant actions are described in the area overviews (starting on page 48) and also in the infrastructure descriptions (starting on page 79).

Infrastructure	National/ International	Status/actions	Total cost* 2012–15	Total cost* 2016–2019
Social sciences and humanities				
CESSDA (ESFRI)	Int	Negotiations to join European collaboration during 2012	8 Mkr	8 Mkr
ESS (ESFRI) ESS (Swedish fund raising)	Int	Negotiations to join European collaboration during 2012	4 Mkr 14 Mkr	4 Mkr 14 Mkr
SHARE (ESFRI)	Int	Negotiations to join European collaboration during 2012	25 Mkr	25 Mkr
Register- and personal-data-based infrastructure	Nat	Pilot study under way	25 Mkr	25 Mkr
Development of SND, data services for social sciences, humanities, and medicine	Nat	Actions after follow-up conducted 2012	25 Mkr	25 Mkr
Survey data and longitudinal studies (HU, E, MH)	Nat	New inquiry	–	–

Infrastructure	National/ International	Status/actions	Total cost* 2012–15	Total cost* 2016–2019
Environmental sciences				
EISCAT-3D (ESFRI)	Int	Action plan presented in 2012	150 Mkr	75 Mkr
Research stations	Nat/int	Part of national network	50 Mkr	80 Mkr
ICOS (ESFRI) Hosting Carbon portal	Int	Negotiations to join European collaboration during 2012	8 Mkr 30 Mkr	10 Mkr 40 Mkr
Lifewatch (ESFRI) Hosting Biodiversity portal	Int	Negotiations to join European collaboration during 2012	20 Mkr 20 Mkr	20 Mkr 20 Mkr
Biology and medicine				
BBMRI (ESFRI)	Int	Negotiations to join European collaboration during 2012	8 Mkr	8 Mkr
ELIXIR (ESFRI)	Int	Negotiations to join European collaboration during 2012	25 Mkr	35 Mkr
INSTRUCT (ESFRI) Swedstruct	Int/ Nat	Negotiations to join European collaboration during 2012	3 Mkr 12 Mkr	3 Mkr 12 Mkr
Technical platforms (proteomics, metabolomics, systems biology)	Nat/Int	Application-driven	250 Mkr	150 Mkr
Materials science				
MAX IV (new experimental stations/beamlines)	Nat	Application-driven, estimated 2-4 new beamlines per 4-year period, of which the Swedish Research Council covers 3 (prelim.)	160 Mkr**	80 Mkr**

Infrastructure	National/ International	Status/actions	Total cost* 2012–15	Total cost* 2016–2019
Physics and engineering sciences				
E-ELT (ESFRI)	Int (ESO)	Directional decision made in 2010	50 Mkr	30 Mkr
LHC upgrade "Super LHC"	Int	Accelerator within framework of CERN membership, experimental stations funded by collaborations	60 Mkr	20 Mkr
e-vetenskap*				
Expanded user support e-Infrastructure (SNIC)	Nat	Strengthen base resources in e-Infrastructures	70 Mkr	90 Mkr
Expanded hardware e-Infrastructure (SNIC)	Nat	Strengthen base resources in e-Infrastructures	100 Mkr	100 Mkr
Service functions and storage resources (SNIC/Swestore)	Nat	Strengthen base resources in e-Infrastructures	30 Mkr	80 Mkr
SUNET, new users	Nat	Strengthen base resources in e-Infrastructures	30 Mkr	150 Mkr

** Estimated total cost during the period (2011 monetary value). The Swedish share of the costs (investment, membership fee, operation) is shown for international infrastructures. For national infrastructures, the total Swedish costs (investment, operation) are shown. Where relevant, footnotes are used to present the Swedish Research Council's share of the cost. See descriptions of the respective infrastructures.*

*** Estimated investment from the Swedish Research Council, total need for approximately 2-4 beamlines per year in next 5-6 years.*

**** Costs for e-Infrastructures in terms of computing, analysis, modelling, and storage resources as well as dedicated network connections, included in most of the infrastructures described.*

Table 2. New infrastructure initiatives, Swedish interest to be determined.

Presented below are infrastructures or areas considered to have potential, but where the uncertainty factor remains high. In several cases, the infrastructure's value to Swedish research will be determined during 2012 to 2015. The infrastructures are described in greater detail later in the guide.

Infrastructures	Timeframe for decision	National/ International	Status/actions	Swedish cost investment* 2012–2015 million SEK	Swedish cost operational* 2016–2019 million SEK
Social sciences and humanities					
CLARIN (ESFRI) language technology	Short/moderate	Int	New inquiry	30 Mkr	9 Mkr
DARIAH (ESFRI)	Short	Int	Participation via SND	6 Mkr	3 Mkr
Environmental sciences					
ANAEE (ESFRI) experimental ecology	Moderate/long	Int	Sweden participating in planning phase	60 Mkr	14 Mkr
EMBRC (ESFRI) experimental ecology	Moderate/long	Int	Sweden participating in planning phase	28 Mkr	68 Mkr
EMSO (ESFRI) experimental ecology	Short	Int	Sweden participating in planning phase	45 Mkr	36 Mkr
EPOS (ESFRI) tectonic plates	Moderate	Int	Sweden participating in planning phase	142 Mkr	91 Mkr
IOPD (new programme) Ocean drilling programme	Short	Int	Studied 2011-12, new programme from 2013	8 Mkr	10 Mkr
SIOS (ESFRI) Svalbard observatory	Moderate	Int	Sweden participating in planning phase	14 Mkr	11 Mkr

Infrastructures	Timeframe for decision	National/ International	Status/actions	Swedish cost investment* 2012–2015 million SEK	Swedish cost operational* 2016–2019 million SEK
Energy					
MYRRHA (ESFRI) test reactor	Moderate/long	Int	Sweden participating in planning phase	270 Mkr	53 Mkr
Biology and medicine					
EATRIS (ESFRI) translational research	Short	Int	Sweden participating in planning phase	6–28 Mkr	3.5–9 Mkr
ERINHA (ESFRI) high-security lab	Moderate/long	Int	Sweden participating in planning phase	50 Mkr	27 Mkr
EU-openscreen (ESFRI)	Short	Int	Sweden participating in planning phase	11 Mkr	45 Mkr
Eurobioimaging (ESFRI) bioimaging	Short	Int	Sweden participating in planning phase	171 Mkr	284 Mkr
ISBE (ESFRI) systems biology	Moderate/long	Int	Sweden participating in planning phase	85 Mkr	114 Mkr
Mouse phenotyping, incl. INFRAFRONTIER (ESFRI)	Short	Nat/Int	Study of infrastructure for phenotyping is under way where national organisation and financing will be clarified in 2012	51 Mkr **	91 Mkr **

Infrastructures	Timeframe for decision	National/ International	Status/actions	Swedish cost investment* 2012–2015 million SEK	Swedish cost operational* 2016–2019 million SEK
Materials science					
EURO-fel (ESFRI) free electron lasers	Short	Int	Sweden participated in planning phase	341–455 Mkr	137–182 Mkr
Physics and engineering sciences					
CLIC/ILC linear colliders	Long	Int	Sweden participating in planning phase	no information	no information
CTA (ESFRI) Cherenkov telescope	Moderate	Int	Sweden participating in planning phase	43 Mkr	11 Mkr
EST, solar telescope	Moderate	Int		24 Mkr	20 Mkr
SKA (ESFRI) radiotelescope	Moderate	Int	Sweden participating in planning phase	100 Mkr (first stage)	114–170 Mkr (first stage)

** For the infrastructures included in the ESFRI roadmap, the cost estimates are based on information in the 2010 roadmap, with the Swedish share estimated at 3%. During the first period (2012-2015) the Swedish share concerns construction, and the second period (2016-2019) concerns operation. These figures are preliminary and will change if Sweden participates, e.g. the cost for the entire project will be further specified, the size of the Swedish share will be negotiated and may be higher or lower than presented here. Further, the construction costs will be calculated over a period longer than 4 years, and in several cases the operational costs will not appear already in 2016. The calculations above do not include possible construction of Swedish nodes, etc. The total Swedish costs (investment and operation) are given for the national infrastructures. See descriptions of the respective infrastructures.*

*** Refers only to the cost for the European infrastructure.*

Table 3. Existing infrastructures financed by the Swedish Research Council.

Presented below are the infrastructures that are fully or partially financed by the Swedish Research Council. Regarding infrastructures that have recently been approved and are under construction, new or increased needs during the forthcoming 4-year period are possible, but remain undefined in most cases. Grant applications to supplement or develop these infrastructures are expected to compete with other initiatives through the annual open call for grant applications for infrastructures. Table 1 presents specific, already prioritised needs. See the full descriptions of the respective infrastructures.

Infrastructures	National/ International	New/under construction	Time of follow-up, possible development/phase-out	Total cost 2012–2015 million SEK	Total cost * 2016–2019 million SEK
Social sciences and humanities					
ESS, European social survey (Swedish fund raising)	Nat		Funded through 2011, recommended ESS-ERIC starting 2012, see Table 1	See Table 1	See Table 1
SND, data services for social sciences, humanities, and medicine	Nat		Evaluation 2011, see Table 1	32 Mkr	32 Mkr
Environmental sciences					
EISCAT, ionosphere research	Int		Partially replaced by EISCAT-3D	20 Mkr	20 Mkr
GBIF, biodiversity	Int		For both GBIF int. and Swedish node at Swedish Museum of Nat. History	9 Mkr	9 Mkr
ICDP/SDDP, deep drilling	Nat/Int		Includes ICDP int. and Swedish SDDP network. Re-negotiate starting 2014	42 Mkr	15 Mkr
IODP/ECORD, ocean drilling	Int		New programme from 2013, see Table 2	5 Mkr (through 2012)	–
Nordsim, mass spectrometer for geology	Int (Nordic)		Re-negotiate starting 2015	4 Mkr	4 Mkr

Infrastructures	National/ International	New/under construction	Time of follow-up, possible development/phase-out	Total cost 2012–2015 million SEK	Total cost* 2016–2019 million SEK
ECDS (prev. SND-KM) data services for climate & environment	Nat		Re-negotiate starting 2014	18 Mkr	18 Mkr
Swedish ICOS, CO_2 measurement	Nat	x	Re-negotiate starting 2014	67 Mkr	40 Mkr
Swedish LifeWatch, biodiversity	Nat	x	Re-negotiate starting 2014	23 Mkr	23 Mkr
Energy					
ITER, fusion reactor	Int		Funded via Euratom	2.5 Mkr	2.5 Mkr
JET, fusion experiment	Int		Funded via Euratom Contract through 2015	7.5 Mkr	7.5 Mkr
Biology and medicine					
BBMRI.se, biobanks	Nat	x	Re-negotiate starting 2014	106 Mkr	80 Mkr
CBCS, chemical biology	Nat	x	Re-negotiate starting 2014	45 Mkr	48 Mkr
BILS, bioinformatics	Nat	x	Re-negotiate starting 2014	70 Mkr	80 Mkr
EMBL, molecular biology	Int		Convention bound. Time of evaluation to be determined.	100 Mkr	100 Mkr
INCF, neuroinformatics	Int		Time of evaluation to be determined.	3.6 Mkr	3.6 Mkr
MIMS, molecular medicine	Nat		Re-negotiate starting 2014	63 Mkr	63 Mkr
SNISS, DNA sequencing	Nat		Re-negotiate starting 2014	38 Mkr	38 Mkr
Swedish bioimaging, imaging	Nat	x	Re-negotiate starting 2014	135 Mkr	135 Mkr

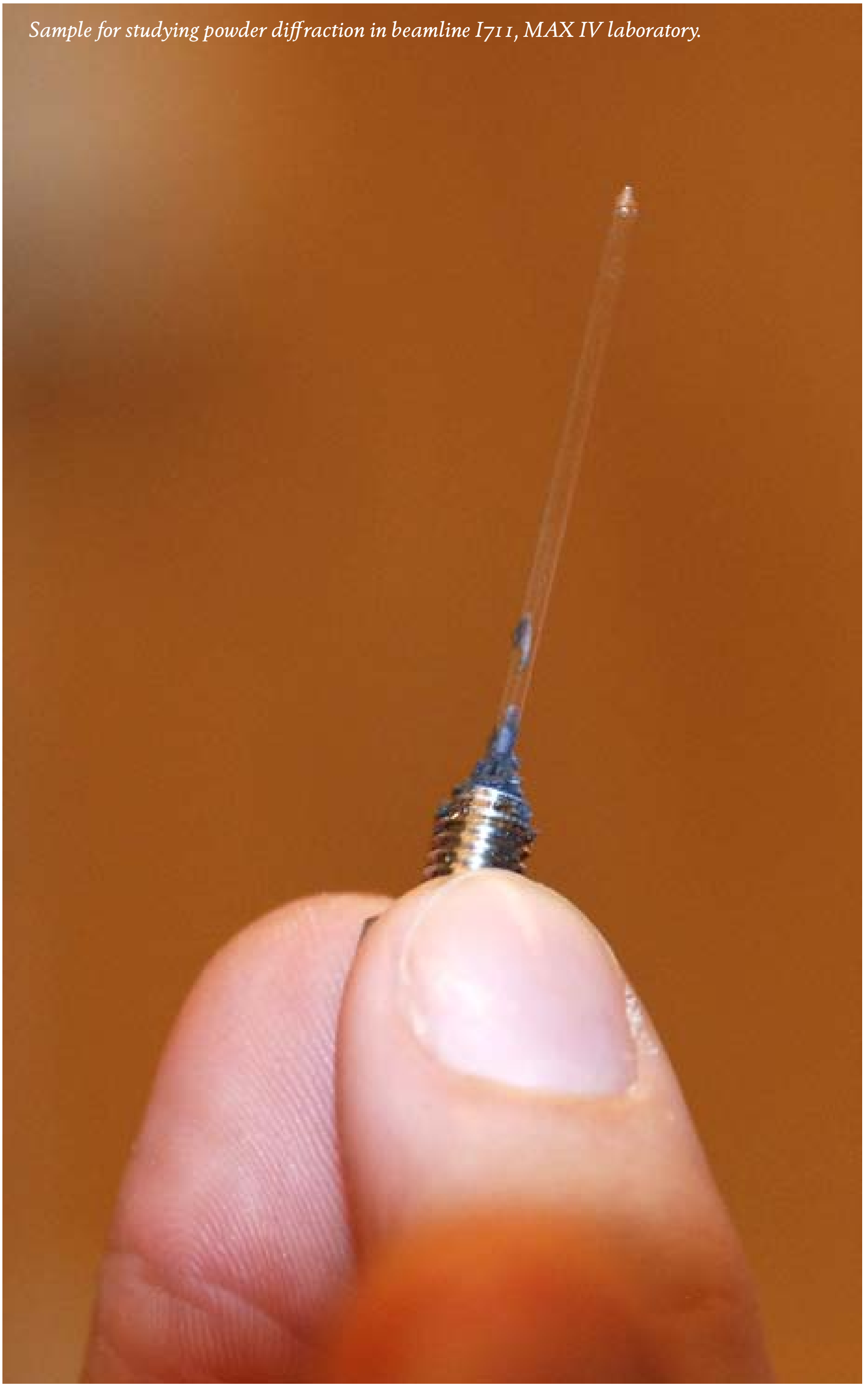
Infrastructures	National/ International	New/under construction	Time of follow-up, possible development/phase-out	Total cost 2012–2015 million SEK	Total cost * 2016–2019 million SEK
Materials science					
ESRF, synchrotron radiation	Int		Convention bound. Time of evaluation to be determined.	69 Mkr	75 Mkr
ESS, spallation source	Int	x		680 Mkr**	680 Mkr**
ILL, neutron research	Int		Re-negotiate 2013	70 Mkr	76 Mkr
ISIS, neutron research	Int		Through 2012	10 Mkr	10 Mkr
MAX IV, synchrotron radiation (incl. MAX-lab)	Nat	x	Excl. construction of new beamline, see Table 1	785 Mkr	880 Mkr
Myfab, clean room	Nat	x	Re-negotiate starting 2014	124 Mkr	124 Mkr
PETRA III, Swedish beamline, synchrotron radiation	Nat	x	Planned start 2014. Follow-up approx. 3 yrs later	10 Mkr	40 Mkr
Super-Adam neutron reflectometer at ILL	Nat	x	Re-negotiate starting 2014	23 Mkr	23 Mkr
XFEL, X-ray free electron laser	Int	x	Convention bound. Time of evaluation to be determined.	76 Mkr	85 Mkr
Physics and engineering sciences					
CERN, particle physics	Int		Convention bound. Time of evaluation to be determined.	880 Mkr	950 Mkr
ESO, astronomy	Int		Convention bound. Time of evaluation to be determined.	153 Mkr	165 Mkr

Infrastructures	National/ International	New/under construction	Time of follow-up, possible development/phase-out	Total cost 2012–2015 million SEK	Total cost * 2016–2019 million SEK
FAIR, nuclear physics	Int	x	Convention bound. Time of evaluation to be determined.	85 Mkr	60 Mkr
Icecube neutron telescope	Int		Operational grant through 2013	5.5 Mkr	5.5 Mkr
ISF, solar telescope	Nat		Re-negotiate starting 2016 (prelim.)	22 Mkr	22 Mkr
NOT, astronomy	Int (Nordic)		Phase-down 2013-2016	15 Mkr	3 Mkr
Onsala Space Observatory, radioastronomy & geodetics	Nat		Through 2013, new decision from 2014	150 Mkr	162 Mkr
e-Science					
Databases	Nat			100 Mkr***	100 Mkr***
NDGF, data grid	Int (Norden)		New org. starting 2012	5 Mkr	5 Mkr
PRACE, computing	Int		Re-negotiate starting 2014	136 Mkr	136 Mkr
SNIC, computing	Nat		New org. starting 2012	280 Mkr	280 Mkr
SUNET, data network (grant)	Nat		Evaluation 2012	168 Mkr	168 Mkr

** Projected costs. The Swedish share of the costs (investment, membership, operation) is shown for international infrastructures. For national infrastructures, the Swedish Research Council's share of the costs is shown. See descriptions of the respective infrastructures.*

*** Swedish Research Council's share of the costs, others go through the Ministry of Education and Research.*

**** Whereof approximately SEK 15 million per year go to grants for large databases awarded to competing applications.*



Sample for studying powder diffraction in beamline I711, MAX IV laboratory.

PHOTO: ANNIKA NYBERG, MAX IV-LABORATORIET, 2011

OVERVIEW OF RESEARCH AREAS

Humanities and social sciences

In our global society we confront several major challenges where the perspectives of the humanities and social sciences are of central importance. This involves understanding revolutionary processes and structural change, but also developing and taking positions on political, economic, and social interpretive models and proposing solutions to problems. We need to understand and act wisely in addressing the widening gaps between people resulting from different economic, social, and cultural conditions in a changing world.

Humanistic and social science research play a key role in understanding our world and our actions. During the past 15 years the great increase in

PHOTO: AFP PHOTO SUCCESSION PICASSO

In our global society we face major challenges where humanistic and social science perspectives play key roles. We need to understand and act wisely in addressing the widening gaps between people resulting from different economic, social, and cultural conditions in a changing world. Due to the greatly increased need for infrastructures in the humanities, social sciences, and health, in a broad sense, the Council for Research Infrastructures established a new evaluation panel in 2011 to address these issues. (Painting: "Maya With Doll", by Pablo Picasso) access to extensive micro-databases has been one of the most important forces driving methodological and theoretical advancements in the humanities and social sciences. Access to large databases containing extensive information at the individual level has enabled researchers to study earlier assumptions and research results under new light. This has created opportunities to study problems that previously could not be analysed in an adequate way.

The areas for development remain very large: structures and common standards must be created that facilitate the collection, structuring, and analysis of empirical data across regional and national boundaries while concurrently promoting collaboration among different research disciplines. Institutions that guarantee researchers open and long-term access to data across institutional and national boundaries constitute another key factor for development in this area. Concurrently, personal integrity must be assured through open discourse on issues involving research ethics and by using the opportunities offered by new infrastructure technologies to safely store data and protect sensitive information.

Due to the greatly increased need for infrastructures in the humanities, social sciences, and health, in a broad sense, the Council for Research Infrastructures established a new evaluation panel in 2011 to address these issues. The Swedish Research Council also has an expert advisory panel on database issues, DISC.

Need for new infrastructures or actions

The most urgent need for infrastructures in the humanities and social sciences is that of creating better conditions for research using databases and registers. It is important to create a comprehensive, overarching agency system for access to registry data and other large bodies of data (e.g. biobank data and cultural heritage data), including data from central and regional agencies and organisations. Such an overarching agency system should take a comprehensive approach towards the organisational, technical, legal, ethical, and political obstacles to research that uses databases and registers, regardless of data type. The development of a system for federated databases that enables data to be accessed and shared in ways other than physical transfer is becoming increasingly necessary from practical and legal standpoints. Development of such systems is also a priority at the Nordic level and a step towards making the unique Nordic data resources accessible internationally. In social sciences and in some areas of medicine it is essential to review the current legal situation regarding the regulations addressing the use of personal information in research, particularly in relation to confidentiality, ethics, and the rules and applications concerning the Personal Data Act.

The Swedish Research Council has identified possibilities for promoting efficiency and quality improvement through coordination of survey data and longitudinal data, and therefore has initiated a study in collaboration with FAS and the Bank of Sweden Tercentenary Foundation.

The Swedish National Data Service (SND) is a service organisation for research in the humanities, social sciences, and medicine that aims to help researchers gain access to existing data in Sweden and internationally. SND was evaluated during 2011, and in 2012 several proposals will be made to clarify SND's mission based on the needs identified.

The trend is towards increasingly coordinated efforts in Europe and globally to construct, improve, and maintain internationally comparable research data. Sweden should participate in ESFRI projects such as the collaborative European organisation and data network, CESSDA (Council of European Social Science Data Archives), ESS (European Social Survey), and SHARE (Survey of Health, Ageing, and Retirement in Europe) to contribute towards and guarantee access to the data that the project generates and to participate in the development of common megadata and common standards. Near the end of 2011 the Swedish Research Council recommended Swedish participation in CESSDA, ESS, and SHARE, which will be negotiated within the respective collaborative infrastructures.

An integrated and standardised research infrastructure for language resources is being created in CLARIN (Common Language Resources and Technology Infrastructure). The Swedish Research Council aims to study the infrastructure needs of language technology, e.g. related to CLARIN, and how Swedish collaboration should be organised. DARIAH (Digital Research Infrastructure for the Arts and Humanities) intends to create a coordinated technical infrastructure to improve and support digitally based research in the humanities.

Initiatives have been taken to coordinate and identify common solutions for the five ESFRI-initiated infrastructures in the humanities and social sciences – DASISH (Data Service Initiative for Social Science and Humanities). The DASISH project is financed by EU's seventh framework programme for 3 years starting in 2012. Sweden is the European coordinator for DASISH.

The digitisation of cultural heritage and how this should be done to benefit research is a current and complex issue for researchers in several fields. One initiative to promote this is the ERA-net project DC-NET (Digital Cultural Heritage Network) that presented its conclusions at the end of 2011. Sweden's participation is coordinated by the Swedish National Archives.

Need for e-Infrastructure

Research in the humanities and social sciences needs greater access to relevant, high-quality data at the macro and micro levels.

Systems are needed to document and connect data from different sources, institute common standards, data collection methods, organisation, and documentation. Central issues are long-term storage of data, including assurance of open and long-term access to data and methods across institutional and national boundaries.

A fundamental aspect of the infrastructure for research in the humanities is access to digital data. Source material managed by agencies and institutions in the so-called ALMC sector (archives, libraries, museums, and cultural environments) represent a large albeit insufficiently utilised resource not only in the humanities but also in the social sciences and natural sciences. Since much of the infrastructure work in the ALMC sector takes place outside of the traditional sector of universities and higher education institutions (HEIs), organisations in this area have less favourable opportunities to access the e-Infrastructure services used within the research and education sector. Regarding data networks managed by SUNET, there are good opportunities to expand the user group to encompass archives, libraries, museums, and cultural environment institutions. This would require an increase in funding. As regards research and research infrastructures related to data in the ALMC sector, a dialogue is needed between the organisations involved. In conjunction with the forthcoming evaluation of SUNET, the Swedish Research Council will also address this question, which even relates to the Government's work on e-Administration and a consolidated action plan for digitisation- a Digital Agenda for Sweden. [9]

Environmental sciences – planet earth

We all depend on the earth's natural resources for our survival. Extraction of natural resources comprises a large part of the Swedish economy, and the forest, mining, and hydroelectric power industries have long been important in driving research and technical development. Together with the academic community and public agencies they have built a large bank of knowledge on Sweden's environment and natural resources. Research in the field is moving increasingly towards understanding and envisioning whole systems. To know how the earth's resources should be allocated, it is necessary to know the processes that determine the replenishment of natural assets and how

---

9 Ku2011/242/KA

The ongoing changes in climate place a focus on research and planet earth. Research on planet earth and its surroundings covers a broad spectrum, both in terms of disciplines and processes. Concurrently, there is a common need for observations of the environment. To conduct high-quality research, infrastructures are needed for observations that often are coordinated across disciplines, e.g. through field stations and satellite programmes.

PHOTO: SCANPIX

human extraction and utilisation affect these assets in the short and long term. Responsible utilisation of resources requires knowledge about how they are distributed in space and time and how resources interact with their environment so that unexpected and undesirable effects can be avoided.

Research on planet earth, i.e. research addressing climate, environment, biology, and geosciences in a broad sense is important not only for natural resources, but it also contributes to a basic understanding of how the earth was formed, has developed, and continues to develop. This is necessary to understand the living conditions for humans and other living organisms now and in the future. Areas such as ecology, climatology, geology, and oceanography base their research on observations, but have taken steps forward and created models showing how planet earth has developed over time and how it will develop in the future. In recent years it has also become necessary for the models to pay greater attention to human activity.

According to the United Nation's Intergovernmental Panel on Climate Change (IPCC), we can expect a period of rapid change in climate and hence in the conditions for all living organisms, including humans. Presumably, considerable effort will be needed to limit the human impact on climate by reducing emissions of carbon dioxide and other greenhouse gases into the atmosphere. Research during the second half of the twentieth century indicated how emissions of environmental toxins, acidic substances, and freons affect the environment. Awareness of the impact of emissions has led to political decisions to limit them.

With the exception of organisms that live in the deep ocean or in bedrock, life on earth depends on the sun and its influence on the earth's system. Solar activity varies in both a cyclical and random manner, and the greatest variations that affect the earth are solar winds. During large eruptions on the sun, the solar wind's charged particles cause major disruptions in technologically advanced equipment, communication and energy transmission systems, and activities in outer space. Solar winds interact with the earth's magnetic field and atmosphere, generating, e.g. northern lights and influencing the chemical composition of the atmosphere. To protect important infrastructures, and ultimately society, it is important to understand the interaction between sun and earth and how these systems function.

Need for new infrastructures or actions

A wide spectrum of research, both in terms of disciplines and processes, addresses planet earth and its surroundings. Concurrently, there is a common need for environmental observations. Measurements conducted to understand how bedrock, the oceans, the atmosphere, ecosystems, and our environment function and develop over time require systematic collection of information. Conducting these observations requires access to networks of measurement stations – automatic and/or manual, staffed field stations for observations and experiments, observatories, research vessels, and satellites. Also, access is needed to advanced laboratories for controlled trials of ecological and geological phenomena. At times, infrastructures for observations can be coordinated across disciplines, which often occurs at field stations and in satellite programmes. Some measurements require large specialised infrastructures to study and understand specific phenomena, e.g. the European Incoherent Scatter Facility (EISCAT) to study how the sun interacts with the earth's magnetic field, and the Onsala observatory, which is used as a geodetic reference point (i.e. for measuring and imaging the earth). Sweden is the host nation for the international organisation, EISCAT, which will gain even greater importance with the construction of the planned EISCAT-3D, the world's most advanced radar facility for research.

Observations from national systems are particularly valuable if they can be connected with the databases of other countries. The infrastructures currently being built in Sweden, e.g. the ICOS for measuring carbon dioxide flow, and LifeWatch and LTER for research on biodiversity, are not only valuable for Swedish researchers but are also important national nodes in coordinated international networks. The Council for Research Infrastructures (RFI) recommended in late 2011 that Sweden actively participate in the construction of ICOS and LifeWatch as international infrastructures. Coordination gives Swedish researchers access to international measurement data and expertise while contributing to greater efficiency since several nations can share the necessary investment and development costs. Similar initiatives are being taken to increase integration in geology and geophysics (EPOS), experimental ecology (ANAEE), marine genomics (EMBRC), and coordination of station-based polar research (SIOS and INTERACT). Swedish researchers participate actively in the development of these infrastructures. A study from 2011 points to the potential for higher quality and better efficiency through national coordination of land-based (terrestrial) research stations. The Swedish Research Council intends to review the opportunities for increased coordination of large-scale infrastructures for both land-based and marine research.

The earth's development, from hundreds to millions of years ago, is documented in lake and ocean floors and other geological layers as well as in glacial ice. Information about the earth's natural variations is therefore accessible to us primarily through studies of drill cores, but also through studies of sedimentary layers. The Swedish Research Council participates in two organisations that manage infrastructures for scientific drilling, IODP in marine environments and ICDP for land and lake drilling.

In addition to infrastructures for field observations, researchers need access to measurement and analytical instruments. Climate research requires, for instance, greater knowledge about radiation balances and the atmosphere's composition. In many areas, the low concentrations of different substances need to be analysed. The analytical instrumentation is often similar to that used in other research areas, e.g. the infrastructure needs for biological research often coincide with those in medical and molecular biological research. Some scientific questions require special analytical equipment. For example, several research disciplines use rare isotopes as markers in studying dynamic processes in the earth, air, and water. This includes research that relies on the joint Nordic infrastructure, Nordic Secondary Ion Mass Spectrometer (Nordsim). This is managed by Sweden, but used jointly by the European countries to determine the presence of basic elements and isotopes that are found only at very low concentrations. The infrastructure required by researchers to study and understand planet earth partially coincides with the infrastructure needed for operative monitoring and mapping of the earth's environment and natural resources. Examples of operatively oriented data collection used in research include the weather service's network of meteorological stations, geological mapping, and the Swedish National Forest Inventory's testing areas, to mention a few. Such multi-utilisation of society's data collection resources should receive attention, and it is important that the needs of researchers are considered in planning operationally orientated data collection. On the other hand, data collected for research purposes can also be used for environmental monitoring and natural resource mapping.

Need for e-Infrastructures

Research addressing the dynamics of planet earth is dependent on lengthy time series, often several decades, to assure that the observed changes can be distinguished from random variation. It is important that the collected data be managed and documented so that they become accessible to researchers in addition to those who collected the data. Special funding to construct and access the databases is needed for this purpose. For instance, we need well-documented databases containing information about ecosystems, including species prevalence and the physical environment. The need for data and data processing varies substantially within the field, where, e.g. atmospheric science has long used powerful computers to run prognostic and climate models and to store substantial volumes of data. The planned EISCAT-3D radar system will need both powerful data networks and large data capacity. SNIC is already engaged in the preparatory work as part of the current planning phase.

Energy requirements are expected to increase rapidly in the near future. This presents a major challenge to researchers, industry, and society at large to meet these needs while simultaneously shifting the energy system towards greater use of renewable energy sources. Large-scale wind turbine facilities are shown to be commercially viable. Since the Swedish wind turbine industry is small, most research has focused on how to integrate wind power into the Swedish energy system.

PHOTO: SCANPIX

Energy research

Energy requirements are expected to increase rapidly in the near future. This presents a major challenge to researchers, industry, and society at large to meet these needs while simultaneously shifting the energy system towards greater use of renewable energy sources. The goals of the Europe 2020 strategy include reducing the emission of greenhouse gases by 20%, increasing energy efficiency by 20%, and reaching the 20% level for renewable energy in EU by 2020. Energy research is obviously a multi- and interdisciplinary enterprise since expertise is needed from different fields of research, including both basic research and applied research. The need for research infrastructures ranges from facilities for basic material analysis and computing resources to industrial development and dedicated test facilities. Swedish higher education institutions, industry, and public agencies participate in several international collaborations, e.g. through the International Energy Agency (IEA) and EU/Euratom. Swedish researchers participate, for instance in the European Institute of Innovation and Technology (EIT) for energy research, the top-level research initiative by the Nordic Council of Ministers, and the development of the ITER fusion reactor. Energy research also has a very high priority domestically, not least through the Research and Innovation Bill from 2008.

The Swedish Energy Agency has an overarching responsibility for research, in Sweden, but the Swedish Research Council has full or partial responsibility for some specific areas such as fusion, nuclear technology, and national research infrastructures. Addressed below are various themes and aspects of energy research and the related need for infrastructures for research and technological development.

Sun, wind, and water

Sweden's small- and large-scale hydroelectric power plants account for approximately half of electricity supplied to the country. [10] More effective utilisation of existing hydroelectric power can be achieved through technological advancements in industry and improved prognostic tools like those used in climate modelling. A new Swedish method that uses linear generators to produce energy from wave power is being tested on the west coast, and trials using slow marine currents are under way in the Dal River (*Dalälven*), but more tests are necessary before the full potential of the method can be evaluated.

Large-scale wind farms are shown to be commercially viable, and in Sweden production has increased by 25% from 2008 to 2009, although it started

10 Source: Swedish Energy

at a relatively low level. [II] Since the Swedish wind turbine industry is small, the research being conducted is primarily targeted at how to integrate wind power into the Swedish energy system.

The rapid development of solar cells during the past two decades is a result of collaboration between basic research, primarily materials research, and technological advancement. Clean room laboratories, coordinated to some extent through Myfab, are an important resource for solar cell research and future investments in facilities for material analysis, e.g. MAX IV and ESS.

Windscanner and EU-solaris are two proposals in the ESFRI roadmap from 2010 aiming at developing an infrastructure to measure and model turbulence around wind turbines and investigate the potential for using concentrated solar energy from mirrors for large-scale energy production. At present, no Swedish researchers have announced interest in participating in the project.

Geothermal energy and carbon dioxide storage

Trial facilities for carbon dioxide storage are operating in Europe, mainly in Germany and Norway, but new trial and demonstration facilities are under way in several countries. Swedish researchers are participating in the EU project CO_2CARE and leading the EU Mustang project that involves field test sites in several countries and small-scale injection experiments. Preliminary studies are under way in Sweden for both separation facilities and storage, and Swedish researchers and industry are also participating in European research projects in these areas.

In Sweden and elsewhere around the world, the use of geothermal energy is increasing, and facilities for large-scale district heat production are available in southern Sweden (*Skåne*). Since the bedrock elsewhere in Sweden differs from that in *Skåne*, technological development is necessary to extract thermal energy on a large scale by circulating water in extremely deep drill holes. The Swedish Deep Drilling Programme (SDDP) plans to start drilling in Sweden via the International Continental Scientific Drilling Program (ICDP). The aim includes basic research concerning Swedish bedrock and evaluating the potential to extract geothermal energy from primary rock.

Nuclear technology

Research on nuclear technology depends on experimental and demonstration facilities to develop and test new methods and to educate future researchers in nuclear technology. Facilities for material analysis are also necessary, both to understand processes in current nuclear energy systems and to develop future systems.

[II] Source: Swedish Energy

In 2010 Sweden signed a collaborative agreement with France, giving Swedish universities and higher education institutions access to the Astrid, ISIS, and Jules Horowitz reactors for education of young researchers and doctoral students. The aim is to further Swedish expertise in research and development of the next generation of nuclear reactors.

The ESFRI roadmap from 2010 proposes a European initiative for a research facility (MYRRHA) for accelerator-based nuclear technology. The Swedish Research Council, after receiving notification of interest from Swedish research groups found that Swedish interest is high, and national coordination is taking place. Hence, the Swedish Research Council approved the participation of the Swedish group in joint planning of the facility on behalf of Sweden.

Fusion

Fusion research, more or less, requires global investment. Swedish researchers are currently conducting research through JET (Joint European Torus) in Great Britain, in part with support from the Euratom programme. The experiments conducted have shown that one of the major challenges in constructing fusion reactors is to develop material that can withstand extremely high heat flow and concurrently tolerate intensive neutron radiation. To ensure that fusion is not only a sustainable alternative for the future but also an economically attractive alternative, not only do the material questions need to be addressed, but also greater fundamental understanding is needed to optimise the properties of plasma cores. Fusion research therefore depends on advancements in materials research, fundamental plasma theory, and large-scale, system-based modelling and simulation.

Seven partners, of which the European Union is one, are constructing basically a full-scale reactor experiment (ITER) in southern France. In turn, this development requires large-scale facilities to optimise different aspects of the reactor construction. The international agreement for ITER includes the construction of an accelerator facility (IFMIF) to test material for the next generation of energy-producing fusion reactors. Extensive computing infrastructures are being built with EU funding to support the optimisation of ITER and to utilise and analyse both ITER and current experiments.

Combustion technology, gasification technology, and biomass

A large part of Sweden's total energy supply comes from fuels such as oil, natural gas, coal, and biofuels. [12] Consequently, improved combustion with lower environmental impact can have major effects on industrial growth

[12] The Energy Situation 2010, Swedish Energy Agency

and human health. The greatest potential in bioenergy is assumed to be found in utilising by-products from the forest and paper industries. Pilot facilities for gasification technology exist in Piteå and Göteborg, and a full-scale facility is being developed in Örnsköldsvik. Combustion and refining of biomass requires different technology than combustion of fossil fuels, and therefore further research and development are needed.

Since the 1970s, Sweden has produced biomass on a small scale for industrial energy production, primarily cultivation of energy forest and to a lesser extent energy crops, and the conditions exist for an increase in Swedish production. Research to develop fast-growing varieties of species already available in Sweden is under way at several universities in fields such as genetics, traditional plant breeding, and experimental cultivation. Genetic research is in need of large-scale sequencing equipment that is currently available, e.g. through SNISS, and secure greenhouses and growing chambers. Furthermore, researchers need access to experimental plots in different climate zones.

Energy storage

Access to energy over time can be managed in part through choosing when to use certain resources such as hydroelectric power or fossil fuels and in part through active storage. Active storage of hydroelectric power (pumped-storage hydroelectricity) is being tested, e.g. in facilities in Porjus. Storage in batteries is becoming increasingly important, particularly for mobile applications and in the motor vehicle industry where interest in fuel cells is also growing. Research related to batteries and fuel cells is being conducted at several Swedish universities, often in collaboration with industry. Since much of this research originates in materials research the infrastructure needs are similar, i.e. infrastructures for material analysis such as neutron and synchrotron radiation sources. A major expansion of intermittent sources such as wind and solar energy in the electrical system may require increased hydroelectric power that can be regulated, including pumped-storage hydroelectricity, and controlled utilisation, primarily of facilities for heating and cooling buildings that may be connected to active programmes for local heat storage.

Distribution

A strong increase in electrical supply from wind power, solar energy, and other renewable energy sources will place new demands on flexibility in the Swedish energy system. The trend is towards so-called “smart grids” that can switch between different energy sources and manage energy storage to effectively match needs and production in the distribution grid. To some extent, such systems are already being used today to manage the production of electricity for large-scale production. Development of systems and test facilities to meet local need is under way.

Need for e-Infrastructures

In addition to test facilities, there is also a need for simulating and modelling smart grids and integrating local systems for supply, storage, and use into large-scale electrical distribution and supply both at the national level and eventually in a Nordic or European network. This will require a powerful computer network and large computing, analytical, and modelling resources similar to those available through SNIC or PRACE.

Biology and medicine

Research in biology and medicine aims to increase the understanding of how living organisms, including humans, function and interact with their environment. An important objective is to illustrate the mechanisms that can lead to the onset of disease. Life processes are complex and depend on the interaction between many different cell types, tissues, and environme-nts. Understanding aspects of a particular life process therefore requires collaboration among researchers from different disciplines, e.g. cell biology, organism biology, molecularly orientated subjects such as biochemistry and structural biology, bioinformatics, and to some extent community medicine

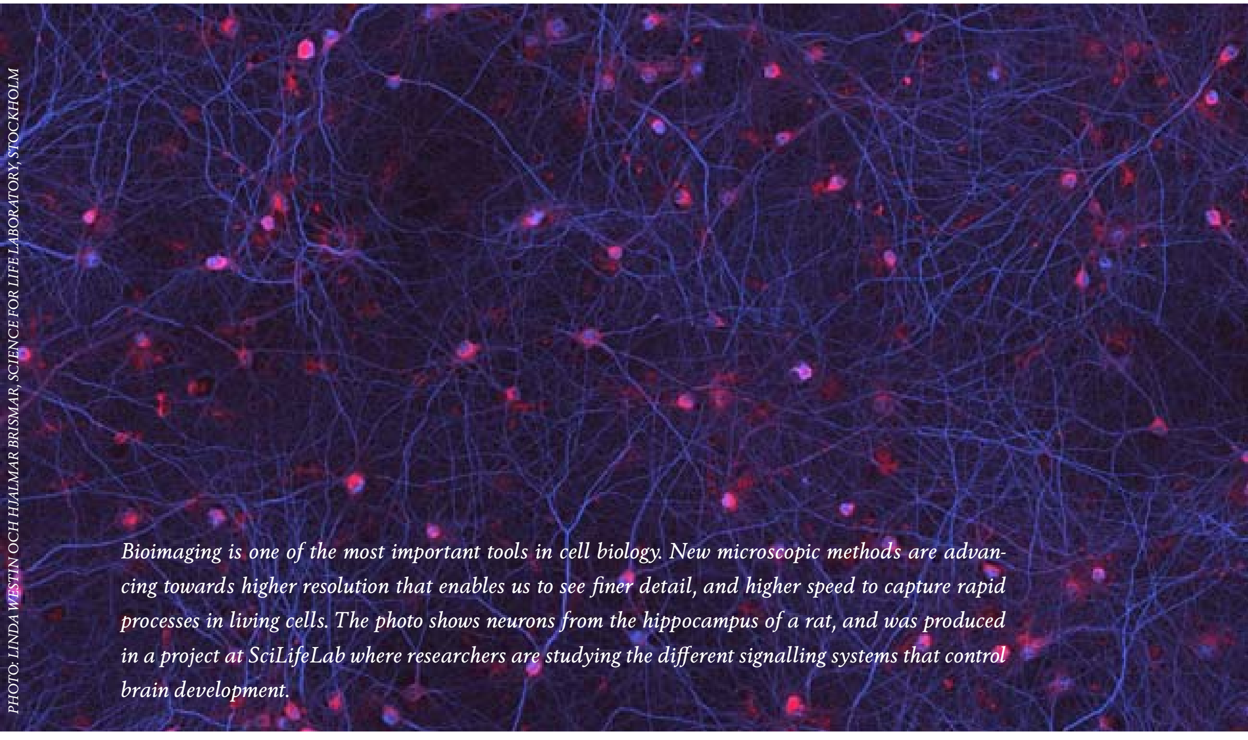


PHOTO: LINDA WESTIN OCH HJALMAR BRISMAR, SCIENCE FOR LIFE LABORATORY, STOCKHOLM

Bioimaging is one of the most important tools in cell biology. New microscopic methods are advancing towards higher resolution that enables us to see finer detail, and higher speed to capture rapid processes in living cells. The photo shows neurons from the hippocampus of a rat, and was produced in a project at SciLifeLab where researchers are studying the different signalling systems that control brain development.

and clinical research, i.e. life sciences in broad sense. The rapid advancement of new technology in biomedical research makes it possible to deal with increasingly complex issues, e.g. in large-scale sequencing where it is now possible to map the sequence of entire genomes, study gene expression, and map variations in metabolites and proteins.

In structural biology, researchers aim to use high resolution in mapping three-dimensional structures in different macromolecules. Access to such information provides a basis for understanding biological functions and also comprises the foundation for development of certain pharmaceuticals.

Modern imaging technology in the biomedical field has made it possible to study biological systems all the way from individual cells in test tubes to whole-body imaging of both animals and humans. The techniques in this area have developed rapidly and range from advanced light microscopy to magnetic resonance imaging (MRI) and positron emission tomography (PET) cameras in healthcare and research. Distributed technology platforms and special resources, e.g. in bioinformatics and image analysis, are needed to process large volumes of data.

In pace with the rapid progress in basic biological research, demand is increasing for changes in the organisation of health services so that new knowledge is more easily accessible in clinical practice. Medical research in the western world places a major focus on understanding the mechanisms behind common diseases such as cancer, cardiovascular disease, diabetes, rheumatism, osteoporosis, obesity, and neurological disorders. Sweden and the Nordic countries have unique opportunities in this context thanks to extensive population- and disease-based registers that integrate epidemiological and clinical information with biological and molecular information from patient groups and healthy individuals that have been followed over time. The goal is to improve the quality of life in humans and concurrently reduce society's costs for health and health services. Similar issues are found in some social science research.

A basic feature in biology is that the construction of genes, proteins, and metabolites can be similar in quite different organisms. How genes interact under certain conditions comprises a growing area in modern functional genomics and system biology. Understanding the mechanisms behind biological processes requires identifying key components (DNA, RNA, proteins, metabolites) and understanding how they are expressed and interact, e.g. by modelling in systems biology. Comparative genomics provides new opportunities for understanding evolution and species diversity through studies of structural and functional similarities and dissimilarities within and between species, including humans. Applications are close at hand, and research of significant importance is being conducted on preventive interventions and treatment of diseases as well as the production of genetically modified plants for forestry and agriculture.

In plant research and plant genomics, Swedish researchers have contributed substantially, e.g. in wood biotechnology where they have described specific molecular processes in growth cells. The understanding of life processes in plants is also important to acquire knowledge about plant requirements and the impact of, e.g. climate changes.

Work involving laboratory animals, including the rapidly growing production of genetically modified organisms, can contribute towards understanding how components in biological systems interact. For instance, investment in large-scale phenotyping of mice with different types of genetic changes (knockout mice) should significantly increase our knowledge about the functions of different genes and proteins. Sweden has a high level of expertise and experience in working with animal models and can play an important role in this mapping effort.

Need for new infrastructures or actions

Biological and biomedical research has changed in character in recent years and is becoming an increasingly large-scale enterprise. New technologies are developing rapidly. Hence, continual oversight of the infrastructure needs of Swedish researchers in different research fields is necessary.

Examples of research with major infrastructure needs include studies of the detailed structure of biomolecules using advanced devices such as high-resolution NMR, electron microscopy, and synchrotron radiation facilities. MAX IV in Lund will offer the potential for cutting edge research not only in materials science, but also in medicine and life sciences through new opportunities, e.g. imaging and structural determination. Likewise, the European Spallation Source (ESS) is expected to open new research fields in biology and medicine.

As regards knowledge transfer between basic research, e.g. mapping molecular mechanisms, and clinical applications, Sweden has great possibilities to strengthen its position and become a pioneering nation. This would require adapting the organisation of health services through better coordination while facilitating opportunities to participate in large research initiatives. An important aspect concerns the conditions for creating and maintaining longitudinal studies over the lifetime of individuals from health to sickness to death. This requires greater coordination and initiatives to bridge the gap between basic biology and medicine. Collaboration with other scientific areas such as behavioural sciences, demographics, language sciences, physics, mathematics, and informatics should also be encouraged.

A proposal is before the government for national coordination of healthcare quality registers in Sweden, where research is one target group. However, strong initiatives are still needed for integration and accessibility of data from different sources, including coordinated technical, legal, and organisational solutions for federated systems. Biology and medicine share many problem areas with social sciences and environmental sciences when it comes to creating effective research infrastructures for agency data and registry data.

Through EU's seventh framework programme, planning for large, population-based research databases and biobanks that meet requirements of quality assurance, standardisation, and harmonisation has been under way for several years through the ESFRI project, BBMRI (Biobanking and Biomolecular Resources Infrastructures). The Swedish Research Council is helping to fund the construction of the Swedish infrastructure for biobanks, BBMRI.se. The European Life Science Infrastructure for Biological Information (ELIXIR) complements the European Bioinformatics Institute (EBI) in England and the establishment of specialised nodes distributed around Europe. In parallel with the European work on ELIXIR, the Swedish Bioinformatic Infrastructure for Life Sciences (BILS) is being constructed. Sweden has actively participated in the preparatory phase of both ELIXIR and BBMRI, and at the end of 2011 the Council for Research Infrastructures recommended that Sweden also participate in implementing and operating these European infrastructures. The type of Swedish involvement is expected to become clearer during 2012.

To effectively manage the generation, characterisation, and storage of genetically modified mouse models, the Swedish Research Council is investigating during 2011 and 2012 how to best organise the coordination and construction of an infrastructure for mouse phenotyping in Sweden. Such a coordinated structure has the potential to strengthen Swedish research and, in the long-term, function as a node for the ESFRI project, INFRAFRONTIER.

The Swedish Research Council finances a national infrastructure for genome sequencing (SNISS). Large-scale technical platforms are also needed for other types of "-omics" data, i.e. transcriptomics, metabolomics, and proteomics as well as structural and systems biology. These resources should be coordinated with other similar initiatives such as "The Human Protein Atlas" that maps human proteins and the development of other technical platforms of national relevance, e.g. the Science for Life Laboratory (SciLifeLab) in the Stockholm/Uppsala region. Continual follow-up is essential since this area is advancing extremely fast.

Bioimaging is becoming increasingly important in studies of processes in living cells. The trend is towards automated microscopic screening of biological processes with storage in large genetic or pharmaceutical libraries, and new high-resolution optical and electromicroscopic systems with the potential to study cellular structures.

Swedish Bioimaging, the national infrastructure for biomedical imaging, aims for national coordination and provides user support for different instruments to image structures and organ systems in living individuals. The network includes equipment based on different types of high-resolution technologies such as MR and STED microscopy. In the future, other imaging techniques will need to be included, e.g. PET, MEG (magnetoencephalography), and other high-resolution technologies for studying cells and tissues. Through Swedish Bioimaging, Sweden also participates in Euro Bioimaging, the European imaging infrastructure.

Need for e-Infrastructure

In constructing infrastructures in biology and medicine, the field of information sciences plays an increasingly central role, with implications for data integration, standardisation, documentation, authentication and authorisation, ethics and legislation, computing, modelling, image analysis, and visualisation. The need for a well-functioning e-Infrastructure that enables efficient data storage and handling will therefore expand greatly in the coming years.

The large data volumes generated by, e.g. genome sequencing and biological imaging create rapidly growing needs for high-speed data networks, data storage, analysis, and informatics. Resources need to be strengthened so that Sweden does not lag behind.

Physics and engineering sciences

Joint research infrastructures first developed in the field of physics, e.g. to search for answers about the origins of the universe and nature of matter. Since the facilities required have become increasingly larger, they have become too extensive and expensive for a single university or country to develop. Hence, researchers are collaborating at national, international, and global levels to construct and operate the facilities needed for new advancements. Large, specialised infrastructures are still primarily centred on astronomy, subatomic research, and nuclear technology.

Several of the questions pursued in astronomy and astrophysics are completely dependent on research infrastructures. Traditionally, astronomy has developed through studies of optics and radio wavelength. In recent decades, observations in infrared, x-ray, and gamma wavelength research have come to play a central role in increasing our understanding of the physical processes, e.g. when stars interact, supernovas explode, and galaxies collide. In all areas, ground-based and space observations complement each other. The space-based infrastructure is not addressed here but handled by the Swedish

The Antennae galaxies as viewed by ALMA and the Hubble telescope. While visible light shows us the stars of the galaxies, ALMA shows us something that cannot be seen in visible light: the clouds of densely-packed cold gas from which new stars are formed. This is the best submillimetre image of the Antennae galaxies that has ever been produced.

PHOTO: ALMA (ESO/NAOJ/NRAO); VISIBLE LIGHT IMAGE: THE NASA/ESA HUBBLE SPACE TELESCOPE.

National Space Board. In astroparticle physics, researchers particularly study the particle flow from astrophysical sources and the fundamental characteristics of these particles. Each of the areas study different aspects of the unknown energy types, dark matter and dark energy, which according to new findings comprise 96% of the energy content of the universe.

In high-energy experiments, researchers collide high-energy particles to study the innermost structures of matter and the forces at work there. The standard models in particle physics answer many of the questions concerning the structure and stability of matter with its six quarks, six leptons, and four powers. The standard models, however, leave many questions unanswered such as: Why are there only three types of quarks and leptons? How do particles acquire their mass? Are there more particles and powers? Are quarks and leptons actually fundamental, or do they also have a substructure? Which particles can give rise to dark matter in the universe?

Researchers also want to study highly interactive matter under extreme conditions such as high temperature and energy density. Collisions between the nuclei of heavy atoms at very high energies are expected to produce a conversion from matter built of interacting particles (hadrons) to a new state of matter (quark-gluon plasma). This state prevailed during the first microseconds after the Big Bang. The particle collisions that take place in laboratories are "small bangs" that can be repeated to experimentally study the state in the early universe.

Nuclear physics involves studies of structure, dynamics, and general characteristics of systems held together by the strong forces, everything from hadrons to atomic nuclei. These systems correspond to 99.9% of visible matter. Studies have led to discoveries and methods that have become highly useful to society, e.g. medical treatments and diagnostics, nuclear energy, radiometry, and carbon-14 methods for dating. However, our understanding of the strong interaction is incomplete, and therefore methods of basic research in nuclear physics are continually moving forward.

Development in nuclear structure physics is moving towards utilising beams of rare radioactive isotopes. This enables the study of atomic nuclei having extreme relationships between the numbers of neutrons and protons. Studies of such exotic atomic nuclei are directly associated with the formation of basic elements since the relevant processes, e.g. in stars and supernovas, involve these to a significant degree.

Need for new infrastructures or actions

The progress that has been made in recent decades in astronomy, astrophysics, and astroparticle physics is largely a result of new instruments and telescopes that enable the detailed study of increasingly dim objects. To come closer to answers for fundamental questions, e.g. questions about the conditions for life in distant solar systems or the properties of dark energy and dark material, researchers need optical telescopes with light collecting surfaces that are larger and resolutions that are higher than today's equipment. Also, radio telescopes with substantially higher sensitivity will be important in this research. Swedish astronomers have given highest priority to the planned European giant telescope, E-ELT, among the future infrastructure projects in astronomy, and the Council for Research Infrastructures preliminarily agreed to Swedish participation at the end of 2010. E-ELT is an optical telescope with a mirror about 40 meters in diameter and will be the world's largest optical telescope. Observations with E-ELT will help answer questions about planets in planetary systems beyond our solar system, follow the emergence of large-scale structures in the universe from the time when the first stars appeared and up to the present, and test the boundaries of physics in the history of the universe by studying the conditions in the strongest gravitational fields and possible variations in the natural constants. E-ELT will represent a quantum leap in optical and infrared astronomy. The European Southern Observatory (ESO) will manage the project, and a decision on its construction is expected in 2012.

Other new astronomy projects of high priority, but are in the more distant future, include the radio interferometer Square Kilometre Array (SKA), the Cherenkov Telescope Array (CTA) gamma-ray instrument, and the European Solar Telescope (EST). Participating in international astronomy projects presents opportunities to Swedish researchers to participate in developing instrumentation and technology, which has the potential to develop further through coordinated initiatives by public agencies and the business sector. Astronomy has strong drawing power in the younger generation, and is therefore a way to stimulate interest in natural and engineering sciences.

New accelerators, where particles of different mass can be collided at much higher energies than currently possible, are necessary to answer the fundamental questions about the origins of the universe and how physical forces interact. One question, for example, concerns the existence of the Higgs boson. The LHC accelerator at CERN began its physics programme during 2010. The accelerator collides protons and heavy atom nuclei at energies that have not yet been available anywhere in the world. The high collision energy and large number of collisions has opened a new window into the particle world, and some aspects of the so-called "standard model" in particle physics have already been thoroughly mapped at higher energies than previously. Even though LHC has not reached its full capacity, an extensive upgrading to a super LHC is being planned to increase the number of particle collisions and thereby improve the basis for analysis. Although the cost of the accelerator is covered within the CERN budget, the upgrade of the detectors will be covered by the international consortium, where Sweden is participating in two of the experiments, ATLAS and ALAS. The LHC programme will continue into the 2020s, with significant upgrades in radiation intensity planned for 2017 and 2021-2022. Upgrades are necessary to fully utilise LHC and to replace parts that are damaged by radiation. In parallel with the super LHC, plans are under way for the next generation of linear accelerators, ILC and/or CILC, which can complement LHC by enabling measurements with even greater precision.

Nuclear and hadronic physics have entered a phase where Europe and the world are investing heavily and planning accelerator facilities with capacities that widely exceed existing ones. The Facility for Antiproton and Ion Research (FAIR) is under construction in Germany and will produce beams of radioactive isotopes and antiprotons with the intent to understand the inner structure of matter and the conditions that existed directly after the Big Bang, before either atoms or protons and neutrons had been able to form. Although most of the project has been funded, there are a few remaining modules that are important to fully utilise FAIR. The timeframe for this later phase is approximately 2016 and onwards.

Need for e-Infrastructure

What the described infrastructures in physics and engineering sciences have in common is that they all produce an enormous volume of data that must be analysed. Hence, physicists have been promoting the development of, e.g. grid technology where processing and storage of data is distributed across a worldwide network of data centres. Sweden has actively participated in this development at the European, Nordic, and national levels. New investment in infrastructures in astronomy and subatomic physics will continue to require extensive development of rapid data networks, hardware, data storage, and grid technology.

No single computer architecture can optimally serve all research facilities. Rather, Swedish researchers should continue to be offered access to a broad spectrum of data resources, such as rapid networks, traditional supercomputers, massive parallel computing, and grid resources, and probably also to distributed systems that utilise inactive work stations. [13]

[13] http://boinc.berkeley.edu/

Materials science

Our everyday lives are controlled largely by the characteristics of solid material. Functions of a material include its hardness, plasticity, conductivity, magnetism, transparency, or corrosive durability. Properties like these determine the quality of construction material used in houses, bridges, automobiles, and aircraft, the functional material that comprises the basis for microelectronics, drugs, and fuel cells. Life itself, with its cells and molecules, is also an advanced form of material. Hence, materials science can be viewed as a collective name for several different research areas in physics, chemistry, geology, and biology where researchers often work together across disciplinary boundaries. Modern materials research aims to increase understanding about material at the atomic level and to develop material with new characteristics. An important development is in the area of nanomaterials with structures that are only a few tenths of millions of a millimetre in size. When dimensions are so small, the properties change radically due to effects of quantum mechanics, surface form, and the surface/bulk relationship that gives rise to new phenomena and characteristics. In developing high-resolution artificial structures, multidisciplinary research targets the interface between life sciences and materials. This may include, e.g. separate miniaturised systems for studying the processes and structures in and between cells. Eventually this can lead towards developing methods for diagnosis and therapy.

In addition to the advancements in nanomaterials, scientists are developing multifunctional materials that combine several properties, e.g. magnetic, catalytic, and electrical properties. Materials of this type are used, e.g. in sensors and in so-called "intelligent materials".

Materials research is largely an experimental science, and is clearly becoming multidisciplinary. Nevertheless, advancements in modern computers make it possible to use theoretical calculations and/or simulations to predict material properties with high precision. Theoretical materials research contributes towards rapid advancement, a reduced need for experiments, and can predict and explain different properties. Theoretical materials science and material simulations represent an area of strength in Sweden.

Traditionally, Sweden has played a strong role in materials research, and much of the nation's export revenue is based on materials and material-based products. Areas of strength in Sweden include steel and metal research, semiconductor research involving silicone chips and optical semiconductors, research on fibres and polymer materials, research on biomaterials and biocompatible materials, thin film synthesis, and classification of materials, e.g. surface analysis and microscopy.

Andre Geim and Konstantin Novoselov shared the 2010 Nobel Prize in physics for the discovery of the material graphene – a substance with largely the same properties as graphite, but which consists of a sheet that is only one atom thick. The atoms are arranged in a hexagonal pattern, which gives the material unique properties. Materials research is a multifaceted and infrastructure-demanding area that requires access to advanced equipment. The heavy demands on infrastructure created a culture at an early stage that involved both coordination and co-utilisation of advanced equipment. This also gave rise to creative research environments such as those that have grown up around synchrotron radiation facilities, neutron scatter facilities, and clean room laboratories.

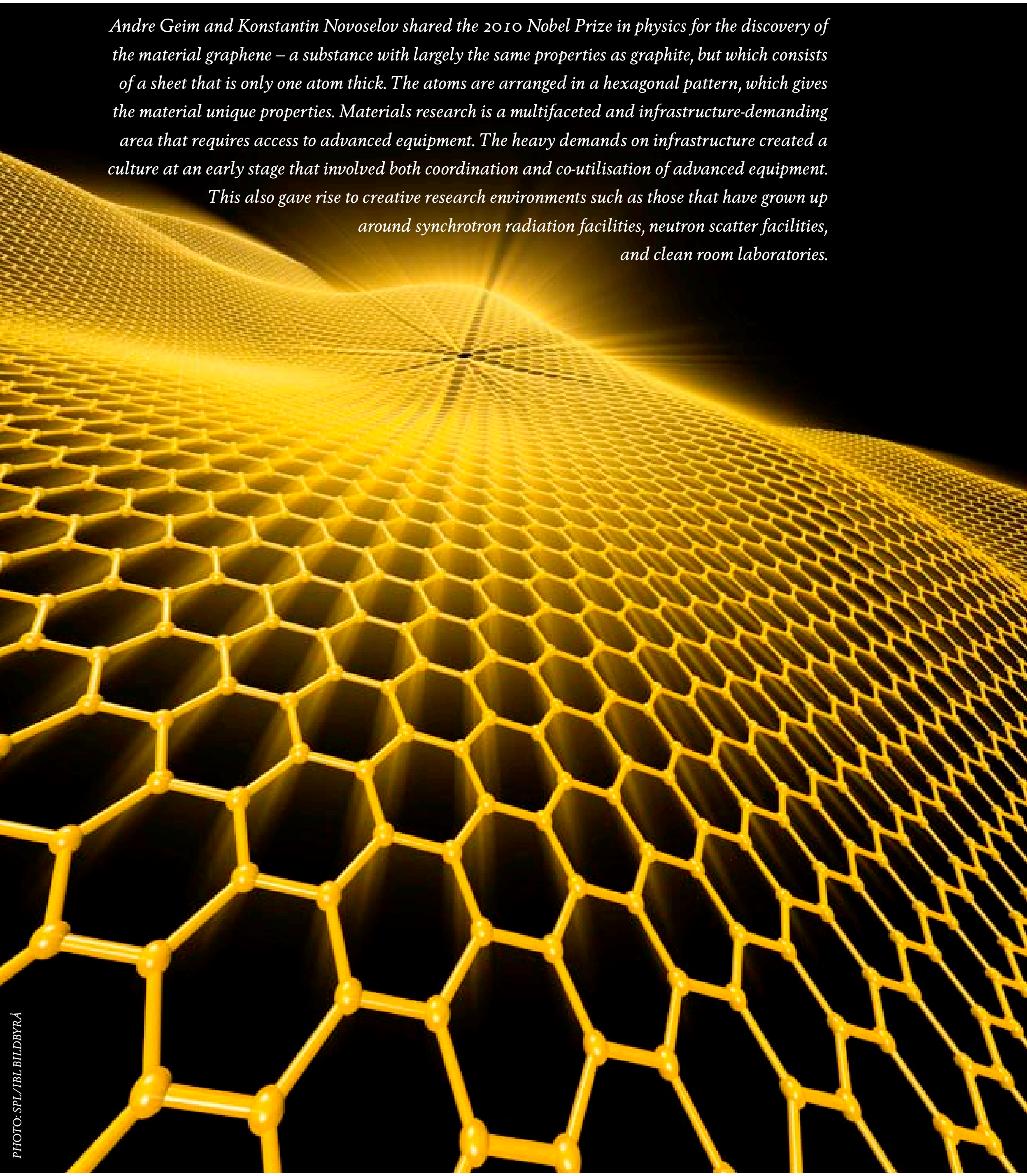


PHOTO: SPL/IBL BILDBYRÅ

The heavy demands on infrastructure created a culture at an early stage that involved both coordination and co-utilisation of advanced equipment, which also promoted a creative research environment. Examples of such environments are those that have grown up around synchrotron radiation facilities, neutron scatter facilities, and clean room laboratories.

The Swedish Research Council has appointed a working group tasked with analysing the consequences of the new initiatives involving neutron, synchrotron, and free electron laser infrastructures and related research.

Need for new infrastructures or actions

Materials science is a multifaceted and infrastructure-demanding area that requires access to advanced equipment spanning the entire field from materials production to analysis and measurement of their properties. Furthermore, it requires access to advanced simulation and computing tools and databases. This requires a combination of infrastructures, including large-scale facilities, networks of local structures, and freestanding tools that serve as "work horses". A review of the long-term needs in this area should consider developmental trends, balance between different subcomponents, and the roles of the Swedish Research Council and higher education institutions.

Modern clean room laboratories are used to produce, structure, and analyse the most appropriate materials for various applications, e.g. electronics, sensors, optics, solar cells, biotechnology, and medical technology. Sweden has a network of clean room laboratories for micro- and nanostructuring (Myfab), which coordinates resources and gives researchers access to nanostructuring and analysis. Given the rapid advancements in the materials' field, there is a continual need to upgrade equipment (e.g. high-resolution microscopy and ion implantation), and further development of Myfab is essential to efficiently develop resources in the nano/material field.

Among the analytical methods that have rapidly increased in use are measurements based on x-ray and neutron radiation at synchrotron radiation and neutron facilities. In 2010, the Swedish Research Council joined with VINNOVA, Lund University, and Region Skåne in financing the construction of the next generation synchrotron radiation source, MAX IV. This will perform well above other synchrotron radiation facilities, but achieving its full potential utilisation requires the development of experimental stations consisting of 20 beamlines, an estimated two per year for the next 5 to 6 years. This will be described in the strategic plan for MAX IV in 2012 (calls for grant applications and evaluation of competing proposals will ultimately determine what is built). In addition to Swedish financing bodies (e.g. research councils, foundations, and universities) other interests in the

Nordic countries, Europe, and the business sector are expected to contribute towards construction. Sweden is also participating in the construction of a beamline at the new German synchrotron PETRA III in Hamburg.

Free electron lasers offer new possibilities to monitor ultra-rapid processes. They can be used to follow chemical reactions or electrical charge distributions and also to image individual molecular structures, e.g. membrane proteins that cannot be crystallised. Since 2009, Swedish researchers have participated in developing the XFEL facility in Germany and are also among the most active users of existing free electron lasers, e.g. FLASH in Hamburg and LCLS in Stanford. The ESFRI roadmap describes the distributed network for infrared-soft x-ray free electron lasers (EuroFEL) where MAX-lab is the Swedish partner in the planning process.

In material analysis, the development of new spallation sources for neutron radiation represents a major success. Information from neutron scattering experiments complements that from synchrotron radiation facilities and is particularly strong in studies of hydrogen-containing systems such as polymers, biomolecules, fuel cell material, and studies of molecular dynamics and magnetism. Swedish researchers currently use the neutron sources ILL in Grenoble and ISIS near Oxford. Preparations are under way for a more powerful pan-European neutron source, the European Spallation Source (ESS) planned for construction in Lund. The decision to start construction is expected in 2013 and, if so, the facility could produce its first neutron beams in 2019. It is essential that Swedish researchers participate in developing the instrumentation for ESS, e.g. by utilising the opportunities given by the contract for research collaboration with France to develop expertise in neutron scattering technology. To best utilise the potential that the new facilities for x-ray and neutron radiation based experiments (primarily in Lund and Hamburg) give to Swedish research, a long-term plan (e.g. for supplying expertise, developing new technology and experiment stations, and developing test environments, detectors, x-ray and neutron optics) should be produced in collaboration with user groups from universities and industry, the facilities, and funding bodies. Accessibility, including education and information about the opportunities for new user groups, is essential to achieve optimum benefits. Enabling new user groups to utilise the facilities also requires the development of grants for new users. This needs to be done in close collaboration with higher education institutions.

Large research facilities have been an important component in developing Swedish materials research into a strong field. In addition to access to analytical methods at the large research facilities, local equipment and methods are also required to provide complementary information at the atomic and molecular levels, something that universities conducting research in the area should provide. Examples include electron and scanning tunnelling microscopes, electron, neutron, and synchrotron radiation-based diffraction and spectroscopy and also short-pulse lasers.

Need for e-Infrastructures

Extensive simulations and computing have become more common in materials research to predict and understand properties of new material, to test theories for complex material properties, and to interpret experiment results. Hence, access to high-performance computer networks and high-performance computers via SUNET and SNIC is necessary in materials science. To increase accessibility for more research groups, the field needs more experts in applications.

Very large volumes of data will be generated from experimental studies at large facilities such as MAX IV, ESS, and the new free electron laser. This will be followed by the need to transmit and store large volumes of data over a longer period and to make research data available through well-functioning networks. An increased need to remotely control experimental stations and various university-based equipment will change the requirements on services and the quality of services in the network. A special computing centre for ESS is being established in Copenhagen.

e-Science

Technological advancements in recent decades have enabled a new approaches towards research, involving rapid data networks, powerful computers, and processing of large data volumes where researchers can pursue new types of questions and engage in geographically-distributed collaboration. This new approach is referred to as e-Science and covers all subject areas. The computer networks, computing resources, and scientific databases necessary for e-Science, and even for traditional research, comprise a special group of infrastructures. Collectively, these are often referred to as electronic infrastructures or e-Infrastructures. In principle, e-Infrastructures are used in all scientific fields and are a prerequisite for effectively using other research infrastructures. Often, e-Infrastructures are described as *horizontal*, or general, which are used by and necessary for other *vertical*, or subject-specific research infrastructures.

The building blocks required for a national e-Infrastructure landscape are:

- data networks with sufficient capacity and accessibility, including mechanisms for authentication, authorisation, access control, etc based on a system of federated identity management

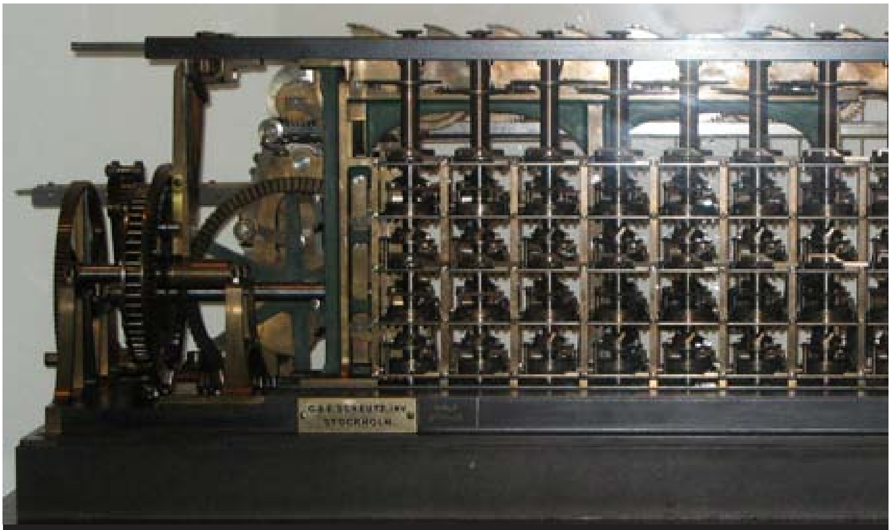


PHOTO: GENI, LICENSIERAD UNDER CREATIVE COMMONS

The world's first functioning difference machine is a mechanical forerunner of today's computers. The machine was constructed in 1843 in Sweden by Per Georg Scheutz and was used to produce mathematical tables. Technical advancements in recent decades have enabled new research methods where the use of high-speed networks, powerful computers, and processing of large volumes of data can address new types of questions and enable broad geographic collaboration. The data networks, computing resources, and scientific databases required for e-Science, and even traditional research comprise a special group of infrastructures that are collectively referred to as electronic infrastructures, or e-Infrastructures.

- computing, analytical, and modelling resources and resources for data storage with sufficient scope and diversity connected to adequate user support
- mechanisms for constructing and maintaining scientific databases
- coordinated development and training to effectively benefit form e-Infrastructures in different areas of application.

For many years, Sweden has had a well-functioning research network, SUNET (Swedish University Network), which gives Swedish researchers access to international data networks and enables participation in international development projects. Since 2002 the SNIC (Swedish National Infrastructure for Computing) meta-centre has coordinated the acquisition and use of large-scale computing and data storage resources for Swedish researchers. Resources for high-performance computing have been developed within SNIC and connected to national infrastructures for distributed computing and data storage, Swegrid and Swestore. The Swedish National Data Service (SND) is a national resource for coordination of existing and new research databases in social sciences, the humanities, and medicine. The corresponding body for climate and environmental data is ECDS, operated by SMHI. In 2006, the Swedish Research Council created the Database Infrastructure Committee (DISC), an expert group assigned to advise the Council on strategic database-related issues.

The e-Infrastructure is not tied to individual projects or individual institutions, but serves society at the national, international, and global levels. The e-Infrastructure is an essential part of a well-functioning research system, comparable to electrical supply and the electrical power grid in society. For instance, different combinations of e-Infrastructures are essential in each scientific area and are a prerequisite for all infrastructures described in this guide. Well-functioning data networks, extensive computing resources, and in many cases well-structured scientific databases are needed for research that relies on accelerators, telescopes, fusion experiments, laboratories, sensors, spectrometers, digitised archive data, lasers, and equipment in medicine and biotechnology.

Within the framework of the government's initiative on strategic research areas, two Swedish e-Science research environments have been formed. They consist of networks for different research groups with expertise in the generic core areas of e-Science and areas of application in e-Science. They comprise a new type of bridge between generic e-Infrastructures and several research areas. Material research, climate research, and life sciences (bioinformatics, complex diseases, evolution, etc) are examples of central research areas in these environments.

Coordination of e-Infrastructure obviously has synergy effects when planning other types of infrastructures. The networks are used both for mass storage and to access databases and computing resources, and they are an integrated part of distributed infrastructures such as federated databases and computing systems. Databases can benefit from mass storage systems and can be used in conjunction with calculations on high performance computers. Technology development is another area where these types of infrastructures share common ground.

Need for new infrastructures or actions

The need for a balanced e-Infrastructure landscape for existing research, and related to the new national infrastructures under construction, is growing rapidly. Concurrently, several groups, e.g. in life sciences, are dependent on e-Infrastructure tools, and several new large-scale national and international initiatives in research and research infrastructures need new types of e-Infrastructure environments.

In this context, e.g. the e-IRG Blue Paper [14] and the Swedish Research Council's evaluation of SNIC in 2010 describe a need to shift the focus from specific hardware resources to advanced user support and development of complete e-Infrastructure platforms adapted to the needs of different groups. The e-Infrastructures should be developed in cooperation with e-Application experts, researchers, and those responsible for infrastructures in different research areas.

To manage the explosive growth of data in networks, hybrid networks of high quality and bandwidth between specific points are required alongside of the service functions available in the standard network. New solutions for very large-scale computing, distributed computing, data management, and data storage need to be developed. In this process, one needs to analyse the cost effectiveness and user needs for different types of solutions, including conventional data centres, grids, and cloud solutions or combinations thereof. Distributed e-Infrastructures require development of authentication methods to establish the user's identity, authorisation to establish the user's right to access different components of the infrastructure, and an accounting of resources and costs when infrastructures span several administrative domains and national boundaries. New approaches in terms of applications also lead to demands for new principles of authentication and allocation of resources.

It is important for Sweden to participate in the development of e-Infrastructures at the Nordic, European, and global levels and to integrate national solutions with these levels. Regarding large-scale infrastructures in different research areas, shared needs for e-Infrastructures must be identified, and solutions must be found to guarantee interoperability to the extent possible. Regarding large-scale research and infrastructure initiatives, the financing options for e-Infrastructures must also be identified, and overall cost effectiveness must be calculated to avoid the construction of several parallel e-Infrastructures.

Through SNIC, Sweden participates in international collaboration in the e-Infrastructure arena, e.g. the PRACE computing infrastructure, the EUDAT storage project, and the EGI and NDGF grid organisations for distributed computing and data storage. At the Nordic level, an action plan has been prepared for joint initiatives within the eNORIA group of Nordforsk. This was launched at the end of 2011 via the Nordic Council of Ministers' framework for globalisation initiatives in e-Science. These joint efforts require resources and developmental work, and they are expected to provide Swedish e-Infrastructures with important benefits in expertise and coordi-

[14] http://www.e-irg.eu/images/stories/eirg_bluepaper2010_final.pdf

nation, and also give Swedish researchers opportunities to utilise international resources.

To effectively use and develop national and international e-Infrastructures, a detailed map of user and developmental needs in the short and longer term should be presented as a rolling 5-year plan. A coordinating group involving SNIC and SUNET is needed for technical development, and other collaborating bodies are needed to develop e-Infrastructures in several research fields.

The need for advanced user support, particularly to meet the needs of larger research initiatives and user groups, places new demands on existing e-Infrastructures. Further e-Infrastructure initiatives are required to cover the needs in environments experienced in large-scale communications, computing, and storage (physics, astronomy, chemistry, etc) and in areas where the need for e-Infrastructures has emerged later (biology, medicine, environment, climate, social sciences, the humanities, etc):

- Access to data storage resources and related service functions needs to be enhanced. Groups in fields ranging from physics and life sciences to language sciences and other areas are demanding new service functions and storage resources in Swestore.
- In a longer time perspective, a continued Swedish initiative for very large computing resources should be connected with PRACE. A replacement for the current system needs to be constructed during 2014, either in Sweden or through Nordic collaboration.

DESCRIPTIONS OF NEW OR UPGRADED INFRASTRUCTURES FOR FUTURE INITIATIVES

Social sciences and the humanities

CESSDA – Council of European Social Science Data Archives

CESSDA is a European infrastructure for social science data. The Swedish National Data Service (SND) serves as the Swedish partner. An application to form CESSDA-ERIC (European Research Infrastructure Consortium) is planned for submission during 2012. Through CESSDA, researchers can access data from over 20 countries in Europe, and through the organisation they can participate in global data collaboration with many countries outside of Europe.

CESSDA includes approximately 25 000 databases and is used by over 30 000 researchers. The data come from the social sciences, e.g. election surveys, opinion polls, and other questionnaire studies.

CESSDA is participating in a process to establish CESSDA-ERIC that will serve as a node for data archives in the Member States (SND in Sweden). CESSDA-ERIC will assure that all members meet common standards. This will enable, e.g. the creation of a European *research passport* giving researchers and data the opportunity to move virtually unhindered across European borders. A common financial base for the project can improve international efficiency and more fully integrate the national data archives. CESSDA will inventory data of international value, describe and document data, and facilitate contacts among data users in different countries. CESSDA will also address regulations on personal security and copyright aimed at strengthening access to data while protecting copyright and developing new methodology and software for data analysis.

The project presented in the ESFRI roadmap from 2006 involves 30 million euros (EUR) and intends to upgrade common documentation systems, develop researcher support, and develop software to serve the distributed environment. CESSDA is also working to incorporate and support new members in the network. At the end of 2011, the Council for Research Infrastructures decided to work towards Swedish membership in CESSDA-ERIC.

The Swedish Research Council aims to investigate the need for infrastructures in the area of language technology, e.g. related to CLARIN (Common Language Resources and Technology Infrastructure) intended to create an integrated and standardised research infrastructure for language resources.

PHOTO: SCANPIX

CLARIN – Common Language Resources and Technology Infrastructure

CLARIN is a European initiative to create an integrated and standardised research infrastructure for language resources, which involves data resources including text and sound archives, corpora (collections of language data), speech databases, dictionaries, grammarians, etc and the technologies and tools needed to store, distribute, and work with data resources – both primary and derived data. These language resources represent an important component in language technology research and development and in the various areas of language sciences generally. Potentially, language resources can play a role in all humanistic and social science disciplines where text and speech are key study objects.

From the outset, CLARIN has targeted: a) researchers in language technology responsible for developing language resources and language tools for the infrastructure and b) researchers in the humanistic and social science disciplines that comprise the primary users of the infrastructure. Eight Swedish institutions are members of CLARIN, the majority of which are also members of a Swedish consortium to create Swedish language resources similar to those targeted by CLARIN. Two basic components comprise the main focus:

(1) A set of language resources (corpora, lexicon resources, speech databases, terminology databases) coordinated with the help of standardised formats and programming interfaces, etc in a basic language resource kit (BLARK).
(2) A national reference corpus with a large and representative set of written and spoken genres. In addition to primary data in language research, such a language database would serve both as training data and standard evaluation measures in developing language tools.

During 2012, the Swedish Research Council intends to evaluate the need for infrastructures in the area of language technology, e.g. related to CLARIN, and how Swedish collaboration should be organised.

CLARIN is presented in the ESFRI roadmap from 2006 and is planned to become an ERIC, which is expected to start up in 2012.

DARIAH – Digital Research Infrastructure for the Arts and Humanities

DARIAH aims to create a coordinated technical infrastructure to improve and reinforce digitally based research in the humanities. The preparatory phase for DARIAH ended in February 2011, and since then the organisation has worked on submitting a DARIAH-ERIC application to start the construction phase. Within the framework of this project, an agreement has been reached and signed by more than ten countries.

The Swedish National Data Service (SND) has participated in the preparatory phase as an associated partner and is monitoring the development of DARIAH.

ESS – European Social Survey

The European Social Survey is a researcher-initiated study of attitudes and behaviour that has been conducted five times in over 30 European countries since it started in 2002. The social survey is designed to describe and explain the interaction between Europe's changing social structures and the attitudes, perceptions, and behaviours of its culturally and socially diverse populations.

ESS conducts high-quality measurements of social conditions and changes in Europe's populations. Another aim is to increase the comparability of questionnaire surveys across borders and language barriers and to develop and implement social indicators alongside of the well-established economic indicators.

ESS provides data freely via a website open to all. Currently, five surveys can be accessed. The sixth round of the ESS is being planned for 2012-2013, and the seventh for 2013–2014.

In 2010, the Swedish Research Council ratified an agreement to continue the construction phase by developing statutes prior to applying for ESS-ERIC as planned at the end of 2011. Sweden has played an active role in ESS and is expected to continue to participate in the new organisation. At the end of 2011, the Council for Research Infrastructures decided to pursue Swedish membership in ESS-ERIC.

SHARE – Survey of Health, Ageing, and Retirement in Europe

SHARE is an interdisciplinary, interview-based survey on health, ageing, and retirement in Europe that is conducted in 15 European countries, e.g. Sweden, and includes 45 000 individuals over 50 years of age. SHARE aims to increase understanding concerning the consequences of the ageing population. The survey focuses on, e.g. work force supply, opportunities for gainful employment, social and economic conditions, family networks, and physical and mental health among people over 50 years of age. SHARE started in 2002 and is planned to continue until 2023, at which time it will have covered 10 rounds of data collection. [15]

At the European level, the Mannheim Research Institute for the Economics of Ageing (MEA) in Germany manages SHARE. FAS finances Sweden's participation in the European collaboration.

In March 2011, SHARE became the first infrastructure in Europe to receive status as a European Research Infrastructure Consortium (ERIC). Sweden

[15] Översyn av de nationella kvalitetsregistren. Guldgruvan i hälso- och sjukvården. Förslag till gemensam satsning 2011-2015. [Overview of the national quality registers. The gold mine in health care. Proposal for joint initiative, 2011-2015].

The SHARE infrastructure is a multidisciplinary, interview-based survey conducted in 15 European countries. SHARE aims to increase understanding concerning the consequences of the ageing population. In March 2011, SHARE became the first infrastructure in Europe to receive status as a European Research Infrastructure Consortium (ERIC). Late in 2011, the Council for Research Infrastructures decided to pursue Swedish membership in SHARE-ERIC.

PHOTO: SCANPIX

is not a member of SHARE-ERIC, but late in 2011 the Council for Research Infrastructures decided to pursue Swedish membership while financing a parallel Swedish infrastructure on a trial basis.

Register- and personal-data-based infrastructures

Sweden, through its system of personal identification numbers and registers that cover the entire population, has unique opportunities to study urgent, multidisciplinary issues addressing the associations between social conditions, economics, and health. Moreover, Sweden has access to extensive biobank material that has been collected over many years for research and medical care purposes. By retrieving and linking biological information from tissue specimens with personal data from registers, the conditions are created to understand associations underlying several major diseases, e.g. cardiovascular disease and cancer. Sweden has extremely favourable conditions to become a leader in this type of research. The problem identified in the most recent (2008) [16] government bill on research and innovation was that these data sources are underutilised, and coordination of infrastructures and databases is limited. The government bill also mentions that regulations and laws for shared utilisation of registry data and other data may need to be reviewed and adapted to new organisational and technical conditions. [17]

The Swedish Research Council recognises that such coordination and supervision of the technical, organisational, and legal conditions within the area of registry data have yet to be achieved, but considers this extremely urgent. Therefore, the Swedish Research Council will continue to pursue the creation of a national infrastructure concerning personal data for research purposes.

SND – Swedish National Data Service

The Swedish National Data Service is a service organisation for Swedish research in the humanities, social sciences, and medicine. SND was established on 1 January 2008 on the initiative of the Swedish Research Council. It is managed by Göteborg University and financed jointly by the Swedish Research Council and Göteborg University.

During 2011, on the initiative of the Swedish Research Council, an international panel evaluated SND. The evaluation panel concluded, e.g. that SND's mission needed to be further clarified before it could fulfil its role as a national infrastructure to coordinate existing and new research databases in its sphere of responsibility and as a service organisation for researchers

[16] Prop.2008/09:50 s.190–191.

[17] *Översyn av de nationella kvalitetsregistren. Guldgruvan i hälso- och sjukvården. Förslag till gemensam satsning 2011-2015*. [Overview of the national quality registers. The gold mine in health care. Proposal for joint initiative, 2011-2015].

throughout the research process. In 2012, several actions will be proposed and initiated to clarify SND's mission in accordance with the needs identified during the evaluation. A clearer mission statement for SND should be formulated in relation to the other actors involved in the field of register-based research in Sweden.

Survey data and longitudinal studies

The Swedish Research Council, in collaboration with FAS and the Bank of Sweden Tercentenary Foundation, has initiated an inquiry to determine which of the existing survey databases and longitudinal studies have the greatest value for Swedish research and whether there are possibilities to increase coordination and improve quality. The inquiry is planned for 2012.

Environmental sciences – planet earth

ANAEE – Analysis and Experimentation on Ecosystems

ANAEE, an infrastructure initiative for experimental ecology, was presented in the ESFRI roadmap from 2010. The aim is to develop a new concept with an integrated European infrastructure involving controlled experiments in forestry and agro-ecosystems and natural ecosystems. The concept involves both experiments *in situ* and in ecotrons where parts of ecosystems are studied under controlled conditions indoors. Umeå University is coordinating the participation of Swedish researchers in the planning phase.

EISCAT/EISCAT-3D – European Incoherent Scatter Facility

EISCAT uses two high-energy radar systems primarily to study how solar winds interact with the ionosphere. The systems are located on the mainland with transmitters in Tromsö and receiver stations in Tromsö, Kiruna, and Sodankylä, and two antennae on Svalbard. China intends to build a third antenna on Svalbard. EISCAT-3D, from the ESFRI roadmap in 2008, is a major step in the development of EISCAT and is being taken to stay on the scientific forefront. The planning of EISCAT-3D is managed at EISCAT's headquarters at the Swedish Institute of Space Physics in Kiruna and is financed by the EU Commission and the Swedish Research Council.

EMBRC – European Marine Biology Research Centre

EMBRC is an infrastructure to connect European coastline marine laboratories as regards genetic studies and access to model organisms. EMBRC was presented in the ESFRI roadmap from 2008 and receives grants from the EU Commission for the planning phase. The Sven Lovén Centre for Ma-

PHOTO: LARS-GÖRAN VANHAINEN

In 2011 the UHF antenna in Kiruna, part of the Swedish radar facility EISCAT, had been operational for 30 years. The antenna enables observation of the northern lights and other phenomena.

rine Sciences at Göteborg University coordinates EMBRC, giving Sweden a leading role in the project.

EMSO – European Multidisciplinary Seafloor Observatory

EMSO is a deep ocean based observation system that aims to develop and construct several underwater observatories for marine research to study biology, water chemistry, georisks, etc. The ESFRI roadmap in 2006 presented a plan for European collaboration. Göteborg University is coordinating Swedish interests.

EPOS – European Plate Observing System

EPOS aims to create a European infrastructure to study movement in the earth's crust, including processes leading to earthquakes, volcanic eruptions, and tsunamis over the long term. EPOS was presented in the ESFRI roadmap from 2008 and plans to continue its work through grants from the Seventh Framework Programme of the European Union. Uppsala University coordinates the participation of Swedish researchers in the planning phase.

GBIF – Global Biodiversity Information Facility

GBIF is a global network that aims to make data and information on biological diversity more accessible for scientific research. Through a virtual library under construction, information is being collected on all species on earth. Information on the molecular, genetic, ecological, and ecosystem levels is being registered. The Swedish Museum of Natural History hosts the Swedish GBIF node.

ICOS – Integrated Carbon Observation System

ICOS aims to coordinate and develop European measurements of carbon dioxide exchange between the ground and atmosphere. Measurement stations for this project are located all around Europe. A Swedish node is coordinated from Lund University. Planning is under way for a European ICOS involving Swedish participation.

ICDP/SDDP – International Continental Drilling Program/ Swedish Deep Drilling Program

With grants from the Swedish Research Council, a Swedish infrastructure, the Swedish Deep Drilling Program (SDDP), is being developed within the International Continental Scientific Drilling Program (ICDP). The programme focuses on basic scientific problems, but questions often relate directly to the economy and environment, e.g. geothermal energy and carbon capture and storage are studied with deep drilling,

IODP – Integrated Ocean Drilling Program/ECORD

Sweden participates in the Integrated Ocean Drilling Program (IODP) through the European Consortium for Oceanic Research Drilling (ECORD). The overarching goal of the programme is to conduct testing in all oceanic areas and in all types of geological stratification. The current programme will conclude during 2012, and discussions are under way regarding the design of a new programme.

LifeWatch

LifeWatch is an attempt to construct and coordinate European e-Infrastructures for research on biodiversity and sustainable development, as outlined in the ESFRI roadmap from 2006. It focuses on developing systems for modelling and data exchange and creating networks among existing biodiversity monitoring systems. A Swedish infrastructure is being constructed at the Swedish University of Agricultural Sciences. Planning is under way for a European LifeWatch with Swedish participation.

LTER – Long Term Ecological Research

LTER is a European network for long-term ecological studies at research stations. The Swedish Research Council supported the admission of Swedish LTER into the international LTER network in 2010, but has not decided on financing. LTER is closely linked to the Swedish Research Council's initiative to coordinate research stations.

Nordsim – Nordic Secondary Ion Mass Spectrometer

A pan-Nordic resource for geological research located at the Swedish Museum of Natural History in Stockholm. The instrument is used in several branches of geology and the mining industry to measure the composition of isotopes and basic elements in specimens.

ECDS – Environmental Climate Data Sweden (previously SND-KM)

The Swedish Research Council has established a national data centre for climate and environmental research, with SMHI serving as host. ECDS aims to construct a national organisation that can manage metadata and certain data from research projects involving climate and the environment in a broad sense. Moreover, the data service should support the work of researchers and higher education institutions by creating its own permanent databases that meet requirements regarding standards and searchability. ECDS is also an operative resource for the Swedish Research Council's ongoing effort to increase researcher accessibility to data.

SIOS – Svalbard Integrated Observing System

SIOS, a Nordic infrastructure initiative, aims to integrate the research activities that several countries (mainly European) are conducting on Svalbard

PHOTO: SCANPIX

During 2011, the Swedish Research Council investigated the possibilities to increase coordination of Swedish land-based research stations, one of which is the Abisko natural sciences station. The study indicated that increased national coordination and improved user support would enhance the already strong Swedish profile in this area and would open further opportunities for Swedish stations, e.g. to become involved in EU projects.

and also increase the capacity for research and observations on and around Svalbard. Swedish researchers are participating in the planning phase of SIOS, which was presented in ESFRI's roadmap from 2008.

Research stations

During 2011, the Swedish Research Council investigated the opportunities to increase coordination of Swedish land-based research stations (Infrastructures for Field-Based Ecological and Environmental Research, Kjell Danell 2011 [18]). The inquiry noted that different governing bodies managed the Swedish research stations and coordination was limited. Many stations were used to only a minor extent by others than those operating the station. Others had many external users, and the Abisko station in particular had a large number of international users. Support for internal and external users also varied widely. Increased national coordination and improved user support would enhance the already strong Swedish profile in this area and provide further opportunities for Swedish stations, e.g. to become involved in EU projects. With this inquiry as a starting point, the Swedish Research Council initiated a dialogue with the governing bodies for the purpose of creating a national network of land-based stations and other field-based infrastructures for ecological and environmental research.

Concerning the activities and infrastructures involving marine field stations, the Marine Environment Inquiry [19] emphasised the increasing need for coordination. In responding to the inquiry, the government established the Swedish Institute for the Marine Environment in July 2008. It is essential to evaluate, as quickly as possible, how to strengthen or change the Institute to better contribute towards cost effective utilisation of infrastructures for marine research.

Technical platforms for research concerning planet earth

Several research areas concerning planet earth and its development require high-quality analytical equipment. Traditionally, individual research groups have acquired basic and highly specialised equipment through grants, e.g. from the Knut and Alice Wallenberg Foundation, the Swedish Research Council, and from the universities themselves. Utilisation of the analytical equipment and its accessibility to other research groups varies, and resources for user support and technical maintenance are often lacking.

---

18 *Infrastrukturer för fältbaserad ekologi- och miljöforskning* [Infrastructures for Field-Based Ecological and Environmental Research], Kjell Danell 2011

19 http://www.regeringen.se/sb/d/108/a/104309

Some equipment needs are shared with other research areas. Ecologists use infrastructures for sequencing and proteomics, and climate modellers collaborate with SNIC regarding their needs for computing capacity. Much of the research on climate and the environment requires specialised equipment. For instance, research in geosciences requires access to advanced equipment for imaging and analysis of trace substances and isotopes, environmental chemistry analyses are needed to track and analyse substances that appear in very small quantities in soil, air, and water, zoologists must have access to instruments for bioimaging, etc. Many of these instruments are expensive and require well-trained staff to function effectively and provide reliable results.

Few initiatives are currently under way to coordinate these instruments and build structures so that climate and environmental research will have access to high-quality analytical equipment. An example of such an initiative is in geoscientific imaging and analysis, where the Swedish Museum of Natural History (NRM) coordinated Swedish researchers around certain necessary equipment. The Swedish Research Council approved funding for the initiative late in 2011. Construction of a centre was proposed based on the equipment already available at NRM, and where Nordsim already plays a key role.

Energy research

Energy research requires knowledge from different research fields, including basic and applied research. The need for research infrastructures ranges from facilities for basic material analysis and computing resources to industrial development and dedicated testing facilities. In Sweden, the Swedish Energy Agency has the overarching responsibility for research, but the Swedish Research Council has full or partial responsibility for certain areas, e.g. fusion, nuclear technology, and national research infrastructures. Here, there is strong potential for greater coordination.

MYRRHA – Multi-purpose hybrid research reactor for high-tech applications

MYRRHA aims to create a lead-cooled, fourth generation research reactor. Swedish researchers are participating in the planning phase. Research and development in this area takes place in Sweden through the GENIUS project involving the Royal Institute of Technology (KTH), Chalmers, and Uppsala University. The Swedish groups focus on fuel development, materials research, and safety, with the objective to construct a smaller lead-cooled research reactor in Sweden, ELECTRA (European Lead Cooled Training Reactor) within a decade. The ESFRI roadmap from 2010 presented the project.

Biology and medicine

ELIXIR – European Life Science Infrastructure for Biological Information

The life sciences have undergone major transformation in recent years as the advancements in genomics, proteomics, and other technologies have generated an enormous volume of data. Even the development of large-scale epidemiological studies, lifestyle studies, and technical platforms in, e.g. biological imaging, have generated large data volumes. Since these data need to be stored, analysed, and interpreted, biology and medicine have been moving more towards becoming information sciences where bioinformatics plays a key role. The need for data storage and expertise in bioinformatics is expected to increase in coming years. This places major demands on research infrastructures in bioinformatics to avoid the risk of a bottleneck effect.

At the European level, ELIXIR (European Life Science Infrastructure for Biological Information) aims to build and operate a sustainable infrastructure for biological information in Europe to support research in life sciences and its applications in medicine, environmental sciences, and the biotechnology industry. Hence, ELIXIR will strengthen research and industries that deal with living systems. ELIXIR is comprised of several nodes at different sites in Europe, with EMBL's bioinformatics institute (EBI) as a central node. The advantages of a distributed infrastructure is that the load on data networks, computing resources, and storage resources can be evened out and that European expertise in bioinformatics can be spread across several countries.

Sweden has been a partner in the planning phase of ELIXIR, which is now entering the construction phase. Sweden is participating in ELIXIR through the national infrastructure, BILS, which provides data storage in close collaboration with SNIC. The Swedish contribution to ELIXIR includes data sources and bioinformatic methods that have been developed in Sweden and are of general interest.

The Bioinformatic Infrastructure for Life Sciences (BILS) will be responsible for coordination at the national level and for participating in international collaboration within the Nordic region and Europe. Another function includes education in bioinformatics at several levels. In particular, at the advanced level (doctoral and post doctoral levels) there is much to gain from coordinating resources and providing specialised courses. The Council for Research Infrastructures decided at the end of 2011 to pursue Swedish membership in ELIXIR.

BBMRI – Biobanking and Biomolecular Resources Infrastructure

Biological tissue specimens with associated data on origins and treatment are invaluable resources for studying biological processes. Biobanks manage and store large numbers of tissue specimens worldwide, often through freezing and archiving of specimens and associated information. Better coordination and structuring of biological resources in biobanks would enhance the possibilities to study disease causes and potential treatment methods. Complementing biobanks with advanced informatics is needed if they are to be fully utilised in research. To fully utilise the potential of biobanks it will be necessary to integrate the resources of health services and universities to a substantially higher degree than is currently the case. Integration at the national and European levels would give access to material for research that cannot be accessed today due to different standards, data structures, and regulations on accessibility and exchange of data and biological material between countries. One of the goals of the proposed European Biobanking and Biomolecular Resources Infrastructure (BBMRI) is therefore to establish a common set of definitions and standards to assure comparability and to give researchers access to the large body of validated biological research material. Sweden participates in BBMRI through the Swedish Research Council and through the Swedish national biobanking infrastructure (BBMIR.se).

BBMRI is currently entering the implementation phase, and the decision on applying to become a so-called "ERIC" is expected during 2012. At the end of 2011, the Council for Research Infrastructures decided to pursue Swedish membership in BBMRI.eu.

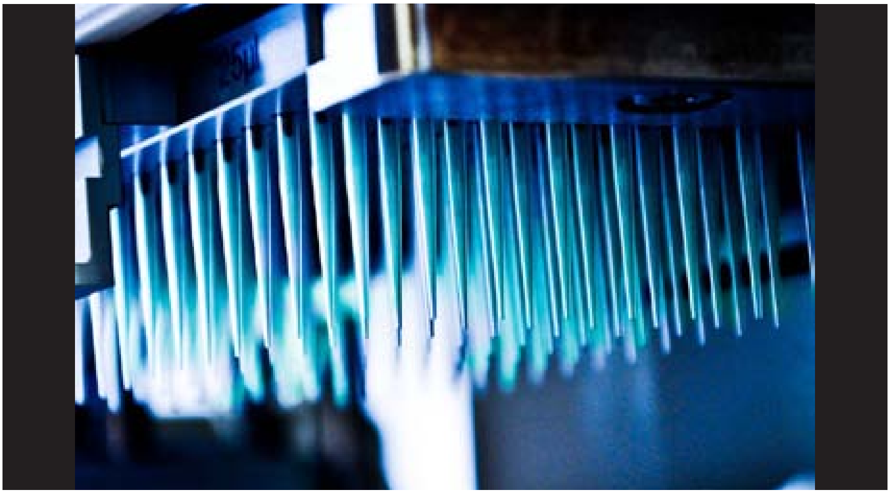


PHOTO: LARS HAMMARSTRÖM, CBCS

The European network EU-Openscreen for open screening platforms in chemical biology includes, e.g. chemistry libraries, databases of screening results, production of new assays, discovery and development of small molecules for further use in research and industry, and education and user support. The Chemical Biology Consortium Sweden (CBCS) is a national infrastructure engaged in, e.g. producing small organic molecules.

EU-Openscreen – European Infrastructure of Open Screening Platforms for Chemical Biology

EU-Openscreen is a European network for open screening platforms in chemical biology. The network includes chemistry libraries, databases with screening results, production of new assays, discovery and development of small molecules for further use in research and industry, and education and user support. CBCS represents Swedish interests.

Structural biology – INSTRUCT/Swedstruct

In recent years, the life sciences have made major advancements, e.g. through mapping the genetic composition of several organisms and studying the variability between individuals. Based on this information, researchers have been able to acquire information on the primary structure of biological macromolecules.

A goal of structure biology is to map, with the highest possible resolution, three-dimensional structures of different biological macromolecules, e.g. proteins, nucleic acids, and complex bonding of different subunits. Access to such information provides a basis for understanding biological functions, which is also the basis for, e.g. structure-based pharmaceutical development.

INSTRUCT, a European initiative, is a distributed research infrastructure that aims to increase the competitiveness of European research in structural biology. The implementation of INSTRUCT is expected during 2012.

Swedish research groups in structural biology have formed Swedstruct, a national counterpart to the European infrastructure. At the end of 2011, the Council for Research Infrastructures decided on financing of the Swedish infrastructure and to pursue Swedish membership in INSTRUCT. The Swedish infrastructure resources in the field of structural biology consist of four centres. MAX-lab in Lund has beamlines for protein crystallography and is planning a beamline for x-ray crystallography, which will improve the effectiveness of determining structures of macromolecules. The Swedish NMR centre for studying molecules in solutions is in Göteborg. Karolinska Institutet is building facilities for cryo-electron microscopy and for large-scale production of recombinant proteins in different types of cells and in cell-free systems in vitro.

ISBE – Infrastructure for Systems Biology

The volume of data on molecular and cellular components at a detailed level is increasing, but our understanding of how these molecules interact in a dynamic, living system is insufficient. ISBE aims to further develop the knowledge from "omics" to descriptions of processes and mechanisms in biological systems. The organisation aims at supplying devices, expertise, and not least computer power and computing. With the help of these resources, simulations and modelling of living systems can be performed based on our knowledge of the biological components. Systems biology will play a key role in our future understanding of biological processes and their regulation. The area will have a substantial need for different types of high-capacity screening, data storage capacity, and computing capacity.

The ESFRI roadmap from 2010 presented ISBE. Sweden has several strong groups in this area, and Swedish researchers are participating in the planning phase with support from the Swedish Research Council.

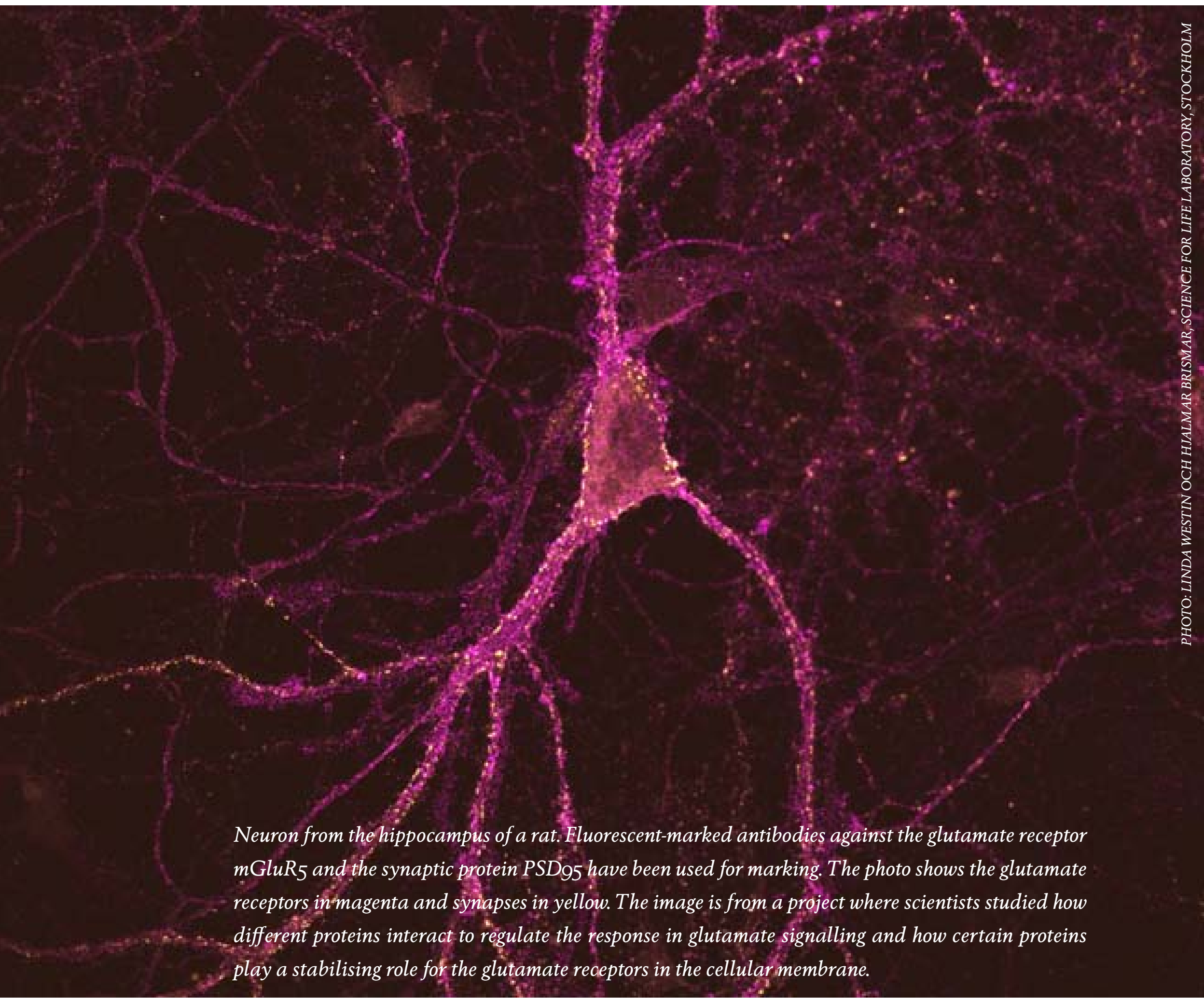
National technical platforms in medicine and life sciences

"Technical platforms in medicine and life sciences (core facilities)" is a general concept that refers to shared, advanced technological equipment and methods that are openly accessible to researchers. These technical platforms offer, e.g. methods for biomolecular analysis, different imaging techniques, and research-orientated surgery/operating rooms. A wide range of professionals staff the facilities, e.g. physicists, biochemists, molecular biologists, veterinarians, and physicians. Technical platforms involve continuous development of methods and instrumentation so that researchers have access to the latest technology. Technical platforms also comprise an educational resource that provides younger researchers access to advanced equipment and methods, enabling them to more quickly establish themselves and their research. Through integrating data from different technical platforms, complicated life processes can be mapped in detail and can provide a clearer image of how organisms function and interact with their environment, a part of systems biology.

In recent years several major investments have been made, for instance by the Foundation for Strategic Research (SSF) and the Wallenberg Foundation, to support the development of technical platforms, e.g. genomics, proteomics, biological imaging. This trend has accelerated, and large-scale technologies based on sequencing fundamentally change the conditions for molecular analysis in medicine and the life sciences. This advancement in next generation sequencing (NGS) encompasses, e.g. DNA sequencing for analysing variations between individuals and organisms, sequencing-based transcriptome analysis, and studies of protein-DNA interactions. Every year, capacity increases substantially while the cost per sequence-determined base steadily decreases, which means that the number of researchers and projects' scope and areas of application will probably grow dramatically in coming years. This trend will require a well-functioning infrastructure and, not least, coordination of existing resources.

Mapping of the genome is insufficient to fully understand protein function since this is influenced by, e.g. post-translational modification that can give the protein completely new characteristics and functions. Key techniques in proteomics are based on mass spectrometry. The construction of reference and service centres with different expertise regarding applications in mass spectrometry are therefore necessary for continued mapping of protein variability, functions, and roles in processes.

The technical platforms available, and those under construction, in Sweden should be organised and developed into national resource centres that have the potential to provide the expertise needed by research in dif-



Neuron from the hippocampus of a rat. Fluorescent-marked antibodies against the glutamate receptor mGluR5 and the synaptic protein PSD95 have been used for marking. The photo shows the glutamate receptors in magenta and synapses in yellow. The image is from a project where scientists studied how different proteins interact to regulate the response in glutamate signalling and how certain proteins play a stabilising role for the glutamate receptors in the cellular membrane.

PHOTO: LINDA WESTIN OCH HJALMAR BRISMAR, SCIENCE FOR LIFE LABORATORY, STOCKHOLM ferent technical areas such as transcriptomics, genomics, proteomics, metabolomics, and biological imaging. The operation and development of the platforms demand scientific and economic longevity and continual advancements in technology and expertise. Collaboration between the Swedish Research Council, universities and higher educations, county councils, and other financers, including coordination of national infrastructures in the government's strategic initiative at SciLifeLab is therefore a prerequisite for continued success in this work. It is necessary to prioritise the technical platforms needed to secure Sweden's competitiveness in biomedicine and life sciences in the long term. The Swedish Research Council intends to further investigate funding needs and types.

Euro-Bioimaging and Swedish Bioimaging

The field of bioimaging has advanced rapidly in recent years, with increasingly higher requirements on advanced facilities and scientific expertise. Imaging technicians in medical research, mainly with the help of new advancements in ultrasound technology, x-ray technology with micro CT, and magnetic resonance imaging (MRI) and positron emission tomography (PET) cameras have enabled researchers and healthcare staff to study biological phenomena in the body without subjecting patients to invasive interventions.

Furthermore, new technologies have advanced rapidly, expanding the boundaries for traditional microscopic solutions. One of several examples is stimulated emission depletion microscopy (STED), which compared to traditional confocal microscopy has improved resolution about tenfold and enabled studies of cellular processes at a completely new level.

Euro-Bioimaging is a European project that aims to coordinate European initiatives and resources in the area of biological and medical imaging. The goal is to make facilities available to European researchers, provide expertise, and make it possible to integrate imaging data with patient information.

The Swedish Bioimaging network is under construction and will form a node in the European network. Swedish Bioimaging is part of the distributed national infrastructure for biological imaging and will coordinate the Swedish imaging facilities. New nodes in the network are expected.

The network includes advanced imaging equipment and scientific expertise, primarily in MRI to begin with, but also Sweden's first ultra-high-field MRI equipment with an intensity of 7 tesla. The latter, located in Lund and financed by the Swedish Research Council, will enable very high-resolution study of the brain and blood flow in the brain. A combined MRI/PET imaging device that offers new opportunities for full body imaging for research, e.g. in cancer, cardiovascular diseases, and neurological diseases, was funded at the end of 2011 and will be purchased during 2012.

Complementary imaging techniques will be needed in several areas, from PET and MEG imaging of processes in living organisms to methods in high-resolution microscopy to study structures and processes in isolated cells and tissue biopsies.

Physics and engineering sciences

CTA – Cherenkov Telescope Array

CTA is a planned detector for high-energy gamma radiation from space. The principles of the detector are based on tracking showers of particles (mainly electrons, positrons, and gamma photons with lower energy) that are formed when energy-rich gamma photons hit the earth's atmosphere. Because of their high energy, the charged particles that are produced move faster than light in air, creating Cherenkov radiation. By using a group of several telescopes, the particle showers can be studied from different angles to determine direction and energy.

Swedish research groups use facilities of similar types and have formed a consortium with participants from Lund, Stockholm, and Uppsala with the aim to participate in CTA. The project draws together astrophysicists and astroparticle physicists that, in addition to pure astrophysical research connected to supernova remnants, pulsars, and active galaxies, assure that CTA with its high sensitivity can provide important answers to questions about dark matter.

The ESFRI roadmap 2008 included CTA. Since American astrophysicists have recently joined CTA, the preliminary studies include approximately 1000 physicists and astrophysicists. The project plan indicates that the detector will be completed around 2018.

E-ELT – European Extremely Large Telescope

The acronym ELT refers to the next generation of giant telescopes. The European Southern Observatory (ESO), of which Sweden is a member nation, has placed an ELT as the highest priority in its long-range strategic plan until 2020. The most important scientific goals for this instrument include: to systematically track and classify planets in planetary systems beyond the solar system; to follow the origin of large-scale structures in the universe from the time when the first stars emerged to the present; and to test the boundaries of physics in the history of the universe through studying the conditions in the strongest gravitational fields and possible variations in the natural constants. The European giant telescope E-ELT has been given highest priority for ground-based astronomy from both Swedish astronomers and ASTRONET, the European Astronomy roadmap.

ESO and its member nations have conducted detailed planning on designing an ELT with a mirror 42 metres in diameter. The planning includes, e.g. industrial contracts for the most critical components in terms of technology

E-ELT is a telescope in the 40-metre class that will capture 15 times more light than today's largest visible-light telescope. The observatory will be built on Cerro Armazones, a mountaintop 3060 metres above sea level in the Atacama Desert of Chile, approximately 20 kilometres from Cerro Paronal, home to ESO's very large telescope (VLT). E-ELT is planned to become operational during the next decade.

PHOTO: ESO

and costs and the first generation of instrumentation. The final decision on the initiative, the total cost of which is estimated to be 1 billion euros, is expected during 2012.

The timeframe for constructing E-ELT is 2012 to 2020. Financing of E-ELT will take place within the framework of the ESO collaboration. The total extra cost for Sweden above the current membership will be approximately SEK 120 million. Special initiatives for Swedish participation in the consortium for instrumentation may be possible.

European Solar Telescope (EST)

European solar physicists are meeting to plan a future European solar telescope (EST) with a 4-metre primary mirror. It is expected that EST will be located in the Canary Islands. The foremost scientific goal of the telescope is to understand the magnetically dominated and dynamic chromosphere of the sun and how this dynamic is determined by processes in the underlying photosphere. The sun offers a unique laboratory to study magnetic plasmas under conditions that cannot be simulated on earth. Understanding of the physical processes that can be observed in the sun's atmosphere is necessary, e.g. for physics research concerning stars, but also to better understand climate changes on earth. "Space weather" generated by the sun's magnetic field influences human activity to a high degree.

EST's design requires a system with several deformable mirrors that compensate for the influence of the earth's atmosphere on incoming light. Here, similar to other instrumentation development for the telescope, the Swedish Solar Telescope (SST) in La Palma and the Institute for Solar Physics (ISF) play important roles.

A conceptual design study of EST, financed by EU, involves institutions from 15 countries including Sweden. The total cost of the telescope is estimated to be 130 million euros. If construction begins in 2014, EST can be completed in 2019. The Swedish contribution is estimated to be approximately 3% of the total cost, i.e. SEK 40 million. The EST project is interested in Swedish contributions in the form of, e.g. telescope instrumentation.

LHC upgrading – Super LHC

The large hadron collider (LHC) particle accelerator at CERN, which became operational at the end of 2009, began a physics programme of 7 TeV proton-proton collisions in the spring of 2010. The accelerator has thus far exceeded the goals established for radiation intensity and stability. The experiment at LHC has already produced a large number of findings on known particles or phenomena at the new energy, which improves the understanding of fundamental particle physics and enables the detection of new phenomena. Concurrently, the search for new particles is under way since LHC has narrowed the area where many hypothetical particles can be found, e.g. leptoquarks, excited quarks, black holes, etc. Regarding LHC's flagship particles, the Higgs boson and super symmetrical particles, more data are required to validate or revise the models.

LHC is a long-term project where the performance of the accelerator and detectors is already increasing. Increased accelerator intensity is being pursued to achieve even higher luminosities and thereby increase data volume to be able to investigate rare phenomena. It is expected that the luminosity and energy for which LHC was constructed, at collision energies of 14 TeV, will be achieved after the operational pause in 2013-2014. The first phase of the super LHC upgrade is planned for 2017 and should increase luminosity by a factor of two. The second phase of upgrading is expected to take place during 2021-2022.

The LHC must be rebuilt for the detectors to handle the upgrade in LHC's luminosity. Swedish researchers are primarily involved in two projects, ATLAS and ALICE. In ATLAS, Swedish researchers participate in the upgrade of the inner tracking detector, trigger, and calorimeters. In the ALICE experiment, there is a need to increase the precision of tracking reconstruction

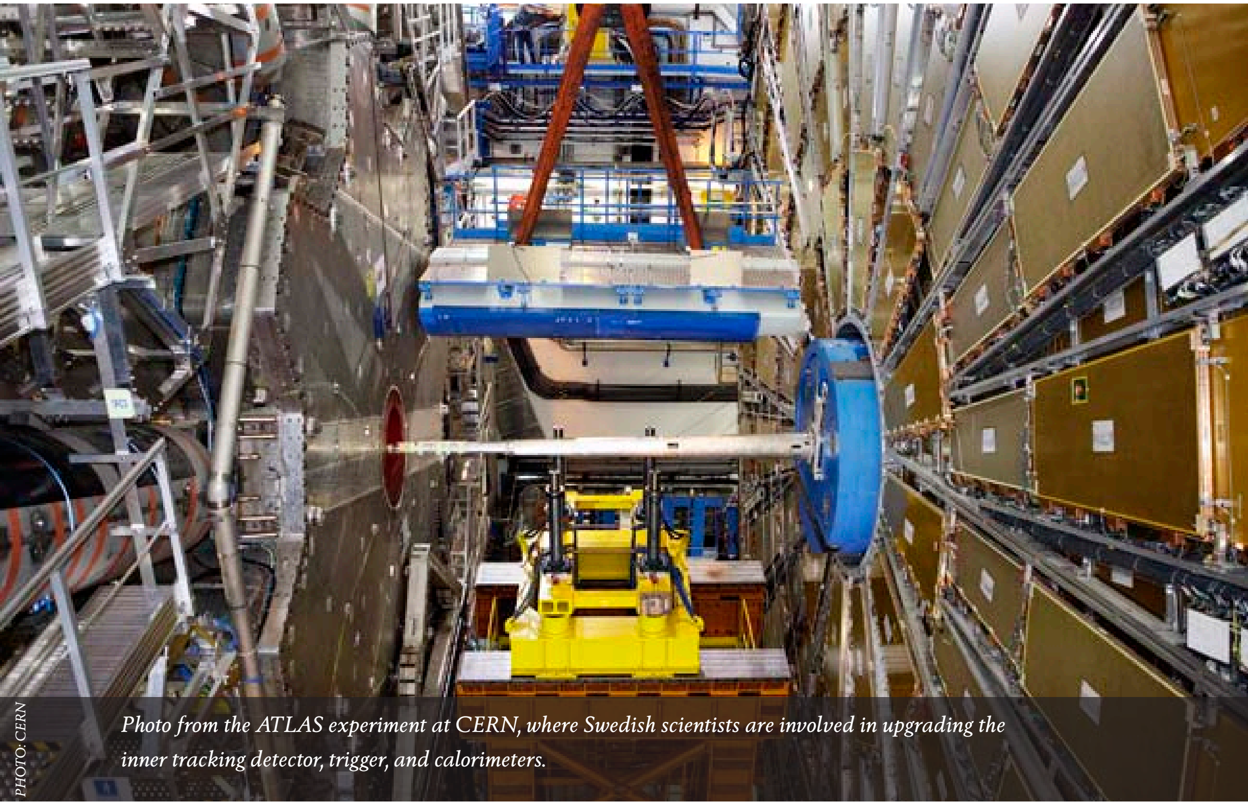


Photo from the ATLAS experiment at CERN, where Swedish scientists are involved in upgrading the inner tracking detector, trigger, and calorimeters.

PHOTO: CERN

in the ongoing programme. The Swedish contribution to the ALICE upgrade involves readout electronics for the central tracking detector. Potentially the same electronics could be used for a corresponding tracking detector in a future linear electron-positron collider.

The investment cost for the full upgrade of the ATLAS detector up until 2021 is estimated to be CHF 365 million. If Sweden were to contribute approximately the same proportion to the ATLAS upgrade as to the detector's original construction, the cost would total SEK 70 million, with the investments spread over a 10-year period. The amount needed for the ALICE upgrade is estimated to be around SEK 10 million between 2012 and 2015.

ILC/CLIC – Linear Particle Colliders

As a result of experiments at LHC, particle physics will acquire a large amount of new information on energy, along with an expectation to detect the Higgs particle (TeV area). The LHC studies will not be able to answer all questions concerning the nature of matter and the universe. However, research at LHC will generate new knowledge that will lead to questions yet unknown. Addressing questions about physics beyond the standard model, e.g. on supersymmetric particles, theories on extra dimensions, and study of details concerning the Higgs mechanism, will require other types of particle accelerators with substantially higher precision than LHC.

The Compact Linear Collider (CLIC) and the International Linear Collider (ILC) are two proposed projects using different techniques to answer these questions. Both are types of electron-positron colliders. Parallel to the continued development of LHC, CERN is running the CLIC project to study and develop technology for a linear accelerator in the energy range of 0.5-5 TeV. ILC involves a worldwide collaboration to establish a design for an accelerator in the energy range of 0.5-1 TeV.

CLIC/ILC will, among other things, improve the possibilities for studying and understanding the Higgs mechanism. Other measurements that would become possible include studies of symmetry violations between particles and antiparticles in the Higgs sector. Developmental work on detector and accelerator technology is under way in Sweden. Collaboration is taking place for a Nordic CLIC, and several EU level projects have been started to coordinate and stimulate further accelerator development, primarily EuCARD (European Coordination of Accelerator R&D) and TIARA (Test Infrastructure and Accelerator Research Area). Here there are possibilities for synergy with accelerator development for, e.g. the European Spallation Source (ESS).

SKA – Square Kilometre Array

SKA is a long-wave radio interferometer that picks up where the more short-wave radio interferometer ALMA in Chile leaves off. The facility will cover a surface area of approximately 1 square kilometre, or around 180 times more than ALMA does. SKA is based on new technology where scientists plan to use a relatively simple antenna design together with highly sophisticated electronics and data processing. The first step in this method is being developed in the Netherlands through LOFAR (Low Frequency Array). A Swedish LOFAR station at Onsala Space Observatory (OSO) commenced in the autumn of 2011.

SKA will combine a very large detection surface with high spatial resolution and large visual field. The facility is highly interesting for studying the formation of the first stars and galaxies in the early universe. Other key areas include studies of protoplanetary disks, cosmic magnetic fields, and the use of pulsars to test the theory of relativity.

The placement of SKA is being discussed, with the most likely options being Australia or South Africa. The first step, which involves a smaller interferometer with approximately 10% of the total surface is being planned and should become operational in 2020. The second step is expected to be completed in 2024. SKA is one of the proposed global projects in the ESFRI roadmap for infrastructures. Together with E-ELT it shares first place on the ASTRONET priority list of research infrastructures in astronomy.

The total estimated cost is around 1.5 billion euros. The initial 10% stage is estimated to cost approximately 350 million euros, of which Europe is expected to contribute the largest share, and approximately 30% of the total cost for SKA. A European SKA consortium, where OSO represents Sweden, has been formed to coordinate European interests. The design phase will start in 2013, and the cost for Swedish participation will be approximately SEK 15 million distributed over 4 years. The OSO budget can probably cover the cost of Swedish participation in the design phase. Researchers in detector development and antenna construction at Onsala and Chalmers have valuable expertise in this context. Prototypes for ALMA resulted, e.g. in Swedish industrial contracts. Since there is substantial technological overlap regarding antenna planned for the ESCAT-3D radar facility, there is interest among the participating research groups to collaborate. The cost of Swedish participation in SKA is estimated to reach approximately SEK 100 million.

Materials sciences

Synchrotron radiation

The development of new light sources for radiation in soft x-rays and the x-ray field is progressing rapidly. Synchrotron radiation facilities in Europe have reached a new level where performance is approaching the theoretical limits. These sources are of major importance for natural sciences generally in the areas of physics, chemistry, biology, and geology because of their ability to provide detailed information about the structure and dynamics of atoms, molecules, and material. Engineering sciences can also benefit substantially from x-ray sources. For instance, synchrotron radiation studies are of decisive importance in energy-related material for catalysers, solar cells, and batteries, in structural biology where structures of the overwhelming share of proteins are determined with the help of synchrotron radiation, in surface physics for functional surfaces, and for development of future material for new types of electronics.

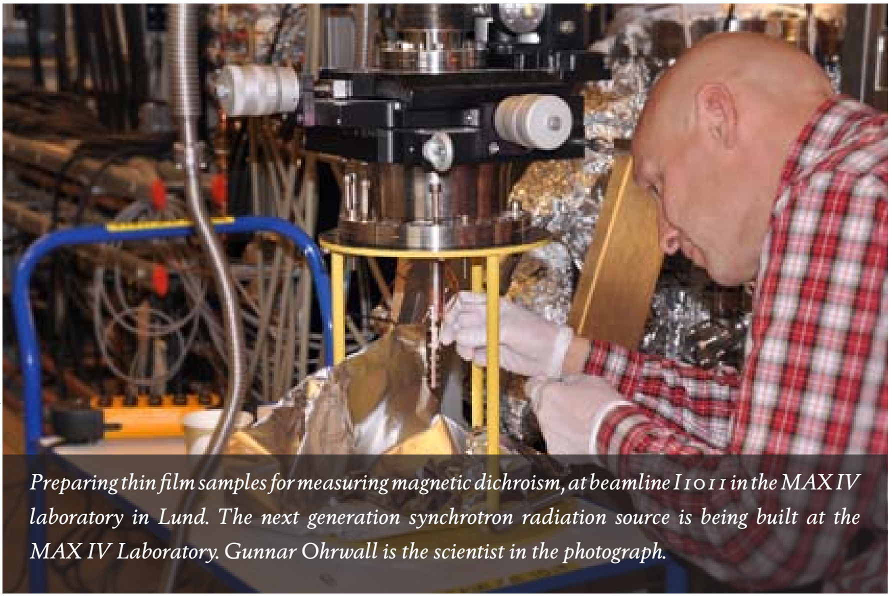


PHOTO: ANNIKA NYBERG, MAX IV-LABORATORIET, 2011

Preparing thin film samples for measuring magnetic dichroism, at beamline I1011 in the MAX IV laboratory in Lund. The next generation synchrotron radiation source is being built at the MAX IV Laboratory. Gunnar Ohrwall is the scientist in the photograph.

MAX IV

The national MAX-lab laboratory in Lund is building the next generation synchrotron radiation source, MAX IV. The facility will have over 20 large instruments (beamlines) to measure different samples using a range of methods when the laboratory is complete. Given its low-emission design, MAX VI will be able to offer beams with the highest brilliance in the world. This will enable studies of very small samples in a broad field, e.g. nanostructured material or protein crystals that are smaller than those currently used. Furthermore, the x-ray radiation from MAX IV will have high degree of coherence, which will enable new methods primarily involving the imaging of tissue or material.

The Swedish Research Council, Region Skåne, VINNOVA, and Lund University are the main financers of the initial version of MAX IV. The facility is expected to deliver the first beams in 2015-2016. Also at this time the first set of experimental stations, 6-7 beamlines financed primarily by the Knut and Alice Wallenberg Foundation, will become operational. For the following 5 to 6 years there will be a need to construct another pair of beamlines per year to meet the demand from the research community and to utilise the scientific potential of MAX IV. The fields concerned include medicine, palaeontology, and materials science. Additional beamlines are yet unfunded, but it is expected that several will be financed by our neighbouring countries, other Swedish research financing bodies, and universities after scientific review and evaluations in a competitive context. Furthermore, several beamlines will be constructed by industrial interests.

The new MAX IV laboratory will consist of two storage rings placed alongside each other: one for the soft x-ray area and one for harder x-ray beams. Plans are also under way for a short-pulse facility that might be turned into a free electron laser (FEL) at a later stage.

Eventually, the existing MAX-lab will be integrated into MAX IV and is expected to continue delivering radiation to over 10 experimental stations until the new facility becomes operational.

Swedish materials beamline at PETRA III

The new German synchrotron, PETRA III in Hamburg delivers extremely short wavelength radiation in the x-ray range (50-150 keV, corresponding to wavelengths of 0.25-0.08 Ångström. Within the framework of a research and collaboration agreement with Germany, the so-called "Röntgen-Ångström Cluster" was formed to promote the use of the large infrastructure initiatives taken by Sweden and Germany, primarily in materials research and structural biology. Through this collaboration, Sweden is building a beamline at PETRA III to study materials. The short wavelength x-ray beams generated from PETRA III have very powerful penetration potential in dense material, such as metals and ceramics. This opens opportunities to either follow rapid transformations, dynamic processes, or to collect information on very small, nanometre-sized, volumes in materials that otherwise could not be studied with x-ray beams. The high energy used also means that such phenomena can be studied deep inside a material, opening the possibilities for imaging in three dimensions, tomography, of particles and interfaces at the nanometre scale. Scientists can also conduct experiments such as monitoring crystal formation in situ or changes in a material in real time during workloads or under extreme conditions. This type of experiment will enable the development of new advanced material for many different applications involving energy, the environment, transportation, information technology, and medicine/health. The synchrotron radiation from PETRA III complements that which will be used at MAX IV (under 30 keV) since MAX IV will be of primary value in studies of soft material and molecules.

Neutron scattering

ESS – European Spallation Source

ESS, a European research facility using neutron scattering methods, is being planned for construction in Lund. It will analyse all types of material to understand how they are constructed and function.

The research areas and industries that will benefit from using ESS include materials and nanotechnology, chemistry, molecular biology, biomedicine, pharmaceuticals, energy technology, and information technology. The facility is planned for construction in the same area as MAX IV in Lund, and together with the XFEL and PETRA III facilities in northern Germany, the Öresund region will have strong potential to develop into a world-class centre for research in materials science, structural biology, and other life sciences. Negotiations with potential member nations are under way. Sweden should make use of the opportunities provided by ESS and MAX IV for leading international research through special calls for applications for research grants, PhD programmes, and collaboration with industry.

The test facility for accelerator development related to ESS is being constructed at Uppsala University in collaboration with ESS and may eventually be expanded.

Illustration of the ultrashort pulse structure of x-ray radiation, which with brilliance one billion times greater than today's radiation sources will enable new studies of phenomena and structures in molecules and material. Several Swedish researchers are involved in the construction phase of the XFEL (X-ray Free Electron Laser) facility in Hamburg.

OTO: EUROPEAN XFEL/MARC HERMANN

Free Electron Laser (FEL)

For studies of the structure and characteristics of materials, molecules, and atoms, one of the most useful tools is light of different wavelengths, from infrared to soft x-ray ranges. Lasers, x-ray tubes, and synchrotron radiation sources have been powerful tools in research for decades. Given the increasing research interest in dynamic processes, the use of pulsed light sources is increasing. The most recent development in free electron laser research has led to a revolution in dynamic studies. A FEL generates extremely powerful and short light flashes of coherent beams even in the x-ray area. These accelerator-based sources enable new experiments that increase the understanding of material construction and dynamics.

Generally, free electron lasers with accelerators having electron energy exceeding 5 GeV reach up to the hard x-ray range (1 Ångström) and are referred to as x-ray free electron lasers (XFEL), while those with lower electron energy are called ultraviolet free electron lasers (UVFEL) or x-ray ultraviolet free electron lasers (XUVFEL).

Globally, the development of free electron lasers is being led by LCLS (14 GeV, 1.5 Ångström) in Stanford, USA, which initiated its successful user activities in 2008. A new initiative, LCLS II, is under construction. Japan, Korea, Switzerland, and Italy are also investing heavily in FEL facilities.

Concurrently, the flagship European XFEL (17.5 GeV, 1 Ångström) is being built in Hamburg at DESY through international collaboration that includes Sweden. This facility is expected to produce beams in 2016, making it the most powerful globally. E-XFEL will deliver x-ray beams in ultrashort flashes at the femtosecond level that are ten billion times more intensive than those available today. The intensive pulses open the door for numerous experiments that scientists have heretofore been unable to conduct, and for new questions in nanosciences, structural biology, condensed matter physics, femtochemistry, materials science, and plasma physics.

The FEL activities at DESY were initiated several years ago after a decision to build a test facility that was later elevated to the FLASH user facility. The technology that serves as a foundation for E-XFEL was tested there.

Swedish researchers have been involved in the development of FLASH and have participated in measurements at its free electron laser. Swedish researchers have also been active at LCLS, and several research groups have participated in measurements. The Swedish Research Council has financed a smaller laboratory at this facility.

Euro-FEL (Formerly IRUVX-FEL) – free electron laser network for the infrared and soft x-ray ranges

Several smaller projects involving free electron lasers are under way in Europe with technical development and test facilities, e.g. MAX-lab in Lund, FERMI (Italy), HZB (Germany), and PSI (Switzerland). FLASH in Germany has an operational free electron laser.

Euro-FEL, which is included in the ESFRI roadmap, is being planned as a distributed infrastructure to encompass several national free electron laser facilities, but each will specialise in a particular type of study. Hence, the different lasers at different sites in Europe will complement each other. The intent is to build the new facilities in sequence so that researchers can test and benefit from the new technical advancements in one facility while the next is being planned and built. This innovative approach offers new ways for European researchers to benefit from systematic development of advanced technology and expertise while concurrently providing good accessibility to the latest technology.

e-Science

Database strategies for research

The prerequisites for working in distributed infrastructures are closely associated with the possibilities for geographically distributed computing. Initiatives for developing resources for computing and/or transmitting data for research in distributed grids have been taken in several fields including medicine, social sciences, humanities, and climate and environmental sciences. The expert group on database issues, DISC, and the national data services for humanities, social sciences, and medicine, SND, and climate and environmental data, ECDS (previously SND-KM) play a unifying role regarding database development. Needs for development can be roughly grouped into regulations for acquiring, storing, and managing shared data resources and technical solutions that promote increased utilisation and improved computing capacity. The distributed systems involve shared utilisation of technology and human resources.

In some cases, data resources must be centralised for efficiency-related reasons. Initiatives such as these can be found, e.g. in BBMRI for biobank data and MONA for social science registry data, where large-scale databases have been constructed using existing resources that are largely centralised, or have been distributed to a few actors that can benefit from building a common structure.

Some infrastructures have been built as distributed systems (e.g. healthcare data on quality of patient care) while others are scattered without being coordinated, e.g. research databases comprised of interview data and other information such as registry data or health surveys, or text and speech/sound used in language science research. The data strategy should aim to coordinate documentation and develop and use common or compatible methods so these resources can be incorporated in nationally and internationally shared networks.

Legal aspects such as ownership, patents, copyright, public accessibility, and privacy protection play a decisive role regarding the potential for research to construct shared resources. Substantial developmental work is required to adapt the regulations to a rapidly changing situation and new needs for information management. The infrastructure work should target the development of those aspects of IT rights that are related to research needs. Associated areas that need to be reviewed on a broad front across several scientific areas include; how to apply open access principles to research data in relation to patents and ownership/copyright, the possibilities to use data networks such as SUNET for transmission, and/or working with sensitive information at a distance.

Development of the technical solutions needed to effectively co-utilise data in distributed/federated systems is still in the preparatory stage. Substantial upgrading and implementation are needed to develop large-scale systems that can connect nodes with large data volumes without needing to physically move them and without jeopardising efficiency in access and computing.

The data strategy in each area should ensure that resources are accessible to as many as possible and should be developed to meet needs in broad and/or particularly important research areas.

SNIC – Swedish National Infrastructure for Computing

The SNIC metacentre was founded in 2002 and forms a national infrastructure for service functions for large-scale computing and data storage for Swedish researchers. The goal of SNIC is to achieve efficient utilisation of available resources and to offer service functions adapted to user needs. Currently, six data centres at Swedish universities and higher education institutions provide these service functions, and SNIC's allocation committee manages the distribution of resources nationally. SNIC also serves as the national participant in major international collaborations involving large-scale computing and data storage.

Most of the users are involved in traditional computing-intensive fields such as physics and chemistry, but in recent years the utilisation of SNIC's resources has both increased and diversified to a broader spectrum of user groups. In particular, this involves large-scale storage of data to meet strong growth in, e.g. the life sciences. Another structural change concerns the increasing level of coordination of SNIC's resources in consortiums and user groups in a range of research areas and other research infrastructures. Often, in turn, these consortiums are part of international collaborations.

During 2010, an international panel of experts evaluated SNIC and emphasised, e.g. the importance of strategic planning. The panel also emphasised that the current trend towards integrated metacentre organisations with a common and transparent interface with Swedish researchers should continue. They also highlighted the importance of continuing to develop user support, particularly for users in new areas. The SNIC organisation continues to change, and starting in 2012, a host university will operate the organisation as a national infrastructure.

SNIC's so-called "landscape document" for 2010-2013 describes plans for continued construction of computing resources, such as basic level systems, larger cluster resources, and a large-scale HPC system linked to participation in the ESFRI initiative, PRACE. Furthermore, continued development of national data storage in SweStore is being planned, as is transparent access to distributed computing, analytical, and modelling resources through service functions in the Swedish infrastructure for distributed data resources, SweGrid. As SNIC converts to a hybrid service-orientated structure, the link between user support and specific SNIC resources will decrease, and user support will become more closely tied to different user groups, classes of applications, and large user consortiums.

SNIC also participates in the project to develop joint Nordic computing resources in accordance with Nordforsk's action plan for Nordic e-Science and to study the possibilities and appropriateness of providing certain service functions, e.g. cloud services, in conjunction with commercial vendors.

PRACE – Partnership for Advanced Computing in Europe

In recent years, the need for large-scale computing in traditional computing-intensive research areas and in new emerging areas has received attention in the United States and Europe. The trend is documented in several reports, and the field is considered of major importance for future research and for society as a whole. In Europe, SNIC participated actively in the early discussions concerning a unified European ecosystem for large-scale data resources, which resulted in the PRACE consortium. Sixteen European partners are involved, including Sweden, which is represented by the Swedish Research Council/SNIC.

The goal is to successfully address, to the extent possible, the most demanding scientific needs conceivable today (grand challenges), broaden the scope of researchers' ambitions, and intensify the development of hardware and software technologies to reach new dimensions and generate effects beyond the PRACE initiative itself. This requires access to a wide selection of applications and computer systems – including the most powerful ones currently available. A primary objective is to provide such resources in Europe, and computing time for the first two very-large-scale PRACE systems has recently been opened to proposals. Through Sweden's participation in PRACE, these resources are available to Swedish researchers, and SNIC has also initiated a special project for user support to help Swedish research groups use this type of massive parallel computer system.

SNIC is involved in building PRACE, e.g. with a prototype system focussed on energy efficiency and with a relatively extensive initiative to adapt applications to massive parallelism. As regards the resources with the highest computing capacity in PRACE, they can be provided only by the largest and most resource-rich nations due to the cost. However, during 2010/2011, SNIC decided to invest in a very large-scale (by Swedish standards) computing system to offer Swedish researchers a step up and facilitate efficient utilisation of the largest computing resources in the world, e.g. in PRACE.

NDGF and EGI (grid infrastructures)

Transparent and flexible access to distributed computing and storage resources is a necessity for distributed research and research infrastructure collaboration in Sweden and internationally. SNIC, along with a consortium led by Swedish researchers in high energy physics, established the Swedish grid initiative early. This is being continually improved to serve Swedish researchers. SweGrid also comprises the foundation for Swedish participation in international collaboration to provide distributed resources on an even greater scale, e.g. the European initiative EGI (European Grid Infrastructure). Nordic collaboration in this area has existed for some time, and the Nordic Data Grid Facility (NDGF) coordinates participation of the Nordic countries in EGI. The resources coordinated by NDGF are being used primarily by researchers in high energy physics, but strong growth is also expected in other areas in conjunction with the planned investment in Nordic e-Science.

The need to remotely control and conduct experiments at a distance will increase along with the initiatives under way, e.g. at the MAX IV laboratory and ESS. This will place new demands on quality of service (QoS) in the grid.

SUNET – Swedish University Computer Network

SUNET has been in existence since the early 1980s and has progressed from an initial research and development project to become a joint organisation and infrastructure for higher education institutions (HEIs). Its mission is to meet the needs of universities and HEIs for domestic and international data communication and data services. The board of SUNET comprises an advisory body within the Swedish Research Council and is responsible for SUNET's activities.

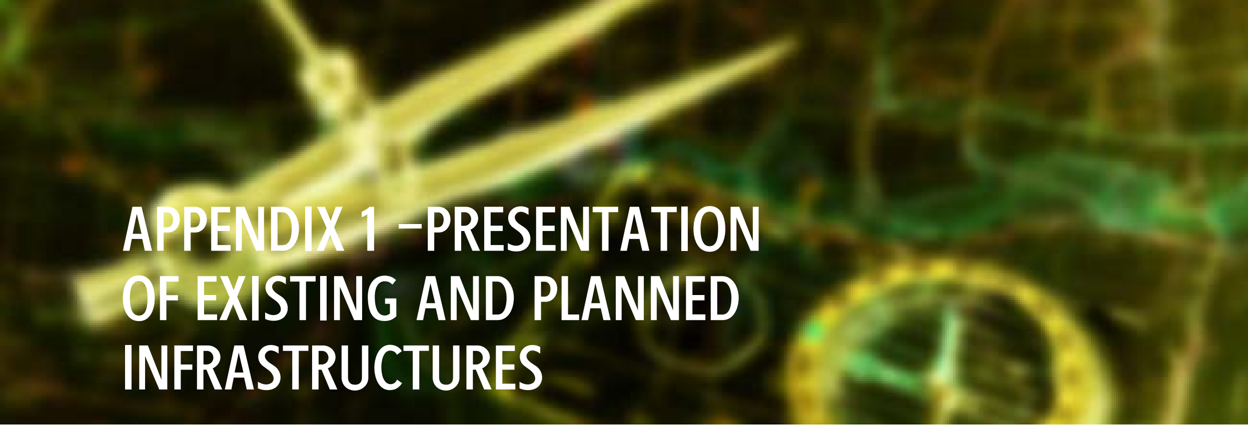
SUNET's latest network, i.e. OptoSUNET became operational in 2007. This network serves the needs of universities and HEIs for general Internet capacity with high accessibility while meeting the needs of individual researchers and research groups for special point-to-point connections.

OptoSUNET is a secure future network where the central components of the network (fibre optic connections and transmission equipment) will meet needs at least through 2015. The network is flexible and can be adapted to new needs and opportunities without having to change the central components.

Through OptoSUNET, Swedish research and higher education have a network that is a central component of the Swedish e-Infrastructure. SUNET is the only way to reach research networks that cannot be reached by general users of the Internet. The network also gives universities and HEIs the opportunity to communicate via the European research network, Géant and with the dominant research networks; Internet2, Abilene, ESnet, and NLR in the United States. SUNET provides the infrastructure necessary to connect high-performance computers, data storage resources, and scientific databases with each other and with the users.

The integration of SUNET's activities with other activities of the Swedish Research Council should be further developed towards increasing the exchange of experience regarding network construction, connecting distributed data and data storage solutions with initiatives to increase knowledge about security, legal, and ethical aspects of research when data are stored in different databases under different regulations. Such collaboration could also lead to improved contact between SUNET and researchers that place high demands on data communication.

There are favourable opportunities for broadening the user group to include archives, libraries, museums, and institutions for cultural environments. This would require an increase in funding.



APPENDIX 1 –PRESENTATION OF EXISTING AND PLANNED INFRASTRUCTURES

Humanities and Social Sciences

CESSDA – Council of European Social Science Data Archives

Distributed infrastructure for social science data. Swedish participation via the Swedish National Data Service (SND). Existing European collaboration plans to form CESSDA-ERIC in 2012.

CLARIN – Common Language Resources and Technology Infrastructure

European initiative to create an infrastructure for language technology. CLARIN encompasses data resources and the technologies and tools needed to store, distribute, and manage data resources. Swedish researchers have been involved in planning the European infrastructure. Discussions will take place in 2012 concerning how to meet Sweden's infrastructure needs regarding language technology.

DARIAH – Digital Research Infrastructure for the Arts and Humanities

DARIAH aims to create a coordinated technical infrastructure to improve and support digitally based research in the humanities. The Swedish National Data Service (SND) has participated in the preparatory phase as an associate partner and continues to monitor the development of DARIAH.

DC-net – Digital Cultural heritage NETwork

DC-net (Digital Cultural Heritage) NETwork is an ERA-net for digitisation of cultural heritage coordinated by the National Archives with support from a national reference group comprised of representatives from the National Archives, the Swedish National Heritage Board, SUNET, and the Swedish Research Council.

DASISH – Data Service Infrastructure for the Social Sciences and Humanities

Umbrella organisation to coordinate the five ESFRI initiatives in the humanities and social sciences, i.e. CESSDA, CLARIN, DARIAH, ESS, and SHARE. The organisations mainly collaborate in quality control of data, archiving of data, accessibility, and legal and ethical matters.

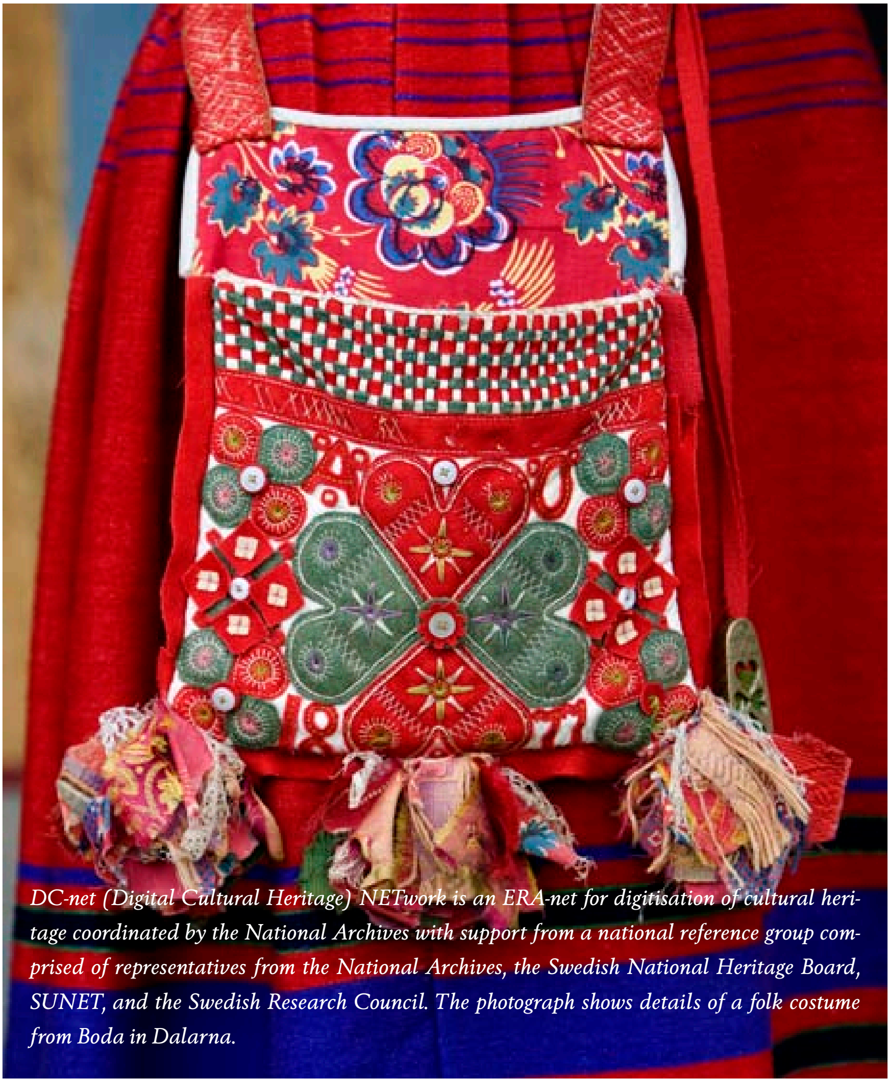


PHOTO: TRONS/SCANPIX

DC-net (Digital Cultural Heritage) NETwork is an ERA-net for digitisation of cultural heritage coordinated by the National Archives with support from a national reference group comprised of representatives from the National Archives, the Swedish National Heritage Board, SUNET, and the Swedish Research Council. The photograph shows details of a folk costume from Boda in Dalarna.

ESS – European Social Survey

ESS conducts questionnaire surveys for the purpose of digitising social data and making it accessible for international comparisons. Data are collected every second year. Existing European collaboration with plans to form ESS-ERIC in 2012.

SND – Swedish National Data Service

SND was formed in the autumn of 2007 at Göteborg University, and within 5 to 10 years is projected to have complete information on central Swedish databases in the humanities, medicine, and social sciences as well as an overview of corresponding databases in other countries. SND develops methods to document and access digital research material that correspond to researchers' needs for efficiency and meet requirements for security and privacy. Through participation in international organisations such as IFDO, CESSDA, DARIAH, and ICPSR, the Swedish National Data Service provides Swedish researchers access to digital material worldwide and gives visibility to Swedish research internationally. Researchers may turn to SND for practical and legal advice in conjunction with constructing new databases.

Environmental Sciences

ANAEE – Analysis and Experimentation on Ecosystems

ANAEE, an infrastructure initiative for experimental ecology, was presented in the ESFRI roadmap from 2010. The aim is to develop a new concept with an integrated European infrastructure involving controlled experiments in forestry and agro-ecosystems and natural ecosystems. The concept involves both experiments in situ and in ecotrons where parts of ecosystems are studied under controlled conditions indoors. Swedish researchers are participating in the planning.

ECORD – European Consortium for Ocean drilling

Sweden participates in the integrated ocean drilling programme (IODP) through the European Consortium for Ocean Drilling (ECORD). The primary goal of the programme is to take samples on the floor of all ocean areas and in all types of geological layers.

EISCAT-3D – European Incoherent SCATter facility

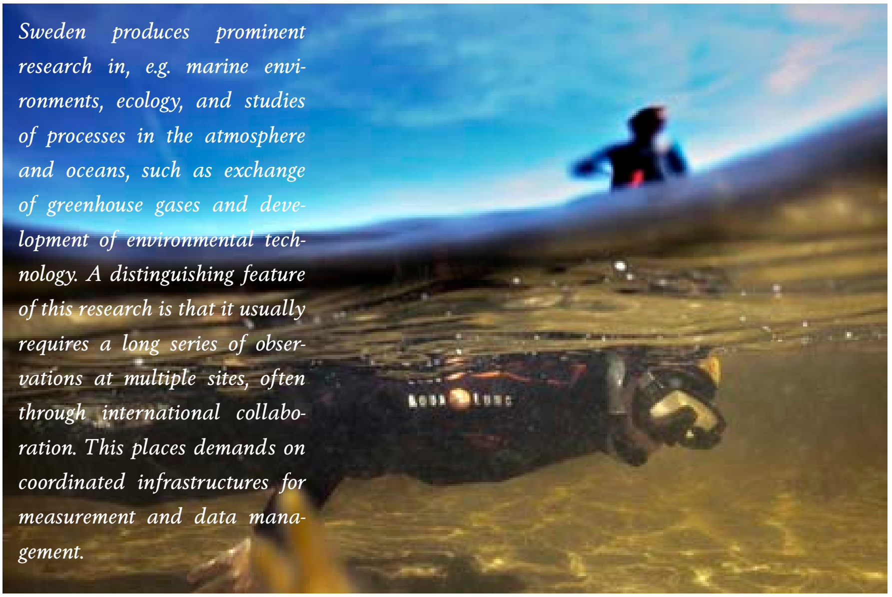
EISCAT uses two high-energy radar systems primarily to study how solar winds interact with the ionosphere. One system is located on the mainland with transmitters in Tromsö and receiver stations in Tromsö, Kiruna, and Sodankylä, and one system is located on Svalbard. China intends to build a third antenna on Svalbard. EISCAT is headquartered in Kiruna.

EISCAT-3D, from the ESFRI roadmap in 2008, is a necessary step forward for EISCAT and must being taken to stay on the scientific forefront.

EMBRC – European Marine Biology Research Centre

EMBRC is an infrastructure that connects costal marine laboratories for genetic studies and access to model organisms. EMBRC was presented in the

ESFRI roadmap from 2008 and receives funding from the EU Commission for the planning phase. The Sven Lovén Centre for Marine Sciences at Göteborg University coordinates EMBRC, giving Sweden a leading role in the project.



Sweden produces prominent research in, e.g. marine environments, ecology, and studies of processes in the atmosphere and oceans, such as exchange of greenhouse gases and development of environmental technology. A distinguishing feature of this research is that it usually requires a long series of observations at multiple sites, often through international collaboration. This places demands on coordinated infrastructures for measurement and data management.

PHOTO: TRONS/SCANPIX

EMSO – European Multidisciplinary Seafloor Observatory

The goal of the deep seafloor-based observation system, EMSO, is to develop and construct several underwater observatories for marine research in biology, water chemistry, geohazards, etc. Planned European collaboration, and Swedish researchers are involved in the planning phase.

EPOS – European Plate Observing System

EPOS aims to create a European infrastructure to study movement in the earth's crust, including processes that control earthquakes, volcanic eruptions, and tsunamis in the long term. EPOS was presented in the ESFRI roadmap from 2008 and is planning its on-going work with grants from the EU seventh framework programme. Swedish researchers are participating in the planning phase.

GBIF – Global Biodiversity Information Facility

A global network that aims to make data and information on biological diversity more accessible to scientific research. The virtual library now being constructed is collecting information about all species on earth. Information at the molecular, genetic, ecological, and ecosystem levels is being registered.

ICOS – Integrated Carbon Observation System

ICOS will coordinate and develop European measuring of carbon dioxide exchange between the ground and the atmosphere. Monitoring stations are being located throughout Europe. A Swedish node is being coordinated from Lund University. Swedish researchers are also involved in planning the European infrastructure.

ICDP/SDDP – International Continental Drilling Program/ Swedish Deep Drilling Program

With grants from the Swedish Research Council, a Swedish infrastructure, the Swedish Deep Drilling Program (SDDP) is being developed under the International Continental Drilling Program (ICDP). Deep drilling is used to investigate questions that often have direct economic and environmental connections, e.g. to geothermal energy and carbon dioxide separation.

IODP – Integrated Ocean Drilling Program

Sweden participates in the international Integrated Ocean Drilling Programme (IODP) through the European Consortium for Ocean Drilling (ECORD). The overriding goal of the programme is to take samples in all ocean areas and all types of geological layers. The current programme will conclude in 2012, and discussions are under way concerning the design of a new programme.

LifeWatch

Constructs and coordinates infrastructures for research on biodiversity and sustainable development. The focus is to develop systems for modelling and data exchange and to create networks among existing biodiversity monitoring systems. A Swedish infrastructure is under construction, and the planning of European LifeWatch is under way.

LTER – Long Term Ecological Research

European network for long-term ecological studies at research stations. The Swedish Research Council supported the entry of Swedish LTER into the international LTER network during 2010, but has yet to decide on possible financing.

Nordsim – Nordic Secondary Ion Mass Spectrometer

A pan-Nordic resource for geological research, located at the Swedish Museum of Natural History in Stockholm. The instrument is being used in several branches of geology to measure elements and isotopes found in specimens.

ECDS – Environmental Climate Data Sweden (previously SND-KM)

The Swedish Research Council has established a national data centre for climate and environmental research where SMHI serves as host. ECDS intends to build up national capacity that can handle metadata and certain data from research projects on climate and the environment, broadly defined. Furthermore, the data service will support the work of researchers and HEIs by creating its own permanent databases that meet required standards and searchability. ECDS is also an operative resource for the continued work of the Swedish Research Council to increase researchers' accessibility to data.

SIOS – Svalbard Integrated Observing System

The Nordic infrastructure initiative, SIOS, aims to integrate research activities of several countries, mainly European, conducted on Svalbard and to expand capacity for research and observations on and around Svalbard. SIOS was presented in the ESFRI roadmap from 2008, and Swedish researchers are participating in the planning phase.

Energy

ECCSEL

Project for carbon dioxide storage and separation, presented in the ESFRI roadmap from 2008. No Swedish researchers participate.

EU-solaris

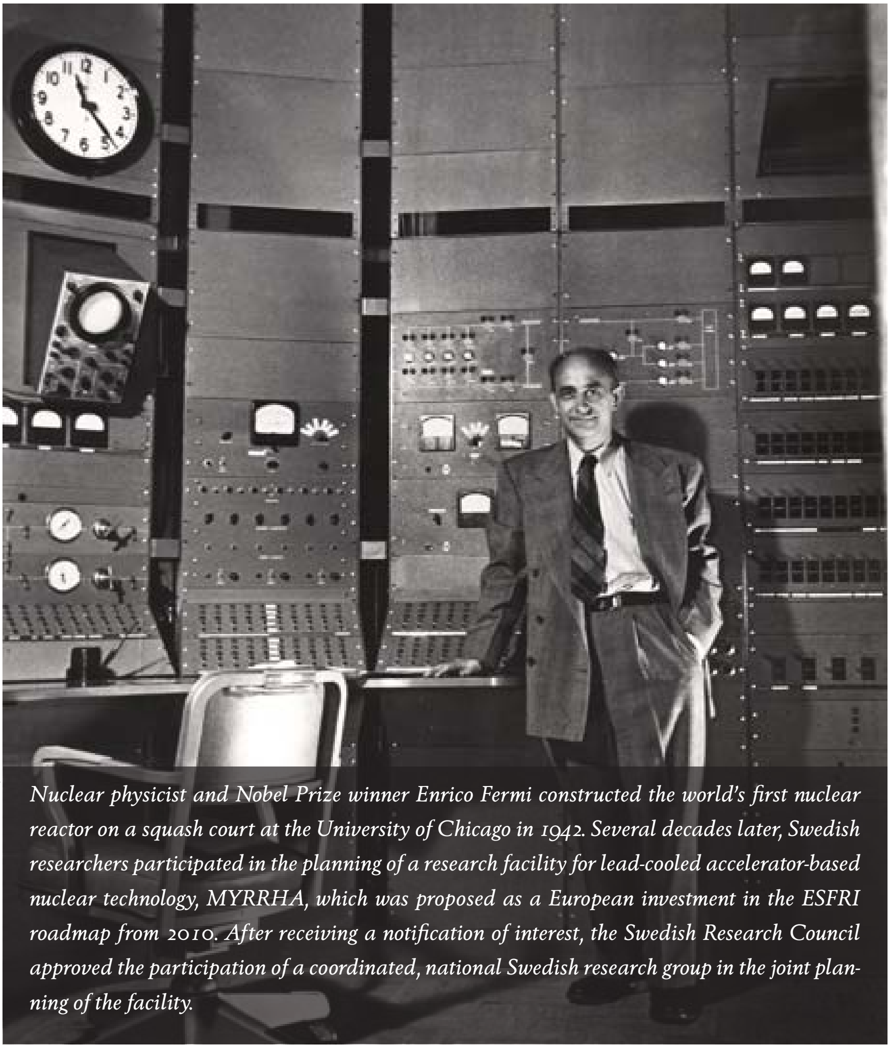
Project from the ESFRI roadmap from 2010, aimed at developing and demonstrating the potential to use concentrated solar energy captured by mirrors for large-scale energy production. No Swedish researchers participate.

ITER

The fusion facility ITER will become the bridge between today's plasma physics studies in research facilities and tomorrow's energy-producing fusion power plants. ITER is being constructed in Southern France in collaboration with EU, India, Japan, China, Korea, Russia, and the United States. Sweden is contributing to the construction of ITER mainly within the framework of the EU framework programme, Euratom.

JET – Joint European Torus

JET is the world's largest and most successful experimental facility for fusion research. The facility is being operated under European collaboration within the EU framework programme, Euratom.



Nuclear physicist and Nobel Prize winner Enrico Fermi constructed the world's first nuclear reactor on a squash court at the University of Chicago in 1942. Several decades later, Swedish researchers participated in the planning of a research facility for lead-cooled accelerator-based nuclear technology, MYRRHA, which was proposed as a European investment in the ESFRI roadmap from 2010. After receiving a notification of interest, the Swedish Research Council approved the participation of a coordinated, national Swedish research group in the joint planning of the facility.

PHOTO: OXFORD SCIENCE ARCHIVE, SCANPIX

MYRRHA – Multi-purpose hybrid research reactor for high-tech applications

The goal of MYRRHA is to create a lead-cooled, fourth generation research reactor. The project was presented in the ESFRI roadmap from 2010, and Swedish researchers are participating in the planning phase.

Windscanner

Project from the ESFRI roadmap from 2010 that aims to develop an existing Danish infrastructure for measuring and modelling turbulence around wind turbines. No Swedish researchers are participating.

Automatic handling, e.g. of plates and liquids, enables the Chemical Biology Consortium Sweden (CBCS) to meet a broad national need for support in developing bioactive small molecules.

PHOTO: CBCS

Biology and Medicine

BBMRI – Biobanking and Biomolecular Resources Infrastructure

BBMRI.se is the national Swedish infrastructure for biobanks. The organisation is being constructed and comprises the Swedish node in the planned European collaboration, BBMRI.eu.

BILS – Bioinformatic Infrastructure for Life Sciences

Distributed research infrastructure with nodes in Linköping, Lund, Stockholm, Uppsala, Umeå, and Göteborg. The nodes include both general bioinformatic support and specialised support. BILS will also manage data storage in close collaboration with the SNIC centre. BILS will form the Swedish node in the European ELIXIR project.

CBCS – Chemical Biology Consortium Sweden

National Swedish infrastructure for chemical biology, e.g. involved in producing small organic molecules. The consortium is being constructed and coordinated from Karolinska Institutet.

EATRIS – European Advanced Translational Research Infrastructure in Medicine

European network of nodes for translational research, i.e. transfer of knowledge from laboratory to clinic. From the ESFRI roadmap, 2006.

ECRIN – European Clinical Research Infrastructures Network

An ESFRI initiative to strengthen infrastructures for clinical research.

ELIXIR – European Life Sciences Infrastructure for Biological Information

Infrastructure for collecting, storing, and managing data concerning bioinformatics. The project developed from the European Bioinformatics Infrastructure (EBI). See BILS.

EMBL – European Molecular Biology Laboratory

EMBL's activities are located at five sites in Europe. They conduct basic research and provide education in molecular biology. Research students have the possibility to receive a doctorate through EMBL.

ERINHA – European Research Infrastructure on Highly Pathogenic Agents (previously BSL4)

European infrastructure for high-security laboratories, presented in the ESFRI roadmap from 2008. The Swedish Institute for Communicable Disease Control coordinates Sweden's involvement.

Euro-bioimaging – Research Infrastructures for Imaging Technologies in Biological and Biomedical Sciences

European infrastructure under construction for coordination, user support, and services for biomedical imaging facilities. See Swedish Bioimaging.

EU-Openscreen – European Infrastructure of Open Screening Platforms for Chemical Biology

European distributed infrastructure for screening platforms (high-throughput screening, library of chemical tools, databases, etc.) in chemical biology. See CBCS.

INCF – International Neuroinformatics Coordinating Facility

An international organisation formed at the initiative of OECD for the purpose of strengthening the field of neuroinformatics. The secretariat is located at Karolinska Institutet.

INFRAFRONTIER – Infrastructure for Phenomefrontier and Archivefrontier

Distributed European infrastructure for production, classification, distribution, and archiving of genetically modified mouse strains (disease models). The goal is to understand the function of genes. A study addressing how to organise Swedish interests in the area will be presented in 2012.

INSTRUCT – Integrated Structural Biology Infrastructure for Europe

INSTRUCT is a European, distributed, research infrastructure in the area of structural biology. It aims to strengthen the competitiveness of European research in structural biology.

ISBE – Infrastructure for Systems Biology Europe

Proposed in the ESFRI roadmap from 2010 for European systems biology. Integrating centres of excellence, data resources, and modelling expertise in systems biology will create a research resource in this field. Swedish researchers are participating in the planning phase.

MIMS – Laboratory for Molecular Infection Medicine Sweden

National molecular medicine laboratory focused on molecular infections and located at Umeå University. Since 2007, the laboratory has been part of FIMM in Finland and NCMM in Norway in collaboration with the Nordic EMBL Partnership for Molecular Medicine. It comprises a node of the European Molecular Biology Laboratory (EMBL).

MIRRI – Microbial Resource Research Infrastructure

Infrastruktur från ESFRI:s vägvisare 2010 med målet att organisera lagring och tillhandahålla expertis för bättre tillgänglighet av mikrobiella stammar för t.ex. bioteknologi, medicin och industriella processer inkluderande olika typer av biobränsle. För närvarande deltar inga svenska forskare i planeringen.

SNISS – Swedish National Infrastructure for Large-scale Sequencing

National distributed infrastructure for large-scale DNA sequencing, under construction in Stockholm and Uppsala.

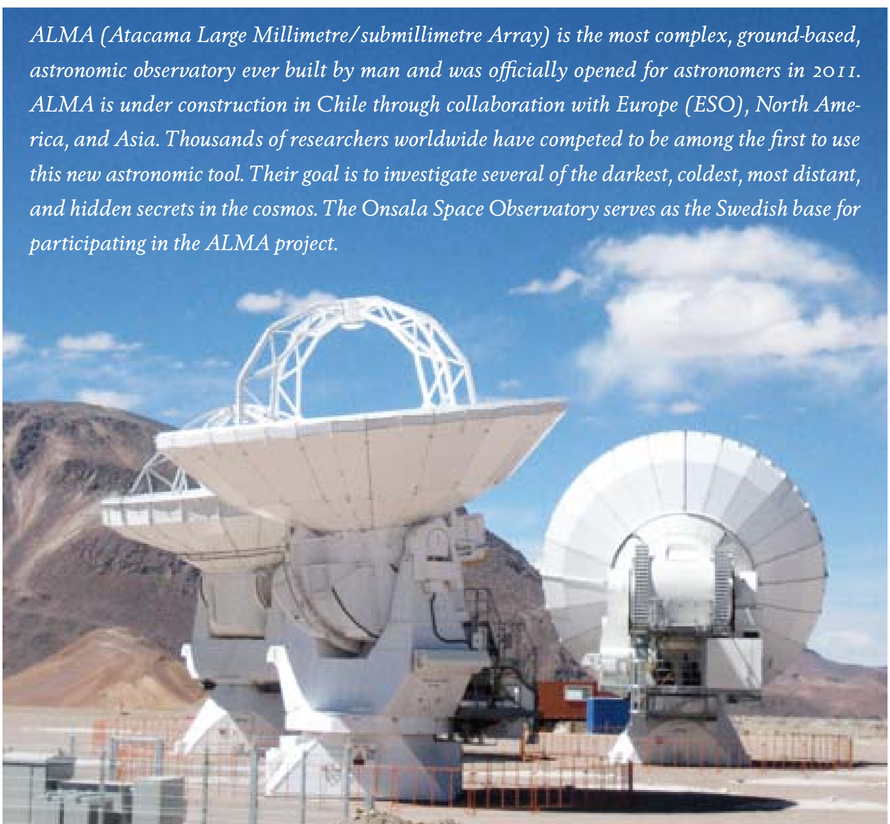
Swedish Bioimaging

National infrastructure for biomedical imaging. The network coordinates imaging equipment (PET, MRI, etc.) and provides user services. Under construction, with several additional nodes expected. See Eurobioimaging.

Physics and Engineering Sciences

ALMA – Atacama Large Millimetre Array

Radiointerferometer under construction in Chile through the collaboration of Chile, Europe (ESO), North America, and Asia. The goal of research at ALMA is to increase understanding about the origin and development of the universe and the galaxies. Under construction.



ALMA (Atacama Large Millimetre/submillimetre Array) is the most complex, ground-based, astronomic observatory ever built by man and was officially opened for astronomers in 2011. ALMA is under construction in Chile through collaboration with Europe (ESO), North America, and Asia. Thousands of researchers worldwide have competed to be among the first to use this new astronomic tool. Their goal is to investigate several of the darkest, coldest, most distant, and hidden secrets in the cosmos. The Onsala Space Observatory serves as the Swedish base for participating in the ALMA project.

PHOTO: CAMILLA JAKOBSSON

CERN

The European Organisation for Nuclear Research (CERN) is the world's leading laboratory for high-energy physics. The Large Hadron Collider (LHC) – which enables researchers to study the smallest particles of matter, e.g. to understand how the universe was formed and the fundamental forces driving our world – became operational in 2009. Swedish researchers primarily participate in the ATLAS and ALICE experiments.

CLIC – Compact Linear Collider

Planned linear electron-positron collider aimed to achieve higher precision in analysing particle collisions than what is possible in CERN's new accelerator (LHC) at corresponding energies. See also ILC. The project is in the planning stage.

CTA – Cherenkov Telescope Array

Planned detector for high-energy gamma radiation from space. Swedish research groups have formed a consortium involving participants from Lund, Stockholm, and Uppsala for the purpose of participating in CTA. CTA was included in the ESFRI roadmap from 2008 and is recommended in European strategy of the ASPERA astroparticle physics network and by the ASTRONET astronomy network.

E-ELT – European Extremely Large Telescope

A planned, giant optical telescope to be built in Chile within the framework of collaboration in the European Southern Observatory (ESO). One of the project's primary goals is to understand the formation of galaxies and stars in the early universe and to study extrasolar planets.

ESO – European Southern Observatory

European organisation for astronomic research that operates large observatories in Chile. Sweden is one of 15 member nations.

EST/ISF – Solar Telescope

The Institute for Solar Physics (ISF) operates the Swedish solar telescope on La Palma in the Canary Islands. EST, the European solar telescope, is in the planning stage.

FAIR – Facility for Antiproton and Ion Research

The European facility, FAIR, which is under construction in Germany, will be one of the world's leading accelerator facilities for hadron and nuclear physics. The facility will be used to understand the inner structure of mat-

At ESO's Very Large Telescope (VLT) on Paranal, mobile auxiliary telescopes complement the main telescope. They can be used individually, or together to form a giant interferometer, enabling researchers to observe up to 25 times finer detail than they could with the individual telescopes.

PHOTO: CAMILLA JAKOBSSON

ter and the conditions that existed immediately after the Big Bang, before atoms or protons and neutrons had time to form. Sweden is participating in the construction of FAIR and will contribute 10 million euros towards construction. The facility will be built as six modules, whereof the first four have been financed and will enable experiments to commence in each of the planned research programmes. Modules five and six will be built in 2017 at the earliest. All Swedish groups in nuclear and hadron physics give FAIR highest priority and intend to conduct most of their research there. Swedish atomic physicists also express strong interest in participating, and several groups are heavily engaged in projects at FAIR.

Icecube

The world's leading neutrino telescope, Icecube, consists of light-sensitive detectors placed deep in the Antarctic ice and covering a volume of one cubic kilometre. The detector will be used to observe high-energy neutrinos – a difficult-to-detect elementary particle – which makes it possible to "see" events extremely far out into the universe. This research aims to enhance understanding about the origin and development of the universe.

ILC – International Linear Collider

Planned linear electron-positron collider aimed to achieve higher precision in analysing particle collisions than what would be possible at CERN's new accelerator (LHC) at corresponding energies. See also CLIC. The project is in the planning stage.

ISOLDE – On-line Isotope Mass Separator

ISOLDE is used to study radioactive isotopes for a broad research programme in nuclear, atomic, astro-, and solid-state physics. The facility is located at CERN.

NOT – Nordic Optic Telescope

Shared Nordic telescope at La Palma, one of the Canary Islands. The observatory is being used increasingly for educational purposes, albeit on a small scale.

PHOTO: ONSALA RYMDOBSERVATORIUM

A Swedish LOFAR station at Onsala space observatory opened in the autumn of 2011. Research in Onsala mainly addresses the formation of stars and galaxies.

Onsala Space Observatory

Swedish national facility. The two telescopes are both used individually for observations and jointly with radiotelescopes worldwide for very long baseline interferometry (VLBI). Research at Onsala mainly involves studying the formation of stars and galaxies. The observatory also serves as a Swedish base for participating in international radioastronomy projects such as ALMA, APEX, LOFAR, and SKA, and serves as a Swedish node for geodetics.

SKA – Square Kilometre Array

Next generation radiotelescope that will be 50 times more sensitive than today's facilities. Will be used to study the early universe in fundamental physics and cosmology. Planned global collaboration.

Super-LHC

Upgrade of the Large Hadron Collider (LHC) at CERN is referred to as super-LHC. Since the accelerator is being upgraded, the detectors must also be rebuilt to handle the higher luminosity.

Materials Science

ESRF – European Synchrotron Radiation Facility

Europe's largest facility for producing synchrotron radiation. The extremely bright beams of light enable the study of material at the atomic and molecular level. Sweden participates in ESRF via the Nordic consortium, Nordsync. ESRF is upgrading experiment stations and accelerators (2010-2015) to meet increasing demands from the research community.

ESS – European Spallation Source

European facility for research involving neutron scattering technology being planned in Lund, Sweden. All types of materials can be analysed at ESS to understand how they are constructed and how they function. Research fields and industries that can benefit from ESS include materials and nanotechnology, chemistry, molecular biology, biomedicine, pharmaceuticals, energy technology, IT and others. By the end of 2011, seventeen countries had declared their interest to participate in the development of ESS. Negotiations on terms and conditions are under way with potential member nations.

ILL

Institute Laue-Langevin (ILL) in Grenoble is currently the world's leading neutron scattering facility for studies of different types of material. Researchers conducting experiments at ILL represent fields such as molecular biology, physics, chemistry, materials science, and environmental research.

Euro-FEL

European network of free electron lasers in the infrared to soft x-ray range (formerly IRUVX-FEL). Free electron lasers are used to increase understanding of the properties of materials, molecules, and atoms by imaging structures and monitoring different dynamic processes. Sweden participates through MAX-lab.

ISIS

Spallation facility for neutron scattering in Oxfordshire. Researchers in physics, chemistry, materials science, environmental research, and other fields conduct experiments at ISIS.

MAX IV-laboratoriet

MAX-lab at Lund University is Sweden's national laboratory for synchrotron radiation research. Users of the laboratory include researchers in material science, structural biology, solid-state physics, chemistry, and geology. The next step is the proposed "future light source" MAX IV.

Myfab

Network for microfabrication laboratories at Chalmers, Uppsala University, and the Royal Institute of Technology. Since 2003, the network has been funded by the Swedish Research Council, the Foundation for Strategic Research, VINNOVA, and the Knut and Alice Wallenberg Foundation. Cleanrooms are used both for research purposes and in industry.

Nordsync

Nordic consortium for participation in the European synchrotron radiation facility (ESRF).

Petra III

The third generation synchrotron radiation facility in Hamburg. Sweden is participating in the construction of an experimental station within the framework of a German-Swedish research collaboration, primarily in materials science and structural biology.

Super-Adam

Super-Adam is an upgrade of the Adam reflectometer at the neutron source ILL (Institute Laue-Langevin) in Grenoble. The instrument uses reflection of neutrons from thin layers and surface structures, e.g. to study the inner structure and properties of various materials.

XFEL – the European X-ray free electron laser facility

The European x-ray free electron laser (XFEL) is an international collaborative project where Sweden participates with funding from the Swedish Research Council. The facility is under construction in Germany and is planned for completion in 2014. XFEL is expected to produce intensive x-ray beams of 10 billion times higher brilliance than those currently available.

e-Science

NDGF – Nordic Data Grid Facility

The Nordic Data Grid Facility (NDGF) for computational resources utilises the linkage of computers through grid technology.

PRACE – Partnership for Advanced Computing in Europe

European metacentre for high-performance computer systems. Sweden participates through SNIC.

SNIC – Swedish National Infrastructure for Computing

SNIC provides computing, analytical, and modelling capacity for research. SNIC consists of the six leading centres for high-performance computing systems in Sweden. A new organisation is being launched in 2012.

SUNET – Swedish University Computer Network

SUNET is a joint organisation and infrastructure primarily for universities and higher education institutions. It aims to serve their needs for national and international data communication. SUNET also provides several services beyond the basic network services. State funding and fees from user organisations finance SUNET's activities. SUNET also participates in international development projects in the area of e-Science.

APPENDIX 2 – MEMBERS OF THE COUNCIL FOR RESEARCH INFRASTRUCTURES AND ITS EVALUATION PANELS

Council for Research Infrastructures 2010-2011

Kerstin Eliasson, *Chair* (from 15 February 2010)
Madelene Sandström, *CEO*, The Knowledge Foundation, *Chair* (through 15 February 2010)
Marcus Aldén, *Professor*, Lund University (from 1 January 2011)
Anders Brändström, *Professor*, Umeå University (through 31 December 2010)
Erik Elmroth, *Professor*, Umeå University (through 31 December 2010)
Claes Fransson, *Professor*, Stockholm University (through 31 December 2010)
Lena Gustafsson, *Professor*, Deputy Director General, Vinnova (through 30 June 2010)
Elisabet Engdahl, *Professor*, Göteborg University (from 1 January 2011)
Eva Lindencrona, *Director*, Vinnova (from 1 October 2010)
Dick Heinegård, *Professor*, Lund University
Erland Hjelmquist, *Professor*, Secretary General FAS
Susanne Holmgren, *Professor*, Göteborg University (through 31 December 2010)
Ulf Karlsson, *Professor*, Royal Institute of Technology (through 31 December 2010)
Anna Ledin, *Professor*, Secretary General, Formas (through 31 December 2010)
Bengt H Ohlsson, *Research Officer*, Formas (from 1 January 2011)
Håkan Olsson, *Professor*, Swedish University of Agricultural Sciences
Henrik Oscarsson, *Professor*, Göteborg University
Juni Palmgren, *Professor*, Stockholm University and Karolinska Institutet, through 30 June 2010)
Ann-Christine Syvänen, *Professor*, Uppsala University (from 1 October 2010)
Kajsa Uvdal, *Professor*, Linköping University (from 1 January 2011)
Lars Wallentin, *Professor*, Uppsala University (from 1 January 2011)
Barbro Åsman, *Professor*, Stockholm University (from 1 January 2011)

Secretary General

Lars Börjesson, *Professor*, Chalmers (through 30 June 2010)
Juni Palmgren, *Professor*, Stockholm University and Karolinska Institutet (from 1 July 2010)

Evaluation Panels (through 31 mars 2011)

Evaluation Panel 1 – Infrastructure for Astronomy and Subatomic Research

Claes Fransson, Stockholm University, *Chair*
Paula Eerola, University of Helsinki
Lars Bergström, Stockholm University
Sofia Feltzing, Lund University
Tord Johansson, Uppsala University
Torbjörn Sjöstrand, Lund University

Evaluation Panel 2 – Infrastructure for Molecular, Cell, and Material Research

Ulf Karlsson, Royal Institute of Technology, *Chair* (through 31 December 2010)
Dick Heinegård, Lund University, *Vice Chair*, *Chair* (from 1 January 2011)
Inger Andersson, Swedish University of Agricultural Sciences
Anne Borg, Norwegian University of Science and Technology, Trondheim
Jan-Otto Carlsson, Uppsala University
Urban Lendahl, Karolinska Institutet
Tor Ny, Umeå University
Ingrid Reineck, Sandvik
Kajsa Uvdal, Linköping University

Evaluation Panel 3 – Infrastructure for Earth and Environmental Sciences

Donal Murtagh, Chalmers, *Chair*
Håkan Olsson, Swedish University of Agricultural Sciences, *Vice Chair*
Ulf Båmstedt, Umeå University
Mari Källersjö, Gothenburg Botanical Garden
Torben Christensen, Lund University
Bengt Ohlsson, Formas
Victoria Pease, Stockholm University

Evaluation Panel 4 – Infrastructure for e-Science

Juni Palmgren, Karolinska Institutet/Stockholm University, *Chair* (through 30 June 2010)
Erik Elmroth, Umeå University, *Vice Chair*, (*Chair* from 1 July 2010)
Anders Brändström, Umeå University
Björn Halleröd, Göteborg University
Dan Henningson, Royal Institute of Technology
Jeanette Hellgren Kotaleski, Royal Institute of Technology
Kersti Hermansson, Uppsala University
Jesper Tegnér, Karolinska Institutet

Evaluation Panels from 1 April 2011

Evaluation Panel 1 – Infrastructure for Astronomy and Subatomic Research

Göran Östlin, Stockholm University, *Chair*
Paula Eerola, University of Helsinki, *Vice Chair*
Marcus Aldén, Lund University
Melvyn Davies, Lund University
Tünde Fülöp, Chalmers
Thomas Nilsson, Chalmers
Lennart Nordh, Swedish National Space Board
Barbro Åsman, Stockholm University

Evaluation Panel 2 – Infrastructure for Molecular, Cell, and Material Research

Jan-Otto Carlsson, Uppsala University, *Chair*
Dick Heinegård, Lund University, *Vice Chair*
John Eriksson, Åbo Academy
Björgvin Hjörvarsson, Uppsala University
Tor Ny, Umeå University
Ingrid Reineck, Sandvik
Stacey Sörensen, Lund University
Kajsa Uvdal, Linköping University
Lars Wärngård, Vinnova
Xiaodong Zou, Stockholm University

Evaluation Panel 3 – Infrastructure for Research on the Earth and its Near Surroundings

Roland Roberts, Uppsala University, *Chair*
Håkan Olsson, Swedish University of Agricultural Sciences, *Vice Chair*
Tim Fristedt, Swedish Defence Research Agency (FOI)
Jörg Gumbel, Stockholm University
Mari Källersjö, Gothenburg Botanical Garden
Lena Neij, Lund University
Auli Niemi, Uppsala University
Bengt Ohlsson, Formas

Evaluation Panel 4 – Infrastructure for e-Science

Pär Strand, Chalmers, *Chair*
Ann-Christine Syvänen, Uppsala University, *Vice Chair*
Dan Henningsson, Royal Institute of Technology
Mats Holmström, Swedish Institute of Space Physics (IRF) Kiruna
Ebba Þóra Hvannberg, University of Iceland
Ingela Nyström, Uppsala University (from 15 September 2011)

Fredrik Ronquist, NMR/GBIF
Kenneth Ruud, Tromsö

Evaluation Panel 5 – Infrastructure for Man, Culture, and Society

Björn Halleröd, Göteborg University, *Chair*
Kristina Alexanderson, Karolinska Institutet, *Vice Chair*
Gunnar Andersson, Stockholm University
Elisabet Engdahl, Göteborg University
Erland Hjelmquist, FAS
Håkan Karlsson, Göteborg University
Margareta Kristenson, Linköping University

Staff working with the Guide at the Swedish Research Council:

Camilla Jakobsson, *Coordinator*, *Project Manager*
Juni Palmgren, *Secretary General*, Council for Research Infrastructures
David Edvardsson, *Research Officer*, Evaluation Panel 1
Elin Swedenborg, *Research Officer*, Evaluation Panel 2
Tove Andersson, *Research Officer*, Evaluation Panel 2
Magnus Friberg, *Research Officer*, Evaluation Panel 3
Mikael Borg, *Research Officer*, Evaluation Panel 4
Eva Stensköld, *Research Officer*, Evaluation Panel 5
Johan Holmberg, *Research Officer*
Per Karlsson, *Research Officer/Head of Unit*
Kristina Sundbaum, *Communications Officer*

The Council for Research Infrastructures would like to sincerely thank everyone who contributed to this update of the Guide.

APPENDIX 3 – REFERENCES

Four main sources have been used to update this new edition of the Guide to Research Infrastructures:

1. Viewpoints received through a review and comment process with universities and higher education institutions. Many viewpoints were also received via the Web forum held in September 2010 and visits to the larger universities in November 2010.
2. Viewpoints received during the process of evaluating the applications for infrastructure grants.
3. Viewpoints received in conjunction with notifications of interest for participating in the preparatory phase of the European projects included in the ESFRI roadmaps from 2008 and 2010.
4. Studies conducted by the Swedish Research Council after publication of the previous edition of the Swedish Research Council's Guide to Infrastructure.

The Council for Research Infrastructures (RFI) and its subcommittees considered all of the viewpoints submitted. The Swedish Research Council's three scientific councils and the Committee for Educational Sciences (UVK) were given an opportunity to review and comment on the previous edition, including an appendix describing major changes in 2008–2010 and the main recommendations presented by the Council for Research Infrastructures in this report.

Reports

Links: www.vr.se > *Forskningsinfrastruktur* > *Vetenskapsrådets guide till infrastrukturen* [Research infrastructure > The Swedish Research Council's Guide to Research Infrastructures]

Evaluation of the Database Infrastructure Committee (DISC)

International Evaluation of SNIC

Infrastruktur för fältbaserad forskning [Infrastructure for Field-based Research]

En studie av investeringar i utrustning för forskning vid svenska universitet, rapport 2010:09 [A Study of Investments in Research Equipment at Swedish Universities, Report 2010:09]

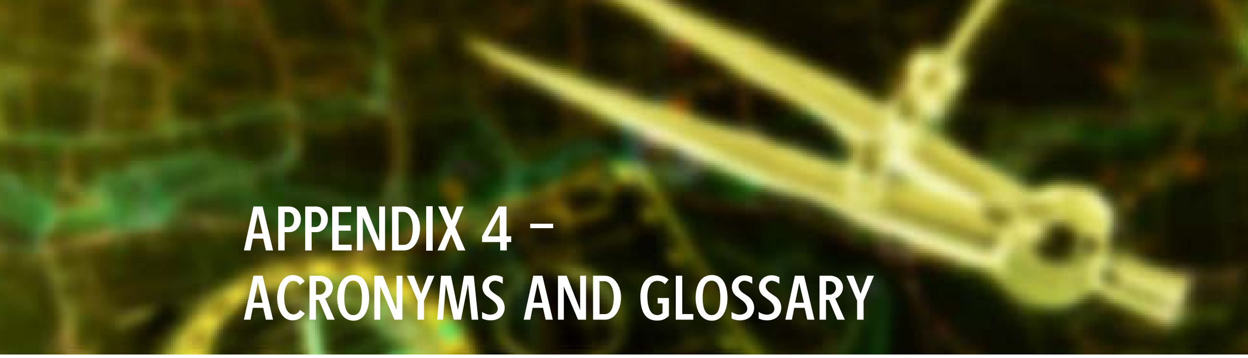
Report from the Review of the MAX Laboratory, Report 2010-05

Evaluation of the Modified MAX IV Proposal 2009, Report 2010-12

International Evaluation of Onsala Space Observatory, Report 2010-07

Rättsliga förutsättningar för en databasinfrastruktur för forskning, rapport 2010:11 [Legal Prerequisites for a Database Infrastructure for Research, Report 2010:11]
Conference report: Global Challenges – Regional Opportunities: How can research infrastructure and eScience support Nordic competitiveness?
A vision for strengthening world-class research infrastructures in the ERA
ESFRI Implementation Report
ESFRI Strategy Report on Research Infrastructures, Roadmap 2010
ESFRI WGR on Evaluation of RIs, 2011
European Roadmap for Research Infrastructures. ESFRI Report 2008
The Swedish Research Council's Guide to Research Infrastructure, Report 11:2007.
Appendix with additions to The Swedish Research Council's Guide to Research Infrastructure, *Vad har hänt 2008–2010* [What has happened 2008-2010?]

Viewpoints on the previous edition of The Swedish Research Council's Guide to Research Infrastructure. Links: www.vr.se > *Forskningsinfrastruktur* > *Vetenskapsrådets guide till Infrastrukturen*> [Research infrastructure > The Swedish Research Council's Guide to Research Infrastructures]
Comments from HEIs and research funding bodies
Web forum: *Tyck till om framtidens infrastruktur* [Your opinions about future infrastructures]



APPENDIX 4 – ACRONYMS AND GLOSSARY

ALMA	Atacama Large Millimeter Array, radiotelescope being constructed in Chile.
ANAEE	Analysis and Experimentation on Ecosystem, European infrastructure for experimental ecology.
BBMRI	Biobanking and Biomolecular Resources Infrastructure, European infrastructure for managing biological samples.
BILS	Bioinformatic Infrastructure for Life Sciences, Swedish infrastructure for bioinformatics.
BLARK	Basic Language Resource Kit, basic resources (data and program) used in language technology.
CBCS	Chemical Biology Consortium Sweden, infrastructure for chemical biology and production of small organic molecules.
CERN	European Organization for Nuclear Research, facility for experiments in particle physics near Geneva.
CESSDA	Council of European Social Science Data Archives, distributed infrastructure for data in social sciences.
CLARIN	Common Language Resources and Technology Infrastructure.
CLIC	Compact Linear Collider, possible future accelerator at CERN, in the planning stage.
DARIAH	Digital Research Infrastructure for the Arts and Humanities.
DISC	Database InfraStructure Committee, the Swedish Research Council's expert panel on database issues.
DNA	Deoxyribonucleic acid, carries heredity information in the genes.
EATRIS	Planned European network of nodes for translational research.
EBI	European Bioinformatics Institute, part of the European Molecular Biology Laboratory (EMBL).
ECDS	Environment Climate Data Sweden, infrastructure to store and make available the data from Swedish climate and environmental research. Previously SND-KM.

ECORD	European Consortium for Oceanic Research Drilling. Sweden participates in the deep oceanic drilling programme, Integrated Ocean Drilling Program (IODP), through ECORD.
ECRIN	European Clinical Infrastructure Network.
E-ELT	European Extremely Large Telescope, next generation European giant telescope.
EISCAT	European Incoherent Scatter facility, network of radar stations in northern Scandinavia, EISCAT-3D is being planned.
ELIXIR	European Life Science Infrastructure for Biological Information, European bioinformatics infrastructure.
EMBL	European Molecular Biological Laboratory.
EMBRC	European Marine Biological Resource Centre, European infrastructure for marine biology data.
EMSO	European Multidisciplinary Seafloor Observatory, deep-sea-based observation system.
EPOS	European Plate Observing System.
ESFRI	European Strategy Forum on Research Infrastructures, European organisation for collaboration on research infrastructures.
ESO	European Southern Observatory, operates telescope in Chile.
ESRF	European Synchrotron Radiation Facility, located in Grenoble.
ESS	1) European Social Survey, questionnaire survey for international comparisons in social sciences. 2) European Spallation Source, planned facility for material studies by use of neutron scattering technology.
EST	Planned European solar telescope.
EuroFEL (previously IRUVX-fel)	Planned free-electron laser network in the area of infrared to soft x-rays.
EU-solaris	The European SOLAR Research Infrastructure for Concentrating Solar Power, planned infrastructure for solar energy.
FAIR	Facility for Antiproton and Ion Research, facility for nuclear and hadron physics experiments, being constructed in Germany.
Femtosecond	One quadrillionth (one millionth of one billionth) of a second, femto=10-15.

Phenotyping	Characterising an organism by describing its observable characteristics, phenotype = genotype + environment.
Fluxnet	Global network for measuring the exchange of carbon dioxide, water vapour, and heat energy between the atmosphere and different ecosystems.
Ganil	Grand Accélérateur d'Ions Lourds, facility in Caen for radioactive ion beams.
GBIF	Global Biodiversity Information Facility, global network to make data on biological diversity accessible for research.
GeV	Gigaelectron volt, unit of energy. $G=10^9$.
GNP	Gross national product.
Hadron	Strongly interacting subatomic particle.
Icecube	Neutrino telescope at the South Pole.
ICOS	Integrated Carbon Observation System, planned system to coordinate and develop European measuring of carbon dioxide exchange between ground surface and atmosphere.
ICPSR	Inter-University Consortium for Political and Social Research.
IFMIF	International Fusion Materials Irradiation Facility, planned test facility for fusion-related material.
IFDO	International Federation of Data Archives.
ILC	International Linear Collider, worldwide collaboration on next-generation particle accelerator.
ILL	Institut Laue-Langevin, neutron scattering facility in Grenoble.
INCF	International Neuroinformatics Coordinating Facility, infrastructure for neuroinformatics.
INFRAFRONTIER	Planned European infrastructure for genetically modified mouse models.
In situ	In medicine and biology, this refers to studies "on site" in the tissue.
Interact	International Network for Terrestrial Research and Monitoring in the Arctic, EU funded.
In vivo	Studies of processes in cells and tissues in a living intact organism.
IODP	Integrated Ocean Drilling Program, international ocean drilling programme for taking samples in all ocean areas.

ISBE	Infrastructure for Systems Biology Europe.
ISF	Institutet for Solar Physics.
ISIS	Neutron scattering facility near Oxford.
ISOLDE	Isotope Separator On Line, facility for radioactive ion beams at CERN.
ITER	International Thermonuclear Experimental Reactor, international test reactor for fusion, under construction in France.
ITPS	Swedish Institute for Growth Policy Studies.
JET	Experimental facility for fusion research.
KAW	Knut and Alice Wallenberg Foundation – funds e.g. infrastructure for research.
LHC	Large Hadron Collider, large particle accelerator at CERN, became operational in 2009.
LifeWatch	Coordination of research infrastructures on biodiversity and sustainable development in Europe.
Lofar	Low Frequency Array, radiotelescope operated from the Netherlands, Onsala is the Swedish partner.
LTER	Long-Term Ecological Research Network.
MAX-lab	Synchrotron radiation facility in Lund, phased in the new MAX IV.
MeV	Megaelectron volt, unit of energy, $M=10^6$.
MIMS	The Laboratory for Molecular Infection Medicine Sweden, laboratory for infectious diseases at Umeå University. The Swedish node in the Nordic EMBL collaboration in molecular medicine.
MIRRI	Microbial Resource Research Infrastructure.
MONA	Microdata Online Access, system for external access to data from Statistics Sweden (*Statistiska centralbyrån*).
MW	Megawatt, unit of power.
Myfab	Network for microfabrication laboratories.
MYRRHA	Multi-purpose hybrid research reactor for high-tech applications, research reactor.
Nanometre	One billionth of a meter, nano=10^{-9}.
NDGF	Nordic Data Grid Facility, organisation for Nordic collaboration on grid technology and grid utilisation.
Nordsim	Nordic Secondary Ion Mass spectrometer, instrument used in geology to measure the composition of isotopes and basic elements. Located at the Swedish Museum of Natural History (*Naturhistoriska riksmuseet*) in Stockholm.

Nordsync	Nordic consortium for participation in the European Synchrotron Radiation Facility (ESRF).
Nordunet	Collaborative organisation for university data networks in the Nordic countries.
NOT	Nordic Optical Telescope on La Palma in the Canary Islands.
NuSTAR	Nuclear Structure, Astrophysics and Reactions, international collaboration in nuclear- and astrophysics.
Petra III	German synchrotron radiation facility.
PRACE	Partnership for Advanced Computing in Europe – European collaboration concerning high-performance computers.
RNA	Ribonucleic acid, molecules that control gene activity by transferring genetic information from DNA to protein.
SGU	Geological Survey of Sweden.
SHARE	Survey of Health, Ageing, and Retirement in Europe.
SIOS	Svalbard Integrated Arctic Earth Observing System.
SKA	Square Kilometre Array, planned radiotelescope.
SLU	Swedish University of Agricultural Sciences.
SND	Swedish National Data Service, infrastructure for research in social sciences, medicine, and the humanities.
SND-KM	see ECDS
SNIC	Swedish National Infrastructure for Computing, infrastructure of resources for computing, analysing, and modelling.
SNISS	Swedish National Infrastructure for Large-Scale Sequencing, infrastructure for large-scale DNA sequencing.
STED	Stimulated Emission Depletion, type of high-resolution microscopy.
STM	Scanning electron microscopy.
SUNET	Swedish University Computer Network.
Super-Adam	Swedish instrument at neutron research facility ILL in Grenoble.
Swegrid	Organisation collaborating with SNIC to develop and test grid technology and construct resources for using grid technology in Sweden.
Sweimp	Swedish Infrastructure for Mouse Phenotyping, planned Swedish node to INTRAFRONTIER.

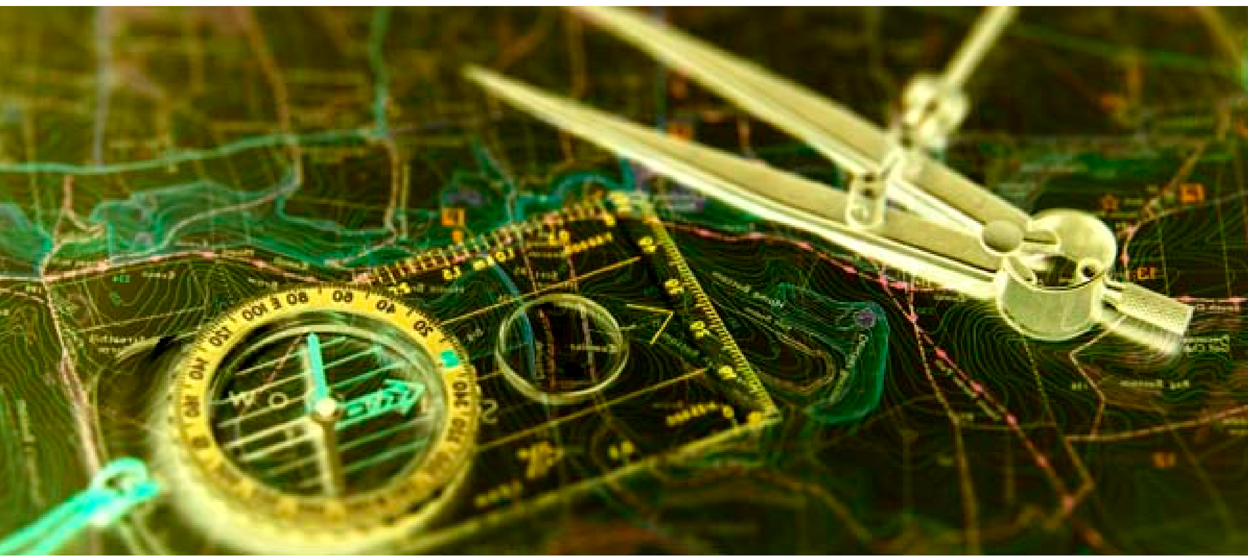
Synthesys	Collaboration among natural history collections and botanical gardens in Europe.
TEM	Transmission electron microscopy.
TeV	Teraelectron volt, unit of energy, $T=10^{12}$.
Windscanner	Infrastructure for measuring wind and turbulence around wind turbines.
XFEL	X-ray Free Electron Laser facility, European x-ray free electron laser under construction in Germany.
Å	Ångström or Angstrom (0.1 nm), unit of length.

Research environments with world-class infrastructures are essential for the advancement of science. They also generate innovation, influence the social climate, and attract talent.

The Swedish Research Council's Guide to Infrastructures presents an overview of the long-term needs for research infrastructures to enable Swedish research of the highest quality in all scientific fields. The guide addresses proposals for new infrastructures that have achieved a sufficiently high level of scientific, technical, and organisational maturity that it is time to determine whether or not to implement them. The guide also presents recommendations for new infrastructure projects or areas where Swedish research would benefit substantially from greater national and/or international coordination.

Research infrastructures encompass central or distributed research facilities, databases, and large-scale computing, analytical, and modelling resources.

The Swedish Research Council published its first guide to infrastructures in 2006, and released an updated version in 2007/2008. This, the third edition of the guide, has been produced by the Council for Research Infrastructures and its evaluation panels in close collaboration with the scientific councils within the Swedish Research Council, other research funding bodies, universities and higher education institutions, and other research groups.



Västra Järnvägsgatan 3 | Box 1035 | SE-101 38 Stockholm | Tel +46-8-546 44 000 | vetenskapsradet@vr.se | www.vr.se

The Swedish Research Council is a government agency that provides funding for basic research of the highest scientific quality in all disciplinary domains. Besides research funding, the agency works with strategy, analysis, and research communication. The objective is for Sweden to be a leading research nation.

ISSN 1651-7350
ISBN 978-91-7307-203-8