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Knowledge Infrastructure for the Fifth Freedom in the Baltic Sea Area

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Nordic co-operation

Nordic cooperation is one of the world's most extensive forms of regional collaboration, involving Denmark, Finland, Iceland, Norway, Sweden, and three autonomous areas: the Faroe Islands, Greenland, and Åland.

Nordic cooperation has firm traditions in politics, the economy, and culture. It plays an important rol in European and international collaboration, and aims at creating a strong Nordic community in a strong Europe.

Nordic cooperation seeks to safeguard Nordic and regional interests and principles in the global community. Common Nordic values help the region solidify its position as one of the world's most innovative and competitive.

Content

Foreword

The free movement of knowledge has in recent times been launched as a fifth freedom, complementary to the established four freedoms in EU; the free movement of people, capital, goods and services. Competitiveness is a key word, and actions proposed involve cross-border research projects, cross-border mobility of researchers, students and teachers in addition to higher education and labour market reforms. The free movement of knowledge in the context of the Baltic Sea Region is a requirement to strengthen the region and to develop our societies into truly knowledge-based societies.

This prestudy takes its starting point in the concept of a knowledge infrastructure that ties the region's key universities, research institutions, researchers and students together, and in doing so enables an effective realization of the free movement of knowledge through utilising high-performance ICT resources, ICT based research and innovation methodologies for collaboration on an unprecedented scale.

The reports' suggestion to formulate a Baltic Sea Region strategy for a knowledge infrastructure for the fifth freedom would be an important element enabling fruitful interaction of education, research and innovation in the region's knowledge triangle. The knowledge infrastructure around the Baltic Sea Region may be envisioned to start as high-end research activities that at a later stage will encompass also other areas of education, innovation and business communities.

Tobias Krantz,
Minister for Higher Education and Research
Swedish Ministry of Education and Research

Executive Summary

There is an outstanding window of opportunity to place the Nordic and Baltic Sea countries[1] at the forefront of knowledge infrastructure for science and innovation. By fully mobilizing research, education, training, and innovation through the next generation information and communication technology (ICT), all countries involved are well-prepared to fulfill their economic, social, and environmental ambitions. The long-term benefits from leading the accelerating globalization of research and to lead the exploitation of disruptive technologies can hardly be overestimated.

The knowledge infrastructure is the foundation for the effective realization of the free movement of knowledge – proposed by the European Union as the Fifth Freedom complementing the free movement of goods, capital, services, and persons. Fundamental to the Fifth Freedom are effective knowledge-sharing, well-coordinated research programs, mobility of competent researchers, and world-class research infrastructures.

Today's research is increasingly characterized by large-scale international collaborations and intensified use of various types of ICT resources. In this context, the word eScience is often used to represent research that is enabled through use of advanced ICT equipment – eScience infrastructures – such as high performance computers, high end computer networks, large-scale scientific databases, network-enabled scientific instruments, and grid infrastructure providing seamless access to these resources. From becoming key to the research process, eScience is now often referred to as the third pillar of the scientific method, complementing the scientific method's classical pair – theory and experiments.

No scientific discipline can be left out when describing eScience. All fields are included, from physics and astronomy to the medical sciences, earth sciences, biology, chemistry, social sciences, and humanities. Areas such as mathematics and computer science are in the core of eScience, providing the methodological and technological foundations enabling eScience breakthroughs.

In the knowledge infrastructure, it is knowledge rather than ICT equipment that is the primary resource made available. Compared to the eScience infrastructure of today, the knowledge infrastructure for research and innovation is expected to provide resources more easily and transparently, to vastly larger number of users, to provide higher-level functionality, and to remove constraints regarding distance, access, and usability.

[1] The Nordic and Baltic Sea countries are Denmark, Estonia, Finland, northern Germany, Iceland, Latvia, Lithuania, Norway, Poland, and north-west of Russia, and Sweden.

Based on an analysis of the current state-of-affairs in all eleven countries in focus, the present study proposes to extend on current eScience activities, aiming at the future knowledge infrastructure.

The proposal is to:

- Establish a joint Nordic-Baltic Sea eScience strategy focusing on
  a) eScience education and training,
  b) eScience research programs, and
  c) cross-border sharing of eScience resources.

- Facilitate the implementation of the strategy by
  a) establishing a Baltic Ring of optical networks and
  b) establishing a coordinating body for the implementation of the strategy.

The analysis also identifies a set of actions deemed feasible and effective to lead the implementation of the strategy.

The arguments for developing a joint strategy rather than relying on national efforts are several and include factors such as aggregating the critical mass of researchers and students, improving cost-efficiency through joint development and resource sharing, and becoming better placed to influence the European and otherwise international arena. In particular, the strategy can facilitate the implementation of a recent European strategy[2] proposed by the European Commission, by reinforcing the coordination of networking infrastructures to the benefit of GÉANT, to support the formation of a federated European grid infrastructure, to prepare researchers for European high-performance computing initiatives, and to promote the emergence of European virtual laboratories.

Moreover, the proposed technological, scientific, and educational efforts are expected to have immediate, short-term, and long-term impact on industry and society in terms of international visibility, technological advances, and competence development.

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[2] ICT Infrastructures for e-Science, Communication from the commission, COM(2009), 108, European Commission, Information Society and Media, Brussels, March 5, 2009.

1. Knowledge Infrastructures for Science and Innovation

With a starting point in current eScience activities, this report aims to ascertain the preconditions for placing the Nordic and Baltic Sea countries at the forefront of knowledge infrastructure for science and innovation – an infrastructure providing the foundation for the Fifth Freedom, the free movement of knowledge. Within the European Union (EU), the free movement of knowledge has been proposed as the Fifth Freedom complementing the free movement of goods, capital, services, and persons. Important for the Fifth Freedom is, for example, effective knowledge-sharing, well-coordinated research programs, mobility of competent researchers, and world-class research infrastructures. This report outlines a strategy aimed to complement and reinforce current EU initiatives, thus contributing to make EU world leading in ICT-supported research.

In the knowledge infrastructure, it is knowledge rather than Information and Communication Technology (ICT) equipment that is the primary resource made available. Compared to the eScience infrastructure of today, the knowledge infrastructure for research and innovation is expected to provide resources more easily and transparently, to vastly larger number of users, to provide higher-level functionality, and to remove constraints such as distance, access, and usability.

eScience

Today's research is increasingly characterized by large-scale international collaborations and intensified use of various types of ICT resources. In this context, the word eScience is often used to represent research that is enabled through use of advanced ICT equipment – eScience infrastructures – such as high performance computers, high end computer networks, large-scale scientific databases, network-enabled scientific instruments, and grid infrastructure providing seamless access to these resources.

Being key to the research process, eScience is often referred to as the third pillar of the scientific method, that is, theory and experiments are now complemented by computer based simulations, computations, and analyses. Often, the simulations, computations, and computer based analysis must replace real experiments when such are too dangerous (analyzing spread of fire), impossible (global climate effects), too expensive (full-scale aircraft crash worthiness simulation), too demanding (comparing genomes), too difficult (testing side-wind effects on moving vehicles), or unethical (predict the social effects from political decisions).

No scientific discipline can be left out when describing the increasing use of eScience infrastructure. All fields are included, from physics and astronomy to the medical sciences, earth sciences, biology, chemistry, social sciences, and humanities. Areas such as mathematics, statistics, and computer science are in the core of eScience, focusing on the general methodology research that together with application-driven method development enables breakthroughs through eScience. For Industry, eScience may accelerate design-to-product processes, and thereby accelerate innovation.

The Nordic and Baltic dimensions

The motivation for the proposed collaboration between the Nordic (Denmark, Finland, Iceland, Norway, and Sweden) and Baltic Sea countries (Estonia, northern Germany, Latvia, Lithuania, Poland, and North West Russia) originates from the fact that several of the countries are small and may benefit from a strategy covering a larger geographical area with a larger number of actors. For example, by joining forces, the national efforts can be more cost-efficiently implemented, the enlarged infrastructure can provide added value, and the countries can by acting as a unified body better benefit from and be placed in a better position to influence the European and otherwise international arena. By making the countries more coordinated, their participation in, for example, federated EU-initiated infrastructures is facilitated, making the realization of these infrastructures more rapid and efficient. Moreover, the potential for successfully attacking grand challenge problems increases with additional groups of researchers working on coordinated research agendas throughout the whole research process.

Strategy proposal

During the past few years, the Nordic countries have successfully worked out a common Nordic strategy for their eScience development, followed by the establishment of a concrete action plan for its implementation. The current feasibility study identifies the potential for successfully broadening the Nordic strategy to a strategy including also the Baltic Sea countries. Based on an analysis of the current state-of-affairs in all eleven countries in focus, the present study proposes:

- to create a joint Nordic–Baltic Sea eScience strategy addressing the same three main areas as are currently in focus for implementation of the Nordic eScience strategy, namely (1) eScience education and training, (2) eScience research programs, and (3) cross-border resource sharing,

- to perform two initial actions to facilitate the implementation of the strategy, namely (1) to establish a Baltic Ring of optical networks and (2) to establish a coordinator for the implementation of the strategy, and
- to perform a set of actions that is feasible in the short term and effective as first steps to implement the strategy. Examples of such actions are given in this report, including short courses, a PhD program, common educational modules, and grid operation.

The remainder of this report presents the background, motivation, and further details of the proposed strategy and its feasibility. Section 2 elaborates on the eScience area as such, by illustrating typical application areas for eScience technology as well as research, education, and deployment challenges to be addressed. The current eScience infrastructures, organization, and strategies in the Nordic and Baltic Sea countries are reviewed in Sections 3 and 4, respectively. Section 5 analyzes opportunities for common actions and Section 6 is devoted to a strategy proposal, including a proposal for initial actions. Section 7 elaborates on the industrial impact of the outlined activities. An appendix to the document includes a short glossary, a presentation of work and reference group members, and a list of institutions consulted.

2. eScience

Besides being key to research in virtually all scientific disciplines, the development of eScience technology has opened a research and development arena of its own. In the following is given a brief introduction illustrating eScience technology use in different scientific disciplines and a characterization of research and development efforts required to enhance eScience technology.

Enhancing science through eScience

Until recently, the area of eScience has mainly been driven by the needs of scientific fields that have a long tradition in performing numerical simulations and computations, like computational physics and computational chemistry. During the past decade, however, there has been a revolution in number of areas using computational techniques and ICT resources, now covering virtually all scientific disciplines. The set of key ICT resources have been broadened from high-performance computers to also include databases, advanced visualization equipment, network-enabled scientific instruments, and distributed collaborative environments. By use of computer networks and grid technology, the combined use of different ICT resources has been facilitated, e.g., in a first step towards creating virtual laboratories and to increase utilization and usefulness of existing resources.

The list of compelling research tasks today benefitting from eScience techniques can be made arbitrarily long. In order to illustrate the power of eScience techniques and the breadth of application areas, some examples are given here.

In material sciences, simulations are performed, e.g., to understand the physical properties of materials based on knowledge about microscopic interactions. Computational biochemistry aims at computing properties of biomolecular systems, e.g., for applications in pharmacology and drug design. In systems biology, the cell's dynamical processes are analyzed, aiming at further understanding of the cell as a dynamical system. The area of evolutionary genetics has been revolutionized by high-throughput genotyping technologies that allows for genome analysis on a massive scale. DNA sequencing technologies represent a leap forward for studying the underlying pathology of human.

In Humanities, computational models of human language processing can be used to test the predictions of linguistic theories and enable practical applications of language technology such as machine translation or multilingual information retrieval. For linguistics and visual information research, studies of perception and interpretation of still and moving pictures can enable new breakthroughs. Demographical, economical, and health data used in concert can provide new understanding of, e.g., economic stress' impact on migration, fertility, and mortality. In climate research, the modeling of the global ecosystem is the key to understand its responses to climate changes.

The eScience technologies applied may differ between these areas, but in common for all of them are that eScience technologies are fundamental to the research process.

Research on eScience technologies

With the rapidly increased spread and utilization of eScience technology, there is a need for research and development on the methods, tools, and software that together with ICT hardware constitute the core enabling technologies for eScience. A brief review of eScience technology research areas is in the following presented in the terms of generic methodology research, application-specific methodology research, and research on the efficient use of eScience infrastructure.

Generic methodology research

The eScience methodology disciplines mainly comprise computer science, mathematics and statistics. Generic research in these areas focuses on fundamental theory, algorithms, and software technology of interest across application areas. The motivation for such research is, for example, to provide methods and tools to solve more complex problems, to compute more accurate solutions, or to facilitate the application developers' use of appropriate methods. Moreover, the development of computer technology leads to a range of challenges, such as to efficiently utilize the increasing number of processors in today's computer architectures or the ever more complex memory systems. In addition, advanced computations rely on efficient use of programming languages and the availability of efficient mathematical software libraries.

Application-specific methodology research

Research on the specific methodology needs of future eScience applications, found in literally all research areas, is key to enabling future discoveries. Examples of this type of research include development of new and improved methods for a wide range of computational problems, specific for particular applications or application domains. The research is often motivated by the need to solve larger or more complex problems in natural sciences and technology, requiring competence not only in method development but also in the specific applications. Moreover, the new eScience application areas in life sciences, social sciences, humanities and economics present a spectrum of database problems to be solved, including research leading to basic understanding on how to structure and annotate databases with content of largely differing character.

Research on the efficient use of eScience infrastructure

Research to enhance and extend on current eScience infrastructures includes improving the grid of today in nearly all aspects, e.g., with the aim to enhance performance and ease of use. Key is the ability to develop grid software that is re-usable for deployment in different grids and for multiple applications, and to align research agendas with international efforts, e.g., on standardization. Substantial research undertakings are also required to develop the grid into the computing infrastructure for the wide spectrum of application areas requiring more advanced functionality than today:s grids can deliver. The development of grid user-interfaces and application-oriented grid tools is also important, as well as research on the efficient use of computer networks for eScience applications.

Development and deployment of a sustainable eScience infrastructure

To fully benefit from the results of research performed on eScience technologies, the final step of software development and deployment must follow on the research. Typically, prototype software developed in research projects needs further development to become of production quality and the efforts needed to maintain software over its lifetime are substantial. These types of activities are typically not supported by traditional research programs and often tasks like software maintenance are not in the scope of the researchers' interest. Hence, in order to maximize the outcome in eScience user communities from research on methods and software tools, funding for software sustainability is required. Organizations like high performance computing centers may also have a vital role in performing these tasks.

eScience infrastructures

The eScience Infrastructures comprise ICT based technology, virtual organizations, and associated services that support distributed global research. The technologies include computer facilities and peripherals, high-performance and high-capacity networks, databases, grids, and collaborative environments.

In order to address the most challenging problems, eScience infrastructure is typically built from high-end ICT components. For computer networks, this means fiber networks for at least major network segments, and state-of-the-art capacity is currently considered to be at least of the Gigabit (10^9) per second level. High-performance computers are available with a range of different technologies and architectures, although most high-performance computers consist of hundreds or thousands of computers connected with high speed networks. A measure of performance is the position in the Top500 list of the world's most powerful computers, published twice a year. As of June 2009, it required a capacity of performing at least 17 trillion ($17 \cdot 10^{12}$) numerical operations per second to enter this list.

In order to facilitate the use of distributed eScience resources, they are often made available in so called grids. The grids are aimed to provide easy and uniform access to heterogeneous resources by providing tools for automatic resource selection, remote job management, easy access to distributed data, etc. The enabler of grids is the software, called middleware, that overcomes the heterogeneity problems and provides the tools just mentioned. Given that the middleware has to function smoothly over large number of heterogeneous resources that are owned and administered by different organizations, topics such as standardization and collaboration is key to grid development.

Authentication (to identify a user) and authorization (to grant the user access) are two important tasks when providing access to grid resources. In order to allow the user to go through the identification process only once when using many resources at different locations, a common security infrastructure based on a type of electronic IDs called certificates must exist. The certificates are provided by a certificate authority.

Large international collaborations are fundamental to the establishment of eScience infrastructures. This is highlighted by the EU, for example, by the establishment of the European Strategic Forum on Research Infrastructures (ESFRI), which has developed a Roadmap for future research infrastructures in Europe. Among ESFRI-projects in eScience is the Partnership for Advanced Computing in Europe (PRACE) which aims to build a persistent pan-European service for high-performance computing and provide the European research community with access to world-class computing power. The preparatory phase of PRACE started in January 2008 and lasts until December 2009.

Among already well-established EU collaborations of major interest to the Nordic and Baltic Sea countries is, for example, the Enabling Grids for E-sciencE (EGEE) project which brings together scientists and engineers from more than 240 institutions in 45 countries world-wide to provide a seamless grid infrastructure for eScience. The third phase of EGEE will end in April 2010, to be followed by a transition to the European Grid Initiative (EGI). In EGI the participating countries are represented by the National Grid Initiative (NGI). An NGI is an invention from the European Grid Initiative Design Study, where it is assumed that each country has an initiative aimed to provide a national grid infrastructure suitable to interface a European infrastructure.

The GÉANT project implements a pan-European multi-gigabit data communications network, dedicated to research and education The GÉANT network provides a vital network infrastructure as well as the necessary resources for information technology and telecommunications development.

The Trans-European Research and Education Networking Association (TERENA) is a forum to collaborate, innovate and share knowledge in order to foster the development of computer network technology, infrastructure and services to be used by the research and education community.

Another example is the Distributed European Infrastructure for Supercomputing Applications (DEISA), which interconnects some of the largest high performance computing centers in Europe, to allow them to operate as a coordinated resource for computer simulations.

In order to facilitate the authentication and authorization of ICT users throughout the academic society, eduroam (EDUcation ROAMing) has been developed as a roaming infrastructure to be used by the international research and education community. Being part of eduroam allows the users to access wireless networks at visited institutions (also connected to eduroam) using the same username and password the users would use at their home institution.

3. eScience Infrastructure in the Nordic Countries

The Nordic countries' development of eScience infrastructure has been given widespread attention during the past decade, including development of national programs, organizations for maintaining national infrastructure, and establishment of Nordic collaborations, joint strategies, and action plans. In the following sections, the current state is briefly reviewed. The presentation is organized by the type of infrastructure, covering all the Nordic countries for each type of infrastructure. In addition to presenting the current infrastructures, some educational efforts are reviewed and some joint Nordic strategy efforts of particular interest to this report are introduced.

Nordic network infrastructure

The Nordic countries have a longstanding tradition in advanced academic networks. All countries created national research and education networks in the mid 1980's, currently operated as Forskningsnet (Denmark), FUNET (Finland), RHnet (Iceland), SUNET (Sweden), and Uninett (Norway). The organization and funding model varies greatly among the countries, but all have state-of-the-art high capacity networks connecting institutions for research and higher education. All five national networks have deployed optical fiber networks and optical transmission technology. This allows use of the latest technology and to always offer the highest capacity available, and to create additional channels as needs arise. In Denmark, Norway, Finland, and Sweden, nearly all institutions have fiber connections; in Iceland some geographical constraints exist outside the Reykjavik area.

The networks offer high-capacity Internet access as well as the ability to create special-purpose connections for large eScience applications, for example for connecting large instruments such as astronomical telescopes or nuclear accelerators, large database and storage systems, large-scale computing resources, and their users. As research is becoming more international and more collaborative, such special-purpose networks are crucial, allowing the creation of infrastructure that matches the virtual organizations in which researchers and students collaborate. International connections are provided by NORDUnet, a regional network jointly owned by the Nordic countries. NORDUnet connects to the European GÉANT research and education network, to neighboring countries and major partners, and to international traffic exchange points. NORDUnet represents the Nordic countries in international network, including GÉANT.

By working together in this way, the Nordic countries have achieved significant efficiency. Additionally, by working together through NORDUnet and in GÉANT, the Nordic countries achieve significant economic leverage for commercial Internet connectivity and critical mass for creating international connections.

Nordic computing, storage, and grid infrastructure

All the Nordic countries have some national organization for high performance computing. These organizations provide or coordinate high performance computing centers. The centers are of varying sizes and characteristics, differing not only in amount of hardware resources and availability of, for example, mass storage systems, but also in terms of types of support provided, size of support and application staff, and specialist competence.

Rather unusual in Europe is the Nordic high performance computing centers' tight integration between traditional high performance computing technology and grid systems. For example, resources provided in grids are often not fully dedicated to the grids but rather fractions of high performance computers also used for other purposes. This fact has also made the Nordic computing centers develop competences and technical solutions required for middleware integration and interoperability.

Computing and storage

Finland, which has a centralized organization for national computing capacity, has a large center named CSC – IT Center for Science. Denmark, Norway, and Sweden have different types of distributed national organizations. In Denmark, the Danish Center for Scientific Computing (DCSC) coordinates five centers located at different Universities. Norway has a national meta-center named NOTUR, hosted by UNINETT Sigma. NOTUR provides resources through five centers at Universities and the Institute of Meteorology. The Swedish meta-center named SNIC provides resources through six centers at Swedish Universities. In Iceland, the computing capacity is provided by a center at University of Iceland in Reykjavik, which also leads a new Icelandic high performance computing initiative.

Regarding current computing capacity, there are, according to the Top500 list of the world's most powerful computing systems, several large systems in Finland, Norway, and Sweden. Denmark and Iceland do not have any systems on the current Top500 list. Besides the nationally coordinated resources, local resources exist at several universities. These installations are typically managed on an institute basis.

Finland, Sweden, and Norway have national initiatives on scientific storage. The aim for these are to make it easier for researchers to store, share and index scientific data as well as to serve large scale research projects with storage space.

The computationally intensive research areas in the Nordic countries include computational chemistry, bioinformatics, materials science, climate research, astrophysics, mechanics (especially computational fluid dynamics) and high energy physics.

Grid computing

The National Grid Initiatives in the Nordic countries are run by national organizations coordinating high performance computing. The grid infrastructures in the Nordics have been operational since the beginning of this decade. NorduGrid was an initiative funded by the Nordunet2 program that resulted in a prototype grid system that was later deployed by the Nordic DataGrid Facility (NDGF) project at most of the Nordic computing centers. The European EGEE project has seen participation from all the Nordic countries, and SNIC is responsible for part of a regional operation center together with Stichting Academisch Rekencentrum Amsterdam (SARA) in the Netherlands. Further, a distributed Nordic infrastructure for storing data produced at CERN is operated by NDGF. Since fall 2008 the operation of EGEE and CERN-related grid resources in the Nordics has been done in collaboration between the Nordic EGEE partners and NDGF resulting in a European reference example of regional collaboration and distributed management.

Nordic database infrastructure

Databases, made available as general research infrastructure, have the potential to revolutionize the way research is performed in humanities, social sciences, health sciences, and earth sciences. In a way similar to how molecular science has been transformed into a computational science, eScience technologies, and in particular databases, have the potential to transform these research areas.

In the Nordic countries the authorities have built up unique comprehensive databases for administrative and other purposes that would be unparalleled on the international arena if effectively made available for research. In addition to providing technical solutions, sustainable organizations for providing scientific databases are important. Among the national initiatives, the establishment of the Database InfraStructure Committee (DISC) as a Swedish infrastructure stands out as a single effort to organize database infrastructure across scientific disciplines and organizations. Norway's national data archives in the social sciences, manifest in the Norwegian Social Science Data Services, also serves as excellent proof of concept for a national database infrastructure initiative. CSC in Finland is a major provider of the scientific databases and digital collections for a broad spectrum of scientific disciplines as part of their national services. Also worth mentioning is that, e.g., Statistics Denmark and Statistics Sweden provide researchers with external access to de-identified micro-data over the Internet. In focus for national and joint Nordic initiatives, key to effectively contribute to the European ecosystem of digital repositories, are technical solutions for federated databases, policy frameworks for harmonization of data and interfaces, as well as administrative and legal issues.

Nordic authentication, authorization, accounting, and identity management

Identity management – the provision of digital, online identities (electronic identity cards) and the mapping of such identities to people, roles, and organizations – is crucial for a successful knowledge infrastructure. An identity management infrastructure allows users to be authenticated and authorized for resource and information access, such as databases, libraries, and computing resources. An accounting infrastructure makes it possible to keep track of who is doing what at any time.

The availability of an infrastructure for authentication, authorization, accounting, and identity management is necessary for the operation of resources for eScience. It is needed for the users to get resource access in a convenient way and to keep track of their resource consumption. Due to its central role, this is also a strategic important competence area, as availability of this technology and knowledge gives high-impact in international collaborations.

Each of the Nordic countries has deployed a national research and education infrastructure (federation) for identity management that allows institutions to manage digital identities and allows the identities to be used between institutions. Ideally, this makes the user able to use the same username and password to access the resources he or she is entitled to use, independently of their location and ownership. In a project named Kalmar2, national infrastructures have been coordinated to allow digital identities to be used across the Nordic countries, facilitating collaboration, access, exchange, and resource sharing. The Nordic countries are active in development of identity management technology and federations, working with international partners and taking a leading role in the European eduGAIN effort, a part of the GÉANT collaboration. Further, the Norwegian UNINETT initiative on coupling federated identity management and compute and storage services has been further supported by NDGF and has now seen active participation from several other European countries resulting in a TERENA service entering operation this fall.

Nordic eScience education

Extensive programs for training and education in the use and development of eScience techniques is key to the long-term success of any effort to extend the use of eScience infrastructure to all scientific areas. Among Nordic eScience education efforts, the Swedish National Graduate School for Scientific Computing (NGSSC) has been a forerunner. After more than ten years as a national graduate school, NGSSC has recently opened up for Nordic participation and advertised its courses on a Nordic level. NGSSC has mainly been targeted towards raising the eScience competence of students active in application areas, although students from technology core areas such as computer science and mathematical sciences have been admitted to some extent.

Notably, in this type of education, the student groups have rather large variations in previous knowledge and training in computational science technology. Coordinated Nordic efforts can more easily attract sufficiently large groups of students to offer tailored education programs depending on their background. For example, NGSSC currently admits 20 students per year which is not sufficient for providing separate courses for different subgroups of students.

A joint Nordic eScience strategy

Research in the areas presented in Section 2 is performed in all Nordic countries, and in several cases in the absolute international forefront. It is beyond the scope of this document to review the research being performed in these areas, but some attention will be given to national and Nordic strategies to improve the conditions for this research. There are several national initiatives focusing on infrastructure, research enhancing eScience technologies, research using eScience technologies, and education on eScience techniques, e.g., with the Norwegian eVITA program (where this type of research is an integrated part) being the first major eScience effort in the Nordic countries and the current Swedish governments funding of eScience as a strategic area being the most recent. However, most of the funding for research in enhancing eScience technologies has been part of regular funding schemes, e.g., from national research councils, without national or Nordic coordination for the area as a whole.

In 2007, the Nordic Council of Ministers developed a joint eScience strategy for the Nordic countries[3]. It was found that by increasing the number and coordination of Nordic researchers there is potential both to increase the impact of Nordic eScience research and to strengthen the ties between the methodology research and the application areas using its results. In 2008, the strategy was followed-up by a Nordic eScience action plan[4], aimed to lead the implementation of the strategy. The action plan, developed by the Nordforsk funded project eNORIA, focuses on three main areas that are expected to be fundamental to the development of eScience on long term. These areas are (1) Creating a Nordic Higher Education Arena for eScience; (2) National and Nordic eScience Programs in Pursuit of Grand Challenges; and (3) Knowledge Creation through Cross-Border Sharing of eScience Infrastructure. The plan also outlines initial actions to be performed on the Nordic level in these areas, actions that are specified with both timeframes and responsible organizations.

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[3] Nordic eScience – Research, Education and Sustainable Infrastructure Services. Nordic Council of Ministers, 2007.

[4] Nordic eScience Action Plan. 10 Concrete actions to implement the Nordic eScience Strategy. Nordic Council of Ministers, 2008.

4. eInfrastructure in the Countries around the Baltic Sea

Key to this feasibility study is an analysis of the current state of affairs regarding eScience infrastructure in the six non-Nordic countries around the Baltic Sea. In a report like this, it is however not possible to include exhaustive presentations for all countries. In order to provide an overview, short summaries of the findings are included here. The summaries focus on current eScience infrastructures, national funding and policy bodies, and major national eScience strategies. The information has been gathered from both eScience specialists and decision makers, mainly through meetings with representatives for all countries.

eInfrastructure in Estonia

The primary funding body for Estonian eScience is the Ministry of Education and Research, which manages also the majority of the EU structural funds that provide significant infrastructure funding. The Ministry of Economic Affairs and Communications also provides funding for e-Infrastructure, partly co-funded by the EU structural funds. A strategy for a knowledge-based society ("Estonian Research and Development and Innovation Strategy 2007–2013.") covers some core eScience areas. A more specific research ifrastructure strategy is likely to be developed by the Ministry of Education and Research in the near future. Major eScience user groups are from high energy physics, bioinformatics, material science, quantum chemistry, linguistics and astrophysics.

The Estonian national research and education network, EENet, has provided network services to the Estonian academic community since 1993, currently on funding directly from state budget. EENet represents Estonia in European efforts such as TERENA, GÉANT, and EGI. EENet uses GÉANT for all international connections, including the commercial Internet. EENet provides, and will according to current upgrade plans, continue to provide good international network capacity. However budgetary allocations for new tasks remain a problem. Many institutions are connected to EENet directly or through campus networks, or through municipal networks, developed in collaboration between EENet and municipal governments; such networks give last mile access for about 500 institutions. In addition to connections, EENet provides a large number of different services for example for e-learning, collaboration environments, etc., altogether to approximately 1,000 organisations.

EENet uses a mix of optical fiber and leased lines. There is optical fiber network connection between major cities, including Tartu and Tallinn. EENet is considering optical fiber connection to Valga on the Latvian border, which would make a cross-border fiber possible, given the necessary funding becomes available. EENet will create such a connection if there is an optical fiber network in Latvia to connect to.

Computing and storage service centers in Estonia are located at university institutes and research organizations and operated by them. The main hardware resources are located at two University Institutes and at the National Institute of Chemical and Biological Physics. There is no formal national coordinating body for the high performance computing resources but some national funding is available. Funding from FP7 infrastructure projects like BalticGrid also contribute to funding the human resources for the grid infrastructure. The National Grid Initiative is run by EENet.

Among Estonian databases of major interest, there are many historical databases and some genome databases, complementing the many small databases from various areas.

Estonia was one of the early adaptors of electronic ID cards for all citizens. As this system is based on technology similar to that normally used for authentication in eScience infrastructures this general system is used also for many eScience services such as access to grids or other computing resources. Since this system is widely deployed nationally, there have been no efforts to build an academic federated identity infrastructure.

The grid certificate authority for Estonia, as well as for many grid users in Latvia and Lithuania are handled by the regional certificate authority, run by EENet and is in the frame of the BalticGrid project. Eduroam is deployed in Estonia on EENet but it is not heavily used.

Estonian participation in ESFRI projects are managed on an institute and researcher level and currently CLARIN is the only ESFRI project with Estonian membership. Industry's involvement in eScience activities is limited, although their interest in recruiting eScience-trained personnel is substantial. An organization to promote innovation has recently been established.

eInfrastructure in Germany

In Germany, eScience infrastructure, research, and other activities are primarily funded by the Ministry of Education and Research. Current funding is following a recent High-Tech-Strategy for Germany, including the research program ICT 2020 – Research for Innovations. The strategy also includes cross-cutting activities with incentives for private-public partnerships. The strategy is supported by all ministries.

Academic network infrastructure is provided by Deutsches Forschungsnetz (DFN). DFN has provided network services for more than 20 years and represents Germany in international collaborations such as

GÉANT and TERENA. DFN has extensive coverage of Germany with optical fiber and optical networking equipment and an advanced IP network, and also has cross-border fiber arrangement with Netherlands, Poland, and France. DFN is active in many European collaborations and EU projects, and traditionally has a strong position in European networking, with a strong commitment to European collaboration.

For high performance computing, Germany has successfully made efforts to create a national infrastructure where computing centers collaborate rather than compete, including developing a joint procurement plan and harmonized reporting. Currently, Germany has 30 Top500 machines including the 3rd largest in the world, operated by the Gauss Centre for Supercomputing at its site in Jülich (Research Centre Jülich). The Gauss Centre is run jointly by three supercomputer centers in Stuttgart, Garching and Jülich and is also aiming to provide one of the major resources in the PRACE infrastructure, which is currently in its preparation phase. There are also several other large computing centers in Germany, including centers in northern Germany, such as Deutsches Klimarechenzentrum (DKRZ) and Deutsches Elektronen-Synchrotron (DESY) in Hamburg and Zuse Institute Berlin (ZIB). Storage is administered and made available by the computer centers. A new initiative for coordinated national storage is driven by the libraries.

In northern Germany, grid activities are concentrated at DESY and the high performance computing activities around DKRZ and ZIB. The German e-Infrastructure activities are highly coordinated through the D-Grid and the Gauss Alliance, the latter being the National Grid Infrastructure of Germany. DESY is a core partner in the development of a storage middleware named dCache, being the storage platform used by many grid projects worldwide.

D-Grid, initiated in 2004, differs from most national grid activities in being an initiative focused on grid software and application projects, rather than on providing the grid resources. Substantial funding is provided, for example, for application projects and middleware development. D-Grid also distinguishes itself from most national grid initiatives by having larger industrial user communities.

GridKa in Karlsruhe operates the German grid certificate authority. DFN has been active in the development of eduroam, which is widely deployed in German organizations. DFN also leads the national federated identify management initiative as partner in the European eduGAIN project.

eScience user groups from several areas are represented in northern Germany, with the largest related to high energy physics and climate research. The main ESFRI projects in the region are centered around the XFEL X-ray laser installation at DESY, but there is also participation in several other ESFRI projects. The German DEISA and PRACE partners are mainly from the southern parts of Germany, but the EGEE and EGI partners also include DESY.

eInfrastructure in Latvia

The Latvian eScience activities are mainly organized under the four Ministries of Education and Science, Economics, Transport, and Regional Development and Local Government. The Latvian Council of Science is a collegiate institution of the scientists with the status of a legal body. The Council's tasks include advancement, evaluation, financing and coordination of research in Latvia. It prepares, jointly with the Ministry of Education and Research of Latvia, the draft of the state’s yearly research budget. In the near future, substantial eScience activities will be coordinated through the new National Academic Network project, to commence in 2010. The network’s coordinating responsibilities include all of eScience although budget constraints will significantly limit initial efforts. Presently, a major part of eScience methodology research is performed under the national research program Scientific Base of Information Technology.

The Latvian government has approved an ambitious plan for upgrading academic ICT infrastructure. The plan will finance a range of infrastructure, not only national networking and high performance computing, but also campus networks and campus data centers. In addition, the plan includes cross border networks to both Lithuania and Estonia.

The scientific disciplines using eScience technology include both traditional and emerging eScience areas such as material sciences, bioinformatics, computational linguistics, robotics, logistics, and medicine. Large scale international collaborations such as the ESFRI project CLARIN (language technology) and the EU funded BalticGrid (grid infrastructure) are important for the current eScience activities. Participation in ESFRI projects are coordinated by the Council of Science.

The Institute of Mathematics and Computer Science at the University of Latvia (IMCS), has provided network services to the Latvian academic community since 1992. IMCS represents Latvia in GÉANT and TERENA, and acts as national research and education network through the SigmaNet. SigmaNet provides a connection to GÉANT and offers hosting, grid and storage services. Institutions connected to SigmaNet fund their own links, so type and capacity of the connections vary significantly.

Compute and storage services in Latvia are provided by local resource centers at two universities – Riga Technical University and University of Latvia. These centers host limited hardware resources and operate with no national or central coordination. Support and operations are handled by local university departments and research organizations. Large computational needs are met by use of computational resources abroad. A national storage service exists, mainly used for medical images and to enable researchers’ easy access and exploration of scientific data. Recent efforts on providing access to major international electronic libraries have resulted in extensive use.

The IMCS runs the National Grid Initiative, thereby representing Latvia in EGI. Grid resources are available through two different middleware. Larger Latvian institutions deploy eduroam for authentication and authorization at participating institutions. IMCS operates a certificate authority for LatGrid while certificates for BalticGrid are issued by EENet in Estonia.

eInfrastructure in Lithuania

The Lithuanian eScience activities are primarily funded as part of the basic funding schemes from The Ministry of Education and Science as direct institutional funding and by the Lithuanian Science council as project funding within a number of research programs. Some national eScience infrastructure, e.g., for networking and grid computing, as well as projects for developing data repositories and coordinate libraries are also directly funded by the Ministry. The area of eScience is currently not addressed as an area of its own, but rather as an integral part of technology and application research, with eScience components included in several research and education strategies. A roadmap for Lithuanian eScience infrastructure including Lithuanian participation in ESFRI projects is under development. Current engagements in eScience-related ESFRI projects include participation in the CLARIN project.

Important eScience usage areas include biology, linguistics, medicine, astrophysics, engineering and nanotechnology. The forthcoming establishment of five centers for education, research, and business, one in each of physical, biomedical, technological, agricultural, and marine sciences will also contribute with eScience activities both for performing the research and for making the center's equipment nationally available. These centers are also expected to effectively contribute to innovation processes with existing or new industry.

Funded as a project by the Ministry of Education and Science, LITNET is since 1991 the national education and research network in Lithuania. Rather than being a legal body, LITNET is a fully federated network with all resources and functions provided by collaborating organizations. The various partners represent LITNET in GÉANT and TERENA. It is planned to gradually expand the current optical fiber network providing the core network between the five largest cities. Funding is available for cross-border fiber to Poland, and a connection is planned when the Polish network reaches the border. There is no cross-border link to Latvia, although such a link may be provided.

In Lithuania the compute and storage service centers have relatively small hardware resources and have support and operation handled locally by University departments and research organizations. Except for some of the grid resources, mentioned below, computing infrastructure is mainly provided through the basic institutional funding.

An effort is currently being planned to create data repositories, mainly for social sciences, humanities, and medicine. A project for coordinating Lithuanian University libraries and facilitating access to electronic publications is funded by the Ministry of Education.

The Lithuanian grid headed by Vilnius University is named LitGrid and includes several partners from relevant Lithuanian institutes. LitGrid is the National Grid Initiative.

Lithuania does not have an academic identity federation initiative, but runs a national certificate authority and makes use of the BalticGrid certificate authority.

eInfrastructure in Poland

The principal funding and policy advising body for eScience in Poland is the Council for Science under the decision-making Minister of Science and Higher Education. For organizing applied eScience research, the National Centre for Research and Development is important, for example, for managing and implementing national strategic scientific research and development programs and to ensure the participation in key EU research programs. Major user groups are found in most areas relevant for eScience, including chemistry, engineering, physics, biology, computer science, mechanics, astrophysics, mathematics, meteorology, and high energy physics.

The Polish national research and education network PIONIER is operated by the Poznan Supercomputing and Networking Center. Since the start in 1992, 21 metropolitan area optical fiber networks have been built for research and education purposes in major Polish cities. Each such network is run by a local organization, with local governance. PIONIER is a consortium formed by the metropolitan area networks, representing Poland in GÉANT, TERENA, and several EU projects. PIONIER has cross border fiber connections to neighboring countries, including Germany, Belarus, Ukraine, Czech Republic, and Slovakia, and fiber to the border of Lithuania is planned. The Polish PIONIER is among Europe’s fastest and largest networks.

In Poland, there are national high performance computing centers, providing computing and storage resources locally and nationally, including resources for grid use. Most of the centers were established in the early to mid 1990’s, now collaborating in various projects. The most powerful computing system, ranked 45 on the Top500 list of June 2008, is located in the Baltic Sea region in Gdansk.

Starting in 2008, Poland is applying for EU Structural Funds for eScience infrastructure and content development. The plan includes major investments for backbone networking, campus networks, computing resources, identity management, virtual laboratories, and video conferencing. Subsequent maintenance and operations will be covered by national funds through the specialized financial streams. An example of a major project funded from the structural funds, converged with the general National Programme for Research and Development, as well as the specialized Minister's Programme for eScience Development, is the project named PLATON (2009–2012) – for eScience services development. From the structural funds are also financed the "Commissioned faculties" aiming at modernizing, promoting and improving, for example, eScience-related higher education and building the innovative ICT centers, but also construction of a national interdisciplinary system of interactive scientific and technical information.

The Polish National Grid Initiative is run by PL-Grid, initiated in 2009 and followed by PROGRESS (2001–2003) and SGI Grid (2002–2005) projects. PL-Grid includes all five national computing centers' and is coordinated by the center named CYFRONET. Resources are made available through grid middleware for the 3 centers in Poznan, Krakow, and Warsaw. Further, the Warsaw center is also partner of DEISA.

The Wrocław metropolitan area network is developing and operating the Polish Certificate Authority which, for example, is used for authentication and authorization to the Grids. Eduroam is deployed nationally by the computing center in Poznan and is available at many institutions.

eInfrastructure in Russia

Funding for eScience comes through the Ministry of Education and Science, the Ministry of communication, and the Academy of Sciences. Federal research programs provide substantial funding for eScience under different scientific disciplines, including application areas such as nanotechnology and basic research in all relevant areas. In addition to tender-based research programs, substantial funding goes directly into research organizations for their own priorities, for example, to the Academy of Sciences. Current strategies include the establishment of a new program named Information Society to commence in 2011. The program is organized under a new presidential council and is supported by all ministries and the Academy of Sciences. The program will cover all of ICT with substantial contributions to eScience.

Application areas are broad and include most areas typically found in eScience contexts, including major user groups in high energy physics, nanotechnology, geophysics, astronomy, and medical sciences.

Russia has a number of academic networks. The major ones are RUNnet, RBnet, and the Russian Academy of Science network. RUNnet (Russian University Network) operation is based in North West Russia and serves institutions for higher education throughout Russia; RBnet serves a number of major research facilities, including high energy physics. RUNnet and RBnet are important partners for Baltic Sea eScience collaboration, and both have strong collaboration with NORDUnet.

RUNnet and RBnet have high capacity networks in North West Russia, with most institutions connected with state-of-the-art capacity. East of Moscow challenges of distance and environment make networking very costly. International connectivity is provided by connections from St. Petersburg to Amsterdam and Stockholm and by a connection to GÉANT from Moscow. An international connection on dedicated fiber is being established between St. Petersburg and Helsinki, in collaboration with CSC and NORDUnet. It is planned to extend this fiber connection between St. Petersburg and Moscow in 2010. A connection from St. Petersburg to the Estonian border also seems possible.

Recently, an association named eArena has been formed with the aim to coordinate Russian academic networks and to provide a common organizational interface to the world. Potentially, eArena may also coordinate Russian grid activities.

Most academic computing centers are located in the Moscow region; the four Top500 machines in Russia are located there. A few resources are located in the St. Petersburg region. There is no central national coordination, and with limited resources outside Moscow, there is no specific national infrastructure for high performance computing. Main data storage facilities are maintained by the high performance computer centers.

There are substantial database efforts, e.g., in the areas of environmental sciences, geophysical sciences including satellite data, space physics, weather predictions, bioinformatics, and medical information systems. Participation in international efforts is made difficult by the fact that most databases contain data in the Russian language.

The National Grid Initiative is run by the Russian Data Intensive Grid in Moscow, which collaborates with the EGEE project. A number of computing sites, mostly in Moscow and North West Russia, are connected to the NGI. RDIG operates the national grid certificate authority.

Despite a history of participating with a major role in EU efforts in the area, it currently seems that Russia will not be included in the deciding bodies of the EU projects GÉANT3, PRACE, and EGI.

5. Opportunities

The present situation and current developments in the Nordic and Baltic Sea countries open up a spectrum of opportunities for enhancing current eScience infrastructures and increase their cost-efficiency. The opportunities also include providing the conditions for extended collaborations by aggregating larger research communities and by enhancing research through cross-fertilization between research areas. Below, some of these opportunities are highlighted.

By joining forces, initiating collaborations, and coordinating research agendas, there is potential for the countries in this region to substantially support and facilitate the implementation of strategies developed on the European level. In particular, there is a multitude of opportunities for joint initiatives in line with the actions called for in *ICT Infrastructures for e-Science*[5]. By actions to coordinate national organizations, reinforce policy coordination, and facilitate co-operation, the countries will in several aspects be better prepared for EU-wide collaborations, in particular for federated governance models.

All the countries have well-established research and education networks with state-of-the-art capacity, at least on major sections. Connectivity to the outside world ranges from good to excellent, but it is identified that there is potential to considerably increase the international connectivity and the connection between these countries by relatively small means since there are only a small number of bi-lateral connections missing to establish a complete ring of fiber network around the Baltic Sea.

The capacity and organization of computing resources varies greatly among the countries. Naturally, small countries with small budgets have difficulties in providing funding and finding a sufficient user base for the largest computers or computers with characteristics of interest to particular types of applications only. By considering a larger geographical area, there is potential to overcome this if arranging for cross-border resource sharing.

The grid infrastructures show many similarities in terms of technologies and challenges to overcome. There are a few different middleware that are used in all or nearly all of the countries, and most of the countries run several of these middleware in parallel on different grids. In order to effectively make the grids work together, a range of policy and middleware interoperability problems are already being addressed on national and Nordic level. Clearly, there is potential to more effectively do this jointly instead of by each country individually.

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[5] ICT Infrastructures for e-Science, Communication from the commission, COM(2009), 108, European Commission, Information Society and Media, Brussels, March 5, 2009.

Joint efforts in the exploration of new technology also give an opportunity for improved cost efficiency. For example, several of the countries are currently interested in investigating if and how cloud computing technology can be used, to improve cost efficiency for data centers, to deliver computing capacity that rapidly can adjust to varying computational needs, to make eScience resources more easily available, or how commercial data centers can be used to cost-efficiently meet peaks in resource demands.

The countries' current efforts in eScience education are of differing character, both regarding if eScience is a teaching area by itself or if eScience education is mainly part of other subjects and if the efforts are made on local or national level. Independently of the character of these efforts, it appears that all countries could benefit from joint efforts, for example, to easier find sufficiently large groups of students for tailoring courses to specific eScience topics, to broaden the group of experts potentially teaching the courses, and to re-use course development efforts.

A positive side-effect of joint education programs is the creation of the formal and informal human networks that are the basis for long-term and future joint adventures. These human networks can also be promoted, for example, by conferences and workshops. A starting point could be the establishment of physical meeting places for such events and other collaborative efforts.

When initiating new collaborations, there is an opportunity to take a more holistic approach to eScience infrastructures. Today, most infrastructures are organized and funded in isolation. In order to make a grater leap forward, infrastructure initiatives should be further coordinated not only between countries but also between different types of infrastructures, aiming at a more unified and easily accessible knowledge infrastructure.

Finally, it should be remarked that the collaborative strategy proposed in this document may facilitate the implementation of the European Union's Baltic Sea Region Programme.

6. Strategy Proposal

This section outlines a long-term strategy for extending current eScience infrastructures and activities through joint efforts between the Nordic countries and the countries around the Baltic Sea. For each topical area, feasible actions for early development are proposed. In addition, two initial actions are proposed, aiming to facilitate the implementation of the strategy.

The long-term objective is to geographically broaden the already initiated Nordic collaboration in the three topical areas presented below. Before further discussing the three areas, some attention is given to two initial actions deemed vital to provide the conditions for effectively implementing the strategy. The two initial actions are to:

- *Establish a fiber ring network through the countries around the Baltic Sea.* The establishment of a fiber ring network through the countries around the Baltic Sea is an important action both to provide the connectivity required for forthcoming joint actions and to foster further collaborations. Previous experiences show that the joint network infrastructure is instrumental in creating joint activities using the network. Regarding the feasibility of this action a more detailed analysis needs to be done to determine the final costs. However, given that most of the physical infrastructure already is in place, the total cost is expected to be on an acceptable level and clearly motivated by the network's value. The network may not only interconnect the countries around the Baltic Sea, but should also be part of GÉANT, thus at the same time saving common funds and giving the countries more cost efficient access to the GÉANT services.
- *Establish a joint coordinator.* Joint efforts among eleven countries calls for a coordinating body. For previous Nordic efforts, organizations like NordForsk, NoriaNet, eNORIA, and NDGF has had co-ordinating roles of different character. Naturally, different specific actions may be per-formed by different groups of organizations and action-specific co-ordination can be managed within such groups. There is, however, a need also for more strategy-embracing co-ordination.
    - The proposal is to create a new light-weight coordinating body. The body should be responsible for the sustainable implementation of the strategy and to continuously refine and extend the action plan in line with the proposed strategy. The operative work for implementing specific actions should be assigned to other, normally already existing, organizations suitable for the tasks. Moreover, this body could naturally be the entry point for EU initiatives calling for a federated organization.

Given the availability of a coordinating body and the fiber network around the Baltic Sea, a range of important actions are of great interest in each of the following strategic areas. Considering that human and economical resources are limited, it is, however, initially only feasible to address a small number of actions. For the startup phase, the following actions are deemed feasible and cost-efficient.

Area A. Creating a higher education arena for eScience. The aim is to extend on current educational efforts among PhD students and established researchers. The rationale is that joint efforts can help overcome the problem that each country and each academic institution lack the critical mass of students required to regularly offer eScience courses tailored to their background and needs. Similarly, these institutions have difficulties to maintain the broad competence required to cover the whole field of eScience technologies. By unified efforts this critical mass and competence breadth can be assured to the benefit of all partners involved. Education activities will also foster human networks between participants, enabling future collaboration.

Feasible initial actions include joint short courses in the use of eScience techniques, mainly aimed for active researchers in application areas, interested in improving their skills in using eScience resources. A geographically broad PhD program is also feasible and highly relevant. By, e.g., providing a set of intense courses for PhD students formally admitted to PhD studies at their home institutions, such a program can effectively be implemented with a minimum of administration. By taking advantage of lecturers throughout all participating countries, the efforts per participating country within such a program can in some respects decrease as the number of countries increases. Hand in hand with a PhD program goes to make available a set of educational modules to be used also by local lecturers teaching local students outside this PhD program.

Area B. Research to address grand challenge problems. The aim is to strengthen the research at all stages of the research cycle required to effectively address computational grand challenge problems. Ideally, this research cycle should involve all of basic methodology research, application specific method development, research on the efficient use of eInfrastructure, and the integrated use of the developed techniques in real grand challenge problems. The potential for finding the most effective collaborations increases greatly with an increasing number of researchers with competence required in a broader set of topics.

Given the present tight economical situation in several of the countries of interest, it is not feasible to initiate a new Nordic-Baltic Sea research program at this time, although such a program is likely to be very effective in providing both research results and increased collaboration. However, in order to fertilize joint Nordic-Baltic Sea research, the national research funding bodies are recommended to encourage and support eScience research projects based on such collaborations. In the slightly longer term, the already planned launch of a Nordic eScience Research Program may in form a building block for a joint Nordic-Baltic Sea research initiative. These efforts, in turn, may facilitate the realization European virtual research communities and their sharing of best practices, software, and data.

Area C. Knowledge creation through cross-border sharing of eScience infrastructures. For small countries, the ability to host computational resources capable of meeting peak load demands is sometimes substantially restricted even if average demands are reasonably well met. Resource sharing across national borders increases the potential for managing high peak loads. In addition, cross-border resource sharing may also be a means to make available hardware and software with increased diversity. For example, technology of particular interest to a small user community in each country can appropriately be made available only at a single or a small number of locations.

A joint effort to improve the efficiency of grid operation and to facilitate the countries' participation in the emerging federated European grid landscape is a natural and feasible initial action related to cross-border resource sharing. Given a substantial commonality in grid middleware used and already established collaborations both within the Nordic countries and between these and some of the countries around the Baltic Sea, this effort is anticipated to be feasible although rather substantial. In particular, the effort could focus on providing sustainable grid infrastructure with a mix of different middleware – a situation that for several reasons is, and is likely to continue to be, reality in most of these countries. The joint efforts may eventually be taken all the way to true joint operation, but the proposal is to initiate this work by a collaborative effort around competence, policy, and software development with actual operation performed by local (national) personnel. A second step may be to take the collaboration further, for example, as a part of a federated European grid infrastructure.

Development of policies and tools required to facilitate cross-border resource sharing is also a feasible initial action. An effort on providing the conditions for resource sharing extended by a small number of pilot projects using cross-border resources will lay the foundation for the technology and policy development needed to meet future demands.

7. Potential Impact

For the research community, the further development of today's eScience infrastructures into the knowledge infrastructure for the Fifth Freedom will have unprecedented impact. Information will be more easily available, the tools for processing information will be more powerful, and the support for combining multiple information and processing resources will be highly advanced and substantially more flexible than today. The development will further facilitate and promote the globalization of research, lowering organizational and geographical boundaries to the benefit of rapid scientific advances. Coordinated research programs and joint education initiatives will further support this development and facilitate increased mobility of researchers. By now taking a major step towards realizing the knowledge infrastructure in the Nordic and Baltic Sea countries, this region can act as a forerunner for EU efforts and facilitate the implementation of strategies proposed by the European Commission.

Regarding impact outside the academic community, ICT in general and network-based technology in particular have recently transformed large parts of the industrial sector and taken a central role in people's everyday life. It can easily be foreseen that recent increase in ICT use, e.g., of on-line market places, to process large amount of data for business purposes, or to form large-scale collaborative networks with access to people and ICT equipment, is still only at the early stages. For industry to stay at the forefront, it is vital not only to follow but also to take the lead in this development.

The high-end eScience technology used for research is likely to transform industry and society in the future. High-end technology used for research today is expected to influence commodity technology for mass markets in only a few years. Theories, methods, and software for large-scale distributed collaborations provide technological advances likely to impact global-scale environments in widely different areas. Besides the Internet itself, the World Wide Web is probably the most extreme example from the past, of an eScience technology developed for research purposes (document sharing among high energy physicists) that has had enormous impact outside the research community. What the future will bring may be hard to predict, but clearly grid and mass-storage technology is already part of current technological developments for industry focusing on software as a service, infrastructure as a service, or everything as a service markets.

The proposed actions for technological, scientific, and educational efforts within eScience are expected to have immediate, short-term, and long-term impact on industry and society in all countries. The impact will be in terms of international visibility, technological advances, and probably most importantly, in terms of competence development. As competence in eScience technology is highly relevant to the industry, direct educational efforts, students' and researchers' access to more advanced ICT technology, and new research achievements on eScience technology will directly and indirectly impact industry. The competence developments obtained in companies recruiting personnel equipped with the competence in new leading technologies should not be underestimated.

The fact that the efforts are to be performed in an extended collaboration between eleven countries is also likely to contribute to the long-term collaboration climate between these countries also in other areas. The collaborations can also have more direct impact, e.g., in terms of joint research and development activities between eScience researchers and relevant industry. Just as this effort partly is motivated by increased potential to take leading roles in large international collaborations, the academic and industrial collaborations can strengthen the competitiveness also for industry both in their markets and in, e.g., EU-funded programs.

Svensk sammanfattning

Denna studie handlar om möjligheten att etablera en gemensam avancerad kunskapsinfrastruktur för Östersjöregionen. Den handlar om att ta tillvara ett gyllene tillfälle att göra Norden och Östersjöländerna ledande inom kunskapsinfrastruktur för forskning och innovation. Kunskapsinfrastrukturen är grunden för förverkligandet av den fria rörligheten av kunskap – något som av den Europeiska unionen lanserats som den femte friheten, att komplettera den fria rörligheten av varor, kapital, tjänster och personer. Grundläggande för den femte friheten är effektiv kunskapsdelning, väl samordnade forskningsprogram, forskningsinfrastruktur i världsklass och forskares rörlighet.

Varför kommer då denna studie nu? Möjligheterna att etablera en avancerad kunskapsinfrastruktur har växt fram genom ett långvarigt nätverksorienterat samarbete. Vidare aktualiserar EUs nya Östersjöstrategi behovet av att ta initiativ som kan stimulera hela regionen.

Med utgångspunkt i dessa länders nuvarande infrastruktur för eVetenskap (eScience) identifierar studien möjligheter för gemensam utveckling av avancerad, lättillgänglig och uthållig kunskapsinfrastruktur för forskning och innovation. Som en geografisk utvidgning av aktuella nordiska initiativ föreslås etableringen av en gemensam strategi med fokus på utbildning inom eVetenskap, eVetenskapliga forskningsprogram, och gränsöverskridande utbyte av infrastruktur för eVetenskap. För att stödja realiseringen av strategin förslås inledande satsningar på en gemensam samordningsfunktion samt kompletteringar av existerande datornät för att etablera ett optiskt nätverk runt Östersjön. Satsningen som helhet kompletterar, förstärker och underlättar förverkligandet av en nyligen utvecklad EU-strategi för att gör EU världsledande inom området.

I kunskapsinfrastrukturen är det kunskap snarare än informations- och kommunikationsteknik (IKT) som är i fokus. Jämfört med dagens eVetenskapsinfrastruktur förväntas framtidens kunskapsinfrastruktur för forskning och innovation ge tillgång till resurser mer enkelt och transparent, till avsevärt större antal användare, med bredare funktionalitet och med hinder undanröjda vad gäller tillgång, avstånd och användbarhet.

Motiven för att utveckla en gemensam strategi snarare än att enbart göra nationella insatser är flera och inkluderar faktorer som att samla den kritiska massan av forskare och studenter, förbättra kostnadseffektiviteten genom gemensam utveckling och samnyttjande och skapa bättre möjligheter att påverka på den europeiska och i övrigt internationella arenan. Dessutom förväntas de föreslagna tekniska, vetenskapliga och pedagogiska insatser ha omedelbara, kortsiktiga och långsiktiga effekter på näringsliv och samhälle i form av internationell synlighet, tekniska framsteg och kompetensutveckling. De långsiktiga vinsterna av att leda den allt snabbare globaliseringen av forskning och att leda utvecklingen i fråga om nyttjande av omvälvande teknik kan knappast överskattas.

I de följande avsnitten sammanfattas denna möjlighetsstudie. För mer utförlig information, inklusive presentationer av nuvarande eVetenskapsinfrastruktur och aktuella strategier i Norden och de sex östersjöländerna hänvisas till det engelskspråkiga huvuddokumentet.

eVetenskap och kunskapsinfrastruktur

Dagens forskning präglas alltmer av storskaliga internationella samarbeten och intensifierad användning av olika typer av IKT-resurser. Ordet eVetenskap används ofta som benämning för forskning som bedrivs med stöd av avancerad IKT-utrustning såsom högpresterande datorer och datornät, storskaliga vetenskapliga databaser och distribuerade system som ger tillgång till dessa resurser över fysiska och administrativa gränser. Från sin centrala ställning i forskningsprocessen benämns eVetenskap numera ofta som den tredje pelaren i den vetenskapliga metoden, komplementet till den vetenskapliga metodens klassiska par - teori och experiment. Ofta är eVetenskap inte bara ett komplement till experiment utan den enda möjligheten, t.ex. då verkliga experiment är för farliga (analysera spridning av brand), omöjliga (studier av långsiktiga globala klimateffekter), för dyra (fullskaliga krasch-tester med flygplan), för krävande (genomjämförelser), för svåra (sidovindsstudier för rörliga fordon), eller oetiska (förutsäga sociala effekter av politiska beslut).

Ingen vetenskaplig disciplin kan utelämnas i en beskrivning av områden som kan nyttja eVetenskap. Alla fält finns representerade, från fysik och astronomi till medicinska vetenskaper, geovetenskap, biologi, kemi, samhällsvetenskap och humaniora. Områden som matematik och datavetenskap är i kärnan av eVetenskap – de ger den metodologiska och teknologiska grunden för eVetenskapliga genombrott.

Listan över spännande forskningsuppgifter som idag kan lösas med hjälp av eVetenskapliga tekniker kan göras godtyckligt lång. Inom materialvetenskap utförs simuleringar, t.ex. för att utifrån kunskap om mikroskopiska interaktioner förstå de fysikaliska egenskaperna hos material. Inom biokemi görs beräkningar för att förstå egenskaper hos biomolekylära system, t.ex. för applikationer inom farmakologi och läkemedel. I systembiologi analyseras cellens dynamiska processer i syfte att öka förståelsen av cellen som ett dynamiskt system. Området evolutionär genetik har revolutionerats av högpresterande genotypningsteknik som möjliggör genomanalys i stor skala.

I humanistiska ämnen kan beräkningsmodeller för mänskligt språk användas för utvärdering av språkliga teorier och ge praktiska tillämpningar av språkteknologi, som t.ex. automatisk översättning eller flerspråkig informationssökning. Inom lingvistik och forskning om visuell information kan studier av perception och tolkning av stillbilder och rörliga bilder möjliggöra nya genombrott. Analyser som kombinerar data från demografi-, ekonomi- och hälsouppgifter kan ge ny förståelse av t.ex. ekonomisk stress inverkan på migration, fruktsamhet och dödlighet. I klimatforskningen är modellering av det globala ekosystemet nyckeln till att förstå klimatförändringarna och dess effekter. Den eVetenskapliga teknik som används inom dessa områden varierar, men gemensamt för dem alla är att eVetenskap är absolut grundläggande i forskningsprocessen.

eVetenskapsinfrastruktur är normalt uppbyggd av mycket avancerade IKT-komponenter för att ge möjlighet att lösa de mest utmanande forskningsproblemen. För datornätverk innebär detta huvudsakligen optiska fibernät. Högpresterande datorer finns med en rad olika arkitekturer, men de flesta högpresterande datorer består av hundratals eller tusentals datorer som är anslutna med någon typ av höghastighetsnät. Forskningsdatabaser tas ofta fram direkt av forskargrupperna som är intresserade av dem, men även myndigheters datainsamlande kan ge oerhörda bidrag till forskningen. För att på ett smidigt sätt komma åt olika typer geografiskt distribuerade resurser finns så kallad grid-programvara som överbrygger heterogenitetsproblem, tillhandahåller information om tillgängliga resurser, hjälper till med resursval och gör det möjligt att hantera resurser på distans.

Stora internationella samarbeten är grundläggande för att organisera många typer av eVetenskapsinfrastruktur. Detta framgår till exempel av EUs European Strategy Forum for Research Infrastructures (ESFRI) som utvecklat en plan för framtida Europeiska forskningsinfrastrukturer, varav ett flertal är direkt inriktade på eVetenskapsinfrastruktur och merparten har beröring med eVetenskap.

Gemensamma satsningar ger nya möjligheter

Under 2007 utvecklade Nordiska ministerrådet en gemensam strategi för eVetenskap i de nordiska länderna. Det konstaterades att det genom att öka antalet och samordningen av nordiska forskare finns möjlighet att öka kostnadseffektiviteten av nordisk eVetenskaplig forskning och att stärka banden mellan den metodologiska forskningen som utvecklar eVetenskapsområdet och de applikationsområden som använder det. Under 2008 följdes strategin upp av en handlingsplan för genomförande av strategin. Detta strategiarbete, som redan fokuserar på insatser som med fördel görs i samarbete över landsgränser, utgör en god startpunkt för ett utökat samarbete mellan Norden och Östersjöländerna. Genom gemensamma initiativ finns det möjlighet för dessa länder att med kraft stödja och underlätta genomförandet av strategier utvecklade på europeisk nivå.

En vidare analys av den nuvarande situationen och den aktuella utvecklingen i Norden och länderna kring Östersjön visar på ett spektrum av möjligheter för att förbättra nuvarande eVetenskapsinfrastruktur och att öka kostnadseffektiviteten för varje enskilt land. Några exempel på sådana möjligheter presenteras nedan.

Samtliga elva länder har, för forskning och utbildning, väletablerade datornätverk och internationella anslutningar av god till mycket god kapacitet, åtminstone för nätens centrala delar. Eftersom det endast saknas ett mindre antal bilaterala förbindelser för att inrätta en komplett ring av fibernät runt Östersjön finns potential att med relativt små medel avsevärt öka kapaciteten för de internationella anslutningarna och anslutningarna mellan länderna.

Kapacitet och organisation av datorresurser varierar kraftigt mellan länderna. Naturligtvis har små länder med begränsade resurser svårt att finansiera och att skapa en tillräcklig användarbas för de största datorerna eller datorer med väldigt specifika egenskaper. Genom att se till en större region ges nya möjligheter till kraftsamling och till ökad flexibilitet genom gränsöverskridande resursutbyte.

De storskaliga distribuerade grid-system som utgör en del av kärnan av eVetenskapsinfrastruktur har många likheter länderna emellan. De flesta av länderna använder ett fåtal olika grid-programvaror för denna infrastruktur, och alla står inför liknande utmaningar för att lösa problem t.ex. med interoperabilitet mellan olika system. Det är uppenbart att det finns besparings- och kvalitetsvinster att göra genom viss samordning av drift och utveckling.

Vid utvärdering eller utveckling av ny teknik finns potential för förbättrad kostnadseffektivitet genom gemensamma insatser. Till exempel är i dagsläget flera av länderna intresserade av att undersöka om och hur så kallad cloud computing-teknik kan användas för att förbättra kostnadseffektiviteten för datacenter, för att leverera beräkningskapacitet som snabbt kan anpassa sig till olika kapacitetsbehov, för att göra resurserna mer lättillgängliga, eller hur kommersiella datacenter kan användas för att möta belastningstoppar.

Ländernas pågående arbete med utbildning inom eVetenskap är av olika karaktär, både i fråga om eVetenskap är ett undervisningsområde i sig eller om utbildning i eVetenskap främst sker som en integrerad del av undervisning i andra ämnen och om insatserna görs på lokal eller nationell nivå. Oberoende av utbildningarnas karaktär bör samtliga länder kunna dra nytta av gemensamma ansträngningar, till exempel för att lättare hitta tillräckligt stora grupper av studenter för att anpassa kurser till studenter med olika förkunskaper, för att bredda gruppen av lärare och genom att återanvända insatser för kursutveckling.

En positiv följdeffekt av gemensamma utbildningsprogram är skapandet de mänskliga nätverk som ligger till grund för långsiktiga samarbeten. Ytterligare stöd till sådant nätverksbyggande kan t.ex. ske i form av skapande av fysiska mötesplatser för utbildning, konferenser, workshops och samarbetsprojekt.

Vid inledningen av nya samarbeten finns det en möjlighet att inta en mer holistisk syn på eVetenskapsinfrastruktur. Idag organiseras och finansieras olika typer av infrastrukturer separat. För att lyfta eVetenskapsinfrastruktur till en ny nivå bör insatser för olika typer av infrastrukturer göras i större samordning, med syfte att etablera en mer enhetlig och lättillgänglig kunskapsinfrastruktur.

Gemensam strategi

Utifrån analys av nuläget och redan etablerade planer för vidareutvecklingen av eVetenskapsinfrastruktur i de elva länderna föreslås inrättande av en gemensam långsiktig strategi för utveckling av eVetenskapsområdet. Strategin utgör en vidareutveckling av Nordiska ministerrådets Nordiska eVetenskapsstrategi från 2007 och dess därpå följande förslag till aktivitetsplan. Den föreslagna strategin fokuserar på följande tre områden:

Område A. Skapa en gemensam arena för högre utbildning inom eVetenskap. Genom gemensamma ansträngningar skapas kritisk massa av studenter och lärare, vilket ger underlag för eVetenskaplig utbildning anpassad för olika studentgrupper och för att tillhandahålla lärarkompetens inom alla delar av eVetenskap.

Möjliga initiala insatser kan exempelvis innefatta gemensamma kurser i användning av eVetenskapstekniker och forskarutbildningskurser i såväl eVetenskapliga grunddiscipliner som tillämpningar. Genom att nyttja lärare från samtliga deltagande länder kan ansträngningen per land minska med ökat antal deltagande länder. Hand i hand med ett program för forskarutbildning går utveckling av allmänt tillgängliga undervisningsmoduler.

Område B. Forskning fokuserad mot grand challenges. Syftet är att utveckla möjligheterna att lösa de allra svåraste problemen genom satsningar som inkluderar alla moment i forskningsprocessen, från grundläggande och tillämpningsspecifik metodologisk forskning till forskning om effektiv användning av eVetenskapsinfrastruktur. Möjligheterna att sätta samman forskarlag med rätt kompetens ökar genom samarbete över nationsgränserna.

Område C. Utbyte och samnyttjande av eVetenskapsinfrastruktur över landsgränserna. För varje enskilt land är möjligheterna begränsade att själva tillhandahålla datorresurser stora nog att möta de största belastningstopparna. Resursdelning över nationsgränserna ökar dessa möjligheter genom samnyttjande av resurser, samtidigt som det ger större mångfald i fråga om hårdvara och programvara. Exempelvis kan teknik av särskilt intresse för en liten användargrupp i varje land på lämpligt sätt göras tillgänglig på en eller ett fåtal platser.

För att stödja realiseringen av denna strategi föreslås två specifika initiala åtgärder:

- Etablera ett fibernätverk runt Östersjön. Denna åtgärd är viktig både för att tillhandahålla den kapacitet som krävs för kommande gemensamma insatser och som fokuspunkt för framtida samarbeten. Kostnaden för insatsen bedöms som relativt låg då merparten av utrustningen redan finns på plats och extrainsatsen kan begränsas till komplettering för korta sträckor över vissa landsgränser. Förutom att förbättra kapaciteten mellan länderna kan detta nätverk också ge högre kapacitet och kostnadseffektivitet för anslutning till det Europeiska GÉANT-nätverket.
- Inrätta en gemensam samordningsfunktion. Förslaget är att skapa ett litet samordnande organ med ansvar för genomförande av strategin och kontinuerlig vidareutveckling av handlingsplaner i linje med strategin. Det operativa arbetet för att genomföra särskilda åtgärder bör tilldelas andra, normalt redan befintliga organisationer. En sådan samordningsfunktion kan också bli inta en koordinerande funktion i ländernas EU-samarbeten inom infrastrukturområdet.

Förväntade effekter för näringsliv och samhälle

För forskningen kommer vidareutvecklingen av dagens eVetenskapsinfrastruktur till morgondagens kunskapsinfrastruktur att få oerhörd betydelse. Infrastrukturen kommer att bli mer lättillgänglig, verktygen kraftfullare, och stödet för att kombinera stora mängder av resurser kommer att bli mer flexiblare och mer avancerat än i dag. Denna utveckling kommer att främja forskningens internationalisering och reducera organisatoriska och geografiska hinder till förmån för snabba vetenskapliga framsteg. Samordnade forskningsprogram och gemensamma initiativ inom utbildning kommer att stödja utveckling och underlätta forskares rörlighet. Genom att nu ta ett stort steg mot etablering av en kunskapsinfrastruktur i Norden och länderna kring Östersjön, kan dessa länder fungera som en föregångare till EU-insatser och underlätta genomförandet av etablerade EU-strategier.

Precis som vi sett vid ett flertal tillfällen tidigare kan den eVetenskapliga spjutspetsteknik som idag används för forskning komma att förändra näringslivet och samhället i en nära framtid. Till exempel ser vi idag att teorier, metoder och programvara för storskaliga distribuerade system ger tekniska lösningar som påverkar utvecklingen inom vitt skilda områden. Utbildningsinsatser, studenters och forskares tillgång till mer avancerade IKT-resurser och nya landvinningar kring eVetenskapliga tekniker ger direkta och indirekta effekter för industrin. Företagens kompetensuppbyggnad genom rekrytering av personal utbildad på den senaste tekniken bör inte underskattas.

Slutligen kommer de föreslagna samarbetena långsiktigt att bidra till ett samarbetsklimat, med effekter även inom vitt skilda områden. Eftersom distansöverbryggande teknik är en integrerad del av eVetenskap är området utsökt som föregångare.

Appendix A.

Acronyms and Abbreviations

CERN	European Organization for Nuclear Research
CLARIN	Common Language Resources and Technology Infrastructure
CSC	The Finnish IT Center for Science Ltd
CYFRONET	High performance computer center in Krakow
DCSC	Danish Center for Scientific Computing.
DEISA	Distributed European Infrastructure for Supercomputing Applications.
DESY	Deutsches Elektronen-Synchrotron
DFN	The German national research and education network
DISC	Database InfraStructure Committee
DKRZ	Deutsches Klimarechenzentrum
eduGAIN	European project for interoperation between different Authentication and Authorization Infrastructures
eduroam	EDUcation ROAMing (project facilitating authentication and authorization across organizations)
EENet	The Estonian national research and education network
EGEE	Enabling Grids for E-sciencE
EGI	European Grid Initiative
eNORIA	Organization implementing the Nordic Council of Minister's eScience strategy
ESFRI	European Strategy Forum on Research Infrastructures
eVITA	Norwegian eScience research program
Forskningsnet	The Danish national research and education network
FUNET	The Finnish national research and education network
GÉANT	a pan-European multi-gigabit network, for research and education
ICT	Information and Communication Technology
IMCS	Institute of Mathematics and Computer Science, University of Latvia
Kalmar2	e-identity Union for a cross-Nordic authentication system
LatGrid	The Latvian national grid
LHC	Large Hadron Collider
LITNET	The Lithuanian national research and education network
NDGF	Nordic Data Grid Facility
NGSSC	Swedish National Graduate School for Scientific Computing
PRACE	Partnership for Advanced Computing in Europe
PIONIER	The Polish national research and education network
PLATON	Polish program for eScience Infrastructure Development
RBnet	Russian Backbone Network
RHnet	The Icelandic national research and education network
RUNnet	Russian University Network
SARA	Stichting Academisch Rekencentrum Amsterdam
SNIC	Swedish National Infrastructure for Computing
SUNET	The Swedish national research and education network
TERENA	European Research and Education Networking Association
NGI	National Grid Initiative
NORDUnet	collaboration by the 5 Nordic National Research and Education Networks
Notur	The Norwegian Metacenter for Computational Science
PL-Grid	The Polish national grid
UNINETT	The Norwegian national research and education network
ZIB	Zuse Institute Berlin

Appendix B.

Contacts from the Countries around the Baltic Sea

People from the following organizations have been consulted.

Estonia
Estonian Education and Research Network (EENet)

Northern Germany
Deutsches Elektronen-Synchrotron (DESY)
Deutsches Forschungsnetz (DFN)
Federal Ministry of Education and Research

Latvia
Academic Network Laboratory of the Institute of Mathematics and Computer Science, University of Latvia (SigmaNet)
Institute of Electronics and Computer Science
Institute of Mathematics & Computer Science, Latvian University (IMCS)
Ministry of Education and Science
Riga Technical University

Lithuania
Academic and Research Network in Lithuania (LITNET)
Institute of Mathematics and Informatics (IMI)
Ministry of Education and Science
Vilnius University

Poland
Academic Computer Centre in Gdansk (TASK)
Ministry of Science and Higher Education
Polish Optical Internet (PIONIER)
Poznan Supercomputing and Networking Center (PSNC)

North West Russia
Computational Science Alliance (CSA), St. Petersburg
Faculty of Physics St. Petersburg State University
Ministry of Education and Science, State Institute “Informika”
Russian University Network (RUNnet)
Skobeltsin Institute of Nuclear Physics, Lomonosov Moscow State University

Appendix C.

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