RESEARCH IN INFORMATION AND COMMUNICATION TECHNOLOGY IN NORWEGIAN UNIVERSITIES AND UNIVERSITY COLLEGES

TO THE RESEARCH COUNCIL OF NORWAY

The members of the Review Panel for Research in Information and Communication Technology at Norwegian Universities and University Colleges hereby submit the following report. The views presented in this report are expressed in consensus among the members of the Review Panel. The members of the Review Panel are further in collective agreement with the assessments, recommendations and conclusions presented.

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Executive Summary

The future well being of a nation is vitally bound up in the degrees to which it pioneers new, powerful, and secure information and communication technologies (ICT) and prepares and trains its citizenry in their use.

This report attempts to provide a perspective on the health of ICT research in Norwegian universities and associated research institutes and to make recommendations on how the current base of expertise and investment can be harnessed to secure for Norway an international leadership role in ICT that is commensurate to its advanced standing by other international measures. It integrates the findings, conclusions, and recommendations of a nine-member international panel of academic peers that assembled for a full week in Oslo, following preparation through advance surveys, to interview many of the principals in ICT in Norway and to confer with each other. The major finding of the panel is that Norway is *underinvesting* in ICT relative to its potential and to many of its peers in Western Europe and America, but that, nevertheless, the country possesses international strengths in several areas beyond what might be expected from its relatively small investments. Due to its size, Norway cannot expect to lead internationally in all areas required for participation in a healthy ICT-driven economy. For instance, we do not expect to see the near-term emergence of major domestic electronic chip fabrication facilities. However, Norway can rank much better than it is currently doing, retain more of the human capital it helps to produce, and enjoy more fruits of future economic benefits by building on strengths, by increasing the share of national research resources dedicated to the ICT arena, and adopting a more incentive-based approach to the allocation of those precious ICT resources.

A similar national assessment was last conducted in 1992, in a time in which the pervasiveness importance of ICT to the nation was arguably less than it is today, and the committee is disappointed to see that many of its findings in 2002 echo those of the 1992 committee. We note:

- A relatively low level of support for basic research in ICT, in terms of professional salaries and equipment;

- A system of distribution of research resources that mirrors education-driven demographics more than merit-based peer review;

- A lack of strategic planning, evidenced by the lack of wide availability and acceptance of metrics (such as citations) and projections (such as the industrial need for doctoral graduates), and leading to inefficient allocation of Norway's most precious resource of all – its people.

We believe that the following concrete responses to this situation will put Norway in a position to exercise international scientific leadership in vital areas of ICT in the future:

- Existing resources should gradually be shifted and new resources introduced in according to merit review by a discipline-appropriate combination of academic peers and institutional customers.

- The reward structure for a research career in ICT should be expanded at the upper levels so as to retain Norway's best future talents without forcing them into industrial careers or industrial side careers.

- University departments and research institutes in ICT should be encouraged to compare their research areas and their research productivity annually with a set of leading peer organizations outside of Norway.

- Norway should cultivate more strong international partnerships that provide basic technologies and expertise for the development of its own research that it lacks the critical mass to foster domestically, in competition with other priorities for a country of its size.

- Domestic ICT organizations should seek to better coordinate their educational offerings, flows of personnel, construction of facilities, etc., to accomplish the sometimes contradictory dual purposes of achieving efficiencies of scale while fostering healthy competition and discouraging "academic inbreeding."

These points and many others in the context of specific groups are expanded upon in the sequel.

1 Introduction

The Division of Science and Technology at the Research Council of Norway has decided to evaluate basic research activities in *Information and Communication Technology* (ICT) in Norwegian universities and colleges. The 2002 international review team of nine was charged with evaluating the area with 56 groups at nine institutions plus four university colleges (primarily undergraduate) and one graduate-only institute. This report of the evaluation committee will form the basis for the future strategy of the Research Council.

It is said that we are living through the information revolution, a period in which information and communication technology (ICT) is transforming the organization and operation of human society as dramatically as agriculture and industrial mass production transformed earlier generations. If so, then the future well-being of a nation is vitally bound up in the degrees to which it pioneers new, powerful, and secure information and communication technologies and prepares and trains its citizenry in their use. In the quest for public attention and support, many "revolutions" are touted as agents of social change and engines of economic development, and justifiably so. What is remarkable about information and communication technology is the way that *it invariably lays at the center of these other revolutions*. For instance, the promise of biotechnology for the improvement of the environment and human health, and the promise of nanotechnology for the improvement of materials and energy production both depend in critical ways on ICT.

Indeed, ICT provides the core enabling technologies for the harnessing of all other sciences and technologies, in that it ameliorates the barriers of distance, scale, and complexity that so quickly otherwise deter our ability to understand and control the systems on which our lives and societies increasingly depend. Another profound dimension of ICT is that it not only provides the tools to organize vast amounts of data that are obtained experimentally and empirically, but it also generates, through simulation, understanding of the behavior of systems that may exist only theoretically. Finally, we note that ICT is a discipline where all of the other disciplines meet for techniques and expertise requirements that they hold in common. A fisheries biologist has little use for a telescope and a structural engineer has little use for a mass spectrometer, but both benefit from advances in data management software or parallel computer hardware that enable them to, respectively, elucidate the structure and expand the level of detail of their physical and abstract scientific universes. It can therefore be argued that lifting the level of ICT lifts all of the other technical and scientific disciplines that are important to a nation.

Increasingly, ICT as an economic locomotive is progressing beyond its origins in science, technology, defense, and business into the consumer and social arenas. Modern society not only depends upon ICT for its survival, but also increasingly turns to ICT for its convenience and pleasure. Digital forms of art and entertainment enrich our lives. ICT is also thus being embedded in all walks of life and social behavior through miniaturization

and pervasive use of intelligent devices, services and communication technologies to the extent that many areas of industrial development, business and media industry are deeply influenced by such developments. One impact of this *digital convergence* and *ubiquitous* nature of ICT applications is that *software* and associated *computational techniques* have become important engines of social and economic development. Pervasive computing and web-connected embedded systems increasingly enter our lives as consumers and participants in a small, vitally interconnected world. Thus, the marketplace of ICT expands not only outward to increasingly more sophisticated and powerful uses, but inward, penetrating the lives of people who never conceived of owning a computer, much less of living and moving through a web of them. The nation that incubates new uses of ICT creates a steady stream of new high-value jobs and industries that are not dependent upon natural resources but are constantly reinventing themselves.

The rest of the report is organized as follows. First the mandate for the evaluation committee is summarized. Then we make some observations based on the evaluations, followed by general recommendations based on these, and some general conclusions. Finally, we evaluate in detail the different departments and research groups covered.

2 The Mandate for the Evaluation Committee

Information and communication technology (ICT) is defined as the basis for development and use of telecommunication and computer systems, digital information and communication systems, and digital contents in general. In addition to technology, ICT also includes organizational, economic, cultural, and practical frameworks that control how ICT is formed and developed in the society. The present evaluation covers those Norwegian ICT institutes having graduate education.

The objective of this evaluation is to review the overall state of basic research in ICT in Norwegian universities and colleges.

Specifically, the evaluation process aims at:

- Offer a critical review of the strengths and weaknesses of ICT research in Norway, both nationally at the level of individual research groups and academic departments, and the scientific quality of basic research in an international context.

- Identify research groups which have achieved a high international level in their research, or which have the potential to reach such a level.

- Identify areas of research that need to be strengthened in order to ensure that Norway in the future will possess necessary competence in areas of importance for the nation. And, as one aspect of this, enable the Research Council of Norway to assess the impending situation regarding recruitment in important fields of ICT.

The evaluation will provide the institutions concerned with the knowledge they require to raise their own research standards. They will be provided with feedback regarding the scientific performance of individual research groups, as well as suggestions for improvements and priorities.

The evaluation will improve the knowledge base for strategic decision-making by the Research Council, function as a platform for future work on developing ICT and represent a basis for determining future priorities, including funding priorities, within and between individual areas of research.

The evaluation will reinforce the role of the Research Council as advisor to the Norwegian Government and relevant ministries.

3 Observations

The following general observations of the state of ICT at Norwegian universities can be identified from the evaluations.

Level of Investment in R&D

It is well documented that Norway is underinvesting relative to its international peers in research and development. Norway's total R&D expenditures are approximately 1.7% of GNP, well below Finland's 3.0% of GNP and less than half of Sweden's 3.8% of GNP. On a more global comparison, the OECD average is about 2.2% of GNP and the portion of GNP spent on R&D in the U.S. is about 2.7%. The NFR's expenditures on research in the period of 1993 to 2001 have not increased after correction for inflation, but have hovered around 2.5BNOK in 1993 terms.

R&D Productivity

Despite less than exemplary national investment, Norway's research enterprise appears quite healthy by some quantitative and qualitative international comparisons. This is a strong credit to the vast majority of hardworking, loyal, and deserving faculty members in the nation's universities and university colleges. For example, the relative citation frequency of Norwegian-coauthored papers in the category of Computer Science is 0.95 on a scale where 1.00 is the world average. This is eleventh in the world, above Sweden (0.91), but below Denmark (1.18), Finland (1.10), and the U.S. (1.25). In the category of Information Technology and Communications, Norway's relative citation score is thirteenth at 1.13, below Denmark (1.67), Sweden (1.43), and Finland (1.20), as well as the U.S. (1.64). Norway's production of scientific articles in English-language refereed journals cited by the ISI is 5.16 per thousand capita in the five-year period 1996-2000. This is below Sweden (7.98), Denmark (6.73), and Finland (6.41), but it is tenth in the world, and still well above the U.S. (4.54).

Finally, the panel notes that Norway's production of an average of about 41 doctorates in ICT per year for the period 1990-2000 reported by the NFR, out of a population of about 4.5 million (about one for every 100,000 of population), compares very favorably to the annual average for doctorates in computer science and computer engineering produced in the U.S., as reported by the Computing Research Association (CRA) over the same period, approximately 1,000 per year out of a population of close to 300 million (about one for every 300,000 of population).

Therefore, the Norwegian system is already functioning closely enough to the top of international ranks that it could instantly benefit from additional investment. There is no reason that Norway could not rise to the very top internationally in all per capita metrics if

funding as a percentage of GNP were increased to more respectable levels. However, structural improvements at the same level of investment could accomplish some of the same benefits of increased investment in the same problem-laden system.

Comparison of Academic Salaries

The Norwegian academic research system is hampered by low salaries. Many new assistant professors in the U.S. earn more than full professor maximum levels in the Norwegian system, in gross terms, without accounting for differential social benefits. Professors in the 90^{th} percentile in the U.S. can easily earn four or five times as much in a year. Salaries are also low relative to neighboring advanced European countries. This makes it very difficult to recruit faculty to Norway from, e.g., a university like ETH, even when international recruitment is emphasized in the filling of a position. International recruitment is sometimes recommended when important areas are poorly represented within the country presently, or when the danger of academic inbreeding reduces domestic choices for the source of new faculty.

A significant fraction of Norwegian-educated PhD students use Norway as a bridge between their underdeveloped native countries to better-salaried research jobs in the West. This is a tolerable pattern if the main goal of supporting graduate students is putting highly qualified students under Norwegian research faculty for the sake of accomplishing research objectives. However, it represents an opportunity lost for the nation, and, in effect, a subsidy for other advanced countries. Norway could easily retain more of the researchers it educates with a more competitive salary structure.

Need for More Merit-based Allocation of Resources

Norwegian research faculty funding should increasingly be based on a meritocracy, as is common in the U.S.

Incentive-based support seems to be catching on among several chairs and deans interviewed in the survey, but the incentives are rather small, e.g., sponsored trips to conferences when a research paper is accepted, and the differentiation in overall rewards between highly productive and marginally productive faculty is not as large as it perhaps should be.

This situation, and the corresponding trend toward a higher percentage of overall support dispensed based on merit, seems to be reflected in federal support, as well, and the panel commends the trend towards merit-based rewards where it is found in both worlds. For instance, the current competition for Centers of Excellence (CoE) has brought out the best efforts of many excellent groups in the ICT area, and obviously created a great deal of excitement and hope for ICT faculty in Norway. The NFR might also consider providing a matching ratio to funds raised outside of the system, e.g., from the European Union, as a way of incentivizing more Norwegian successes in this arena.

There is a general need to establish traditional metrics and to refer to them more frequently than once in ten years at a time of international peer review of entire programs. Such

metrics include citation studies, listings of publications in high quality journals and conferences, and listings of invited international talks. Such attention to metrics is not easy to motivate if it has little consequence in the reward structure.

While the following suggestion may be too revolutionary to adopt anytime soon, we suggest consideration of mechanisms (besides company formation) whereby faculty can augment their standard annual salaries, such as the more entrepreneurial system in the U.S., where most faculty are regarded as paid for nine months and successful researchers can augment their university-administered income with external grants in the summer.

Comments on Academic Workloads

Typical teaching load for ICT faculty throughout Norway seems to range from two to four courses per year, occasionally higher. The panel heard from many faculty members who believe that two per year is too high. We disagree. A load of two courses per year is entirely consistent with research productivity. Even the best institutions abroad usually require at least this much formal teaching. A load of four courses per year is on the border of what would be considered acceptable in much of the rest of the academic research world.

Comments on Future Faculty Development

Except in the very best ICT groups in the country, faculty recruiting is a problem, in the sense that there are too few applicants for each vacancy (often just a few). While the professorate in Norway is not highly remunerative, as noted elsewhere, this seems low relative to the prestige and quality of lifestyle that the professorate commands elsewhere, and may be somewhat cultural. Many academic institutions in the U.S. have programs, such as "Preparing Future Faculty," in which graduate students are mentored in their pedagogical skills and in survival skills for tenure track faculty. Norway may wish to emulate these seemingly successful programs. Such programs may be especially successful in increasing the level of people underrepresented in academia, which includes women in the Norwegian ICT academic world.

Targets for Doctoral Production

Not too long ago the goal of academic doctoral programs in Norway was simple self-replacement, since there was little recognized demand for doctoral researchers in industry. The acceptance of PhDs in industry appears to be heating up in Norway presently, however, and there is a need to go beyond replacement levels in academia, as well. The panel recommends that the NRF makes a study of the doctoral market, document needs, and make official, referenceable projections for needs.

Desirability of Multiple Sources for Doctorates

The concept of having multiple universities with the same specialties, for cross-fertilization, in contrast to a single campus, for critical mass, is relatively new to Norway. For instance, Trondheim used to be the only place where graduate engineers were trained in the entire country. It is healthy for competition and for the generation of original new ideas

for there to be a diversity of sources for any specialty, and the panel commends the replication of doctoral programs (up to a point) at multiple universities.

Desirability of Mechanisms for Close Collaboration

Though diversity of sources of production for PhDs is important, Norway has a relatively small population and cooperation within the country is also important as a way of creating critical mass.

The recommended critical mass for healthy graduate research, in which students lift one another's standards and enrich each other's learning, is probably larger than we see in most Norwegian academic research groups.

Geography is an inhibiting factor, however, and the cost of internal air transport is high. This suggests the value of investment in very high bandwidth networking technology linking all research locations in the country. The "Access Grid" virtual conferencing system is a good model. There are now close to a hundred research institutions (mostly universities in the U.S) linked via the on the Access Grid, and this number is rapidly increasing. Norwegian institutions belong on the Access Grid, for reasons of international collaboration, as well as national.

Comments on University and University College Curricula

Though the international review panel was not charged with evaluating curricula in any systematic way, we inevitably made some observations on the ICT curriculum, since an academic researcher's life and work closely integrates research and teaching.

University departments in ICT areas are often organized, according to the statements of their own academic leaders (deans and chairs), along curricular lines. Faculty are hired and grouped with a primary eye to covering the curriculum, rather than with a primary eye to creating the highest value return research programs. There are exceptions, and they are noted in the departmental write-ups.

Ironically, the situation tends to be exactly the reverse at the mainly undergraduate institutions. The university colleges surveyed seem, almost to a rule, to concentrate on somewhat nonstandard research niches, to the possible detriment of the students. Faculty tend to specialize in areas not well covered by the major universities, in order to have a chance at becoming national leaders in specialized areas, and the curriculum often appears to follow. Therefore students at the university colleges are not always fed a standard curriculum of computer science or informatics. Instead of algorithms, databases, operating systems, data structures, etc., their courses may be in industrially applied areas.

Attribution of Credit for Doctoral Production

The common situation of attributing doctoral graduates to one of the major universities for students, most of whose academic credits are earned and most of the supervision for which is done at one of the university colleges, is an unfortunate one for the university colleges. A

similar situation exists with the graduate-only institution at Kjeller. Care should be taken within the NFR to take note of the “real” sources of educational production.

4 Recommendations

Given the existing resources, incentives, and research environment Norwegian academic groups are doing well in their research efforts. There is a genuine and vigorous effort to engage in high quality research, and most groups surveyed are well on par with international leaders. The universities obtain a satisfactory quality of talented and motivated PhD students, though the domestic supply is not as large as the faculty can accommodate. Nevertheless, there are several disconcerting characteristics in the way in which ICT research is funded and organized in Norwegian universities, which affects research output, quality, and scope. This is recognized and discussed in several of the self-evaluation reports in an admirably candid and constructively critical manner. In a young, fast growing, and critical field like information and communication technology negative structural characteristics have a more pronounced influence. If the goal of the Norwegian Research Council and Norwegian educational system is to improve the competitiveness of Norwegian research in this field, such issues should be addressed immediately though modifications in policy and strategy.

This observation is more alarming since ten years ago, an international review team of five international experts focused on *Informatikk* surveyed 22 research groups at four major universities (Bergen, Oslo, Tromsø, and Trondheim) and made several observations of the structural problems in Norwegian ICT research. In this section we will first iterate recommendations of the 1992 report. Section 1.3 (pp. 10—13) of the 1992 predecessor report *Informatikk: Research and Teaching in Norway* contained nine general recommendations, in addition to many other recommendations specific to individual campuses and research groups. We here revisit these recommendations to see whether they have been implemented, need to be reasserted, or can now be relaxed. While there has been some progress, the 2002 review team finds the need to reassert a disappointing number of these recommendations. After that we shall raise a number of new urgent issues, which heed for attention by policy makers and those responsible for funding and directing national research system.

1. Form larger groups that actively cooperate.

As observed in 1992, not all of the research groups presenting themselves as such seem to function as "real" groups that coordinate their teaching, research, and leaves of absence. Some groups appear to have been identified primarily for the sake of the evaluation, rather than being consciously designed. A typical group consists of about three full-time faculty members, plus an adjunct ("Professor II") or two. The range spans from one full-time faculty member to about ten faculty members. We repeat the recommendation of 1992 that larger groups with a long term research focus are helpful in attaining the goal of having internationally visible, multigenerational research activities, and providing sufficient critical mass, wherein students in effect teach each other and leverage off of each other's

work. We therefore also recommend that the current ratios of PhD in relation to the number of faculty should be increased — especially in places which show very good or excellent research output. The current ratio of approximately 1 PhD student per professor should be changed into a ratio of 2:1 or 3:1. The universities should also be more active in providing Post-doctoral positions, especially for active and well performing research groups. We also repeat the observation that excellent research groups best congeal around a senior investigator at the top of his or her career, who can afford to act selflessly on behalf of the group.

2. Focus research quality and improve publications.

The 2002 review team finds that the publication level of many groups is not up to international standards in quantity and in the quality of the journals and conference venues chosen — the same situation that prevailed in 1992. This is attributable in some cases to insularity and in some others to lack of critical mass within a research area, since progressive research in information and communications technology is often built on top of complex systems into which many person-years of a group have been invested. Partly this is also attributable to the lack of long-term focus in research teams and in depending on too much on individual initiative. Finally, this reflects the fact that systematic incentive systems and targets are not set for publishing in internationally recognized research outlets by department heads, deans and the managers of the research groups.

3. Concentrate on the successful recruitment of senior personnel.

The 1992 review team found a shortage of senior personnel with international research recognition to mentor the junior researchers in Norwegian Informatikk departments. This is not inconsistent with the finding of the 2002 team that there is a relatively large contingent of faculty in their 60's, whose replacements will need to be recruited within the next five years or so. Not all of these senior faculty are in the right areas to develop junior faculty in the growth areas of ICT, and not all of them are well connected internationally, so as to introduce the junior faculty to "movers and shakers" in their fields. Nevertheless, the 2002 team is encouraged to find a healthy contingent of energetic and ambitious full professors exercising international leadership in specific areas, including many areas rated "Excellent" or "Very Good" in the group evaluations herein.

4. No promotion to a tenured position before significant achievements.

The 2002 review team finds that a situation noted by the 1992 team still persists – a number of faculty members in departments with aspirations to train significant numbers of PhDs lack PhDs themselves. This is consistent with an often-voiced frustration in attracting sufficient applicants for faculty openings. We also find significant "academic inbreeding" wherein PhDs are immediately hired by their own institution. This used to be perhaps more necessary than it is today, when there are now multiple research groups nationally in similar areas. We concur with the 1992 team that significant caution must be exercised in filling faculty positions non-competitively, as this constitutes a mortgage for several

academic generations under Norway's current policy of systematic promotion in the academic ranks.

5. Spend research time abroad.

The 2002 review team agrees with the 1992 team that faculty sabbaticals, as much as possible, should be spent abroad, and that doctoral students should be encouraged, as part of their training, to spend at least one-half year abroad. Even undergraduate and MS degree candidates would benefit from a semester exchange. Some of the universities provide sabbatical opportunities frequently (e.g., every fifth or six year) and take the obligation to spend it abroad seriously. Even some of the university colleges seem to be exploiting sister-campus relationships systematically. We noted that those groups rated "excellent" or "very good" were systematically more well connected and utilized the opportunities to spend research time abroad.

6. Take advantage of the high-speed network.

The 2002 review team agrees with the 1992 team that, as a country with a large geographical spread and a relatively small population, Norway stands to gain more than most from exploitation of high-speed networking. With the exception of UniK, Norwegian universities do not seem to be oriented towards distance education. Furthermore, interest in Grid-based research and service technologies seem underrepresented in Norway, relative to other advanced countries. We encourage Norwegian ICT groups to lead the national science and engineering community in embracing network technologies for telepresence of all kinds – distance education, sharing seminars nationally, and international collaboration. A model may be the "Access Grid" currently growing in the United States and many other countries, with approximately one hundred sites, and growing. Such technologies should also be used to overcome the limitations in group size and paucity of research talent and leadership in many areas of ICT research.

7. Form a common Norwegian informatikk curriculum.

The 1992 review team recommended a common first-year informatikk curriculum through Norway, and suggested the 1989 ACM recommendation by Denning, *et al.* (There is a revised ACM curriculum recommendation as of 2001.) The rationale given earlier was easier movement between universities by students, jointly developed courseware, and cooperation in research. The 2002 committee did not specifically assess progress towards this goal and finds the curricular situation to be of less concern, generally, than the situation in research.

8. Update equipment every three years.

The 1992 review team performed site visits and found the currency of the equipment in the Departments of Informatikk to be very satisfactory. The 2002 team performed no such site visit, and so did not inspect facilities directly. We did interrogate, however, the facilities and equipment available for different departments and research groups. We observe, that despite the constant decreases in the cost of computing, the equipment situation demands

constant vigilance in the ICT area, due to the progression to obsolescence within a few years from acquisition for ICT equipment. ICT, after all, is a laboratory and an empirical science. Access to up-to-date equipment is critical in many areas of research in ICT. Some major supercomputing facilities appear to be refreshed at the recommended interval of about three years. However, some laboratory facilities (e.g., clean rooms, bioinformatics laboratories) are going to demand near-term major investment, without flagging in computational facilities for teaching and research. We also observed that many departments were cutting their operational budgets while increasing the number of faculty and did not currently have adequate funding levels for equipment. This situation should be remedied in the future or there is a real danger of making the research equipment obsolete in a new few years.

9. Increase the number of long-term visitors.

The 1992 review team promoted the idea of supporting senior visiting researchers (3 to 4 per year at each of the major research universities), in terms both of short-term and permanent international Professor II relationships. The 2002 team agrees that this remains a good goal, especially in the currently prevailing situation in which it is difficult to attract large number of applicants per faculty position. Such people are most easily attracted on sabbaticals, while partially supported by their foreign institution, since Norwegian faculty salaries are too low to hire foreign top-flight researchers on a full salary replacement basis. Additional funds and other arrangements (though housing or tax arrangements) should be made available to persuade top level researchers to stay and visit more in Norwegian research institutions.

In addition we want to notify the following issues in the ICT research environment that need more attention in near future.

10. Unify and organize better PhD education

In general, universities fund PhD students through internal or external funds. Students are normally accepted through some screening process, which is not clearly formalized. Students are then expected to work in some research groups or by themselves. There is very little, if any, organized education program offered as part of the PhD education and students are not admitted to formally organized “schools” or “programs”. Consequently, there is little emphasis on developing systematic practices at the departmental level to control the progress of the PhD students through the program (e.g., advising groups of multiple faculty, and departmental exams) and exercise quality control. No institute in its own self-study discussed how they organized and managed their doctoral education. Since PhD students carry out a bulk of the research work and output, this is a major concern. It results in varying quality in PhDs produced (in terms of their methodological skills and communication skills) and also increases the variance in how much time it takes to obtain the PhD. Addressing minimum quality requirements for PhD programs and forecasting their resource requirements is therefore a critical policy issue in improving future competitiveness of Norwegian research system. This recommendation may extend well beyond the area of ICT covered in this review. We believe that without such measures it is very difficult to increase adequately the production of PhDs to the level required by both

Norwegian industry and the research institutions. One way to improve the situation would be to allocate special funds to support Research Schools promoting PhD education in selected areas. Models for such schools exist in the other Nordic countries.

11. Increase domestic cooperation in research and PhD education

The Norwegian research system is very heterogeneous and distributed, and as a result there are few groups with truly comfortable critical mass. This is not improved by the fact that there are also separate research institutions (like SINTEF, UniK, and Simula Research Laboratory) which carry out similar research without direct accountability to engage in PhD education (though such institutes have their own justification). A more striking fact is that such centers have been established over the recent years, which seem to increase the diversification within the field.

Most cooperation between the universities and research groups takes place currently through sharing adjuncts ("Professor II") across departments and institutions. This may be a good way to share and channel resources across departments with similar interests — especially when such resources are thin – as it improves educational offerings and helps mentoring of candidate thesis work. As a downside, it burdens human resources that are already scarce and may result in minimal impact for the departments using the adjuncts, in terms of actual improvement in research quality and output. Of course, this depends on how these relationships are organized and managed. At the same time few attempts were observed to organize cooperation at the level of providing joint doctoral courses, seminar, workshops, or organizing mutual mentoring relationships for doctoral education. In a small country with a large land area and a few small research groups in each area scattered around the universities, such a situation is not beneficial. It decreases the level of exploitation of resources, impedes networking between PhD students and researchers with similar interests, impedes access to top level international research, and thereby over time keeps research quality and quantity below full potential. One way to solve such problems would be to install joint PhD education offerings across major areas such as computer science theory, software engineering, telecommunications, or information systems. Such networks have been organized with good results, for example in Finland, to overcome similar problems. Therefore resources, and incentives that increase cooperation and research activities between the universities should be made available at the national level. We feel also that departments should be more proactive in initiating such activities, and insulation between different departments and groups should be discouraged. Such networks should be orthogonal to the research projects, and should not reduce intellectual freedom in individual research projects.

12. Improve strategic goal setting and install systematic evaluation measures

The self-evaluations of most departments and research groups lacked clear goal statements and lists of policy measures designed to improve their research position and activity. Nor did they report the criteria by which they evaluate whether the research has reached expected standards. For example, none of the evaluation reports and only one of the panel presentations included citation statistics. Normally, understanding the criteria by which research quality is rewarded in a department provides a better understanding of the quality

and strategy of the department than does a report of their regular activities. The lack of explicit goals and criteria reflects the lack of such tradition in executing research policies, and also reflects a research culture in which such goal setting and measurement is not a regular administrative duty, and in which agreeing on such measures may be difficult or alien. A cultural change should be effected by promoting policies that require such statements as part of research allocation and promotion decisions.

13. Increase research funding and decrease understaffing at the departments

The Norwegian research system within ICT is plagued by the same problems as plague many other nations. Due to the rapid in demand for undergraduate and graduate teaching, inefficiencies exist in allocating resources to growing areas within universities, to ad hoc measures to educate the required number of PhDs, and noncompetitive salaries, the field is struggling to maintain adequate levels of research, and also to maintain adequate levels of competent people while obtaining new ones. This is aggravated by the lack of strategic and long term research funding. It is simply a wonder that some research groups and departments perform as well as they do. Most of these issues are beyond the control of department heads, and competent research managers in the groups — they can only adapt to them through some means like finding funding from industry, arranging possibilities for working abroad, and so on. The responsibility for overcoming serious structural problems in available research funding, salary compensation, and the amount of faculty lies within the national educational and research system. Policy makers within the university system and those who set directions and execute research policies must understand their responsibility. If they want to achieve world-class results in a fast growing and strategically important field like ICT, they must also provide adequate means to achieve them. Therefore the funding for educating the expected number of ICT personnel and the funding for ICT research should be seen as a national urgency. As a first step, Norwegian research levels should be made equal (per capita) to those of its Nordic neighbors — Sweden and Finland.

A general impression is that the lack of adequate sources for external research funding based on assessment of general scientific quality rather than initiatives in special areas is a severe weakness in the Norwegian system. In particular, this means that it is difficult for successful research groups to expand and build critical-size centers of excellence. Thus the balance between external and internal funding ought to change in the direction of an increased share of research funding being distributed after national peer review rather than by the universities themselves.

14. Align incentive systems that recognize excellence

The Norwegian research system does not currently recognize and reward world-class research and research groups, as it should. This means not only providing adequate research funds to excel; it also deals with how talented people are compensated. More flexible and performance-based compensation schemes should be made available and installed to reward world-class performance.

15. Increase PhD education

The output of PhDs within Norwegian research system is not at the adequate level to meet the demands of replacements, growth in the field and emerging demands of the industry. This requires more active measures in funding made available for the departments, and more systematic organization and management of PhD education.

16. Increase awareness of the national benefits of PhD education

One future market for PhDs in the ICT area is Norwegian industry and business. We saw several examples of the increased interest and awareness among industry to hire and promote PhDs. There is, however, a large portion of untapped potential to place more PhDs into industry and also to improve the funding from industry to extend the PhD education. To this end departments should market their PhDs more actively to industry and there should also be national policies that improve the placement of PhDs into industry. This is not only a benefit for the universities; it also directly benefits the competitiveness and capabilities of the Norwegian industry.

5 Conclusions

We propose the following major steps to strengthen the Norwegian research within the ICT area:

- Increase the staffing at all levels of the ICT field and set minimum staffing requirements for all student cohorts. Provide direct support for strategic fields like ICT for expanding and maintaining their educational programs.

- Enable more competitive market-based salaries for starting PhDs and all faculty members in the ICT field (this has been implemented in some areas already).

- Develop university level or specialized national funding for doctoral programs in strategic areas to increase PhD output.

- Develop better and more flexible incentive systems which recognize world-class performance in research and PhD education in salaries, teaching loads, and research support. These should be installed as part of the strategic allocation of resources and goal setting for universities and departments.

- Increase long term and strategic research funding through university level allocations or through direct funding from the NFR. This research funding should focus on maintaining and increasing the research competencies and skills of Norwegian ICT in the long term (ten years). The research funding should be divided in a way that maintains a healthy balance between different areas of ICT and should be based on criteria used in specific fields. The reports included some bitterness towards other departments and NFR because the funding was seen to be short term, and biased towards specific areas of ICT or towards specific types of ICT research. These statements can and should be interpreted as a serious signal of a failure to communicate directly the criteria by which research funds are allocated, or a failure in executing fair resource allocations. If so they should be recovered by changing these policies and improving the transparency of decision-making.

6 Evaluation of Research Groups and Departments

The following sections summarize the evaluations of the departments and research groups based on information provided as of April 23rd 2002. For every department and group a summary of its research profile is given, followed by an evaluation and recommendation. The grades are relative and should not be directly compared with other NFR evaluations. The grade *excellent* indicates work that is equal to or comparable to the best international research in the area. The state of ICT research in Norway is of good quality, which gives an above average overall grading.

7 Norwegian University of Science and Technology

Faculty of Physics, Informatics and Mathematics

7.1 Department of Computer and Information Science (IDI)

Department summary

IDI is the largest IT educational program in Norway, providing 30% of all ICT university-level teaching in the country. Approximately 50% of the teaching in the department is in service courses, with 1,125 full-time students served in 2000. With 3% of faculty resources, and 5% of Norwegian University of Science and Technology (NTNU) budget, IDI carries 11% of the NTNU teaching load. The Department, like NTNU overall, is set up around its teaching mission, not around its research mission. The four Divisions of the IDI contain ten separately presented research units. These units were all physically united in 2001 in a renovated building, providing new opportunities for collaboration. The NTNU engineering IT degree is the only Norwegian program requiring majoring in math and physics from high school and students are recruited extremely competitively.

The understaffing, as evidenced by the data above, is quite severe, both relative to the rest of NTNU and in international comparisons. Many of the 40 faculty members in their personal statements complain that this inhibits their research progress. The Department has made the wise short-term decision of hiring temporary instructors when they can afford them, rather than hiring less-than-internationally-competitive permanent faculty, to ease this shortage. The Department has a goal of reaching a faculty size of about 60. There does not seem to be any standard funding formula tied to teaching service courses that will automatically correct the imbalance of resources relative to the teaching mission. The Department has good diversity for an ICT academic unit, with 20% women. There is also considerable international diversity for a Norwegian academic unit.

IDI has about 50 Norwegian industry collaborators, many concentrated in the local research parks. This is a remarkably well spread technical influence for a group of about 40 faculty. Several current faculty members have, in fact, started companies. Industry has reportedly asked NTNU to double the number of IT MS graduates from 200 per year to 400 per year. “Fra innsikt till industri” (“from insight to industry”) is a motto of the department. There is a good climate in IDI for founders and for collaboration with industry. There are many instances of companies founded during the last few years. A large number of staff members are founders and this experience is a strength for the students. The Department sees a need

to train more doctorates and to recruit them as native Norwegians, for retention in a national academic system that does not have high wages on an international scale.

Trondheim being a center for medical informatics, NTNU has launched a program of teaching in bioinformatics, in conjunction with the medical school, to position itself for a 300 MNOK program to be launched by federal government. The Department has three strategic areas for growth: bioinformatics, health technologies, and ICT in learning systems. Three of the groups described below cooperate in the area of bioinformatics. There are also ties to other departments at NTNU, especially biology.

Doctoral stipendiats are currently awarded for three years. The PhD period can be extended to a fourth year as a teaching assistant; then a candidate is in principle "up and out" beyond four years. The average is, in fact, 4.5 years. To hasten the doctoral degree, the department is currently moving to a three-person doctoral committee per candidate, rather than just a primary advisor.

The Department provides small financial incentives for publication, including conference travel allowances. There is a policy of awarding sabbaticals every six years, to encourage international networking – a good policy. There is an effort to locally organize international conferences in Trondheim – to increase international visibility and exposure of students to the international community. Like most ICT faculty throughout the world, IDI faculty tends to concentrate their publication in international conference proceedings.

While private partnerships have proven successful for the department, public research grants are much more important to the morale and long-term research outlook of young faculty, and these have been scarce in ICT in Norway (outside of IKT2010) during the past ten years, due to the Research Council's emphasis on short-term industrially oriented research programs.

7.1.1 Algorithm Construction and Visualization Group

Group summary

This group of 5 faculty members (1 professor, 1 associate professor, 1 assistant professor, 1 adjunct professor, and 1 adjunct associate professor) regularly offers ten courses. Some of these courses in visualization are especially popular with students. It currently supports three PhD students, which can be increased. The group works on algorithms for search engines, information retrieval and telecommunication, and visualization. There is some domestic industry and international academic collaboration. Commercial and professional activity is frequent; however, publication in archival journals is rare outside of one faculty member. The faculty members have gone in and out of industrial assignments over their careers, which may be useful experiences for students to draw upon.

Fastsearch (fastsearch.com, alltheweb.com) websearch software, which originated in the group, now has a 2.4 GNOK market valuation. It also has offspring technology: the Interagon system in bioinformatics

One member of the group was part of the team that won the 1996 ITEA prize for commercialization of a university project, for his work in a project on ultrasound. (There is one such prize per year for all of Europe.)

The impressive RAVE visualization lab is an important attraction to students. There is some hint that the effort required to set up a visualization laboratory, and the price in terms of lack of publications, does not get the recognition that it deserves within the department. The RAVE facility has the potential to serve many departments through NTNU, in training students and in research.

Group evaluation

This group is to be strongly commended for several software highlights and also for productivity in teaching computer science, with popular courses. It has achieved a lot with relatively small faculty mass.

Grade: very good

Group recommendation

For stronger recognition within international academic circles, the members of this group should make a priority of increasing their scholarly publications. One way to achieve this in the immediate future is likely to flow naturally from their recent software productivity – through research collaborations with users from applied sciences and technology.

7.1.2 Computer Architecture and Design Group

Group summary

The emphasis in this group is evolvable hardware (the CAOS project) and parallel architecture (the BSPlab project). There are 3 faculty (1 professor, 1 associate professor, and 1 lecturer) offering 9 courses. There are 4 active PhD students.

The biological projects (in conjunction with the Knowledge Systems Group) are noteworthy and the main source of international scientific collaboration.

The building of the RENNS multiprocessor provided a commendable educational experience for the students.

The BSPlab project promotes a useful and elegant parallel computing model; however, it is not clear how much further it can be pushed as a research topic. This should now be regarded primarily as an educational activity.

NTNU has a new SGI system, one of a sequence of machines upgraded regularly as a national resource. (A Paragon, and two Cray machines preceded this machine in the past.) Norwegian weather forecasting is one of the sponsors and users. The Computer Architecture and Design group could well play a more major role in promoting parallel computing technology throughout the university.

The group has expressed a wish for technical staff for the HW lab for the last 10 years. Such support can well be justified for its teaching function; research users can be asked to budget their own operational expertise.

Group evaluation

The primary research accomplishments of this group are in experimental activities that are rooted in the last wave of hardware and software architecture, or whose extensions would seem to require much larger critical mass and hardware resources than it is reasonable to assume being added in the near future. It does not possess a strong central focus beyond its role in maintaining parallel facilities and providing training and consulting for the same.

Grade: good

Group recommendation

The group might be well advised to maintain its important "service role" in providing cycles and training, while focusing research priorities on just one or two innovative areas that it has a chance to be among the leaders of, nationally and internationally. One such area may be in computational biology, biotechnology, and bioinformatics. In addition, for the service role it provides, it is reasonable to request that the university add a full-time (or at least half-time) parallel systems staff member, so that faculty need not be constantly burdened with systems-related issues that do not directly play into their research.

7.1.3 Database Systems Group

Group summary

The group has 7 faculty members (4 full professors, 2 associate professors, and 1 adjunct professor) and 1 post-doc. It supervises 7 PhD students. The group has recently doubled in size by recruiting several scientifically highly qualified professors from industry. Some of these recruited professors have very good publications in primary database conferences and journals. This has strengthened the group and makes it very solid and adequately staffed.

The group has a long tradition in research on basic database technological issues such as efficient relational algebra interpretation, distributed databases, transaction processing, etc. It has also been involved in applying database techniques in various areas such as multi-media and geographical databases, cooperative systems, etc.

It is an internationally well-known database group. The group has mutual exchanges with well-known database research institutes. The group is bidding to host the scientifically very respected conference VLDB 2005.

It has a good publication record in the international scientific database literature, with several publications in the conferences VDLB, and ICDE, which are high quality scientific conferences, comparable to the primary journals on the subject.

The group has an excellent record on industrial technology transfer. During the recent years the most notable achievement was the development of the ClustRA distributed database system with very high performance and availability. ClustRA is now sold to SUN Microsystems.

The group teaches many courses (ca 17) in areas of database technology, distributed systems, operating systems, high availability, etc. These are all very important and central areas in computer science with many important industrial applications.

Group evaluation

The group is solid, internationally well connected, has many quality publications, teaches important subjects, and has been very successful in establishing industries based on the research.

Grade: excellent

Group recommendation

Given the size of the group with many highly qualified members, the group should be able to produce even more high quality publications. It should also be possible to increase the number of PhD students to reflect the extended senior staffing.

7.1.4 Image Processing Group

Group summary

This group has 3 faculty members (1 professor, 1 associate professor, and 1 assistant professor). It teaches seven courses and has five active PhD students.

The faculty in this small group address a variety of topics in image processing, as individually led, including pattern recognition, multisensor fusion, medical ultrasound, and a project entitled “The Body in Motion.” There is a knowledge-based flavor in much of the work, and there is also collaboration with the CAOS project of the Computer Architecture and Design group. The faculty investigate both scientific and cultural/digital entertainment applications. Hierarchical representation of visual images is a recently started focus, and an important one from the perspective of inhomogeneous computing systems and networking.

The group has active collaborative ties at other universities, including regular international exchanges, and some have consulted with industry.

One member of the group maintains over 250,000 lines of C code in his image-processing library. As elsewhere, the writing of software seems less appreciated than papers. There is not a great deal of archival publication in the group.

Group evaluation

This group is small in absolute terms, yet has among the better teaching and doctoral student ratios, as well as a good record of scientific outreach. No one project has emerged as a "signature" topic within the wide area of contemporary image processing – one by which the department would be widely known.

Grade: good

Group recommendation

The high productivity of the image-processing group cannot substitute for archival publication and conference presentations as a means of achieving further growth and international rating. These it ought to pursue.

7.1.5 Information Systems Group

Group summary

The group has 6 faculty members (2 full professors, 1 associate professor, and 3 adjunct professors). It has seven PhD students and teaches 11 courses. The size is adequate and the group works in a cohesive manner. Academic leadership is evident under a defined research strategy and operational plan.

The group has a long tradition and is one of the top groups in Europe in Information Systems Engineering. Its main focus has been on conceptual modeling of information systems and this remains the core activity of the group. Currently the research is oriented towards semantic Web information systems modeling, structuring model repositories and developing access facilities using formal domain ontologies.

The publication records of the group is excellent; the group publishes in average 10 to 15 publications per year including publications in leading conferences and high quality journals. Since 1989, the group has produced 17 Dr.ing. Theses.

The group is internationally well known and connected; it plays an important role in the IFIP Working Group WG8.1 on Information Systems Design, in the VLDB foundation and in the foundation of the CAiSE series of Conferences. Group members also serve as key

officers at well-known conferences in the field (ER, CoopIS etc.). During the 1990's the group participated actively to ESPRIT projects. Since 1996, and the change in EU funding policy, the group is using mainly national funding. It co-operates with industry that provides fellowships in addition to the ones provided by the projects funded by the Norwegian Research Council.

Group evaluation

One of the strengths of the group is the consistency of the research approach, which has led to the formation of a center of competencies in conceptual modeling of information systems from a large number of perspectives. Another strength is the integration of model development with formal foundations and construction of software tools that are applied to various applications. The group's research activity has varied over the years due to inadequate staffing, shifting research focus and huge teaching load.

Grade: very good

Group recommendation

The group has the potential to reach world-class excellence if adequate and continuous funding is provided, if the group maintains a sharp focus, and if new young researchers can join the group.

The committee recommends publishing more systematically in journals, to seek international cooperation and develop long-term industrial contacts.

7.1.6 Knowledge Systems Group

Group summary

This group of 4 faculty members (2 professors, 1 associate professor, and 1 adjunct associate professor) offers nine courses and currently has eight active PhD students. The group has good international contacts, and is very healthy in terms of educational productivity, research productivity, and archival publication. One of the group's PhD students was recently nominated for the best doctoral thesis within Artificial Intelligence in Europe; another is now teaching at Harvard Medical School.

Data mining, particularly in bioinformatics, is a focal point. In cooperation with Warsaw University, a data mining toolkit has been designed and implemented. This Rosetta toolkit is a popular international download with 3,600 users worldwide. In another project in cooperation with the Norwegian Cancer Hospital, The PubGene tool for browsing gene-to-gene interaction networks has led to a publication in the high-prestige journal Nature Genetics and a company has been setup by the former PhD student.

Much of the research of the group grew out of logic programming, in particular the subfield of partial deduction. This group is one of three in the department that cooperates in the area of bio-informatics, which is one of the department's strategic initiatives. The university-wide microarray data analysis laboratory is here.

A priority for further support is technical staff for the experimental program.

Group evaluation

The leading researchers in the group are very productive and internationally well established in dynamic areas such as data analysis/computational biology and agent technologies. Activities include an internationally leading position in rough sets and successful implementation of tool systems such as Rosetta and Agora.

Grade: excellent

Group recommendation

The group has broken new ground in its area of research and established fruitful contacts and co-operation with other disciplines. It has been extremely productive in terms of students and scholarly metrics. However, the success of the group is heavily dependent on individual researchers and care should be taken to secure long-term stability of the group. The group should be supported in its efforts to overcome the difficulties caused by their leader being on the move. It is strongly recommended to attempt to build upon the Rosetta project through appointments to this group or by strengthening collaborative ties, or it is at risk of being captured, due to its "marketability" in the burgeoning area of bioinformatics.

7.1.7 Software Engineering Group

Group summary

Group summary

The group has 4 faculty with two full and two associate professors. It has also 2 post-docs. It has 6 PhD students and teaches 10 courses. The size is adequate for its current research direction and teaching responsibility.

The group has a long history in software engineering. Over time, it has progressively moved from 'hard' issues such as versioned databases, process modeling and enactment to 'softer' issues such as process improvement and empirical studies. It has also moved its focus from fine grained to coarse-grained software components. Currently the three key research issues are software architecture, software quality and co-operative aspects of software development.

The group has been one of the leading groups in Europe on process-centered environments. It has an impressive publication record: 49 journal papers, 18 book chapters, 6 edited books, 255 refereed conference papers and 85 miscellaneous publications. The group has produced 7 Dr.ing. Graduates since 1996. The group co-operates with Norwegian industry and SINTEF as well and has been involved in a number of European projects. It has recently started cooperation with Simula institute and University of Oslo (prof Dag Sjøberg).

Group evaluation

The past performance over the ten years is excellent. The research work in process modeling and enactment was in its time ground breaking. The group demonstrates its ability to work in a co-operative manner for building innovative software solutions based on sound theoretical basis.

Grade: very good

Group recommendation

Given the shift of the group's research focus it is quite early to tell whether it can perform on the same level as before. First, there is a risk that the research can diversify into too many areas and it will loose depth and coherence. Second, the group has to obtain research skills that match with the new research directions. Third, there is a risk for too industry driven research. The committee recommends taking active measures to mitigate these risks. So far, the group has been capable of securing the necessary competences to carry out the projected research. Managing this situation requires effective leadership and additional research funding which enables reflection and theory development.

7.1.8 Human-Computer Interaction and Systems Development Group

Group summary

The group has 4 faculty (2 full professors, 1 associate professor, and 1 assistant professor). It supervises 4 PhD students locally and in addition 7 PhD students affiliated with other institutions. The group has produced two PhDs during the last five years. The group teaches courses in a diversity of areas, for instance Software Engineering, "ICT, Culture and Society", Pedagogical Software, Human-Computer Interaction and also in System development work and organizations. There are relatively few publications in some of the areas covered by the group, but with a good spectrum. This is not really an HCI group, but there is some activity in the area and some good research reported in international publications. The most important activity in the group is the area of large-scale integrated systems with studies of the socio-technical interplay of development, use and subsequent uptake of information systems in organizations.

Group evaluation

The group is diversified with no coherent research focus, although there is a potential for an interesting blend of HCI and learning as an important aspect. The work on of large-scale integrated systems is of particular interest.

Grade: good

Group recommendation

The present direction of research in the group does not have a clear focus. It might be reason reconsider the group structure and possible connections to other groups in the department. In particular the work on of large-scale integrated systems should be continued. The area of HCI and interaction design is presently underdeveloped and needs to be strengthened.

7.1.9 Artificial Intelligence and Learning Group

Group summary

The group has 6 faculty (2 full professors, 2 associate professors, and 2 assistant professors). It supervises 8 PhD students. The group teaches courses in a diversity of areas, for instance AI and machine learning, but also in more general areas such as programming, operating systems, etc. There are an appropriate number of publications, especially in the fields of case-based reasoning, evolutionary programming, and machine learning.

The common subject of the group is learning in machines and humans and the goal is to produce useful software and shed light on interesting scientific questions.

Group evaluation

The group has an established position in case-based reasoning and growing activities in intelligent learning systems and artificial life. There is a good mix of theoretical and application based research. It has impressive results in applied projects such as oil drilling and medicine.

This is a comparatively large group with international visibility in, for instance, case-based reasoning. There is also good work in living/intelligent systems and mechanisms for learning, though people in the group seem to cover quite a broad area of interests.

This group covers a lot of ground and does it well. As is often true with AI topics, the theoretical going is tough and requires long-term investment. The blend of theoretical and practical issues is appropriate for the environment in which this group is functioning.

Grade: very good

Group recommendation

We approve the plans to move together with the other groups in intelligent systems, including image processing

7.1.10 Information Management Group

Group summary

The group that was established in 1996 has 2 faculty (1 professor, and 1 associate professor currently on leave). This is an inadequate size for a group unless the group can fill in the two vacant positions. It has 1 PhD student and is responsible for 4 courses.

The strategy of this group is to develop in Norway a research group on digital libraries, which has an international recognition. The chosen research subject is topical and fits well with other areas like database research, text-based retrieval and system modeling.

The group has established an international connection with European and American teams in the field. It has been involved with several European projects and is currently involved in the Delos network of excellence on digital libraries.

Group evaluation

The topic fits well with the overall research activities of the department and is also fitting in the research map of the country. The group has established international relationships.
The weaknesses are a lack of clearly defined research program and insufficient human and financial resources. With the current size, the group is not viable.

Grade: good

Group recommendation

Maintaining research competence in the growing field of digital libraries is critical for Norway in a national scale. Therefore, the committee recommends that the department mandates the group to develop a systematic research program for digital libraries and integrate this with hiring decisions and a resource plan. If the group cannot meet its requirements in a short term, the group should be integrated in another group of the department.

Faculty of Electrical Engineering and Telecommunication

7.2 Department of Telematics

Department summary

The Department of Telematics was created to meet the need to provide a broad education in telecommunication technology, services and economy at the MS (sivil ingenior) level at NTNU. This application orientation is unusual in academic institutions, but the department has been successful in attracting MS students and in meeting an industrial need for graduates with strong skills and experience in telecommunication services.

From an educational viewpoint, the department is therefore a success, although it seems to not be as attractive to students as the Department of Computer and Information Science. The educational success has, however, not lead to strong research. The group lacks a clearly stated research vision and scientific leadership. The research production of the academic personnel in the department is well below the average of other ICT groups at NTNU, and the publication rate is unacceptably low even when one considers the inherent difficulty of publishing in areas outside traditional areas of inquiry.

Department evaluation

The Department has a strong educational program, but lacks scientific leadership and focus. The scholarly productivity and publication rates are unacceptably low

Grade: fair

Department recommendation

The committee's recommendation is that the Department of Telematics continues in its present form as an educational unit, but that it is restructured as a research group. Within the newly reorganized faculty structure at NTNU, the researchers now in Telematics should join research groups in the Department of Computer and Information Science and the Department of Physical Electronics. If properly executed, such a reorganization of the research structure will provide focus, scientific leadership, and create groups of critical mass better able to confront tomorrow's research challenges.

7.3 Department of Telecommunications

Department summary

The department consists of three groups: Acoustics, Radio Technology, and Signal Processing. It has 21 faculty (10 professors, 5 adjunct professors, 5 associate professors, and 1 assistant professor). The total number of graduate students is 35. During 1998-2000 they graduated 22 PhD or similar. The ratio of external grant to total grants is approximately 33%. Their activities represent a good combination of applications (acoustics & radio) and fundamentals (radio & signal processing). They have some collaborative research projects and with a good potential for that also in future.

We find it somewhat difficult to motivate the current organization. From a telecommunications point of view, the acoustics department is disproportionately large, and they also have many activities that are not directly telecommunications. More importantly though, we find that the department structure within the faculty can be improved and such a process seems to be under discussion. The reorganization represents an opportunity to create a more cohesive structure. The current structure seems to be based on educational needs rather than research needs. Instead, we feel it is more appropriate to have an organization that fulfills the research needs, and to keep the responsibilities for the educational programs at a faculty level. It is important that the educational program serves the needs of the students and not primarily the desires of the departments and groups. It seems that currently there is disagreement over the educational programs which has a negative impact on the research results. Our overall advice would be to merge physical electronics, telecommunications, and the telecom part of telematics, while the computer science part of telematics could be merged with computer science. We believe this would make a strong research organization. On the group level, we recommend that the new group structure is based on units that can develop a unifying vision for the research direction.

The research collaboration between the groups seems to have been quite small previously. However, the department has a number of ongoing and new projects which indicate that the level of collaborative activity and publications rate will increase in the near future. This is highly appreciated by the committee.

7.3.1 Acoustics Group

Group summary

The national acoustics laboratory has a long history, and includes electro-acoustics, underwater acoustics, building acoustics, musical acoustics, ultrasound, noise, and vibration. It is the largest R&D acoustics group in Norway with 5 faculty (3 professors, 1 adjunct professor, and 1 assistant professor). The group maintains extensive and diverse experimental laboratory facilities. There is a regularly offered graduate course in numerical acoustics, and the Group maintains a finite element acoustics code. However, there are no parallel computer users in the simulations; they run on local workstations. Altogether, there are four undergraduate and two graduate courses taught each year. There are approximately 10-15 students per year for final-year theses. There are currently 2 post-docs and 6 PhD students. There is a sense in the group that the size and quality of the field of doctoral applicants is decreasing.

The group covers an impressive range of practical topics with relatively few people. There appear to be three offshoot commercializations (Morset Sound Development – for measurements, NACRE AS for military wireless ear pieces, and Silence International AS – for active noise control of engines). There is a commercial collaboration with Digital Audio Effects (virtual instruments). There is a diverse range of scientifically innovative (e.g., sound data mining) and socially beneficial (e.g., road noise reduction) projects, as well as commercially useful activities, such as the use of sound in seabed reservoir characterization (with SINTEF).

The professors have taken international (e.g., CNRS, Waterloo, Kobe, ARL, NATO) and federal visiting assignments. They have published somewhat in good archival journals, e.g., in *J. Acoust. Soc.,* and are active in conferences. Like other groups in Telecommunications, important members of the group are close to retirement. There is a need to recruit junior successors. (The current assistant professor is not a junior faculty member in the same technical tracks, but an accomplished musician/composer with specialized acoustics expertise.)

This group is a strategic complement to the usual E&M composition of a Telecommunications Department and is a national resource. In fact, this group is one of 40 nationally in the second-round in the National Centers of Excellence competition. (This follows a down select from 130 applicants. There will be approximately ten centers awarded ultimately.) The acoustics group hopes to be awarded approximately 900 000 NOK/year for ten years from the NRF under this initiative.

Group evaluation

The acoustics group has a well-focused and internationally recognized research program, and the researchers in the group are active in international collaborations. It is a strategic complement to the usual E&M composition of a Telecommunications Department and is a national resource.

Grade: very good

Group recommendation

The acoustic group should continue their tradition of very good research and active participation in international collaborations. As in other groups in Telecommunications, important members of the group are close to retirement. There is a need to recruit junior successors. Moreover, as acoustics is a computational application that has an insatiable appetite for resolution (due to its wave nature, which requires fine resolution everywhere for acceptable accuracy over required timescales), the group may wish to give some attention to developing a parallel simulation capability to accompany its other excellent research modalities. This direction could be a good one in which to reinvest faculty resources as retirements occur, and would lead to synergisms with other groups at NTNU and elsewhere in Norway and the rapidly growing international simulation community.

7.3.2 Radio Systems Group

Group summary

The radio technology group consists of 9 faculty (3 professors, 3 associate professors, 1 professor emeritus, and 2 adjunct professors) and 2 post-docs. It supervises 5 PhD students. Their areas include radio communication, radio hardware design, antennas, navigation, radar, and remote sensing. They teach courses in radio communication, navigation, remote sensing, microwave, and antenna theory and techniques. The have an antenna laboratory and laboratory equipment for radio frequencies.

We notice that the group has a low publication rate in spite of the attention the field of wireless has received over the last decade. Of the publications that have been made, too few are in good international journals. One reason for this might be the quite low number of PhD students in the group and the lack of major research projects that they have had. Currently they are involved in at least one major research project together with the signal processing group (Wideband radio access). We strongly recommend this group to get involved in more major research projects, such that a larger number of PhD students can be funded and educated. The major results of their research should be published internationally, not only at conferences but also more importantly in good international journals. In this way it is more likely that the group will have some impact on the radio technology area, which seems to be missing currently.

The three professors of the group are all above 60 years of age and the group is facing the situation of having to replace them. We get the feeling that there is still not solid strategy for how this replacement is going to be done, and we strongly advice the group and the department to work our such a strategy. The department has a list of wanted areas for new professors that include replacement of these three professors, but it was clear that this was only a wish list. Since the final decisions on professors are taken at the faculty level, it is important that the work needed to obtain decisions that are good for the department and its activities are started very soon. We also got the impression that the supply of well qualified candidates for professor positions played the major role in deciding which areas to proceed with, but we feel that it is more important to think of the areas needed to build up a strong research group that can support the educational programs.

Group evaluation

The group has a low publication rate and too few publications in good international journals. They have a low number of PhD students and take part in few projects. The group is facing a generation shift, which might become a severe problem. However, this group covers a lot of topical ground in areas important to Norway.

Grade: good

Group recommendation

We strongly recommend that this group get involved in more major research projects, such that a larger number of PhD students can be funded and educated. The major results of their research should be published internationally, not only at conferences but also more importantly in good international journals. In this way it is more likely that the group will have some impact on the radio technology area, which seems to be missing currently.

7.3.3 Signal Processing Group

Group summary

The signal processing group consists of 8 faculty (4 professors, 2 associate professors, and 2 adjunct professors) and 1 post-doc. supervising 13 PhD students. Their research areas include information and coding theory, speech and image processing, general signal processing, and digital communications. They teach about 10 undergraduate courses every year, mainly in the Communications Technology program. The major research projects are spoken dialog systems, wideband radio access, bandwidth-efficient adaptive transmission schemes for wireless multimedia communications, turbo codes, access network technologies related to UMTS, universal multimedia access for wires and wireless systems, universal access to multimedia portals, and inverse multiplexing of VDSL systems on copper cables.

The group has a rather good production of PhDs and publications. The number of publications varies from many to quite few over the group members. However, we think that the number of publications in international journals is too low for all group members and certainly recommend the group to improve on this. Each PhD dissertation should lead to at least 3 journal papers on average, as a benchmark to strive for in top research groups. One argument given for the low number of journal papers was that PhD students write monographs, but we do not see that this is a restriction. Also with monographs, the included work can be published either before the dissertation or after, and this is done at most other universities where students write monographs.

The group is collaborating with several international researchers and research groups and also a number of companies.

Group evaluation

This group is significant in size, in its topics, and in the magnitude of its scholarly activities. The group has a large potential that is currently partly unused. It is active in a number of interesting and important projects, but the outcome in the form of publications in international journals is far too low. The group also seems to lack the international and national cooperation that their area deserves. The group also seems to lack a plan and clear goals for the future.

Grade: very good

Group recommendation

A larger number of journal papers would be advantageous for the group when they apply for research projects with peer reviews, since journal papers are normally considered more important than conference papers in this field. Some additional collaboration with other academic groups in Norway would be an advantage both for the group itself and also for the other research groups in Norway. With a better planning and the development of clearer goals for the future, we anticipate that the grade of this group soon becomes excellent.

7.4 Department of Physical Electronics

Department summary

The Department of Physical Electronics has strong programs in traditional electrical engineering and applied physics disciplines. The Circuits and Systems group, together with the group at UNIK, is focusing on VLSI design and test, mixed signal design, and device modeling like electronic circuit design. The researchers in the electric and optic materials and components group are active in long-wavelength semiconductor laser fabrication technology, functional thin films, and surface acoustic wave devices. This group runs several advanced laboratory facilities, including an electron spectroscopy laboratory, clean rooms for microfabrication, and a Molecular Beam Epitaxy facility for growth III-V semiconductor thin films. The photonics group is working in the fields of medical applications of lasers and in fiber optic communication. A potential area for growth of the department is fiber optic systems and networks. Increased emphasis in these areas would also tie the department closer to other ICT groups at NTNU and elsewhere.

The research activity in the focus areas is strong in the department, with all members of the department publishing in the best journals in their respective fields at satisfactory, but not exceptional, rates. The extensive network of national and international contacts of the faculty is a very significant strength considering the geographical isolation of NTNU. The collaboration with UNIK is particularly important in that regard.

The department is successful in attracting both MS and PhD students, with student-to-faculty ratios which are roughly average for NTNU. The department is, however, the steward of several very sophisticated laboratories, which are expensive to maintain and operate. Given the funding structure at NTNU ("funds follow students"), an average number of students are therefore not adequate for this department, and the faculty members should make every effort to increase the numbers of students at both the MS and PhD levels without increasing the academic staff. This will lower the percentage of the department funds that are spent on faculty salaries, and free up funds for research and equipment.

The external funding level in the department is fluctuating from year to year (14% of the budget in 1999 and 39% in 2000), and seem to be generally too low to allow full utilization

of the experimental facilities. The department should find ways to increase external funding and broaden the user base for its facilities.

Most of the professors in the department got their advanced degrees from the institution where they now work. This is not unusual in Norwegian universities and it is understandable, given the limited number and size of technically oriented universities in Norway. Nevertheless, academic inbreeding is a potential problem for continued academic vigor of the department and should be addressed in future faculty recruitment.

7.4.1 Photonics Group

Group evaluation

This is a very strong group with outstanding research contributions from all members of the group. The research conducted in this group is on the highest international level and the publication record is quite good.

Grade: very good

Group recommendation

The group is relatively small and perhaps it would be better to focus its resources rather than divide them on two fields, as is presently the case. Several members of the group are approaching retirement age and the department has an opportunity to decide if it wants to continue to support two different areas of research in photonics, or if it should focus on one. If the latter alternative is chosen, fiber optic communication seems like the natural choice, but biophotonics and medical applications of optics are clearly also important growth areas.

7.4.2 Electronic and Optic Materials and Components Group

Group evaluation

This group's research achievements and publications are on a high international level, and the publication record is very good across the group. As is the case for the Photonics group, this group has a majority of members with advanced degrees from NTNU.

Grade: very good

Group recommendation

This group is primarily responsible for the experimental facilities within the department, and must therefore increase its external funding, as well as the percentage of internal funds that are available for research and equipment.

7.4.3 Circuits and Systems Group

Group evaluation

The research in circuits and systems group in the Department of Physical Electronics span a wide range from fundamental research at the highest academic level to very application-oriented research, which in some instances is better characterized as product development. The publications of the group mirrors this wide range of activity, with some of the members of the group having very good publication records over a long period of time, but others that are not publishing at a sufficiently high rate. External funding and the industrial contacts created by this group are very good.

Grade: very good

Group recommendation

There seems to be good potential for increasing the funding as well as the number of projects and PhD students even further. One of the challenges this group must face is to identify external projects that are of a fundamental nature, and avoid projects that are focused on product development.

7.5 Department of Engineering Cybernetics

Department summary

The department consists of three groups: Motion Control, Process Cybernetics, and Industrial Computer Systems. Two of the groups are research oriented; one has more the character of a support group, bringing in knowledge of computer implementations in different areas. The twelve professors with 33 PhD students are engaged in a wide variety of activities, ranging from basic research to product development.

7.5.1 Motion Control Group

Group summary

Two professors and four staff are working with 10 PhD students in many different areas of motion control.
Methods for modeling and nonlinear control of mechanical systems, with special emphasis on maritime systems, are the focal point of the activities. Work ranges from basic studies in non-holonomic systems to applications. The group is well integrated nationally and internationally. It operates a laboratory for testing of control systems.

Group evaluation

This is a very active group with widely visible results. It has an outstanding achievement with many publications in the best journals in the field and several prizes.

Grade: excellent

Group recommendation

The group is encouraged to continue the development of methods and methodologies ranging from basic theories to practical applications.

7.5.2 Process Cybernetics Group

Group summary

Three professors are supervising 10 PhD students in the area of process modeling and control. Modeling and identification for nonlinear models and on-line optimization in control applications are the most important topics. OO-modeling, fault detection, and applied research in process industries are additional important topics. The group is very well recognized at the national and international level and has excellent contact to both the university and the industry sector.

Group evaluation

The group has an excellent publication record with several prizes. It is internationally known as a top group in the areas of modeling both from data and from first principles. Three spin-off companies have been formed out of the activities of this group.

Grade: excellent

Group recommendation

The plan to move more into the fields of natural gas and energy products is supported.

7.5.3 Industrial Computer Systems Group

Group summary

This group is headed by three professors. Work is done in different areas: industrial computer systems, safety, real-time and embedded systems, wearable computers, operating theatre, underwater objects, robotic prostheses, energy production, and aqua cybernetics (fisheries, aquaculture, sea ranching etc.).

Group evaluation

The group is actively and successfully building devices and systems in a wide area. The group seems to treat mostly problems that appear in these very different fields; it does not seem to have many international contacts.

Grade: very good

Group recommendation

The group should make efforts to become more visible internationally by establishing networks and by putting more emphasis on publications.

8 University of Bergen

Faculty of Mathematics and Natural Sciences

8.1 Department of Informatics

Department summary

The Department of Informatics has24 faculty divided into six groups. Noticeably, in contrast to some self-reported difficulties in other ICT groups surveyed, this group seems to be able to recruit faculty at an internationally high level of quality, from many applicants, when they have vacancies. They have had ten such vacancies in recent years – a chance to restructure their research focus, which they have exploited well, responding to suggestions from the 1992 international review. They draw and graduate excellent students and are a magnet for international collaborations in all areas and industrial collaborations in some areas. More than half of the department's research activities are externally supported. This support is understandably concentrated more in areas with ready industrial application (e.g., computational science) than in others that have maintained a more theoretical focus (e.g., algorithms). Overall, the faculty has zealously guarded its freedom to do basic research, while engaging in applied activities of choice and impact.

It is a conscious strategy at Bergen to achieve critical mass in a small number of areas (in this case, six) within the vast domain of ICT, in order to achieve international research visibility and reputation in each, rather than to be spread too thinly based on the needs of education alone. This is counter to the dominant strategy observed in Norway. They have succeeded in four of the groups already, and appear likely to succeed in all, as two are being built from youthful beginnings. Such a visible research center should make an effort in its next round of appointments to promote more diversity of gender on its faculty. (Only one of 24 permanent faculty members currently is a woman.) There are surprisingly few PhD students per faculty member, perhaps because of the theoretical orientation of the department.

The Department is a host to one of Norway's two principal supercomputer centers, Parallab, serving both academic and industrial users. They do not do computer architecture *per se*, but they are pioneers of algorithms adapted to advanced parallel architecture. They were also the first department in the Nordic countries to adopt Java as the main introductory programming language for undergraduates.

Some business ventures begun by faculty have materialized into highly profitable companies.

The faculty has no complaints concerning the teaching functions of the department. The teaching load was estimated uniformly as one course per faculty member per semester. There are many MS students. Counting student contact hours, they estimate that teaching requires about half of their time, the rest being dedicated to research. The overall spirit of the department was one of excitement, interdisciplinarity, and high job satisfaction, despite Norway's relative low financial rewards for the professorate. The only collective complaint of the faculty was that the department receives about 30% less per faculty member than other ICT departments in Norway for operating expenses.

8.1.1 Algorithms Group

Group summary

This group has 3 faculty members (1 professor and 2 associate professors), who are relatively newly appointed and young, after their internationally well-known research leader left three years ago. Corroborating with their self-report, those who remain are also visible internationally and collaborate extensively with top European and American colleagues. Their concentration is in graph algorithms, which arise not only in discrete mathematics but also in numerical analysis, where they describe sparse relationships and predict and model complexity in core operations, such as linear systems of equations. A particular interest of the group is the exploration of efficient algorithms for special graphs where, for general graphs, no efficient algorithms are known.

This group acknowledges that its theoretical interests are not readily fundable under the currently dominant NFR mechanism of IKT2010, but has decided to stick with its strengths, rather than adapting to trends heavily influenced from industry. Considering the history of industrially relevant fruits from basic research left alone for the long term, the review panel commends this approach, which is complementary to the philosophy of the ICT groups in the university colleges.

To make up for their small size, they host many visitors each year. They also hosted the latest instance of a major Scandinavian meeting in algorithms.

Group evaluation

The scientific level of the group is good. So far the scope has been narrow. The restructuring of this small group with new appointments since 1992 is progressing well. International archival publication is very good on a *per capita* basis and the group has the recognition of international specialists in its areas of concentration.

Grade: very good

Group recommendation

The study of efficient algorithms for special graphs will not offer enough material in the long run. Other topics are recommended for PhD students.

The current ratio of two PhD students for three faculty members should be increased for the long-term health of the group and for the educational experience for the students.

8.1.2 Bioinformatics Group

Group summary

This group was formed with faculty resources recovered from the previous group in Artificial Intelligence, in response to a recommendation from the 1992 international review committee. At Bergen, bioinformatics is the development and application of methods from computer science to solve molecular biology problems. Historically, the focus has been on algorithms for comparing biological sequences (DNA, protein, etc.) and search algorithms for sequence databases. Bergen's program in bioinformatics was the earliest in Norway and consists of 3 faculty members today (2 associate professors and 1 assistant professor). It has produced its first PhD and currently offers four courses.

Collaboration with Bergen's molecular biology department is very active, and there are international collaborations, including the U.S., Germany, and the U.K., the latter including adjunct professorships which were foundational in the early years of the group.

Two software packages developed at Bergen, J-Express and Pratt, have become widely used. J-Express is downloadable from the web pages of the prestigious journal *Science* and is the basis of a new company.

Group evaluation

This new group is charting an opportune course. Archival publication is good, with much international co-authorship.

Grade: very good

Group recommendation

Since resources will never be large enough within this informatics-hosted bioinformatics group to cover this entire rapidly expanding field, this group should continue its strategy of collaborating with local and international biology-hosted bioinformaticists. Commercial collaborations are appropriate and appreciated as a good source of future funding and valuable experience for students, but should not come to dominate the entire scientific enterprise of the group. Given the successful existing concentrations of algorithms and computational science at Bergen, this group should seek to make its contributions to

bioinformatics in a way that draws these other units in and exploits their complementary strengths.

8.1.3 Coding Theory and Cryptology Group

Group summary

The coding theory and cryptology group of 5 faculty (4 full professors and 1 adjunct professor) and 1 post-doc. may be the best ICT group of any kind in Norway and occupies a distinguished position in the international community. One of the professor positions is currently vacant as is the adjunct professor position.

It has existed at Bergen since the 1970s, making its mark in data transmission and coding theory (e.g., noise reduction) in the early years and in information security in recent years. The cryptography research was originally mainly due to one member of the group but in later years an important addition to that has been made. This was partly in response to a recommendation given the last time the ICT program was evaluated in Norway. It has placed numerous graduates in the information security industry, including four in Norwegian banks. There are currently four PhD students.

The main persons have shown their capabilities of doing research on a very high international standard. This can be seen from many facts of different kinds: the remarkable collection of collaborators and co-authors (over half of their publications have international expert co-authors), the really impressive publication lists (more than 300 papers in international refereed journals), most of the work being published in leading journals, numerous visits of scientists to and from Bergen, and the organization of leading conferences. Their algorithmic work has found applications in international standards. The present research focuses on very modern aspects. Some parts of it are also remarkably applications oriented. The group is likely to attract the cooperation of the best foreign researchers. It could also be a forum for consultation for domestic IT technology in the very important issues of data transmission and data security. Internationally the group could become a leading center in the world combining cryptology and coding theory.

The group was awarded a Strategic Research program by the NFR, it was the sixth-ranked program in all of Europe for a Marie Curie Training center, and is one of four finalist groups in ICT in the current national competition for a Center of Excellence.

Group evaluation

This group is one of the gems of the Norway scientific scene, not just in the context of ICT. The past performance of this group is excellent. Their contributions in coding theory are in the very international forefront. They have lately also started to become recognized in the area of cryptography, but a vacant professor position may now become a problem for the groups attempt to reach the international forefront also in cryptography.

Grade: excellent

Group recommendation

Information security being a critical new area of development worldwide, this group should continue to seek to couple its theoretical advances with applications. It should consider trying to double its current ratio of PhD students per faculty member. Such an enhanced graduation rate could probably be absorbed entirely within Norwegian industry in the next few years, but even if not, it is beneficial for the reputation of the ICT enterprise in Norway as a whole to seek to export some graduates in an area such as this that is widely in demand, and in which the country is so distinguished. The only major obstacle for the group that the committee can see is the vacant professor position in cryptology. To keep the current strength in this area, it is important that this position is soon filled with an internationally recognized researcher. If the group becomes a Center of Excellence, one could also visualize that the group is divided into smaller research units, some of them being very applications oriented.

8.1.4 Computational Science Group

Group summary

This group has five full professors and also presently supports four senior scientists and three post-docs, the latter two categories mainly on externally raised and specifically designated funds. The professors enjoy international recognition for original contributions to large-scale scientific computing and other areas. They are one of the few self-labeled "computational science" groups in Europe – a recognizable specialty which is now becoming much more common in academic centers of excellence in the US. More of the funding for this group comes from the European Union through international peer review than from Norway's own research council.

Bergen is one of the internationally leading centers in the development and popularization (among industrial and government users) of domain decomposition methods for distributed simulation of systems governed by the partial differential equations of engineering and physics. They have been particularly focused on structural engineering with applications to complex structures such as oil platforms, and on reservoir simulation. The group has hosted one of the international conferences in this domain decomposition, and has maintained the administrative books and publishing operations of the scientific committee for this fourteen-year-old organization over much of its lifetime.

Another fundamental computational science methodology led by Bergen is so-called "geometric integration", referring to computational quadrature that preserves integrals of motion, symplecticity, etc. There are other areas of excellence, as well, as evidenced through archival publication. Students trained by the group (MS and PhD) in recent years have landed very selective positions abroad as PhD students and post-docs.

This is one of the few groups in Norway that is actively exploiting the computational Grid, in particular in their lattice rule quadrature research. It is common to exploit the Grid in computational science and other types of projects that are data and processor-intensive in the U.S. and an increasing number of countries. Since transcontinental collaborations are possible with today's network capacities, Norway and other relatively small and geographically not central countries should especially encourage this type of research activity.

International archival publication is excellent, as are international contacts. There is leadership and active participation on international journal boards within the group.

Parallab

Parallab is a research and cycle-serving organization, with a staff of about eight (six scientific, two administrative), closely related to the scientific computing group. Parallab keeps Norway on the leading edge of parallel supercomputer acquisition through highly leveraged deals with major vendors, which are very cost-effective for the national user community. The financing of the current 0.5 Teraflop/s IBM Power4 machine was very creative: with an investment of 8MNOK from the NFR they acquired a machine with a list price of approximately US$5M, after contributions from other sources (university, federal, and industrial) and an undisclosed discount from the vendor. They have had early placement deliveries of many machines throughout the past two decades, including Intel hypercube, MasPar, Paragon, and Origin, in the past and most recently the IBM SP machine.

Parallab serves a wide variety of Norwegian industries as well as other universities and research establishments. To justify the purchase of such high-end machines, Parallab has lined up internal consulting expertise and external collaborations that attempt to ensure efficient use of the resources as soon as they are plugged in. Eight on-going projects spanning a variety of scientific areas from physics, engineering, networking, and numerical mathematics are briefly described in their self-study. Within the department, the critical mass of expert computational science users have lured other areas into an exploration of parallel computing, notably the Cryptology group. Parallab has brought significant EU ESPRIT projects to Norway, and it participates in four of the five national NOTUR Transfer of Technology Projects (TTP).

Parallab attracts many international visitors to Bergen, more for the sake of interaction with the critical mass of research personnel at Parallab than for the necessity of being local to use the resources, which are anyway well networked.

Since Parallab is more of a laboratory for the Computational Science group than an academic unit, we do not separately evaluate it. In quality and impact, it shares in the evaluation of the parent group.

Group evaluation

Though not large, this is one of the finest computational science groups in existence and one of the most readily identifiable (as such) within Europe. This evaluation stands in two respects: the development of methodology and the application of the methodology to scientific and engineering problems, which is a legitimate test of a computational science effort.

Grade: excellent

Group recommendation

There are currently five doctoral candidates in the group which should be increased based on the number of five full professors. It is understood that the training of senior scientists and post-docs is often more productive for research, and this is certainly reflected in the group's output, but such a prominent group could be training more doctoral candidates than the approximately one per year they have produced in the past decade (nine since 1992). Core funding was described as the only limiting factor in increasing the number of PhD students, not faculty time, energy, or project opportunities. The computational scientists at Bergen should seek to provide applications focus for some of the other ICT groups, as alluded to in the subsequent subsections of this report.

8.1.5 Optimization Group

Group summary

This is a group of 3 faculty members (2 professors and 1 associate professor) with a strong international reputation, collaborating with the best international optimization groups. Their focus is on efficient solution kernels for optimization problems, as opposed to the modeling of systems as optimization problems. However, they also have developed a practical specialty in the mathematics of finance. They have also documented a new interest in object-oriented programming in optimization. This is an excellent area in which to begin working now, since it is relatively uncolonized by optimization specialists, who tend toward the theoretical and towards modeling as a community, and since it is a way of recruiting good informatics students into the area.

They are well funded. The level of archival publishing in the past decade is excellent.

Group evaluation

Though small, this is a critical group for Norway, containing some academic stars, and (together with the small group at Oslo) giving the country an international presence in optimization.

Grade: excellent

Group recommendation

The group needs more PhD students, as they currently have just three for three faculty members. One excellent way in which to pursue this aim is co-direction of students with other science or engineering groups that awaken (as many are in this era of very large scale computation) to the opportunities of applying formal optimization techniques to processes and systems that were formerly controlled only heuristically. As is always desirable for academic collaborations, the philosophy here would be one of mutual intellectual benefit and the discovery of new external sponsorships, as confronting new practices ripe for optimization brings new challenges. Long before the time of the next ten-year review, this group should be working tightly with the computational scientists at Bergen and with many other groups.

8.1.6 Programming Technology Group

Group summary

This group, consisting of 5 faculty members (1 professor and 4 associate professors), works on theoretical computer science with emphasis on type theory, automated theorem proving, and logic representations. Five faculty members is a healthy number in this area by international comparisons, whereas for some areas it would seem small. Systems work includes marine information systems and scientific software development. It is one of two groups in Norway (the other in Oslo) with a focus on formal methods. There is a progressive flavor present of object-oriented software and component technology.

The group's focus is on the theoretical side of programming. Most research has been carried out on algebraic methodologies and specification techniques. There is also considerable and high quality research into logic theory and type theory. The group has recently obtained considerable research funding on modularization technology. It has good contacts with some of the leading researchers in the field of algebraic specifications. The group has strong international contacts and has participated and run several large international research projects.

The group was successful in landing an IKT-2010 project in modularization technology, called MoSIS. It has participated in EU ESPRIT projects in the past.

The group currently supervises five PhD candidates, has produced seven doctorates and over 30 MS graduates in an eight-year period, and has created a popular undergraduate web-based course in Java programming.

Group evaluation

The publication record of the group in theoretical computer science is very solid. It has prestigious international collaborators and is charting a balanced course between theory and practice. Its training rate of MS candidates is remarkable.

Grade: very good

Group recommendation

The title of the group is somewhat a misnomer in that there is very little research in programming technology within the group. It might be rather called programming theory unless the group is planning to change its focus. Computational science is one area in which programming technology is undergoing a renaissance, with a new focus on object orientation and with its earliest steps beyond libraries with rigid interfaces to components. This group should consider teaming with the locals in this area to look for thesis projects for more PhD students.

Faculty of Social Sciences

8.2 Department of Information Science

Department summary

The Department of Information Science has currently 20 faculty members, though several of the positions are not filled at present. The part of the department covered by this evaluation comprises 4 full professors, 2 associated professors, 3 adjunct professors, 2 adjunct associate professors, one assistant professor, one post-doc. and 18 PhD students. It includes two groups: one on Information Systems Design and Evaluation and one on the FLEXIBLE work and Learning. Whereas the latter is involved with the Intermedia initiative, the former is working more closely with the Informatikk department of the University. It appears that a major problem in the department is the high percentage of temporary and part-time employees compared to tenured faculty. Most of the PhD students are recruited fairly recently, which means that the output of PhDs so far has not been very high. Obviously the low salaries for PhD students in the Faculty of Social Sciences are a problem for recruitment in the ICT area.

The Department of Information Science (IFI) belongs to the Faculty of Social Sciences at the University of Bergen and it is thus working in a slightly different context than most of the other departments covered by the current evaluation. The department offers degrees in Information Science at all levels from undergraduate to PhD The strategic research areas chosen for the department are: *Knowledge Systems, Models and modeling languages* and *Design and evaluation of systems for new technologies.* Three research groups study various aspects of these areas. Two of the groups are reviewed below, while the third group dealing with *System Dynamics* is not covered by the present evaluation. There are also a

few faculty members in the department who have chosen not to join any of the three research groups.

An interesting initiative is the new research center, InterMedia, established by the Faculty of Social Sciences in 2001 as a co-operation between Information Science and Media Science. At the same time, this initiative has created a problem for the FLEXIBLE group, which is still under-critical in size and with its leader spending most of her time as head for InterMedia.

8.2.1 Information Systems Design and Evaluation Group

Group summary

The group comprises 6 tenured faculty members (3 professors, 2 associate professors, and 1 assistant professor). There are 3 additional part time faculty members. The group supervises currently 6 PhD students and teaches c.a. 300 one-year student equivalent annually; that is considerable when taking into account the size of the group. This is due to the structural and budget constraints imposed by the department's location at the Faculty of Social Sciences. High teaching load and low staffing are repeatedly mentioned in the report.

The strategy of the group is in line with the department strategy formulated as follows:
'to carry out research on a high international level within information science …and to contribute positively to society through its research'.

The group focuses on the design and evaluation of information systems from social, humanistic and psychological perspectives with a solid grounding in the computer and information sciences. On the design side examples of research topics of the group are enterprise modeling, intelligent agent modeling, analogical case-reasoning, and analogical reuse of system models. The group develops also solutions to evaluate the different aspects of the introduction of ICT.

The group has an international visibility and a quite good rate of publications. Since 1997, the group has published 14 journal papers, 12 book chapters, 20 refereed international papers; a total of 46 entries (2 references a year per person in average). The group wants to increase its rate of publications in the future. The group is represented in a number of PCs of international conferences, and organizes events and special issues in journals. During the 97-01 period, the group edited eight proceedings and six special issues of internationally renowned journals.

The group has developed a strong international orientation. The faculty members routinely co-author research papers with colleagues from other countries. The international co-operation seems to be based primarily on personal relationships: one researcher co-operating with institutions abroad through personnel contacts. However the group has participated to some EU projects such as Renoir and IDEELS. The funding from the Norwegian Research Council has been low, though improving during the last year. The

department complains about this. The group has close contacts with industry though master thesis work from which it gets student fellowships and project funding.

Group evaluation

The group has a unique organization and focus among all the departments being evaluated in that it is located in the Faculty of social sciences, but it still maintains a technological focus in its teaching, which currently is difficult to carry out within the existing budgeting constraints. The group appears to have overcome many of the concerns and issues raised by the 1992 report concerning its teaching organization, and cooperation with the other informatikk department in Bergen University. This is a positive development, and it is expected to continue in future, as the departments are further consolidating their teaching capabilities. This should also give more time for research in future for the group.

The research in the department is clearly in the formation stage after the earlier leader of the department has retired. The department has hired some promising and talented faculty during the recent years, which should help in improving the research productivity and quality also in the future. The research activity in the department is good, but dispersed into too many small areas given the size of the group.

Grade: good

Group recommendation

If any higher-level research output is desired, something has to be done first to the teaching loads and research funding levels, including the number of PhD students and their salaries. The current faculty PhD student ratio is too low. This requires either that the funding policies nationally for all ICT groups are handled similarly and the group is funded according to the same principles as other departments in the ICT area, or that the department is moved into the Informatik Department in the Science Faculty with a responsibility and obligation to teach students in social sciences while maintaining their current teaching and research focus. One solution is to establish a separate school for ICT area in The University of Bergen. The group should also consolidate its research and develop a more focused research agenda that is unique and draws upon the strengths of the group. Currently, the only group, which has adequately well defined research agenda is the flexible work and learning group.

8.2.2 FLEXIBLE Work and Learning Group

Group summary

The FLEXIBLE Work and Learning Group has 3 faculty (1 full professor and 2 adjunct professors) and 1 post-doc. supervising 6 PhD students. The group is primarily concerned with the use of ICT in support of work and learning. A significant activity for the group is the establishment of the Intermedia initiative, a multidisciplinary meeting place jointly

created with the Department of Media Science. The group leader of FLEXIBLE is also the scientific leader of Intermedia.

The group has good international contacts in the area of ICT and learning. The Systems Dynamics group in the same department, though not covered by the present evaluation, conducts research in a related area with relevant connections to the FLEXIBLE group. The group is teaching two graduate courses in the area of pedagogical information science and has also been active in organizing a Nordic research school.

Group evaluation

The research holds good quality, but is currently hampered by the supervisors having part-time appointments or being engaged in administrative duties. Still, the group has a good international publication record and has attracted significant external grants. The production of doctoral degrees could be improved.

Grade: good

Group recommendation

The group should continue and strengthen the research cooperation within the Intermedia initiative. With respect to the administrative duties involved, the group is currently understaffed and need additional permanent faculty.

9 University of Oslo

Faculty of Mathematics and Natural Sciences

9.1 Department of Informatics

Department summary

The Department of Informatics at Oslo has 40 faculty divided into eleven groups with very broad coverage, ranging from systems to software, from algorithms to scientific applications. Two of the groups are small, with just two faculty, and these are quite recently formed, which suggests that two faculty is not intended to be the asymptotic size, but a snapshot of staffing at the time of the review. The specialties of the groups making up this department are so diverse that it is difficult to imagine synergies and common student populations between many pairs of them. There is probably sufficient overlap to maintain coherence and communication but perhaps not enough to arrive at unanimously accepted priorities and direction. The perceived quality of the groups is more variegated than in any other department examined in this report, with two groups commended as Excellent, two just Fair, the rest split between Very Good and Good. Therefore, it is important to look beyond this departmental summary to the detailed group evaluations below.

The ratio of PhD students to faculty averaged over the Department of Informatics at Oslo is about 1:1, which the review committee considers very low. However, most of these students are concentrated into four of the eleven groups, and these four groups had relatively high ratings, suggesting both that students are drawn to excellence, and that students help to form the basis for future excellence, by contributing to visible publication efforts, etc. The two groups with *excellent* ratings (Computational Mathematics and Scientific Computing) support 12 of their current 15 PhD students externally. A general feeling of the committee is that this national flagship department should attempt to produce more students, and that resources from the NFR should predominantly following quality indicators and external recognition.

The Department of Informatics has more than its share of faculty who are internationally recognized for eminence in research and pedagogy both. Progressive movements in informatics, notably Object Orientation in Programming Languages and Software Engineering in Computational Science have been internationally led and influenced by some highly productive and persuasive faculty at Oslo. As with overall quality, however, the international orientation of the department is uneven. Some groups should concentrate

much more in developing international peer collaborations, which could contribute to improved ratings.

The department has a very promising research strategy with weight on cross-disciplinary research in medical applications, bio-informatics, media and technology, and applied mathematics.

Three of the groups have been selected to populate the new SIMULA Research Center, which represents an excellent opportunity for them and for the Department of Informatics as a whole. However, with this geographical partitioning of the department comes the challenge of remaining and acting like one department. Operating the Simula Research Laboratory within the department may not be easy at all because of the different boundary conditions of a separate research lab from those at a normal university laboratory. Because of the visibility of this new national project and the opportunity to collaborate with other ICT colleagues from around Norway who are named as collaborators in SIMULA projects, the Department of Informatics could serve as a nexus for ICT within the country. This is a natural role, given its eminent history and capital city geography.

The research group organization is only in place since 1998 and the Simula Research Laboratory, with a focus on Communication Technology, Industrial Systems Development and Scientific Computing, has only been established in 2001. We are therefore assessing a structure that is relatively recent and leaves the impression that much is still to be done to fully implement the new vision of the department.

9.1.1 Bioinformatics Group

Group summary

The Department is to be commended for establishing bioinformatics as a research focus within Informatics in January 2001. There are currently 2 faculty members in this group (1 professor and 1 associate professor) and one post-doc.

The departmental track record in bioinformatics had been building based on the efforts of the current senior researcher prior to its recognition as a research unit. Bioinformatics has begun to emerge internationally as the rapid growth area of the information sciences. The group concentrates on biostatistics, with major applications in survival analysis and molecular genetic data analysis from DNA microarrays. As is appropriate for this focus, it has forged ties with academic medical hospitals and academic statistics groups within and beyond Norway.

Though the group is small, it is on track. It well complements the more discrete math-based focus of the Bergen bioinformatics group and the more software development oriented group in Knowledge Systems in Trondheim.

The amount of publication within the past ten years, largely in international medical and biological journals, is impressive. Commendably for the department, the faculty members feel free to continue to publish outside of traditional informatics journals without losing respect and opportunities within the department.

Group evaluation

For such a new and small group, this one is off to a great start, which is most clearly discernable in the matter of quality publication.

Grade: very good

Group recommendation

An additional faculty member in bioinformatics at Oslo University, possibly with a focus in proteomics analysis but best chosen in coordination with the university molecular biology group to cover courses in this new growth area, would be appropriate in positioning the department to cover the next "push" in the subject and attract the best students.

9.1.2 Computational Mathematics Group

Group summary

This group of 5 faculty members (4 professors and 1 associate professor) with three decades of history represents the classical core of computational mathematics – PDEs, linear algebra, optimization, spline and multiresolution analysis, etc. There are currently eight PhD students in the group, all but one funded externally.

The group is innovative in its educational initiatives, showing scientific leadership by integrating computation into the teaching of mathematics, ranging from introductory calculus to a new five-year program specializing in computational mathematics. It is a finalist in the ongoing Norwegian Center of Excellence competition – the only finalist in mathematics. The panel commends Oslo and also the NFR for its perspective that computational mathematics belongs as part of an ICT review. When pursued by faculty with the proper orientation and attitude (which seem present here), this field indeed has important integrations with ICT.

In recent years, the group has made contributions in an important application area: the geometric and mechanical modeling of human organs.

The researchers are well archival published and some are well known international leaders, both through their books and through their service on the boards of international journals. This program has active collaborations with prestigious computational math programs in the U.S., Europe, and Israel and has long been a central gem in the Norwegian scientific crown.

Group evaluation

This traditionally strong group has avoided resting on its laurels by continually refocusing on contemporary issues in computational mathematics – in research and also in pedagogy. Mathematicians are usually less well funded than computer scientists in any country. This group is to be commended for its CS-like eagerness to pursue funding opportunities, as evidenced by the external support of most of its students.

Grade: excellent

Group recommendation

By international norms, this group should be allowed to support more students on internal funds, and if the students are available within Norway, they certainly could afford to increase their current output by 50% or more without overtaxing the time and creativity of the faculty.

9.1.3 Digital Signal Processing and Image Analysis Group

Group summary

This group has 5 faculty members (3 professors, 1 associate professor, and one adjunct professor). They currently support four post-docs. and five PhD students.

Their historical strengths are in texture analysis and classification, and feature extraction for high-dimensional datasets. More recently, they have built up a strong focus on signal processing. While possessing a strong theoretical base, they are presently substantially applications driven, with a healthy interplay between theory and application. Applications include remote sensing, environmental imaging, sonar, seismic, medical imaging, acoustic imaging, and ultrasound.

The senior members of the group possess strong international archival publication records. Overall, the group is a locomotive for entrepreneurism and international collaborations. As an instance of this, they have initiated an entrepreneurship program, which after 3 years includes the Norwegian universities and several district colleges, where students are dropped in the middle of Silicon Valley, Boston, or Singapore for three months as part of their training. Furthermore, they participate in a highly rated EU ESPRIT project (NICE) on medical image acquisition, and in the development of multiple input/multiple output systems (MIMO) for exploitation of arrays in wireless communication.

Group evaluation

The outreach of this group into applications is to be commended. They are also very productively and creatively involved in training.

Grade: very good

Group recommendation

The group should continue to look inside and outside of Norway for suitable collaborators in the applications of image and signal processing. Wireless communication may or may not have become a saturated domain for research, but there remain numerous other areas for both observed and simulated data. A strong interdisciplinary reputation can be built upon the foundation already possessed here.

9.1.4 Information Design Group

Group summary

This is a recently formed group of two researchers with a background in algorithms moving into the field of information design. The group consists only of two associate professors and no PhD students or visiting researchers at the time of reporting. They work with a special approach to information design, polyscopic modeling, which is said to be different from all traditional approaches. In this area, it is stated that journals, conferences and even the publishing areas as such are not yet properly established. The group leader has worked with the polyscopic modeling concept for some ten years and the group is also involved in projects developing information infrastructures for distributed corporations and for the health sector. Courses are taught in diverse areas of information design, societal aspects of informatics, and in teaching algorithm theory.

Group evaluation

The virtues and value of polyscopic modeling as a scientific approach to information design is yet to be established. Though the group is trying to publish their work internationally, the impact of publications so far is limited.

Grade: fair

Group recommendation

The extent and quality of the research in this group is not yet at a level that motivates a status as independent group. A closer relationship to the Systems Development group would be natural, both in order to promote a research environment of critical size with active interaction with other research paradigms and since general areas of interest seem to overlap.

At the same time, information design is a comparatively important area with respect to undergraduate education. Though one should allow new research ideas and paradigms to emerge in an area, it may be a bit risky to base all activities on a single, not yet proven

approach. The department should thus have reason to consider the need to strengthen this area, for instance also with cognitive science background in information and interaction design.

9.1.5 Precise Modeling and Analysis of Dependable Systems Group

Group summary

The group consists of currently of 5 faculty (1 professor, 1 associate professor, and 3 associate professors II) and one PhD fellow. The group teaches several courses on programming methods and formal specification techniques.

The group continues the research line started by late Professor Ole Johan Dahl that has focused on the development and use of formal specification techniques and development of object oriented programming languages. The latter line of research seems to have increased lately. The main research focus in the group lies in formal specification techniques for modeling and analysis of concurrency and distribution within an object oriented environment, OO distributed real-time (Dahl tradition), real-time and hybrid systems, The group has developed its own specification methodology called Oslo University Notation.

The group's publication activity has been limited during the last years, which can be partly explained that the group is in the midst of generation shift and is also currently hiring new faculty. Some of the research results have been published in top outlets. The group has vivid connections to industry and has good international connections with several top departments in Europe. Moreover, the group has participated in several EU projects and influenced standardization activity in OMG (UML 2.0).

Group evaluation

For its size the group has had considerable impact research that deals with formal specification techniques and their use in industrial settings. We in particular are impressed by the application of nonclassical logics on proof-search and an extension of Meseguer's rewriting logic. The group's current focus on analyzing and formalizing non-functional requirements looks very promising.

Grade: very good

Group recommendation

The generation shift has led to problems that have not yet been fully overcome. A clear vision of the activities of the group has not yet emerged. The group's work should be better supported. In particular, the group needs support to maintain a healthy number of PhD candidates.

9.1.6 Industrial Systems Development Group

Group summary

The group consists currently of 4 faculty (1 professor, 2 associate professors, and 1 adjunct associate professor) supervising 3 PhD students. The group teaches software engineering techniques and related topics. It has been established in 1999 so that it is in its formative stages. The group is active in software engineering at the SIMULA research center, which may influence negatively the group's collaboration with other groups (like PMA or systems development groups.

Work is being done in OO-analysis and design, planning and risk analysis, process improvement, and production quality. Publications are primarily in the areas of software and software engineering. The group focuses on methods, techniques, and tools for system (software) development in industrial contexts, and is especially interested in carrying out empirical investigations of the effects of different models, methods, and techniques on processes and products. The main areas are the impact of OO analysis and design techniques on SD planning, and cost estimation and risk analysis on process improvement and product quality.

The group has published quite extensively during the past years in SE journals and conferences dealing with empirical aspects of SE resulting in about 5-6 journal publications, and a larger number of workshop and conference presentations during the last 3-4 years. Some of them have been published in top-level outlets. The group is well connected to industry and has good international connections.

Group evaluation

This research group carries out research that is industrially extremely relevant. Its strength is a combination of both theoretical and tools related work with empirical investigations. The research group has good industry relations and is developing a cumulative research effort for studying risk, cost estimation, and the impact of tools and technologies on software development effectiveness. The main weakness in the research group seems to be so far inadequate connections to leading research groups in the world, not sufficient attention to develop a strong theory basis to understand software development behaviors, and the need to carefully improve measurement and instrumentation (though the group has recently started some interesting trials in this area (SESE). These problems plague many groups studying empirical SE processes, however, so these issues raised are not unique. It needs to focus better on developing its own "niche" in the research landscape. This currently seems to be cumulative research on experiments.

Grade: good

Group recommendation

The report of the group - though otherwise informative - is not very instructive how it seeks to develop and solidify its research agenda. The group needs to develop a stronger profile in the chosen area software development in an industrial context and develop the relevant empirical research methods for that context. The group should also improve its international collaboration and seek help from leading research groups and scholars in the field both in Europe, and in the US. The group can also improve its internal collaboration with the PMA and System development groups.

9.1.7 Communication Technology Group

Group summary

This new research group has 3 professors and it supervises 3 PhD students.

The research area is on network architecture and adaptable middleware for distributed systems. Important aspects are Quality of Service (QoS), performance, and interoperability of multi-media streams. Challenges include managing heterogeneity while maintaining QoS and optimizing total system performance. The research focuses on middleware platforms and the influence of network components on Internet service levels.

During 2001 this group was selected to be broken off from the *Communication Systems* (Sec. 9.1.8) group at UiO. Increased and continued close cooperation with the Communication Systems group is expected to be maintained. The group has close cooperation with Tromsø university. It has collaboration with several European universities and research institutes, including SINTEF, Lancaster, Trinity College, and Ålborg.

The group has two internally funded and one new NFR-funded project. A new EU project (LANCE) is being planned.

Group evaluation

The group is internationally well connected and has a fair amount of publications.

Grade: good

Group recommendation

This group has a potential to grow significantly. It is a central part of the Simula Research Center. Continued cooperation with Communication Systems at UiO, Tromsø, and Lancaster University is important for an internationally strong research environment. The group should increase the number of publications in high quality conferences and journals within its specialty area.

9.1.8 Communication Systems Group

Group summary

The group has 2 faculty positions and 2 new are announced. It supervises 3 PhD students. A part of the original group recently moved into the separate *Communication Technology* group in the *Simula Research Center* (separate evaluation). The main focus of the group is on system software for multi-media communication, delivery, and quality of service with main applications in distributed multimedia systems. This area is very important with the rapid growth of Internet and distributed systems.

The specialty of the group is to combine network, operating system, and database system software. For the database part there is very close cooperation with the *Software Engineering and Database* group. On the network side there is close cooperation with the *Communication Technology* and with Tromsø university. The group participates in several externally funded research projects in cooperation with other Norwegian universities. A new project proposal for an EC project has been submitted. It has cooperated with several international research institutes and leading industries. An exchange visit with Oregon Graduate Institute is planned.

The group has a very good publication record in the area of network software. A significant achievements is the INSTANCE project for high-performance network communication that provides significant communication performance inprovements over conventional TCP/IP by careful design of network communication and caching methods. The group participates in the OMODIS project for distributed education. Both these projects are joint projects with the database sub-group of the Software Engineering and Databases group (Sec. 9.1.10).

Group evaluation

The group is internationally well connected and has a number of quality publications.

Grade: very good

Group recommendation

This group has a potential to grow significantly. It is a strong and central part of the Department of Informatics.

9.1.9 Microelectronic Systems Group

Group summary

This group of five faculty members covers a wide range of research disciplines from computer science to analog and digital circuit design. In most universities, this group would be housed in the electrical engineering department, and the group would probably benefit from the establishment of a school of engineering at UiO. In the present structure, the group is academically isolated. The group lists as one of their strengths that they are doing microelectronics in a computer science environment, which they claim leads to strong research. No evidence of such synergistic effects is presented, however, and there seems to be a general lack of vision and academic leadership in the group. Another problem is the relatively low number of PhD students that the group is able to recruit and support. The planned reorganization in which the group will be co-located with the electronics group at the Physics department in close proximity to the new microfabrication laboratory might help the group address some of these problems.

Group evaluation

The quality of the research varies across the group with some members having good publication records and strong international collaborations. Overall, the publication rate is relatively low, but the rate is increasing, which bodes well for the future.

Grade: good

Group recommendation

The Microelectronic Systems Group should use the planned relocation to refocus its research. To continue the positive trend demonstrated by the increasing publication rate, it is imperative that the group breaks out of its academic isolation, starts meaningful collaborations with other academic institutions and with industry, and increases the number students both at the MS and PhD levels.

9.1.10 Software Engineering and Databases Group

Group summary

The group has 6 faculty members supervising 2 PhD students. Another three new PhD students are expected. A part of the group works on database technology and the rest works on object-oriented programming technology. The database group has very close cooperation with the Communication Systems group and has participated in and lead several successful joint projects on multi-media communication and database systems. The OMODIS project on distributed education is lead by a member of the database group. (See also evaluation of Communication Systems in Sec. 9.1.8). The three new PhD students are expected to work in cooperation with Communication Systems. The use of state-of-the-art communication software combined with database technology is an important research direction for multi-media database systems. Members of the group have participated in international OMG, ODMG, and UML standardizations. The non-database part of the group works on object-oriented programming languages and software.

Group evaluation

This group lacks clear direction. The strong part of the group is the close collaboration of the database part with the Communication Systems group. The publication record is reasonable.

Grade: fair

Group recommendation

The organization of this group should be reconsidered. It is important to maintain the close cooperation with Communication Systems. The group should strengthen its publication record in high quality database conferences or journals.

9.1.11 Systems Development Group

Group summary

The group currently consists of 12 faculty (6 associate professors, 1 professor emeritus, 1 professor II, and 4 associate professors II). It has currently 22 PhD students and the number is expected to grow. The teaching area of the group is quite popular and therefore the group has recently grown in size. The group teaches system development courses and related topics and has a large burden of thesis guidance.

The name of this group, though it has its origins on late Kristen Nygaard's work on system development approaches (like Delta) is somewhat of a misnomer. The research carried out in the group has quite little to do with actual development and design of the systems, but rather it involves more socio-technical issues surrounding systems design like participation, organizational impacts, or organizational and technological conditions and processes enabling, or constraining such activity. Much of the research work in the group focuses on neglected, but not necessarily unimportant "marginal" topics in systems development like SD in developing countries, SD and gender issues, and globalization issues around SD in terms of distribution of work and development. A promising research area during the last years has been the work on large-scale institutional issues in systems development (called "infrastructures"). The group has recently extended the area into global issues in information systems design (e.g. developing countries), and global outsourcing related to software development.

The group has published quite extensively during the past years in information systems area. This has resulted in about over 10 journal publications and a larger number of workshop and conference presentations during the last 3-4 years. Some of them have been published in top outlets. The group is well connected to industry and has good international connections with several top departments in Europe (Cambridge, LSE, Erasmus) especially to Third World (South-Africa, Mozambique).

Group evaluation

The research carried out in this area – though heterogeneous – is innovative and some parts of it have been submitted and published in good, or very good outlets. The group is most internationally known for its work on infrastructures, but the work seems to be developing into many separate directions without a clear research center. The group lacks academic leadership and focus, which it also admits itself. Some parts of the research do not seem to fit with the general profile of the group. For example, the work on OO design principles would have a better fit in the SE group. Overall the research activity within the group varies from fair to very good. Overall the research productivity in the group has been improving and there is also focus on getting out results with a long-term impact (like monographs).

Grade: good

Group recommendation

The group should seek to develop a theory-based, or research-methodology based research focus, and should further solidify its research topics into fewer interrelated areas. The group should also improve its methodological skills and research rigor. The group has recently focused on this by improving its research skills to investigate simultaneously social and technical issues in large-scale systems (e.g. hiring a person with excellent research skills in qualitative research methods). Such developments should be strengthened and the group should draw better upon existing research skills. The group should also publish less, but on a higher level to improve its international visibility and increase its research quality

9.1.12 Scientific Computing Group

Group summary

This group has 6 faculty members (3 professors and 3 associate professors), plus a number of part-time faculty members and post-docs. They currently support seven PhD students, all but two funded externally. Post-docs are highly competitively recruited (recently forty applied for two positions). Doctoral graduates of this group and of the Computational Mathematics group go substantially into industry in Norway (petroleum, medical, etc.). There is not as much industrial support for the education of PhDs as might be appropriate for this record of placement.

The scientific computing group is concerned with applying modern software engineering practices to scientific software. The group has achieved international distinction by calling attention to the feasibility and desirability of subjecting scientific software – a niche area – to this discipline. DIFFPACK (now commercialized) has wielded an enormous influence on other scientific software around the world.

The publication record of this group is impressive, and includes internationally published books that go a long way to defining scientific software engineering, including three brought out by Springer in their new *Lecture Notes in Computational Science & Engineering* series.

This group registers no complaints regarding the access to necessary high-end computing equipment, which is an excellent commendation for the NFR and for the universities where the national facilities are located (Trondheim, Bergen). There is apparently good networking and easy administrative access to high-end facilities.

The group has engaged in medical and reservoir applications, harnessing its expertise in differential equations, scalable solvers, visualization, modeling, etc. Their expertise includes the mechanics being modeled, as well as the modeling techniques and technology. They have been well funded. They sit on many important boards and conference-organizing committees.

Group evaluation

This group exerts an international influence on scientific software engineering that is disproportionate to its size. It is to be commended for its publication efforts, as well as its successful raising of support in a niche area that is far smaller than that of software engineering as a whole. It has done this by effectively bringing applications along.

Grade: excellent

Group recommendation

No change of course for this group would be necessary, but it is undergoing one, anyway. This is one of three groups making up the new Simula Research Laboratory at Fornebu. As such, it will need to expend conscious effort to maintain natural interdisciplinary ties to Computational Mathematics and other groups in the department.

10 University of Tromsø

Faculty of Science

10.1 Department of Computer Science

Department summary

The department consists currently of 6 tenured faculty positions. Two full professors are currently vacant. The department has a large number of adjunct (professor and associate professor II) positions 11 (5+6). Prominent and well-known scholars that do actively research in department's main research areas fill many of them. The department has currently 15 PhD students and 250 MS students. The department has produced 1 PhD between 1998-2001 but the number is expected to grow to 2 PhDs year in the next years.

The department's research focus is on experimental computer science research and especially in the building and analysis of large scale distributed systems, which involve mobility (of clients and services). It has carried out over the last decade several successful projects that cover high performance distributed computing platforms (e.g. GRID computing), operating system support for mobile software agents (TACOMA), and mobile client applications (Virtual Secretary, The Global Distributed Diary). It has recently extended this research into studies of support for elderly people, environments to support small children to engage in electronic communications, reflective middleware (Arctic Beans), and personal overlay network systems (PONS). Many of these involve collaboration with leading computer science departments in USA and Europe and they have been funded by NFR or other external funds, which are now being terminated.

Group evaluation

Overall given the circumstances and the environment the department has produced outstanding results. The department can also congratulated for following the recommendations made 10 years ago by the international evaluation committee in which it has achieved good results in improving international visibility and cooperation. Another issue is whether the chosen research area – distributed large-scale systems with an experimental focus – is the best area to do research in a remote place. But this cannot be changed anymore. The performance of the department shows that with right focus, good management, and talented people departments and research groups in remote areas can achieve global visibility and excellence in research. The report was also easy to read and focused in the sense that it gave a good understanding how the department wanted to

improve its profile, and what it saw as its main blockades. Given the amount of teaching and the amount research carried out the results achieved within the department have been outstanding. It is also one of the few departments, which focused on how to improve their PhD education. The department possesses strong industrial contact. International cooperation, especially with the U.S., is impressive. The department's publication record has shown also continued improvement, though the number of publications in refereed journals needs to be increased in the future. Also the PhD production needs to be increased.

Grade: very good.

Group recommendation

Given the impressive achievements of the department the committee feels that the group needs strong support. The location of the department calls for extra measures that help maintain the viability of the group and to obtain new qualified people into the faculty. The committee is convinced that given the right type and level of support both the number of PhDs and the research productivity of the department can be further increased. The department should also focus more on publishing in top tier journals, which the quality of the research they show should entitle them to do. The group is planning to move to new areas like bioinformatics and computation theory. Though this can be beneficial from the viewpoint of obtaining teaching capability and increasing external funding the group should be cautious of not extending its spread too much.

11 Agder University College

Faculty of Engineering and Science

11.1 Department of Information and Communication Technology

Department summary

The Department of ICT at Agder University College belongs to the Faculty of Technology and Science. It has 21 faculty (4 professors, 9 associate professors, 1 adjunct professor, and 7 assistant professors) supervising 5 PhD students. Agder University College does currently not have the rights to grant PhD degrees but provide PhD educations by cooperating with other universities.

The research activities in the department are organized in six research groups. These groups conduct research in mobile communication, systems security, open systems development, systems dynamics, information, communication management, and applied ICT. Each group is under the supervision of a professor or adjunct professor.

The vision is to combine selected disciplines in ICT research to obtain interesting results in mobile communication systems, communication security, and network related research. The department has a close industrial cooperation with ICT industry within both research and education.

From the six groups presented in the material, only four were represented at the meeting. A brief summary of the activities will follow.

Department evaluation

The committee finds that there are too many relatively unconnected activities in a wide area. There are also relatively few publications at journal level.

Grade: fair

Department recommendation

A clear vision for the development of the department is needed. Work should become more focused and a competitive research strategy should be developed, based on the strength

available in some of the areas mentioned above. Mobile communication could form the core of such a development.

11.1.1 Mobile Communication Systems Group

The research group consists of 1 professor, 3 assistant professors, and 2 PhD students. The group is quite new with the professor being hired about one year ago. They take part in teaching in a bachelor of engineering program in telecommunications and a master of engineering program in communications. Theses programs have a quite high number of students and seem to serve the local industry in a very good way. People from the local industry also take a major role in teaching in the programs. The PhD program is run in cooperation with Aalborg University in Denmark.

The group is running three research programs, with one of them being recently started. The two first programs are devoted to radio channel properties, while the third one includes a bit more of transmission and reception algorithms too. Still we feel that the research considered is very narrow and some widening would be recommended. The production of the research groups is very low, mainly due to its short existence, but we feel that they have a good chance of reaching a reasonable production pretty soon. Some of members of the group have a reasonably good set of publications from before joining the group, some of which are in good international journals that is appreciated by the committee.

11.1.2 System Security Group

The group consists of 4 faculty (1 professor, 2 associate professors, and 1 assistant professor) and one PhD student. It studies problems in computer and information security with applications to mobile and wireless systems. Topics of special interest are cryptographic foundations and algorithms, and secure e-business and privacy protecting schemes.

11.1.3 Open Systems Group

The group consists of 4 faculty (1 adjunct professor, 1 associate professor, and 3 assistant professors) and one PhD student. Open standards for representing and exchanging information (Linux Internet access, multimedia applications, servlets, and quality of service) form the area of interest of this group.

11.1.4 System Dynamics Group

The group consists of one professor and one PhD student. Research interests of this group cover modeling of human aspects of security, and human learning and problem solving in complex dynamic systems.

11.1.5 Information and Communication Management Group

The group consists of 3 faculty (1 professor and 2 associate professors). Application and service oriented research is carried out in this group. Decision support, cognitive modeling, electronic commerce, mobile services, CSCW are typical areas of interest.

11.1.6 Applied Information and Communication Technology Group

Two associate professors and three assistant professors form this group. Unrelated research activities are collected in this informal group.

The Faculty of Economics and Social Sciences

11.2 Department of Information Systems

Department summary

The department is part of Faculty of Economics and Social Sciences at AUC. It offers programs at undergraduate and graduate levels and is seeking to start its own PhD education. Currently it has permanent scientific staff of 12 faculty, two adjunct (Professor II) positions and 1 PhD student (at University of Bergen). The number of students is little less than 300. The department's teaching covers most important areas of organizational aspects of designing, managing and implementing information systems.

The research in the department is its formative stages and it has only started since the mid 1990's when the department hired its first permanent professor. The research in the department has focused on conceptual and empirical issues in measuring and assessing IT competency, IT in non-profit sector, systems development and organizational implementation, and E-business (especially in SME's). The research has received small support from local government and EU. The department has established active and intensive ties with several foreign universities including University of Georgia, University of Aalborg, and Helsinki School of Economics

Department evaluation

This is a young IS department, which is in its formation stage where it is being transformed from a purely teaching oriented lower level college to a research oriented university department. Only the future can tell how they will succeed, but the department has taken several steps in the right direction: by hiring an internationally known professor with excellent research contacts and research experience, by inviting and collaborating with some of the leading faculty in the field, and by focusing on developing a research program around a few research themes that match with the current competencies and profile of the department staff. The department can be also congratulated for being quite open and honest for stating their weaknesses, which deal with the limited research experiences and relatively thin research competence when measured by the number of faculty with a PhD. One step in furthering this goal – as rightly pointed out – is to start its own PhD program. The overall current performance in the department can be evaluated to be currently fair (the past performance over 10 years) but the last 3 years have shown outstanding improvements in the research performance, which can be expected to improve if the department can sustain its current momentum.

Grade: fair

Department recommendation

We were positively surprised by the department. Though the department has not so far produced extensive results and world class research the department's leaders seem to be aware what is required to achieve that level of performance. Therefore the department's efforts to improve research that we did not see being addressed in other departments we surveyed, like IT in non profit organizations and development of organizational competencies related to IT, deserve support. The department must, however, sharpen its research focus, develop more theory or research methodology based research strategy, and hone better international contacts that improve directly their research competencies if they want to achieve their ambitious research goals.

12 Molde University College

12.1 Department of Informatics and Mathematics

Department summary

This is a primarily teaching department, with the principal aim of research being to maintain the international sharpness of the faculty. There is no current PhD program, though one is being established in logistics. There are ten full-time and three other faculty members in the Department of Informatics and Mathematics. This is one of four departments at the College, which has 70 faculty members and 1400 students altogether. The teaching load for a full-time faculty member in the department is an average of one course per semester – similar to other institutions throughout Norway.

There is joint work with the Telecommunications Department at the University of Pittsburgh on visualization and user interfaces, and also network management – over fifty MS students from Molde at Pitt in the past ten years. There are exchanges and adjunct appointments with faculty at Pitt, as well. This appears to be a healthy experiment – one that is perhaps worthy of imitation by other small universities. Collaborations within Norway include the Department of Informatics at the University of Bergen and SINTEF.

Two of the full-time faculty members are well archival published. There are instances of international collaborations in the Optimization group. It is in the interests of the university and the country to keep them satisfied at a small, remote institution. Faculty recruitment is mentioned as a difficulty; greater federal research investment in the university college system being mentioned as an important hope for the future.

Many faculty members apparently focus their publications in industrial trade journals, rather than the usual academic journals. Not all maintain a personal research discipline. The review committee believes that internationally ranked research means much more than "staying current".

Department evaluation

The department has dedicated faculty and has some strategies for distinction, among them the undergraduate exchange program and the research niche in just-in-time industries. However, in terms of international research standards, there is not yet enough evidence, on a department-wide basis, to demonstrate that they have arrived, this being a new standard to apply to their historical mission. The derivatives certainly have the correct sign.

Grade: fair

Department recommendation

The strength of the department is in industrial logistics and operations research, to adapt Norway's high-wage manufacturing industries (primarily maritime products) to complex, custom, just-in-time markets. Molde aspires to be *the* national leader in this applied discipline, and the faculty and students have on-going applied projects with industry. This aim seems both feasible and worthwhile to the committee, and gives shape to a plan for a higher rating of the department in the future.

13 Stavanger University College

School of Science and Technology

13.1 Department of Electrical and Computer Engineering

Department summary

The department consists of three research groups: Signal processing, control engineering and computer science.

The signal processing group has 8 members in the academic staff and 5 PhD students. The research activity is focused on telecommunication, signal and image processing with applications in medical signal and image analysis, and seismic data processing. The group is proud of their research in the area of medical applications where one of the goals is to improve the treatments of heart attacks. The group is responsible for a three-year bachelor's program in telecommunications engineering and a master's program in signal and image processing. The group also has a PhD program in collaboration with Aalborg University and the Department of Telecommunications at NTNU. Seven PhD students have obtained their degree through this program. The group is working on obtaining the rights to grant PhD degrees.

The control engineering group has 2 members in the academic staff. The research activity is focused towards the oil and gas industry and topics related to the process and pipeline simulation.

The computer science group has 5 members in the academic staff and 1 PhD student. There are activities within technology development for the new, open and globally distributed information structure. Fundamental theory and methods, short-term practical applications, and more experimental long-term applications are examined. Practical aspects of distributed computer systems are combined with theoretical aspects of distributed algorithms. The activities include cryptography, information security and error detection, distributed systems, algorithms and object oriented programming, Internet, digital money, electronic commerce, communication protocols and architectures for mobile data systems, and mobile agents.

The signal processing group is very active in their research discipline and has established very good international relations and publication records. It should also be noted that SUC,

perhaps as a natural consequence of being a relatively small university, does not show any tendency towards academic inbreeding in their hiring.

The groups have not been able to attract much funding from the research council and the private sector. This does not seem to be due to the quality of their research but rather a lack of funding. We believe it would be an advantage if more funds were made available at least to the signal processing and computer science groups since they have a very good potential of producing very useful results.

From the three groups presented in the material, only the signal processing group was represented at the meeting. A brief summary of the activities follows.

Department evaluation

Both the Computer Science and the Signal Processing Groups are visible both nationally and internationally. There are a relatively small number of refereed publications.

Grade: good

Department recommendation

Develop the strengths and concentrate on the areas of signal processing and computer science.

13.1.1 Computer Science Group

The group has 5 faculty and 1 PhD student. It develops technology for the new, open and globally distributed information structure (cryptography, information security and error detection, distributed systems, algorithms and object oriented programming, internet, digital money and electronic commerce, communication protocols and architectures for mobile data systems, and mobile agents)

13.1.2 Signal Processing Group

The group has 8 faculty members and 5 PhD students. It works on theory and applications for telecommunication, and signal/image processing.

13.1.3 Control Engineering Group

The group has two staff members working focussing on process simulations for oil and gas industries.

14 Østfold University College

Faculty of Computer Science

14.1 Departments of Informatics and Computer Engineering

Department summary

The Faculty of Computer Science has two departments, Informatics in Halden and Computer Engineering in Sarpsborg. However, the research activities are not distinguishable between the departments and they will thus be treated together here. The departments have in all 24 faculty (2 full professors, 11 associate professors, 8 assistant professors, 1 professor II, and 2 associate professor II) supervising 2 PhD students.

Department evaluation

The research is carried out in four main areas, with certain strength in neural networks applied to pattern recognition and artificial sensing. In other areas activities seem to be more ad hoc or in a build-up phase. Considering the extensive teaching duties in the college, research activities are quite limited.

Grade: fair

Department recommendation

There is a potential for expansion of research in several areas, but faculty need to increase their research activities and PhD students promoted, also by taking care of currently active students close to finishing their degree. In order to create a research environment of international visibility, a more focused research program and more active research leadership is needed.

15 UniK - Center for Technology at Kjeller

Center summary

Kjeller (UniK) was established in 1987 by the University of Oslo and three Kjeller research institutes. Its legacy is in the Norwegian Defense Establishment and Atomic Energy institutes of the 1940s. Its programs are for graduate and continuing education students. There are currently five substantial-time professors, in addition to a number of 20%-time adjuncts. There is a recent history of approximately three PhD graduates per year. Currently, there are approximately 25 PhD students enrolled – a healthy ratio of five per full-time faculty member. There is cooperation with University of Oslo and NTNU, including joint listing of faculty, and shared residency of students. Students actually get their degrees from Oslo or NTNU.

Quality of Service is a major focus, with an emphasis on multimedia. The Future Communications Systems (FUCS) program is a new industrial collaboration driven by the need for more PhD students – there are eight enrolled in this program presently. Kjeller has fulfilled its quota for PhD students but has not attracted as many MS students as contemplated.

The institute conducts some very progressive research projects, focusing on contemporary problems and opportunities; some of them are international, and internationally funded. Current funding profiles are reasonably healthy, since the PhD students often come from industry on a multi-year leave, and therefore come with their own funding. The advising faculty members sometimes lecture at the companies as a service. Seventeen (17) industrial businesses are currently targeted

Kjeller is a niche institution. It complements existing university programs with its specialized offerings (e.g., volume visualization as a tool for turbulence research). It provides mostly continuing education for professionals, and is able to respond quickly for new initiatives. Kjeller is one of Norway's pioneers in distance education.

The institute gives the country a very flexible, rapid, and industrially integrated means of following rapidly developing fields. There is no commitment to an undergraduate population requiring regular offerings of basic courses. There is good immersion in the proximate industrial park. The negative side of this is an impression that Kjeller does not function much like a campus socially, or in terms of student support services. This is in the process of changing, as new housing units are being readied, and as a large community college campus moves to the countryside Kjeller site, approximately 25 km outside of Oslo.

Standard metrics need not be applied to all faculty members. Some of the faculty have many patents, and tend to publish more reports than archival papers. The four core faculty whose CVs are furnished with the Self Evaluation have international visibility, with PhDs from the University of Utrecht, Brown University, and the University of California at Berkeley (2).

UniK does contribute to fragmentation of an already small academic activity in ICT in Norway, but it also provides an important connection to resources in the research institutions at Kjeller. On the balance, it seems that UniK is a valuable addition to the academic ICT activity in Norway. The research in the Electronics and Photonics Group is very strong, and the group members enjoy excellent publication records and international reputations.

Center evaluation

The Electronics and Photonics Group at UniK has a strong research focus as evidenced by their excellent publication record and international reputation. The group provides an important function by connecting the research centers at Kjeller with academic institutions around the country.

Grade: very good

Center recommendation

The center is in an unusual and challenging situation of being geographically separated from the University of Oslo and other academic institutions, while working very closely with personnel at the research centers at Kjeller. It is therefore important that the center continually work to not get academically isolated. It is therefore recommended that it gets more involved in undergraduate and graduate teaching.

15.1 Electronics and Photonics Group

The Electronics and Photonics group sprung out of the institutes devoted to applied research that are located at Kjeller, and continues to benefit from close interactions with the researchers at these centers. The group has two full professors, one who concentrate on design of microelectronics and one who concentrate on optical communication technology. The group has close connections to both NTNU and UiO, with both professors having joint part-time (20%) appointments in these institutions. These connections, as well as the group's extensive network of international collaborators, help the groups avoid academic isolation, which could become a problem in a very small organization like UniK.

The weakness of the group is the relatively low involvement in undergraduate teaching (the professors are involved in undergraduate teaching as adjunct professors at NTNU and UiO), but the group has an above-average number of PhD students. The total number of PhD students is 8 for the 2 professors. Many of PhD students have contracts with sponsor companies. A typical contract might specify that the student work in the company for a specified period of time after graduation. These arrangements improve the visibility and penetration of the PhD degree, with positive effects on Norwegian ICT industry in both the short and long term.

15.2 Industrial Mathematics Group

The small group of 2 staff and 2 PhD students is working in a wide area with very ambitious research goals: Cybernetics (estimation and control engineering), signal analysis and image processing, numerical methods for partial differential equations, and volume visualization. As would be expected from such a small group, there are relatively few international contacts and also relatively few publications.

Appendix A

CV's of the ICT Committee Members

Prof. Sture Hägglund, Linköping University, Sweden:

Sture Hägglund is a Professor of Computer Science at Linköping University since 1988. He received his PhD in Computer Science from Linköping University, 1980. He has a Bachelor of Science from Uppsala University 1972, with majors in Mathematics, Theoretical Physics and Numerical Analysis. He has been employed at Linköping University since 1976, where he has been the leader of the Applications Systems Laboratory since 1980.

Sture Hägglund is the author or co-author of a number of conference and journal papers, primarily in the areas of Knowledge-Based Systems and Human-Computer Interaction, but also in Software Engineering, Office Information Systems and Educational Systems. During the last ten years, he has delivered more than 100 presentations at conferences, universities, and industrial research centers. Hägglund is currently program leader for the national e-Society research program. He is also program director for The Industry Research School in Applied IT and Software Engineering. He has served in program committees for several international conferences and is member of the editorial board of the journals EXPERT SYSTEMS: Research and Applications, JAI Press inc. and The Knowledge Engineering Review, Cambridge University Press.

Hägglund has extensive experience of co-operation with industry. He was co-founder of Epitec AB in 1984, a spin-off company in the expert systems area and chairman of its board during the first years. He has also been on the board of several other software companies, educational organizations, and research institutes. He is a member of the Scientific Advisory Board of Saab Training Systems Inc, a member of the board of the Swedish AI Society and of the East Chapter of the Swedish Society for Information Processing. He is also member of the Council for Renewal of Undergraduate Education and member of several research granting committees in Sweden, for instance The Knowledge Foundation, etc. Hägglund was elected member of the Royal Swedish Academy of Science.

Prof. David Keyes, Old Dominion University, U.S.A.:

David E. Keyes is the Richard F. Barry Professor of Mathematics & Statistics at Old Dominion University, an Adjunct Professor of Computer Science at ODU, the Director of the Center for Computational Sciences at ODU, the Acting Director of Institute for

Scientific Computing Research (ISCR) at the Lawrence Livermore National Laboratory, and an Associate Research Fellow of ICASE at the NASA Langley Research Center.
Keyes received his PhD in Applied Mathematics from Harvard University in 1984. He has an MS in Applied Mathematics, also from Harvard, awarded in 1979, and prior to that he graduated *summa cum laude* with a B.S.E. in Aerospace and Mechanical Sciences and a Certificate in Engineering Physics from Princeton University in 1978.
Keyes is the author or co-author of more than 90 publications in computational science, numerical analysis, and computer science. He has co-edited 7 conference proceedings concerned with parallel algorithms. Keyes has delivered over 200 presentations at universities, laboratories, and industrial research centres in 22 countries. With backgrounds in engineering, applied mathematics, and computer science, and consulting experience with industry and national laboratories, Keyes works at the algorithmic interface between parallel computing and the numerical analysis of partial differential equations, across a spectrum of aerodynamic, geophysical, and chemically reacting flows. Newton-Krylov-Schwarz parallel implicit methods, introduced in a 1993 paper he co-authored at ICASE, are now widely used throughout engineering and computational physics, and have been scaled to thousands of processors on the ASCI platforms.
Among Keyes' awards are the Gordon Bell Prize for High Performance Computing, Special Category (shared), 1999 and the National Science Foundation Presidential Young Investigator Award, 1989. He has led an NSF "Grand, National, and Computational Challenge" Center and a DOE ASCI "Level 2" Center. He currently directs a nine-institution Integrated Software Infrastructure Center (ISIC) for the Office of Advanced Scientific Computing Research of the DOE, one of seven such centres nationally under the Scientific Discovery through Advanced Computing (SciDAC) initiative. Homepage: http://www.math.odu.edu/~keyes.

Prof. Kalle Lyytinen, Case Western Reserve University, U.S.A.:

Kalle Lyytinen is a Professor at Case Western Reserve University in Information Systems and an adjunct Professor at the University of Jyväskylä, Finland. He serves currently on the editorial boards of several IS journals including, AIS journal, Information Systems Research, EJIS, JSIS, Information & Organization, Requirements Engineering Journal, and Information Systems Journal. He has published over 150 scientific articles and conference papers and edited or written eight books on topics related to system design, method engineering, implementation, software risk assessment, computer supported cooperative work, standardization, and ubiquitous computing. He has recently edited a special issue on social and design issues related to pervasive computing for Communications of the ACM (December 2002), and a special issue on the role of standardization in the building of information infrastructures focusing specifically on wireless services (Telecommunications Policy 2001). He is currently involved in research projects that look at the IT induced innovation in software development, architecture and construction industry, and is developing a high level requirements model for large scale systems. He is also engaged in a project supported by NSF that focuses on the institutional forces involved the development of global electronic commerce. His research interests include information system theories, computer aided system design and method engineering, system failures and risk assessment, computer supported cooperative work, nomadic computing, and the innovation

and diffusion of complex technologies and the role of institutions in such processes. He is the recipient of IFIP silver cord award (1995, 1998). His major industrial innovation deals with the development of a flexible meta-modelling and method engineering environment MetaEdit+, which has been successfully used in several domain based software development improvements that have lead to 10 increases in software productivity. For example, c.a. 300 million Nokia phones are powered with software generated through MetaEdit+.

Prof. Tore Risch, Uppsala University, Sweden:

Tore Risch is Professor of Database Technology at Uppsala University (Sweden) where he leads the Uppsala DataBase Laboratory (UDBL) research group. He was previously Professor at Linköping University (Sweden). Before Linköping he was research staff member in the Database Technology Department at Hewlett-Packard Laboratories (Palo Alto, California), and Visiting Scholar from HP in the database group at Stanford University. Prior to joining HP, he worked for Syntelligence Inc. (Sunnyvale, California) designing a product for large scale knowledge bases combining AI and database technologies. He also worked on the Prospector expert system (SRI, Menlo Park, California), on integrating Prolog with relational databases (Uppsala U., Sweden), and as post-doc. at IBM's Almaden Research Center (San Jose, California) on functional knowledge representation. He made his PhD 1978 at Linköping University (Sweden) on query optimization in a meta-database system. He is author of 90 technical publications and holds 4 US patents. He was General Chair of two international scientific conferences and member of the program committees of 34 international scientific conferences. He reviewed papers for 10 scientific journals and is on the editorial board of the VLDB Journal. He is member of the IFIP Working Group 2.6 on Databases, IEEE, and ACM. Home page: http://user.it.uu.se/~torer.

Prof. Colette Rolland, Paris 1 University, France:

Colette Rolland is currently Professor of Computer Science in the Department of Mathematics and Informatics at the University of PARIS-1 Panthéon Sorbonne where she has worked since 1979.

Her research interests lie in the areas of information modelling, databases, temporal data modelling, object-oriented analysis and design, requirements engineering, design methodologies and CASE and CAME tools, change management and enterprise knowledge development. She is Director of the Centre de Recherche en Informatique and supervises a team of 10 full-time assistant-professors and 20 research students that are active in these areas. She has supervised 72 PhD theses and has an extensive experience in leading research projects and conducting co-operative projects with the industry. Her research work has been supported by funding of the CNRS (Centre National de la Recherche Scientifique), INRIA (Institut National de la Recherche en Informatique et Automatisme), MRT (Ministry of Research and Technology) and by the Commission of the European Communities under the ESPRIT programme (TODOS, BUSINESS CLASS, FROM

FUZZY TO FORMAL, ELEKTRA, ELKD, E-UTILITIES) and the Basic research programme (NATURE, CREWS).

Professor Colette Rolland is the originator of the REMORA methodology for the analysis, design and realisation of Information Systems. She is the co-author of 5 textbooks, editor of 8 books and author or co-author of over 200 invited and referred papers. She is in the editorial board of the Journal of Information Systems, the Journal on Information and Software Technology, the Requirements Engineering Journal, the Strategic Information Systems Journal, the Journal of Networking and Information Systems, Data and Knowledge Engineering Journal, Journal of Data Base Management and the Journal of Intelligent Information Systems. She has been member of over 60 programme committees and chair-person of 12. She is in the board of AFCET, the French Computer Society, the French representative in IFIP TC8 on Information Systems and has been the chairperson of the IFIP WG8.1 during three years.

Prof. Arto Salomaa, Turku University, Finland:

Professor Arto Salomaa is an Academy Professor Emeritus and One of the Twelve Fellows in the Academy of Finland. Currently he works as a researcher in the Turku Center for Computer Science.

He received his PhD in 1960 and was altogether 33 years professor of mathematics at the University of Turku. Dr. Salomaa was visiting professor of Computer Science in London, Canada 1966-68; Aarhus, Denmark 1973-75; Waterloo, Canada 1981-82; and has made shorter visits to 150 universities in Europe, Asia and North America.

Dr. Salomaa was EATCS President 1979-85 and is currently the editor-in-chief of the EATCS Text and Monograph Series published by Springer-Verlag, as well as an editor or managing editor of ten international journals of computer science. He has authored 400 scientific publications in major journals, as well as eleven books, some of which have appeared also in Chinese, French, German, Japanese, Romanian, Russian and Vietnamese translations.

Dr. Salomaa has supervised 25 PhD students and holds the degree of doctor honoris causa at seven universities, two in Finland and five abroad. He has been an invited speaker at numerous conferences in computer science and mathematics, and a program committee member or chairman for major computer science conferences, including STOC, ICALP, MFCS, FCT.

Dr. Salomaa is a member of the Academy of Sciences in Finland 1970-present, the Swedish Academy of Sciences of Finland 1980-present, Academia Europaea 1992-present, Hungarian Academy of Sciences 1997-present.
He was the Professor of the Year in Finland in 1993. He has received three major yearly prizes in Finland, most recently the prize of the Nokia Foundation in 1998.

Dr. Salomaa's research interests are in formal languages, automata theory, formal power series, mathematical logic, complexity, cryptography and DNA computing. He was also in the team evaluating Informatikk in Norway in 1992.

Prof. Walter Schaufelberger, ETHZ, Switzerland:

Since 1983 Walter Schaufelberger is full Professor of Automatic Control at the Control Laboratory of ETHZ.

He graduated in Electrical Engineering at ETHZ in the early sixties. After getting his PhD in the area of adaptive control at the Institute of Control and Industrial Electronics at ETHZ and working for a year as visiting lecturer at Queen's University, Kingston, Canada, he was appointed assistant Professor at ETHZ in 1972 and promoted to associate Professor in 1977.

His interests in education and research in control are focused on applications and on the use of computers, which are important for the design and the implementation of control systems. Many different techniques and theories have to be used for successful work in this area; a special emphasis is therefore placed on a problem solving approach to control system design and implementation. The development of frameworks for control applications is the dominant theme of investigation. From 1991 to 1995 he was Dean of Undergraduate Education and since 1998 he is Dean of International Relations of ETHZ.

He is active in different international societies and projects, i.e. as President of the Société Européenne pour la Formation des Ingenieurs (SEFI) from 1997 to 1999 and as Treasurer of the International Federation of Automatic Control (IFAC) from 1993 to 2002.

Prof. Olav Solgaard, Stanford University, U.S.A.:

Olav Solgaard received the BS degree in Electrical engineering from the Norwegian Institute of Technology and the MS and PhD degrees in Electrical Engineering from Stanford University, California. He held a post-doctoral position at the University of California at Berkeley, and an assistant professorship at the University of California at Davis, before joining the faculty of the Department of Electrical Engineering at Stanford University in 1999.

His research interests are optical communication and measurements with an emphasis on semiconductor fabrication and MEMS technology applied to optical devices and systems. He has authored more than 80 technical publications, and holds 11 patents. He is a co-founder Silicon Light Machines, Sunnyvale, CA, and an active consultant in the MEMS industry.

Prof. Arne Svensson, Chalmers Technical University, Sweden:

Arne Svensson received the MS (Civilingenjör) degree in Electrical Engineering from the University of Lund, Sweden in 1979, and the Dr.Ing. (Teknisk Licentiat) and Dr. Techn. (Teknisk Doktor) degrees at the Department of Telecommunication Theory, University of Lund, in 1982 and 1984, respectively.

Currently he is with the Department of Signal and Systems at the School of Electrical Engineering at Chalmers University of Technology, Gothenburg, Sweden, where he was appointed Professor in Communication Systems in April 1993. Before 1985 he held various teaching and research positions at the University of Lund. From April 1985 to July 1987, he was a Research Professor (Docent) at the Department of Telecommunication Theory, University of Lund. In Aug. 1987, he joined the Airborne Electronics Division at Ericsson Radio Systems AB, Mölndal, Sweden. After a company reorganization in Jan. 1988, he became employed by Ericsson Radar Electronics AB, where he first was a member of the New Projects Group at the Airborne Electronics Division and then from Sept. 1990 to Dec. 1994 a member of the Mobile Telephone Systems Group at the Microwave Communications Division. His current interest include channel coding and decoding, digital modulation methods, channel estimation, data detection, multiuser detection, digital satellite systems, wireless IP based system, CDMA and spread spectrum systems, personal communication networks, and ultra wideband systems.

Professor Svensson has published almost 30 journal papers/letters and more than 120 conference papers. In 1986, he was recognized with the IEEE Vehicular Technology Society Paper of the Year Award, and in 1984, he received the Young Scientists Award from the International Union of Radio Science, URSI. He was an editor of the Wireless Communication Series of IEEE Journal of Selected Areas in Communications until 2001, and is now an editor for IEEE Transactions on Wireless Communications. He is a fellow of IEEE, a member of IEEE Communications Society, IEEE Signal Processing Society, IEEE Information Theory Society, IEEE Vehicular Technology Society, and the Swedish URSI committee (SNRV, Svenska Nationalkommitten för Radiovetenskap). He is a member of the councils of SER (Svenska Elektro- och Dataingenjörers Riksförening) and NRS (Nordiska Radiosamfundet).

Appendix B

Review of basic research in Information and Communication Technology in Norway

Mandate for the evaluation committee

I INTRODUCTION

The Division of Science and Technology at the Research Council of Norway has decided to evaluate basic research activities in Information and Communication Technology (ICT) in Norwegian universities and colleges. The report of the evaluation committee will form the basis for the future strategy of the Research Council.

The objective of the evaluation

The objective of this evaluation is to review the overall state of basic research in ICT in Norwegian universities and colleges.

Specifically, the evaluation process will:

- Offer a critical review of the strengths and weaknesses of ICT research in Norway, both nationally and at the level of individual research groups and academic departments, and review the scientific quality of basic research in an international context.

- Identify research groups which have achieved a high international level in their research, or which have the potential to reach such a level.

- Identify areas of research that need to be strengthened in order to ensure that Norway in the future will possess necessary competence in areas of importance for the nation. And, as one aspect of this, enable the Research Council of Norway to assess the impending situation regarding recruitment in important fields of ICT.

The long-term purpose of the review

The evaluation will provide the institutions concerned with the knowledge they require to raise their own research standards. They will be provided with feedback regarding the

scientific performance of individual research groups, as well as suggestions for improvements and priorities.

The evaluation will improve the knowledge base for strategic decision-making by the Research Council, function as a platform for future work on developing ICT and represent a basis for determining future priorities, including funding priorities, within and between individual areas of research.

The evaluation will reinforce the role of the Research Council as advisor to the Norwegian Government and relevant ministries.

II MANDATE

The committee is requested to make use of the departments' self-evaluations in its assessment of the overall state of ICT and to draw up a report with a set of specific recommendations for the future development of this field. The committee is requested to evaluate scientific activities with respect to their quality, relevance and international and national collaboration, bearing in mind the resources available. The committee is further requested to evaluate the way in which research in ICT is organized and managed.

The conclusions of the committee should lead to a set of recommendations concerning the future development of research in ICT in Norway.

Specific aspects to be considered:

1. General aspects

- Which fields of research have a strong scientific position in Norway and which have a weak position? Is Norwegian research being carried out in fields that are regarded as relevant by the international research community? Is Norwegian research in ICT ahead of scientific developments internationally within specific areas?

- Is there a reasonable balance between the various fields of Norwegian research in ICT, or is research absent or underrepresented in any particular field? On the other hand, are some fields over-represented, in view of the quality or scientific relevance of the research that is being carried out?

- Is there a reasonable degree of co-operation and division of research activities at national level, or could these aspects be improved?

- Is the ICT of today relevant to the needs of Norwegian industry and society? Do research groups maintain sufficient contact with industry and the public sector?

2. Academic departments

- Are the academic departments adequately organized?
- Is scientific leadership being exercised in an appropriate way?
- Do individual departments carry out research as part of an overall research strategy?
- Is there sufficient co-operation in the use of expensive equipment?

3. Research groups

- Have research groups drawn up strategies with concrete plans for their research, and are such plans followed up?
- Are the size, organization and leadership of the research groups reasonable?
- Are the results that are being obtained, e.g. number of fellowships awarded and articles published, reasonable in terms of the resources available?
- What roles do Norwegian research groups play in international co-operation in individual subfields of ICT? Are there any significant differences between Norwegian research on ICT and research being done in other countries?
- Do research groups take part in international programs or use facilities abroad, or could utilization be improved by introducing special measures?
- Is there sufficient contact and co-operation among research groups at national and international level?

4. Training and mobility

- Is recruitment to doctoral training programs satisfactory, or should greater emphasis be put on recruitment in the future?
- Is there an adequate degree of national and international mobility?
- Are there sufficient educational and training opportunities for PhDs in industrial research?
- Where do graduates go after completion of higher degrees?

5. Miscellaneous

- Are there any other important aspects of Norwegian research on ICT that ought to be given consideration?

Appendix C

ICT Evaluation 2001/2002

Parameters for the ICT Committee's Work

The Science and Technology Division of the Research Council of Norway has conducted a number of subject-specific evaluations (physics, geo-sciences, chemistry, bio-sciences) in recent years . The following parameters for the ICT Committee's Work are based on experience derived from these evaluations:

1. Hearings with the institutes/research groups
The Research Council has found that organising hearings with the institutes has favourable effects, both professionally and administratively speaking, as an alternative to having the expert committee visit each individual institution (site visits). Accordingly, the ICT Evaluation will be based on conducting hearings; each individual research group will appear before the ICT Committee to present itself and be interviewed.

2. Evaluation at the research group level
Research groups will be the smallest units in the evaluation. This means the evaluation will not extend to the individual level. Further, the names of individual researchers are not to be mentioned in the evaluation report per se. Consequently, the research group's name must be topical and not based on the name of the group's chairperson.

3. Quality assurance of facts in the evaluation report - Description of procedure
The Research Council wants to ensure that the final evaluation report does not contain factual errors about the institutes/research groups under evaluation. Factual errors are perceived in a very negative light by the groups involved. Accordingly, the Research Council requires that the facts the committee elects to include in its evaluations of each institute be subject to quality assurance by the institutes in question before the report is submitted.

The following procedure will be instituted once the Research Council has received a draft evaluation report from the committee (spring/summer 2002):

Each institute will receive a letter from the Research Council, accompanied by the chapter of the report that refers to that particular institute's research groups. The institute will be asked to identify any factual errors in the report[1].
The institutes will provide feedback by mail regarding any factual errors in the report.
The committee will collect the feedback from the institutes.
The committee will consider the feedback from the institutes/research groups, correct any factual errors and hold a separate meeting to consider the consequences of the feedback, if any, for the final evaluation report.
The ICT Committee's final report will be submitted to the Research Council and published (August 2002).

[1] The Research Council's letter will explain what is defined as facts and thus what the institute has the opportunity to change.