Vetenskapsrådet

THE SWEDISH RESEARCH COUNCIL'S GUIDE TO INFRASTRUCTURE

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

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

The research councils are: the Swedish Research Council, the Swedish Council for Working Life and Social Research and the Swedish Research Council for Environment, Agricultural Sciences, and Spatial Planning. VINNOVA is the Swedish Governmental Agency for Innovation Systems.

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FOREWORD

This document, the second edition of the Swedish Research Council's Guide to Infrastructure, represents a major update of the first edition in 2006. It responds to an additional task of providing a roadmap of research infrastructure in areas outside of the normal areas of responsibility for the Swedish Research Council. The guide describes the long-term needs of research infrastructure for future Swedish research of the highest quality. It intends to provide a basis for discussion concerning financing of future infrastructure for research in Sweden and for participating in joint international research infrastructures.

In 2005, the Board of the Swedish Research Council established the Committee for Research Infrastructures (KFI). The primary aim of KFI is to support the development and utilisation of infrastructure to promote the conditions for Swedish research of the highest scientific quality. Consolidating infrastructure issues within the same committee promotes greater clarity in managing infrastructure matters, enables better planning with longer time horizons, and facilitates a more comprehensive overview of international activities.

An important aspect of KFIs work is to collaborate with other research financers to develop a long-term strategic plan to give Swedish researchers access to research infrastructures that enable research of the highest quality within all research fields. The plan should be updated regularly and cover everything from planning, development, and operation to the phase-out of research infrastructures. The Swedish Research Council's Guide to Infrastructure was prepared by KFI and its subcommittees through extensive consultation involving the scientific councils of the Swedish Research Council, other research financers, universities and university colleges, and various research groups.

The second edition has been produced to update the contents in line with the studies and assessments conducted at the Swedish Research Council since publication of the first edition. It is also relevant to relate to the European Roadmap for Research Infrastructures, published in 2006. The second edition of the Swedish guide will also provide important background documentation for the report that the Swedish Research Council will submit to the Government at the end of 2007, ahead of the next research policy proposition.

Stockholm December 2007

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SUMMARY

The Swedish Research Council's Guide to Infrastructure provides an overview of the long-term needs for research infrastructures to enable Swedish research of the highest quality in all scientific fields. This report updates the first version of the Swedish roadmap for research infrastructures, published in 2006. The Swedish Research Council has developed the Guide in collaboration with FAS (Swedish Council for Working Life and Social Research), Formas (Swedish Research Council for Environment, Agricultural Sciences, and Spatial Planning), and VINNOVA (Swedish Governmental Agency for Innovation Systems) to reflect the need for basic research and needs-driven research. Research infrastructures include, e.g. central or distributed research facilities, databases, and extensive data networks.

Studies conducted under the auspices of the Swedish Research Council since publication of the first Guide have influenced the contents of this edition. The European Roadmap for Research Infrastructures has also played a role, as has input from universities, university colleges, other research funding bodies, and individual researchers.

Environments surrounding outstanding infrastructures are not only essential for the advancement of science; they also generate innovation, influence social climate, and attract talent. Also, corporations with needs for high-level expertise prefer to establish themselves near these research environments.

The research infrastructures included in this report should meet several general criteria: they should be of national interest, offer the potential for world-leading research, be too extensive for single groups, include long-term planning, and be openly accessible to researchers. Where demand is high, prioritisation systems based on research quality should determine who should have access to the infrastructures.

To strengthen Swedish research in the long term, the Swedish Research Council recommends the following:

- Sweden should participate actively in the development of common international infrastructures – primarily by contributing to the 15 projects from the ESFRI* Roadmap for Research Infrastructures that have been given highest priority by Swedish researchers. The Swedish Research Council is participating in the planning of seven projects judged to be of particular interest. They are: ELIXIR (European Life Sciences Infrastructure for Biological Information), ESS (European Spallation Source), PRACE (Partnership for Advanced Computing in Europe), FAIR (Facility for

* European Strategy Forum on Research Infrastructures

Antiproton and Ion Research), Infrafrontier (Infrastructure for phenotyping and archiving of model mammalian genomes), LifeWatch (e-science and technology infrastructure for biodiversity data and observations), and XFEL (X-ray Free Electron Laser).
- Research infrastructures should be coordinated at the national level to increase the quality of research and utilise resources more efficiently. Current examples include systems for managing environmental and climate data and the coordination of biobanks.
- National nodes should be developed to collaborate with international infrastructures. Resources are also needed on the home front to develop technology, expertise, and methods.
- Sweden should offer to host one or more international infrastructure, for example, ESS (European Spallation Source). Other possibilities would be the MAX IV synchrotron radiation facility and the upgrading of EISCAT (European Incoherent Scatter Facility).
- Advancements in eScience are revolutionising many disciplines. eInfrastructures for large-scale computing, communication, and storage of data should be strengthened to benefit all research fields.

In planning research infrastructures it is essential to consider the full lifecycle – from concept and construction to operation and phase-out. Hence, the Swedish Research Council recognises the need for new types of grants that facilitate long-term planning and promote long-term projects and competition in operating and using infrastructures. For instance, establishment of a long-term investment fund has been proposed for large investments in research infrastructures. Financing should aim to achieve a balance between investment and operational resources and resources to enable researchers to use the infrastructures.

The Crab Nebula is the remnants of a supernova that exploded approximately 6000 light-years from Earth.

Photo: ESO

PART 1

Introduction

This is a new edition of the Swedish Research Council's Guide to Infrastructure (also referred to as the Guide in the following text).[I] The Guide aims to provide an overview of the long-term needs for joint research infrastructures for Swedish Research of the highest quality within all research fields. In particular, it addresses new infrastructure proposals that have achieved a sufficiently high level of scientific and technical maturity that it is time to decide whether or not to implement them. The Guide provides a basis for discussions and decisions concerning financing of future research infrastructures in Sweden and concerning Swedish participation in joint international infrastructures. This edition of the Guide addresses both the need for research infrastructures in basic research and the more applied fields that normally fall within the sphere of responsibility of the Swedish Council for Working Life and Social Research (FAS), the Swedish Research Council for Environment, Agricultural Sciences, and Spatial Planning (Formas), and the Swedish Governmental Agency for Innovation Systems (VINNOVA).

Importance of Research Infrastructures for Research and Society

Cutting-edge research is important for the advancement of society. It is the foundation for our understanding of our place in the universe, the origin of matter, the development of life, and the advancement of society. It also serves as the base for developing countless technical and medical innovations. Greater knowledge can lead to better environment, health, and economy for a sustainable society.

The most innovative and highest-quality research takes place where the conditions are most favourable. Such conditions include everything from having access to the most advanced methods to an intellectual and creative environment with opportunities for research careers. The most talented re-

[I] Research infrastructure refers to, e.g. central or distributed research facilities, databases, or extensive data networks.

Society benefits from the applications of many techniques that have emerged from leading infrastructures. Photo of a PET scanner.

Photo: SXC

searchers are attracted to environments with the highest potential for conducting outstanding research. An important element for such conditions is a competitive research infrastructure, where researchers have access to the most advanced tools for scientific discoveries.

Infrastructure such as advanced accelerator facilities, computing resources, data networks, and databases are often decisive factors behind advancements in research. For example:

- Extensive databases are prerequisite for much of the research in social sciences, biology, and medicine.
- Knowledge concerning the inner structure of matter is completely dependent on particle accelerators.
- Knowledge about the universe and its development depends on observations with different types of telescopes.
- Knowledge about the atomic structure and function of biomolecules and materials depends on the combination of a large set of methods, where synchrotron and neutron radiation facilities play a decisive role.
- Opportunities to study polar regions and the seabed depend on research vessels.
- Climate research depends on global detection systems to monitor climate change.
- High-performance computers are decisive for our ability to analyse extensive sets of data or carry out simulations and modelling in most areas of science.

Photo from MAX-lab, a Swedish facility for research involving synchrotron radiation technology.

Photo: Annika Nyberg, MAX-lab

Many researchers often share these advanced and complex research tools. Preferably, use is regulated through scientific competition so that the best researchers and the most promising projects gain access to the most advanced infrastructures. Since the leading infrastructures enable researchers to tackle the greatest scientific challenges, it is in these settings where advancements in scientific methods and technology are driven to the outer limits of what humans can achieve. Hence, they play a key role in current and future pioneering research.

Attractive research centres are not only positive for the advancement of research, they also generate ideas for innovations, influence the social climate, offer incentives to attract talent, etc. This, in turn, provides an argument for corporations needing advanced expertise and development to establish themselves near these centres.

Experience and studies show that good research infrastructures not only provide unique conditions for scientific breakthroughs, they also are:

- drivers of technology[2]
- incubators for new scientific ideas
- interdisciplinary and international meeting places
- generators of community and business development.[3]

A decisive factor behind the function of infrastructure as a tool for research is its ability to provide advanced service to researchers and to provide qualified education in using the resources.

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[2] Technology driving even for areas outside of science, e.g. needs at the particle physics laboratory CERN led to developing the World Wide Web and detectors for health care.

[3] Major socioeconomic effects are found, e.g. in studies of the development of the European Synchrotron Radiation Facility ESRF and the neutron source ILL in Grenoble and CERN in the Geneva area. In macroeconomic calculations, ITPS (the Swedish Institute for Growth Policy Studies) has also shown major effects from the proposed European Spallation Source (ESS).

Concurrently, there is a risk that an established research infrastructure can, in the long term, become conservative for science since it ties up extensive capital and intellectual resources. This can and should be counterbalanced by well-developed plans for follow-up, assessment, and re-evaluation.

Criteria to Support Research Infrastructures

Research infrastructure refers to, e.g. concentrated or distributed research facilities, databases, or extensive data networks. The concept of research infrastructure may include several widely diverse components and may be defined differently in different contexts. The European Strategy Forum on Research Infrastructures (ESFRI) uses the following definition:

> "...the tools that provide essential services to the research community for basic or applied research. They may concern the whole range of scientific and technological fields, from social sciences to astronomy, going through genomics or nanotechnologies. Examples include libraries, databases, biological archives, laboratories, clean rooms, communication networks, research vessels, satellite and aircraft observation facilities, coastal observatories, telescopes, synchrotrons, and accelerators. They may be 'single-sited', 'distributed', or 'virtual'. What we are dealing with are the necessary tools for the future to do research in many areas at the cutting edge."

ESFRI has also added a criterion concerning open accessibility for researchers in respective fields.

The Swedish Research Council has determined that for a research infrastructure to be fully or partly funded it should meet the following general criteria. It shall:

- be of broad national interest
- provide scope for outstanding 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 use
- be open and easily accessible for researchers and have a plan for improving accessibility (concerns both use of the infrastructure, access to collected data, and presentation of results)

Other aspects can also be considered in decisions on funding, e.g. the strategic importance of the infrastructure for research, or its role in building up expertise.

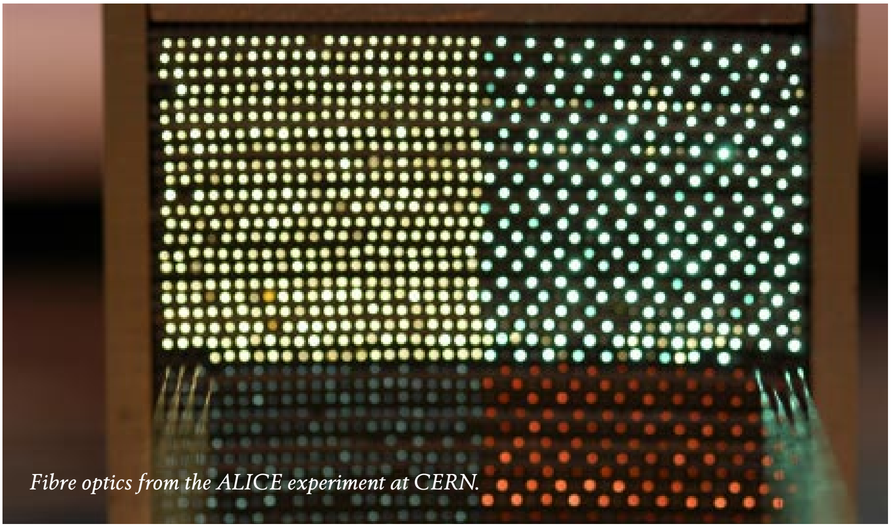
Fibre optics from the ALICE experiment at CERN.

Photo: CERN

Developing Joint European and International Research Infrastructures

Achieving new breakthroughs in science often depends on having access to increasingly advanced accelerator facilities, more powerful computing resources, higher resolution microscopes, faster data networks, more comprehensive and accessible databases, e.g. in epidemiology, social sciences, and climate research. Hence, scientists in many fields collaborate in an ever-broader context, nationally, internationally, or globally to be able to create the facilities needed for new advancements. Examples of fields that are extremely dependent on advanced infrastructure include particle physics, which searches for knowledge about the innermost structure of matter and the origins of the universe, and fusion research that aims to achieve infinite energy sources on earth by mimicking the processes that occur in the sun. In both instances, researchers in global organisations collaborate to establish the complex facilities required to take the next step in development. The tendency towards broadening infrastructure collaboration, both in terms of larger individual facilities and in distributed infrastructures, is clearly noticeable in other areas such as the humanities and social sciences, environmental and climate research, materials research, and medicine and life sciences. Trends towards large-scale and/or international infrastructures place increasingly greater demands on long-term thinking, planning, and coordination among researchers and funding bodies.

For a relatively small country like Sweden, participating in international infrastructure projects is often essential to give Swedish scientists access to the most advanced research facilities. Complementary domestic resources are, on the other hand, important for developing methods that can be used in conjunction with the international infrastructures. Otherwise, there is a risk of missing out on the real breakthroughs in research. It would be desirable to have one or more of the European infrastructures operating from Sweden since they serve as research magnets and attract important expertise to our country. This, in turn, has positive effects for stimulating the quality of research in the country, and provides other long-term benefits to society through the inflow of experts and new ideas.

Nordic collaboration

Working with other Nordic countries can provide substantial collaborative benefits both for establishing infrastructures in Scandinavia and for jointly becoming a stronger partner in international projects. Examples of previous Nordic collaboration include the Nordic Optical Telescope (NOT), the NORDSYNC Consortium for participating in the European Synchrotron Radiation Facility (ESRF), the Nordic DataGrid Facility (NDGF), and various database registries.

Future Nordic collaboration could involve the establishment of large international infrastructures in Scandinavia, such as ESS (European Spallation Source), the MAX IV synchrotron radiation facility, and the new EISCAT-3D (European Incoherent Scatter Facility), or a competitive Nordic initiative addressing eInfrastructures. Collaboration could also involve infrastructures to meet special Nordic research needs or promote areas of strength, such as climate and the environment, Polar research, demographics, language technology, and fields that utilise individual databases and biobanks, e.g. epidemiology.

Roadmap for infrastructures in various countries

Several countries are working with strategies to develop 'roadmaps' for research infrastructures.[4] In the United States, the Department of Energy (DOE), National Science Foundation (NSF), and the National Institutes of Health (NIH) are among the bodies involved. In Australia, the National Collaborative Research Infrastructure Strategy (NCRIS) was launched in 2004 and includes long-term planning and a roadmap for infrastructure. In

[4] See Appendix 2, References

Europe, extensive effort has been dedicated to developing a joint roadmap for pan-European research infrastructures in all fields of research. The European Strategy Forum on Research Infrastructures (ESFRI) has directed this effort. ESFRI's first roadmap was complete in the autumn of 2006, and an updated version will be finished in the second half of 2008.

Joint European roadmap

ESFRI's roadmap, the European Roadmap for Research Infrastructures, addresses infrastructures in the humanities and social sciences, biomedicine and life-sciences, energy, material sciences, nuclear physics, astronomy and astroparticle physics, and high-performance computer resources. The infrastructure projects in the roadmap have been evaluated and found to be of high scientific value. Furthermore, they are sufficiently mature from a technical and scientific standpoint to develop further. Implementing these infrastructures will then involve bi- and multi-lateral negotiations. Since EU's budget for constructing new infrastructures is almost non-existent, financing must come from the member countries. However, there are opportunities within the Seventh Framework Programme to finance efforts to prepare for new infrastructures, ranging from design studies to the production of documents for multilateral contracts.

The ESFRI roadmap and its implementation represent the beginning of a major change in European research. Increasingly, more European countries recognise that being competitive against the United States, Japan, and growing world powers like China and India, requires collaboration on the most advanced scientific resources. World-leading, stationary research infrastructures provide long-term competitive advantages and attract many of the best researchers to the region. European researchers in all scientific fields are engaged in organising the implementation of projects from the ESFRI roadmap, both at the European level and the national level, which is expected to have major structural effects on research.

The first projects from ESFRI's roadmap are beginning to take shape. The X-ray Free Electron Laser (XFEL) and The Facility for Antiproton and Ion Research (FAIR), for example, have received such strong support that Germany's Minister of Research approved facility construction, starting in June and November 2007 respectively. Preparation for pan-European agreements will start for most of the 35 projects from the ESFRI roadmap with funds from EU's Seventh Framework Programme. Of these, the European Spallation Source (ESS) is one of the projects that is most mature and where Spain, Sweden, and Hungary have offered to be the host nation. A decision on building ESS should therefore be expected soon.

Many European countries have also developed, or are developing, their own roadmaps for research infrastructures.[5] In addition to Sweden, other countries that have published roadmaps include United Kingdom, Denmark, Spain, and Ireland. Among other effects, this has led to noticeably larger budgets for research infrastructures in Denmark, Spain, and Ireland.

Swedish participation in European research infrastructures

It is important for Swedish research to participate in several of the infrastructure projects identified in the ESFRI roadmap. Several of the proposed infrastructures involve research fields where Sweden currently holds a leading position. By participating in the formation phase, Swedish researchers gain access to highly competitive infrastructures and have the opportunity to sharpen their expertise in conjunction with the developmental phase. In some instances it might be possible to link Swedish facilities as local nodes, particularly in life sciences, social sciences, and environmental and climate research. New research infrastructures are often technology driven, and it is important for both technological and methodological developments for Swedish researchers, doctoral candidates, and students to participate in the most recent developments at the most advanced facilities. It is necessary to further investigate how Swedish scientists can best contribute to the development of joint infrastructures to gain access to the advanced instruments in different fields.

During the spring of 2007, the Swedish Research Council implemented a process to determine which ESFRI projects the agency would support during the preparatory phase. Research groups that planned to participate in applications under EU's Seventh Framework Programme for joint construction of projects were therefore asked to submit a notification of interest. After reviewing the proposals, the Swedish Research Council decided to be a co-applicant in applications concerning:

- European Life sciences Infrastructure for Biological Information (ELIXIR)
- European Spallation Source (ESS)
- Facility for Antiproton and Ion Research (FAIR)
- High-Performance Computing / Partnership for Advanced Computing in Europe (EU-HPC / PRACE)
- European Infrastructure for Phenotyping and Archiving of Model Mammalian Genomes (Infrafrontier)
- Biodiversity Infrastructure (LifeWatch)
- X-ray Free Electron Laser (XFEL)

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5 See Appendix 2, References

Furthermore, the following projects were given a letter of support:

- European Biobanking and Biomolecular Resources Infrastructure (BBMRI)
- Council of European Social Science Data Archives (CESSDA)
- Common Language Resources and Technology Infrastructure (CLARIN)
- European Advanced Translational Research Infrastructure in Medicine (EATRIS)
- European Multidisciplinary Seafloor Observatory (EMSO)
- European Social Survey (ESS)
- Integrated Carbon Observation System (ICOS)
- Free Electron Laser Network for Infrared to Soft X-rays (IRUVX-FEL)

Photo: SXC

LifeWatch, a distributed infrastructure, plans to collect research data concerning biological diversity – from the genetic level via species to entire ecosystems – so that over time we can understand and predict changes in ecosystems and the effects of change.

Work with global research infrastructures is under way in several fields. These include, e.g. a fusion reactor (ITER) under construction in France, the planned millimetre telescope Square Kilometre Array (SKA), and the next generation linear collider for particle physics (ILC). Many of the pan-European projects from the ESFRI roadmap can become global, e.g. the Facility for Antiproton and Ion Research (FAIR). Sweden also participates in the development of the neutrino telescope IceCube at the South Pole in collaboration with the United States, Germany, and Belgium.

Categorising Research Infrastructures

Research infrastructures can differ widely in character. They can be categorised in several ways, e.g. based on subject area, scope of distribution, or how they serve the user.

There is a plethora of terms that more or less define different types of research infrastructures, e.g. research facility, international and national facility, national resource, core facility, technical platform, or competence centre. Furthermore, some of these concepts are used differently in different contexts.

We have selected category headings that aim to avoid ambiguity. Infrastructures for research are divided in categories based on their accessibility to Swedish researchers and on how the responsibility for their operation and use is regulated. The categories are:

A Infrastructures operating under international conventions.

B Infrastructures operating via other international collaboration and that are openly accessible.

C Infrastructures at the national level that are openly accessible to all researchers.

D Networks of type-E nodes (below) at the national level that promote open accessibility among researchers and specialisation and complementary support among the nodes.

E Equipment or databases used jointly by research groups, mainly at a faculty or larger institution.

F Equipment in a research group's laboratory, or databases at the research group level. Used mainly by the research group, but also partly in collaboration with other research groups.

Under this method of categorisation, similar infrastructures can be found in different categories depending on how they are used. For instance, a biomedical core facility used mainly by research groups at a university department belongs to a different category (Category E) than an identical facility with national accessibility and where the use is determined by scientific prioritisation based on peer-reviewed applications for use (Category C).

Swedish authorities support and administer research infrastructures in all categories, but funding is handled differently. Public agencies usually manage Category A, but the central government decides on participation, leading to agreements among countries. Public agencies usually create, manage, and finance Category B infrastructures. Public agencies and other research funding bodies, in collaboration with universities and university colleges, usually manage categories C and D. The Swedish Research Council can provide funding for categories E and F via grants for expensive scientific equipment, funding for large databases, or project grants.

Examples of coordination aimed at making category E and F facilities more accessible for general national use include laboratories for nano- and microfabrication (Myfab), computing resources (SNIC), and databases for research in medicine and social sciences (DISC).

Different types of accessibility

Although infrastructures are accessible to the research community, different levels of accessibility may apply:

- Accessibility limited by availability, e.g. of user time or computing resources. In such cases, some type of allocation mechanism is necessary, e.g. peer review, to guarantee access for the best research.
- Accessibility limited by legal requirements, e.g. protection of individual integrity or animal rights. Utilisation must be preceded by ethical review.
- Unlimited access to researchers in the field.

Several international and larger national infrastructures currently issue a general call for applications, and utilisation is determined through competitive, quality evaluation. Experience shows that developments in infrastructure and research can benefit when the best projects are granted access.

Centralised versus distributed infrastructures

Another important aspect concerns how centralised or distributed the infrastructures are, since this influences function, financing, organisation, and responsibility.

Centralised infrastructures, such as synchrotron radiation facilities, particle accelerators, or telescopes often require major investments, lucid and stable management, long-term financing of operations and upgrading by the participants, and different types of on-site services including technicians, workshops, housing, and restaurants. They have also developed different peer review systems to assure that the best researchers have access to the infrastructures. These types of facilities are most common in the natural sciences and technical fields.

Distributed infrastructures, such as monitoring stations covering large areas, interlinked individual databases, or infrastructures for computing (e.g. grids), often involve major operational costs, long-term collection, data storage and accessibility, and a functioning network organisation encompassing many interests. These types of facilities are most common in the social sciences and humanities, medicine, and climate and environmental research.

Funding of Infrastructure

Development of research infrastructures includes several phases. For example, an infrastructure's lifecycle might include the following phases:

- Idea
- Concept development
- Design studies
- Planning of construction
- Coordination of involved parties
- Construction
- Operation
- Upgrading
- Phase-out

The need for financing differs by phase. The idea and concept development phases generally focus on research and fit within the framework of project grants. Design studies and construction planning have the specific objective of creating an infrastructure and usually require special financing. The construction phase involves major investment costs for a limited time. In the operational phase, the minimum level of financing needs to be assured for a longer period, and the accumulated total costs can be high. Generally, infrastructures need to be upgraded occasionally or gradually to maintain their competitiveness, which requires financing new investments. Finally, most infrastructures are eventually phased out, which is associated with substantial costs for decommissioning of technical equipment and phase-out of staff, etc. Hence, a phase-out plan should be established even before the decision is made to construct an infrastructure.

Meeting the long-term infrastructure needs of Swedish researchers requires a range of different funding options. Of the funding options available from the Swedish Research Council, the following are relevant from an infrastructure perspective:

- *Project grants* to generate ideas and concepts
- *Planning grants* for design studies and planning of construction or collaboration
- *Grants for expensive scientific equipment* that can be used to construct joint infrastructures and equip individual groups.

- *Grants for large databases* to develop and maintain quality assured databases made accessible to researchers
- *Operational grants* to operate joint research infrastructures.

In addition, the Swedish Research Council pays for membership in several international infrastructures, giving Swedish researchers access these facilities. The phase-out of infrastructures initially involves cutting back on operational grants for several years to enable the phase-out of staff.

Other public research funding bodies also contribute to the research infrastructure. For instance, the Swedish Research Council for Working Life and Social Research (FAS) partly finances several international databases and also databases at the national level. The Swedish Research Council for Environment, Agricultural Sciences, and Spatial Planning (Formas) does not directly fund infrastructures, but like the Swedish Research Council provides support to research projects and medium cost scientific equipment (up to 2 million SEK[6]) that can generate ideas and concepts. The same applies to the Swedish Governmental Agency for Innovation Systems' (VINNOVA) programmes. The Swedish National Space Board finances various distributed projects, e.g. in astronomy and environmental and climate monitoring.

Over the years, the Knut and Alice Wallenberg Foundation has been the dominating source of funds for investments in advanced equipment and infrastructures. Hence, the Foundation has played a decisive role in many of the infrastructures that Swedish researchers use and for advanced equipment at Swedish universities.

The Bank of Sweden Tercentenary Foundation finances the preservation of cultural heritage and digitisation of images and text material, among other things.

Proposal for new types of funding

A long-range investment framework for large infrastructures should provide substantially better opportunities for strategic planning of new or upgraded infrastructures. This applies mainly to participation in the development of larger international or national research infrastructures, e.g. those included in the ESFRI roadmap, etc. Currently, there are not specific grants for long-range construction of extensive infrastructures.

A type of grant for education addressing the use of infrastructures would substantially increase effectiveness in the utilisation of research infrastructures. New infrastructures involve strategic investment, often in new and uncertain or risky research. A major investment in infrastructure should therefo-

[6] SEK = Swedish Krona. 100 SEK = 10.60 EUR, 7,90 GBP, 15,60 USD. (January 2008)

re be combined with *targeted project grants* for a limited time in conjunction with the start up of infrastructures to achieve efficiency in the investment and to assure broad use among research groups.

Responsibility for financing infrastructures

Based on the definition of infrastructure used by the Swedish Research Council, the Council mainly provides grants for research infrastructures that are openly accessible to Swedish researchers in the field and that give scientists opportunities for research on the cutting-edge internationally.

Swedish Research Council funds for infrastructures should focus on categories A to C (see above), but could also be provided to category D where initially department-based infrastructures are changing to accommodate users nation-wide.

Fiscal responsibility for operations in categories E and F (see above) should rest primarily with the university departments, institutions, or research groups.

The Swedish Research Council also provides certain grants for investing in and constructing equipment and databases in categories E and F mentioned above. However, responsibility for financing the operation of such infrastructures should rest primarily with the university departments, institutes, or research groups.

A recent study[7] shows a rapidly declining level of investment in equipment at universities and university colleges. Investments have declined continuously, totalling a 30%-decrease since the peak in year 2000. The effects of research are long-term and do not become fully apparent until years after funds are invested. The decrease is occurring despite the fact that equipment grants from the two largest sources, i.e. the Swedish Research Council and the Knut and Alice Wallenberg Foundation, have remained constant during this period. This suggests that the decrease is due either to cutbacks by other external funding bodies (foundations or corporations), or cutbacks in the use of departmental funds for investments. Such a drastic decrease in investments at universities and university colleges raises questions about the distribution of responsibility concerning equipment financing.

Long-term planning in a changing economy

Member contributions for infrastructures in category A are often related to Sweden's GNP. Hence, if the Swedish economy is good, the membership fees increase automatically without an increase in state funds for the Swe-

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[7] See Appendix 2, References

dish Research Council, which in turn leads to a reduction in other funds not tied to a convention. This is an illogical way to finance infrastructures and leads to problems in long-range budgetary planning. Hence, it would be desirable if the level of state funding for the Swedish Research Council would follow the fluctuations in expenses related to international memberships, or that the council is given the possibility to use credit or increase the amount it can save for this purpose.

Defining the Swedish Research Council's field of responsibility

It is important to realise that research also depends on infrastructures administered or financed by agencies and organisations other than the Swedish Research Council. For instance, the Swedish Research Council does not manage libraries or museum collections, various types of data archives on climate or individuals, or the resources of university hospitals, greenhouses, and different animal facilities – even though these are infrastructures used by researchers and could be classified as research infrastructures under the definitions used here. An expansion of the sphere of responsibility for infrastructures that can be used in research outside of the current limits of the Swedish Research Council is conceivable, but would need to be followed by corresponding expansion of funding opportunities. Mechanisms to expand the collaboration among actors and the potential influence by the Swedish Research Council can often be more effective and less complicated than providing researchers with influence over infrastructures that are used only partly for research purposes.

General Recommendations

Several general recommendations for planning and financing of research infrastructures are presented below. Specific recommendations that address the maturity of the infrastructures or fields are presented in Table 1 of the next section and in the following descriptions of the respective infrastructures. The Swedish Research Council's Guide to Infrastructure will be revised regularly. Events that would lead to updated versions include development of new infrastructures, new needs and investigations, and continued development of joint European projects.

International collaboration:

- The European Roadmap for Research Infrastructures has led to a major revision in the European policy for infrastructures. Sweden should take an active role in creating a common European policy on infrastructure.

- Several new areas are ready to begin developing a joint international infrastructure, particularly in biosciences, humanities and social sciences, and climate and environmental research. It is important for Sweden to support this activity, e.g. by participating in the ESFRI projects.
- With the increasing number of joint international research infrastructures it is important to have the resources to support them. Grants can take the form of membership fees, but also, e.g. in-kind contributions where Swedish universities and other research institutions develop infrastructure components or create nodes for international infrastructures in Sweden.

Financing:
- An investment fund should be established for large international infrastructure investments. An alternative would be to develop forms of financing that utilise investment loans at the Nordic Investment Bank or its European counterpart.
- In planning for research infrastructures, budgets should address the entire lifecycle process, from idea to phase-out.
- In financing research infrastructures, a balance should be achieved between investments in and operation of infrastructures and the use for research.

Agency roles and responsibilities:
- The division of responsibility regarding the investment in and operation of research infrastructures must be clarified among institutions, universities, and research funding bodies.
- Co-ordination of research infrastructures should take place whenever possible to effectively utilise resources and expertise.

Accessibility and transparency:
- Research infrastructures financed with public funds, and the data produced, should be openly accessible to researchers.
- Accessibility to data from public agencies and scientists needs to be improved in several areas, e.g. climate and environmental research, social sciences, and epidemiology.
- Where demand on infrastructure utilisation is high, a prioritisation system should be in place so that access to facilities is granted to the highest-quality research.

Recommendations on Infrastructure Projects in the Near Future

In addition to the existing infrastructures that were surveyed in the overview of research fields, several infrastructure projects were identified that have a strong potential in future Swedish research. Table 1A shows future projects found to fulfil the criteria for research infrastructures (see previous section on criteria). These projects are perceived to have substantial scientific value and be of major importance for the future advancement of Swedish research – as well as the potential to attract a large share of the researchers within the field. It is important to note that Table 1A does not indicate that the Swedish Research Council will finance the projects listed, but only that the projects are found to have major potential for Swedish research. Possible decisions on financing will be subject to special evaluation and prioritization.

Table 1A is divided into large research areas to give an overview of the infrastructure projects. It is worth noting that many of the infrastructures span multiple research areas, e.g. computing resources are listed under eScience but are used in all areas, while synchrotron and neutron facilities are listed under material sciences but are used widely in medicine and life sciences, among other areas.

The table indicates whether the project is mature enough for short-, medium-, or long-term decisions, which is important in budgetary planning for an infrastructure. The economic scope presented applies to an entire infrastructure. In cases involving international infrastructures, the Swedish share is considerably less. For example, the Swedish share in current pan-European collaborations is 1.0% to 2.5%. Table 1 B presents an estimate of the amount that Sweden contributes, per subject area, to create infrastructures.

Infrastructure projects are summarised in the subject area descriptions (Part 2) and also in greater detail in relation to the respective infrastructures (Part 3).

Table 1A: Infrastructures for future investment

	Type of infrastructure				Timeframe			Estimated cost	
	Central or distributed	Geographic coverage	Type of collaboration (Cat. A-F)	New/ upgrade	Short-term decision (<4 yr)	Medium-term decision (4-8 yr)	Long-term decision (8-15 yr)	Total estimated investment costs (million SEK)	Estimated operational costs (million SEK/yr)
Astronomy, Astro-, Nuclear-, and Particle Physics									
E-ELT (Optical telescope)	Centr.	European	Cat. A	New	X			7 780	366
EURISOL (Facility for subatomic physics)	Centr.	European	Cat. A	New			X		
FAIR (Accelerator for subatomic physics)	Centr.	European	Cat. A	New	X			11 000	1 100
ILC/CLIC (Electron-positron colliders)	Centr.	Internat.	Cat. A	New			X		
SKA (Radiotelescope)	Centr.	European	Cat. A	New			X	10 500	900
eScience									
SNIC/PRACE (Metacentre for high-performance data systems)	Distr.	Swedish/ European	Cat. C/B	Upgrade	X			1 880-3 760 (PRACE)	940-1 880 (PRACE)
Energy**									
Earth and Environmental Sciences									
DISC (Infrastructure for databases, upgrade in environmental research)	Distr.	Swedish	Cat. C	Upgrade	X				10
EISCAT (Radar system)	Centr./Distr.	Internat.	Cat. B	Upgrade	X			500	22
EMSO (Seafloor observation system)	Centr.	European	Cat. B	New		X		1 500	200
ICOS (Facility to measure greehnouse gases)	Distr.	European	Cat. B	New		X		2 250	130
LifeWatch (Storage and analysis of biodiversity data)	Distr.	European	Cat. B	New		X		3 700	700
Humanities and Social Sciences									
CESSDA (Database network in social sciences)	Distr.	European	Cat. B	Upgrade	X			275	55
Language technology/CLARIN (Language technology project)	Distr.	Swedish/ European	Cat. C/B	New		X		990 (CLARIN)	92 (CLARIN)
ESS (Survey of social values)	Distr.	European	Cat. B	Upgrade	X			83	83

Materials Sciences									
ESRF Upgrade (Synchrotron radiation facility)*	Centr.	European	Cat. A	Upgrade		X		2 100	N/A
ESS (Neutron scattering facility)*	Centr.	European	Cat. A	New	X			12 000	880
ILL 20/20 (Neutron source reactor)	Centr.	European	Cat. B	Upgrade		X		1 400	N/A
IRUVX-FEL	Distr.	European	Cat. B	New	X	X		6 840	600
MAX IV (Synchrotron radiation facility)*	Swedish/ Centr.	Nordic	Cat. B or C	New	X			2 200	240
XFEL (Free electron laser)*	Centr.	European	Cat. A	New	X			9 000	760
Medicine and Life Sciences									
BILS/ELIXIR (Bioinformatics)	Distr.	Swedish/ European	Cat. C/B	New	X			5 000 (ELIXIR)	65 (ELIXIR)
Biobanker/BBMRI (System for managing biological samples)	Distr.	Swedish/ European	Cat. C/B	New	X			1 500 (BBMRI)	130 (BBMRI)
EATRIS (Translational research)	Distr.	European	Cat. C	New		X		7 300	2 700
National core facilities in functional genomics, etc	Distr.	Swedish	Cat. C or D	New	X	X		100 - 200	100-200
SweImp/Infrafrontier (Mouse facilities)	Distr.	Swedish/ European	Cat. C/B	New	X			2 900 (Infrafront.)	320 (Infrafront.)

N/A=Not applicable, operational costs are included in the investment cost

* Also used extensively in Medicine och Life Sciences

** The fusion reactor ITER and its continued development towards an energy-producing reactor is being financed by EU. All infrastructures listed under material sciences in the table are relevant in the energy sector. Also, many of the projects under Earth and Environmental Sciences are important in monitoring the effects of the energy sector.

SEK = Swedish Krona. 100 SEK = 10.60 EUR, 7.90 GBP, 15.60 USD. (January 2008)

Budgetary Needs for Investments and the Operation of New Infrastructures

Investments

Table 1A presents the proposed new joint research infrastructures that are viewed to be most urgent if Sweden is to maintain research of the highest quality. The table also presents the estimated total cost of construction and annual operation of the respective infrastructures and the projected time-frame for decisions. Most of the projects in the table involve international infrastructures (e.g. ELT, FAIR, XFEL) where Swedish participation is judged to be essential, or the construction of Swedish nodes to internationally distributed infrastructures. The latter primarily concerns research in environmental and climate areas, biomedicine and life sciences, the humanities and social sciences, and the PRACE computing facility. Some of the infrastructures have a more national character, e.g. the core facilities for functional genomics.

Table 1B. Estimated needs, above current budgets, for new Swedish investment in research infrastructures as presented in Table 1A.

Area	Need for investments in joint infrastructures up to the year 2012 (Billion SEK)
Astronomy, astro-, nuclear-, and particle physics	160
E-science	180
Earth and environmental sciences	180
Humanities and social sciences	50
Materials science	220
Medicine and life sciences	400
MAX IV*	1610
TOTAL	2800

* MAX IV is presented separately in the table since it is interdisciplinary (involves all other areas in the table) and because the investment need is significantly greater than for any of the individual areas. A property management corporation is presumed to invest in the buildings.

Estimates of the new need for investment to implement the infrastructures in Table 1A are presented by area in Table 1B for the period up to 2012. The estimates reflect a possible Swedish share of the total investments needed to establish and upgrade infrastructures. Estimates regarding the international infrastructures are based on a Swedish share that is roughly proportional to the nation's GNP compared to the total GNP of all nations expected to participate. In cases concerning the construction of Swedish nodes to international infrastructures, the estimated investment needs reflect the Swedish node and the Swedish share in the international project.

Table 1B specifically presents the MAX IV project since it is interdisciplinary and clearly represents the largest post. Investments in infrastructure projects under construction such as LHC, IceCube, ALMA, and DISC have not been included in the estimates for new infrastructures shown in the table. Likewise, the investments for the European Spallation Source (ESS) are not presented here. [8]

Table 1B shows that to finance the highly prioritised new infrastructures (Table 1A), an additional 2.8 billion Swedish kronor (SEK) will need to be invested during the 5-year period up to 2012. Hence, around 550 million SEK per year would be needed for the next 5 years to construct future infrastructures in all disciplines (including MAX IV). A similar level of investment should be used as a starting point for subsequent periods in the long-term plan for research infrastructures.

In addition to the need to invest in common infrastructures, there is a neglected general need to invest in equipment for certain research groups and university departments. Investment in capital equipment has decreased drastically since 2000.[9] Strengthening the equipment level at universities calls for increased investment in instrumentation of approximately 400 million SEK annually. This would put investments back at a level corresponding to the year 2000.

Operations

Greater investment in common national or international research infrastructures is naturally accompanied by a greater need for operational grants when these infrastructures are ready to start up. Since development takes place successively, and most projects take several years to construct, the total grant should increase progressively. It is estimated that operational grants for research infrastructures need to be at least 250 million SEK per year higher in 2012 compared to the current level.

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[8] The Government has reserved funds for 30% of the construction costs during the construction period (approximately 8 years).

[9] See Appendix 2, References

Table 2: Current and budgeted infrastructures financed by the Swedish Research Council

	Type of infrastructure			Estimated cost		Comments
	Central or distributed	Geographic coverage	Type of collaboration (Category A-F)	Annual cost (million SEK)	Sweden's share of annual cost (million SEK)	
Astronomy, Astro-, Nuclear-, and Particle Physics						
ALMA (Radiotelescope)	Centr.	International	Cat. A			Financed within the ESO budget. Under construction.
CERN (Particle physics lab, incl. ISOLDE for subatomic physics)	Centr.	European	Cat. A	6 000	155	LHC is financed within the CERN budget.
ESO (Optical telescope)	Centr.	European	Cat. A	1 800	32	
Ice-Cube (Neutrinotelescope under constr)	Centr.	International	Cat. B	1 800	1	
NOT (Optical telescope)	Centr.	Nordic	Cat. B	16	4	
Onsala (Radiotelescope)	Centr.	Swedish	Cat. C	34	34	Co-financed by VR and Chalmers
Energy						
ITER (Fusion research facility under construction)	Centr.	International	Cat. A	2 000	0.5	Mostly financed by EU's framework programme
JET (Fusion research facility)	Centr.	European	Cat. A	650	1.7	Mostly financed by EU's framework progr.
e-Science						
DISC (Infrastructure for databases)	Distr.	Swedish	Cat. C	60	60	
NDGF (Data grid facility)	Distr.	Nordic	Cat. B	18	4.5	
NORDUnet (Computer network)	Distr.	Nordic	Cat. B	100	27	Swedish share included in cost for SUNET
SND (Swedish National Data Service)	Centr.	Swedish	Cat. C	4.8	4.8	
SNIC (Metacentre for high-performance computing)	Distr.	Swedish	Cat. C	48	63	
SUNET (Computer network)	Distr.	Swedish	Cat. C	160	160	Mostly financed through fees

Earth and Environmental Sciences						
ECORD/IODP (Collaboration on ocean drilling)	Distr.	International	Cat. B	100	3.6	
EISCAT (Radar system)	Distr.	International	Cat. B	22	5.4	Headquarter in Kiruna
GBIF (Database on biodiversity)	Distr.	International	Cat. B	30	2.4	
Nordsim (Ion spectrometry for geological material)	Centr.	Nordic	Cat. B	1.38	0.65	Co-financed by Swed. Museum of Natural History
Humanities and Social Sciences						
ESS (Survey of social values)	Distr.	European	Cat. B	80	6.5	Co-financed by VR, RJ, FAS
EUI (Research institute for humanities and social sciences)	Centr.	European	Cat. B	350	6	
Mathematics						
Institut Mittag-Leffler (Institute for matematics research)	Centr.	Swedish	Cat. C	10	1.1	
Materials Science						
ESRF (Synchrotron radiation facility)*	Centr.	European	Cat. A	700	13	Sweden participates via Nordic consortium
ILL (Neutron source reactor)	Centr.	European	Cat. A	600	13	
ISIS (Spallation neutron source)	Centr.	European	Cat. B	500	4	
MAX-lab (Synchrotron radiation facility)	Centr.	Swedish	Cat. C	75	75	Co-financed by VR and Lund University
MyFab (Network, microfabrication lab.)	Distr.	Swedish	Cat. D	20	20	Co-financed by VR, KAW, SSF, VINNOVA
Medicine and Life Sciences						
EMBL (Molecular biology laboratory)	Distr.	European	Cat. A	1 000	25	
IARC (Institut för cancerforskning)	Centr.	International	Cat. A	100	7	
MIMS (Molecular medicine lab under construction)	Centr.	Swedish	Cat. C	100	15	

* Also used extensively in Medicine och Life Sciences

SEK = Swedish Krona. 100 SEK = 10.60 EUR, 7.90 GBP, 15.60 USD. (January 2008)

NOTE: The above table is limited to research infrastructures that the Swedish Research Council finances either fully or in part. There are important international infrastructures that the Swedish Research Council does not finance, and Swedish infrastructures that are financed by other fundng bodies.

PART 2 – DESCRIPTION OF SCIENTIFIC FIELDS

Astronomy and Subatomic Research

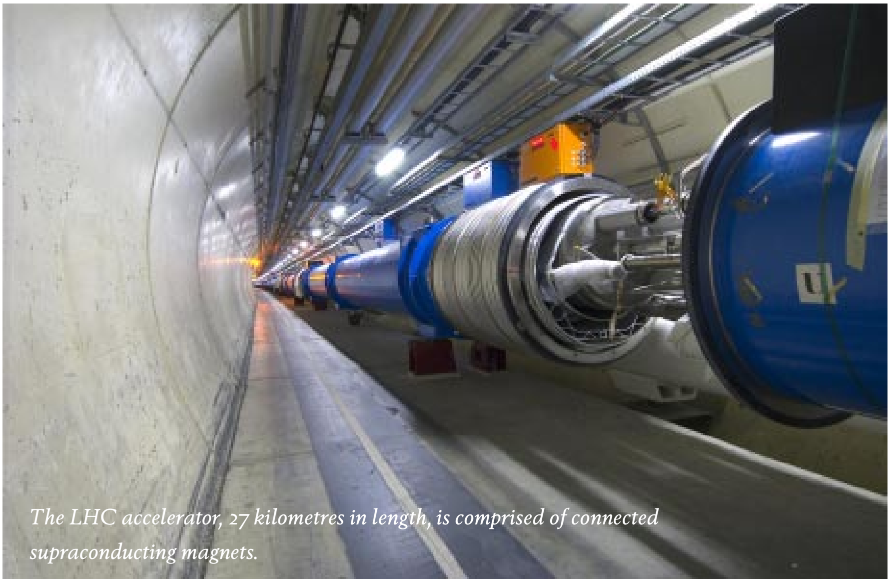
Astronomy and subatomic science investigate major questions about the origin of the universe and the nature of matter. The field is dependent on advanced infrastructures, and for years, scientists in this field have been leading in national and international or global collaboration to establish the facilities needed for new advances. The trend towards large-scale infrastructure places major demands on long-range thinking and planning by scientists and research funding bodies.

The active Centaurus A galaxy probably has a black hole at its centre.

Photo: ESO

Astronomy. In astronomy, several questions of particular research interest are also the focus of many infrastructure projects. How did the universe begin and how did its current structure of galaxies and even larger structures form? When were the first stars formed? How are stars formed generally, and with them all of the elements? How do the planets form that orbit around at least 10% of all stars, and what conditions are necessary for biological life to form on them? Other highly interesting questions are associated with the most extreme processes and conditions, e.g. supernovas, neutron stars, and black holes.

In the sub-areas of astrophysics, scientists have observed and analysed electromagnetic radiation from various objects, but in recent decades they have also studied the particle flux of, e.g. neutrinos, protons, and antiprotons from the universe. Astroparticle physics is a field where scientists study the particle flux from astrophysical sources and the fundamental characteristics of these particles. In both areas, scientists study different aspects of unknown types of energy, dark matter and dark energy, which according to recent discoveries comprise 96% of the energy content of the universe.



The LHC accelerator, 27 kilometres in length, is comprised of connected supraconducting magnets.

Photo: CERN

High-energy physics. High-energy experiments utilise collisions of high-energy particles to study the inner structures of matter and the forces at work. The standard model in particle physics provides answers to many questions concerning the structure and stability of matter and its six quarks, six leptons, and four forces. However, the standard model leaves many questions unanswered: Why are there only three types of quarks and leptons? How do particles get their mass? Are there more particles and forces? Are the quarks and leptons actually fundamental, or do they also have a substructure? Which particles can give rise to the dark matter in the universe?

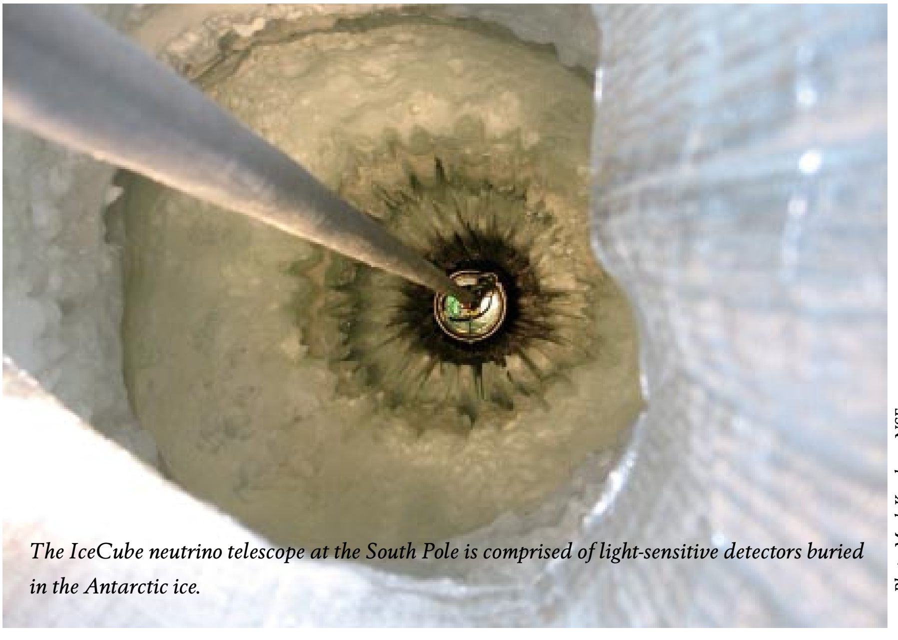
Furthermore, researchers want to study strongly interacting matter under extreme conditions, e.g. high temperature and energy density. Collisions between heavy atomic nuclei at very high energies are expected to result in a transition from hadronic matter (hadrons are strongly interacting particles) to a new state of matter, so-called quark-gluon plasma. This state existed in the first microseconds following the Big Bang. The particle collisions that take place in laboratories are "Small Bangs" that can be repeated in experiments to study the conditions in the early universe.

Nuclear physics. Nuclear physics covers structures, dynamics, and general characteristics in systems held together by the strong force – everything from hadrons to atomic nuclei. These systems are found in 99.9% of visible matter. The studies have led to discoveries and technologies that have brought substantial benefits to society, e.g. medical diagnostics and treatment, nuclear energy, radiometry, and the carbon-14 dating method. Understanding of the strong interaction is, however, far from complete. Hence, scientists are continuously developing methods for basic research in nuclear physics.

In nuclear structure physics there is a trend towards using beams of rare radioactive isotopes. This offers the opportunity to study atomic nuclei with extreme relationships between the number of neutrons and protons. Studies of such exotic atomic nuclei have a direct link to the synthesis of nuclei in the universe since they are largely involved in the relevant processes, e.g. in stars and supernovas.

Need for infrastructures

To establish themselves at the absolute cutting edge in their research fields, it is vital that scientists in astronomy, astrophysics, and nuclear and high-energy physics have access to research infrastructures. Infrastructures in these fields



The IceCube neutrino telescope at the South Pole is comprised of light-sensitive detectors buried in the Antarctic ice.

Photo: Mark Krasberg, NSF.

are so large and complex that neither individual research groups nor nations can finance and operate them – they require international collaboration.

The significant progress in astrophysics and astroparticle physics in recent decades are largely a result of new instrumentation and telescopes that enable the study of fainter and fainter objects in more detail. To be able to answer fundamental questions, such as questions concerning dark energy and the characteristics of dark matter, requires optical telescopes with large light-collecting surfaces and higher resolution than those currently available. Also radiotelescopes with substantially greater sensitivity than those in use today will play an important role in this research. There are also many important infrastructures in space-based astronomy and solar system research. Since most of the newly proposed projects in this field fall under the responsibility of the European Space Agency (ESA), and are included in the Cosmic Vision initiative, they are not addressed here.

New accelerators, where particles of different mass can be collided at much higher energies than currently possible, are necessary to answer the fundamental questions of particle physics, e.g. the existence of the Higgs boson. The LHC accelerator at CERN will collide 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 will open a new window into the particle world. Electron-positron colliders can complement LHC by enabling precision measurements.

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. New detector systems are experiencing a parallel trend. An excellent example is the planned Facility for Antiproton and Ion Research (FAIR) in Germany that will produce beams of radioactive isotopes and antiprotons.

Energy Research

The development of a sustainable and safe energy system is one of the global community's greatest challenges – probably the greatest. The energy issue is intimately associated with economic growth, our standard of living, and living conditions. Challenges include securing a sustainable energy supply in the foreseeable future for various actors and countries, without creating economic stagnation, unemployment, or global or regional conflicts. This should also be done without generating unacceptable effects on the environment and climate.

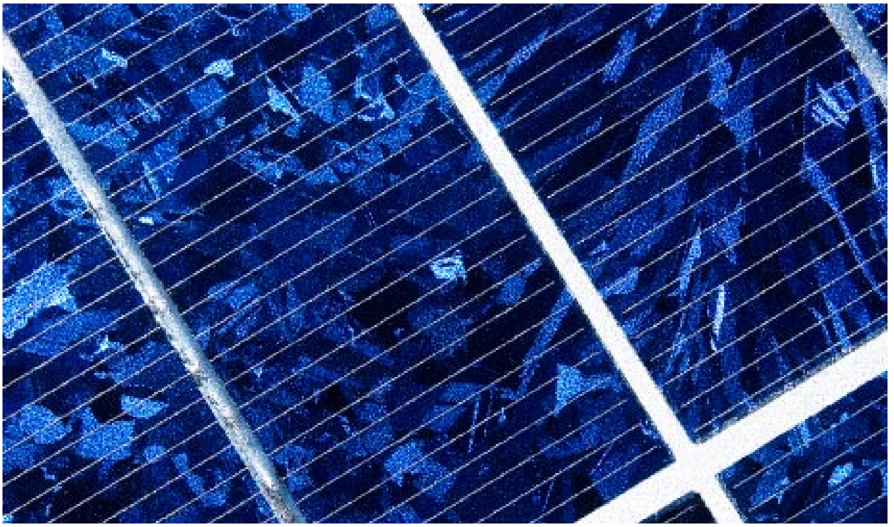


Photo: SXC

To fully utilise the potential of solar cells, scientists are developing both existing materials and new, more effective, types of solar cells.

Research and development in the energy field involves many different time scales, from relatively rapid actions (within 10 years) aimed at improvement and efficiency of the current energy system and the use of fossil fuels, to long-range investments of 10 to 30 years or longer to develop sustainable systems, e.g. utilising solar energy to a much greater extent.

The energy sector is often divided into energy supply, storage, and use. Major opportunities exist in all of these areas to improve current technologies and to find new solutions and disruptive technologies.

Currently, global supply is comprised mainly of fossil fuels, with nuclear power, hydroelectric power, and biofuels playing lesser, albeit important roles. Sweden uses less fossil fuel, e.g. oil, with a comparably large share of energy coming from nuclear and hydroelectric power. Examples of sustainable supply technologies involve solar energy in many forms, wind, waves, hydroelectric power, solar electric power, solar heating, biofuels, geothermic energy, and gravitational energy in ocean tides. The level of development among these technologies varies.

Storage is a major challenge, but effective solutions would reduce the need for increased production and would have positive environmental effects in the industrial, housing, and transportation sectors. This field covers everything from large-scale storage, e.g. dams and natural lake-based systems for hydroelectric power plants, to more technology-based storage in batteries and means of hydrogen storage involving chemical compounds such as metal hydrides.

Energy consumption is linked directly to energy saving or more efficient energy utilisation. Major opportunities exist to increase efficiency in the industrial, housing, and transportation sectors through developing new methods and technologies.

A substantial share of energy research in natural science/technology disciplines is associated with material sciences and material technology, including manufacturing technology. The importance of nanoscience and nanotechnology is expected to increase. Thinner silicon layers and more efficient types of solar cells, e.g. thin-film cells and Grätzel cells, are needed in solar cell technology. Storage requires new materials for batteries, fuel cells, and hydrogen storage. The transportations sector needs lighter construction materials that take less energy to produce, but still assure safety. Lighter materials would also lower the energy consumption of vehicles. These are but a few of many examples.

Other areas associated with energy include chemical processes and technologies, e.g. catalytic methods to produce chemicals, and food technology. Advanced sensor technology can substantially improve control and efficiency of manufacturing and process technologies. Biomass is a potentially large area for sustainable fuel production, placing a focus on agricultural and forestry methods. Geotechnology is obviously essential in the production of geothermal energy. Likewise, marine technology is important for offshore wind and wave power production. Vehicle technology including automobiles, trains, boats, and aircraft as well as locomotion and combustion technologies for internal combustion engines and gas turbines are key to the entire transportation sector. Hydrogen production via bacteria, mimicking of photosynthesis, and more efficient biomass-producing plants enhances the role of biotechnology and gene technology in future energy supply. Advances in the latter areas, driven mainly by opportunities and needs in medicine and biotechnology, can have important spin-off effects for the energy field.

Nuclear and reactor technologies appear in conventional fission power, new fission technology, and fusion technology. The goal of fusion technology is to develop energy-producing reactors that would provide nearly unlimited energy reserves while generating little environmentally hazardous waste. This is a long-range research area requiring substantial coordinated investment.

Need for infrastructures

Strong synergies are found between infrastructures for material and energy research. A large part is dependent on advanced material synthesis, and development requires access to technologies for synthesis and analysis at well-equipped laboratories for micro- and nanofabrication. An increasingly important role is being played by Myfab, a national distributed infrastructure involving three large micro- and nanofabrication laboratories. Examples of energy materials requiring such facilities include new and functional materials used in solar cells and fuel cells.

Advances in material-related energy research are becoming increasingly dependent on the sophisticated measurement methods often found at national and international facilities. Synchrotron radiation facilities, e.g. MAX-lab in Lund and the European Synchrotron Radiation Source (ESRF) in Grenoble, and neutron sources such as the ILL research reactor in Grenoble, provide many researchers with the most advanced analytical tools available. In the foreseeable future, the planned European Spallation Source (ESS) and the free electron lasers, e.g. the planned XFEL in Hamburg, will provide new advanced opportunities for different types of material studies. Other key facilities include laser centres, electron microscope laboratories, and laboratories that focus on specific analytical methods.

Photo: P. Ginter, ESRF

Much of the research on energy can be linked to developments and studies of new material. Photo from the European Synchrotron Radiation Facility, ESRF.

Advancements in experimental fields also create demands for better infrastructures in information technology (IT). One trend is that one can study advanced systems with higher spatial resolution and monitor dynamical processes over increasingly wider time ranges. This generates enormous quantities of data that must be managed and analysed. Theoretical modelling is most important in many branches of energy research; it includes everything from basic computing of electron structures as a basis for designing new functional materials to simulation of combustion processes or global climate effects. There is substantial use of the Swedish National Infrastructure for Computing (SNIC) in the energy field, and the need is expected to increase.

At the other end of energy research one finds a need to scale up laboratory facilities to handle nearly full-scale experiments. Examples of such areas in Sweden include facilities for black lye gasification, biomass gasification, or ethanol production.

Fusion research is an area that requires some level of global investment. Seven partners, of which EU is a key collaborator, signed an agreement in 2005 to construct a full-scale reactor experiment (ITER) in southern France. In turn, this requires large-scale facilities to optimise various aspects of reactor construction, not least in material technology. The international agreement on ITER includes the construction of a large accelerator (IFMIF – International Fusion Materials Irradiation Facility) to test material under high neutron irradiation for the next generation of energy-producing fusion reactors.

Other types of infrastructures associated with the energy system are those used to study the climate effects of energy use, e.g. research vessels, aircraft, satellites with capacity for remote analysis, and various types of monitoring stations.

CERN's particle physics laboratory is a large consumer of computer resources, and CERN researchers are among those leading the way in grid technology. Shown here are servers that will manage data from the new LHC accelerator.

Photo: CERN

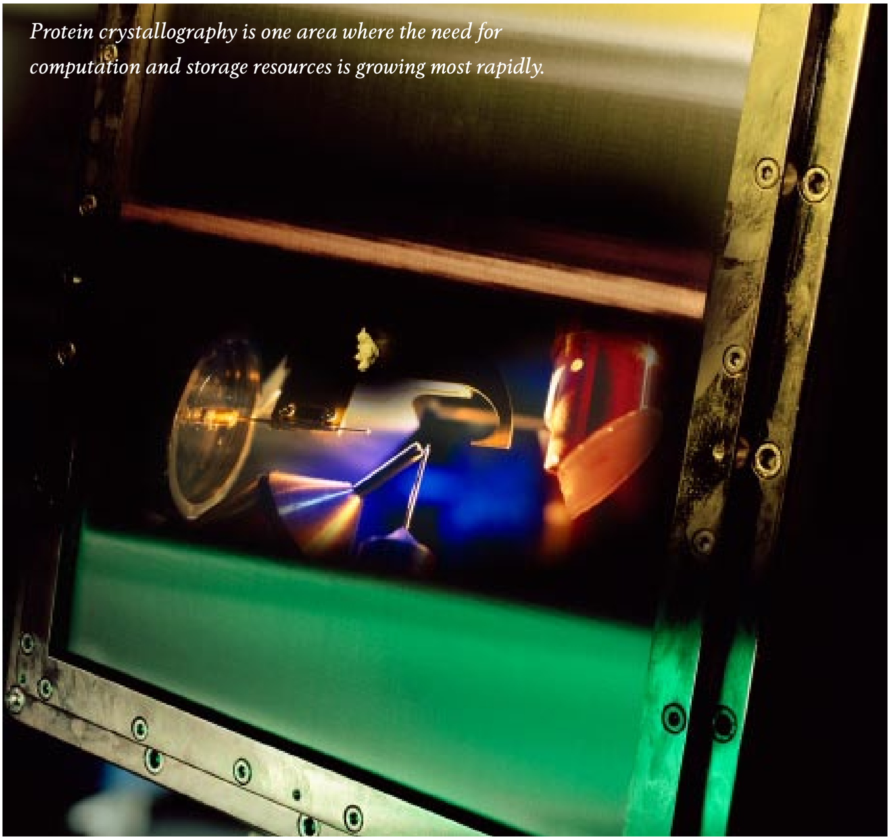
eScience

eScience refers to science that reaches a new dimension by utilising the potential of modern information technology to address problems of a scope and complexity that could not be managed without electronic devices, and the opportunity to benefit from geographically dispersed resources, both technical and human. Traditionally, eScience applications have mainly involved extremely compute intensive research in technology and natural sciences that could only be carried out only with the help of supercomputers. Today, eScience research covers many more domains and uses multiple interacting computers that communicate with each other via rapid networks. By offering researchers geographically dispersed computing resources in a grid structure, it is possible to create massive computing resources and give researchers access to the rapidly expanding resources for data management. Computing power, and access to data that can be generated in many different ways, enables sophisticated analysis and high-quality presentation of results, e.g. via advanced visualisation. The grid structure enables research that would be impossible if the researcher had access to only one computer, even if it were a supercomputer.

Currently, grid technology is used for storage and computing mainly in particle physics and astronomy, and to some extent in theoretical chemistry and biosciences. Particle physicists are driving the technological development through the enormous quantity of data generated by experiments via the new LHC accelerator at the European CERN laboratory. It is important to note that similar to the World Wide Web – which started as a CERN project but grew into a necessity for the entire world – the grid technology that CERN uses is being developed in collaboration with Enabling Grids for eScience (EGEE), and in the future could have yet unimagined benefits for the scientific and the business communities alike. In principle, eScience can develop within widely diverse scientific fields. The concept of eScience was introduced in the United Kingdom as early as 2001 and has become instrumental in social sciences, medicine, the humanities, and environmental and climate research. For years, Sweden has had leading infrastructures for research networks and coordination of computing resources, but only recently has the software for distributed databases received serious attention.

Initiatives by the Swedish Research Council in 2006 to increase the utilisation of Sweden's population-based registers for research are expected to promote Swedish eScience in social sciences and medicine. Important investments are being made in biology and medicine by integrating data from model organisms and humans, with the aim to construct and understand functional networks at the molecular, cellular, organ, individual, and population levels. The challenge for eScience in this case is to integrate information from data sources of different structures and use mathematical and computing models to generate knowledge from them.

Opportunities to systematise and integrate databases in climate and environmental research were surveyed in 2007. (See section on DISC expansion into climate and environmental areas under "Description of Infrastructures for Future Investment").



Protein crystallography is one area where the need for computation and storage resources is growing most rapidly.

Photo: ESRF

Need for infrastructures

eScience depends on access to large-scale computing resources with adequate software, high-capacity computer networks, infrastructures for secure and effective mass storage, and advanced visualisation resources. Of particular importance is the software that controls communication among computers and "middleware", i.e. programs that enable computers in a grid to be utilised jointly in conducting the extensive calculations required to solve a complex problem. Sweden has a well-functioning research network, i.e. the Swedish University NETwork (SUNET). Since 2001, the Swedish National Infrastructure for Computing (SNIC) has coordinated the allocation and use of the computing resources at Sweden's six centres for high-performance computers. A national grid infrastructure has been established through the SweGrid Consortium, which is closely connected to Sweden's research in particle physics. Sweden is actively involved in developing Nordic grid collaboration within the framework of the Nordic DataGrid Facility (NDGF) headquartered at NORDUnet A/S, which started as an organisation for Nordic computer network collaboration.

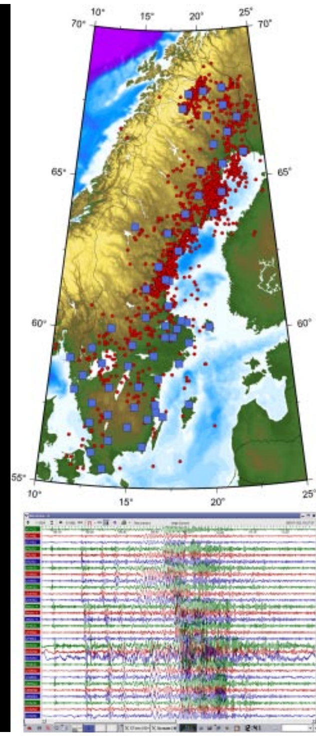
At the end of 2006, the Swedish Research Council, inspired in part by the experiences of SNIC, created a new organisation – the Database Infrastructure Committee (DISC) – to promote infrastructure issues concerning databases. Initially, DISC is focusing on registers and databases in social science and medicine, but with ambitions to cover a broad spectrum of scientific fields. eScience applications and research vary across scientific fields, and typically assumes collaboration between data experts, mathematicians, statisticians, and researchers in the respective branches of science. Sweden has good potential to develop eInfrastructure and eScience in a broad range of fields. Collaborations are being planned with the United States, the United Kingdom, and other countries in EU, as well as designing a joint Nordic strategy for eScience. NordForsk has granted funds for a Nordic initiative to establish a Nordic committee for eScience that could formulate programmes to finance research, e.g. for a Nordic infrastructure for databases and education in eScience technologies.

Earth and Environmental Sciences

Research on Earth and environmental sciences, including its atmosphere and the life within, originally focused on observing, cataloguing, and systematising. Leading biologists such as Carl von Linné systematised plants and animals, meteorologists described weather phenomena, and geologists classified minerals, rocks, and fossils. Leading research is still being conducted that aims primarily at observing and describing, but much research in the field is now primarily aimed at understanding and even predicting entire systems. Fields such as ecology, climatology, geology, and oceanography base their research on observation, but have taken steps to create models showing how the planet

The Wandering Albatross is a mythical globetrotter, and much of its life has been unknown to researchers. Scientists can now tag them with GPS transmitters and monitor their movement around the world's oceans.

Photo: Susanne Åkesson, Lund University.



The map shows the locations of stations (blue squares) in the Swedish Seismological Network and several of the earthquakes they have registered (red dots). By observing the same earthquake from several stations (lower image) simultaneously, seismologists can calculate the earthquake's strength, depth, and location.

Picture: Björn Lund, Uppsala University.

and its resources have changed over time, and how they will change in the future. Also, it has become increasingly important to consider human activity in the model.

Research concerning Earth and environmental sciences is important to understand living conditions for humans and other living organisms now and in the future. We expect a period of rapid change in climate and thereby in the conditions for all living organisms, including humans. Considerable effort should be directed at limiting the human impact on climate by reducing emissions of carbon dioxide into the atmosphere. Research during the second half of the 1900s pointed to the environmental impact of releasing environmental toxins, acidic substances, and freon. Awareness about the effects of emissions has led to political decisions to restrict their release.

Humans also impact on their environment through extensive consumption of natural resources – some are finite while others are renewable. Occasionally, renewal outpaces consumption, but often this is not the case. To understand how to manage the Earth's resources, we need to know about the processes that originally formed our natural resources and how human extraction and utilisation affects them in the short and long term. Utilising resources responsibly requires knowledge on how they are distributed geographically and over time, and also how resources interact with their environment so that we can avoid unforeseen and undesirable effects.

Need for infrastructures

Research concerning planet Earth and its atmosphere is diverse, and there is a common need for observations of the environment. In some cases, infrastructures for observation are coordinated across disciplines, which often occurs at field stations and distributed programmes. In other cases, specialised infrastructures are required to study and understand specific phenomena; for example the European Incoherent Scatter Facility (EISCAT) that studies how the sun interacts with the magnetic field of the Earth, and the Onsala Observatory that is used as a reference point for geodesy, i.e. measurements for mapping the shape of the planet.

Measurements aimed at understanding how bedrock, oceans, atmosphere, ecosystems, and near space function and develop over time require the systematic collection of information. To make these observations, access to networks of stations – automated and/or manual, manned field stations for observations and experiments, observatories, research vessels, and satellites, are needed. Frequently, access to advanced laboratories for controlled trials of ecological and geological phenomena is also needed.

Research on the dynamics of Earth and environmental sciences require long timeframes, 30 years of more, to assure that the observed changes can be differentiated from random variation. An interruption in measurements could mean that previously collected data might lose some or all of its value. Hence, it is important to correctly manage and document the data collected. Securing the operation of infrastructures needed to collect and preserve long time-series is therefore of great importance. It is also important to correctly manage and document collected data. Hence, the Swedish Research Council has initiated the expansion of the Database Infrastructure Committee (DISC) mandate to also cover data of interest for environmental and climate research.

Time series concerning the Earth's development reaching back hundreds to millions of years are preserved in glacial ice and in seabeds, lakebeds, and other geographic layers. Consequently, we can access information about the Earth's natural variation by studying drilling cores, but also through other studies of sedimentary layers.

In addition to infrastructures for field observations, researchers also need access to measurement and analytical instruments, e.g. to analyse low concentrations of several of the substances in our environment and to study biological material. The analytical instruments are often the same as those used in other research fields, e.g. infrastructure needs in biological research often coincide with those in medical and molecular biology research. Some scientific questions require special analytical devices, e.g. several research fields use rare isotopes as markers to study dynamic processes in the Earth, air, and water. This includes research using the joint Nordic infrastructure called the Nordic Secondary Ion Mass Spectrometer (NORDSIM). It is placed in Sweden, but run jointly with Norway, Finland, and Denmark to measure elements and isotopes that are found only in very low concentrations.

Humanities and Social Sciences

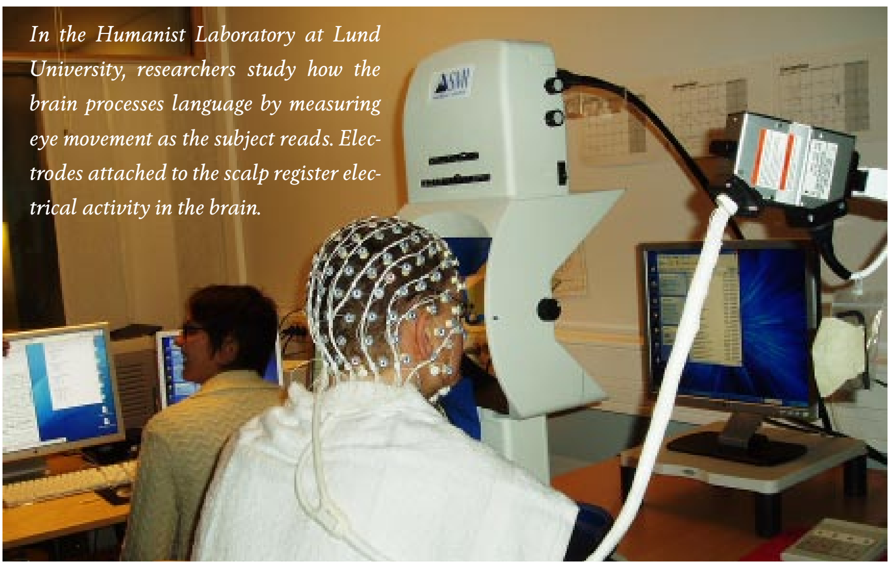
In our global society, we confront several major challenges, where the perspectives of the humanities and social sciences are of central importance. This involves understanding revolutionary processes and structural change, but also developing political, economic, and social explanations and possible solutions to problems. A central issue in Sweden concerns the rapidly aging population and the increasing proportion of elderly that depend on care and support to live with dignity. In several parts of the world, increasingly fewer people must support a growing population within a framework of an unchanged economic structure and in pace with a falling birthrate. In other areas we find the constant threat of overpopulation and starvation. The refugee situation, immigration and emigration affecting various parts of the world, and the expansion of the European Union promote greater population mobility and changes in traditional cultural patterns.

Research in the humanities and social sciences plays a key role in understanding the world around us, and our actions. For instance, what can we learn from history to understand the future? Photo: A war cemetery in Normandy.

Photo: SXC

Environmental problems raise questions concerning the relationship between humans and the environment and the demand for sustainable development. We need to understand and act wisely given the widening gap between people caused by differences in economic, social, and cultural conditions and the policies implemented in any given period.

Humanistic and social science research plays a key role in understanding our world and our actions. Theories and methods need to be further explored and developed. This requires greater access to relevant, high-quality data at the macro and micro levels. During the past 15 years the great increase in access to extensive databases on individuals has been one of the most important driving factors behind methodological and theoretical advancement in the humanities and social sciences. Large databases with extensive



In the Humanist Laboratory at Lund University, researchers study how the brain processes language by measuring eye movement as the subject reads. Electrodes attached to the scalp register electrical activity in the brain.

Photo: Merle Horne, Lund University

information on many individuals enable researchers to study old questions in new and better ways, thereby creating opportunities to study problems that were impossible to analyse previously. Structures must be created that facilitate the collection, structuring, and analysis of empirical data across regional and national boundaries and that facilitate collaboration among research disciplines. 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.

A distinguishing factor in social sciences and the humanities is the variation, complexity, and unmanageability found among the units studied.

Much of the existing data on humans themselves, the results of their activities, their communities, and society are multilingual, history-specific, geographically distant, and often highly diverse in content. Sophisticated compute resources, data networks, and software tools create opportunities for collecting, organising, and making data accessible and thereby enhance our understanding of the human experience. Hence, an important task is to create systems in the form of infrastructures to document and tie together data from different sources. Researchers need common definitions, common standards, and common methods of data collection, organisation, and documentation. Institutions must guarantee that researchers have open access to data across institutional and national borders.

Need for infrastructures

The most urgent need for infrastructures in the humanities and social sciences are national and international institutions that can address the organisational, legal, and political barriers against development, maintenance, and accessibility of common databases. In the spring of 2006, the Swedish Research Council established the Database Infrastructure Committee (DISC) for this purpose. DISC aims to address the problems mentioned above and coordinate its efforts with the international research community. Currently, DISC focuses on improving infrastructures based on registry data, language technology, more extensive questionnaire surveys, and data archives.

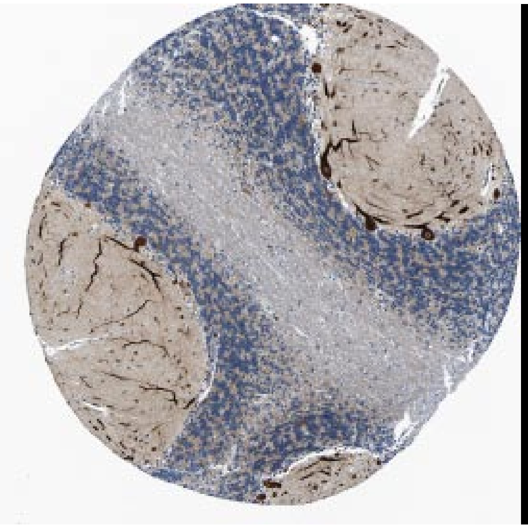
The Swedish National Data Service (SND) was established in the autumn of 2007 at Gothenburg University. Within 5 to 10 years, SND aims to have comprehensive information on Swedish databases in social sciences, medicine, and the humanities and also an overview of corresponding databases in other countries. SND will help provide rapid, inexpensive, and secure access to data.

The humanities laboratories have the potential to provide important tools and training for those in the humanities who want to better utilise the opportunities presented by information technology, e.g. data collection and analysis.

Projects in the humanities and social sciences increasingly aim at coordinating efforts in Europe and worldwide to construct, improve and maintain internationally comparable data on global population. Sweden should participate in projects like the CESSDA database network and the European Social Survey (ESS) to contribute and gain easy access to the data that these projects generate. Sweden should also participate in developing common metadata and common standards.

ESFRI includes several initiatives in the humanities and social sciences with which Swedish research groups and DISC intend to collaborate. The Common

Language Resources and Technology Infrastructure (CLARIN) is creating an integrated and standardised research infrastructure for language resources. The Digital Research Infrastructure for the Arts and Humanities (DARIAH) will make data on cultural heritage accessible via the Internet. Digitalisation of Swedish cultural history should be studied and can be linked to DARIAH in the future.



By using antibodies that specifically bind to a particular protein, we gain understanding about the protein's function. Shown here is human brain tissue where antibodies against an unknown protein bind to the nerve cells' cytoplasm and outgrowths (brown), indicating that the protein has a function at these particular sites. The cell nuclei appear as blue in the photo.

Source: Human Protein Resource-projektet (HPR), KTH

Materials Sciences

Most of our everyday life is controlled by the characteristics of fixed material. Functions of a material include its hardness, plasticity, conductivity, magnetism, transparency, or corrosive durability. Characteristics like these determine the quality of construction material included in houses, bridges, automobiles, and aircraft, the functional material that comprises the basis for micro electronics, drugs, and fuel cells. Life itself – with its cell and molecules – is also an advanced form of material. Hence, material sciences can be viewed as a collective name for several different research areas in physics, chemistry, and biology.

Modern material research aims to increase understanding about material at the atomic level and to develop new types of material with better or different performance than those offered by existing material. An important development in this field concerns nanostructural materials. This material is constructed with structures that are only a few tenths of millions of a millimetre in size. When dimensions are so small, the characteristics change radically due to effects of quantum mechanics and new phenomena appear.

In addition to advancements in nanostructural material, research is also being conducted on so-called multifunctional materials and material combinations. This means that material has several characteristics – for example, it can be magnetic, catalytic, or electric. Such material can be used in sensors and so-called intelligent material, for instance. An example would be to build in a function so that lathe steel senses when it is worn out and needs to be changed.

The development of short pulse lasers has enabled scientists to study ultrafast reactions in molecules and material (Zewail, Nobel Prize in chemistry, 1999). This has major importance for understanding processes such as photosynthesis and molecules such as haemoglobin and chlorophyll. Materials that mimic the function of these types of molecules may contribute towards producing more efficient solar cells.

Material research is largely an experimental science. Nevertheless, advancements in modern computers make it possible to use theoretical calculations and/or simulations to predict material characteristics with high precision. Theoretical material research is important since it, apart from providing increased understanding, reduces the laboratory time needed for operating and testing.

Traditionally, Sweden has played a strong role in material research. Areas of strength in Sweden include steel and metal research, semiconductor research with silicon chips and optical semiconductors, research on fibres and polymer materials, research on biomaterials and biocompatible materials, thin film syntheses, and classification of materials, e.g. surface analysis and

Material includes construction material used in houses, roads, bridges, automobiles, and aircraft, but the cells and molecules that form all life are also an advanced type of material. Researchers in modern material science study material at the atomic level and develop new materials having advanced characteristics.

Photo: SXC

microscopy. Theoretical material science and material simulation are also areas of Swedish strength that have led to the establishment of thermodynamic modelling programs for research and industry.

Need for infrastructures

As described above, research in material science is largely experimental and is clearly becoming multidisciplinary. Chemists, physicist, technical material scientists, and biologists work in teams, which places rigorous demands on research infrastructure and access to first-class instrumentation.

To carry out controlled and reproducible experiments, material scientists must have access to advanced and modern instrumentation that can monitor the structure and chemical composition at atomic and molecular levels. Examples of such include electron and scanning tunnel microscopes, synchrotron-radiation-based diffraction, spectroscopy, and short pulse lasers.

The development of more complex materials will place demands on better and more advanced equipment. X-ray examinations are usually carried out in the laboratories of research groups, but high intensity x-rays from synchrotron radiation facilities provide the opportunity for detailed analysis that is many times greater. This advancement was introduced in material science, but later emerged in biology, where protein crystallographers now represent one of the largest user groups of x-ray instrumentation involving synchrotrons. Swedish researchers currently have access to synchrotron radiation experiments, mainly in the national MAX-lab, but also in the European Synchrotron Radiation Facility (ESRF) in Grenoble. This technology is rapidly developing, and MAX-lab has recently concluded the design work for the next generation synchrotron radiation facility, MAX IV. Furthermore, plans are at an advanced stage to upgrade ESRF for new types of experiments.

Free electron lasers offer new opportunities to monitor ultrafast processes. They can be used to follow chemical reactions or charge dynamics by stroboscopic filming of the atoms, but also to image structures of individual molecules, e.g. membrane proteins that cannot be crystallised. Recently, over 10 European countries (including Sweden) jointly decided to build a free electron laser for coherent x-rays (XFEL) in Hamburg.

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 has its strength particularly 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. Intensive planning is under way for a more powerful co-European neutron source, the European Spallation Source (ESS), where Lund in Sweden is a prime candidate for the site.

Investments in strong, experimental, multidisciplinary environments provide opportunities for co-ordination of infrastructure resources and for cross-fertilisation of ideas from different fields. Examples of such environments include those that have emerged near synchrotron radiation facilities, neutron scattering facilities, and cleanroom facilities. The latter are used in nanostructuring of materials, and analyses for development of quantum computers, tomorrow's electronics, biocompatible material, nanobiotechnology, and nanomedicine. A network of cleanroom facilities for micro- and nanostructuring, Myfab, has recently developed in Sweden and provides open access to researchers for nanostructuring and analysis, and coordination of resources. Another task of the network is to profile the laboratories. Further development of Myfab is essential for resource-efficient advancement of the nanoscience field.

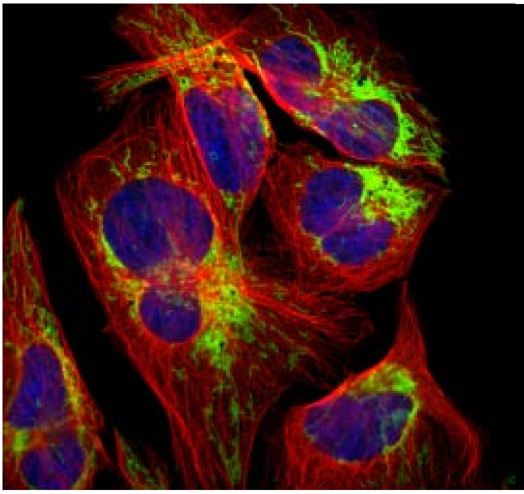
Continued advancement will require access to different types of high-resolution microscopes and accelerators for ion implantation. These facilities will be user-based to a greater extent, requiring more technical support than what is currently the case.

Extensive simulations and calculations have become more common in material research to predict and understand characteristics of new material, to test theories for complex material characteristics, and to interpret experimental results. Hence, access to high-performance computers is necessary in material science. In this context, the Swedish National Infrastructure for Computing (SNIC) is an important resource.

Medicine and Life Sciences

Research in medicine and other life sciences aims at increasing understanding of how living organisms function and interact in their environment. Life processes are usually complex, and the collective behaviour of a group of cells, or a set of physiological reactions, depend on the interaction between many different cell types and tissues. Understanding a whole life process therefore requires extensive collaboration among researchers in medicine, biology, biochemistry, biophysics, and bioinformatics – in other words, integration with a broad range of topics in the life sciences and natural sciences.

A fundamental characteristic in biology is that the composition of genes, proteins, and metabolites are similar in widely different organisms. How genes interact in networks under different conditions comprises a growing



The structures of living cells can be visualised by binding specific fluorescent-stained antibodies and using confocal microscopy in 3-dimensional imaging. The photo shows cultivated eukaryote cells, clearly visualising the cell nuclei (blue), cytoskeleton (red), and mitochondria that form an important part of the cell energy process (green).

Source: Human Protein Resource-projektet (HPR), KTH

part of modern functional genomics. Understanding the mechanisms behind biological processes requires identifying key components (DNA, RNA, proteins, metabolites) and understanding how they are expressed and work together. Comparative genomics provides new opportunities for understanding evolution and diversity of species through studies of structural and functional similarities and differences within and among species, including humans. Likewise, leading research that is being carried out on genetically modified plants is of major importance for forestry and agriculture, and places considerable demands on specific infrastructures.

Animal studies, including the rapidly growing production of genetically modified organisms, can contribute towards understanding how components in biological systems work together. For instance, investment in large-scale phenotyping of mice with different specific genetic changes (knockout mice) should be able to significantly increase our knowledge about the function 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.

Swedish researchers have made major contributions in plant research and plant genomics, e.g. in forest biotechnology where researchers have successfully described specific molecular processes in plant cells, making it possible to use wood as starting material in several new technical applications and as a base for new materials. Understanding the life processes of plants is also important to enhance knowledge about plant conditions and effects, e.g. on climate change.

Medical research in Western countries is investing heavily to better understand the mechanisms behind common diseases such as cancer, cardiovascular diseases, diabetes, rheumatism, obesity, and neurodegenerative diseases. The border between basic biology and medicine has largely vanished, and collaboration with other scientific fields such as the behavioural sciences, demography, language sciences, physics, mathematics, and informatics has increased. By combining genetic data with information from disease registries and with community and lifestyle data, researchers aim to develop sharper disease classifications, new preventive interventions, and individually tailored instruments for early diagnosis and treatment. The ultimate goal is to increase the quality of life in large groups of people and concurrently reduce the cost to society for health and medical services.

At the same time, the knowledge gap between medical research and applied clinical practice is increasing, due in part to the fact that health services are not adapted to integrated and large-scale research processes. It is important to secure Sweden's opportunities to use its extensive population and disease registries to integrate epidemiological and clinical information with biological and molecular information from large groups of patients and healthy individuals. Translational research forms a bridge for the transfer of knowledge between experimental research and clinical applications. Sweden has a strong potential to strengthen its position as a leading country within and outside of Europe. However, this requires changes that promote the integration of medical research with clinical practice in the health service organisation, in education, and in career pathways for researchers, and the further development of biomedical research infrastructures.

Need for infrastructures

Medicine and life sciences have considerable needs for access to diversified data, distributed technical platforms, and special resources. Considerable research – mainly in biotechnology, but also in other life science areas – takes place at large facilities such as synchrotron radiation facilities for high-resolution structural studies of biomolecules to clarify molecular mechanisms in detail.

Several major time-limited technology investments by, e.g. the Swedish Foundation for Strategic Research (SSF) and the Wallenberg Foundation in genomics, proteomics, biotechnology, and imaging have supported development in functional genomics and systems biology. Research centres are set up and national collaborations are supported in several important areas, e.g. analysis of genetic variation and expression patterns in humans and model organisms, coordination of biobanks, large-scale protein classification, and laboratory animal projects. Expertise in these and similar technologies/infrastructures takes many years to fully develop, and is essential for cutting-edge research in Sweden. Hence, it is important to find a system for sustainable financing and management of national resources and for Swedish participation in international infrastructure efforts to secure continual rejuvenation and high-level technological development.

Long-term infrastructure investments in medicine have hitherto been financed mainly by county councils through equipment at our university hospitals. Integration between biology and medicine creates new demands on organisation and financing. The field is becoming similar to information science, with implications for construction of database systems, standardisation, documentation, ethics, legislation, computing, modelling, imaging analysis, and visualisation.

The Swedish Research Council has recently undertaken several initiatives that can, in the long term, strengthen infrastructures in medicine and life sciences. For instance, the Swedish Research Council supports the preparatory phase for several ESFRI projects and also contributes towards planning to construct national infrastructures.

One of the projects in ESFRI's roadmap concerns the European bioinformatics project ELIXIR to further develop the European Bioinformatics Institute (EBI) near Cambridge, England, and establish specialised nodes distributed across Europe. EBI manages databases and tools for information

Photo: SXC

Swedish researchers are successful in forest biotechnology. They have mapped the molecular processes of plant cells, making it possible to use wood as the fundamental material in several new technical applications and as the base for new material.

management in molecular biology, and is expanding rapidly as regards integration of data sources distributed across Europe.

Under EU's Seventh Framework Programme, a coordinated effort is being planned to construct large population-based research databases and biobanks with associated standards for quality assurance, standardisation, and harmonisation. The Biobanking and Biomolecular Resources Infrastructure (BBMRI) is another project of the ESFRI roadmap to coordinate biobanks and biomolecular resources that interface with EBI and ELIXIR. In autumn 2007, the Swedish Research Council initiated an investigation on how biobanks could become a national resource for research. The results will be presented in the beginning of 2008.

The European Advanced Translational Research Infrastructure in Medicine (EATRIS) is planning to establish several research units at the European level, each of which specialises in a particular area of disease. In conjunction with this effort, investing in a national infrastructure for translational research and a standardised clinical trial centre would have great importance for clinical research in Sweden.

In parallel with the European work, a Bioinformatic Infrastructure for Life Sciences (BILS) is being planned in Sweden, as is reinforcement of Swedish biobank resources and development of the Swedish mouse phenotyping facility, SweImp. The latter is intended to serve as a node to the planned European Infrastructure for Phenotyping and Archiving of Model Mammalian Genomes (Infrafrontier). Development of a national infrastructure gives Sweden a natural opportunity to participate in and influence future European investment in this area.

In biology, databases for research on biodiversity, e.g. the Swedish species databank, the Global Diversity Information Facility (GBIF), and the biodiversity project LifeWatch from ESFRI's roadmap exemplify ongoing and planned infrastructure investments coordinated at the national, European, and global levels.

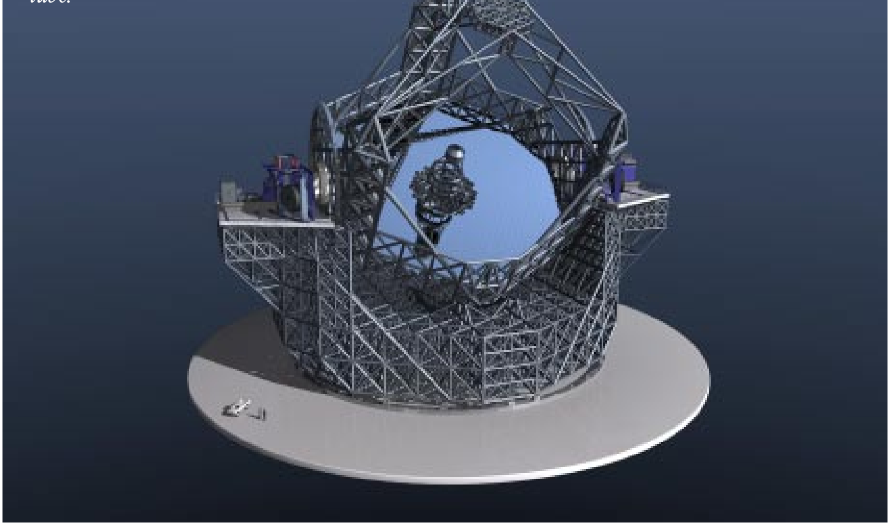
PART 3 – DESCRIPTION OF INFRASTRUCTURES FOR FUTURE INVESTMENT

Astronomy, Astro-, Nuclear-, and Particle Physics

E-ELT – European Extremely Large Telescope

The acronym ELT stands for 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.

ESO's Extremely Large Telescope (E-ELT) is projected to be 42 metres in diameter. The larger the telescope, the more important it is for the optical elements to be flexible so they can correct the image for movement in the atmosphere and mechanical bending of the mirrors and telescope tube.



Picture: ESO

After having developed and assessed several possible designs for an ELT, in December 2006 the ESO Council decided to begin detailed planning and design of a telescope with a mirror in the 30- to 60-meter interval. The detailed plan also includes the first generation of complementary instrumentation. The final decision on this infrastructure, the total cost of which is estimated to be nearly one billion Euros, is planned for 2009. The timeframe for completing the E-ELT project is 2015 to 2020, and it has been included in the ESFRI roadmap for infrastructures from 2006. A European steering committee for ELT development and a standing ESO committee to assess the project proposals are active. The Swedish Research Council and the Swedish astronomy community are represented on both committees. Financing of E-ELT will fall within the framework of the ESO collaboration. Special investments for Swedish participation in the consortium for the complementary instrumentation can be expected. Two major North American telescopes are also in the planning stage, the Thirty-Meter Telescope (TMT) and the Giant Magellan Telescope (GMT), but in many respects, the E-ELT will be more powerful.

Another concept, developed mainly at Lund University, called Euro50 involves a mirror with approximately 50 meters in diameter. Opticon, a related European development project, is under way and includes adaptive optics that will have increasingly greater importance, not least for an ELT. Since much of this technology is unproven and places extremely high requirements on optics, electronics, and mechanics, it is important to develop several different parallel concepts during this phase.

EURISOL – European Isotope Separation On-Line Radioactive Ion Beam Facility

A way to better understand how the universe is formed is to study atomic nuclei that are far from stability, so-called exotic nuclei. Such experiments can answer questions regarding how heavier elements are formed in the universe, e.g. in supernovas, and about the structure of these heavier nuclei. There are two primary facilities for research in these areas, ISOLDE at the particle physics laboratory CERN in Geneva, and GANIL-SPIRAL in Caen, France. Both facilities are being upgraded, and the upgrades can be viewed as preliminary studies for EURISOL.

EURISOL can be described as a highly upgraded version of ISOLDE. The facility will provide ion beams that are 100 to 1000 times more intensive than those currently accessible. This, in combination with new instrumentation, will open new opportunities for researchers in this field.

The scientific motivation for EURISOL is the study of atomic nuclei far from stability. Exotic, short-lived atomic nuclei are not only short-lived variations of the stable or long-lived nuclei that are found in material in our everyday lives. They also show a large number of structural characteristics that modify the view of how complex multiparticle quantum mechanical systems are constructed. These phenomena often influence the reactions that lead to the formation of elements in the universe. Radioactive ions can also be used as trace elements in, e.g. semiconductors or biological systems, and can therefore be used in several research fields and in industry.

Several alternative sites for the location of EURISOL have been discussed. One possibility is to construct the facility at CERN, which would then have a broader user-base. This also has synergy benefits, since technological and scientific expertise is already on site and the linear accelerator could also be used to increase the luminosity at LHC and enable several new programmes, e.g. neutrino beams. The timeframe for construction and operation of EURISOL is roughly 2020.

FAIR – Facility for Antiproton and Ion Research

Understanding the inner structure of matter is fundamental for understanding the universe, how matter is created in the stars and the properties of atoms. Refining the knowledge available today requires increasingly bigger and more specialised accelerators and better detectors. Europe and nations around the globe are investing heavily in the field of nuclear and hadron physics.[10]

FAIR will be Europe's leading future laboratory for studies in nuclear physics, as emphasised in the ESFRI roadmap, but the scientific programme also spans studies in atomic physics and astrophysics.

Scientifically, FAIR will produce beams of rare radioactive atomic nuclei with unprecedented intensity, providing the opportunity to study nuclei with extreme ratios between the number of neutrons and protons. Some of these are directly associated with the formation of basic elements in the universe. The facility will also be capable of delivering intensive antiproton beams. The annihilation process of these antiprotons will provide an excellent opportunity to create new particle conditions, and systematic studies will offer a powerful instrument to investigate the dynamics of the strong interaction and origin of new forms of matter.

Originally a German project, FAIR has developed into an international collaborative project where Germany accounts for 75% of the investment cost of approximately 1.2 billion Euros. The other countries involved will

[10] A hadron is a nuclear particle.

Researchers at FAIR will study the internal structure of materials.

Photo: A. Zschau, GSI

share the cost of the remaining 25%. Construction of the facility is planned for 2008 to 2015. Most of the contribution by participating nations for construction is expected to be in-kind, e.g. parts for accelerators and detectors. Operational costs are expected to be 120 million Euros per year, whereof Germany will pay half. The Swedish Research Council has participated in the preparatory phase to produce necessary technical and scientific documents as well as contracts and cost-calculations. In November 2007, Sweden signed a declaration to participate in the building phase and will contribute 10 million Euros to the construction.

All Swedish research groups in nuclear and hadron physics give FAIR the highest priority and intend to do most of their research there. Atomic physicists in Sweden also have strong interest in participating.

ILC/CLIC – Linear Particle Colliders

When the new particle accelerator, Large Hadron Collider (LHC), in CERN becomes operational, the field of 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

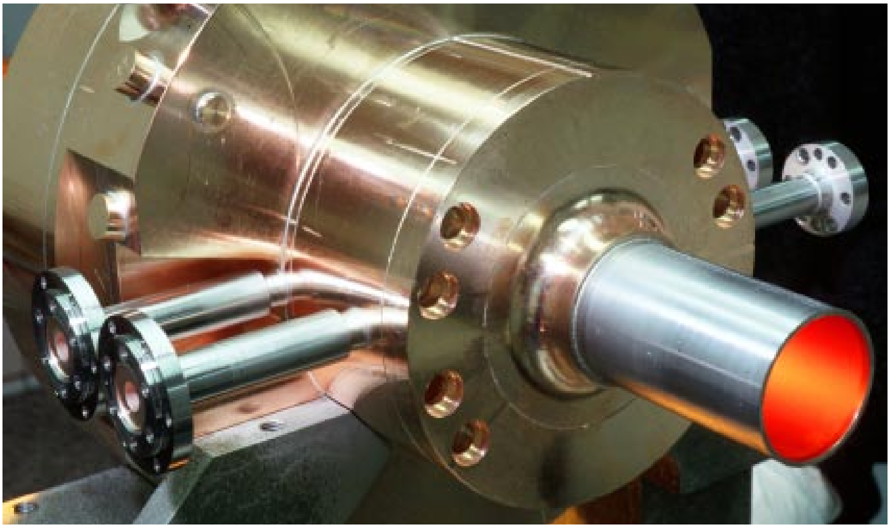


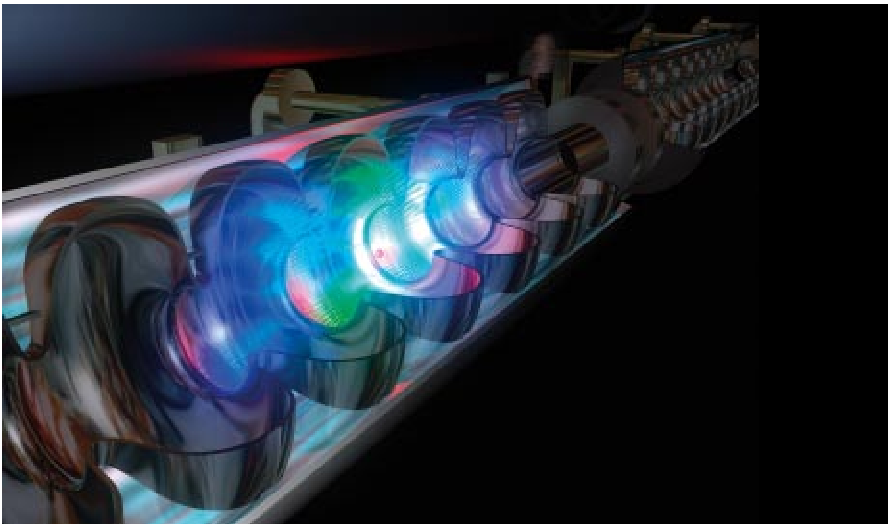
Photo: CERN

Prototype of the CLIC linear collider at CERN.

concerning the creation 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.

Long-term planning of the next generation of accelerators has been under way for some time. The Compact Linear Collider (CLIC) and the International Linear Collider (ILC) are two proposed projects using different techniques aimed at finding ways to address these other questions. Both are types of electron positron colliders. Parallel to the construction of the LHC, CERN is running the CLIC project to study and develop technology for a linear electron-position collider in the energy range of 0.5-5 TeV. ILC involves a worldwide collaboration to establish a design for the next generation of electron-positron particle accelerators in the energy range of 0.5-1 TeV. The technical level of maturity and the timeframe within which the projects can be built is widely different. The main technology is already developed for ILC, but scientists are still working with the design concept and preliminary prototype studies for CLIC.

Simulation studies show that CLIC/ILC can potentially contribute towards the understanding of fundamental questions in physics that cannot be answered with LHC. The reason involves both projects' combination of high energy and experimental precision. CLIC/ILC will, among other things, improve the possibilities for studying and understanding the Higgs



Picture: DESY

The image shows a test design for ILC at the DESY laboratory in Hamburg.

mechanism, i.e. the mechanism concerning the Higgs particle, which is the missing piece of the standard model to explain how all matter is organised. This can take place by studying rare decay in the energy range where the Higgs particle is expected to appear (the so-called Higgs sector), or by detection of one or more heavy Higgs bosons. Other measurements that would become possible include studies of symmetry violations between particles and antiparticles in the Higgs sector.

SKA – Square Kilometre Array

SKA is a long-wavelength radiointerferometer for studies of, e.g. the early universe. The facility will cover a surface area of approximately one square kilometre. By comparison, that is approximately 180 times larger than the total surface of the ALMA radiotelescope in Chile that covers 6600 square meters. SKA will complement ALMA for longer wavelengths. It is based on new technology using a relatively simple antenna design together with very sophisticated electronics and data processing. A first step towards this technology is being developed in the Netherlands with the Low Frequency Array (LOFAR) facility.

SKA will combine a very large detection surface with high spatial resolution and sensitivity. The facility can be used to study the formation of the first stars and galaxies, i.e. the reionisation epoch in galaxy formation. Other key areas include studies of protoplanetary discs, and testing the theory of relativity with the help of pulsars. Location of the interferometer is now being

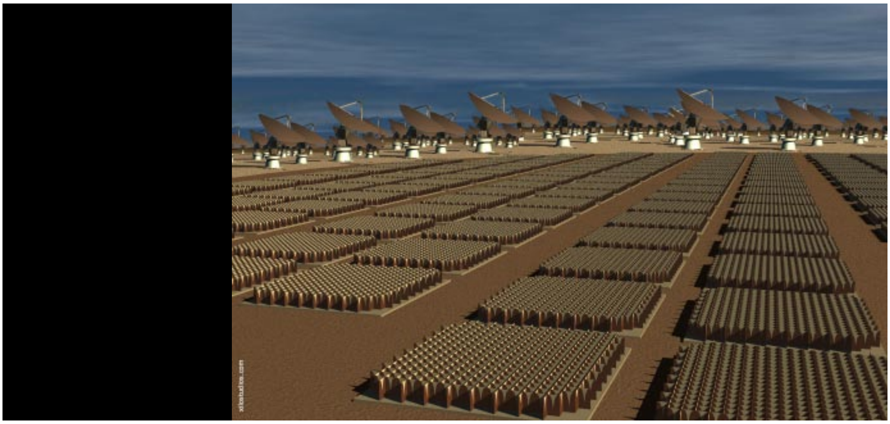


Photo: SKA (Xilostudios)

A possible model of the Square Kilometre Array (SKA). The telescope consists of many antenna elements for low frequencies and several parabolic antennas for higher frequencies. The total antenna surface is 1 km^2. Advanced computer technology enables much of the sky to be observed simultaneously. Hence, one can quickly detect supernovas and gamma ray bursts. The most important goal is to observe radiation from the first galaxies.

discussed, with the most likely alternatives being Australia or South Africa. The timeframe for SKA is 2020 and beyond. The first stage, using a smaller interferometer of approximately 10% of the total area, will probably start a few years after 2010. SKA is one of the proposed global projects in the ESFRI roadmap for infrastructures.

Total costs are estimated to fall between 1.2 and 1.5 billion Euros. The initial 10% stage is estimated to cost approximately 250 million Euros. It is highly probable that SKA will become a global project similar to ALMA. A European SKA consortium has been formed to coordinate European interests.

eScience

SNIC – Swedish National Infrastructure for Computing

The SNIC metacentre was founded in 2002 and provides Swedish researchers with a national infrastructure for large-scale computing and data storage that is easily accessible and has high-quality capacity. SNIC's resources are available at centres for high performance computing (HPD) in Umeå, Uppsala, Stockholm, Linköping, Göteborg, and Lund. In addition to coordinating the Swedish Research Council's investments, SNIC also administers and operates resources that have received contributions from other funding bodies.

The primary goal of SNIC is to provide balanced resources for computing and data storage that will cost-effectively meet the current and future needs of users. Currently, most users are in physics and chemistry. However, in recent years, utilisation of computing resources has not only increased strongly, but has also diffused to a broader spectrum of user groups. An example of an area with strongly increasing computing needs involves the simulation of geophysical processes, e.g. in climate research. Also, there is currently an increase in research groups with new needs for large-scale data storage, e.g. in biology, medicine, and space physics. SNIC is building and developing a general research infrastructure that can be used in a flexible way by researchers in several fields. Descriptions of other areas in this document, and developments in ESFRI show that increasingly more Swedish researchers will need large-scale computing and storage services that can be provided through SNIC.

Photo: Maggie Bartlett, NHGRI

Researchers working with DNA sequencing represent one of the categories of scientists having major and growing needs for computing resources.

During 2006, SNIC presented a landscape document describing planned activities and investments from 2006-2009. In this context, an international assessment of SNIC showed that the ambition level among Swedish researchers was somewhat restrained by insufficient computing resources. The needs analysis in the document shows that the annual investment in SNIC needs to increase to approximately 90 million SEK. An increase in resources has been started, but the search demand on the existing SNIC system nevertheless continues to be high. To meet their needs, individual research groups are seeking funds for dedicated systems from, e.g. the Swedish Research Council and the Knut and Alice Wallenberg Foundation (KAW). SNIC recently agreed to a partial upgrade of the national computing and storage resource SwedGrid. This is a way to meet part of the demand for data storage and computing capacity following the start of the new LHC accelerator at CERN.[II] KAW and SNIC have initiated a collaborative effort to contribute towards covering the increasing needs of certain groups. However, to meet the increasing needs of Swedish researchers, SNIC must further strengthen the capacity and the capability of computing resources.

In the near future a joint European infrastructure for very-large-scale computing will emerge. SNIC is actively participating in planning this service (see section on PRACE), The goal is to give Swedish researchers access to the most powerful global resources for computing-based science. SNIC also participates in the operation and development of the Nordic and European Grid System, e.g. through NDGF and EGEE projects.

PRACE – Partnership for Advanced Computing in Europe

The need for high end computing in traditional computing and in new, emerging areas is currently receiving major attention in the United States and Europe. The trend is documented in several reports, e.g. by the HPC in Europe Task Force (HET). This area is projected to be of major importance for future research and society as a whole.

SNIC has participated in HET along with 10 other nations and is developing a European computing strategy at several levels. The strategy can be equated with a type of European ecosystem for large-scale computing resources where different types of systems work together as a functioning whole.

Sixteen European partners, including SNIC, formed the PRACE (Partnership for Advanced Computing in Europe) consortium in April 2007 with the aim to actualise these plans. All participating nations in PRACE should contribute some type of computing and storage resources along with their expertise. The resources should be shared by all and can be found in many different countries. As regards the resources with the highest computing capacity, cost factors will probably limit them to the largest nations having the strongest resources.

PRACE will make it possible to meet the most demanding scientific challenges conceivable (Grand Challenges), broaden the boundaries for research

[II] According to the plans of the LHC consortium, further investment in SweGrid is needed to cover LHC's data-storage needs for 2008 and 2009.

ambitions, and intensify the development of hardware and software technologies to reach new dimensions and generate effects far beyond the project itself. This requires access to a wide selection of applications and computer systems – including the most powerful ones that exist.

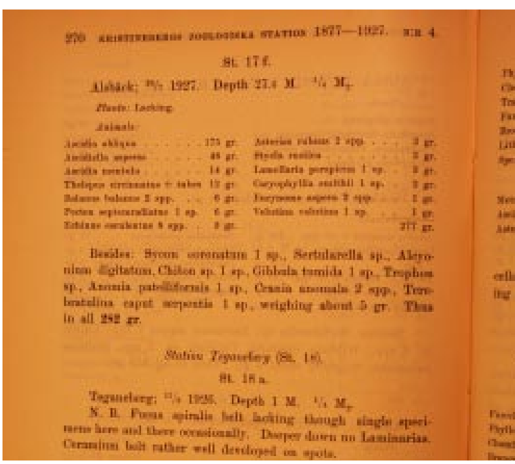
PRACE is attempting to utilise the fact that all developed nations have a hierarchy of computer resources – from desktop systems and institutional resources up to regional centres and national-level resources – that can all perform tasks in both centralised and grid-based constellations.

SNIC's study on the needs of Swedish researchers for large-scale high-performance data (HPD) systems emphasises PRACE and recommends that Sweden participate with a relatively extensive investment. The Swedish Research Council is a co-applicant, seeking financing via EU's Seventh Framework Programme to plan for PRACE. SNIC plans to contribute by funding a pilot system that provides opportunities to develop further technical expertise on future large-scale computing systems.

Earth and Environmental Sciences

Infrastructures for Databases – DISC Expands to Climate and Environmental Research

The Database Infrastructure Committee (DISC), was formed in 2006 to help make Swedish research a world leader in goal-oriented development of large databases and registers, striving for rational, shared utilisation of these data sources. To date, DISC has focused on coordination of databases in the humanities, social sciences, and epidemiology. In the longer term, activities


270 KRISTINEBERGS ZOOLOGISKA STATION 1877—1927. N:R 4

St. 17 f.

Besides: Sycon coronatum 1 sp., Sertularella sp., Alcyonium digitatum, Chiton sp. 1 sp., Gibbula tumida 1 sp., Trophon sp., Anomia patelliformis 1 sp., Crania anomala 2 spp., Terebratulina caput serpentis 1 sp., weighing about 5 gr. Thus in all 282 gr.

Station Tegnerberg (St. 18).

St. 18 a.

N. B. Fucus spiralis belt lacking though single specimens here and there occasionally. Deeper down no Laminarias. Ceramium belt rather well developed on spots.

The possibility to link observations with other information gives us opportunities to create models concerning the changes in nature. These models can then be used to develop projections and understand how events today might influence nature in the future.

Shown here is Torsten Gisléns Epibioses of the Gullmar Fjord I & II; A Study in Marine Sociology. Kristineberg's Zoological Station, 1877-1927. Almqvist & Wiksell 1930.

are being expanded to include all scientific areas where shared databases and continuing national data supply comprise an important prerequisite for research.

The most recent expansion of DISC's activity concerns research databases in climate and environmental research. A needs study was commissioned by the Swedish Research Council. It found that researchers in this area are meeting obstacles and have needs that are very similar to those that DISC must deal with in the humanities, social sciences, and epidemiology. Hence, DISC will aim to assure that data of interest for climate and environmental research will be accessible now and in the future. This applies to data collected by an agency as well as by individual researchers/research groups within the framework of research projects.

EISCAT – European Incoherent Scatter Facility

EISCAT operates Europe's largest and most advanced radar system for studying the atmosphere, ionosphere, and near space above Northern Scandinavia and Svalbard. A transmitter sends pulses of radiowaves, and the signals are then reflected by the ionosphere and received by several receiver stations. The scatter of the radiowaves provides information about the characteristics of the ionosphere and phenomena such as the Northern lights, meteors, and solar winds. Other EISCAT activities include so-called heating experiments where the ionosphere is disturbed in a controlled manner, enabling scientists to study stimulating processes under controlled conditions.

EISCAT is owned and financed by research councils or corresponding organisations in seven countries and has been operational since the mid 1980s. The organisation is located and headquartered in Kiruna, Sweden. By upgrading and developing innovative software, the facility has been able to maintain a leading position in the field, which has encouraged Japan and China to recently join the organisation.

Swedish researchers have played a prominent role in the advancement of basic research on the ionosphere and structure of the Northern lights, and have made strong contributions to technical advancements in the current facility and the proposed upgrades.

EISCAT is currently carrying out an EU-financed pilot study aimed at developing a new, more modern, radar system with electronically controllable beams. The new system will perform at a many times higher spatial resolution and enable studies of rapid processes in the ionosphere. The technical pilot study of this new radar system will be completed in 2009. The investment costs are estimated at approximately 500 million SEK, and the operational costs at 22 million SEK per year.

EISCAT radar facility and the northern light

Photo: Torbjörn Lövgren

EMSO – European Multidisciplinary Seafloor Observatory

The European Multidisciplinary Seafloor Observatory (EMSO) aims to coordinate and construct deep-ocean-based observation systems for long-term marine studies of ecosystem functions, global climate change, and geohazards. The plan is to place several deep ocean observatories in ocean environments of special interest and equip them with sensors to study the marine environment. An important direction for EMSO is to develop new sensors to perform measurements that are impossible with present technology, but that are important for understanding the marine environment. In the system of observatories, each of them should have the possibility for real-time measurement from the marine continental shelf to deep ocean pools. The fundamental components of each system include cables for information transfer and power supply connected to a land-based centre. EMSO is estimated to cost around 50 million Euros per observatory system, excluding sensors that conceivably cost equally as much. The first system is projected to become operational in 2012.

In reality, the high cost means that one or two observatories may be possible. More than 10 sites have been proposed, but if only one or two are built,

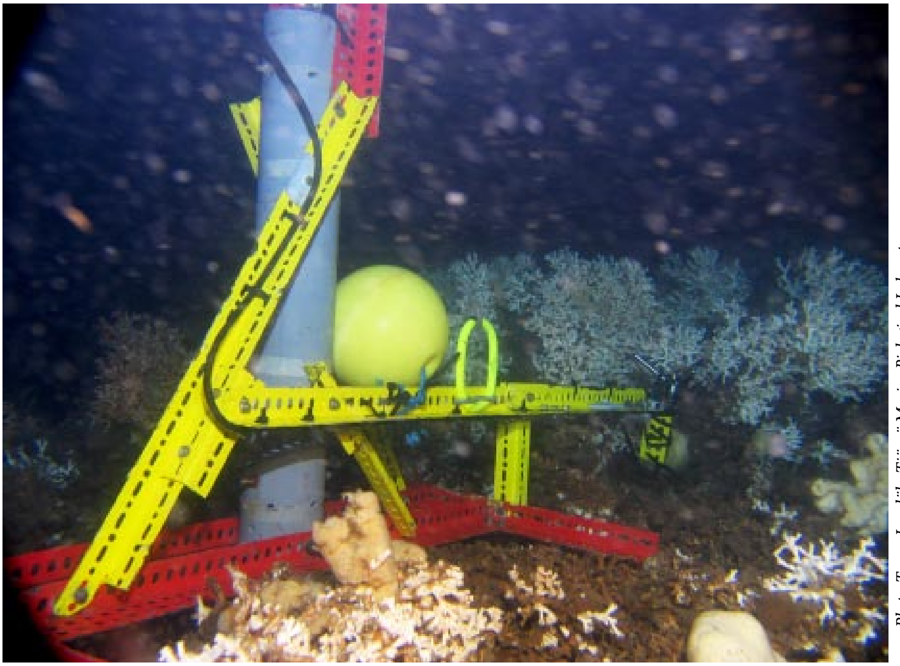


Photo: Tomas Lundälv, Tjärnö Marine Biological Laboratory.

Our knowledge of ocean dynamics is limited since scientists must often rely on still images showing a limited area. The photo shows an instrument that measures water flow around the coral in Kosterfjorden on the west coast of Sweden. If EMSO stations are built, researchers will have new opportunities to monitor ocean dynamics and study the human impact.

placement becomes a critical question. The Fram Straight, west of Svalbard, is a site that would serve Swedish interests well. Observations in this area would complement Swedish polar research in a remarkable way, and at the same time would contribute towards monitoring changes in the marine climate within an area with relatively few measurements. Sweden also has a major interest in developing different types of sensors for placement in observatory systems. Several groups at Swedish universities and university colleges are involved in this type of development, and Swedish corporations have also expressed interest.

Sweden is represented in the EMSO executive committee, and several researchers from Swedish university departments and corporations are also interested in participating in EMSO. Several Swedish agencies have expressed support for EMSO. Planning of EMSO is under way, with Sweden participating via one of EU's Network of Excellence projects, European Seas Observatory Network, that started on March 1, 2007. The aim of this project is to form an organisation to equip, operate, and maintain multidisciplinary deep-sea based observatory systems along the European coastline.

The cost of Swedish participation in EMSO depends on how many systems are built and how many countries participate. An estimate based on two observatories is 200 million Euros, and with the participation of countries with relatively extensive marine research it can cost 25 million SEK per year from 2010 to 2013 to build the system. Operational costs depend on how many sensors are placed and how their operation is financed.

The Swedish Research Council has submitted a letter of support for EMSO's application for planning grants from EU's Seventh Framework Programme.

ICOS – Integrated Carbon Observation System

Micrometeorological measurements from specially equipped towers can calculate the exchange of carbon dioxide and other greenhouse gases, mainly methane and nitrous oxide, between the atmosphere, vegetation, and the ground. As a rule, measurements are taken several meters above the vegetation and the results reflect gas-exchange between the atmosphere and specific ecosystems. Also, 100- to 200-meter towers are used for high-precision measurement of greenhouse gas concentrations. These data are used for so-called inverse modelling aimed at determining gas exchange on a re-

Photo: Anders Linderoth, Lunds University

The Norunda mast is a flux measurement tower used to measure the exchange of carbon dioxide between the atmosphere and surrounding forest. Swedish research in this field has shown that the association is more complex than previously thought; using forests to produce biofuel can, in some instances, increase the release of carbon dioxide into the atmosphere.

gional scale. To enhance understanding of the association between vegetation characteristics, gas exchange, and climate, one needs long time-series and repeated measurement sites for several different types of vegetation, e.g. forests of various ages and with different conditions of humidity. The measurements also need to be coordinated among nations. Hence, it is important for Sweden to participate in the European collaboration now being established via ICOS. The Swedish Research Council has submitted a letter of support for a planning grant application from ICOS to EU's Seventh Framework Programme.

Swedish researchers have been among the pioneers in this field of research, e.g. Norunda (near Uppsala) has the oldest continuous measurements in the world. Several research groups from the major universities and from the national sciences stations in Abisko are measuring and modelling the exchange of greenhouse gases between vegetation and the atmosphere. Currently, Sweden is coordinating a Nordic Centre of Excellence (NECC[12]) in the field, with participation by 15 institutions from all Nordic countries and financed by NOS-N and the Nordic Councils of Ministers. Together with another centre in the area of aerosol-climate (BACCI), coordinated from Finland, a joint research school with nearly 100 doctoral candidates is involved. Extensive international collaboration is taking place within the framework for Global Fluxnet[13], with participation by more than 205 flux measuring sites distributed around the world.

The infrastructure required for research on greenhouse gases has been financed mainly through short-term external research grants. To cover variations in climate it is essential to finance more long-term measurements. The goal would be to form a "Fluxnet Sweden" where exchange of greenhouse gases over time can be studied from forests of different ages, from different types of forests, and from other land uses, e.g. in the subarctic. The level of ambition can vary in scale, but an ideal, long-term project would include approximately 14 low masts and 2 high masts in Sweden. This investment would require 10 million SEK and 6 million SEK per year in operational costs. A minimum level for Swedish participation would require investments of about 5 million SEK and an operational budget of 2 million SEK per year.

LifeWatch

LifeWatch aims at building an infrastructure to effectively utilise biodiversity data from biological collections and field stations, and to develop analytic and modelling tools to process such data. The intent is to bring together

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[12] http;//www.necc.nu

[13] http://www.eosidis.ornl.gov/FLUXNET

the facilities that generate biodiversity data with the digital laboratories that analyse and model the data. This information is important for understanding ecosystem functions, biodiversity, and development of long-term and sustainable use of natural resources.

Sweden plans to participate in LifeWatch, a biodiversity infrastructure. Shown here is an experiment at Kristineberg Marine Research Station, one of the Swedish parties involved in the project.

Photo: Camilla Jakobsson

LifeWatch is associated with the Global Biodiversity Information Facility (GBIF). GBIF intends to collect and coordinate information – found at universities, museums, institutions, etc in different countries – on the Earth's species as part of the effort to map biological diversity. Forty-seven countries support GBIF, and Sweden participates through the Swedish Research Council's financial support of the Swedish GBIF secretariat at the Swedish Museum of Natural History. LifeWatch should be able to integrate biological data, life history and diffusion of different species, biodiversity data, and environmental factors (data from environmental surveys and fixed testing areas) viewed from a species and biotope perspective. The database is expected to have intrascientific importance for many European (including Swedish) researchers, and for teaching, and public information. The Swedish Species Information Centre (ArtDatabanken), the Swedish University of Agricultural Sciences (SLU), and the Swedish Environmental Protection Agency (Naturvårdsverket) all have major interest in LifeWatch.

Eight existing, EU-financed Networks of Excellence serve as a base for LifeWatch. Researchers from Sweden participate in at least four of these networks.

The Swedish Research Council intends to participate in the preparatory phase for LifeWatch via EU's Seventh Framework Programme along with the other active Swedish organisations – the Kristineberg Marine Research Station, the Swedish Natural History Museum, and the Swedish University of Agricultural Sciences. Additional Swedish research institutions that have expressed interest in participating include, e.g. the Evolution Museum in Uppsala, the biological museums in Lund and Göteborg, the Swedish Species Information Centre, and several marine research stations with large collections and many years' documentation of plant and animal life. Furthermore, a proposed new organisation – the West Coast Marine Research Centre – and a recently formed national institute on ocean environments are expected to have an interest in LifeWatch. Other parties interested in studying terrestrial ecosystems are also expected to participate.

Humanities and Social Sciences

CESSDA – Council of European Social Science Data Archives

CESSDA is a distributed infrastructure for social science data of the type that the Swedish Research Council is attempting to develop through DISC's activities – within MONA and the Swedish National Data Service (SND) – that have been developing since the autumn of 2007 at the University of


Picture: SXC

Upgrading of CESSDA, the distributed infrastructure for social science data, means that researchers and data can move virtually unobstructed across European borders.

Gothenburg. SND will serve as the Swedish partner in CESSDA. Through CESSDA, researchers have access to data from 21 countries in Europe and (via the organisation's participation in global data collaboration) also to many countries outside of Europe, e.g. the Inter-University Consortium for Political and Social Research (ICPSR) in the United States.

CESSDA includes approximately 15 000 databases and serves over 20 000 researchers. Currently, CESSDA has data in the social sciences and also census data, election surveys, opinion surveys, and other questionnaire surveys.

Upgrading of CESSDA involves the creation of a European "research passport" that gives researchers and data the opportunity to move virtually without obstacles across European boarders. A common financial base for the project enables international efficiency to improve, and more complete integration of the national data archives can be achieved. CESSDA will: make an inventory of data of intranational value; describe and document data; facilitate contacts among data users in different countries; develop regulations on personal security and copyright aimed at strengthening access to data while protecting confidentiality and copyright; and develop new methodology and software for data analysis.

The project presented in the ESFRI roadmap involves 30 million Euros and intends to upgrade common documentation systems, develop researcher support, and develop software (middleware) to serve the distributed environment. CESSDA is also working to incorporate and provide support to new members in the network.

CLARIN – Common Language Resources and Technology Infrastructure

Among the ESFRI projects being considered for funding, as regards a joint European infrastructure in the humanities, is the CLARIN language technology project. This project is a European initiative to create an integrated and standardised research infrastructure for language resources, which involves data resources including corpora, 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 important study objects. CLARIN will construct a grid-like infrastructure using Semantic Web technology. Beyond data resources, and technologies and tools in a limited sense, CLARIN will address two areas comprising the basic prerequisites for distribution and sharing of language resources, namely standardised metadata and dealing with intellectual property issues.

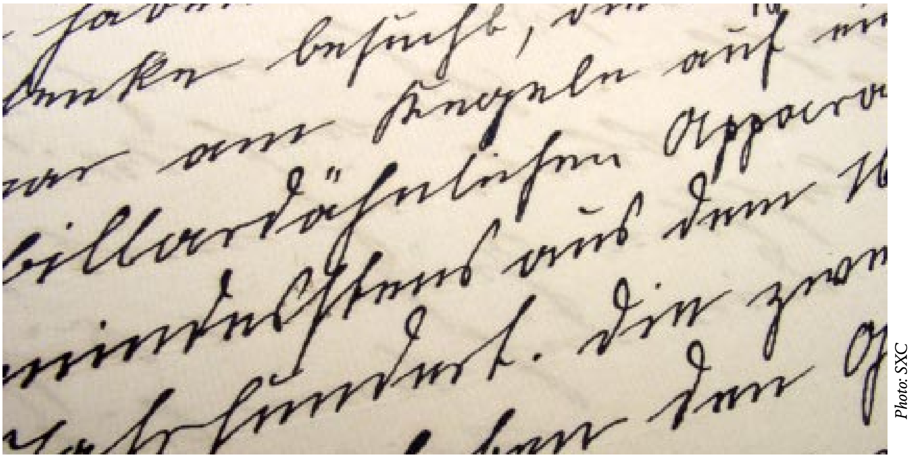


Photo: SXC

CLARIN is a planned European infrastructure for language resources, e.g. corpora, speech databases, dictionaries, and grammarians.

The timeframe for CLARIN covers 6 years (2007-2012), including an introductory preparatory phase of one year, and an estimated total budget of 108 million Euros. Four Swedish institutions are members of CLARIN, and they also belong to a Swedish consortium to create Swedish language resources of the type targeted by the CLARIN project. Language technology involves both language-independent and language-dependent aspects. This means that results from language technology research concerning Swedish and other languages in Sweden are relevant for the international research community, but also that language technology for Swedish (or Swedish in contrast to other languages, e.g. for translation applications) does not just appear; it must be created in Sweden. Language technology research and development of language technology systems require an infrastructure of generally accessible and standardised basic resources, i.e. data and programs to work with these data. A basic kit of such resources is called the Basic LAnguage Resources Kit (BLARK). Resources must be created for each language individually. There are important benefits from doing this through international collaboration, e.g. the CLARIN project. Research requires both unilingual and multilingual text corpora reflecting the fact that Swedish is a standard language with a long written and oral tradition, but that it lives and functions in today's world with two-way multilinguistics: outward towards the Nordic languages, English, and other world languages, and inward towards the minority and immigrant languages in Sweden.

A report commissioned by DISC includes a survey of language technology research in Sweden. It supports the perception that language technology is an active field in need of the type of international collaboration promoted by participating in CLARIN. The report will be completed during 2008.

ESS – European Social Survey

The European Social Survey is a researcher-initiated social survey designed to define and explain the interaction between Europe's changing social structures and attitudes, conceptions, and behaviour among its culturally and socially diverse populations. In its third version, the survey includes 27 nations and adheres to a uniform methodology to increase quality and comparability. The fieldwork was financed by EU's fifth and sixth framework programmes, the European Science Foundation, and national contributions, e.g. from the Swedish Research Council and the Swedish Council for Working Life and Social Research (FAS). The Swedish Research Council's commitment to this comparative study is well motivated, and Sweden has participated since the first round in 2001. The third round of interviews was conducted during autumn 2006, and the fourth is currently being planned.

Photo: SXC

The European Social Science (ESS) study compares attitudes, opinions, and behaviour among Europe's culturally and socially diverse populations.

ESS aims to conduct high-quality measurements of social reality and change in Europe's populations; to increase comparability in the questionnaire survey across national boarders and languages barriers; and to develop and implement social indicators alongside the well-established economic indicators.

Data from the project are directly and easily accessible on the Internet. The current initiative includes upgrading to correct weaknesses in the present programme.

Organisation of the project requires national coordination, data collection, translation of questionnaires, and fieldwork. Researchers at Umeå University are coordinating the Swedish part of the study.

Materials Sciences

ESS – European Spallation Source

The European Spallation Source (ESS) is a planned pan-European facility for multidisciplinary research utilising neutron scattering techniques. ESS will be one of the world's primary tools for research on advanced materials. The neutron scattering techniques makes it possible to acquire direct information about the atomic structure of molecules and materials, and about microscopic dynamics such as vibrations and diffusion of atoms and molecules, but also about magnetism at the atomic and molecular levels. A special feature of neutron scattering is that it enables the study of light atoms, e.g. hydrogen. Research fields that will be able to use ESS include materials- and nanosciences, chemistry, molecular biology, biotechnology, pharmacology, energy technology, and micro-electronics.

One of the potential sites for ESS is near Lund.

Photo: ESS-S

For some years, Europe has been planning to construct a new and powerful neutron facility – the European Spallation Source (ESS). Many European countries have been involved in the technical design and have shown interest in collaborating on the construction. A spallation source produces neutron beams with the help of an accelerator via a so-called spallation process instead of in a nuclear reactor. This method of producing neutron beams has been used for some time at the world's currently largest spallation source, ISIS at Rutherford-Appleton laboratory in the United Kingdom. A new powerful spallation facility recently became operational at Oak Ridge Laboratory, Tennessee (USA). In 2008, a corresponding facility will be completed in Japan.

ESS Scandinavia (ESS-S) is a consortium promoting the proposal that Sweden should offer to host ESS in Lund. Locating a large European research facility in Sweden would have positive effects on Swedish research and growth, and therefore financing the facility is motivated for research and industry equally.

Construction of ESS is estimated to cost approximately 12 billion SEK, and operational costs would be approximately 1 billion SEK annually. The costs would be distributed among the participating countries, but the host country is expected to take a comparatively larger share for construction and operation.

In February 2007, the Swedish Government offered other European countries the option to participate in constructing ESS in Sweden, under the condition that Sweden would cover approximately 30% of the total cost and approximately 10% of the operational cost. The offer by the Government is based on ESS Scandinavia's proposed facility design and placement in Lund. Several other countries have also shown interest in hosting the project. The decision process and financial issues are, however, complex since they involve agreements between many European governments on both site of construction and on funding. Regardless of where ESS will be located though, the facility will be of interest to Swedish researchers.

Upgrading ESRF – European Synchrotron Radiation Facility

The European Synchrotron Radiation Facility (ESRF) in Grenoble is one of the world's most advanced synchrotron radiation sources. The ESRF project covers the full scientific spectrum from fundamental studies in basic sciences to applied research in areas such as structural biology, material physics, structural chemistry, geology, etc. Since the electron energy of the accelerator reaches as high as 6 GeV the activities at the facility are focused on structural studies using hard x-rays.

ESRF became operational in 1994, and approximately 6000 researchers visit the facility annually. Eighteen European nations are members of ESRF. Sweden is a member in the organisation through a Nordic consortium, NORDSYNC. The consortium accounts for 4% of the member contribution to ESRF, whereof Sweden contributes just over 1.5% at a cost of approximately 12 million SEK per year. Physicists, chemists, biologists, geoscientists, physicians, environmental researchers, and industrial researchers use the facility. Over 50 researchers from Sweden conduct experiments at ESRF annually. Currently, the utilisation by Swedish researchers mainly involves protein crystallography and structural biology, but also some materials sciences.

Synchrotron radiation research is advancing rapidly, and ESRF is discussing an upgrade of the facility. This process is motivated in part by the fact that several European countries are building synchrotron radiation laboratories with storage rings that could successfully compete with ESRF in terms of performance in its low-energy range of x-ray beams. NORDSYNC should consider these changes before considering any change of its membership contribution to ESRF.

Arial photo of ESRF.

Photo: Denis Morel, ESRF

ESRF claims that the facility must upgrade to give European researchers the possibility to conduct cutting-edge research at ESRF during the forthcoming 10 to 20 years. The primary components in the upgrade include: to radically improve performance of the beamlines and open the possibility for new ones; to improve and develop x-ray sources; to broaden and improve the scope of instruments for experiments; and to develop greater research collaboration with academic groups and industry. This would also involve other costs, e.g. expanding the experiment hall. The total cost of the planned ESRF upgrade is estimated at 232 million Euros during 2008 to 2017. However, the costs do not appear to be evenly distributed throughout this period.

The ESRF Council is expected to make a decision on upgrading of ESRF in the early summer of 2008.

Upgrading the Institut Laue-Langevin Neutron Source

Institute Laue Langevin (ILL), a reactor-based laboratory in Grenoble, is said to be one of world's most productive and reliable resources for slow neutrons used in studies of condensed matter, e.g. magnetic structures and dynamics in material, superconductors, polymer dynamics, biomembranes, and hydrogen transport in fuel cell materials. Upgrading of the laboratory is judged to be one of the most cost-effective ways to meet user demands for neutron scattering in the short to medium term.

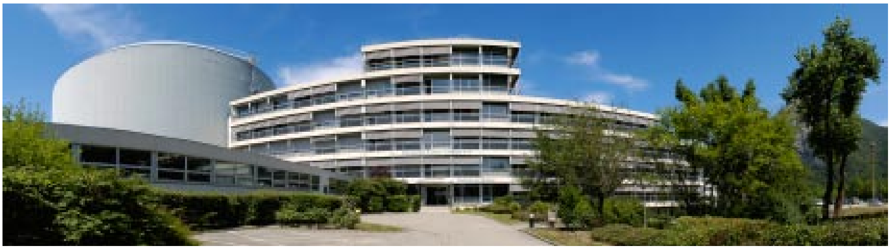


Photo: ILL

Institut Laue-Langevin.

ILL is currently the world's most advanced facility for neutron scattering. It has had a complete array of beamlines and instruments from the outset in the mid 1970s, which has since been continuously developed and upgraded. The nearby synchrotron facility ESRF has provided additional value to European users that have access to complementary technologies and joint support facilities in Grenoble.

Recently, ILL has presented a rather extensive and focused refit programme, the Millennium Programme, to maintain its world leadership and its scientific value for the international research community. The programme includes proposals to optimise neutron sources and their moderators, and also neutron guides and instrumentation. By improving complementary support facilities for users, it becomes easier for new research fields to make efficient use of the neutron instruments. Examples include the deuterium isotope exchange-laboratory for biological samples that opened in November 2005 and is included in the partnership for structural biology and also a facility for material technology.

The upgrade of neutron production and instrumentation at ILL, called the 20/20 plan, will extend competitiveness. Added value is gained through partnership in material and technological science and in soft material. A laboratory for high magnetic field strength is planned in collaboration with ESRF to lend support to instruments in the neutron and the synchrotron radiation sources. Special efforts will be made to facilitate technology transfer.

The project will be implemented in two consecutive 5-year periods from 2007 through 2011 and from 2012 through 2016. The ILL 20/20 proposal is estimated to cost 1.5 billion SEK.

The Swedish Research Council currently has a contract with ILL that gives Swedish researchers the opportunity to access 1.5% of the beam time.

IRUVX-FEL Free Electron Laser Network for Infrared to Soft X-rays

Light beams of different wavelengths, from infrared to soft x-rays, comprise one of the most useful tools for studying the characteristics of materials, molecules, and atoms. Recent advancements in technology have led to the development of free electron lasers that can generate extremely powerful and short light flashes with coherent beams. Free electron lasers enable completely new experiments that will increase understanding about the characteristics of materials, molecules, and atoms by being able to image structures and to determine different dynamic processes by "filming" with stroboscope-like methods. Free electron lasers can also be used to lithographically nanostructure material, or to produce and study plasma, e.g. for studies of fusion processes.

IRUVX-FEL, which is included in ESFRI's roadmap, will become a distributed infrastructure to encompass several national free electron laser facilities. However, each will specialise in a particular type of study. Hence, the different lasers at different sites in Europe will complement each other. Researchers in Europe will be able to use the facilities that best serve their particular studies of materials, molecules, or plasma. The development of free electron laser technology is rapidly advancing, and the intent is to build the new facilities in sequence so that researchers can test and benefit from the new technical advancements of 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.

The free electron lasers will be used in many different areas and to address many different questions, e.g. concerning nanoscience, material science, biomaterials, plasma physics, and cluster physics, and to study chemical reactions. They can also be used in studies related to environmental science, energy technology, astrophysics, geology, microelectronics, etc. Europe is leading the way in free electron lasers. A facility for wavelengths as short as six nanometres, FLASH, was recently built in Hamburg. It is currently the most advanced facility in the world. Gains in technology from this and other test facilities, whereof MAX-lab in Lund is one, will be used in constructing the new facility, Fermi, in Trieste. Several proposed projects participate in the European IRUVX network with technical designs and tests, although decisions on implementation have yet to be made. They include BESSY-FEL in Berlin, 4GLS in Daresbury UK, and a free electron laser in the second phase of the MAX IV project in Lund. The project in Lund focuses on, e.g. new technological concepts (seeding) to achieve more well-defined pulses.

The investment in each of the facilities is estimated to cost from 1 to 2 billion Swedish Kronor (SEK), and operational costs are estimated to be around 100 million SEK annually per facility.

Synchrotron Radiation Facility MAX IV

Advancement is fast-paced as regards new light sources for radiation in soft x-rays and the x-ray field. Not least, the performance of synchrotron radiation facilities has improved substantially in recent years. This is of major importance for broad areas of natural sciences, e.g. in physics, chemistry, biology, and geology, because of the ability to provide detailed information on the structure and dynamics of atoms, molecules, and material. Examples of research fields where synchrotron radiation studies are of decisive importance include: energy-related materials for catalytic converters, solar cells, and batteries; structural biology where the overwhelming portion of proteins are structurally determined using synchrotron radiation; in surface physics for functional surfaces; and in development of future materials for new types of electronics.

MAX-lab in Lund has developed a new design for the next generation synchrotron radiation source, MAX IV. The facility will include over 20 large instruments for measurement of x-rays and soft x-rays. The proposed design will enable MAX IV to offer radiation of the highest brilliance in the world – hence, enabling studies of very small samples in a broad field, e.g. of nanostructured material or of smaller protein crystals, than has been possible previously.

The plan for the MAX IV facility includes two electron storage rings, one placed on top of the other, a 1.5 GeV ring for soft x-rays, and a 3 GeV ring for hard x-rays. Furthermore, a free electron laser is being planned for a later stage.

During autumn 2005, MAX-lab sent a report to the Swedish Research Council describing the technical design of the accelerator system. An international group of experts assessed the proposal, and their report stated, among other things: "The committee finds the design concept sound. It offers a source with an order of magnitude of higher brightness than other third generation synchrotron radiation sources, and it is judged by the committee to be a base for a detailed design study".

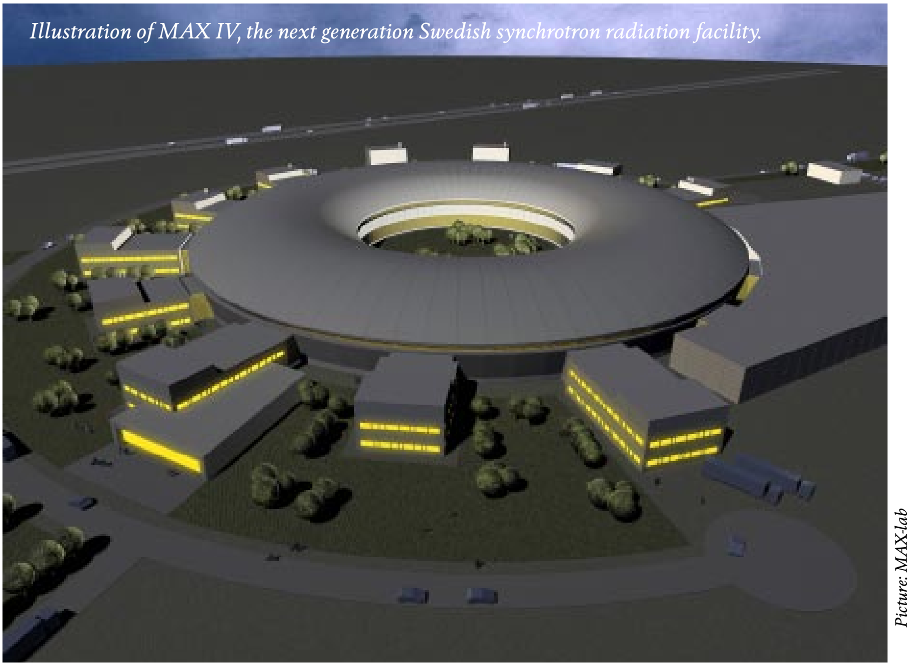


Illustration of MAX IV, the next generation Swedish synchrotron radiation facility.

Picture: MAX-lab

MAX lab has also developed a "Conceptual Design Report" that covers a scientific programme for MAX IV and a detailed plan for enhancing the first 15 beamlines. The international group of experts that assessed the scientific motives for MAX IV during the autumn of 2006 recommended that the facility should be financed as quickly as possible at the level requested.

Combined, the assessments show that the MAX IV facility would be a world leader in synchrotron radiation and would provide researchers access to new opportunities for conducting leading research in a broad range of natural sciences.

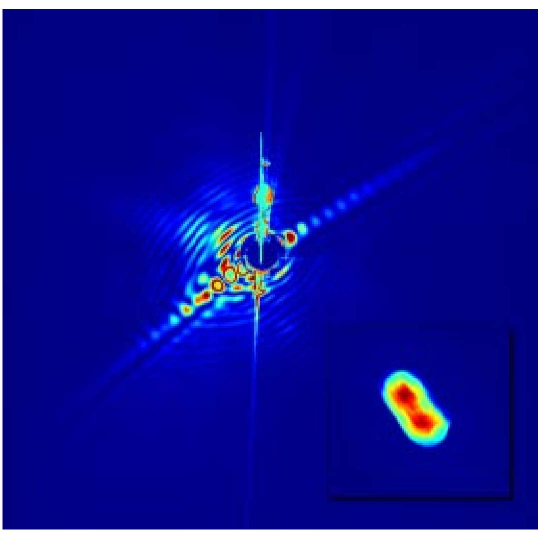
XFEL – X-ray Free Electron Laser Facility

The X-ray Free Electron Laser (XFEL) will signify a major breakthrough in the natural sciences. The facility will deliver x-rays that are 10 billion times more intensive than what is available today in ultrashort flashes at the femtosecond level. The intensive pulses open the door for many experiments that could not be conducted previously and for new questions in nanoscience, structural biology, condensed matter physics, and femtochemistry, but also in material science and plasma physics. New experiments enabled by the x-ray free electron laser will include: "filming" the structure of atoms in a molecule or a material while a chemical reaction is occurring; determining detailed structures of individual biomolecules that cannot be crystallised, e.g. membrane proteins; and creating new material conditions such as hot dense plasma, the characteristics of which we can only guess at today.

Originally a German project, XFEL has developed into an international collaborative project where Germany accounts for 60% of the investment cost of approximately 1.1 billion Euros, and the remaining 40% is shared among the other participating countries. Construction of the facility is planned for 2008 to 2013. Part of the contribution for construction provided by participating countries is expected to be in-kind, i.e. delivery of components for accelerators, instruments, detectors, etc. Operational costs are expected to be 84 million Euros annually. The Swedish Research Council has participated in the preparatory phase to develop necessary technical scientific documentation as well as contracts and cost calculations. In early June of 2007, Sweden signed a declaration to participate in construction of the facility and contribute at least 12 million Euros.

Swedish researchers in several disciplines are involved in the development of instruments, detectors, x-ray optics, and guidance systems for XFEL. Several research groups also participate in planning the experiments that will take place at the facility.

The new free electron laser sources have generated high expectations both in Sweden and internationally. During 2007, over 10 European countries (including Sweden), China, and Russia decided to participate in the construction of XFEL in Hamburg. Construction on the facility will start early in 2008 after an international convention is signed by the participating countries and a joint corporation has been formed.



Initial results from attempts to image individual cells using a free electron laser. The image shows diffraction from a living pico-plankton measured with the FLASH soft X-ray laser in Hamburg, with a pulse length of 10-femtoseconds and a wavelength of 13.5 nanometres. The insert shows the reconstructed cell (reconstruction: F. Maia). The results support calculations showing that free electron lasers such as XFEL can be used to image living cells and molecules.

Experiment and picture: J. Hajdu, F. Maia, M. Svenda, I. Andersson, M. Bogan, H. Chapman et al.

Medicine and Life Sciences

Infrastructure in Life Sciences – BILS and ELIXIR

In recent years, the life sciences have undergone major transformation as the advancements in genomics, proteomics, and other technologies have generated an enormous volume of data. Since these data need to be stored, analysed, and interpreted, biology and medicine have been moving much more towards becoming information sciences. Bioinformatics plays an important role in developing and managing tools and methods so that data sources can be used effectively, e.g. to study the functions of genes and proteins.

The aim of the planned Swedish infrastructure – Bioinformatic Infrastructure for Life Sciences (BILS) – and its European counterpart i.e. European Life Sciences Infrastructure for Biological Information (ELIXIR), is to build bioinformatic support for the life sciences.

As stated in ESFRI's roadmap from 2006: "Bioinformatics is today a prerequisite for all experimental and applied biology, including drug discovery, human genetics, and epidemiology". The planned ELIXIR project from ESFRI's roadmap is based in part on a major upgrading of the European Bioinformatics Institute (EBI) in the United Kingdom and in part on integration of other data sources distributed across Europe. Hence, European bioinformatic expertise will be spread across several nations. The goal of ELIXIR is to construct and operate a sustainable infrastructure for biological information in Europe to support life science research and applications in, e.g. medicine, environmental science, biotechnology industry, and society at large. Hence, ELIXIR will strengthen all research and all business that concerns living systems. Sweden is participating as a partner in the planning phase of ELIXIR.

At the national level, the proposed BILS project is intended to provide both local support and specialised services and function as a Swedish node to ELIXIR. The organisation is being viewed as a network with nodes at different universities and bioinformatic organisations. Each node provides both general bioinformatic support and expertise to local university researchers. Furthermore, some nodes will have national responsibility for specific areas, e.g. microarray data storage, plant bioinformatics, orthology analysis, membrane proteins, and molecular modelling.

The bioinformatics network is intended to be responsible for coordination at the national level and for participation in international collaborations, both in the Nordic countries and with Europe generally. Another function includes education in bioinformatics at several levels. In particular at the advanced level – from doctoral courses and above – there is much to gain from coordinating resources and providing specialised courses on a national level.

Source: Lena Henriksson/Alwyn Jones, Uppsala University

Advanced bioinformatics make it possible to interpret complex datasets and study biomolecules in detail. The illustration shows parts of a high-resolution structure of the DXR enzyme in the bacteria Mycobacterium tuberculosis. The enzyme is important for metabolism of the bacteria, and knowledge about the enzyme's structure can contribute towards development of pharmaceuticals to treat tuberculosis.

Biobanks. BBMRI – Biobanking and Biomolecular Resources Infrastructure

Biological tissue samples with associated data on origins and treatment constitute invaluable resources for studying biological processes in situ, i.e. on site in tissue. Biobanks handle and store a large number of tissue samples worldwide, often through freezing and the archiving of samples 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.

Sweden has a structural advantage compared to most other countries. Because of our comprehensive registries, personal ID numbers, public health services, and research-friendly population we have exceptional opportunities to better utilise existing biobanks for research and to create new, more informative biobanks. Researchers using biobanks require everything from advanced logistics (to assure the quality of sample collection) and adapted information systems (to gather relevant phenotype information) to powerful technologies for conducting analyses in, e.g. genomics, transcriptomics, proteomics, and metabolomics. Management of biobank material is resource-intensive in terms of time and knowledge among those performing the collection work. Those who handle and classify human biological material are usually physicians and staff within several different specialities. Also necessary is the expertise of several different research fields, e.g. health informatics, statistics, genetics, bioinformatics, epidemiology, various clinical specialties, technology, and molecular biology to analyse the specimens. To fully utilise the potential of biobanks, it is necessary to integrate health care and university resources to a substantially higher degree than what is the case today.

Photo: Kennet Ruona, Swedish National Biobanking Program

Biological tissue samples are stored in biobanks at -80°C to minimise the risk for degradation of DNA, RNA, and proteins.

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. BBMRI is one of the 35 projects presented in ESFRI's roadmap from 2006. The Swedish Research Council has submitted a letter to the Seventh Framework Programme to support the grant application by the network of researchers involved in planning BBMRI.

The Biobank Information Management System (BIMS) – Swedish system for handling biological samples and associated phenotype information – is integrated in several European biobanks and is also included as a component in the planned pan-European infrastructure.

Although several of Sweden's human biobanks have a good standing from an international perspective, the research field as a whole is small and fragmented. The previous edition of the Swedish Research Council's Guide to Infrastructure identified biobanks as an area that required further study. Such a study is under way, and the results will be presented in the beginning of 2008. At a public kick-off meeting for the study, most of the interested parties – researchers, biobank owners, and agencies – were found to agree on the need for more coordination, long-term thinking, and rigorous prioritisation, but opinions varied concerning how to achieve this.

National Core Facilities in Medicine and Life Sciences

In medicine and life sciences, "core facility" is a collective term covering common high-tech equipment and methods that are openly accessible to researchers. Examples of core facilities include methods for biomolecular analysis, various imaging technologies, and research-oriented surgery/operating theatres. The individuals that staff these facilities may include anyone from physicists to biochemists, molecular biologists, veterinarians, and physicians. Core facilities continuously develop methods and instruments that give researchers access to the latest technologies. Core facilities also comprise an educational resource and give younger researchers access to advanced equipment and methods that allow them to establish themselves quickly in their line of research. By integrating data from different technical platforms, complicated life processes can be mapped in detail and show more clearly how the organisation functions and interacts with its environment, i.e. systems biology.

For example, the imaging field is advancing rapidly, and the volume of data and its complexity is sharply increasing. This development also requires new management strategies. Many bioimaging devices are of the size and cost that they should be coordinated under a national infrastructure with facilities for imaging at different levels – full animal, cell level, and molecular level. There is an increasing need to integrate image information with genetic information and patient information to be able to use the information to its full potential. Sweden is an international leader in image analysis. This, combined with our valuable patient databases and biobanks, offers the prerequisites for substantial advancement in research if resources are well managed and widely accessible within the research community.

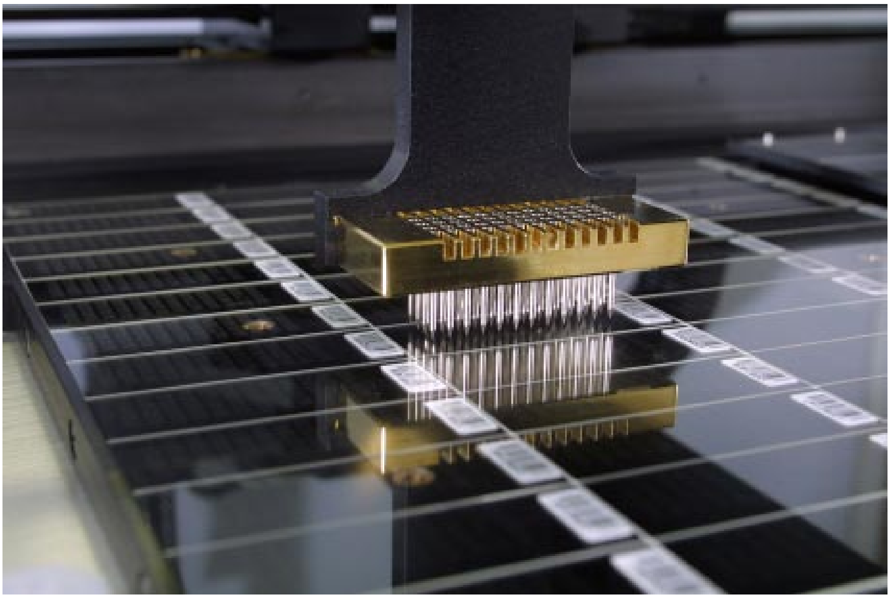


Photo: National Research Council of Canada.

With high precision, a robot places tens of thousands of nanolitre-sized drops containing different biomolecules on each glass slide. The molecules can then be attached to the glass and used for parallel analyses of large numbers of genes or proteins.

In recent years, several major time-limited investments have been made, e.g. by the Swedish Foundation for Strategic Research (SSF) and the Wallenberg Foundation to support the development of core facilities, e.g. in genomics, proteomics, and biological imaging. The facilities available in Sweden as well as those being developed, should be organised and shaped into national resource centres that can serve researchers' needs for highly specialised expertise in various technical fields. Scientific and economic long-term perspectives, and continuous improvement of technology and expertise, are needed for the operation and development of these facilities. Collaboration between the Swedish Research Council, universities and university colleges, county councils, and other funding bodies is necessary for continued success. There is a need to prioritise the core facilities that will be needed to secure Sweden's long-term competitiveness in biomedical and life sciences. The Swedish Research Council intends to investigate this area further.

EATRIS – European Advanced Translational Research Infrastructure for Medicine

The European Advanced Translational Research Infrastructure in Medicine (EATRIS) is a pan-European project aiming to improve the transfer of research-based knowledge into clinical practice. A reason behind this effort is the widening knowledge gap in many European countries between basic experimental research and clinical research. This knowledge gap, due in part to changes in the organisation of health services and the educational and career paths of researchers, is thought to be one of the reasons why the pharmaceutical and biotechnology industries have developed at a slower pace in Europe than in the United States.

Major advances have been made in biomedical research as a result, e.g. successes in genomics, proteomics, and cell biology, and knowledge transfer between these fields via bioinformatics and other means. It is important to use these advancements to solve practical clinical questions facing health services in a range of areas, e.g. the increased frequency in diabetes and other metabolic diseases, cardiovascular diseases, and cancer. Research is also important to understand and treat recently-detected diseases and problems such as SARS, HIV, avian influenza, and the increasing resistance in treating tuberculosis and common infections.

The term "translational" implies knowledge transfer and research activities that connect basic research with health and social services and industry. Investments in translational research yield large dividends by creating

Photo: SXC

Translational research involves the transfer of knowledge between basic research and health services.

complementary structures within the various organisations, and even yield "profits" in terms of improved health care. EATRIS will function as a distributed infrastructure for translational research, forming a network of research centres that specialise in various disease areas. These centres will be multidisciplinary, bringing together experts with various backgrounds that work in these specific disease areas. The network will also collaborate closely with other European networks in clinical trials, with different technical platforms and thematic translational research projects, and resources for bioinformatics and advanced data processing. Hence, this interlinked structure will serve to assess new strategies for treating diseases effectively and can be used to improve health services.

EATRIS is included in the ESFRI roadmap. Initially, the project aims to establish six research centres in Europe to convert basic research into clinical practice. Each node in the network will focus on one of the following common diseases: metabolic diseases, cancer (imaging and oncology), in-

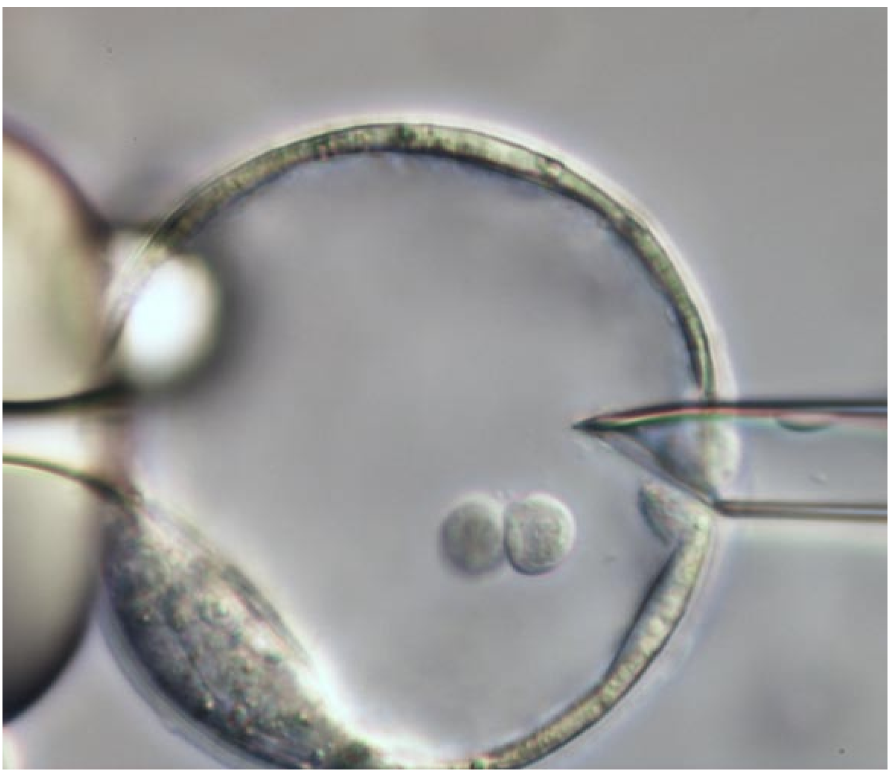


Photo: Johannes Wilbertz, KI

Embryonic stem cells with modified DNA are injected into an early mouse embryo (blastocyst). This is an important part of the process in creating the so-called knockout mice used to study the effects of various genetic changes in vivo.

fectious diseases, cardiovascular diseases, or neuropsychiatric diseases. One of the nodes, the metabolic diseases node, will be located in Sweden at the Karolinska Institutet in Solna. The Swedish Research Council supports Swedish participation, and is a co-applicant for funding under EU's Seventh Framework Programme for the preparatory phase of EATRIS.

Phenotyping and Archiving of Animal Models – SweImp/ Infrafrontier

In-depth studies involving model organisms generate a great need for advanced knowledge and resource centres. No experimental systems can replace the study of normal and pathophysiological biological processes in vivo, i.e. in an intact organism with cells and intracellular signal mechanisms active in their natural context. This can be illustrated by the fact that particularly important, multipotent and potentially regenerative cells in different tissues are regulated by their placement in special tissue pockets or niches. In medical research, mice represent a particularly interesting model system since they show many genomic similarities to humans (95%) and are well suited to genetic studies because of their short generation time. Consequently, mice have been well studied, but worms, fish, and flies are also valuable model organisms.

To map functions in vivo for all identified genes and gene variants, a European initiative, Infrafrontier, intends to construct an infrastructure for the phenotyping and archiving of different mouse models. The aim is to produce large-scale, genetically modified mice to study the effects of different genetic changes and draw conclusions on the function and interaction of genes and their importance in the course of disease. The project will cover thousands of different genetic mice varieties and will therefore be demanding in terms of time and expertise.

Two complementary and distributed networks will be developed within Infrafrontier. Phenomefrontier will offer a European platform for phenotyping of medically relevant mouse models and emphasise non-invasive tools such as imaging. The other network, Archivefrontier, will provide a European resource for archiving mouse models and make them accessible to research. The development of this structure is based on existing networks and collaboration, e.g. the European Mouse Mutant Archive (EMMA).

In ESFRI's roadmap, Infrafrontier is presented as an infrastructure for bringing together European resources in mouse genomics. Initially, 15 of the leading mouse facilities in Europe will be integrated in the network, including the mouse facility at Karolinska Institutet in Solna. Sweden has extensive expertise and experience in animal models and can play an important role in map-

Photo: Maggie Bartlett, NHGRI

The mouse offers major advantages as a model system for research on human diseases, e.g. because of its short generation time and genetic similarity to humans.

ping genetically modified mice, contributing towards better disease models. However, Swedish resources are fragmented and need to be coordinated for stronger participation in Infrafrontier. The SweImp network (Swedish Infrastructure for Mouse Phenotyping) was recently formed to strengthen the field by bringing together Swedish researchers of mouse models into a national organisation that can also serve as a node in Infrafrontier. The Swedish Research Council supports Swedish participation in Infrafrontier by serving as a co-applicant for funding from EU's Seventh Framework Programme for the preparatory phase of Infrafrontier.

APPENDIX I – MEMBERS OF KFI AND KFI'S EVALUATION PANELS, 2006–2007

Committee for Research Infrastructures (KFI)

Madelene Sandström, *Director General, Swedish Defence Research Agency (FOI), Chair. Leave of absence during commission for the government (from June 1, 2007).*

Susanne Holmgren, *Professor of Zoophysiology, Göteborg University, Vice Chair. Acting Chair from June 1, 2007.*

Anders Brändström, *Professor, Director of the Demographic Database, Umeå University*

Claes Fransson, *Professor of Astrophyiscs, Stockholm University*

Hans-Åke Gustafsson, *Professor of High-energy Heavy Ion Physics, Lund University*

Lena Gustafsson, *Professor, Deputy Director General, VINNOVA (Swedish Governmental Agency for Innovation Systems) (from Oct 3, 2006)*

Erik Elmroth, *Associate Professor, Computer Science, Umeå University (from Jan 1, 2007)*

Merle Horne, *Professor of General Linguistics, Lund University*

Ulf Karlsson, *Professor of Material Physics, Royal Institute of Technology*

Karl-Eric Magnusson, *Professor of Medical Membrane Biophysics, Linköping University*

Hans-Örjan Nohrstedt, *Associate Professor, Acting Secretary General, Programme Director, Formas (the Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning)*

Juni Palmgren, *Professor of Biostatistics, Karolinska Institutet and Stockholm University*

Anders Ynnerman, *Professor of Scientific Visualisation, Linköping University. (through Dec 31, 2006)*

Rune Åberg, *Professor, Secretary General, Swedish Council for Working Life and Social Research (FAS)*

Evaluation Panel 1 – Infrastructure for Astronomy and Subatomic Research

Hans-Åke Gustafsson, *Lund University, Chair*

Claes Fransson, *Stockholm University, Vice Chair*

Paula Eerola, *Lund University*

Lars Bergström, *Stockholm University*

Bengt Gustafsson, *Uppsala University*

Tord Johansson, *Uppsala University*

Elisabeth Rachlew, *Royal Institute of Technology*

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

Ulf Karlsson, *Royal Institute of Technology, Chair*

Karl-Eric Magnusson, *Linköping University, Vice Chair*

Inger Andersson, *Swedish University of Agricultural Sciences*

Anne Borg, *Norwegian University of Science and Technology, Trondheim*

Lena Falk, *Chalmers*
Urban Lendahl, *Karolinska Institutet*
Ulf Olsson, *Lund University*

Evaluation Panel 3 – Infrastructure for Earth and Environmental Sciences

Susanne Holmgren, *Göteborg University, Chair. Leave of absence during KFI chairmanship, (from June 1, 2007).*
Håkan Olsson, *Swedish University of Agricultural Sciences, Vice Chair. Acting Chair starting June 1, 2007.*
Leif Anderson, *Göteborg University*
Eve Arnold, *Stockholm University*
Christopher Juhlin, *Uppsala University*
Anders Karlqvist, *Swedish Polar Research Secretariat, Observer*
Donal Murtagh, *Chalmers*
Victoria Pease, *Stockholm University*
Susanne Åkesson, *Lund University*

Evaluation Panel 4 – Infrastructure for eScience

Juni Palmgren, *Karolinska Institutet/Stockholm University, Chair*
Erik Elmroth, *Umeå University, Vice Chair*
Anders Brändström, *Umeå University*
Kersti Hermansson, *Uppsala University*
Ulf Körner, *Lund University*
Bengt Persson, *Linköping University*
Elisabeth Thomson, *Stockholm University*

Staff at the Swedish Research Council working with the Guide

Tove Andersson, *Research Officer Evaluation Panel 2*
Lars Börjesson, *Secretary General KFI*
Magnus Friberg, *Research Officer Evaluation Panel 3*
Camilla Jakobsson, *PR Manager KFI*
Finn Karlsson, *Head of unit KFI*
Per Karlsson, *Research Officer Evaluation Panel 1*
Olle Thylander, *Research Officer Evaluation Panel 4*

To everyone who contributed towards updating the Guide – Thank you!

KFI would particularly like to thank the members and the secretary generals of the three scientific councils within the Swedish Research Council – the Scientific Council for Humanities and Social Sciences, the Scientific Council for Medicine, and the Scientific Council for Natural and Engineering Sciences – the Committee for Educational Sciences, Sverker Holmgren, Bengt Kasemo, Nils Mårtensson, Stefan Nobel, Peter Rohlin, and Magnus Stenbeck.

APPENDIX II – REFERENCES

Three main sources have been used to update the new edition of the Guide:

1. Viewpoints submitted following a consultation process with universities and university colleges. Many opinions were also submitted through a) the Web-forum that opened in November-December 2006 and b) an open seminar on the infrastructure guide in November 2006.
2. Viewpoints received during the process that the Swedish Research Council conducted during the spring of 2007 regarding participation in the preparatory phase of the pan-European projects in the ESFRI roadmap.
3. The studies conducted by the Swedish Research Council after release of the first edition of the Swedish Research Council's Guide to Infrastructure.

The Committee for Research Infrastructures (KFI) and its subcommittees considered all of the viewpoints submitted. The three scientific councils and the Committee for Educational Science (UVK) of the Swedish Research Council were given an opportunity to review and comment on both the first edition and a preliminary draft of the second edition.

* Available in Swedish only

Reports

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- An International Evaluation of the MAX IV Technical Concept. Swedish Research Council's Report 5:2006.
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- Scientific Evaluation of the MAX IV Proposal. Swedish Research Council's Report 20:2006.
- Evaluation of the Swedish ECORD/IODP Membership, with Recommendations. Swedish Research Council's Report 7:2007.
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- The European Strategy for Particle Physics. CERN 2006.

Find infrastructure roadmaps from other countries at:

www.vr.se > Internationella samarbeten > ESFRI

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- Data för svensk klimat och miljöforskning. Will be finished early in 2008.*
- Biobanks – the integration of human information to improve health. Will be finished early in 2008.
- Digitalisering inom humaniora. Will be finished in 2008.*
- Utredning om språkteknologi. Will be finished in 2008.*
- Utrustningsbehov och investeringar vid universitet och högskolor. Will be finished early in 2008.*

Find information from meetings and hearings at:

www. vr.se > Forskningspolitiska frågor > Forskningsinfrastruktur

- Öppet möte om infrastrukturguiden: Vilken infrastruktur behöver svenska forskare? 23 november 2006.*
- Webbforum: Diskutera framtidens infrastruktur. 23 november till 17 december 2006.*
- Hantering av data för klimat- och miljöforskning. 17 januari 2007.*
- How can science be improved by e-science? 14 februari 2007.
- Infrastruktur inom bioinformatik. 27 mars 2007.*
- Utveckling och samordning, hur ska µ-fab utvecklas? 10 september 2007.*
- Biobanker som en resurs för forskning. 18 september 2007.*

APPENDIX III – DESCRIPTIONS

Descriptions of the infrastructures presented in tables 1 and 2. For more detailed descriptions see the sections on the respective infrastructures in Part 3, "Description of Infrastructures for Future Investment".

Astronomy, Astro-, Nuclear-, and Particle Physics

ALMA (Atacama Large Millimetre Array)
A radiotelescope being constructed in Chile in collaboration with the European Southern Observatory (ESO), where Sweden is a member nation, as are the United States, Canada, and Japan. The goal of research at ALMA is to increase understanding about the origin and development of the universe and the galaxies. Under construction.

CERN
The European Organisation for Nuclear Research (CERN) is the world's leading laboratory for high-energy physics. The next major event at CERN will be the start-up of the Large Hadron Collider (LHC) that will enable researchers to study the smallest particles of matter, e.g. to understand how the universe was formed and the fundamental forces driving our world. Swedish researchers participate primarily 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 will be possible at CERN's new accelerator (LHC) at corresponding energies. See also ILC. The project is in the planning stage.

E-ELT (European Extremely Large Telescope)
A planned, giant optical telescope within the ESO framework. One of the projects primary goals is to understand the formation of galaxies and stars in the early universe and to study extrasolar planets. Planned European collaboration.

ESO (European Southern Observatory)

A European organisation for astronomic research that operates large observatories in Chile and is participating in constructing ALMA, see above. Sweden is one of 12 member nations.

EURISOL (European Isotope Separation On-Line Radioactive Ion Beam Facility)

Facility for subatomic physics. The project is in the planning stage.

FAIR (Facility for Antiproton and Ion Research)

FAIR plans to become one of the world's leading accelerator facility for hadron and nuclear physics. The facility will be used to understand the inner structure of matter and the conditions that existed immediately after the Big Bang, before atoms or protons and neutrons had time to form. Under construction in Germany.

Ice-Cube

The world's leading neutrino telescope, Ice-Cube, 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 will 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 more for educational purposes.

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 the laboratory 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, and SKA.

SKA (Square Kilometre Array)

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

Energy

ITER

The fusion facility ITER will become the bridge between current 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. The facility will become operational in 2016. Sweden is contributing to construction of ITER mainly within the framework of the EU framework programme, Euratom. Under construction.

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.

eScience

DISC (Database InfraStructure Committee)

DISC is intended to coordinate existing and new quality-assured research databases and address issues concerning accessibility, quality assurance, and integrity.

NDGF (Nordic DataGrid Facility)

The Nordic DataGrid Facility (NDGF) utilises computational resources linked in a production grid.

NORDUnet

A collaborative organisation involving the university data networks in the Nordic countries.

PRACE (Partnership for Advanced Computing in Europe)

Metacentre for high performance computer systems. Planned European collaboration.

SND (Swedish National Data Service)

SND will become a national data archive, but also contribute towards the development of expertise and services. SND aims to provide fast, inexpensive, and safe access to data for researchers. Organisationally, this service is under the Database InfraStructure Committee (DISC) of the Swedish Research Council. Under construction at Göteborg University.

SNIC (Swedish National Infrastructure for Computing)

SNIC provides computing capacity for research. SNIC consists of the six leading centres for high-performance computing systems in Sweden.

SUNET (Swedish University Computer Network)

SUNET is a collaboration among universities and university colleges to assure that institutions of higher education have good data communications.

Earth and Environmental Sciences

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 (European Incoherent Scatter Facility)

Researchers at EISCAT use radar waves to study the influence of solar wind on the earth's atmosphere and magnetic field. The organisation operates radar stations in Sweden, Norway, Finland, and on Svalbard.

EMSO (European Multidisciplinary Seafloor Observatory)

The goal of the Seafloor-based observation system EMSO is to develop and construct several underwater observatories for marine research within biology, water chemistry, geohazards, etc. Planned European collaboration.

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 spread around Europe are projected. Planned European collaboration.

IODP (Integrated Ocean Drilling Programme)

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.

LifeWatch

An attempt to construct and coordinate 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. Planned European collaboration.

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 that are found only in very low concentrations.

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, upgrading is planned.

CLARIN (Common Language Resources and Technology Infrastructure)

European initiative to create an infrastructure for language technology. CLARIN encompasses both data resources and the technologies and tools needed to store, distribute, and work with data resources. Planned European collaboration.

ESS (European Social Survey)

ESS conducts questionnaire surveys for the purpose of digitalising social data and making it accessible for international comparisons. Data are collected every second year. Existing European collaboration, upgrading is planned.

EUI (European University Institute)

EUI in Florence contributes to the development of Europe's cultural and scientific heritage in its uniqueness and diversity. Researcher education and research in history, economics, law, and social sciences are carried out at EUI.

Mathematics

Institute Mittag-Leffler

Swedish institute for mathematics research. Has an extensive international visiting researcher programme in various areas of mathematics.

Material 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 a Nordic consortium, Nordsync.

ESS (European Spallation Source)

Facility for research involving neutron scattering technology that could possibly be placed 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 material and nanotechnology, chemistry, molecular biology, biomedicine, pharmaceuticals, energy technology, IT and others. Planned European collaboration.

ILL (Institute Laue-Langevin)

ILL is currently the world's leading neutron scattering facility for studies of different types of material. Researchers that conduct experiments at ILL include those in molecular biology, physics, chemistry, material science, and environmental research.

IRUVX-FEL

Planned European network of free electron lasers in the infrared to soft x-ray area. Free electron lasers are used to increase understanding of the characteristics of materials, molecules, and atoms by imaging structures and following different dynamic processes.

ISIS

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

MAX-lab

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 for both research purposes and in industry. Myfab was assessed in 2006.

XFEL (X-ray Free Electron Laser)

The European X-ray Electron Laser (XFEL) will be available for new areas of research in structural biology and certain areas in chemistry, physics, and material science. The intensive x-rays, with one billion times higher brilliance than currently available radiation sources, will enable completely new studies of phenomena and structures in molecules and material. Under construction in Germany.

Medicine and Life Sciences

BBMRI (Biobanking and Biomolecular Resources Infrastructures)

System for managing biological samples. Planned European collaboration.

BILS (Bioinformatic Infrastructure for Life Science)
Project in bioinformatics proposed by Sweden and can be included in the European ELIXIR project. The project is in the planning stage.

EATRIS (European Advanced Translation Research Infrastructure in Medicine)
Network of nodes for translational research, i.e. transferring knowledge from the laboratory to the clinic. Planned European collaboration.

ELIXIR (European Life Sciences Infrastructure for Biological Information)
Infrastructure for collecting, storing, and managing data in bioinformatics. The project developed from the European Bioinformatics Infrastructure (EBI). See also BILS. Planned European collaboration.

EMBL (European Molecular Biology Laboratory)
EMBL is one of the world's leading research organisation in the field of molecular biology. Activities are located at 5 sites in Europe that conduct basic research and provide education in molecular biology. Research students can receive a doctorate at EMBL.

IARC (International Agency for Research on Cancer)
IARC is a centre for international cancer epidemiology, cancer toxicology research, and cancer statistics and education.

INCF (International Neuroinformatics Coordinating Facility
International organisation for research in neuroinformatics. A portal for increased access to data within this field is under construction.

Infrafrontier (Infrastructure for Phenomefrontier and Archivefrontier)
Infrastructure for production, classification, and archiving of genetically modified mouse strains. The goal is to understand the function of genes. See also SweImp. Planned European collaboration.

MIMS (Laboratory for Molecular Infection Medicine Sweden)
Molecular medicine laboratory focused on molecular infection medicine at Umeå University. This new initiative aims, e.g. to promote career opportunities for young researchers. In October 2007, the laboratory joined universities in Helsinki and Oslo in the "Nordic EMBL Partnership for Molecular Medicine" and serves as a node to the European Molecular Biological Laboratory, EMBL. Under construction.

SweImp (Swedish Infrastructure for Mouse Phenotyping)

Mouse facility that may become a Swedish partner in the European Infrafrontier project. The project is in the planning stage.

APPENDIX IV – ACRONYMS AND DEFINITIONS

ALMA	Atacama Large Millimetre Array, radiotelescope being constructed in Chile, to be completed 2010.
ALTER-Net	European network to monitor the ecosystem.
BBMRI	Biobanking and Biomolecular Resources Infrastructure, system for managing biological samples.
BILS	Bioinformatic Infrastructure for Life Sciences, planned Swedish node to ELIXIR.
BioCASE	Biological Collection Access Service for Europe, collaboration on data concerning biological collections and observation.
BLARK	Basic Language Resource Kit, basic resources (data and program) used in language technology.
CERN	European Organisation for Nuclear Research, facility for experiments in particle physics.
CESSDA	Council of European Social Science Data Archives, distributed infrastructure for data in the social sciences, includes 15 000 databases.
CLARIN	Common Language Resources and Technology Infrastructure.
CLIC	Compact LInear Collider, possible future accelerator at CERN, in the planning stage.
DEMO	DEMOnstration Power Plant, demonstration reactor for fusion, in the planning stage.
DISC	Database InfraStructure Committee, organisation in the Swedish Research Council for coordination of databases.
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.
ECORD/IODP	Sweden participates in the deep ocean drilling programme, Integrated Ocean Drilling Program (IODP) via the European Consortium for Oceanic Research Drilling (ECORD).

EDIT	European Distributed Institute of Taxonomy, European collaboration on software concerning taxonomy.
E-ELT	European Extremely Large Telescope, next generation European giant telescope, in the planning stage.
EISCAT	European Incoherent Scatter facility, network of radar stations in Northern Scandinavia and at Svalbard .
ELIXIR	European Life Science Infrastructure for Biological Information.
EMMA	European Mouse Mutant Archive.
EMBL	European Molecular Biology Laboratory.
EMSO	European Multidisciplinary Seafloor Observatory, deep-sea-based observation system.
ESFRI	European Strategy Forum on Research Infrastructures, European organisation for collaboration on infrastructures.
ESO	European Southern Observatory, operates telescopes in Chile.
ESRF	European Synchrotron Radiation Facility in Grenoble.
ESS	1) European Social Survey, questionnaire survey for international comparisons. 2) European Spallation Source, planned facility for material studies by use of neutron scattering technology.
EUI	European University Institute in Florence.
EURISOL	European Isotope Separation On-Line Radioactive Ion Beam Facility, a facility for radioactive ion beams, in the planning stage.
EUR-OCEANS	Ocean Ecosystems Analysis, European collaboration to construct models showing how ocean ecosystems are affected by climate change.
FAIR	Facility for Antiproton and Ion Research, facility for hadron and nuclear physics experiments, under construction in Germany.
Femtosecond	One quadrillionth of a second, femto = 10^{-15}.
FLUXNET	Global network for measuring the exchange of carbon dioxide, steam from water, 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 available to researchers.
GeV	Gigaelectron volt, unit of energy. G = 10^9.
GMT	The Giant Magellan Telescope, North American telescope in the planning stage.

GNP	Gross National Product.
Hadron	Subatomic particle that interacts strongly.
HET	HPC in Europe Task Force – working group that developed a plan for a European collaboration involving the use of high-performance computers.
IARC	International Agency for Research on Cancer in Lyon.
IASC	International Arctic Science Council, an international collaborative agency on Arctic research, secretariat at the Royal Swedish Academy of Sciences.
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.
IFMIF	International Fusion Materials Irradiation Facility, test facility for fusion-related material, in the planning stage.
ILC	International Linear Collider, worldwide collaboration on the next-generation particle accelerator.
ILL	Institut Laue-Langevin, neutron scattering facility in Grenoble.
INCF	International Neuroinformatics Coordinating Facility, secretariat at Karolinska Institutet in Stockholm.
Infrafrontier	Planed European infrastructure on genetically modified mouse strains.
In situ	In medicine and biology it refers to examinations on site in the tissue.
In vivo	Studies of processes in cells and tissues in a living intact organism.
IODP	Integrated Ocean Drilling Program, takes samples in all areas of the oceans.
IRUVX-FEL	Planned European network of free electron lasers in the infrared to soft x-ray area.
ISIS	Neutron scattering facility near Oxford.
ISOLDE	Isotope Separator On Line, facility for radioactive ion beams at CERN.
IT	Information technology.
ITER	International Thermonuclear Experimental Reactor, international test reactor for fusion, to be completed in France ca 2016.
ITPS	Swedish Institute for Growth Policy Studies.
JET	Experimental facility for fusion research in Oxfordshire.
KAW	Knut and Alice Wallenberg Foundation – funds research equipment.

LHC	Large Hadron Collider, large accelerator at CERN, to be finished in 2008.
LifeWatch	Coordination of research infrastructures on biodiversity and sustainable development in Europe.
LOFAR	LOw Frequency ARray, radio telescope in the Netherlands.
MarBEF	Marine Biodiversity and Ecosystem Functioning, a network to disseminate information concerning marine ecosystems.
MAX-lab	Synchrotron radiation facility in Lund.
MeV	Megaelectron volt, unit of energy, $M = 10^6$.
MGE	Marine Genomics Europe, a genomics network aimed at marine ecosystems.
MIMS	The Laboratory for Molecular Infection Medicine Sweden at Umeå University.
MONA	Microdata Online Access, system for external access to Statistics Sweden's (Statistiska centralbyrån) data.
MW	Megawatt, unit of power.
Myfab	Network for microfabrication laboratories at Chalmers, Uppsala University, and the Royal Institute of Technology.
NDGF	Nordic Data Grid Facility, organisation for Nordic collaboration on grid technology and grid utilisation.
Nmrad	Nanometre radian. m*rad (=metre * radian is the product between beam width and its scatter angle) is a unit of emittance. The unit is used for particle beams, particularly in an accelerator.
NORDSIM	Nordic Secondary Ion Mass spectrometer, instrument used in geology to measure the composition of isotopes and basic elements.
NORDSYNC	Nordic consortium for participation in the European Synchrotron Radiation Facility (ESRF).
NorduNET	Collaborative organisation for university data networks in Nordic countries
NOS-HS	Joint Committee for Nordic Research Councils for the Humanities and the Social Sciences.
NOS-M	Joint Committee of the Nordic Medical Research Councils.
NOS-N	Joint Committee of the Nordic Research Councils for Natural Sciences.
NOT	Nordic Optical Telescope.
NuSTAR	Nuclear STructure, Astrophysics and Reactions, international collaboration in nuclear- and astrophysics.
OWL	OverWhelmingly Large telescope, ESO's proposed design for the E-ELT giant telescope.

Phenotyping	Classifying organisms by describing their characteristics, phenotype = genotype + environment.
PRACE	Partnership for Advanced Computing in Europe – European collaboration concerning high-performance computers.
RF Technology	Radiofrequency technology.
RNA	Ribonucleic acid, molecules that control gene activity by transferring genetic information from DNA to protein.
SASE	Self Amplification of Spontaneous Emission, process to generate pulses in accelerators.
SGU	Geological Survey of Sweden.
SKA	Square Kilometre Array, radiotelescope, in the planning stage.
SLU	Swedish University of Agricultural Sciences.
SND	Swedish National Data Service, infrastructure for research in social sciences, medicine, and the humanities. Under construction at Göteborg University.
SNIC	Swedish National Infrastructure for Computing, infrastructure for computing resources.
SSF	Swedish Foundation for Strategic Research.
STM	Scanning electron microscopy.
SUNET	Swedish University Computer Network.
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 Infrafrontier.
SYNTHESYS	Collaboration among natural history collections and botanical gardens in Europe.
TEM	Transmission electron microscopy.
TeV	Teraelectron volt, unit of energy, $T = 10^{12}$.
TMT	Thirty Meter Telescope, North American telescope in the planning stage.
XFEL	X-ray Free Electron Laser facility, under construction in Germany.
Å	Ångström or Angstrom (0.1 nm), unit of length.

Environments surrounding outstanding infrastructures are not only essential for the advancement of science; they also generate innovation, influence social climate, and attract talent. Also, corporations with needs for high-level expertise prefer to establish themselves near these research environments. The Swedish Research Council's Guide to Infrastructure provides an overview of the long-term needs for research infrastructures to enable Swedish research of the highest quality in all scientific fields. In particular, it addresses new infrastructure proposals that have achieved a sufficiently high level of scientific and technical maturity that it is time to decide whether or not to implement them.

This report updates the first version of the Swedish roadmap for research infrastructures, published in 2006. Research infrastructures include, e.g. central or distributed research facilities, databases, and extensive data networks.

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