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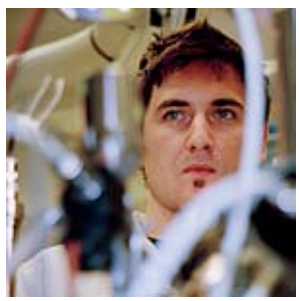

INTERNATIONAL RESEARCH ASSESSMENT EXERCISE 2008
PROJECT REPORT

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Excellence in research for humankind and for the environment

In order to stay competitive internationally it is necessary to establish priorities in research. It was therefore decided to undertake a thorough evaluation of the quality of KTH's research. The present report summarizes the outcome of this Research Assessment Exercise (RAE). The results are extremely positive for KTH and have provided a basis for the formulation of KTH's strategy for the next four years. We at KTH will continue to focus on quality and excellence in research.

Stockholm in December 2008

Prof. Peter Gudmundson
President, KTH Royal Institute of Technology

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Preface

"Advances in science and technology form the basis of welfare in modern societies. A capacity for such advancements, and the subsequent innovations they provide to the economy, requires excellence and leadership in research."


Prof. Tuula Teeri

Quality assessments that seek to identify excellence and leadership have come to play a significant role when public resources are distributed to higher education institutions worldwide. To build quality, successful higher education institutes have embraced external, international evaluations of their work that encourage faculty to view their output in a global context. In addition to helping national funding bodies focus their resources towards the most internationally competitive units, such research evaluations can equally well serve as a tool for institutions to assure themselves of the quality of research efforts undertaken – and for faculty to strengthen that quality.

The government in Sweden has decided to use quality criteria to steer the allocation of basic resources to universities. This initiative aims to both increase the volume and quality of free basic research and stimulate entrepreneurship and innovation. To ensure quality in basic research, it is essential that Swedish universities identify and focus on those areas of their research with the highest potential for scientific progress. Ensuring the quality of applied research requires an aligned focus.

Technical universities in particular have a unique responsibility to take scientific advances forward into society, supporting existing companies as well as laying the foundations for emerging industrial sectors. At a technical research university,

excellence in basic research must be matched by excellence in applied research and excellence in knowledge dissemination and exchange.
This year KTH set itself the challenge of conducting an international review of its entire research base. This is the first time that a technical university in Scandinavia has set itself such an ambitious goal. During eight weeks this spring, all members of faculty were involved in the compilation of "Evaluation Packages" that described the strengths and achievements in their research. Strategies for future research directions were also articulated in these packages. In June, 80 international Experts visited KTH to review the university's research performance. These Experts visited 47 research units over four days, meeting senior faculty, upcoming faculty and research students. After these visits the Experts submitted reports, providing a written evaluation of the different research groups. In addition, KTH conducted a separate Bibliometric Analysis of publications from these units.

This report presents a summary of the current research environment and conditions in Sweden, it goes on to review the quantitative data collected in the Evaluations Packages, and provides summaries of the assessment reports from the Expert Panels. The Bibliometric Analysis is also reported. Findings at the KTH level are also put forward.

Information gathered during this process is being used to steer the development of KTH's Strategic Plan for 2009–2012. It is also providing input to the subsequent strategies of KTH's Schools.

Prof. Tuula Teeri
Director, KTH International RAE 2008

Executive Summary

The present research assessment exercise identified a number of strategic and structural strengths at the university level; it also identified weaknesses. The general strength of KTH is the overall high quality of research, with half of the units performing at an international top level. The units with the best performance have a good balance between basic and applied research and a healthy age and competence profile with both established and young faculty. The Bibliometric Analysis confirmed the excellent performance of those research areas which have a strong tradition in publishing in peer reviewed international journals. However, in many areas of engineering sciences, and to some extent social sciences and management, other criteria were found to be important for assessing research excellence. The many Centres of Excellence at KTH were identified by the Expert Panels as catalysts for creating strong and mutually beneficial relationships with academia and industry.

The industrial interactions at KTH were found to be many and vital, with a large number of research centers and research contracts with industrial partners. KTH also has a good innovation performance with many successful patents and some fast-growing and highly profitable start-up companies. With better routines for supporting patenting and technology transfer, an even stronger innovation footprint can be achieved in the future.

The weaknesses identified by the Expert Panels included an internal resource allocation system that gives few incentives and poor stability for excellent basic research. This was considered to be a nationwide weakness. Another area identified as weak was support for experimental infrastructure, both in research and education. Experimental competence is a key element of successful engineering and must be supported at the university level.

Scholarship – as defined by high quality, independent basic and applied research, free of financial and political control, to promote the well-being of society – was generally found to coincide with an overall strong performance in basic and/or applied research. Based on the expert evaluation, KTH can be considered to be at the forefront of technology development and academic leadership in over half of its research bases.

In terms of vitality and potential, the Expert Panels noted an ageing personnel structure in many key areas of excellence, and an efficient renewal process was therefore recommended in order to rapidly vitalize such research fields. A recruitment strategy must be put in place that will include clear career paths and support for young faculty, and sufficient start-up funding for newly recruited staff. Another identified threat for international visibility and competitiveness was that research in many potential areas of strength was split into groups that were too small to achieve international visibility and benefits of scale. Better coordination and communication of research activities is thus necessary.

Following the recommendations of the Expert Panels, it will be proposed that the future research strategy of KTH focus on the consolidation of research efforts in key areas of strength such as materials sciences, energy and environmental technology, information and communication technologies and medical technology.

The internal research allocation system will be reformed to support academic excellence, as well as societal relevance and business outreach. The main focus of future staff recruitment will be on young researchers who could proceed towards higher academic positions through a clear career track, supported by stable basic funding. These changes will improve international visibility and strengthen the KTH brand in these areas, thus paving the way for true international leadership.

Part 1. Introduction

Focusing on quality – principles behind the international RAE

At the start of 2008, KTH (the Royal Institute of Technology) set itself the challenge of evaluating the entire scope of its research base. This evaluation took place over six months and engaged all of KTH's research staff as well as 80 international research experts. It was the first time that a technical research university in Sweden had undertaken a project of this type and scale. The purpose of the evaluation was to enable KTH to identify areas of existing research strength and emerging potential against an international benchmark. The evaluation itself was designed to initiate a strategic process across the university, within which all research staff would consider the future direction of their work.

Evaluation as a mechanism for strengthening KTH's research profile

Ever increasing research opportunities and limited funding have meant that resource allocation has become an issue for higher education institutes. Evaluations of research quality have come to play a significant role in resource allocation as they enable universities to focus funding on their most successful groups with the strongest future potential – or to identify where further investments might be necessary to increase quality.[1] The distribution of resources is also an issue at a national level, and several countries now routinely distribute funds on the basis of country-wide research evaluations. The United Kingdom's Research Evaluation Exercise is the most thorough example of such activity.[2]

By focusing resources on areas of high quality, a university actively focuses and strengthens its research profile. The skills and resources required to achieve scientific breakthroughs make it increasingly hard for a university to spread its research activities too thinly. International competition for funding, contracts, students and researchers has also encouraged universities to specialize, articulating their areas of activity and goals more clearly.

1) OECD, *The Evaluation of Scientific Research: Selected Experiences* Paris: OECD, 1997
2) Geuna, A. and Martin, B.R., "University Research Evaluation and Funding: An International Comparison", *Minerva* 41: 277–304, 2003; Elton, L., "The UK Research Assessment Exercise: Unintended Consequences", *Higher Education Quarterly.* 45: 274–283, 2000; Hills, P.V. and Dale A.J., "Research and Technology Evaluation in the United Kingdom", *Research Evaluation*, 5(1): 35–44, 1995.

Within the Nordic countries, the University of Helsinki has assessed its research quality in 1999 and 2005.[3] Uppsala and Lund Universities conducted research evaluations in 2007 and 2008 respectively.[4] The purpose of these evaluations was to help the universities focus their research profiles and better distribute their resources. Sweden at a national level is currently moving towards a research funding system within which the results of research assessments will play a more significant role.[5] This is clearly articulated in the most recent research policy declaration of the Swedish Government.[6] KTH must thus also manage the manner in which its limited resources are allocated and strengthen its research profile in order to continue to play a vital role on the national and international stages. Results from the current evaluation process will thus be used to plan how KTH can best distribute its internal resources – both funding and people – in the future.

Evaluation as an active strategic process

KTH's decision to engage in a research evaluation also represents a deeper process at work within the university. In the increasingly competitive world of international research, a university must understand its strengths and weaknesses to plan for its future. These days almost all universities and their constituent parts produce strategic plans based on these strengths and weaknesses, and KTH is no exception. Those more limited number of institutions that succeed in *carrying out* their strategy, within the unique environment of academia do so by engaging their research staff in the strategic process.

The KTH research evaluation set out to be an exercise in strategy formulation that would engage every member of the university's research staff and the university's leadership in a productive dialogue. Through this process KTH has come to understand its research profile and abilities better at every level. The new strategy that KTH will publish in December 2008 is in large part based on knowledge that has resulted from this bottom-up process.

Through this process KTH has also ensured that the "know-how" and value of strategic research planning is embedded in each and every part of the university. Indeed, within the KTH RAE, the strategic abilities and ambitions of each research group were assessed. An institution, research group or individual that is able to picture and plan for the future is able to play an active role in the creation of that future, taking a leadership position within academia and society. Academic leadership and outreach in its areas of strength is a key contribution that KTH can make to Sweden.

3) http://www.helsinki.fi/research2005/english/index.htm
4) *Quality and Renewal 2007: An overall evaluation of research at Uppsala University,* Uppsala University: Uppsala 2007; http://www.lu.se/lund-university/research/research-evaluation---rq08
5) *Resurser för Kvalitet,* Statens Offentliga Utredningar 2007: 81; Engwall, L. and Nybom, T., "The Visible Hand Leaving Decisions to the Invisible Hand: Allocation of Research Resources in Swedish Universities" in Richard Whitely (ed.), *The Changing Governance of the Sciences: the Advent of Research Evaluation Systems*, Berlin: Springer 2007.
6) *"A Lift for Research and Innovation"* Government Proposition, 22nd October 2008

In addition, by acquiring quantitative data and informed opinions through the evaluation process, KTH considers that it will be in a better position to make stronger, information-driven decisions. This will provide greater transparency, empowering researchers at all levels by illustrating clearly the criteria for success that KTH values and will reward.

Evaluation of quality in a technical research university

The responsibilities of a technical university are many and complex. Such a university should contribute both to scholarship and to society by fostering basic and applied research in a host of fields – and by building relationships between these approaches and fields. A technical research university has a particular responsibility to transfer its research findings to, and interact with, industry and society when executing its strategy. It is thus necessary to assess multiple criteria when evaluating the quality of research outputs from a technical university.[7]

When forming this Research Assessment Exercise, KTH has striven to adopt a versatile set of assessment criteria that best describe the multidisciplinary excellence required of a technical research university. The assessment system hereby adopted for this purpose is inspired by a recent report *"Measuring Excellence in Engineering Research"* published by the Royal Academy of Engineering in the UK. [8]

In practice, the researchers were asked not only to report their academic performance in terms of international publications, but also to consider the social impact of their research in the formulation of strategy. They were given the opportunity to submit applied research outputs such as patents, software and materials and these were given an equal weighting with research papers. Indicators reflecting their impact on industry and society (such as income from industry and government agencies, industry sponsored PhDs, industry professors, patents and company formations) were also recorded. Applied research quality was made an explicit criterion of evaluation, and at least one member of each Evaluation Panel came from industry.

Setting an international benchmark to strengthen an international reputation

With increasing international competition and globalization, national universities must reach high international standards if they are to fulfill their role as key actors in research and education. KTH is already an international university and has set itself the goal of being consistently ranked among the top technical research universities in Europe. It is thus vital that the research activities of KTH should be evalua-

7) le Pair, C., "Formal Evaluation Methods: their Utility and Limitation" *Int. Forum on Information and Documentation* 20, 4: 16–24 (1995); Frankel, M.S. and Cave, J., *Evaluating Science and Scientists*. Center for European University Press: Budapest 1997
8) *Measuring Excellence in Engineering Research,* Royal Academy of Engineers: London 2000

ted by international peers against international standards. The external group advising KTH on its approach to research evaluation included members from Europe and the USA. The majority of Experts commissioned to undertake the evaluation came from outside of Sweden. The Experts were asked explicitly to evaluate KTH's research against a high international benchmark and to compare KTH with world-leading technical research universities.

In conclusion, KTH has aimed to identify an evaluation model that reflects its profile, role in society and future ambitions. At the same time, the university has worked to identify a model that is useful not only to the university management, but also to individual research groups and staff. All parts of KTH have a vital role to play in determining KTH's future, and the research evaluation was designed to give them an opportunity to voice their view of that future.

KTH and the changing environment of technical research universities

KTH in brief

The Swedish university sector has expanded considerably since the 1970's, with 47 Higher Education Institutes (HEI) operating today.[9] Four of these universities are technical research universities, 21 are allowed to award postgraduate degrees and all but three are public institutions. After a strong trend over many years towards the creation of regional universities, the emerging trend now is towards consolidation.

Founded in 1827, KTH today accounts for one-third of Sweden's technical research and higher engineering education capacity at university level, making it Sweden's largest technical university.

TODAY KTH IS ORGANIZED IN 9 SCHOOLS THAT ARE RESPONSIBLE FOR RESEARCH AND EDUCATION:

- School of Architecture and the Built Environment (ABE)
- School of Biotechnology (BIO)
- School of Computer Science and Communication (CSC)
- School of Electrical Engineering (EES)
- School of Industrial Engineering and Management (ITM)
- School of Information and Communication Technology (ICT)
- School of Chemical Science and Engineering (CHE)
- School of Technology and Health (STH)
- School of Engineering Sciences (SCI)

9) This total includes both Universities and University Colleges, as listed by the Swedish National Agency for Higher Education (Högskolverket)

Each of these Schools comprises a number of research areas and interdisciplinary Centres of Excellence. In addition KTH has a unit for Scientific Information & Learning and a unit for Business Liaison that are organized as independant entities reporting directly to the President.

The main campus of KTH is located in central Stockholm. In addition, KTH carries out research in biotechnology and physics at the Alba Nova Centre to the north of the main campus. Alba Nova is a cooperative engagement with Stockholm University. The School of Technology and Health is located south of Stockholm and here KTH cooperates with the Karolinska Institute. The School of Information and Communication Technology is located on the Kista campus north of Stockholm. In Kista, KTH collaborates with Stockholm University, various Research Institutes and industry thus creating Sweden's largest resource in information technology. In addition, almost half of the research within Sweden's independent Research Institutes is performed in localities within KTH's various campus areas.

ACCORDING TO THE 2007 ANNUAL REPORT, KTH HAS:

- 11,927 enrolled students
- 1,434 active research students, with 209 PhDs granted in 2007
- 14 M. Sc Engineering Programmes and an Architecture Programme
- 52 International Masters Programmes
- 259 Professors
- 202 Associate Professors
- 84 Assistant Professors
- 2,795 total staff members
- 1,800 refereed publications in the year
- Turnover of 312 MEuro; 201MEuro of which is for research and graduate education

Swedish research in a global perspective

The development of universities is to a large extent governed by the cultural and economic environment in which they operate. In Europe, the Lisbon Treaty established that the total research and development (R&D) expenditure of the EU member states should reach 3% of GNP by 2010, with at least two thirds coming from the business sector. At a national level, Sweden met this target in 1993. By 2005 R&D expenditure reached 3.9% of GNP for the whole economy, and 2.9% for the business sector – 72% higher than the average for the OECD and considerably higher than Germany, Japan and the US.

However, as a country with a population of only 9 million, Sweden's share of global R&D is quite low. According to an OECD comparison, the volume of R&D in the US is about 30 times that in Sweden. Sweden's international share will certainly continue to shrink in coming years due to the considerable ambitions of developing countries such as China, India and Brazil.

Parallel to this expansion in developing countries, Europe has witnessed a change in research funding driven by both a declining public financing and an increasing emphasis on the roles universities can play in *regional and local* development. Research funding at a local government level in Sweden is increasing, thus creating opportunities for universities to focus their research efforts on areas of regional importance. However, those universities who best serve their region do so by remaining competitive at an international level. MIT in Boston, for example, contributes to its region through being a top ranked university internationally.

Research funding trends in the Swedish higher education sector

R&D expenditure in the university sector in Sweden reached 0.81% of GNP in 2005 and has since remained at this level. Again, in international comparison this level of investment is high. It reflects Sweden's commitment to being a knowledge-driven nation and a political decision to focus public R&D resources at universities, rather than Research Institutes.

However, in a historical perspective, the proportion of direct government funding to Swedish universities, relative to their external financing, has been gradually declining from about 70% in 1981 to less than 50% in 2005.[10] This is following the general European trend, with the exception of France, which has increased the proportion of direct funding to universities from about 50% to close to 70% in the same period. At KTH, the proportion of direct government funding for research was 36% in 2007. The pressing economic situation with a constantly increasing dependence

10) Vetenskaprådets rapportserie 1:2008. *Finansiering av forskning inom den svenska högskolan* 1995–2006. ISBN 978-91-7307-126-0

on external research grants has not been optimal for building up and maintaining basic research excellence and the necessary infrastructure.

However, the Swedish government has recently decided to boost its spending on research by SEK 5 billion.[11] Part of this investment will be made by direct increases to faculty funding in Swedish universities. The distribution of such funds will depend on research quality indicators such as citations and the level of external research grants, again emphasizing the importance of the assessment of research quality in Swedish universities. Another significant part of the increased research funding will be directed to strategic research initiatives in three key areas of national strength and future relevance: Climate, Technology and Medicine. These funds will also be delivered as a part of the basic faculty funding of the universities which, however, will have to compete for these funds. As shown by the present RAE, KTH has clear research strengths in these areas and should be able to successfully compete for such funds. This is a much needed opportunity for KTH to stabilize and strengthen its research environment, and thereby develop an ambitious research agenda that forms the basis of true international excellence.

Research funding trends at KTH

As mentioned previously, KTH is today highly dependent on external research funding, with just over one third coming directly from the government. As shown in Table 1.1, the manner in which competitively awarded R&D funding is distributed in Sweden is quite complex with many actors with different strategies and agendas. Reflecting the status of KTH as a technical research university, its relative share of national funding is highest amongst those funding bodies that are application-oriented or those that focus on strategic research (e.g. Vinnova and SSF). Over the past decade, the budgets of these national funding agencies have remained relatively stable with the exception of the local government sector which has had increased resources to distribute. If this trend continues, KTH should increase its relative share of the national funding by further strengthening its links within the Stockholm region (see below).

In an international perspective, KTH presently wins 13% of the total EU funding awarded to Sweden. This translates to about 9% of KTH's total research budget. This category of funding has clearly grown in recent years and it is therefore essential to maintain and improve the competitiveness of KTH for obtaining such grants.

11) "*A Lift for Research and Innovation*" Government Proposition, 22nd October 2008

TABLE 1.1 A SUMMARY OF R&D EXPENDITURE IN SWEDEN DURING 2005–2007 (MEAN ANNUAL LEVEL) AND THE KTH SHARE THEREOF (SOURCE: THE HSV[12] DATABASE).

Contributions to research and research education	Actual level MSEK	Trend % per year	KTH Actual share, %
Governmental authorities, excluding VINNOVA	2 425	1	7,9
Swedish Research Council (VR)	2 174	2	8,6
Swedish non-profit private organizations	1 966	-4	5,6
EU	990	10	13
VINNOVA Research Council	466	0	20,2
Swedish Foundation for Strategic Research (SSF)	457	-5	16
FORMAS Research Council	436	3	6,5
Firms in Sweden	414	-4	11,2
Firms abroad	108	-5	10,9
Contracted research			
Firms in Sweden	602	4	11,3
Governmental authorities	472	1	3,8
Local Government	322	12	0,4
Firms abroad	172	0	3,3
Contracted education			
Governmental authorities	491	0	0,3
Communities	250	-8	0,5
Firms in Sweden	152	2	5,9

The data collected in this Table is given at the price level of 2007. "Trend" means the approximate annual change in fixed prices during 2001–2007. The funding in the Table represents over 95% of the external funding to KTH research and almost 100% of contracted research and education

Business sector financing of HEI sector R&D

Direct financing of HEI sector R&D by industrial companies in Sweden only contributes 5% of total financing, with this trend showing a slight decrease over recent years. This figure, however, does not capture the whole picture since the accounting system currently used does not register all economic contributions from industry such as the employment of industrial PhD students in universities, in-kind contributions in research centres and programs, and the use of equipment. The estimated total contribution of industry to research in the HEI sector when these factors are included is closer to 7%, which is comparable with that in many other countries. In 2007 KTH received 14% of its income from Swedish industry and private organisations, again reflecting its status as a technical research university.

12) The Swedish National Agency for Higher Education (Högskoleverket)

In 2005 (*the last year for which data is available*), 42% of the financing for the HEI sector from Swedish companies, and 18% of the financing from international companies, was for research in the field of Technology. Whilst the top industrial R&D performers (such as Ericsson, AstraZeneca, VOLVO, SCANIA, SAAB, ABB, Telia, Electrolux and Atlas Copco) are of great significance for KTH, small companies (10–49 employees) in the Stockholm region are of growing interest. Although the share of total R&D in the business sector of such small companies is only 8%, a more detailed analysis reveals that they account for 20% of all research-educated research personnel, 20% of all EU financed R&D, 19% of all R&D contracted to other firms and 15–17% of all R&D contracts with Swedish and foreign universities. These overall figures imply that these small companies play important roles in the national innovation system, connecting resources within universities and institutes to both their own R&D needs and, as R&D subcontractors, to larger firms. About half of these small firms operate in the Stockholm region. Thus for KTH these firms constitute a local/regional multidisciplinary collaboration asset far beyond that available to any other Swedish technical university. Even in a European context, this close-by collaboration market represents an impressive opportunity.

International trends in university development

A global increase in university spending and numbers of students has dramatically reshaped the HEI landscape in recent times. Taking China as an example, its R&D level has increased from just under 0.5% of GNP in 1990 to close to 1.5% in 2006. China's 15-year plan for science and technology sets a GNP target of 2.5% for 2020 and it is currently building 50 new universities. Other nations in Asia, the Middle East and South America have also developed their HEI activities considerably; Dubai, for example, recently establishing a 10 billion dollar foundation to "develop world-class knowledge" in the region.

According to UNESCO, the global population of students has grown by 40% over the past seven years to 138 million, and 2.7 million of these students are studying internationally.[13] In comparison, the segment of the population of university age in western economies is becoming smaller; during 2010–2018 the number of 19 year olds will decrease in Sweden by approximately 30%. Future expansion of the university sector and the availability of trained personnel in developed countries will therefore rely heavily on international students. At the same time, competition to recruit the best international students will toughen; according to the British Council, the current downturn in the number of Chinese students willing to travel internationally to study is caused not by a reduction of university-aged students or their incomes but by better internal provision.

13) OECD; *Education at a Glance* (2008)

In response to these changes, universities in developed countries have turned their attention to establishing active international strategies. In practice these strategies have tended to focus on the recruitment of international students, with the UK, for example, currently recruiting 300,000 students a year, these providing a 5 billion pound boost to the UK economy. University franchising and the construction of campuses in overseas locations have also become fashionable with the universities of Nottingham and Liverpool from the UK and universities of Cornell, NYU and Georgetown from the US setting up satellite campuses abroad. EPFL in Switzerland will join this trend, setting up a campus in India.

KTH is currently Sweden's largest educator of international students, with over 2000 international students embarking on KTH educations each year. This number has increased rapidly over the last years. These students tend to be attracted to the fifty or so master programmes that KTH offers in English. It is also notable that KTH's most rapidly expanding source of research income is international, with funding from EU programmes increasing. KTH's environment, its student and research communities are all internationalising rapidly in an HEI sector that is moving from national to global.

From "Ivory Towers" to "Entrepreneurial Universities"

Considering the various challenges and opportunities outlined above, how should KTH respond? The traditional role of universities as the cradle of new knowledge, with curiosity as the only incentive, is changing. Whereas nations previously invested in "general" research universities with broad, department-based research profiles, today there is a trend towards more focused universities within which departments and interdisciplinary research themes each play roles.

Such focused interdisciplinary research environments have been acknowledged as fertile ground for new scientific breakthroughs and innovation. For example, Stanford University in the USA has created dozens of new multidisciplinary centers and programs in order to promote teamwork and cross-fertilization. The most extreme recent examples of such a trend include the Arizona State University in the USA and the newly established King Abdullah University (KAUST) in Saudi Arabia. Both universities are abandoning the traditional discipline-based faculty structure and have instead been organized into interdisciplinary research institutes.[14]

Some now also position universities as global gateways for "regional marketing" that attract inward investments. Universities are also seen as sources of knowledge and technology, supporting established businesses in the region and generating new businesses. Furthermore, universities are positioned as resources for human capital growth through graduate retention and continued professional education, and as creators of cultural contents and contexts.

14) http://www.newsweek.com/id/151686

Universities have attempted to meet these challenges by encouraging a more "entrepreneurial" spirit in their operations. "Entrepreneurial" universities open up to an influx of steering impulses from non-academic actors.[15] In response, university management styles are gradually shifting from administrative procedures based on "control" (and quality) to managed opportunity seeking and "action".

Navigating this complex new world requires that a university moves toward a more engaged style of management and clarifies its external roles and responsibilities in its steering documents. Universities must also communicate the deeper meanings in these steering documents into the faculty, and make substantial investments in people who can fulfil the "entrepreneurial" obligations beyond the traditional roles of universities. The concept of the "entrepreneurial" university is one that KTH has been exploring over the past five years.[16] The present strategic process, including the KTH RAE 2008, is considered as a means towards the creation of a better, more entrepreneurial style of management at and within KTH. The key challenge is, of course, to manage this entrepreneurial approach without losing the inherent quality of research; excellent basic research is essential for the long term capacity of the university to deliver new knowledge and innovations.

In summary, there are several strong general trends that presently govern the development of the HEI sector. In economic terms, universities have witnessed a change from relatively generous and stable basic funding to a distribution of basic funding based on research quality assessment and an increased dependence on competitive external funding. To a certain extent, this has forced universities to rely on an industrial and societal, rather than a purely scientific, research agenda.[17] An increasing requirement for visible societal benefit has encouraged universities to move towards problem-oriented, interdisciplinary modes of operation and to adopt more entrepreneurial strategies. Globalization has increased competition for research grants, faculty and students, making it necessary for universities to operate by strictly international, rather than national standards. At the same time, the responsibility remains for universities to maintain excellence in basic research, the very foundation of new knowledge, scientific discoveries and innovations. The challenge set to the modern universities is thus to balance the production of high-quality, curiosity-driven basic research and the interactive transfer of that knowledge acquired to the further benefit of society.

15) Clark, B.R., *Creating Entrepreneurial Universities: Organizational Pathways to Transformation* Pergamon IAU Press 1998; Cherwitz, A.R. Creating a culture of Intellectual Entrepreneurship" *Academe 91* (5) 2005.
16) *The Entrepreneurial Faculty Project*, Vinnova: Stockholm 2004
17) *What are Universities For?* League of European Research Universities: Leuven 2008

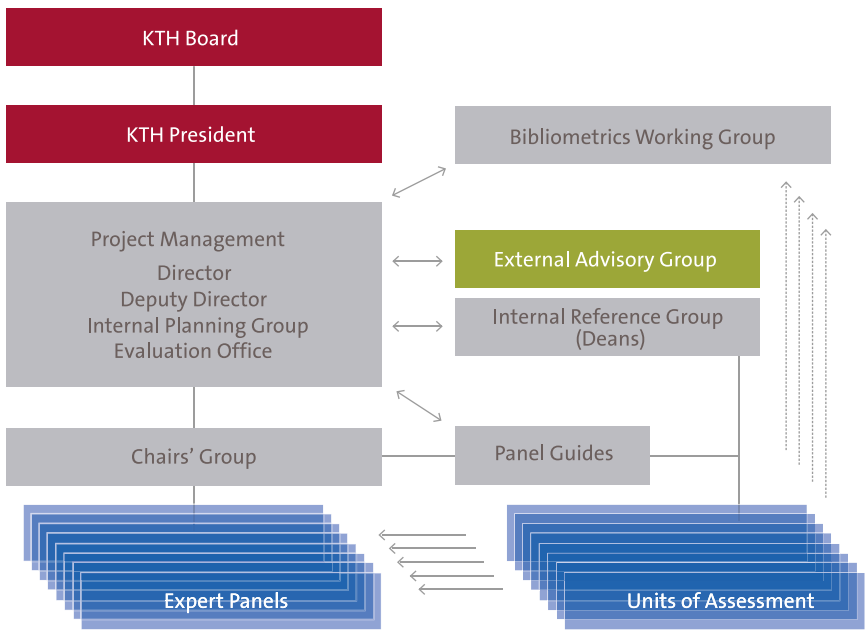
The approach of the KTH RAE 2008

This section of the report summarises how the KTH RAE was organized and gives details of its constituent parts: the Self Evaluation, Peer Review and Bibliometric Analysis. It also outlines the criteria of assessment used by the Expert Panels.

Organisation of the KTH RAE

The international RAE was an initiative from KTH's new leadership put forward to the KTH Board in February 2008. It was run by a Project Management Team headed by the Deputy President with responsibility for Research, Professor Tuula Teeri, and run through an Evaluation Office headed by Dr Emma Källblad from the University Administration.

PROJECT ORGANISATION



An Internal Planning Group was formed to provide advice on the strategy taken towards the evaluation. It consisted of the following members:

- Professor **Tuula Teeri**
- Dr **Emma Källblad**
- Professor **Sigbritt Franke**, former Universities' Chancellor for Sweden and Guest Professor at KTH
- Professor **Folke Snickars**, Faculty Dean, KTH
- Professor **Eric Giertz**, Head of KTH Business Liaison
- Professor **Arne Johnson**, Deputy Dean of the School of Engineering Sciences, KTH
- Professor **Annika Stensson-Trigell**, Head of Vehicle Dynamics, KTH
- Dr **Sandra Di Rocco**, Department of Mathematics, KTH

In addition an international External Advisory Group was established. Members of this group included:

- Professor **Marja Makarow** (Finland, France), CEO of the European Science Foundation
- Professor **Peter Nijkamp** (Neatherlands), President of the Governing Board of the Netherlands Research Council (NWO)
- Professor **Richard Murray** (USA), Thomas E. and Doris Everhart Professor of Control and Dynamical Systems, CALTECH and former Head of the Division of Engineering and Applied Sciences
- **Börje Ekholm** (Sweden), CEO of Investor AB
- Professor **Sigbritt Franke** (Sweden), former Universities' Chancellor for Sweden and Guest Professor at KTH
- **Dan Brändström** (Sweden), Government Advisor on quality in research
- Professor **Joseph Nordgren** (Sweden), Director of the Uppsala University Research Evaluation and Vice-Rector for Science and Technology at Uppsala University

KTH is most grateful to these Experts for the support they gave to the evaluation. The RAE project was scrutinized by an Internal Reference Group consisting of the Deans of all the Schools, as well as by the KTH Board and the President's Advisory Group.

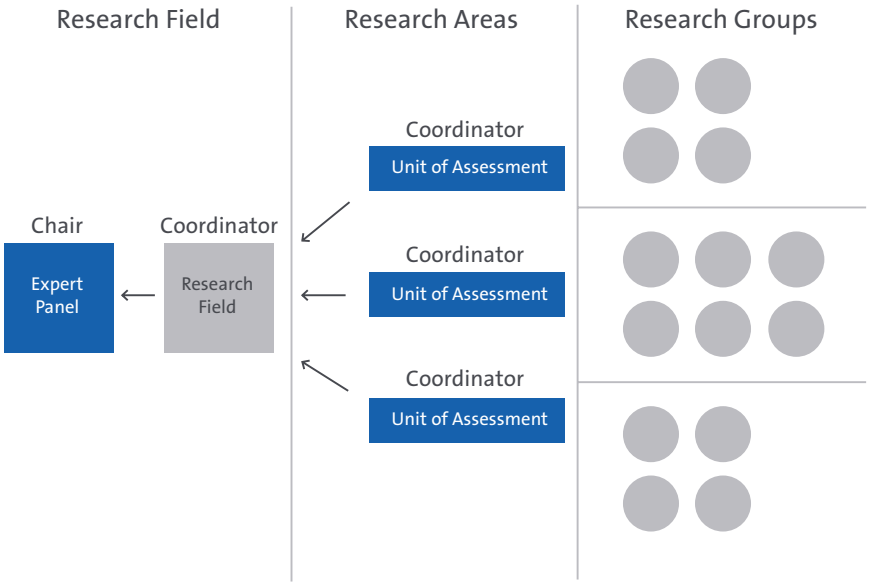
The RAE Evaluation Office was responsible for running the project and project administration. A group consisting of KTH student ambassadors acted as Panel Guides. A bibliometric expert, Dr Ulf Sandström, working together with a Bibliometrics Working Group, was engaged to carry out a Bibliometric Analysis of KTH's research publications. This study was kept separate from the Peer Review process and its results were *not* made available to the Expert Panels (see below).

The timetable for the project was as follows: the Evaluation Packages were sent to the Units of Assessment in March for completion by the end of May and submission to the external Experts in June. The bibliometric data was collected and analyzed in parallel with the Peer Review process. The Expert Visit Week took place at the end of June and the Expert Panel Reports were submitted in July. Following initial feedback from KTH, the Panel Chairs were asked back to KTH for a Response Meeting in August. The Project Report was written following this meeting and published in December. Further background documents, and the full Expert Panel Reports can be found on the RAE website: http://www.kth.se/rae

INTERNATIONAL RAE TIMETABLE 2008

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Establish organisation												
KTH Board approval												
Preparation of instructions, documents												
Define Units of Assessment (UoAs)												
Recruit International Experts												
Extract central data												
Send Evaluation Packages to UoAs												
Work by the UoAs												
Evaluation Packages completed												
Briefing materials to international Experts												
Visit Week												
Expert Panel Reports submitted												
Chairs' Response Meeting												
Bibliometric Analysis												
Write Project Report												
Publish Project Report												
Evaluation implementation												

DEFINING THE UNITS OF ASSESSMENT



Defining the Units of Assessment

When the results of research quality assessments are used to change research priorities and to allocate research funds, it is essential that the comparison is made between units and subjects that are similar to each other. Some three years ago, KTH carried out a major reorganization of its activities into nine Schools, which are responsible for the research and education in different areas of mainly natural and engineering sciences. In connection to this, the research allocation systems was also changed, and instead of allocating basic faculty funding for research groups headed by individual professors, broader units reflecting specific research areas were established. These research areas, or Divisions, are defined as groupings of researchers that are able to form a coherent strategy which in turn forms the basis for common funding of their activities. These research areas, covering the entire scope of the KTH's research base were used as the basis for defining the 47 Units of Assessment (UoA) in the KTH RAE 2008. As this system for grouping of research activities is relatively new, some heterogeneity remains between the different UoAs, which is further reflected in the outcome of the RAE. The Evaluation Packages and the information for the Bibliometric Analysis were collected from each UoA. The UoAs were then combined into Research Fields, which gathered coherent and overlapping UoAs together. These were evaluated by 12 International Expert Panels.

The following Research Fields and UoAs were identified at KTH:

TABLE 1.2: RESEARCH FIELDS AND UNITS OF ASSESSMENT AT KTH

Expert Panel	School	Units of Assessment
Panel 1: Mathematics and Computer Science KTH Coordinator: Professor Anders Forsgren Panel Chair: Professor Olavi Nevanlinna	SCI	Mathematics
	SCI	Mathematical Statistics
	SCI	Optimization and Systems Theory
	CSC	Computer Science
Panel 2: Information and Communication Systems KTH Coordinator: Professor Carl-Gustav Jansson Panel Chair: Professor John S Baras	EES	Network, Information and Control Systems
	EES	Telecommunications
	CSC	Human Communications
	ICT	Computing and Communication Systems
	ICT	Information and Software Systems
Panel 3: Physics and Theoretical Physics KTH Coordinator: Professor Bengt Lund-Jensen Panel Chair: Professor Michael Albrow	SCI	Experimental Physics
	SCI	Theoretical Physics
Panel 4: Applied Physics and Medical Technology KTH Coordinator: Professor Hans Hertz Panel Chair: Professor Wolfgang Eberhardt	SCI	Applied Physics and Medical Imaging
	STH	Medical Technology
	ICT	Materials Physics
Panel 5: Energy Technology and Electrical Engineering KTH Coordinator: Professor Stefan Östlund Panel Chair: Professor Tuija Pulkkinen	SCI	Nuclear Power Safety, Reactor Physics and Reactor Technology
	EES	Electrical Power Engineering
	EES	Fusion and Space Plasma Physics
	ITM	Energy Transformation
Panel 6: Electronics and Photonics KTH Coordinator: Professor Mikael Östling Panel Chair: Professor Patrick Dewilde	EES	MEMS
	ICT	Optics and Photonics
	ICT	Semiconductor Components
	ICT	Embedded Electronics and Computer Systems
Panel 7: Applied Mechanics KTH Coordinator: Professor Dan Henningson Panel Chair: Professor Peter Olsson	SCI	Vehicle Engineering
	SCI	Solid Mechanics
	SCI	Fluid Mechanics
	SCI	Mechanics - Biomechanics

Expert Panel	School	Units of Assessment
Panel 8: Industrial Technology and Materials Science KTH Coordinator: Professor Bengt Lindberg Panel Chairs: Professor Fritz Fahrni and Professor Torsten Ericsson	ITM	Material Science and Engineering
	ITM	Industrial Product Development
	ITM	Production Engineering
Panel 9: Chemistry KTH Coordinator: Professor Christofer Leygraf Panel Chair: Professor Erik W. Thulstrup	CHE	Chemistry
	CHE	Chemical Engineering
	CHE	Fiber and Polymer Technology
	BIO	Theoretical Chemistry
Panel 10: Biotechnology KTH Coordinator: Professor Stefan Ståhl Panel Chair: Professor Gergory Winter	BIO	Medical Biotechnology
	BIO	Industrial Biotechnology
	BIO	Protein Atlas
Panel 11: Technology for the Built Environment KTH Coordinator: Professor Bengt Ljungqvist Panel Chair: Professor Andrew Collop	ABE	Civil and Architectural Engineering
	ABE	Land and Water Resources
	STH	Health
	STH	Industrial Ecology
Panel 12: Architecture, Built Environment and Management KTH Coordinator: Professor Björn Hårsman Panel Chair: Professor Klaus Kunzman	ABE	Architecture
	ABE	Real Estate and Construction Management
	ABE	Philosophy and History of Technology
	ABE	Urban Planning and the Built Environment
	ABE	Transport and Economics
	ITM	Industrial Management

The Expert Panels

In order to set an international benchmark, the majority of Experts commissioned to undertake the evaluation came from outside of Sweden. 17% came from the USA, 14% from the UK, and 40% from other European countries. Experts were selected on the basis of their academic or industrial merits and 12% of the Experts had an industrial background. An equal gender balance was a goal in the recruitment of the Experts, though in the end only 14% of the Experts, including one Chair,

were women. Chairs were recruited based on previous high level experience of research evaluations. The number of Experts recruited to any particular Panel was proportional to the number of professors within that Research Field. The size of the Expert Panels therefore varied between 5–9 individuals. Each Panel had one member who was familiar with the Swedish HEI sector. The Experts were approved by the President's Advisory Group and KTH Management Group before being formally appointed.

KTH is most grateful to the Experts for the committed manner in which they undertook this evaluation and the informed opinions expressed in their Panel Reports.

The visit process

The Expert Panels visited KTH between the 23rd and 27th June 2008. The Expert Panel Chairs were asked to arrive first and attended a Briefing Meeting with the KTH President and RAE Director. Upon arrival, the rest of the Expert Panel also received a briefing from the President and a further introduction to the principles of the RAE. They were introduced to the Panel Guides who would escort them during their time at the university. The Expert Panels then spent four days with their respective Research Fields. After receiving a short general overview of the Research Field, each Expert Panel spent time with the UoAs within their Research Field. Each UoA introduced the scope of its research and future strategy to the Expert Panel before the parties engaged in a discussion of future research directions. UoAs were encouraged to involve younger members of faculty in their presentations and to ensure that the Experts met research students during their visits. On the final day of the visit week, the Expert Panels provided their UoAs with an initial evaluation. The Expert Panel Chairs then joined the KTH management for a debrief before submitting their Panel Reports two weeks after the visit week. A report template was provided to the Chairs to support them in focusing the comments of their Expert Panels. All members of a Expert Panel were invited to contribute to the evaluation of all UoAs within their Research Field.

Once received, the unedited Panel Reports were forwarded to the UoA coordinators and they were asked to check the Panel Reports for errors of fact. At this stage, no comments were allowed on the actual evaluation content of the Panel Reports. Comments of fact from the UoA coordinators were submitted to the Panel Chairs ahead of a final Response Meeting between the KTH leadership and the Panel Chairs. KTH used this meeting to put forward its summary of the Panel Reports to the Chairs in order that routes forward might be discussed.

The Evaluation Method

Research in the university sector can be evaluated at several levels, both individual and group/department, and in several different ways.[18] Individual evaluation is usually conducted by a **classical peer review**.[19] The core idea behind this type of review is an understanding that only individual experts with a research focus closely matching those they are assessing are able to comprehend research output and therefore pass judgment on the scientific quality of applications for research grants, drafts for articles, theses or applicants seeking appointment.

Whilst this is a valuable type of evaluation, research groups, departments, research programs, disciplines and research fields also need to be reviewed. This shift of analytical level introduces new types of problems as the focus moves away from the individual to the group and has bought about a standard known as **modified peer review**.[20] It is called "peer review" because colleagues in the scientific community perform the evaluation; "modified" because the task and focus of evaluation have changed. In this context, peers are not evaluating manuscripts, research proposals or individuals, but the performance of groups, departments, programs, disciplines or large research fields.

A radically different third model is the **performance indicator model**, which is based on bibliometric indicators and economic input-output models. This model has proved popular, particularly as it can be conducted remotely and is therefore low cost. However, as a remote system it is unable to provide opinion and insight. Thus a fourth model has been developed, the **informed peer review model**. This is a mixture of modified peer review and the performance indicator standard within which panels of Experts are asked to review groups of scientists using both interviews and background data. The key benefit of this approach is that it is able to combine "hard" data with "soft" opinions providing both quantitative and qualitative insights and therefore the fullest picture of activities.

For the present international RAE, KTH uses a combination of modified peer review and the performance indicator model. The Expert Panels were provided with substantial amounts of information about the inputs and outputs of units; they were not however given access to the bibliometric study.

18) Hansen, Hanne Foss & Borum, Finn: The Construction and Standardization of Evaluation. *Evaluation* vol 5(3):303–319.
19) Langfeldt, Liv (2002): "Fagfellevurdering" pp 57–75 in (Ed.) Stensaker (red) *Kunnskaps- og teknologi vurdering. Perspetiver, metoder og refleksjoner.* Oslo: Cappelen Akademisk forlag.
20) Sandström U & Harding T (2000), avaliable at <http://www.forskningspolitik.se/studier.asp>, jfr. Irvine, John, *Evaluating Applied Research: Lessons from Japan*. Pinter, 1988, Martin Ben M & Irvine, John, *Research Foresight: Priority-Setting in Science*. Pinter 1989.

Assessment Elements

There were three operational aspects to this model:

- Self Evaluation
- International Expert Review
- Bibliometric Analysis

SELF EVALUATION

In preparation for the Expert Panel evaluation, the UoAs were asked prepare an Evaluation Package (see Appendix 1). In Part A of the Evaluation Package, each UoA was asked to articulate its strategic ambitions for the future based on current strengths. In Part B, the UoA was asked to quantify certain aspects of its research activities, particularly those indicating international quality or showing high potential for renewal.

INTERNATIONAL EXPERT REVIEW

The international Expert Panels received the Evaluation Packages generated by the UoAs two weeks before a site visit to KTH. Further information including the CVs of all research staff from a UoA, a full lists of publications by these research staff and selected key publications including papers and books, were available to the Expert Panels during the site visits.

Assessment Criteria

Success in engineering research depends on achieving a good balance between different types of activities from basic and applied research and education to technology transfer and social engagement. Managing this balance requires strategy, leadership and good resource management. In order to get a complete picture of the many activities necessary for achieving excellence in a technical research university, five different criteria of evaluation were used, as described below.

In order that a technical research university function in an integrated manner, it is necessary that some parts of it focus more on basic research, others on applied research. Different profiles against the criteria used are, therefore, valid for different research areas and of equal value.

Where possible the Expert Panels were encouraged to qualify their evaluation in terms of comparisons with activities in other international groups. The Expert Panels were encouraged to use the entire range of definitions provided to reflect the *performance* of the UoA, meaning that even such research that focuses on Sweden or Scandinavia can be considered world-leading if the approach, methods used and

results are such. The Expert Panels were also encouraged to highlight a particular Research Group or individual making an exceptional contribution to the UoA within each of the criteria noted.

Scientific Quality (Basic Research)
Scientific quality is the essential prerequisite to excellence in knowledge creation and innovation and, therefore, constitutes the first criterion of assessment. Scientific quality includes originality of ideas and methods, scientific productivity, impact and prominence. A university (or country) that does not underpin its technical research with deep scientific knowledge is relatively ill-placed to develop the powerful innovations that spring from new scientific knowledge.

Indicators of use in evaluating Scientific Quality in this RAE include but are not limited to: quality of scientific publications and other research outputs, competitive national or international research grants, career of PhD students, national or international Centres of Excellence, major international collaborations, major engagements in scientific society.

Being aware of the relative heterogeneity of many of the UoAs, the definitions of scientific quality were defined for the majority or parts of the units as follows:

- The majority of the UoA currently performs at a world-leading standard
- Part of the UoA currently performs at a world-leading standard with the main part performing at an internationally high standard
- The majority of the UoA currently performs at an internationally high standard
- Part of the UoA currently performs at an internationally high standard with the main part performing at a nationally high and internationally recognised standard
- The majority of the UoA currently performs at a nationally high and internationally recognised standard

Applied Research Quality
Researchers in a technical university have a particular responsibility to consider and respond to the long-term needs of industry and society. The successful application of knowledge requires deep insight and the development of innovative methods; interdisciplinary approaches are also often required. Success also necessitates that communication challenges are well negotiated and that any gap in understanding between academia and industry or society is addressed. Excellence in this criterion is characterized by high value interactions with industrial partners or other

research customers, successful entrepreneurial activities or productive people-centred activities such as consultancy.

Relevant indicators of applied research quality include but are not limited to: external income for strategic/applied research, major research contracts with industry or government, innovation activities (spin-offs or other companies, patents or other intellectual property, software etc), career of PhD students, national or international Centres of Excellence that include non-academic partners.

Applied research quality was evaluated using the same definitions of performance as described above for scientific quality.

Scholarship

The Royal Academy of Engineering defines scholarship as "high quality, independent basic and applied research, free of financial and political control, to promote the well-being of society".[21] A scholarly research area has achieved visibility in society as a source of independent authority. Its researchers show academic leadership, setting a direction for future knowledge production which is often evidenced by a capacity to break paradigms. As a result of their leadership, researchers from these groups are often called upon as senior advisors to national governments, international organisations e.g. UN or World Bank, or industries. By valuing independent scholarship in its own right, it is possible to protect interests that are not served by wealth creation alone, and in so doing, to protect the integrity of technical university researchers as independent and trusted sources of knowledge.

Scholarship is indicated by **a strong combination** of the following: major commissions of trust in scientific society, major awards and prizes, major engagements with government, inter-governmental organisations or commercial organisations, visibility in society in general, overall quality and originality of scientific production, the attractiveness of the research environment (e.g. number of PhD students, postdoctoral fellows, guest professors), employment of PhD students in visible positions in society.

Scholarship was evaluated by using the following definitions of quality:

- Outstanding across the majority of the UoA
- Excellent in some parts/individuals of the UoA
- Emerging across the majority of the UoA
- Emerging in some parts/individuals of the UoA
- Not evident within the UoA

21) See *Measuring Excellence in Engineering Research*, Royal Academy of Engineers, UK, 2000: http://www.raeng.org.uk/news/publications/list/reports/Measuring_Excellence.pdf

Vitality and Potential

To produce excellence in either basic or applied research – or achieve scholarly success – a research area must thrive and renew itself. The vitality of a research area is a function of group size and strength, quality and diversity of the researchers, group interactions, mobility of researchers, interdisciplinary activities and essential supporting infrastructure such as equipment, administrative and technical support. Vitality should be sustained through the development of continued learning, good career paths and strategic recruitments as well as an active approach to developing facilities.

Indicators of use in evaluating vitality and potential include but are not limited to: total income, size and profile (gender/age) of the research staff, quantity (as well as quality) of publications, quantity and quality of external engagements, number of PhDs produced, mobility of researchers, new recruitments and the fostering of emerging talent.

Vitality and potential were described as:

- Excellent across the majority of the UoA
- Excellent in some parts of the UoA, good in the remainder
- Good across the majority of the UoA
- Good in some parts of the UoA, needs to be improved in the remainder
- Needs to be improved across the majority of the UoA

Strategy

To achieve impact and excellence in the above criteria, a research area must direct and focus the scope of its activities and to build a critical mass of research activities. A strategic ability to navigate multiple demands in order to produce outstanding results is the defining characteristic of a successful research group in a technical research university. [22] Strategic planning, resource management and approaches for knowledge exchange and/or technology transfer determine the eventual impact of technical research; how the work is taken forward to its selected communities of interest; and how the UoA plans to develop excellence in the other criteria.

Strategy was evaluated based on the Self Evaluation and strategic plans of the UoA as presented in Part A of the Evaluation Package and past performance of the UoA within and across the other criteria used above. The evaluation was based on the UoAs skill in formulating an insightful, focused and ambitious but nevertheless realisable strategic plan.

22) See *Measuring Excellence in Engineering Research*, Royal Academy of Engineers, UK, 2000: http://www.raeng.org.uk/news/publications/list/reports/Measuring_Excellence.pdf

A UoAs strategy can be evaluated as:

- Outstanding with real potential to achieve
- Excellent but challenging to achieve
- Good with real potential to achieve
- Good but challenging to achieve
- Weak

BIBLIOMETRIC ANALYSIS

To complement the Peer Review and data collected in the Evaluation Packages, a Bibliometric Analysis of KTH's research quality was conducted. The aim of this study was to assess the current scientific potential of the personnel presently employed at KTH; all publications produced during 2000–2006 by all members of the research staff were assessed, whether accumulated when employed at KTH or elsewhere. This is different from the approaches usually employed that consider publications arising from a university, as defined by its address, under a given period of time. A limitation specific for the current approach is that direct conclusions cannot be drawn between the present quantitative indicators such as e.g. personnel structure or research income and the bibliometric indicators.

The study is based on quantitative analysis of scientific articles in international journals and serials processed for the Thomson Reuters Web of Science versions of the Citation Indices (SCI, SSCI and A&HCI). The Web of Science was used because this database represents the only source that covers the most prestigious journals and serials in all fields of science.

Publications and citations (which are a direct measure of impact) form the basis of the indicators used in the present study. The key consideration that has guided the approach is to make use of multiple indicators in order to better describe the complex patterns of publications at a technical research university. Therefore, the study makes use of several methods, each deepening the understanding generated of a UoAs publication output from a different angle of incidence. None of the single indices should be considered in isolation.

While the impact of a UoA can be assessed by looking at the number of times its publications have been cited, it is important to keep in mind that there are limitations. The general limitations of the bibliometric analyses are discussed in detail in the complete report of this project available on the RAE website (http://www.kth.se/rae), and are only summarized here. According to several studies citation-based methods enable us to identify excellence in such subfields of science where publication in the serial literature is the main means of communication. However,

these methods cannot, with certainty, identify the absence of excellence (or quality) in subfields with a different tradition of publication in e.g. conference proceedings and books, or using languages other than English. The quality of research in fields with a strong applied or societal focus may not be accurately reflected by bibliometric analyses alone. Bibliometric indicators should therefore not be interpreted without detailed knowledge about the research units under assessment and the context of their research. This means that results presented here should be used as a *starting point* for a deeper discussion on the positioning of research groups by faculty and the KTH management; especially if there is need for strategic change.

Part 2. Summary of results at the KTH level

The RAE provided KTH with several unique and valuable sources of information about its research base. As well as summarizing this information, in this section of the Project Report, KTH also undertakes an analysis of the information to explore what conclusions can be drawn about the university's activities to date – and what future activities may be necessary. A goal of this evaluation was better informed and transparent decision making at KTH; it is the aim of this section to move KTH towards this style of management.

There are three sections to this summary:

A. KTH performance within the criteria of assessment based on the Peer Review
B. Analysis of the quantitative data
C. Bibliometric analysis 2000–2006

Summaries of the Expert Panel Reports by Research Field can be found in Part 3 of the Project Report. The full Expert Panel Reports and the full Bibliometric Report are available at www.kth.se/rae.

A. KTH performance within the criteria of assessment based on the Peer Review

General observations and recommendations at the university level

The Peer Review identified a number of strategic and structural strengths, but also weaknesses, at the university level. A **general strength** of KTH identified by the Expert Panels is the overall high quality of research with over half of the units performing at the international top level. The units with the best performance according to the RAE generally have an excellent balance between basic and applied research and a healthy age and competence profile with both established and young faculty.

Industrial interactions at KTH are many and vital with a large number of research centers and research contracts with industrial partners. The overall level of investment by industry in KTH research, the number of Swedish companies interacting with KTH and the long-term nature of relationships with Swedish industries were considered impressive. A number of different educational programs for key industrial partners were also noted. Industrial PhD students represent an important and well established form of industrial interactions in many units of assessment. KTH also has a competitive innovation performance with many successful patents and some highly profitable, fast-growing start-up companies. With well established routines for supporting patenting and technology transfer, an even a stronger innovation footprint could be achieved.

The **weaknesses identified** by the Expert Panels include an internal resource allocation system that gives weak incentives and poor stability for excellent basic research. Start-up funding for newly recruited staff is insufficient and the structures for career planning and support are weak. This seems to be a nation wide problem. KTH has an ageing personnel structure in may key areas of excellence, with about 30% of the professors and 20% of lecturers reaching retirement age in the coming four years. An efficient renewal process must therefore urgently be put in place to vitalize many areas.

Another weakness that was identified was weak support for experimental infrastructure, both in research and education. There are insufficient resources both for the necessary research equipment and the laboratory space needed to accommodate them. Experimental competence is a key element of successful engineering and must be supported at the university level.

An important point raised by the international Experts was the commitment to education made by many UoAs. This is epically true of Panel 8 (Industrial Technology and Materials Science), Panel 11 (Technology for the Built Environment) and Panel 12 (Architecture, Built Environment and Management). Although this RAE focused on assessing research quality, graduates are well recognised at all levels of KTH as significant "outputs". In many cases, however, there was a poor balance between research and education. Some units, such as Mathematics and Industrial Economy have very heavy teaching loads, while others, often those with ample external financing, teach very little. This weakens the links between excellent research and education, a problem that needs attention in a university that aims to be one of the leading forces in technical research *and* higher education.

Finally, research in many potential areas of excellence was split into groups that were too small to achieve international visibility and strength. In particular, research in key areas of strength such as Materials Sciences and Energy Technology was scattered in many different locations at KTH. On the other hand, there were also examples of the successful consolidation of research efforts this stimulating much improved performance. This was evident for example in the unit Fiber and Polymer Technology that is now harvesting the fruits of a fusion of the research areas pulp and paper technology and polymer technology seven years ago.

A **key opportunity** for KTH that was identified by the Expert Panels was for consolidation of research efforts in key areas of strength such as Materials Sciences, Energy and Environmental Technology, Information and Communication Technologies and Medical Technology. This would improve the international visibility and strengthen the KTH brand in these areas, thus paving the way for true international leadership. The excellent research in Mathematics at KTH would also benefit from a stronger common strategy to build an internationally leading research environment. In the social sciences, economics and industrial management, there is a clear opportunity to communicate KTH's expertise on the Swedish societal structures and traditions in an international context.

In summary, the key short term challenges at the KTH level are to achieve a critical mass, better international visibility and vitalization of the key areas of scientific and technological strength and to improve the career paths and funding for young scientists. With a strong international brand and excellent faculty, KTH has clear potential to achieve its goal of becoming a top international technical research university.

Basic and Applied Research strengths of KTH

A striking result from the RAE was that many research groups at KTH excel at both basic and applied research. Of the 47 UoAs evaluated, over half (25) were ranked as at or close to world leading standard in both basic and applied research. This illustrates a successful continuity from basic science through to application – and an

ability to reflect applied needs in the design of basic research strategies. Thus, KTH *does* fulfil a unique role as a technical research university. World leading quality in both basic and applied research was identified in the majority of the UoAs in Information and Communication Systems (Panel 2), Applied Physics and Medical Technology (Panel 4), Electronics and Photonics (Panel 6) and Chemistry (Panel 9). UoAs with world leading research quality outside of these Panels include Fluid Mechanics and Solid Mechanics (Panel 7), Materials Science and Engineering (Panel 8) and Protein Atlas (Panel 10). In Panel 12, the UoA Philosophy and History of Technology represent two very good research groups that have exceptionally close collaborations with engineers and empirical scientists. The good balance between applied research and the accompanying fundamental skill base makes KTH a valuable participant in Swedish society. It provides KTH with a unique academic profile and illustrates the significance the university gives to the application of research.

There were also UoAs with a different balance between basic and applied research. Units with a clear focus on excellent basic research but somewhat weaker performance in applied research include Mathematics (Panel 1), Theoretical Physics (Panel 3), Fusion and Space Plasma Physics (Panel 5), as well as Mechanics and Biomechanics (Panel 7). As a technical research university it is vital that KTH maintains its scientific depth, but there seems to be potential for groups within these areas to also consider how their findings might be used. This could be done by forming links with other research groups with a more applied focus to ensure that the novel basic concepts can be gradually brought closer to application.

On the other hand, excellence in mainly applied research was identified in the UoAs Nuclear Safety, Reactor Physics and Reactor Technology, and Electrical Power Engineering (Panel 5), Vehicle Engineering (Panel 7), Industrial Product Development and Production Engineering (Panel 8), Medical Biotechnology (Panel 10) and the majority of the UoAs in Panel 11 (Technology for the Built Environment). In these areas the main focus is on industrial applications and societal interactions while the academic performance is somewhat weaker. However, as the overall quality of research was generally considered good, there are clear opportunities to develop a bolder academic research agenda in these units. This was considered one important element in raising the international profile of KTH as a top technical research university.

Centres of Excellence were identified by several Expert Panels as a positive catalyst in the creation of strong and mutually beneficial relationships with industry. These forums provide a framework for *actively managed* knowledge exchange. Those research areas with fewer actively managed centres seem to be weaker in their applied research capabilities.

Scholarship

Excellent scholars are academic leaders that possess the competence, capacity and courage to break established paradigms thus opening new frontiers of human knowledge. They are generally considered as role models for the younger generation and valued as independent and trusted authorities in society. Although scholarship was somewhat difficult to assess, there were UoAs such as Telecommunications (Panel 2), MEMS (Panel 6), Embedded Electronics and Computer Systems (Panel 6), Fluid Mechanics (Panel 7) Material Science and Engineering (Panel 8), and Protein Atlas (Panel 10) that were described as outstanding by this criteria. The scholarship of another 23 of the 47 UoAs was considered excellent in parts of the UoA. As expected, excellent scholarship generally coincides with overall excellent performance of a UoA. Based on this assessment, KTH can be considered to be at the forefront of technology development and academic leadership in over half of its research areas.

Vitality and Potential

Vitality and Potential gauges the ability of a unit to manage its resources – people, finances, labs and equipment – for future growth. 29 of the 47 units assessed were considered as having excellent vitality and potential, though this was not always of an even quality within the units. In particular the entire of Chemistry (Panel 9), and the majority of UoAs in Electronics and Photonics (Panel 6), and Information and Communication Systems (Panel 2), were praised for their active approach towards the management of resources for the future. The units of Solid Mechanics and Fluid Mechanics (Panel 7), Protein Atlas (Panel 10) and Transport and Economics (Panel 12) were also singled out for special notice. With regard to staffing levels, it was clear that these units had put in considerable effort to correctly planning for research activities. It was also apparent that they had recruited or developed younger research staff and were supporting the career development of these staff through activities such as mentoring. Despite good staff age profiles, several of the units mentioned above were, however, still struggling to recruit and promote women.

A tendency to favour internal relative to external recruitment of faculty was pointed out by the Experts for some research areas. Considering the data collected on new recruitments at KTH during 2003–2007, there is generally a healthy balance between recruits with a doctoral degree from KTH (internal), from the rest of Sweden (external) or from outside of Sweden (international). However, based on the data collected in the Evaluation Packages, at the Research Field level there is indeed some variation. The Research Field Energy Technology and Electrical Eng-

ineering (Panel 5) stands out with more than 50% international recruitments while the Research Fields Electronics and Photonics (Panel 6) and Industrial Technology and Materials Science (Panel 8) make mostly internal recruitments (65–70%).

Over the next five years, one third of KTH's research faculty will reach retirement age. Those units that did not perform so well against the Vitality and Potential criterion had tended not to plan for these upcoming retirements. The units Medical Technology (Panel 4) and Materials Science and Engineering (Panel 8), Physics (Panel 3), Chemical Engineering (Panel 9), Industrial Biotechnology (Panel 10), Civil and Architectural Engineering (Panel 11) and Industrial Management (Panel 12) were identified as having to address a serious threat to their research strengths from upcoming retirements. When looking at the age profiles of academic staff at KTH in 2007, the Research Field Technology for the Built Environment (Panel 11) has the lowest proportion (12%) and Information and Communication Systems (Panel 2) the highest proportion (49%) of staff under the age 40.

The RAE has helped KTH understand better where key members of staff will be lost and the university will now take an active role in considering how these situations will be managed. In some cases it is clear that new members of staff must be recruited, in others, retirements create an opportunity for the research groups to reconsider their directions. Whatever the case, it is apparent that this situation must be actively managed.

With regard to labs and equipment, it is clear that KTH faces several serious threats. In the first place, it was noted by several Panels that the ground rents charged to faculty are high, this making the running of large scale testing facilities expensive. In addition, the cost of new equipment for experimental work is far outstripping research funds from central KTH. Large experimental facilities and up to date equipment are especially essential at a technology university. KTH must explore how it can better finance these types of investments, building partnerships with other institutions and industry where necessary. Where KTH has built good resources e.g. the Electrum Laboratory, these were singled out as having an excellent impact on research results. A note of caution was raised by both Panel 6 (Electronics and Photonics) and Panel 10 (Biotechnology) about the extensive use they witnessed of graduate students as technicians. This was seen as compromising the academic focus of their training, taking away the time of these students from activities research.

Strategy

Those units that had the best overall performance generally also had the most developed and ambitious strategies for future research activities, current strategic abilities no doubt powering them to their present status. However, several units that were well evaluated against other criteria, such as Computer Science, Mathe-

matics, and Optimization and Systems Theory (Panel 1) as well as Mechanics and Biomechanics and Vehicle Engineering (Panel 7), were strongly recommended to strengthen their strategies further. In particular, a need for better synergies between research groups was identified in units e.g. Information and Software Systems (Panel 2), Industrial Biotechnology (Panel 10) and Industrial Management (Panel 12). The Experts argued that a more closely targeted and coherent strategy could significantly improve the overall performance of these units. Several Experts also suggested that KTH at a central level must provide a clearer strategy so that research groups can appreciate and align their activities with those of other groups and KTH as a whole. Although such strategic challenges are perhaps not uncommon in academic institutions, KTH considers strategic abilities as an increasingly vital academic skill and will work with faculty to ensure that this skill is more deeply embedded in the culture of the university.

B. Analysis of the quantitative data

In Part B of the Evaluation Package, the UoAs were asked to submit certain quantitative data reflecting the number of staff in different categories, the amount of public and private funding, major research activities and outcomes, international collaborations and actions for renewal etc. This data gives a comprehensive overview of research activities within KTH. To provide some background for the Expert Panel Reports, the data collected is briefly summarized here.

Staff

Staff, scientific equipment and funding provide the main inputs into KTH's research process. The academic research staff at Swedish Universities is divided in Professors, whether externally recruited or promoted, Associate Professors, some being Lecturers ("Universitetslektor") and others "Docents" with no formal position at the University, and Assistant Professors, again divided to Junior Lecturers ("Biträdande lektor"), which is a tenure track position, and Research Assistants ("Forskarassitent") with no possibility of internal promotion. In addition, the academic system accommodates postdoctoral scientists, often with time-limited contracts and researchers, often with permanent positions.

The staff resources, as defined by the total full time equivalents available over time for the period 2003–2007 are shown in Figure 2.1. The tendency is that the group of professors (recruited and promoted) increases over time. At the same time the group of associate professors and contract researchers decreases in size. This is largely due to a 1999 Government reform establishing a lecturers' right to be promoted to professor if they fulfil the formal requirements for a university professorship. In most countries with a well functioning educational system, promotion towards a professorship is subject to performance evaluation against challenging criterias, likewise promotion from assistant to associate professor. However, the tenure track system in Sweden is not yet fully developed, although the need is acutely acknowledged.

A more detailed analysis of data underpinning Figure 2.1 reveals that the number of professors under forty years of age has exhibited a marked increase. This is partly a reflection of the promotion system in which, after an initial period when senior lecturers of older age groups were shifted in large numbers to the professorial category. In international comparison, the proportion of Assistant Professors and Postdoctoral Fellows is low at KTH.

As shown in Figure 2.2, the Panels at KTH have quite different research capacities in terms of professors. The KTH share for professors in their sixties is 28% but the age distribution varies significantly between the Panels. Half of the professors in Panel 12; Technology for the Built Environment are in their sixties.

FIGURE 2.1: THE DEVELOPMENT OF THE ACADEMIC STAFF AT KTH DURING 2003-2007 TOTAL FULL-TIME EQUIVALENTS

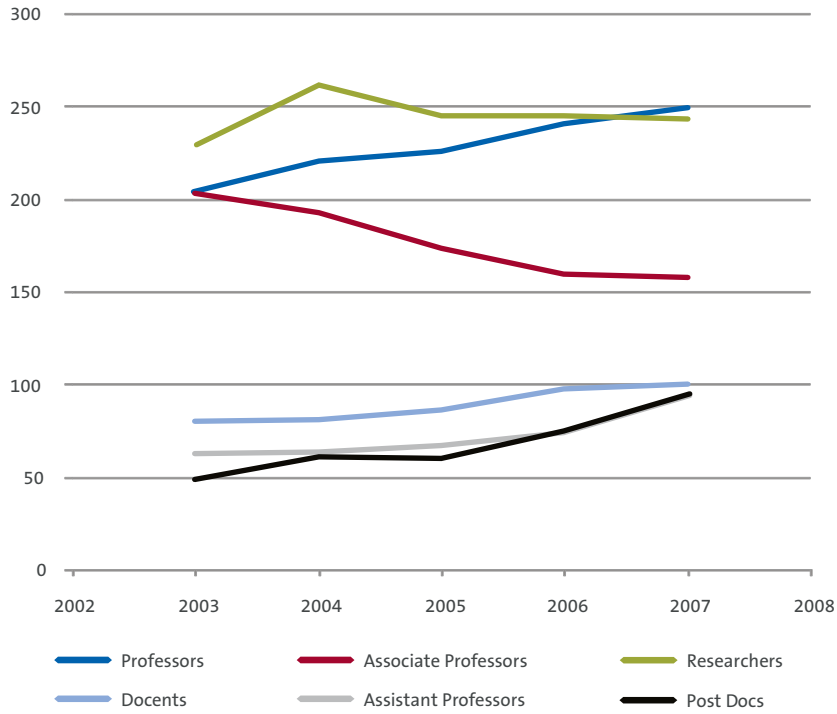
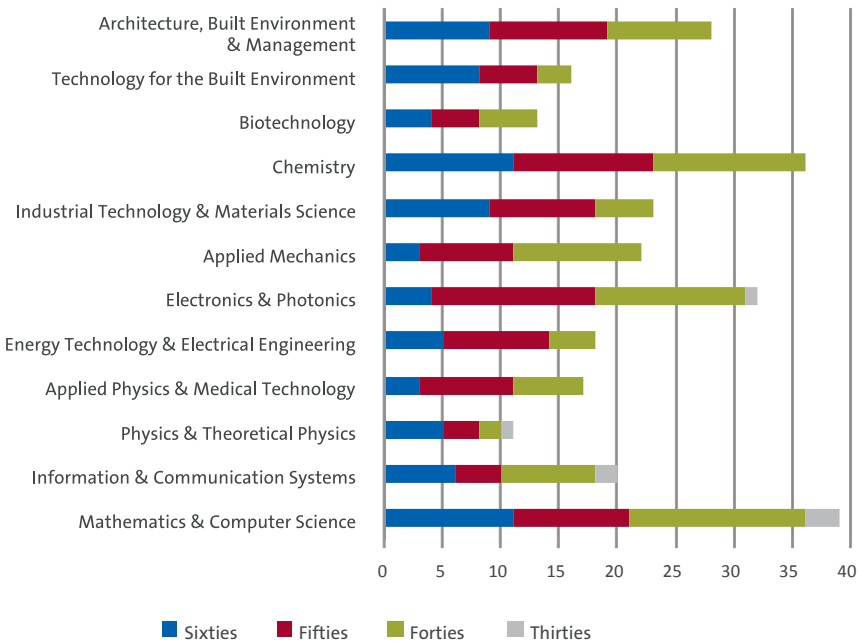


FIGURE 2.2: THE PRESENT AGE DISTRIBUTION AMONG PROFESSORS AT KTH.



In five years, almost one third of the professors in the oldest age bracket will have achieved the retirement age. In addition, one out of five among the lecturer group will also retire during the same period of time (data not shown). This is both a threat and an opportunity. On one hand, it will open possibilities for renewal and refocusing of the research profile of KTH. On the other hand, certain areas risk becoming under-critical unless a revitalization plan is rapidly put in place. The number of professors under forty years of age is rapidly increasing. This is partly a reflection of the promotion system as stated above. However, promotion through the tenure track system alone will not solve the renewal challenge since there are only some eighty assistant professors and of these only 30% have tenure track positions. As will be seen below, this is an issue that is repeatedly noted in the Expert Panel Reports.

FIGURE 2.3: SHARE OF WOMEN AMONG NEWLY RECRUITED TEACHERS AND PERSONS PROMOTED TO THE TITLE OF DOCENT IN 2000-2007.

The gender balance of personnel is an issue in most universities worldwide but particularly so in technical universities. The proportion of women is 15% among all

academic staff at KTH but only 8% among professors. The proportion of women at the professorial level has not changed much during the last five years. However, as shown in Figure 2.3, there is a steady increase in the share of women both among newly recruited teachers (at all levels) and those who have been awarded the academic title of docent. The proportion of women increases among assistant and associate professors, presently reaching 27% among young faculty (under 40).

The share of women recruited during 2002–2007 at KTH is about 12%, but this varies between Panels (and Schools). However, all Schools have been active in renewing their recruitment strategies. Even though the tendency is towards a balanced gender distribution, it is a slow process. To speed it up, KTH has launched a special programme for female guest professors; at the moment this involves some 10–12 persons. The guest professors are normally offered a period of employment of between three and five years, where after a formal recruitment process can be launched to make these persons part of tenured faculty. In this way KTH can move faster towards new research directions and speed up its faculty renewal.

For the RAE, the analysis focus was placed on the performance of the UoAs as a whole, not individual research groups. The persons holding tenured professorship positions were considered to be the main drivers of the development in the UoAs. As a starting point for the discussion to follow, Table 2.1 summarizes the professorial capacity in each Panel.

TABLE 2.1:
PANEL NUMBER, TITLE AND TENURED PROFESSORS MEASURED IN FULL TIME EQUIVALENTS.

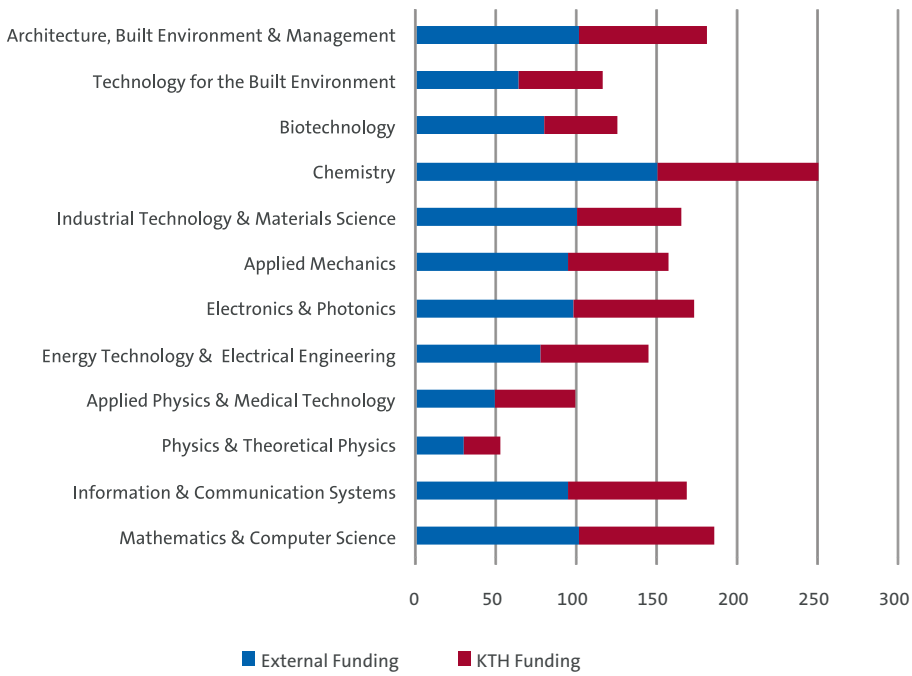
Panel	Title	FTE Professors
P01	Mathematics & Computer Science	26,1
P02	Information & Communication Systems	29,5
P03	Physics & Theoretical Physics	11,1
P04	Applied Physics & Medical Technology	17,9
P05	Energy Technology & Electrical Engineering	17,3
P06	Electronics & Photonics	15,0
P07	Applied Mechanics	21,3
P08	Industrial Technology & Materials Science	19,8
P09	Chemistry	31,8
P10	Biotechnology	16,5
P11	Technology for the Built Environment	15,9
P12	Architecture, Built Environment & Management	27,8
KTH	KTH	250,0

The table shows that there are 250 tenured professors as measured in full time equivalents. Chemistry is the largest Research Field, and Physics & Theoretical Physics the smallest. There is a difference in capacity on a factor of almost three between these panels. It should also be noted that the total academic staff is substantially larger than the number of professors. On average there are more than three additional academic staff members for each professor, though this ratio differs quite radically between UoAs and Panels. In some Panels there is a concentration of researchers who do not hold formal teacher positions but are employed as researchers. They add considerably to the different research outputs of the groupings.

Funding

The amount of funding and the way that it is used determine the volume and quality of the research output of a university. Personnel resources are at the core of academic activity. Funding is needed to support the teachers employed, the scientific equipment they need for their research and the additional funding they need to involve enough contract researchers, post docs and PhD students in their research activities.

FIGURE 2.4: KTH AND EXTERNAL FUNDING FOR RESEARCH IN DIFFERENT RESEARCH FIELDS.



At a KTH level, the amount of basic faculty financing is 36% of the total research expenditure. As shown in Figure 2.4, the Research Fields at KTH have rather different amounts of resources available. In addition, the balance between internal faculty funding from KTH funding and external funding varies considerably. Chemistry (Panel 9) has by far the most economic resources followed by Mathematics (Panel 1), Computer Science and Communication (Panel 2) as well as Architecture, Built Environment and Industrial Management (Panel 12). Chemistry (Panel 9) has a larger than average share of KTH funding while Physics (Panel 3) is the smallest in terms of total research funding.

It should be noted that there is not a direct linkage between the size of resources, either internal or external, and the composition of academic staff at the UoA level. Thus, some parts of KTH perform their research with a considerably larger number of professors than others. This composition effect is also important to bear in mind for the subsequent analysis.

Research outputs, such as academic publications, can be related to the total input of funding. Such an analysis risks being biased by different production costs and different publishing traditions across the Research Fields. Since the research of KTH spread across a range of disciplines in engineering, natural science, social science and the humanities the results should be interpreted with care. However, from a macro point of view one might still compare research outputs for a million SEK spent on research irrespective of whether it comes from KTH internal resources or external.

When measured in this way, the publication productivity at the KTH level was about four papers per one million SEK a year in 2007 for the most publication-intensive units of assessment and less than one for the least publication-intensive ones (data not shown). Some ten units exhibit an intensity of publication above two papers per million SEK and year. These units are spread across different panels and include those that also received the most positive quality statements by the peers. Among them are the UoAs of Philosophy (Panel 12), Chemistry (Panel 9), Telecommunications (Panel 2), Materials Science & Engineering (Panel 8) and Optics & Photonics (Panel 6).

Research Centers

A large share of KTH research is performed under the auspices of Competence Centres or Centres of Excellence; these can either be internal to KTH, involving more than one School, or external, involving other universities as well as industry and government. The bulk of that research is funded from external sources attained after heavy competition. In the RAE data base, some 220 members of UoAs have recorded involvement in such centers, see the summary in Table 2.2.

TABLE 2.2: INVOLVEMENT OF KTH RESEARCHERS IN RESEARCH CENTRES 2003–2007

Panel	Board member	Director	Partner
Mathematics & Computer Science	0	8	13
Information & Communication Systems	1	9	16
Physics & Theoretical Physics	0	0	5
Applied Physics & Medical Technology	0	4	5
Energy Technology & Electrical Engineering	2	8	12
Electronics & Photonics	0	8	6
Applied Mechanics	1	8	6
Industrial Technology & Materials Science	0	8	13
Chemistry	0	8	32
Biotechnology	1	6	6
Technology for the Built Environment	0	3	6
Architecture, Built Environment & Management	1	6	8
KTH	6	76	128

The main category of involvement is through partnership in research. The second largest type of involvement is through directorship either as a single leader or as a joint director. The directorship is also often related to being instrumental in setting up the centre. It should be noted that the involvement is not only with centres internal to KTH but also centres whose major linkages are with other Swedish or international universities. Researchers belonging to the Chemistry (Panel 9) recorded the largest level of involvement followed by the Information & Communication Systems (Panel 2) and Energy Technology & Electrical Engineering (Panel 5).

International activities

When measuring international activity in terms of the number of longer (>2 months) research visits abroad and the number of visiting researchers at KTH, it is evident that KTH is actively engaged in international collaborations. An average UoA at KTH made or hosted between three and four such international visits per year during 2003–2007.

Since most postdoctoral researchers come from outside of Sweden, and often return to their home countries after a period at KTH, the number of postdocs is also a measure of international activities. The quantitative data collected for 2007 shows however, that only 20 of 47 UoAs employed postdoctoral fellows and thus had the opportunity to build their international network in this manner. Interestingly, the presence of postdoctoral fellows seems to correlate with higher academic productivity with an average number of 3,1 journal articles per academic staff for the groups with postdoctoral researcher against 2,2 for the group with no postdoctoral fellows.

Engagements in scientific society

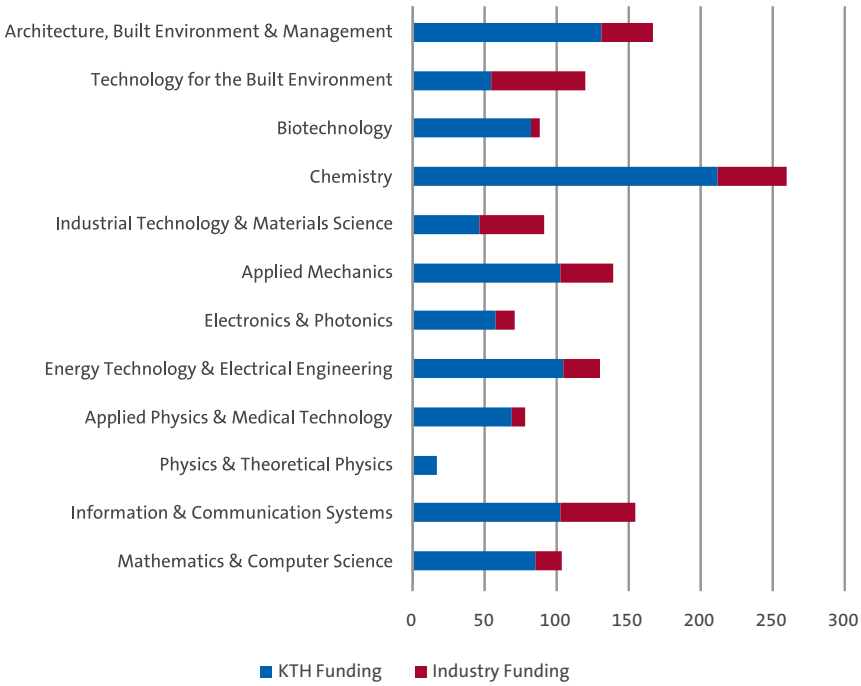
Some quantitative data points were also collected concerning the level of activity within scientific society at large. These parameters give an indication of the levels of trust and impact established by each UoA in their respective scientific field and thus indicate different aspects of scholarship and academic leadership. During 2003–2007 the 250 tenured professors at KTH reported 422 appointments in editorial boards, 183 international awards and prizes, 495 memberships in academic and learned societies and 278 memberships in international scientific councils. In total, the UoAs gave 1307 plenary or keynote talks at international conferences. When these activity numbers were divided by the number of professors, there was a fairly even distribution between the Research Fields with Architecture, Built Environment & Management (Panel 12) at a top position with about eight commissions of trust per professor.

Engagements in industry

In addition to their overall income from industry, UoAs were asked to report the number of industrial research contracts exceeding 500,000 SEK during the evaluation period. A total of 451 such major engagements were recorded by 36 UoAs. The top seven UoAs, Nuclear Power Safety, Vehicle Engineering, Materials Science & Engineering, Chemistry, Fibre & Polymer Technology, Industrial Biotechnology and Transport & Economics reported over 20 major agreements in the five year period. However, 11 UoAs reported no activities with industries on this scale. There thus seems to be further potential and opportunities for KTH to improve its industrial interactions.

The number of joint PhD students with industry is one measure of industrial interactions of a UoA (Figure 2.5). These students are sponsored by partners from industry and often work both at KTH and their parent organisation. This dual experience makes them strong researchers for industry and excellent potential ambassadors for KTH. A total of 355 Industrial PhD students were registered at KTH during the evaluation period by a total of 41 UoAs.

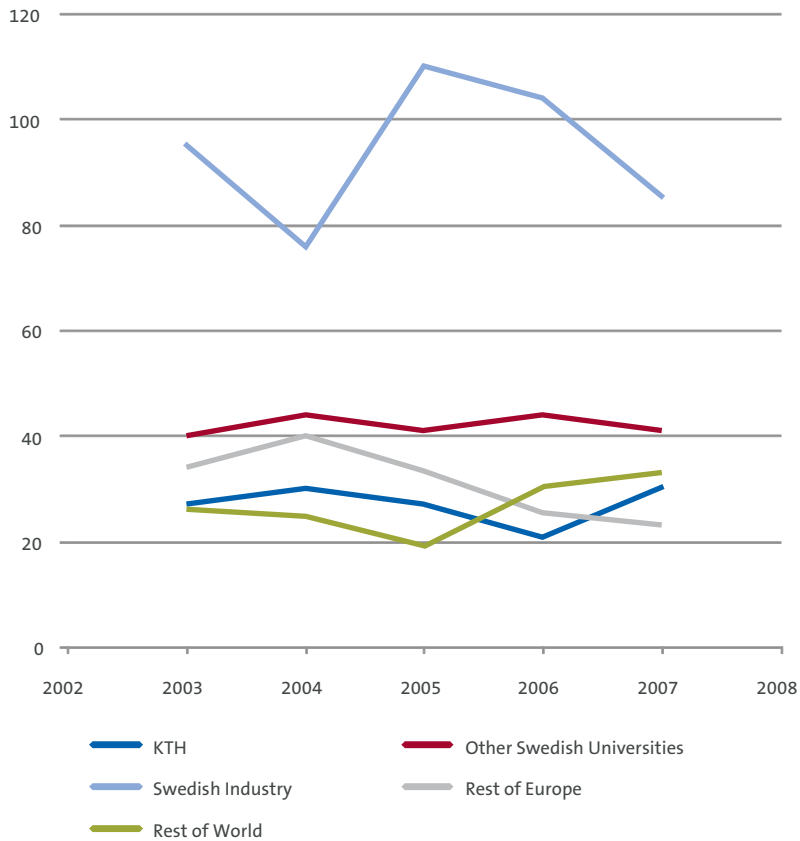
FIGURE 2.5: STOCK OF KTH PHD STUDENTS BY PANEL ACCORDING TO FUNDING CATEGORY.



On the lower side of the list, we find areas that focus mainly on basic research, such as Physics, Theoretical Physics, Materials Physics, Theoretical Chemistry, History of Technology and Mathematics but also areas where industrial engagement might be expected such as MEMS, Chemical Engineering, and Computing & Communication Systems. The top 5 UoAs in terms of industrial PhD students were Health, Civil & Architectural Engineering, Energy Transformation, Land & Water Resources and Biomechanics. The UoAs with many industrial PhD students also have many courses tailored for industry or government and many industrial contracts or assignments.

Another measure of industrial – and societal – impact of a university is the career of its former PhD students. During 2003–2007, a total of 1100 PhDs degrees were awarded by KTH (see Figure 2.6). In May 2008, 64% of these young PhDs were working outside academia. However, this ratio is different for those with appointments abroad with 58% working in academia.

FIGURE 2.6: EMPLOYER DISTRIBUTION OF PHD DEGREE HOLDERS FROM KTH GRADUATING IN THE PERIOD 2003–2007.



Entrepreneurial activities

KTH researchers reported an engagement as founders in 55 companies established between 2002–2007 that were still in operation (Table 2.3) in 2008. The majority of these firms were started during 2005–2007. At least 30 of them could be classified as research-based spin-offs, 16 as knowledge-based consulting firms and 8 as manufacturing firms. Many of the firms had more than one founder from KTH. In total, about 80 persons had recent founder experience from active firms, and eight of these from at least three different start-ups. The bulk of the spin-off firms had their origins in the Panel of Applied Physics & Medical Technology (Panel 4).

TABLE 2.3: FOUNDATION OF NEW COMPANIES 2002–2007 BY STAFF IN THE DIFFERENT KTH PANELS.

Panel	Consulting	Manufac-turing	Spin-off	Total
Mathematics & Computer Science	2	3	0	5
Information & Communication Systems	2		5	7
Physics & Theoretical Physics	0	0	0	0
Applied Physics & Medical Technology	1	4	13	18
Energy Technology & Electrical Engineering	2	1	1	4
Electronics & Photonics	0	0	4	4
Applied Mechanics	0	0	1	1
Industrial Technology & Materials Science	3	0	2	5
Chemistry	5	0	2	7
Biotechnology	1	0	3	4
Technology for the Built Environment	0	0	0	0
Architecture, Built Environment & Management	0	0	0	0
KTH	16	8	31	55

At least 20 of the research-based firms spun out during 2005–2007 are based on researcher-owned patents, giving a return on investment of three to four such firms per billion SEK in research expenditure. This is an impressive figure, even when compared with the internal patenting offices in US Universities, where a typical number of spin-offs, also for Stanford and MIT, would be two to three.

Furthermore, it is worth noting that a large portion of the entrepreneurial outflow from KTH is not captured by these data which do not cover firms started by students or by teachers and researchers leaving their employment at KTH in connection with a start-up. Moreover, earlier investigations have shown that most of the entrepreneurial outflow is realized a few years after the end of the university studies or employment, and may thus be visible in the present dataset.

During 2003–2007, more than 120 persons employed by KTH have been assigned as one of the inventors in about 155 awarded patents, Table 2.4. There is a core group of about 30 persons that frequently use patenting as a way toward research commercialization. Here, the Research Fields Information and Communication Systems (Panel 2), Electronics and Photonics (Panel 5), Chemistry (Panel 9), and Biotechnology (Panel 10) stand out as the best performers. Close to 30% of the KTH patents are awarded in the USA, 40% by the World or European Patent Offices and some 10% by national offices in Europe or Asia.

More than 50% of the patents are in a process of commercialization. About two thirds of these patents are sold, transferred or licensed to established industry, mostly large Swedish global concerns. The remaining third is sold, transferred or licensed to small, young research-based spin-offs, active almost entirely in the biotechnology or medical technology fields with KTH-researchers among the founders.

TABLE 2. 4 PATENTS AWARDED TO KTH PERSONNEL DURING 2003–2007.

Panel	2003	2004	2005	2006	2007	Total
Mathematics & Computer Science	5	1	0	1	1	8
Information & Communication Systems	8	2	3	7	3	23
Physics & Theoretical Physics	0	0	0	0	0	0
Applied Physics & Medical Technology	0	0	1	4	2	7
Energy Technology & Electrical Engineering	1	0	0	2	0	3
Electronics & Photonics	10	6	4	4	7	31
Applied Mechanics	1	0	0	0	0	1
Industrial Technology & Materials Science	2	1	2	3	2	10
Chemistry	11	6	9	6	7	39
Biotechnology	6	4	6	2	12	30
Technology for the Built Environment	0	0	1	2	0	3
Architecture, Built Environment & Management	0	0	0	0	0	0
KTH	44	20	26	31	34	155

The patenting performance of KTH is internationally competitive. In the USA, annual national surveys indicate that about 15 patents per year are awarded per billion SEK of research expenditures. This is about the same level as for KTH, even if some US Universities like MIT and Stanford report much higher levels. However, in Great Britain only a handful of the renowned universities reach figures as high as KTH. It is thus obvious that KTH is successfully spinning off new start-ups and patents, thus fulfilling its entrepreneurial mission in the society.

Engagements with society

In addition to engagements with industry, KTH also has a total of 322 research contracts of a value above 500,000 SEK with public bodies. As perhaps expected, relations with public bodies were most fully developed in the UoAs of Urban Planning and Environment, Civil and Architectural Engineering, Health and Industrial Ecology. These units play important roles in the development of Sweden's national infrastructure. Energy Transformation and Nuclear Power Safety are also important sources of knowledge for their respective public partners.

A total of 3830 activities recorded as Other Societal Engagements were performed by UoAs during the evaluation period. These include 828 popular science papers or books and 2434 popular science presentations. The UoAs of Chemistry, Fibre and Polymer Technology, Civil and Architectural Engineering, Urban Planning and Environment, Architecture as well as Transport and Economics were highly active in these areas. In addition, a total of 138 textbooks were published by KTH faculty during the evaluation period.

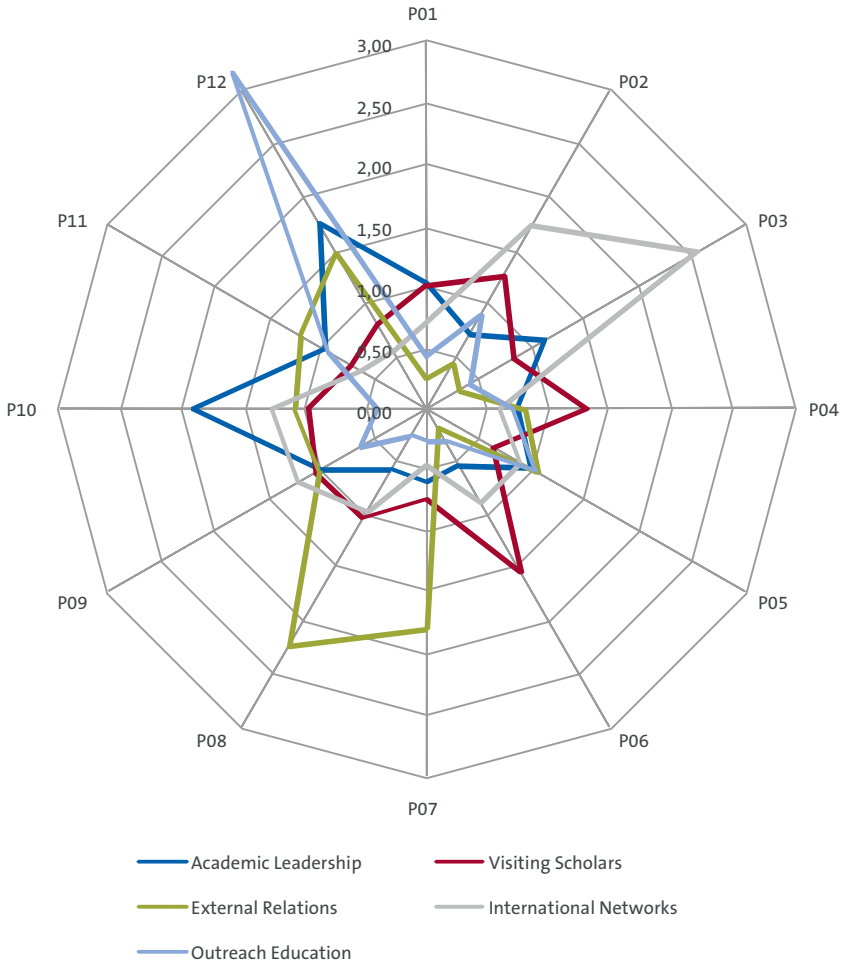
Figure 2.7 provides a summary of the profiles of the different panels according to a set of indicators on scholarship and academic leadership. The indicators have been defined by summations of the numbers recorded for different aspects of academic leadership, external relations, visiting scholars, international networks, and outreach education.

The Academic Leadership indicator is formed by combining the numbers concerning awards and prizes, keynote addresses, memberships of editorial boards, engagements in learned societies and research council committees, and other scientific assignments. The International Networks indicator is the recorded number of institutional networks to which the UoAs in the Panel belong, while the Outreach Education indicator is formed by summing the number of popular papers and popular talks with the number of tailored courses and textbooks. The Visiting Scholars indicator is formed by adding the number of incoming visitors and the number of outgoing visits from the UoAs of the Panel. Finally, the External Relations indicator is the summation of the number of engagements with government and industry plus the national and international societal networking activities in which the researchers in the different UoAs of the Panel are involved.

The numbers in the graph have then been formed by relating the values for each Panel to the KTH average (set to one). Thus, the number two means that the activity is doubly important for the UoAs in the Panel than the KTH average.

The profile for Visitors is relatively even across Panels. Academic Leadership is also relatively evenly spread across the panels. The UoAs in Panel 12 are strongly specialised in Outreach Education. The UoAs Urban Planning and Environment and Real Estate and Construction Management stand out in particular. Panels 2 and 3 are strongly specialised in International Networking whereas Panels 7 and 8 have a specialisation in industrial and societal relations in relation to the KTH average. Panels 10 and 12 exhibit strong scholarship.

FIGURE 2.7: SCHOLARSHIP INDICATORS BY PANEL AS RECORDED BY UOAS FOR THE PERIOD 2003–2007 RELATIVE TO KTH AVERAGE.



Quality indicators at the KTH level

The activities of a university or any of its units can be summarized graphically by a research profile generated by using a number of relevant indicators. The figure below shows the research profile of KTH. The research profiles of the individual UoAs are given in part 3 of the project report.

FIGURE 2.8: KTH RESEARCH PROFILE 2007

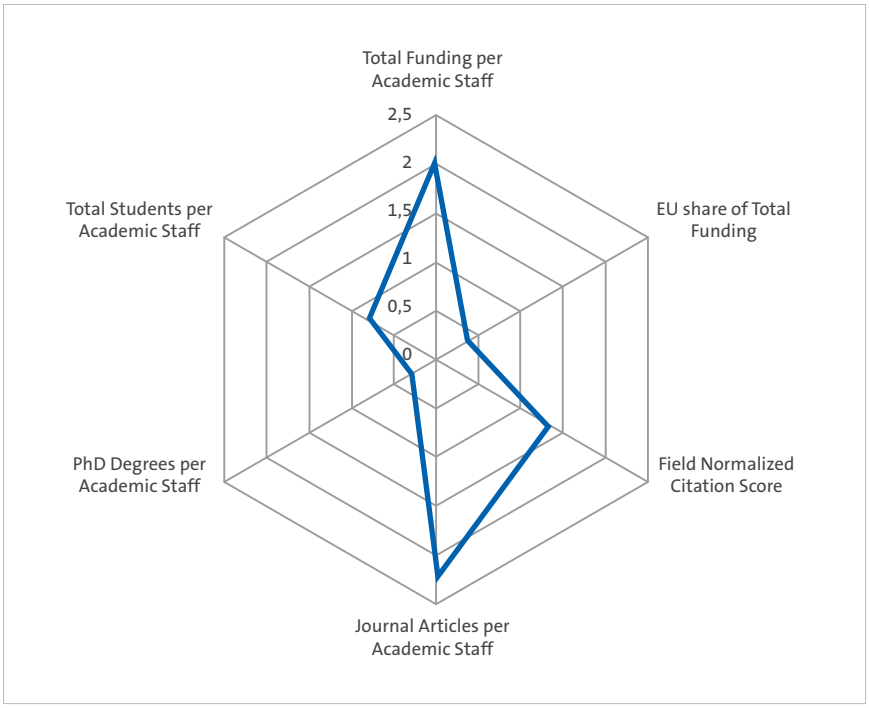


Figure 2.8 provides a summary picture of the KTH research profile in 2007. Six dimensions have been selected and these will also be used to provide a profile of individual UoAs in the following section of the Report. In those graphs the profiles will generally be related to the average performance of the UoAs at KTH. The first two dimensions depict the resource input profile of KTH. The first dimension shows total research funding available per academic staff member. The second dimension shows the competitiveness of KTH in attracting EU funding in relation to other sources. In the presentations for each UoA, the share of EU funding is related to the KTH average.

The following two dimensions show aspects of research output, both in terms of field normalised citation scores and journal article productivity. The former indica-

tor is not related to the KTH average but rather normalized in relation to the global average. In the graphs for each UoA, the indicator also refers to the position of that group in relation to the global average. The two remaining dimensions in the graph refer to the education activities of KTH addressing the production of PhDs and numbers of students. Research education output, and output of classroom education, are both related to the total academic staff input for KTH.

The different dimensions of the research profile in Figure 2.8 are not directly comparable. The KTH profile has been included to form a frame of reference to the profiles for each UoA. Since these profiles are related to the KTH average, they will give a comparable indication of the pattern of specialisation in research and education of the different research groups.

C. Bibliometric analysis 2000–2006

The present bibliometric study

In parallel with the expert peer review process, KTH conducted a bibliometric study of the research output and impact of its researchers. This study focused on the publication records of researchers within each UoA and compared the impact of their publications with the average for an international community of peers i.e. researchers within the same research field. To reflect the present and future potential of KTH, all publications of the present research staff were considered, whether produced at KTH or elsewhere. Reflecting the time lag associated with citations to accumulate, the citation data collected – for this part of the RAE only – covers the period of 2000–2006. As mentioned previously, the bibliometric reports were not available for the Panel members during the Peer Review process.

A bibliometric analysis cannot be summarized by using one indicator only. Although the Crown Indicator is often considered the best measure of impact, other indicators such as CPP(2YR), SCSf and TOP5% make the picture more complete. The indicators used in this report (Table 2.5) are a selection of the most important variables used in the full Bibliometric Report.

TABLE 2.5: BIBLIOMETRIC INDICATORS IN THE REPORT

Abbr	Name of Indicator	Explanation
P	Number of Papers	Number of papers published by the UoA during 2000–2006.
Frac P	Number of Fractionalized Papers	Sum of author fractionalized papers (articles, letters and reviews) published by the UoA during 2000–2006.
CPP	Citations Per Paper	Number of citations received per paper (until Dec 31 2007).
CPP(2YR)	CPP 2 YEAR	Citations per paper with a 2 year citation window
NCSj	Journal Normalized Citation Score	CPP normalized in relation to the UoA journal set (average=1.00).
NJCS	Normalized Journal Citation Score	The impact of the journal set normalized in relation to its sub-fields (average=1.00).
NCSf	Field Normalized Citation Score	CPP normalized in relation to the UoA sub-field set (average=1.00).
SCSf	Standard Field Citation Score	Log of Z-score standardized citations in relation to the UoA sub-field set (N.B! average=0.00).
TOP 5%	TOP 5%	Percentage of papers above the 95th citation percentile.
SelfCit	% Self-Citation	Percentage of self-citations.
Pnc	% Not Cited Papers	Percentage of not cited papers during the period.
Vitality	Vitality	A measure of how recent the references are
AUm	Author mean	Mean number of authors per paper
IntCollm	International collaboration	Mean number of countries per paper

The Journal Normalized Citation Score (NCSj) as an indicator give citations per publication related to the reference value, which in this case is the average number of citations per publication in the journals in which the UoA appears, taking document type and year of publication into account.

The Normalized Journal Citation Score (NJCS) is a measure used to estimate the average journal impact in relation to other journals in the same sub-field(s).

The Field Normalized Citation Score (NCSf) give citations per publication related to a reference value built on the global averages for all articles in the sub-fields to which the UoA papers are assigned.

Major differences between the different areas of science call for an alternative measure that takes the deviation of citations into account. Since citation data are skewed we use the logarithm of citations before calculating the standard deviation. This measure is called *Standardized Citation Score*, SCSf (f=field), and measures citations as number of standard deviation from the average. This indicator is used to complement the indicator NCSf.

Top 5% is another measure that takes the citation skews into account. More precisely, this indicator shows how many of the UoA papers that are above the 95th percentile regarding citations in their sub-fields.

Results of the present Bibliometric analysis

The results of the bibliometric study indicate that the present research staff at KTH has high capacity for internationally competitive research. The citation impact at the University level is about 30% above the global average (Table 2.6). Nine out of the 47 UoA's have a publication impact approaching global excellence (Table 2.7).

TABLE 2.6: THE DATA AND MAIN RESULTS AT THE KTH LEVEL

Abbr.	Indicator	Score 2000 – 2006
PERS	Number of Personnel	922*
P	Number of Papers	7 992
Frac P	Number of Fractionalized Papers	3 281
CPP	Citations per Paper	7.00
NCSj	Journal Normalized Citation Score	1.15
NJCS	Normalized Journal Citation Score	1.16
NCSf	Field Normalized Citation Score (Crown Indicator)	1.31
SCSf	Standard Field Citation Score	0.27
TOP5%	TOP 5%	7.5 %
SelfCit	Percentage Self-Citations	24.1 %
Pnc	Percentage Not Cited Papers	12.2 %

Note: *Ten of these have a double affiliation and appear in more than one UoA.

The main results per Unit of Assessment are shown in Table 2.7, organized according to the Panels, as the different UoAs are roughly comparable to each other within a Panel only. The numbers of papers per researcher differs a lot within panels. This can be explained by several factors e.g. the age structure and composition of personnel, and, of course, productivity differences between groups. However, there are differences both within and between units that obviously cannot be explained by these factors. While in some of the UoA's the tradition for doctoral students is to publish their articles in their own name without the supervisor as a co-author, the normal at KTH would be to publish together with the supervisor. Several UoA's in the Panel 12 apply the former publication strategy and accordingly their number of publications are lower that other UoA's.

TABLE 2.7: BIBLIOMETRIC RESULTS 2000–2006 PER UNIT OF ASSESSMENT

UoA (School) [No of personnel]	P	Frac P	CPP	CPP (2YR)	NCSj	NJCS	NCSf Crown	SCSf	TOP5%	Pnc	Scit	Vitality	AUm	Int Collm
Panel 1														
Computer Science (CSC) [51]	351	173.9	5.80	2.15	1.16	1.34	1.58	0.34	9.3%	34.9%	9.0%	1.07	2.3	1.4
Mathematical Statistics (SCI) [8]	28	10.6	2.90	0.99	0.90	1.03	0.65	-0.12	1.0%	35.3%	32.6%	1.06	2.6	1.9
Mathematics (SCI) [35]	227	148.6	4.91	1.82	1.20	1.44	1.72	0.44	8.5%	28.8%	14.5%	1.03	1.6	1.4
Optimization Systems Theory (SCI) [6]	58	28.5	5.76	1.33	1.03	1.34	1.63	0.55	11.4%	21.7%	13.7%	0.93	2.1	1.4
Panel 2														
Human Communication (CSC) [46]	110	58.4	2.43	0.80	0.81	0.92	1.95	-0.02	3.4%	54.4%	6.0%	1.12	2.2	1.2
Network Info Control Syst (EES) [19]	96	48.6	8.03	3.15	1.61	1.14	2.00	0.44	11.8%	38.3%	4.6%	1.19	2.3	1.3
Telecommunications (EES) [15]	314	128.1	5.09	2.66	1.22	1.09	1.37	0.27	9.9%	25.7%	13.9%	0.99	2.6	1.6
Communication Systems (ICT) [16]	73	23.5	1.65	0.61	1.38	0.88	0.64	-0.07	1.5%	53.5%	6.9%	1.12	3.4	1.5
Information Software Syst (ICT) [8]	52	27.5	0.82	0.33	1.06	0.55	0.49	-0.25	2.4%	61.6%	3.2%	1.07	2.1	1.3
Panel 3														
Physics (SCI) [13]	295	48.3	7.66	3.98	1.45	1.04	1.19	0.34	2.5%	16.0%	9.4%	1.18	7.8	2.7
Theoretical Physics (SCI) [13]	174	86.9	10.23	4.52	1.01	1.36	1.21	0.20	8.8%	24.3%	15.3%	1.08	2.2	1.4
Panel 4														
Materials Physics (ICT) [12]	304	71.8	6.85	3.33	1.16	1.23	1.33	0.23	8.7%	21.1%	10.4%	1.15	4.7	1.7
Applied Physics Med Imaging (SCI) [23]	296	101.7	8.34	3.54	1.08	1.34	1.25	0.40	5.9%	12.2%	13.4%	1.10	3.9	1.3
Medical Technology (STH) [22]	138	37.2	6.88	2.93	1.48	0.96	1.20	0.26	2.8%	16.9%	5.3%	0.98	4.2	1.3
Panel 5														
Electrical Power Engineering (EES) [25]	46	21.9	5.78	1.48	1.40	0.88	1.34	0.26	15.2%	35.1%	7.6%	0.98	2.7	1.3
Fusion Space Plasma Physics (EES) [23]	295	82.7	4.72	2.37	0.94	1.00	0.88	0.02	3.5%	25.2%	14.1%	1.02	5.0	1.9
Energy Transformation (ITM) [20]	62	31.5	3.23	0.97	0.88	0.97	1.00	0.04	5.7%	45.5%	20.1%	1.08	2.4	1.1
Nuclear Power Reactor Phys (SCI) [13]	95	34.4	4.39	2.05	1.34	0.91	1.28	0.19	6.4%	40.2%	20.1%	0.98	3.1	1.5

*Explanations to the indicators are given in Table 3.1. The crown indicator (NCSf) is highlighted in the table.

TABLE 2.7: (CONTD). BIBLIOMETRIC RESULTS PER UNIT OF ASSESSMENT

UoA (School) [No of personnel]	P	Frac P	CPP	CPP (2YR)	NCSj	NJCS	NCSf Crown	SCSf	TOP5%	Pnc	Scit	Vitality	AUm	Int Collm
Panel 6														
Mems (EES) [6]	65	26.9	9.79	3.64	1.09	2.03	2.22	0.84	17.1%	7.4%	9.2%	1.30	3.6	1.1
Embedded Electr Comp Syst (ICT) [12]	115	52.2	1.56	0.61	0.50	0.69	0.41	-0.30	0.1%	52.6%	10.8%	1.14	2.9	1.3
Optics & Optonics (ICT) [19]	277	101.9	8.99	4.38	1.65	1.16	1.90	0.43	13.8%	19.2%	10.1%	1.15	3.3	1.6
Semiconductor Components (ICT) [17]	473	156.4	4.69	2.15	0.87	0.90	0.80	-0.04	4.0%	27.9%	14.2%	1.16	4.4	1.4
Panel 7														
Fluid Mechanics (SCI) [19]	145	69.2	5.86	2.40	1.06	1.39	1.52	0.41	8.1%	17.5%	16.7%	1.07	2.5	1.3
Mechanics Biomechanics (SCI) [8]	51	29.2	3.66	1.39	0.87	0.85	0.82	-0.11	3.8%	35.1%	32.2%	0.94	1.9	1.2
Solid Mechanics (SCI) [11]	122	64.8	7.83	2.57	1.65	1.19	2.02	0.41	13.1%	31.0%	18.0%	0.99	2.2	1.1
Vehicle Engineering (SCI) [35]	127	79.0	2.17	0.98	1.00	0.98	1.03	0.12	4.8%	30.9%	15.6%	1.08	1.8	1.1
Panel 8														
Industrial Prod Development (ITM) [23]	55	27.4	2.84	0.96	0.99	1.24	0.84	0.14	0.9%	31.8%	5.0%	0.97	2.4	1.1
Materials Sci Engineering (ITM) [31]	701	251.3	6.14	2.35	1.15	1.24	1.20	0.27	5.2%	25.3%	12.8%	0.87	3.4	1.5
Production Engineering (ITM) [13]	25	11.1	2.10	0.83	1.16	0.71	0.52	-0.18	0.0%	39.4%	11.8%	0.96	2.5	1.1
Panel 9														
Chemical Engineering (CHE) [28]	303	124.2	6.22	2.27	0.91	1.19	1.16	0.24	6.5%	21.5%	11.4%	1.02	2.8	1.2
Chemistry (CHE) [42]	977	366.7	10.99	4.85	1.10	1.25	1.37	0.34	8.1%	16.8%	12.3%	1.02	3.3	1.3
Fibre Polymer Technology (CHE) [27]	520	222.0	9.93	3.88	1.38	1.30	1.86	0.56	13.2%	13.5%	11.5%	0.99	3.2	1.2
Theoretical Chemistry (CHE) [9]	350	126.3	11.38	5.35	1.21	1.21	1.40	0.41	10.6%	5.7%	9.6%	1.06	4.1	1.6
Panel 10														
Industrial Biotechnology (BIO) [21]	253	72.6	10.49	4.82	1.21	0.97	1.20	0.29	3.9%	10.5%	6.3%	1.00	4.6	1.4
Medical Biotechnology (BIO) [11]	223	58.8	15.66	7.78	1.22	1.15	1.47	0.43	9.8%	2.8%	6.4%	1.12	5.4	1.3
Protein Atlas (BIO) [9]	127	33.7	16.85	8.45	1.29	1.11	1.49	0.50	11.6%	3.1%	7.4%	1.22	4.9	1.2

*Explanations to the indicators are given in Table 3.1. The crown indicator (NCSf) is highlighted in the table.

TABLE 2.7: (CONTD). BIBLIOMETRIC RESULTS PER UNIT OF ASSESSMENT

UoA (School) [No of personnel]	P	Frac P	CPP	CPP (2YR)	NCSj	NJCS	NCSf Crown	SCSf	TOP5%	Pnc	Scit	Vitality	AUm	Int Collm
Panel 11														
Civil Architectural Eng(ABE) [20]	65	28.9	2.06	0.49	1.44	0.49	0.74	-0.16	1.7%	45.6%	14.1%	0.95	2.3	1.2
Land Water Resources(ABE) [24]	143	62.6	6.12	2.21	1.00	1.04	1.00	0.12	5.2%	27.7%	16.0%	1.00	2.5	1.4
Industrial Ecology (ITM) [7]	21	8.1	5.29	2.80	1.27	0.90	1.03	0.14	0.0%	24.8%	7.8%	1.05	3.2	1.3
Health (STH) [1]	5	1.3	12.19	6.08	1.19	1.24	1.84	0.70	19.6%	15.7%	4.2%	0.99	3.9	1.8
Panel 12														
Architecture (ABE) [17]	2	0.6	1.00	0.57	0.34	0.80	0.27	-0.30	0.0%	0.0%	0.0%	0.91	3.4	1.0
History (ABE) [11]	7	4.3	2.23	0.55	1.18	1.07	1.07	0.29	23.3%	34.9%	0.0%	0.90	1.6	1.1
Philosophy (ABE) [5]	63	53.2	2.39	1.32	1.35	1.10	1.40	0.20	8.8%	29.3%	21.8%	0.98	1.4	1.0
Real Estate Construction (ABE) [20[	17	9.7	2.00	1.09	0.73	0.92	0.57	-0.02	0.0%	21.6%	5.0%	0.82	2.1	1.4
Transport Economics (ABE) [27]	91	54.5	3.05	0.98	1.05	0.88	0.76	-0.06	1.2%	26.9%	14.6%	0.93	1.9	1.2
Urban Planning Environ (ABE) [44]	68	34.5	4.57	2.62	1.68	0.88	1.41	0.32	8.2%	20.9%	6.3%	1.12	2.3	1.2
Industrial Management (ITM) [35]	11	8.5	1.06	0.24	0.34	0.85	0.40	-0.18	0.0%	47.1%	0.0%	0.85	1.5	1.2

*Explanations to the indicators are given in Table 3.1. The crown indicator (NCSf) is highlighted in the table.

As expected, a comparison of the Bibliometric Analysis results with those of the Peer Review indicate a relatively good correlation for those UoAs that do have a strong tradition of publication in international journals covered by the Web of Science. A meaningful comparison is possible for those UoAs that have a rate of publication in such journals at a statistically reliable level (which would necessitate at least 30 publications). Among these, the UoAs that get top ratings in scientific quality as assessed both by the Peer Review and the Bibliometric Analysis include the UoAs Computer Science, Optimization Systems Theory, and Mathematics (Panel 1), Network Information and Control Systems, and Human Communication (Panel 2), Optics and Photonics, and MEMS (Panel 6), Solid Mechanics (Panel 7) as well as Fiber and Polymer (Panel 9). However, as discussed above for using bibliometric indicators to assess the quality of engineering sciences, some of the units that are assessed as world leading by the Experts do not receive high citation scores in the bibliometric analysis. These include for example the UoA's Communication Systems (Panel 2), Embedded Electronics and Computer Systems, and Semiconductor Components (Panel 6), Mechanics and Biomechanics (Panel 7), and Transport Economics (Panel 12). These are examples of research areas that tend to have slightly different publication traditions for the dissemination of results e.g. in reports to industrial partners, conference proceedings or publications in Swedish.

Summary of other bibliometric studies of KTH

Since 2007 KTH has been involved in several other bibliometric projects, three of which are briefly summarized here as these studies complement the work done within the RAE:

- Sandström & Sandström (2007). Bibliometric Analysis and Visualization of Cluster Universities 1998–2007.
- Evidence Ltd. (2007). Benchmarking the research performance of KTH against that of selected UK universities of technology by using a series of different indicators. (unpublished)
- Sandström & Sandström (forthcoming 2009). The KTH Input-Output Report (in Swedish).

The Consortium Linking Universities of Science and Technology for Education and Research (CLUSTER) is a network of leading European Universities of Technology (www.cluster.org). The performance of the CLUSTER universities, including KTH, was analysed for all publications identified by the university address during the period 1998–2006. The citation analysis indicated that KTH had a field normalized citation score of 1.21, i.e. twenty per cent above global average. This is somewhat lower that that obtained in the present analysis (33%) which may be

taken as an indication of successful recruitment of new faculty since 2000. Three of the ten CLUSTER universities, EPFL, Eindhoven and Imperial College, were significantly better in impact; after these, KTH and Helsinki University of Technology were close competitors. One key conclusion was that KTH is highly competitive in the fields Computer Science and Physics.

The Evidence Study compared KTH with ten British universities as assessed in the UK RAE 2001. The bibliometric analysis covered a ten year period 1995–2004, and the publication performance was compared with data for research income, research personnel etc. The study could be seen as an attempt to compare the 'return on investment' of research resources at KTH and universities of a similar profile in the UK. However, the data obtained shows that such an objective is hard to meet in the absence of far-reaching matching procedures.

The so called "KTH Input-Output Study" also aims to combine bibliometric analyses with data on research income and personnel at KTH. Although both the units of assessment and the bibliometric methods were slightly different from the present RAE, some conclusions are supported by both studies. The School of Electrical Engineering (EES) was generally assessed as having both high scientific impact and strong funding base. Other research areas with strong performance include Optics and Photonics, Biotechnology, Fluid Mechanics, Fiber and Polymer as well as Reactor Physics. Parts of Mathematics had, in the international context, exceptionally high quality but the performance was considered somewhat uneven within the entire research field.

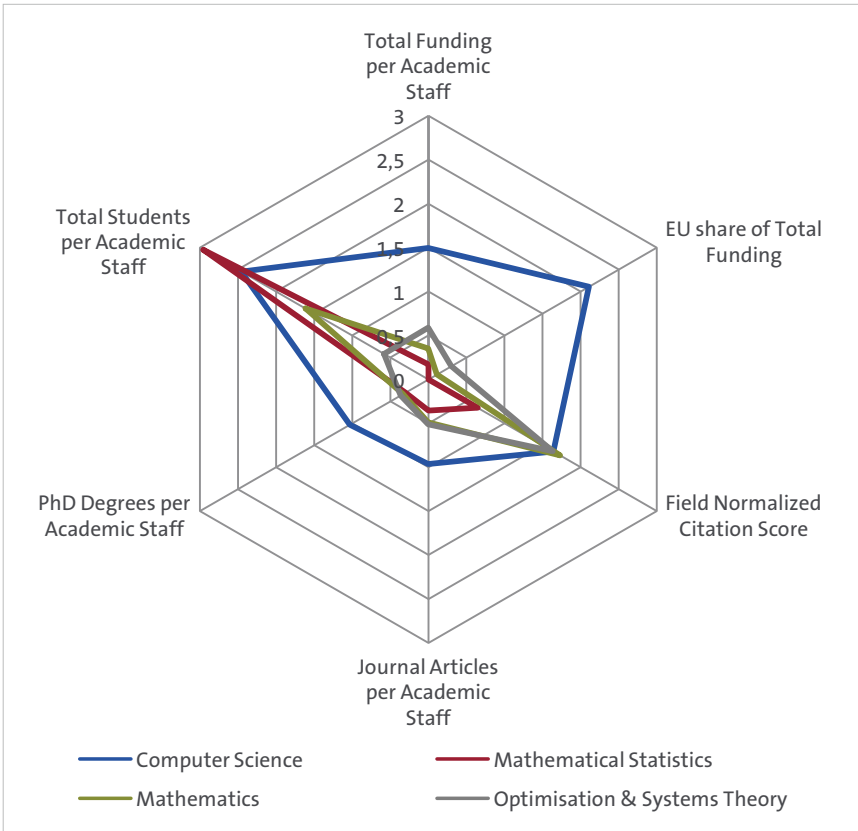
An analysis of consortia that had submitted applications for different Centers of Excellence indicated that KTH indeed has unique opportunities to build extremely strong research environments by appropriately consolidating its research activities. Two examples of such consortia with an exceptional shared research excellence included the ACCESS Center at the School of Electrical Engineering, and the Linné Flow Center at the School of Engineering Sciences. An interesting observation was that the formation of Research Centers leads to a measurable stimulation of publication quality of the participating research groups. Another conclusion was that while it is tempting to compare and rank the different research groups and departments within a university, it is the international benchmarking and ranking of the departments against similar activities in other universities that are likely to give the most useful input to the future strategic development of universities.

Part 3.
Summaries of the Expert Panel Reports

Here, summaries of the Expert Panel Reports by Research Field and Unit of Assessment are given. The value of the Expert Panel Reports, and subsequent summaries, lies in the informed opinion given by the international Experts. Full versions of the Expert Panel Reports are available on the RAE website (www.kth.se/rae). In order to broaden the picture of each Units of Assessment, selected information from the Quantitative Analysis and Bibliometric Analysis accompanies the Expert Panel Reports.

Expert Panel 1: Mathematics and Computer Science

RESEARCH PROFILES OF THE UOAS IN QUANTITATIVE TERMS



The Expert Panel Report

GENERAL OBSERVATIONS AND RECOMMENDATIONS

This is a research field with great scientific strength and potential, particularly at the level of individuals and groups. If it is to become world leading, these individuals and groups should join forces to build a tightly coupled and integrated research environment. Further strategic work is recommended at the KTH level to inspire active engagement with current and future challenges, including this field's wider responsibilities within society.

UOA MATHEMATICS (SCI)

This is a high quality unit which includes some 10 world-leading scientists; overall its research is of an internationally high quality in both the basic and applied

arenas. The bibliometric analysis reveals an exceptionally high productivity and a field normalized citation score which is 73% over the international average. There is a healthy balance of established and up-coming faculty. The approaching retirement of many full time teachers offers an opportunity to further strengthen the unit, provided that competitive working conditions, including proper career paths, can be offered for new recruits. The attainment of scientific excellence is somewhat compromised by very substantial teaching loads; finding a better balance between teaching and research could further strengthen the unit. Academic leadership in the unit is strong overall though more could be done to communicate the importance of mathematics to a wider community. The unit as a whole would benefit from a stronger strategic process to identify and communicate its collective strengths.

UOA MATHEMATICAL STATISTICS (SCI)

This is a small unit with a highly successful program in financial mathematics. Both the basic and applied research of the unit was considered to be of high international standard, although the field normalized citation score was somewhat below the international average. Recent strategic recruitments at both junior and senior faculty levels have strengthened the unit; moving forward the unit might benefit from tighter synergies with other related activities such as mathematics, optimization and systems theory and theoretical computer science. Academic leadership is emerging, especially as the young faculty gain experience. An extremely high teaching load threatens to stifle the further development of research activities in this unit and to curtail the links being forged with the financial industry. The strategy of developing financial mathematics has been extremely successful in attracting students and may well attract significant external funding in future.

UOA OPTIMIZATION AND SYSTEMS THEORY (SCI)

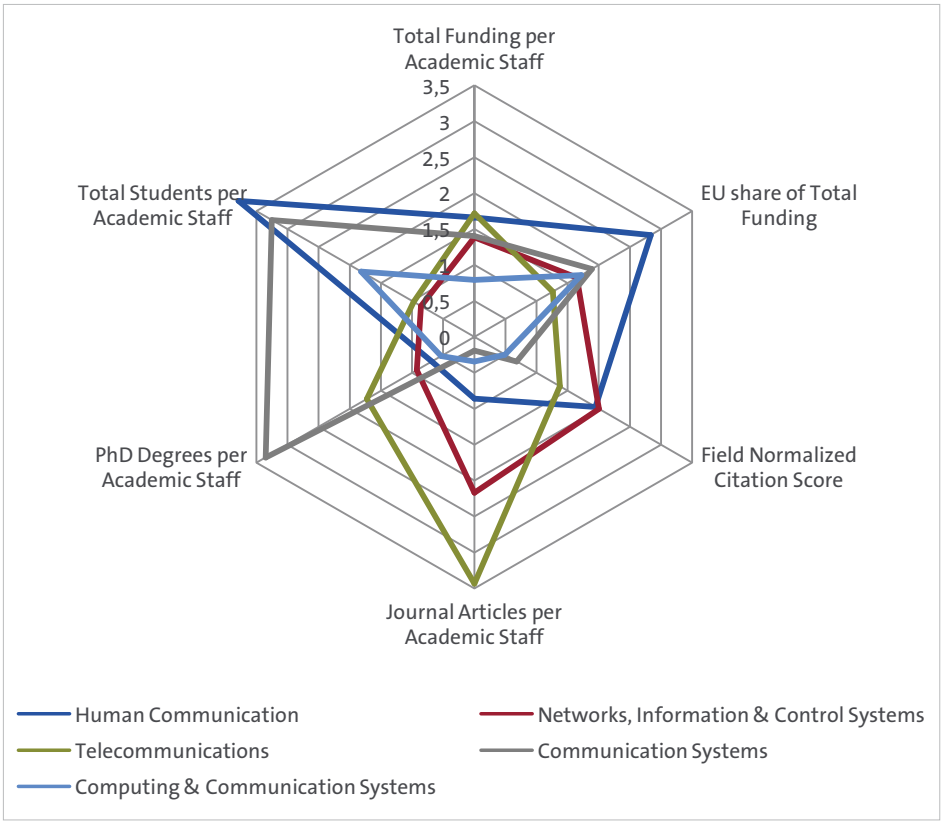
This is a small unit which is, however, well linked within KTH to other research units and centers. It plays an important role in bridging pure mathematical theory with applied projects. Parts of the unit perform at world leading level with the rest of the unit performing at high international level, in both basic and applied research. The field normalized citation score was 63% over the international average and the unit employs one of the best known scientists in mathematical systems theory. However, the heavy administrative load carried by professors threatens the scientific development of the unit. The unit is actively involved in many research projects of both academic and industrial natures and is well funded by external grants. Academic leadership is strong and several members of the unit serve on editorial boards of international journals. The strategy of the unit was considered good and realistic.

UOA COMPUTER SCIENCE (CSC)

Several parts of the unit perform at a world leading level in both basic and applied research with the remainder performing at a high international level. The unit has a number of top-notch computer scientists and has achieved some spectacular research breakthroughs. The scientific productivity of the unit is exceptionally high and the field normalized citation score is 58% over the international average. The unit is successful in attracting research funding. Both academic leadership and future potential are strong and the unit has terrific young researchers with an exciting and dynamic research agenda. This unit ranks high in scholarship according to most measures. However, considering the applied nature of the research focus of the unit, greater applied impact and visibility in society could be achieved. Each department within the unit was able to outline a vision about its future goals and directions, but a stronger common view towards advancing the goals of the unit as a whole should be encouraged.

Expert Panel 2:
Information and Communication Systems

RESEARCH PROFILES OF THE UOAS IN QUANTITATIVE TERMS



The Expert Panel Report

GENERAL OBSERVATIONS AND RECOMMENDATIONS

Information and Communication Systems is a field that increasingly permeates all aspects of life and work, and all sciences and technologies. Several groups in this Research Field at KTH are world leading and most have excellent collaborations with industry and society. The field is very heterogeneous, involving many disciplines, and its components are relatively young with some research lines just emerging. Overall, the units comprising this field are currently not as integrated as they could be and achieving better synergies at the university level could propel KTH to a world leading position in this critical field. There are opportunities to develop

a very strong program in systems engineering by developing a broad synergy on systems view and methods of systems design, testing and validation, including cost, risk and business aspects. Furthermore, given the exploding demand for broadband wireless communications and computing, better integration of all relevant research activities at the university level would give KTH an opportunity to lead the development of mobile information networks.

UOA HUMAN COMMUNICATIONS (CSC)

The quality of basic and applied research is of a high international standard overall with parts of the unit performing at a world leading level. The unit has a very high field normalized citation score 95% over the international average. Researchers in this unit work in cross-disciplinary teams and their results are well respected by international colleagues. The unit participates in several multi- and interdisciplinary activities via Centres of Excellence. The *single strongest aspect* of the unit is the world-leading research group in Speech and Sound. The Media Technologies and Music Acoustics groups are also internationally well recognized. The Human Computer Interactions and the Language groups, whilst also strong in research terms, could benefit from better defining, differentiating and communicating their positions within their respective research fields. Academic leadership, vitality, potential and gender balance were excellent across the unit. Younger faculty have been developed and included in current research projects and future plans. Whilst the individual research groups had strong strategies, considerable potential was identified to strengthen strategic planning across and between groups within the unit.

UOA NETWORK, INFORMATION AND CONTROL SYSTEMS (EES)

The quality of basic research in this unit is of a high international standard overall, with parts of the UoA performing at a world leading level. The field normalized citation score corroborates the high international quality of this unit. The quality of applied research is world leading overall, as evidenced by many joint projects with industry and an excellent record in the transfer of research results to industry. Several technical areas and trends were initiated by faculty from this unit. There is a good balance between senior and junior faculty with several prestigious national and international prizes awarded to the junior faculty. However, the gender balance of the faculty needs to be improved. The *single strongest aspect* of the unit is its work on the convergence of communication and control in networked systems under the Linnaeus Center for Autonomic Complex Communication Networks, Signals and Systems (ACCESS). Its *single weakest aspect* is a lack of integration of the industrial information/control systems group in the unit. The future strategy of the unit was considered excellent although challenging to achieve. The unit is extre-

mely well positioned to take KTH and Sweden towards an internationally leading position in the area of networked information and control systems.

UOA TELECOMMUNICATIONS (EES)

The research program of this unit involves several disciplines with very good integration in most areas of the research. Basic research in this unit was assessed as world-leading across the majority of the unit and the field normalized citation score was 37% over the international average. There were many collaborations between groups, creating a globally unique research environment. The unit has an outstanding innovation and commercialization performance with over 50 patens and several strong start-ups. Scholarship is outstanding across the unit with several pace setting results and papers in communication theory, wireless communications, speech coding, physical layer modelling and experimentation. Younger faculty have been recruited, excellently mentored and developed and they are a vital part of the group. However, the gender balance of the unit must be improved substantially. The research funding of the unit is excellent, with many grants obtained in prestigious and tough competitions (both national and EU). The *single strongest aspect* of the unit is its world leading research in communication theory and wireless communications. Its *single weakest aspect* is a lack of integration of the antenna work within the unit. The strategy of the UoA was considered excellent, though challenging to achieve.

UOA COMPUTING AND COMMUNICATION SYSTEMS (ICT)

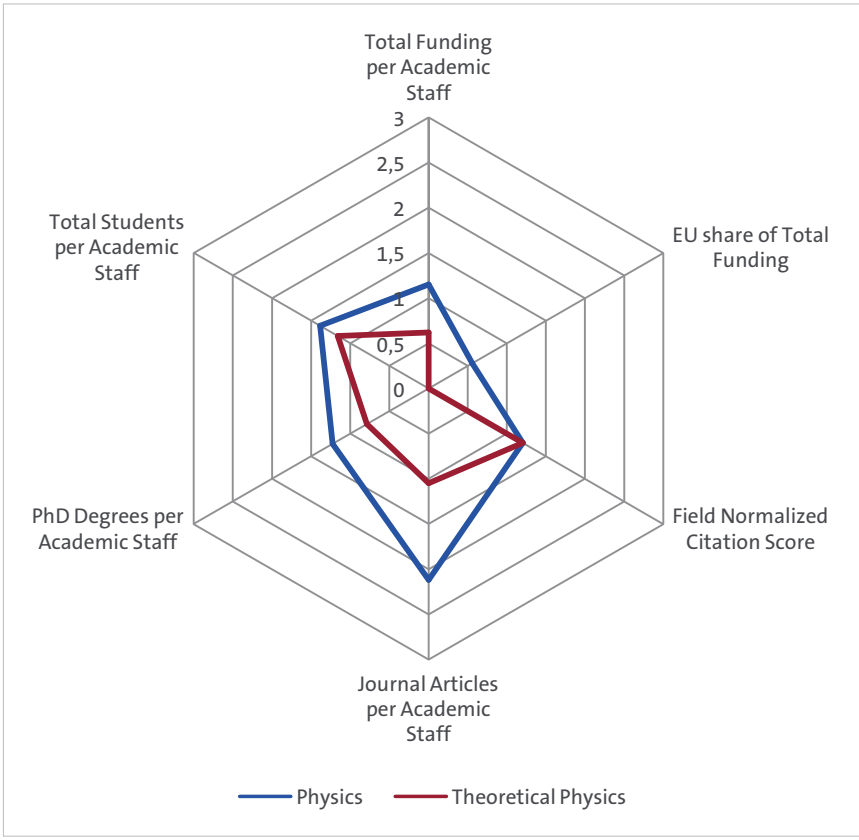
Several parts of the unit conduct basic research at a world leading level, while the quality of applied research is world leading across the majority of the unit. However, the field normalized citation score was somewhat below the world average. The research groups are well integrated and combine their disciplinary expertise into projects with a strong application focus and a pervasive systems approach. The *single strongest aspect* of the unit is the Wireless@KTH center which has become a world leading consortium for industry-university collaboration in wireless networks. As a whole, the unit was considered world leading at the systems level research and implementation of wireless networks, mobile computing and associated services. The weakest aspects of the unit include insufficient methods and frameworks for application development for the mobile environment, and lack of integration with the world leading group in wireless communications (Telecommunications unit). There was clear evidence of academic leadership with several trendsetting results and research areas. While the balance between senior and junior faculty was good, the gender balance need to be improved. The unit has an excellent vision of the needs for wireless, wireless mobility and services in the next decade.

UOA INFORMATION AND SOFTWARE SYSTEMS (ICT)

The quality of basic research in this unit is at an international level with parts of the unit attaining a high international standard. The field normalized citation score for the unit however indicated a publication performance below the international average. Whilst all professors perform well in their respective area of interest, their activities are under-critical in size. The small size of groups is prohibitive to both innovation and industry engagement. The *single strongest aspect* of the unit is its strong tradition in conceptual modeling. Its *single weakest aspect* is the lack of coherency as a unit and lack of technical strength in systems engineering. Scholarship was considered as emerging in parts of the UoA but there is considerable scope to strengthen the publication tradition beyond a good tradition of conference participation. The vitality and potential of the unit needs improvement overall but the gender balance is very good. The research areas identified by the unit are driven by correctly perceived needs but the overall strategy was considered weak and difficult to achieve with the present composition of the groups.

Expert Panel 3: Physics and Theoretical Physics

RESEARCH PROFILES OF THE UOAS IN QUANTITATIVE TERMS



The Expert Panel Report

GENERAL OBSERVATIONS AND RECOMMENDATIONS

The two units have many young, dynamic and visible professors who are, however, too dependent on external grants making it difficult to bridge finances between projects. The number of international faculty should be increased throughout and the apparently strong tradition of internal recruitment should be balanced by increasing external recruitments. At present materials-related research in a broad sense is spread over different departments at KTH and Stockholm University. This area would benefit significantly from better coordination and consolidation of research activities, for example through the formation of a "Materials Science Centre". In a

university of technology, it is important that the groups innovating instrumentation are very mindful of commercial applications, patents and technology transfer and there is scope to further improve these activities. It should be noted that other physics groups within KTH were assessed within other units and Panels.

UOA EXPERIMENTAL PHYSICS (SCI)

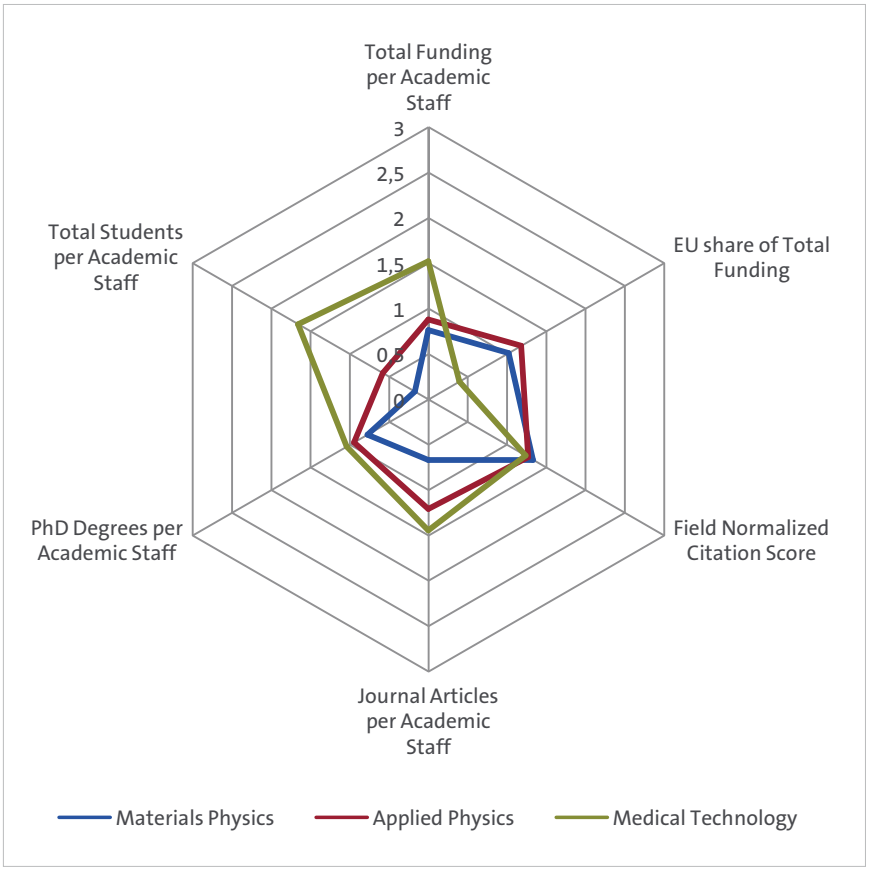
The basic and applied research quality of this unit is of high international standard throughout with a field normalized citation score 22% above the world average. Overall, the key strength of the unit is its excellent international links, which gives experimental physics at KTH a visibility worldwide. Research activities span multiple scales from elementary particles to astrophysics, with nuclear, atomic, molecular, materials and biological processes in between. This diversity is a strength as it gives a richness to the program and, in a few cases, allows cross fertilization. On the other hand, in a unit of this size it also results in fragmentation with activities focused in many small groups. The *Experimental Nuclear Physics* group, including theoretical nuclear physics, has excellent synergy between experiment and theory. This is less evident in *Experimental Particle Physics*, and the *Astroparticle Physics* element within this group does not have the benefit of a direct counterpart in the Theoretical Physics Group. There were clear indications of academic leadership in the unit as a whole. The vitality and potential were excellent in parts of the unit, while upcoming retirements call for renewal in other parts. The strategies of the individual groups were well focused, future oriented and realistic but need to be supported by more stable basic funding, increasing the critical mass of the research groups and better coordination of research efforts.

UOA THEORETICAL PHYSICS (SCI)

The quality of basic research is world leading in several parts of the unit while applied research quality is at an internationally recognized level. The field normalized citation score indicates publication performance which is 21% above the international average. The theory groups are small and too often lack adequate funding, with the risk that they become under-critical. Better integration and synergies between the groups is thus recommended. Further strength could be built by improving collaborations with the research institute Nordita, located at the KTH Campus. Activities could also be consolidated with research groups focusing on materials physics and chemistry at KTH and Stockholm University. Scholarship is strong in some groups and emerging in others. Vitality and potential are good in parts of the unit but the small size of most of the groups is a general threat. The strategies of the individual groups are ambitious but there is a need to focus and prioritize.

Expert Panel 4:
Applied Physics and Medical Technology

RESEARCH PROFILES OF THE UOAS IN QUANTITATIVE TERMS



The Panel Expert Report

GENERAL OBSERVATIONS AND RECOMMENDATIONS

This Research Field has excellent overall quality in both basic and applied research. The leadership of the coordinators is outstanding with a clear vision and excitement that is conveyed to the various research groups and their members. All units show a very impressive entrepreneurial spirit with a good track record in commercializing their ideas and innovations.

The present fee structure imposed upon laboratory space, is a serious hurdle in developing laboratory infrastructure, especially clean room facilities, that are central for many of the activities. In a few cases stronger coordination and a development of a common strategy between the units could create further synergies. In addition to the units of this research field, KTH and Karolinska Institute have other prominent research groups of considerable relevance for the future development of the field of Medical Technology (e.g. Biotechnology, Biomechanics) and all these research efforts should be better coordinated.

UOA MATERIALS PHYSICS (ICT)

Both basic and applied research in this unit are of high international standard overall, with parts of the unit performing at word leading level. The field normalized citation score is 33% above the international average. The *Materials Physics* group presents a good mix of physics and surface science and many young scientists are pursuing very competitive programs. The *Semiconductor Materials* group concentrates on materials and device processing for optoelectronics with high application potential. The *Functional Materials* group has an impressive research and publication record. The unit is of clear interdisciplinary character, and possesses good industrial and entrepreneurial potential. It is well positioned in Sweden in sensor and detector development and it has a promising spintronics development under way. Scholarship was excellent across the unit while vitality and potential were overall good and excellent in parts. The strategy of the unit was considered excellent, even if challenging. Given a large number of collaborating institutes, the number of international exchanges was modest. Work in materials and nanoscience work is currently spread out over too many research units. The unit would also benefit from a closer interaction with theory and atomistic scale modelling of materials and devices.

UOA MEDICAL TECHNOLOGY (STH)

The quality of both basic and applied research in this unit is of high international standard overall, with parts of the unit performing at word leading level. The filed normalized citation score is 20% above the international average. Key research themes include the validation and development of non-invasive imaging techniques and automatic analysis of muscular motion, especially in cardiology, the combination of neurotrauma and mechanics to facilitate early diagnosis and prevention of (secondary) injuries after an accident, and, the utilization of electron microscopy to visualize biological objects at the cellular and molecular levels. This unit is committed to "useful science"– quickly applicable to the health care sector. The implementation of results is facilitated by unique and well functioning collaborations with the Karolinska University Hospital. The achievements of this unit are

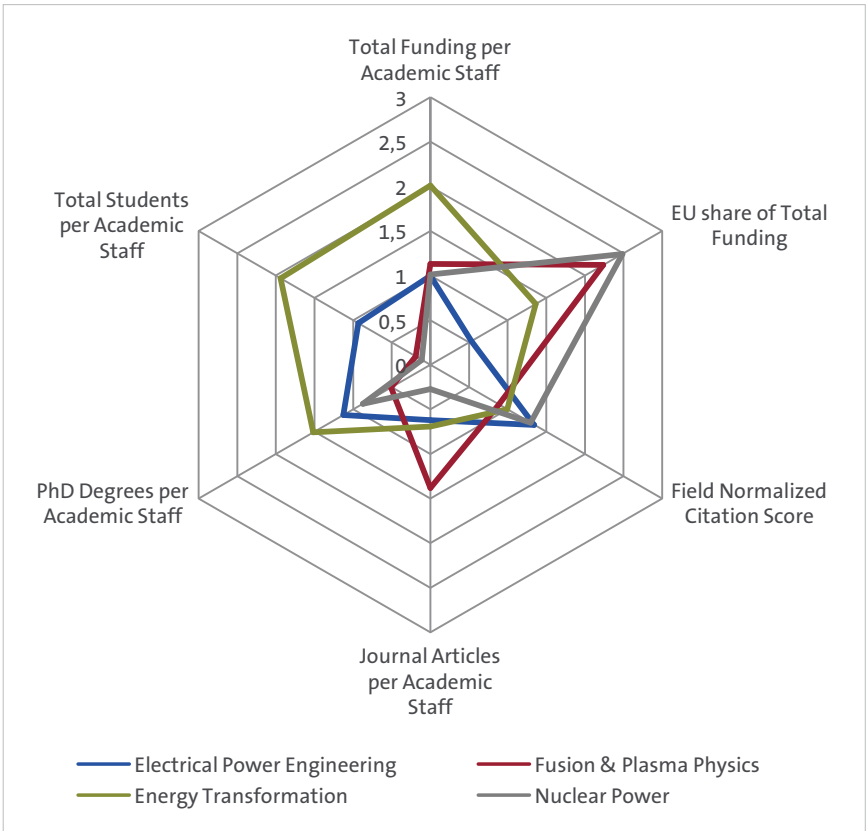
clearly appreciated by Swedish society, and beyond, and there exists an optimistic entrepreneurial spirit within research groups. Academic leadership was excellent throughout, though the number of external research grants won by the research groups were quite low. The strategy was considered excellent but challenging. A major challenge for this unit is an age distribution heavy in senior researchers, which is threatening the future potential of the unit.

UOA APPLIED PHYSICS AND MEDICAL IMAGING (SCI)

The quality of both basic and applied research was considered world leading throughout the unit. The field normalized citation score is 22% above the international average. Applied science, arising from a foundation of excellent basic research, is paired with an extraordinary ability to foster entrepreneurship. Outstanding achievements include X-ray microscopy and X-ray source and detector development, pioneering work in single molecule spectroscopy, the development of confocal life-time microscopy of biological specimens as well as the development of (medical) instrumentation. Synergies between the Applied Physics and the Biotechnology groups, as well as physics at Stockholm University are clearly evident both in terms of infrastructure and projects. Scholarship and future potential were considered as excellent across the unit. This is an extremely vital unit that has attracted a number of young and very talented researchers and substantial external funding over the past years. The strategy of this unit was considered both outstanding and realistic.

Expert Panel 5:
Energy Technology and Electrical Engineering

RESEARCH PROFILES OF THE UOAS IN QUANTITATIVE TERMS



The Expert Panel Report

GENERAL OBSERVATIONS AND RECOMMENDATIONS

This research field consists of four units with very different research topics and profiles. The units *Energy Transformation* and *Electrical Power Engineering* focus mainly on applied research and education, the unit *Fusion and Space Plasma Physics* is engaged mostly in basic research through large international experimental programs and the unit *Nuclear Power Safety, Reactor Physics and Reactor Technology* services the maintenance of nuclear engineering skills in Sweden. Given this diversity of approaches, it is not surprising that there are only few and rather weak links between the units, while some of them have intense collaborations with other

departments at KTH. The units compete both nationally and internationally and manage multinational, complex projects with multiple funding sources. Present and upcoming retirements within the units call for top-level strategic decisions about future research directions. In particular, the high-quality research conducted on energy and the environment should have a higher visibility and more active branding within KTH and beyond.

UOA ENERGY TRANSFORMATION (ITM)

The unit focuses on sustainable power generation and sustainable energy utilization in the built environment. A large portion of the work is motivated by a need to mitigate and adapt to climate change – and the consequent need for new innovative technical solutions in various energy-related problems. Basic research at the unit is of an overall high international standard, with parts of the unit performing at world leading level. Applied research was considered world leading throughout. The field normalized citation score indicates publications performance at an average international level. Due to recent retirements and new recruitments, the research balance is shifting from studies of individual components to more systems-level studies. The unit has excellent international contacts within education, and these should be expanded and complemented by enhanced research collaborations with European universities or research institutions. Scholarship is emerging across this unit. Its strategy is considered good and realistic though perhaps not quite as ambitious as it could be. To become an internationally leading partner in Energy and Environment research, expertise and collaborations need to be developed beyond those currently available in the unit.

UOA ELECTRICAL POWER ENGINEERING (EES)

This unit is one of the largest power engineering units within European universities and is in many ways the most advanced university unit in its field in the Nordic countries. It has close ties to the Swedish power industry and its applied research quality is at a world leading level. The work of this unit is associated with mitigation and adaptation to climate change. The unit is well organized and it has significant interdisciplinary activities especially with the information technology sector and material sciences. Despite a high level of industrial funding, the unit has a coherent strategy with well-defined areas of expertise that form the unit's intellectual backbone. However, the emphasis on applications somewhat compromises the unit's academic performance. Although the field normalized citation score is currently 34% over the world average, with a slightly heavier emphasis on basic research there is potential for a much higher impact. In view of upcoming retirements of key scientists, the opportunity should be taken to balance mainly internal recruitment with external hires to provide renewal.

UOA FUSION AND SPACE PLASMA PHYSICS (EES)

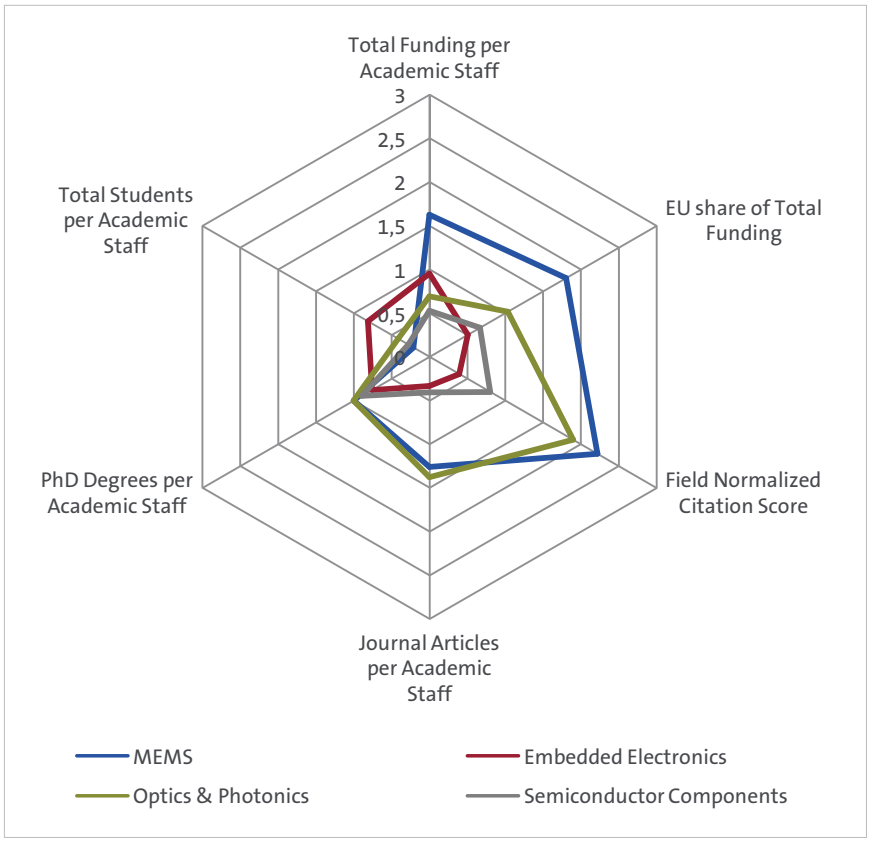
This unit consists of the groups of fusion and space plasma physics, these working independently. Both groups have an impressive number of international projects with the fusion group working within the EURATOM fusion program, including ITER, and the space group within the ESA science program. The unit should strengthen its strategy to seek influence in the governing bodies of large international organizations. Both activities need in-house experimental development work to enter the large international consortia and it is vital that KTH support these experimental facilities at an adequate level. The scientific quality of the unit was assessed as world leading throughout; although the field normalized citation rate is just below the world average. The applied research of the unit was considered to be of high international standard. The plasma activities provide an excellent opportunity to train physicists and engineers for exploitation of the largely unused potential for technological plasma applications. Academic leadership is excellent, the research environment is healthy and the programs are maintained by long-term projects. However, staff size is small overall, given their tasks and responsibilities and the number of senior staff has decreased in recent years. Staff mobility in terms of longer visits abroad is modest and recent recruitments have mainly been internal. The strategy of the unit is highly ambitious but it appears to be feasible provided the excellent track records of the groups are maintained.

UOA NUCLEAR POWER SAFETY, REACTOR PHYSICS AND REACTOR TECHNOLOGY (SCI)

This unit focuses on nuclear power safety, reactor physics and reactor technology through both modeling and experimental testing. Basic research is at a high international standard, while parts of the unit carry out world leading applied research. The field normalized citation score is 28% above the world average. This unit is known for its activities in severe reactor accident research and transmutation of nuclear waste. Basic research funding cuts based on the nuclear phase-out legislation in Sweden have resulted in poor vitality and potential creating difficulties in recruiting permanent research staff and talented students. This has resulted in modest scientific production and academic scholarship, as well as a relatively weak research strategy. Long term contracts from the Swedish nuclear regulators and power industry provide stability for the work, but at the same time makes the unit more like a "national center" for maintaining nuclear engineering competence rather than a research oriented university department. A strategic decision is thus needed on the future of nuclear power technology research at KTH. If research in this field is continued, the academic research component needs to be strengthened and funding from KTH needs to be increased to an adequate level.

Expert Panel 6: Electronics and Photonics

RESEARCH PROFILES OF THE UOAS IN QUANTITATIVE TERMS



The Expert Panel Report

GENERAL OBSERVATIONS AND RECOMMENDATIONS

Research in this field at KTH is of high international standing throughout. The teams are well formulated, with a strong leader and a range of interests with significant breadth and depth within each unit. The Electrum Laboratory is an excellent state of the art facility that supports much of the work of the research units and contributes to the technological quality of the research work. Levels of collaboration between the units could, however, be increased. The standard of publications is very high, with a good balance between original research papers and textbooks aiming to translate new knowledge rapidly into the mainstream curriculum. All units are very active in generating external grants to support their activities, and most of them are also active spinning off research results. However, the 'value

chain' from devices and process technology, over circuit design to embedded systems and architectures is not completely covered, and the distance between devices and systems is, therefore, not well bridged. The units must also strive to push their ideas into new fields.

UOA MEMS (EES)

The basic research quality of this unit is at a high international standard overall with parts of the UoA performing at world leading level. The field normalized citation score is 122% above the average and indicates a publication performance at a world leading level. The main research themes of the unit are all extremely actual. The unit has developed a deep understanding of fluidics, mechanics, (bio) chemistry and electrical physics at the micro-level over many years. The unit has an excellent understanding of material physics and the MEMS fabrication processes. More recently, there has been a concerted effort to study fluidic phenomena at the nano-scale. The applied research of the entire unit is world leading. The unit has developed pioneering, world leading MEMS applications, generated significant intellectual property and spun out several successful companies. The scholarship exhibited by the unit, particularly its leader, is outstanding. The vitality and potential of the unit are excellent with a new generation of extremely able Associate Professors. However, it should be possible to achieve a better gender balance in the unit. The strategy of the unit is excellent but appears to focus on income generation at the cost of independent long-term research goals. Such a long-term strategy, building on research strengths, needs to be developed and longer term investments by the University are needed to allow new areas to be pursued.

UOA EMBEDDED ELECTRONICS AND COMPUTER SYSTEMS (ICT)

This is a large unit divided into the sub-themes: *Electronic Systems Design, Media Electronics, Radio Electronics, Circuit Theory* and *IT Systems*. Basic research at the unit was considered world leading in the main topics and large scale collaborations are visible throughout Europe. The field normalized citation score of the unit, however, is below international average. Applied research quality is at a high international level with parts of the unit performing at a world leading level. The unit has been leading Europe in setting the scientific foundations for System on a Chip and Networks on a Chips design, and some of these insights have been largely applied in industry. An excellent balance has been achieved between new concepts, industrial relevance and dissemination of ideas through landmark papers and books. However, with the exception of the Center of Excellence I-Pack, direct industrial contacts seem to be few. Scholarship as well as vitality and potential of the unit are outstanding throughout. The strategy of the unit was good and realistic but the long term strategy was somewhat confused. Better communication should be developed between research groups within this unit. A stronger 'chain-

management' should be developed from devices and circuits to systems, by stronger cooperation with the other unit in this research field.

UOA OPTICS AND PHOTONICS (ICT)

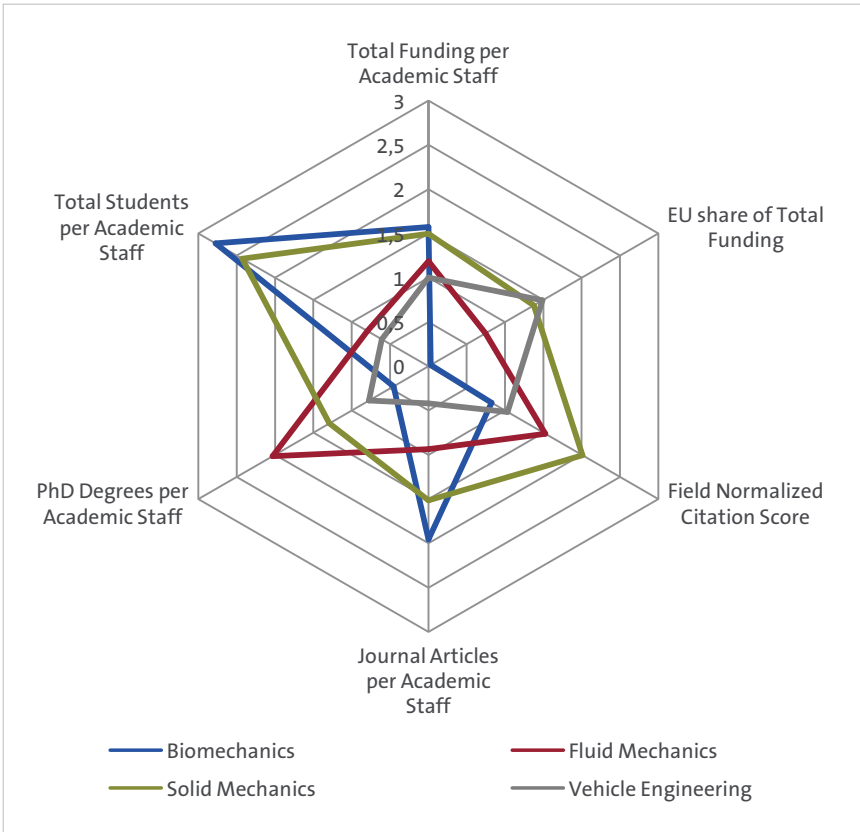
The entire unit performs at a world leading level in basic research with a field normalized citation score 90% above the international average. There is strong emphasis on the enabling nature of photonics technologies for a variety of industries and applications. The unit has a long history and broad knowledge base ranging from classical optics to integrated optics, optical networking, optical signal processing, photonic crystals and quantum optics. The unit exhibits a proven tradition in optics for telecommunications but they also show a successful diversification after the telecoms downturn in 1999–2000. Excellent new developments have been achieved in nano-waveguides. Parts of the unit perform at a world leading level in applied research with the rest of the unit performing at a high international level. There is a long history of supporting Ericsson with trained personnel and research in telecoms optics. More recently, good performance and an active entrepreneurial attitude are evidenced by the generation of spin-out companies. The unit has secured a number of competitive national and international grants and participates in important industry-oriented projects. Scholarship is excellent; the group leaders have a top international status and visibility. There is a reasonable age distribution. The strategy of the unit was considered excellent but challenging.

UOA SEMICONDUCTOR COMPONENTS (ICT)

This is a unit of true international excellence which, however, faces many challenges in the future. Basic research is world leading in parts of the unit and of a high international standard in the rest. The scientific productivity of the unit is exceptionally high though the field normalized citation score is slightly below the world average. Applied research quality is world leading across the entire unit. The unit covers a wide range of research topics reducing the focus on classical capital-intensive CMOS (complementary metal–oxide–semiconductors). There is a general switch from supporting conventional semiconductor industry to supporting SMEs. There are good links with MEMS and Embedded Electronics but relatively poor links with Optics and Photonics, where there should be a natural synergy. The unit has developed, maintains and uses the Electrum laboratory extensively. This facility is a major asset for KTH and deserves a much broader support base than is presently available. Scholarship is considered excellent, especially by the unit leader. The vitality and potential are good but the unit is a relatively small by comparison with similar efforts elsewhere in Europe. There are too few PhD students and female staff. The strategy is considered excellent but challenging. Activities in the circuit area need to be enhanced to cover the whole chain from devices to systems, by so doing it will become more appealing to potential applicants.

Expert Panel 7: Applied Mechanics

RESEARCH PROFILES OF THE UOAS IN QUANTITATIVE TERMS



The Expert Panel Report

GENERAL OBSERVATIONS AND RECOMMENDATIONS

There is much excellent research being carried out within this research field at KTH. There is a clear consensus amongst all the units that graduate students are the single most important output from research activities. There is, however, definite potential to better exploit research synergies within the field. Another threat that must be addressed by the university as a whole is that posed by the high space charges. In particular, the excellent experimental work in *Applied Mechanics* area is threatened by this, but the problem seem to be system wide. Furthermore, the present scarcity of decentralised administrative support at KTH results in an inefficient utilization of the talent in the organization.

UOA VEHICLE ENGINEERING (SCI)

Basic research in this unit is of a high international standard overall and the field normalized citation score is at an international average. The *Lightweight Structures* group is internationally renowned for its work. The production of knowledge is good, but interest in publishing in good journals should be increased to improve international visibility. The applied research quality is of a high international standard overall with parts of the unit performing at word leading level. The strength of this unit relies on both their high emphasis on educating engineers for industry, and their awareness of industrial problems. At the same time, this strong industrial focus somewhat compromises the unit's scientific focus. Scholarship is emerging in the entire unit with excellent leadership visible. Its vitality and gender balance are good but some of the groups are too small. The career paths of young faculty are partially unclear, this however seems to be a university wide problem. The larger groups have strategies for their specific areas, but a stronger overall strategy needs to be formulated to restructure the activities into groups of critical mass.

UOA: MECHANICS – BIOMECHANICS (SCI)

Basic research in this unit is of a high international standard overall with parts of the unit performing at word leading level. Productivity in terms of international publications is good though the field normalized citation score is slightly below the international average. Applied research is of an internationally recognized standard, with parts of the unit performing at high international standard. Scholarship is emerging but vitality needs to be improved in most parts of the unit. The amount of external funding is low. The unit is of sub-critical size and needs to work on either focusing and strengthening its research activities or assimilating with other larger units at KTH.

UOA SOLID MECHANICS (SCI)

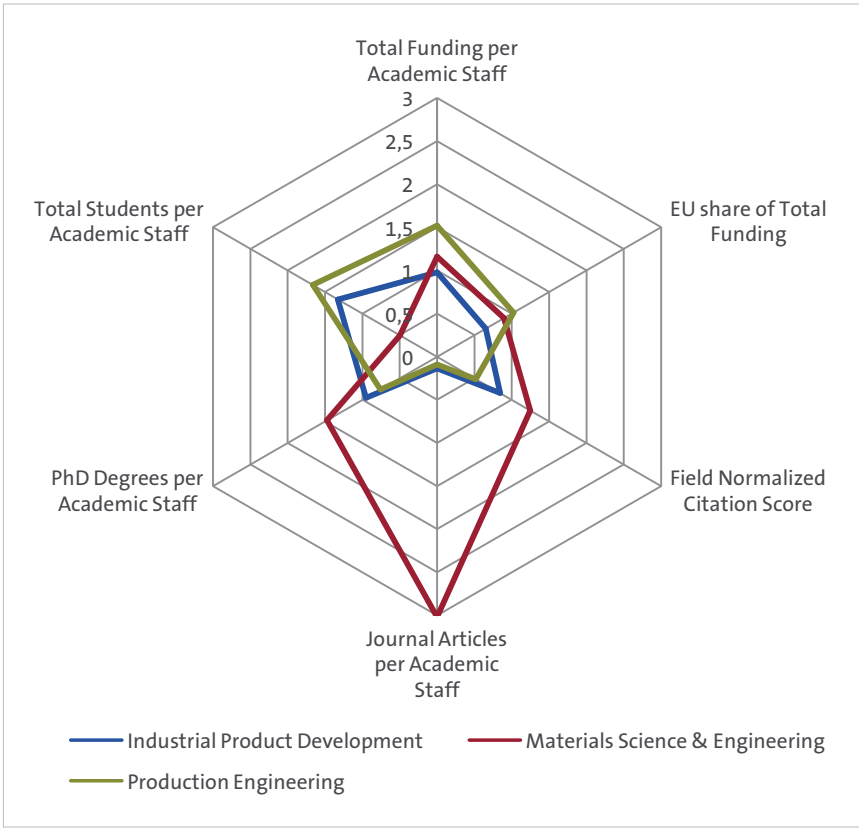
Both basic and applied research in this unit are world leading throughout. The unit gave the impression of a homogeneous group with a strong focus on high quality research in several areas of material modeling and strength of materials. The experimental facilities were impressive, illustrating an ability to perform a wide range of mechanical testing, from large specimens down to the micrometer range. Tests are carried out for industry, which helps funding this expensive activity but it is essential to ensure continuity on the experimental support side. The record of international scientific publications is excellent, a field normalized citation score 102% above world average corroborating this. The industrial relevance and impact of research produced by the unit are outstanding. Scholarship and vitality are excellent and there is a relatively large proportion of very competent upcoming junior staff. The strategy is outstanding and realistic.

UOA FLUID MECHANICS (SCI)

This is a large group in the field of fluid mechanics, even within a European perspective. Basic research is world leading with a field normalized citation score 52% above the international average. Applied research is of high international standard with parts of the unit performing at word leading level. The unit combines experimental, theoretical and computational research projects and there are many fruitful connections and successful collaborations with peer institutions, both in Europe and overseas. The infrastructure of the laboratory was impressive and could be used both for basic research and for applied fluid mechanics. Easy access to a new high power computer will facilitate numerical work to a considerably higher level. Scholarship and vitality are outstanding across the majority of the unit. An excellent strategy is in place for the recruitment of younger staff members in order to keep up the highest standards in teaching and research. The strategy is outstanding, realistic and timely, focusing on problems of relevance to energy and climate change.

Expert Panel 8:
Industrial Technology and Materials Science

RESEARCH PROFILES OF THE UOAS IN QUANTITATIVE TERMS



The Expert Panel Report

GENERAL OBSERVATIONS AND RECOMMENDATIONS

This research field comprises the activities of three departments in the School of Industrial Engineering and Management at KTH. A fairly good collaborative spirit has been established and synergies are being made use of, although there is still room for improvement. The offices, laboratories and infrastructure of the three units are within walking distance on the KTH campus which helps internal communication. Relations with industry are very good, providing a strong contextual underpinning for both research and teaching and forming a strong basis for future development. Cooperation activities with the remainder of KTH are adequate and

particularly good with certain areas of physics, mechanics and material sciences. The staff is strongly dominated by Swedish nationals, with non-Swedish professors being an exception. In the future, more internationalization will be essential and KTH must consider how it makes itself an attractive destination for international staff. The integration of high quality education within the research framework and industrial collaboration was impressive. Commitment to teaching was excellent and there is enthusiastic participation by students at all levels. However, for two units this commitment has affected the basic scientific productivity, which was considered average.

UOA INDUSTRIAL PRODUCT DEVELOPMENT (ITM)

Applied research at this unit is of a high international standard with parts of the UoA performing at world leading level. Basic research is of a reasonable international standard overall, though the field normalized citation score is somewhat below the world average. Relations with industry are good and the number of external PhD students and industrial and governmental research contracts is impressive. Applied research is the strong point of this unit and relevant areas have been identified in collaboration with Swedish industry. This is to some extent at the expense of basic research, as reflected by a low number of qualified publications in international top-journals produced by most teams. Scholarship is emerging in the entire UoA with leadership and impact visible mainly within Sweden. Vitality and potential are excellent in parts of the unit. Recent appointments of junior staff indicate that a renewal process is ongoing but long-term basic funding should be made available to encourage new, young researchers. The strategy is good and realistic but perhaps not as ambitious as it could be. The unit's future strategy focuses on breadth. Achieving this breadth whilst maintaining quality will take considerable resources to achieve and the Panel suggests the unit prioritise its goals strictly. It would also benefit from broadening its context of operation further, for example including more international-based bench marks in research.

UOA PRODUCTION ENGINEERING (ITM)

This unit conducts applied research at high international standard, with parts of the unit performing at world leading level. Many of the selected research topics are fuelled by the needs of Swedish industries and there are a remarkable number of external doctoral students. The unit actively monitors industry development and puts forward creative responses to industry needs. The potential benefits of new technologies and processes are also monitored continuously. However, the unit's output of patents and the number of spin-offs has been rather moderate. A focus on industrial relations and high quality teaching has taken its toll on academic publishing with the unit's field normalized citation rate being below average. Research

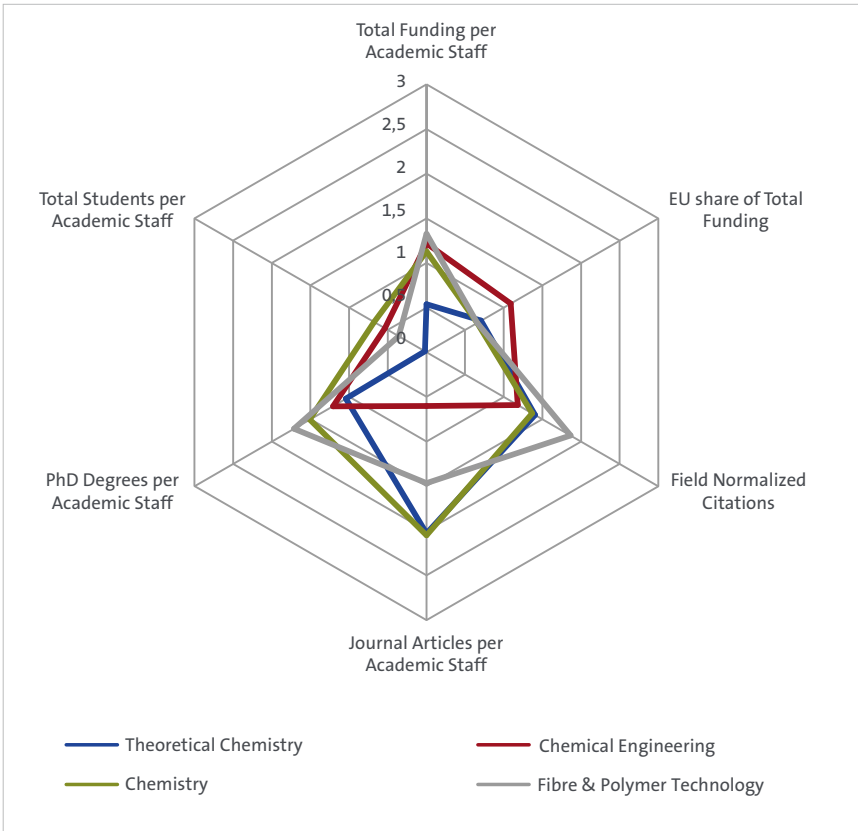
relies on capital intensive equipment and infrastructure. The present financial allocation system at KTH does not favour this type of research and thus makes it difficult to remain internationally competitive. Scholarship is emerging throughout the unit and the recent increase in the number of successful EU project applications should lead to greater international collaboration. Vitality and potential are good and excellent in parts. Synergies and cooperation between the different activities of the unit are visible but not pursued to their fullest extent. The strategy is good and realistic but could be more ambitious. It will be essential for the unit to continue to pick up new trends and possibilities at an early stage and concentrate on trendsetting applied research. At the same time, a broader foundation will be needed for basic research in order to form a better basis for further innovative applied research

UOA MATERIAL SCIENCE AND ENGINEERING (ITM)

The quality of basic research conducted in this unit is of the highest international standing. The field normalized citation score is 20% above the international average. The unit combines the disciplines of material properties, material structure and material processing. It forms an ideal entity, with solid scientific fundamentals and strong practical applications in material products and production technologies. Several computer programs with worldwide applications have been developed. Levels of international collaboration are extraordinary, as indicated by joint projects and student exchange as well as visiting professors and scientists. Applied research quality is world leading in the entire unit. Scholarship is outstanding as evidenced by international visibility and a large number of assignments and awards. Vitality and potential are good, excellent in parts. It is of strategic importance for the Swedish materials producing industry that the strength of this unit is maintained and developed. Here, the upcoming retirements of key professors is a threat. Rapid action is thus required to renew the faculty which should however be easy because of the excellent reputation and international networks, and support from Swedish industry. The strategy of the unit is excellent but challenging and the more fundamental work needs long-term financing. It will be important to focus on exploring new fields without losing focus and balancing between basic research and industrial relevance.

Expert Panel 9: Chemistry

RESEARCH PROFILES OF THE UOAS IN QUANTITATIVE TERMS



The Expert Panel Report

GENERAL OBSERVATIONS AND RECOMMENDATIONS

The research in all of the four units is highly competitive at an international level and some research groups are world leaders in their field. Strengths include both basic and applied research, and research training of high quality and sufficient volume. The units interact in many ways with the outside world most notably through successful applied research collaborations with Swedish industry. Researchers are not only key figures in international research cooperations but also editors of international journals and hosts for conferences in all areas of chemistry. They help promote an interest in science and technology in the next generation of Swedish students, and also take part in the domestic debate on environmental and oth-

er timely issues. Important strategic changes directed at merging small groups into bigger units have greatly facilitated interdisciplinary work in the research field.

UOA FIBER AND POLYMER TECHNOLOGY (CHE)

The unit *Fiber and Polymer Technology* results from a strategic merger of several different research groups some six years ago. It is now clear that the benefits of this merger have been substantial, as evidenced by extensive publications, high citation counts and patenting levels, and clear international visibility. The unit today conducts basic research of a high international standard overall with some researchers recognized as world leaders in their field. The scientific productivity of the unit is exceptional with a field normalized citation score 86% above the world average. The quality of applied research is world leading overall with excellent industrial collaborations and over 30 granted patents during 2003–2007. Scholarship is excellent throughout and senior researchers in the unit are members of international editorial boards of some 30 scientific journals. Both senior professors and junior staff have an enthusiastic attitude towards education. The vitality of the group is outstanding, with a good age-profile and gender balance. There are several younger researchers with obvious potential to become future leaders, thus minimizing the threat of upcoming retirements of senior staff. The large amount and variety of external research creates a solid basis for future educational and scientific activity within the unit. The unit's strategy is both outstanding and realistic. The introduction of elements of entrepreneurship in the educational programs is likely to increase the competitiveness of graduates in the job market through a broader understanding of market opportunities.

UOA THEORETICAL CHEMISTRY (BIO)

The basic research of this unit is at the forefront of international theoretical and computational research. The productivity in terms of published papers, graduated PhDs, and computer software developed for quantum chemical calculations is outstanding. The field normalized citation score is 40% above the international average. Grant and contract funding is high in comparison with other theoretical and computational activities internationally. The applied research quality is of high international standard with parts of the unit performing at a world leading level. There is a positive attitude towards work on real life applications, for example in molecular electronics and photonics. The unit is involved in many cooperative projects though at KTH alone there seems to be several additional opportunities for cooperation. Scholarship is excellent across the entire unit. Senior researchers have also participated in radio broadcasts on the role of science in society. Vitality and potential are excellent. The unit maintains an impressive multicultural research environment with researchers from twenty different countries, employs numerous

brilliant foreign students, and has the prospect of continued growth and renewal. However, the gender distribution of the staff needs some attention. The strategy of the unit is both outstanding and realistic including initiatives in both basic and applied research. The unit plans to seek a greater role in the undergraduate curriculum. The increasing importance of modeling and simulation in all engineering sciences should make it imperative that such a development takes place.

UOA CHEMISTRY (CHE)

Both the basic and applied research quality of this unit is of high international standard, with parts of the unit performing at a word leading level. The unit has an extremely high rate of productivity and a field normalized citation score 37% above the world average. There are many patents, excellent cooperative projects with industry and a very large number of national networks and centers of excellence. Three spin-off companies have been formed and eight patents have been submitted during the review period. The unit also produces a large number of excellent PhDs. The *Solar Cell* group is among world leaders and the *Industrial NMR Center* is an outstanding center for interdisciplinary research and application. The new *Surface Chemistry* group comprising corrosion science, surface chemistry and physical chemistry is about to establish an external partnership on campus to create a world leading center in corrosion research. The large *Organic Chemistry* group is involved in innovative synthetic work. Scholarship is excellent. The unit comprises leading figures in Swedish science with many national and international awards, over eighty keynote lectures were given during the review period and researchers participated in over twenty editorial boards. The unit also contributes to political debates and pursues outreach activities including television debates and popular science presentations to children and young scientists. Vitality and potential are good overall and excellent in parts of the unit. The unit has been very successful in attracting high quality research students and highly motivated staff who actively participate in international exchanges. The overall strategy, which is considered excellent but challenging, focuses on the re-organization of traditional research areas into new groupings that will open up new opportunities for research and funding.

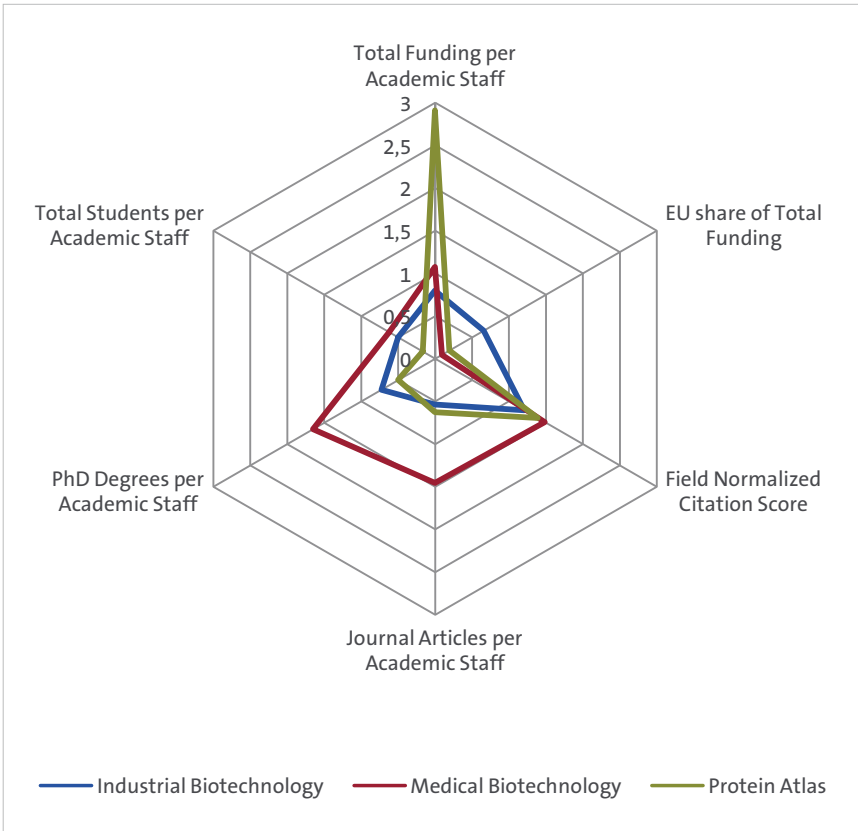
UOA CHEMICAL ENGINEERING (CHE)

The applied research of this unit is of world leading quality overall and its basic research is of a high international standard. The field normalized citation score of the unit is 16% above the world average. Selected research directions are traditional and defined within long-term strategic partnerships with leading industrial companies. Major applications have been identified in energy systems for vehicles, bio-energy, environmental technology, and chemical production engineering and

technology for developing countries. PhD students are highly appreciated by Swedish employers and the unit has been involved in the establishment of new start-up companies. Scholarship is emerging across the entire unit, as defined by participation in different committees and advisory boards, as well as the societal debate on environmental and energy-related issues. However, greater visibility needs to be established in the more fundamental research areas. The age-profile in the unit is very poor with many highly qualified researchers about to retire. The unit must therefore be vitalized by new recruitments to bring in new research visions and to correct the poor gender balance. The strategy presented was considered good and realistic but perhaps not as ambitious as it could be. The main strategic direction towards renewable energy and a sustainable environment is of great societal importance and relevance. The unit does have potential to provide unique solutions to related industrial challenges and needs but it is vital that it focuses on those research directions with the highest potential. There is a clear opportunity to establish a strong chemical and biochemical engineering activity which should be assessed.

Expert Panel 10: Biotechnology

RESEARCH PROFILES OF THE UOAS IN QUANTITATIVE TERMS



The Expert Panel Report

GENERAL OBSERVATIONS AND RECOMMENDATIONS

This is a broad Research Field addressing the engineering and applications of the key polymers of life: nucleic acids, proteins and carbohydrates. Research activities focus on gene technology, protein engineering, carbohydrate engineering, nanotechnology and bioprocess technology. Technology development and applications range from high throughput DNA sequencing, human proteomics and imaging of human tumors with novel reagents to the creation of novel biocomposite materials. Indeed, the scale and vigor of biotechnology activities at KTH is rare, covering several of the most important strategic areas of biotechnology. Synergies have emerged from major common elements of technology, particularly gene and protein techno-

logies. The collaborative interactions have also been driven by inter- and multidisciplinary projects and concepts for example within the *Protein Atlas* unit, the Strategic Research Center *Biomime* and a new project *Bioamines*. Such common threads of technology or common projects have helped build critical mass and coherence within and between units.

UOA MEDICAL BIOTECHNOLOGY (BIO)

This is a productive unit performing basic research at an internationally high standard overall. The field normalized citation score of the unit is 48% above the international average. The unit provides a high technology resource in Sweden and expertise in genetic and protein technology. The applied research quality of this unit is of a high international standard overall with parts of it performing at a world leading level. Work is inspired by the development of technologies for applications. Several spin-off companies have been established based on patents obtained by staff. There is a clear synergy with developments in the *Protein Atlas* unit. Scholarship is excellent and considerable effort is put in to making this area of science attractive to the broader public. The vitality and potential of the unit are good overall and excellent in parts of the unit with a large number of lively, questioning and committed PhD students. Senior researchers demonstrate a clear enthusiasm, energy and vision for research. A relatively large number of EU grants have been obtained and members of the unit participate in several centers of excellence. The strategy of the unit with its focus towards increasing synergies within the unit and with other groups within Biotechnology is good and realistic but could be more ambitious. For the unit to be at the forefront of international research, it will probably be necessary to accept bigger challenges.

UOA PROTEIN ATLAS (BIO)

This unit is essentially an inter-disciplinary project established to map the protein landscape of the human body; the mastery of technology shown, its boldness and broad explanatory scope are truly thrilling. Both basic and applied research is considered as world leading. The field normalized citation rate of the unit is 49% above the world average. However, it should be noted that project results are well documented and promptly published on the web, helping to explain why the number of traditional publications is less than expected for the scale of operation. The Atlas represents a valuable, publicly available information resource, and the antibodies produced are further resources towards broad and wide ranging medical applications. Scholarship is outstanding; the Protein Atlas is visible in Sweden and represents a trusted source of information that can promote the well being of society. However, the international visibility and awareness of the project could be improved. Vitality and potential are excellent across the majority of the unit and

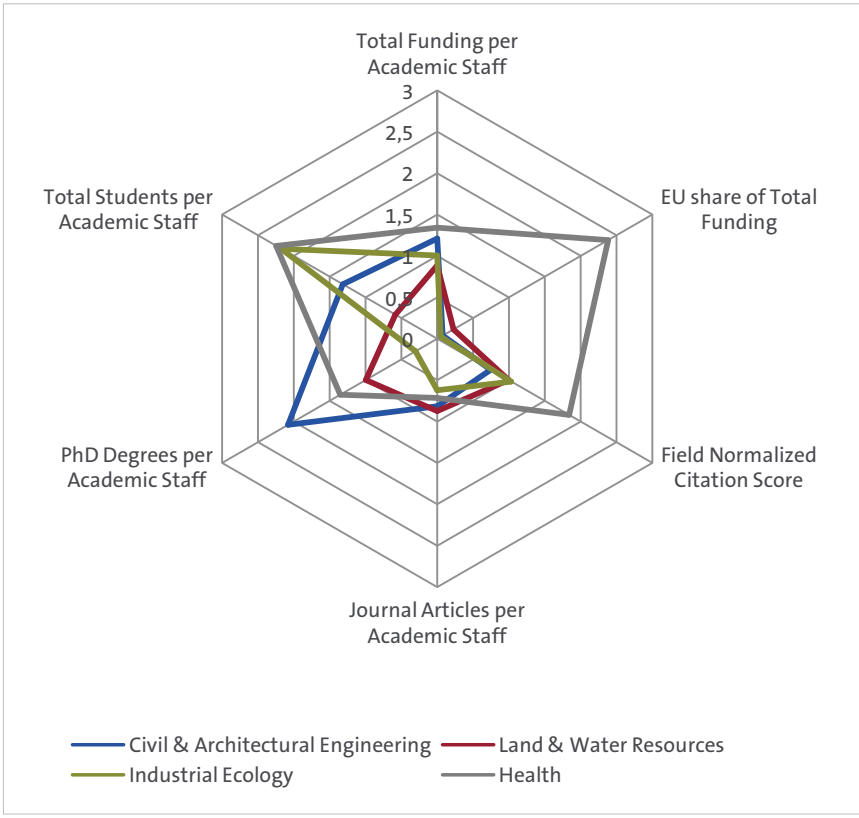
the unit provides a useful training for young graduate technicians. The strategy of the unit is outstanding and realistic. Although the project in its present form will be finalized by 2014, the unit can be seen as the current face of Human Proteomics at KTH, rather than a large project with a finite end.

UOA INDUSTRIAL BIOTECHNOLOGY (BIO)

Part of the UoA was considered to perform at an internationally high standard with the main part performing at a nationally high and internationally recognised standard in both basic and applied research. In contrast, the field normalized citation score of the unit was 20% above the world average. The quality of operations was very uneven across the unit, however, reflecting the fact that the unit consists of four very disparate research groups with few links to each other. The *Biomime* center, focusing on the development of advanced biomaterials, is highly interdisciplinary with high quality basic and applied science and clear evidence of scholarship. Work on biocatalysis and pyrosequencing was also of high international standard. The *Bioamines* project attempts to develop emerging synergies within the unit between *Bioprocess Technology* and *Biochemistry*. The divisions of *Biochemistry* and *Wood Biotechnology* had a variety of international academic collaborations, including EU projects. Parts of the unit had filed patents and engaged with industry, including spin-off companies. Vitality and potential vary since three of the four groups are in a state of flux with recent (*Bioprocess Technology*) or impending retirements (*Environmental Microbiology and Biochemistry*) of key-faculty members. However, the *Wood Biotechnology* group has some excellent younger faculty and a lively collection of postdocs and PhD students. Due to the disparate nature of the unit and impeding retirements, the panel had some difficulties in fully understanding the likely future strategy of three of the four groups in this unit. Owing to these impending retirements, the unit now has considerable power to shape its future by new appointments to reinforce or re-engineer synergies within the unit and with other units in the School of Biotechnology.

Expert Panel 11:
Technology for the Built Environment

RESEARCH PROFILES OF THE UOAS IN QUANTITATIVE TERMS



The Expert Panel Report

GENERAL OBSERVATIONS AND RECOMMENDATIONS

This research field covers a diverse range of areas at KTH. Whilst this diversity is, to some degree, a product of different research topics, there is also a lack of focus meaning that possible synergies have not been taken advantage of fully. Strong leadership is required to define a coherent, long-term strategy and a more rationally organized structure, especially as several new lines of research within the field have significant potential. Reflecting this lack of strategic direction, succession planning is poor, though it was noted that promising staff have been recruited in to some of the units. Laboratory-based research groups are disadvantaged by high space charges. Intellectual property management is not yet an integral part of the culture or strategy.

UOA CIVIL AND ARCHITECTURAL ENGINEERING (ABE)

This unit consists of the divisions *Building Materials, Building Services Engineering, Building Technology, Concrete Structures, Geotechnical Engineering, Highway and Railway Engineering, Industrial Safety Ventilation, Structural Design and Bridges, and Environmental* and *Natural Resources Information Systems*. The quality of basic research was of high international standard overall with the *Building Services Engineering* and *Highway and Railway Engineering* performing at a world leading level. However, perhaps reflecting the non-academic publication tradition of the unit, the field normalized citation score was below the world average. The unit provides a focus on building and transportation infrastructure which is of critical importance for the Swedish economy. Applied research at the unit is of a high international standard overall with *Building Services Engineering, Concrete Structures, Geotechnical Engineering, Highway and Railway Engineering, Industrial Safety Ventilation* and *Structural Design and Bridges* performing at a world leading level. There are many examples of projects that are closely aligned with industrial priorities. Scholarship is emerging across the unit and levels of engagement in scientific society are good. Many of the research divisions are small in size and a significant number of senior professors are due to retire in the next few years. These factors weaken the vitality and potential of the unit. The teaching load varies significantly across the divisions. The future strategy of the unit involves the formation of four cross-disciplinary research areas: Long-Life Buildings and Transportation Infrastructure, Sustainable Design and Construction, Engineering Systems and Management, and Environment and Construction. Critical to achieving this strategy, however, is a realization that groups will have to be merged to achieve significant mass. New appointments must also be made to address retirements in key areas and this represents an opportunity to increase the amount of international faculty.

UOA INDUSTRIAL ECOLOGY (STH)

In spite of the difficulties of establishing a new disciplinary area at KTH, this is a coherent group with critical mass and good leadership. The unit is one of the world leaders in establishing a research agenda for industrial ecology. Research is deeply grounded in theoretical understanding whilst showing the breadth necessary for a developing area. The unit has a good international profile. However, given the quality and extent of its research, more extensive publication in international journals could be expected. The quality of applied research was world leading across the unit. The LCA-based Environmental Load Profile approach is a widely applicable practical manifestation of Industrial Ecology and the contribution of this group to the debate over Sustainable Consumption has already attracted notice internationally. Scholarship, vitality and potential were excellent across the unit. Industrial Ecology clearly provides a stimulating intellectual environment with the

gender and age profiles across the unit being good and evidence of emerging talent. The strategy of the unit was considered excellent, even if challenging to achieve, with a clearly articulated mission, vision statements and implementation plans. Synergies with other groups at KTH need to be recognized and encouraged, in particular with *Urban Planning and Environment* or *Energy Transformation*.

UOA HEALTH (STH)

The quality of basic and applied research in this unit is of a high international standard overall. The field normalized citation score was well above the international average but the low number of publications from this small unit makes this value statistically insecure. The *Fluid and Climate Technology* Division uses established techniques in ventilation, indoor air quality and aerosol transportation to understand the impact of indoor air pollutants on human health. More recently the division has expanded into low temperature heating and ventilation systems with the aim of reducing energy consumption for buildings. The *Ergonomics* Division has developed a comprehensive approach to injury prevention and safety. The research undertaken by the *Design, Work Environment, Safety and Health* Division covers important areas relating to safety and the well-being of individuals at home and in the workplace. Scholarship is emerging across the unit. However, the unit will need to pay more attention to publication to ensure that its research has a higher degree of scholarly output, in addition to solving practical problems in the field. Vitality and potential were considered good in the unit overall. In all three Divisions, there is adequate representation by female academics but the age profile is a point of some concern. The strategy of the unit was considered good and realistic, but not as ambitious as it could be. The main challenge facing this unit is the training of young researchers to take on leading roles when senior professors approach retirement. There is also scope for streamlining and re-aligning activities between divisions and other units at KTH.

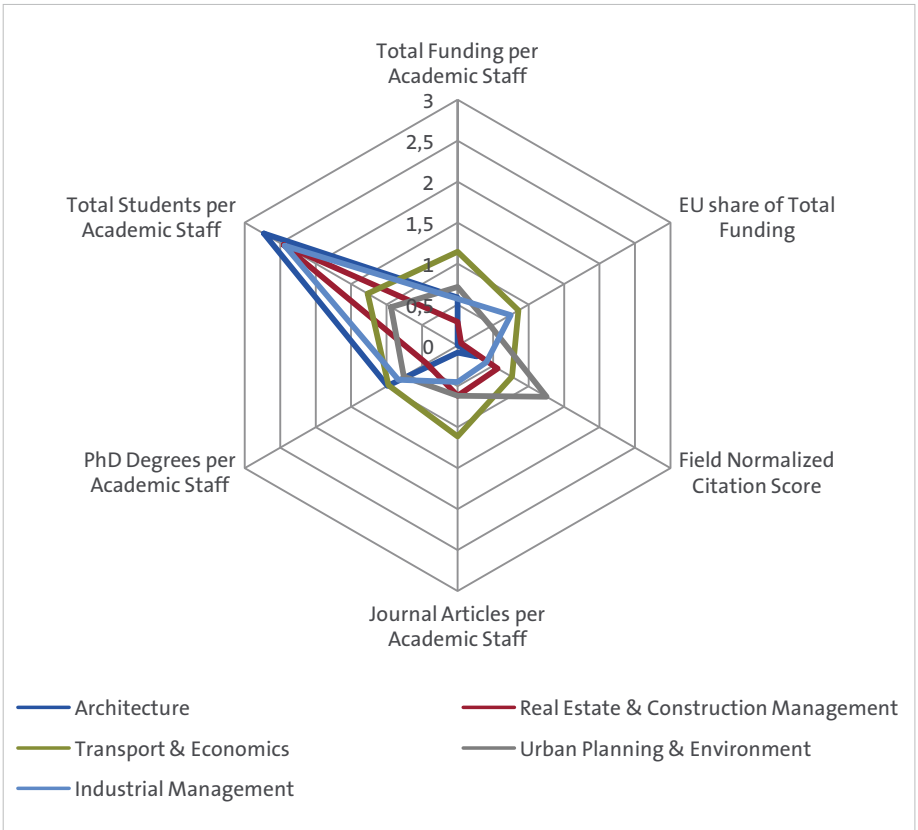
UOA LAND AND WATER RESOURCES (ABE)

This unit comprises *Ecosystem Technology, Water Resources Engineering, River Engineering, Water, Sewage and Waste technology, Water Management, Environmental Management* and *Assessment and Engineering Geology and Geophysics*. The quality of basic research is of a high international standard overall with a field normalized citation score at an internationally average level. Applied research is also of a high international standard overall with parts of the unit performing at a world leading standard. The Land and Water Resources division is outstanding in its ability to solve tough problems in the Swedish environment. This division also plays a significant role in international applied research. Vitality and potential were considered good across the unit as was the gender balance. There are positions important to

the vitality of the department that have not been filled. Greater integration with the European and international community could be achieved through external recruitments, this also will bring in new ideas and new ways of doing research. The strategy of the unit is considered good, but may be challenging to achieve. Although individuals and research divisions have strategies to accomplish their own goals, a common strategy for the unit as a whole must be further progressed. This strategy must also be written in a more global perspective. Substantial potential synergies should be realized concerning the relationship of society and the environment with the Department of Industrial Ecology and the Department of Civil and Architectural Engineering at KTH.

Expert Panel 12. Architecture, Built Environment and Management

RESEARCH PROFILES OF THE UOAS IN QUANTITATIVE TERMS



The Expert Panel Report

GENERAL OBSERVATIONS AND RECOMMENDATIONS

The units within this Panel perform an essential role within KTH as an interface between technology and the built environment and also as an interface between industry and society. They have targeted their efforts on education, forming highly qualified manpower (architects, engineers, surveyors and economists) for Sweden. Applied research also plays very significant role with many researchers providing up-to date knowledge in the political and legislative arenas as well as to the labor market and to civil society in Sweden. This focus makes the units in this field distinctive and possibly more challenging to assess using the same criteria. The dependency of units within the field on student numbers, including PhD students, is a serious impediment to the advancement of internationally competitive basic research. The number of foreign researchers and visiting scholars is far too low for a university which aims to be one of the best technical universities in Europe. The potential of research conducted in Sweden is not efficiently used when developing and profiling international research strategies; world leading research could very well have a "Swedish" dimension. Further strategic co-ordination between the units and the academic "marketing" of their research in Sweden and beyond would help strengthen activities.

UOA ARCHITECTURE (ABE)

Foreword

Research is a difficult concept within architecture. It is familiar in the sense that every time one creates an object or explores a design solution, new outcomes are being "researched". However, it is unfamiliar because "research" in the common sense of producing publishable papers is not central to the discipline, unless one is working on architectural history, criticism or theory. Therefore, when measuring "research", one can measure the quality of the design output by professors and their students or one can measure scholarly articles produced. In addition, "research" in architecture cannot be separated from education. In a profession that is driven by service-based commissions, one rarely gets to explore innovative approaches in professional work. Rather, it is teaching that offers the outlet to explore riskier ideas and new approaches. Furthermore, for scholarly publications within architects, there are very few refereed journals in which one can publish; hence this standard for success is not really reliable. This is certainly reflected in the relatively modest performance of the unit in the bibliometric study and it is questionable whether bibliometrics is an appropriate assessment tool to use in this case. In the end, like design itself, any measure of research quality in this area is more subjective than in other fields.

Assessment

There are continuous attempts in the unit to bridge the distance between the two forms of research and to embed "research" in teaching. The manner in which the unit is attempting to do this is consistent with international trends, by i) insisting that design incorporate intellectual ideas based on cultural/social research; that ii) design also incorporate investigations of new technical – digital and material – innovations; and that iii) design teaching is itself a research forum. The theoretical underpinnings of design work seemed strong and original thought was evident in many of the projects. It is comparable to international work, but does not lead it. The work of the design studios is of high quality, although likewise it does not yet break new ground. Written scholar output is visible in social science texts, architectural history texts and architectural /cultural theory texts. In student work there was a willingness to do work of experimental nature and engage with complex issues. Whilst there was virtually no design work shown to the Panel by the faculty making it impossible to evaluate, it was clear that the themes students pursued were encouraged and fuelled by professors who are clearly intellectually engaged, well read and culturally current in their interest. In terms of written scholarly output, there was a good atmosphere for exploration, although it was largely the younger staff that participated in this form of scholarly research. New liveliness and imagination is seen in the school as it is now formulated, both as scholarly work enters the design work and also as the new technology of digital fabrication gets embraced. The strategy of the unity was considered adequte The balance of full-time academics to part-time practitioners is right. The focus on research as education and research as practice is strong and vital.

UOA REAL ESTATE AND CONSTRUCTION MANAGEMENT (ABE)

This unit primarily concentrates on good teaching but also provides considerable legal and real estate expertise to the politico-administrative environment in Sweden. The quality of basic research was considered of a high international standard overall but the field normalized citation score was below the international average. The Valuation of Real Estate Index is an outstanding achievement of the divisions of *Real Estate Planning and Land Law* and *Building and Real Estate Economics*. The Index is well grounded in theory and used by many actors in Sweden. The *Centre for Banking and Finance* has the strongest traditional research profile and has shown remarkable leadership in research on comparative retail banking, publishing in high impact international journals. *Real Estate Planning and Land Law* is disadvantaged by the fact that the institutional – Swedish – framework limits an extensive global orientation. Applied research quality was considered of a high international standard overall. Many researchers have excellent local impact within Sweden and the Nordic Region but overall, given their strong base in Sweden, researchers

in this unit should seek to apply their knowledge in a more international arena. Scholarship was considered as emerging across the unit. Many researchers from all the groups within this unit play an active and important role with the national administration. Indeed, this unit seems to be one of the most visible in Sweden from KTH and therefore is an important ambassador for the university. Vitality and potential was considered good in the unit overall. There is a clear strive to find new openings to strengthen the research. The gender balance among young researchers and doctoral students is satisfactory. The strategy of the unit was considered good and realistic. The unit operates in a coherent manner and there are clear synergies between the different research groups. A more significant orientation towards international academic circles would be beneficial for the reputation of the unit and KTH.

UOA URBAN PLANNING AND THE BUILT ENVIRONMENT (ABE)

This unit was established during 2003–2004 and consists of *Urban Studies and Planning, Regional Studies and Planning, Environmental Strategic Analysis and Geoinformatics*. The quality of basic research was considered of high international standard in the unit overall with parts of it performing at a world leading level. The field normalized citation score of the unit is 41% above the world average. Considering the heavy educational load of the unit and limited funding from KTH for basic research, these are noteworthy achievements. Contributions from the Swedish experience of urban planning and local development have become a particular strength of the group in the international academic community. Senior researchers have an international reputation in the fields of social integration and of methodological advancement in particular. However, the international visibility of the group is still limited with some considering the role of the unit as primarily that of a Swedish policy advisor. The number of articles in international refereed journals is still below the intellectual and knowledge potential of the group. The quality of applied research was of a high international standard overall with parts of the unit performing at a world leading level. The majority of the unit's research is applied research in urban and regional studies, mainly financed by contracts from public institutions in Sweden. Scholarship is emerging across the entire unit. Vitality and potential is considered good in the unit overall. The number of visiting scholars, post-docs, visiting professors or guest lecturers should be increased to open up the unit to international dialogues. The strategy of the UoA was considered ambitious though challenging to achieve. The unit should thus carefully narrow down it research ambitions and deepen its competence within a field which reflects long-standing Swedish or Nordic experience. This would require some international benchmarking to identify the particular international research potentials of the unit.

UOA TRANSPORT AND ECONOMICS (ABE)

Foreword

This Unit consists of *Transportation, Center for Transport Research, Safety Research (CTS), Economics* and *Geodesy*. The Panel decided to assess *Economics* and *Transportation* separately, since these two subunits are very different from each other, both in what they study and also in their programmatic stages within the unit. Geodesy consists of a single senior professor and does not have sufficient intellectual and programmatic connections with the other two subgroups. With no specialist geodesist on the panel, this group was not assessed.

Assessment

The quality of basic research in the *Economics* group was considered of high international standard overall with parts of the group performing at a world leading level. New strategic initiatives have been taken that have the potential to underpin significant new basic research outputs in the future. The applied research quality of this group was of high international level although its research focus is best described as a "niche market" with little competition from elsewhere in Sweden. The *Transportation* group has a strong international reputation though it must be noted that it does little basic research as it is strongly and successfully involved in applied projects. Through the *Centre for Transport Studies* this group is well equipped to study all aspects of transportation planning and modeling from traffic analysis at the micro level to forecasting and modeling trip generation and location demands. Applied research quality is world leading in parts of this group. Scholarship is excellent in *Economics*, and outstanding in *Transportation*. Both groups show a great deal of vitality and potential for continuing success and growth, which is attested by their ability to make the international recruitments. The strategies of both *Economics* and *Transportation* are well rationalized and they are set to log in continuing successes in applied research and – with some effort – could also contribute to basic research. The execution of the strategy is promising and a bit clearer in the case of *Transportation* but potentially very promising in the case of *Economics*.

UOA INDUSTRIAL MANAGEMENT (ITM)

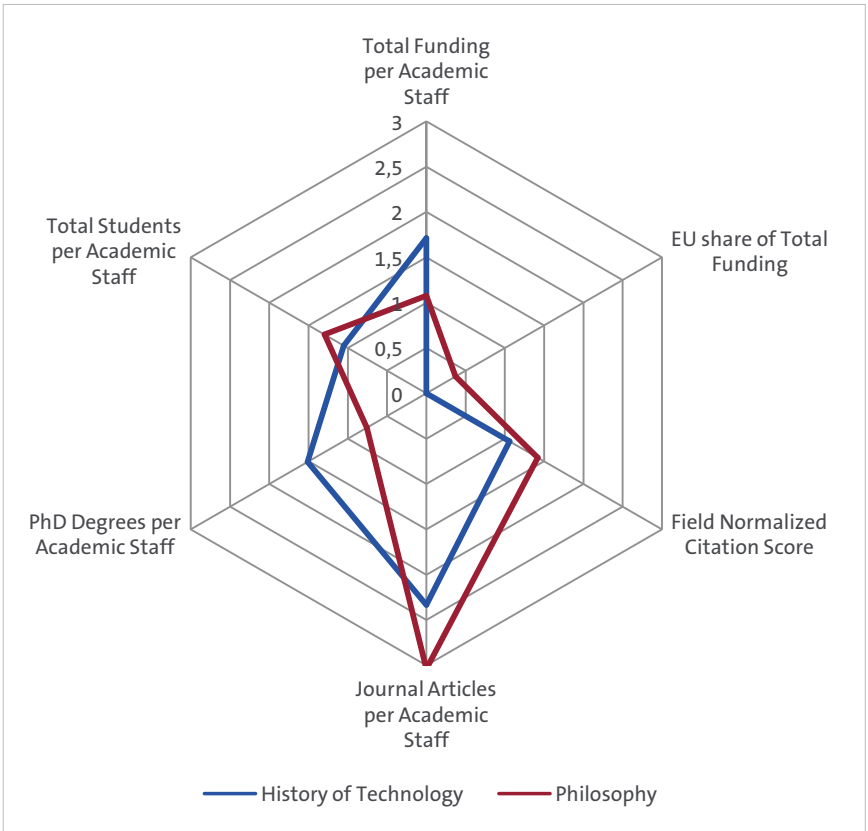
This unit is divided into nine sections covering different and heterogeneous areas of teaching and research. The teaching activities of the unit are very successful and contribute considerably to the profile of KTH in Sweden. (International) basic research does not seem to be a priority of the unit and the field normalized citation score is below the international average. Applied research, which is strongly linked

to education, is of an internationally recognized standard. The (applied) research environment at the unit reflects a free and open organizational culture that makes room for a broad spectrum of themes in the fields of industrial management, organization and dynamics, many of which are interesting and unconventional. The fields of industrial dynamics, industrial work science, and gender and organization are relatively strong in terms of funding, publication and international visibility. The (applied) research output focuses strongly on monographs and conference papers, and has a strong bias towards Swedish as the publishing language. Scholarship is emerging across in the entire unit. The international visibility of research outputs from the unit as a whole is weak. Whilst vitality and potential are good in parts, there are clear opportunities to improve this element of the unit. There is no concise and visible research strategy for the future development of the unit as a whole. Sustainable mechanisms to promote regular strategic debates and related decisions within the unit should be explored to enhance internal communication and cooperation.

UoA Philosophy and History of Technology (ABE)

This unit contains the groups of Philosophy of Technology and History of Technology which, at the request of the groups, have been assessed separately within the RAE. Their individual research profiles are given below.

RESEARCH PROFILES OF THE UOAS IN QUANTITATIVE TERMS



These are two very good groups with strong international track records beyond Scandinavia and Europe. Basic research is at world leading level in *Philosophy* and in parts of *History of Technology*. *Philosophy* has a strong tradition in international publication and a field normalized citation score 40% above the world average. History has a lower academic productivity and an internationally average field normalized citation score. Applied research quality is considered world leading and scholarship is excellent in both groups. The close cooperation of the philosophy group with engineers and empirical scientists is unique in the field. Members of

both groups are very successful 'academic entrepreneurs' and have a very high level of external funding. However, there appears to be an imbalance between internal and external funding which may risk the internal coherence and continuity, leaving insufficient room for basic research. Vitality and potential is considered excellent in parts of both groups and good overall. The strategies of both groups were considered excellent, even if challenging to achieve. The *Philosophy* group has a clear view on its future research agenda; apart from continuing research in these fields it intends to set up new research projects in behavioral science and risk research, ethics of medical technology and philosophical issues related to technical education. The strategy of the *History* group aims at large research programs that cut right across the various nuclei within the group. So far, the two groups operate separately although they would certainly benefit from internal debates on a common vision of the role of the humanities within a Technical University.

Part 4. Conclusions

The KTH International RAE 2008 was designed as a strategic process that would engage the entire staff of KTH. The considerable effort faculty and support staff put in to preparing and completing the Evaluation Packages, as well as hosting the Visit Week, represents a considerable investment from all at KTH in this process. As a result, KTH now has a deep and broad appreciation of its research base. The work done and the insights obtained have laid solid foundations for the further development of KTH at all levels. It is now essential that the process is followed up with a strong strategy and incentives that encourage staff to develop KTH as a top European university of technology. KTH's leadership will actively manage the implementation of recommendations made in the RAE, drawing the project's findings in to its Strategic Plan for 2009–2012. At the same time, the RAE is also a bottom-up process and individual members of faculty, research groups and Schools should also make use of the RAE's findings in defining their future research strategies.

The observations and insight into the KTH research base that were obtained by the RAE process are many and valuable. The key result, both from the Peer Review and the Bibliometric Analysis, is an affirmation that KTH does indeed have a strong, internationally competitive research base, successfully combining basic and applied perspectives. The types and levels of industrial relations and entrepreneurial activities revealed by RAE confirm that research carried out at KTH is taken forward effectively and to the benefit of society. The majority of KTH graduates, both engineers and doctors of technology work in industry, mostly in Sweden but also abroad. Many KTH researchers are prominent scholars that push forward the frontiers of science and technology and make significant contributions to societal development. KTH has dedicated teachers, many of whom are also committed to outreach activities.

The RAE process has also identified several areas where corrective actions and renewal are needed. Two main observations stand out; first, there is a need to provide better career paths and support for young faculty and second, there is a need to improve basic funding so that excellence in long term fundamental research can

be supported. Even though both are considered nation wide weaknesses, there are actions that KTH can take.

By prioritizing and focusing its research efforts, and actively managing up-coming retirements, KTH can free resources for renewal. Tenure track positions need to be opened for up-coming faculty, and a mentoring system developed to support them in growing into strategic roles in their chosen research areas. It is apparent that KTH must also continue to actively support the development of female faculty and to add further international dimensions to its recruitment processes. *KTH will focus on recruiting and developing high quality staff.*

New scientific discoveries and true innovations spring from new knowledge and deep understanding of fundamental phenomena. Foundations for new technology and discoveries are laid by results from more curiosity driven basic research. Notably, the RAE shows that it is the skillful combination of basic and applied research that characterizes the top research environments at KTH, leading to technical research of high quality *and* societal impact. To ensure that KTH continues to thrive, it is essential that there is room for excellent basic research in the future. KTH has today a strong external funding base, both for basic and applied research. Further resources will now be made available to those parts of the university that were shown by the RAE to perform at an international top level. *KTH will focus on quality.*

Equally importantly, bridges must be built from basic research towards applications by creating strong interdisciplinary networks; within the university and between different actors along the value chain. Therefore, key areas of strength at KTH which are important for the future development of society such as energy technologies, new materials, information and communication technologies, technology for medicine and health as well as transport systems will be supported in working together to deepen interdisciplinary insights and gain critical mass. Questions of intellectual property rights and entrepreneurship must be addresses effectively, both within the university and with strategic partners. In such chains of research and innovation, Research Institutes can play important roles as a link between the university and industrial spheres. *KTH will focus on consolidating its research base and building high quality relations with partners in society.*

Large parts of engineering research rely on experiments supported by complex research equipment and infrastructure that require significant investments. National governments often compete for the most prominent international investments in large scale infrastructures, but it is equally important for a nations' competitiveness to constantly update and renew the research infrastructure of its universities. The RAE points out the difficulties within the current system to keep an up to date experimental infrastructure of KTH, both in research and education. This issue needs to be addressed if international competitiveness is the goal Another concern is the increasing cost of laboratory space, which is difficult to fund from external

sources. Again, corrective actions and a strong strategy are needed to ensure that engineers educated at and performing their research within KTH acquire, maintain and further develop their experimental competence. *KTH will focus on ensuring it has the necessary high quality equipment, infrastructure and support staff to deliver advances in research.*

The RAE also suggests that KTH should more actively communicate its successes. In the face of increasing international competition, KTH will need to strengthen its brand, especially internationally. The high numbers and citation rates of papers published suggest that KTH is visible within the academic circles. The university can, however, take a more active approach to communicating its work outside of these circles. *KTH will focus on improving the communication of its research strengths to wider audiences beyond the academic arena.*

In summary, the value of undertaking projects like the present RAE is becoming increasingly apparent; it is rare that a university has an opportunity to participate in a single activity together and discuss the future of their university as an entity. The RAE has given KTH this opportunity; providing indispensable background and insight into the Strategic Plan of KTH. Are there things we might have done differently? Possibly; it was challenging to assess those parts of the university with a highly distinct research profile e.g. architecture, using a single model. Are there things we could have done better? Undoubtedly; the project would have benefited from further administrative support at a central level to reduce the burden on research groups. KTH has learnt from the experience of conducting its first research evaluation. What is perhaps of most significance is the fact that, despite the manifold difficulties involved in conducting a research evaluation, KTH took on the challenge and has now delivered the results. This ability to address challenges, and to address them together, will be essential in shaping the future of KTH. It is a culture that will enable us to succeed, ensuring we continue to produce excellent science for society.

Appendices

Appendix 1: Evaluation Package

Appendix 2: Membership of the Expert Panels

Appendix 3: Biographies of the Expert Panel Chairpersons

Evaluation Package

There are two parts to this Evaluation Package:

- Part A. Strategic Information from the Units of Assessment
- Part B. Quantitative Data of the Unit of Assessment

The parts should be understood as complementary; together should give a full picture of research activities, quality and strategy for the future at the Unit of Assessment. Information given in either part should support and reinforce information given in the other.

The assessment period for this RAE is January 2003 to December 2007. The census date is the 31st December 2007.

Part A. Strategic Information from the Units of Assessment

INTRODUCTION

Part A of the Evaluation Package is designed to help the Units of Assessment to develop and to communicate a common research strategy that meets the objectives of high scientific quality, innovation potential and strategic relevance.

A1. SUMMARY OF PRESENT RESEARCH ACTIVITIES

Give a summary of the current research activities in the Unit of Assessment including important infrastructure, academic and industrial networks and interdisciplinary aspects. Comment on the present strategic impact of the Unit of Assessment on society and industry. The strategic impact might contain elements such as for example trained personnel, new knowledge and technology, intellectual property, new companies or services etc.

A2. SELF ASSESSMENT OF THE STRENGTHS, WEAKNESSES, OPPORTUNITIES AND CHALLENGES OF THE UNIT OF ASSESSMENT

This analysis should be carried out from the scientific, strategic, organizational and financial points of view.

Describe how the Unit perceives itself in the international context and identify its most relevant role models or competitors (research groups or organizations). Comment on what distinguishes the Unit's research from its competitors. What is the 'niche' of the Unit in the global research arena?

A3. SUMMARY OF THE MOST PROMISING FUTURE RESEARCH DIRECTIONS OF THE UNIT OF ASSESSMENT IN AN INTERNATIONAL AND STRATEGIC PERSPECTIVE

Based on A1–A2, evaluate the Unit's future potential – over the next 8–12 years – in contributing to the development of society. Means towards this end could be e.g. new knowledge and technology, innovations, supporting existing industries, laying the basis for new industries etc.

Comment on the conditions required to develop these future activities.

If relevant, describe the units view on emerging industrial concepts and the research that is required to support such development. How does the Unit position itself in such a development?

FACTORS FOR THE EXPERT PANEL TO CONSIDER

Units of Assessment have an opportunity here to briefly note circumstances they consider may affect their performance in the RAE for the Expert Panels e.g. recent retirement of a senior researcher, inclusion of Lecturer research outputs in the Evaluation Package.

Part B. Quantitative Data of the Unit of Assessment

This Part of the Evaluation Package requests quantifiable information about the Unit of Assessment. It has three sections:

- B1: Facts and Figures
- B2: Summary of Major Research Activities and Outcomes
- B3: Actions for Renewal

B1: FACTS AND FIGURES

B1.1 Staff

Statistics on all Staff employed by the Unit of Assessment (UoA) during the period January 2003 to December 2007.

This table will be completed, as far as possible, by the KTH central administration from central records and given to the UoAs to check.

Research Staff are defined as KTH employees attributable to the categories listed below in table B.1.1. Categories for Other Research Staff and Other Staff are also listed below. Each member of staff may only be attributed to one staff category. Full Time Equivalent "FTE" information is requested.

In addition to the total FTE in each category, Unit of Assessment are asked to quantify the number of FTE women in each category and the number of FTE under the age of 40. This information will help the Unit of Assessment and KTH understand the potential for renewal. The "T" column is for Total FTE staff number, the "W" for number FTE of women "U" for the FTE number under 40.

STAFF

Research Staff		2003			2004			2005			2006			2007		
Category of Staff	**Swedish**	T	W	U	T	W	U	T	W	U	T	W	U	T	W	U
Research Staff																
Professor (recruited)	Professor															
Professor (promoted)	Professor															
Associate Professor	Universitetslektor															
Assistant Professor	Biträdande lektor/ forskarassitent															
Docent*	Docent*															
Researcher	Forskare															
TOTAL																

Other Research Staff

Guest Professor	Gästprofessor															
Adjunct Professor,	Adjungerad professor															
Postdoc	Forskare**															
PhD Students	Doktorand**															
TOTAL																

Other Staff

Lecturer	Adjunkt															
Technical Support Staff	Tekniker															
Administrative Staff	Administratör															
STAFF TOTAL																

* Docent is a title earned based on scientific and teaching merits, and allows a researcher to supervise PhD students as the main supervisor.
** Any form of employment with at least a one year contact to work at KTH

B1.2 Research Funding

Amounts and sources of research funding for the Unit of Assessment during 2003–2007.

This table will be completed by the KTH central administration from central records. Completed tables will be given to the Unit of Assessment to check.

B1.2.1 External

EXTERNAL

Year	EU	Other International	Research Councils	Vinnova	Ministries
2003					
2004					
2005					
2006					
2007					

Year	Industry	Foundations	Other	Total
2003				
2004				
2005				
2006				
2007				

B1.2.2 Total

This table will be completed by the KTH central administration from central records. Completed tables will be given to the Unit of Assessment to check.

Summarise the amount of External and Internal Funding but do not include funding for undergraduate teaching ('GRU').

TOTAL

Year	External	KTH	Total
2003			
2004			
2005			
2006			
2007			

B1.3 Scientific Publications

Units of Assessment are asked to submit the total number of publications, by type, published by all members of a Unit of Assessment during 2003 – 2007.

SCIENTIFIC PUBLICATIONS

Publication Type	2003	2004	2005	2006	2007
Journal Article					
Review Article*					
Conference Paper					
Authored Book					
Edited Book					
Chapter of Book					
TOTAL					

* a review article reflects on the "state of the field", and most often comments on the work of others; it should appear in a peer reviewed publication.

B1.4.1 Number of PhDs

The total number of PhDs awarded by the Unit of Assessment between 2003–2007. Again, the total number ("T") and number of women ("W") should be recorded.

This table will be completed by the KTH central administration from central records. Completed tables will be given to the Unit of Assessment to check.

PHDS AWARDED	2003		2004		2005		2006		2007	
	T	W	T	W	T	W	T	W	T	W
No of degrees										

B1.4.2 Career of PhD Students

List here the names and present place and form of employment of all the doctoral students graduated from the Unit of Assessment during 2003–2007. Where possible give the current job title as well as stating whether the role is research or non-research based.

PHD CAREER

Name	Year of PhD	Present Employer	Role: Research/Non-Research	Gender: M/F

For those whose present employment is not known, "Not Known" should be entered.

B2: SUMMARY OF MAJOR RESEARCH ACTIVITIES AND OUTCOMES

Introduction

In this section each Unit of Assessment is asked to describe those major research activities and achievements that indicate the quality of research undertaken in the unit. Submissions in this section should reflect and justify the description of the Unit of Assessment and its strategy submitted in Part A. Submissions are permitted from all Research Staff (including Other Research Staff as defined in B1.1) within a Unit of Assessment who have been employed at KTH during the assessment period of 2003–2007.

B2.1 Major Research Outputs

Each Unit of Assessment is asked to submit its major Publications and/or other Research Outputs achieved during 2003–2007 that provide the strongest possible profile of the Unit.

To reflect KTH's status as a technical research University, in addition to printed academic work, other research outputs may be submitted that include, but are not limited to: new materials, devices, images, products and buildings; intellectual property, whether in patents or other forms such as software, companies; major reports for governments, agencies or companies, major exhibits or events; work published in non-print media.

Maximum number of Research Output Submissions

The number of research outputs, whether publications or other research outputs, is limited to the total number of full Professors (i.e. both recruited and promoted) within a Unit of Assessment multiplied by 3. For example, a Unit of Assessment with 4 Professors is permitted to submit 12 research outputs. Research Outputs can be the work of any member of Research Staff or Other Research Staff.

B2.1.1 Major Publications

MAJOR PUBLICATIONS

Principle Authors	Full Title	Journal, Year, Volume, Pages	DOI* if available

*DOI=The Digital Object Identifier System, for scientific publications this is given e.g. in the following format: DOI: 10.1016/j.tibtech.2007.05.002

B2.1.2 Other Major Research Outputs

OTHER MAJOR RESEARCH OUTPUTS

Type of Output	Person/s Responsible	Research Group	Description	Date of public availability

B2.2 National or International Centres of Excellence

Here, a Unit of Assessment should note all Centres of Excellence that it is or has been a member of during 2003–2007. All Centres listed here must receive external income.

CENTRES OF EXCELLENCE

Name of Centre	Home-page	Person Responsible at the UoA	Role of UoA e.g. coordinator, partner	Other Partners	Total Funding for the UoA	Duration

B2.3 Major International Collaborations

Each Unit of Assessment should record the number of major international activities undertaken with partners outside of Sweden during 2003–2007 by the Research Staff or Other Research Staff (as defined in Table B1.1).

INTERNATIONAL COLLABORATIONS	Total Number
Number of collaborating institutions*	
Research visits abroad (of at least 2 months' duration)	
Visiting Researchers (of at least 2 months' duration)	
Other major international activities according to the traditions of the research field (specify; scientific expeditions, field work etc)** 1. 2. etc.	

* Research collaborations given here are limited to those with joint research grants and/or joint publications.
** A maximum of 5 examples may be provided.

B2.4 Major Engagement in Scientific Society

Units of Assessment should entre those activities undertaken during 2003–2007 that illustrate high quality interactions with their scientific peers. Submissions may be included from any member of Research Staff or Other research Staff (as defined in Table B1.1).

ENGAGEMENT IN SCIENTIFIC SOCIETY	Total Number	Number of Individuals Contributing
Plenary or keynote talks at international conferences		
Assignment as editor or member of the editorial board		
Member of international scientific councils		
Member of academic and learned societies		
Awards, Prizes of international standing		
Other, specify (e.g. hosting a major international conference, competition, exhibition...)*		

* A maximum of 5 examples may be provided

B2.5 Major Engagements with Industry and Government

Units of Assessment should entre those activities undertaken during 2003–2007 that illustrate a commitment to working with industry and government both in Sweden and abroad. Government and Industry Assignments should be understood to be projects of significant budget, billing in excess of 500,000 kr. Submissions may be included from any member of Research Staff or Other research Staff (as defined in Table B1.1).

MAJOR ENGAGEMENT WITH INDUSTRY AND GOVERNMENT	Total Number
Adjunct Professorships	
Industrial PhD students	
Major Industry Assignments (contract research)	
Major Government Assignments	
Tailored Educational Courses run for Industry or Government	

B2.6 Innovation Activities

As well as engaging with industry through contract research or education, researchers today sometimes patent their findings, commercialising these through multiple routes. Researchers also form companies either based on patents, other forms of intellectual property e.g. software or experience. These activities are often referred to as "innovation activities" and are highly valid outcomes for research conducted at KTH that will be regarded positively in this RAE.

Units of Assessment should entre those innovation activities undertaken during 2003–2007, noting their current status as of 31st Dec 2007. Submissions may be included from any member of Research Staff or Other research Staff (as defined in Table B1.1).

B2.6.1

INTELLECTUAL PROPERTY

Patent Number*	Short Description	Person(s) holding at the UoA	Date of Registration	Current status e.g. awarded, sold, licensed to established industrial partner, transferred to spin-off, abandoned

*only awarder patents, not applications

B2.6.2

COMPANIES FOUNDED

Company Name*	Founder(s) from the UoA	Company type: Spin-Off**, Consultancy or Service	Date of Formation	Current status e.g. company trading actively, company closed, company sold

* To be included a company must have, or have had, an income in excess of 250,000 kr per year
** A Spin-Off company should be based on a patent developed through kth research.

B2.7 Major Engagement in Society in General

Units of Assessment should entre those activities undertaken during 2003–2007 that illustrate a commitment to working with society in general both in Sweden and abroad. Submissions may be included from any member of Research Staff or Other research Staff (as defined in Table B1.1).

ENGAGEMENT IN SOCIETY	Total Number
Popular science papers or books	
Textbooks	
Popular Science Presentations	
Other societal assignments, specify (e.g. performances, events)*	

* A maximum of 5 examples may be provided

B3: ACTIONS FOR RENEWAL

Introduction

As its staff are responsible of all KTH achieves, it is critical that this "resource" at KTH is renewed and opportunities are created for merit-based advancement. In this section, Units of Assessment should quantify those actions it has taken to renew and refresh its Faculty. Again, information should be collected from 2003–2007. The aim of this section is to gauge the potential for quality at the Unit of Assessment in future years.

B3.1 New Recruitments

In this instance, recruitments are valid only when made to the Research Staff, as defined previously in B1.1. Again the total number "T" and number of women "W" should be recorded.

NEW RECRUITMENTS	Number	
	T	W
External Recruitments (with a doctoral exam from another university)		
Internal Recruitments (with doctoral exam from KTH)		
International Recruitments (with a doctoral exam from outside Sweden)		

B3.2 Emerging Talent

A Unit of Assessment should note significant awards won by Research Staff or Other Research Staff (as defined in Table B1.1) under the age of 40. Awards of international standing recognising young talent e.g. Ingvar, VR-Rådsforskarna, Gustafsson, EU Young Scientist, European Research Council Starting Grant, EURYI (European Science Foundation Young Investigator Award), European Commission Marie Curie Excellence Grant, amongst others, should be noted.

EMERGING TALENT

Name	Gender M/F	Award	Year

Appendix 2: International Expert Panels

PANEL 1: MATHEMATICS AND COMPUTER SCIENCE

Expert Panel Members:

Chair:	Olavi Nevanlinna	Head of the Institute of Mathematics Helsinki University of Technology
	Rosa-Maria Miro-Roig	Professor, Department of Algebra University of Barcelona
	Pekka Koskela	Vice Dean, Faculty of Mathematics and Science, University of Jyväskylä
	Joachim Rosenthal	Professor of Applied Mathematics University of Zürich
	Paul Verschure	Research Professor, Catalan Institute of Advanced Studies, ICREA Director Institute of Audio-Visual Studies University of Pompeu Fabra
	Andrew D. Barbour	Professor of Biomathematics University of Zürich
	Sanjeev Khanna	Professor and Rosenbluth Faculty Fellow, Department of Computer and Information Science University of Pennsylvania

KTH Panel Coordinators:

Research Field Co-ordinator:	Anders Forsgren	
Unit of Assessment Co-ordinators:	Kurt Johansson Timo Koski Anders Lindquist Jens Lagergren	Mathematics Mathematical Statistics Optimization and Systems Theory Computer Science
Student Ambassador:	Jakob Li	

PANEL 2:
INFORMATION AND COMMUNICATION SYSTEMS

Expert Panel Members:

Chair:	John S Baras	Professor, Lockheed Martin Chair in Systems Engineering University of Maryland
	Sture Hägglund	Professor, and Research Director at Santa Anna IT Research Institute AB Linköping University
	Henrik Berndt	Professor, Senior Vice President and Chief Technology Officer DoCoMo Communications Laboratories Europe GmbH
	Javier Rodríguez Fonollosa	Professor, Head of the Signal Theory and Communications Department UPC Barcelona
	Rahim Tafazolli	Professor, Head of Mobile Communications Research University of Surrey
	Moira Norrie	Professor, Instsitute for Information Systems ETH, Zurich
	Walter Bender	Executive Director of the MIT Media Laboratory, MIT

KTH Panel Coordinators:

Research Field Co-ordinator:	Carl-Gustav Jansson	
Unit of Assessment Co-ordinators:	Rolf Stadler	Network, Information and Control Systems
	Mikael Skoglund	Telecommunications
	Anders Askenfeldt	Human Communication
	Jens Zander	Communication Systems
	Paul Johanneson	Information and Software Systems
Student Ambassador:	Victoria Karlsson	

PANEL 3:
PHYSICS, THEORETICAL PHYSICS

Expert Panel Members:

Chair:	Michael Albrow	Senior Scientist, Division of Particle Physics, Fermi National Lab, USA
	Karl Fredrik Berggren	Professor, Department of Theoretical Physics, University of Linköping
	Isabelle Grenier	Professor, Astroparticle Physics CEA & U Paris VII
	Kevin Bedell	Vice Provost for Research, and Rourke Professor of Physics, Boston College
	Dirk Schwalm	Professor, Head of Heavy Ion Physics Group, Max Planck Institute for Nuclear Physics

KTH Panel Coordinators:

Research Field Co-ordinator:	Bengt Lund-Jensen	
Unit of Assessment Co-ordinators:	Bengt Lund-Jensen Mats Wallin	Physics Theoretical Physics
Student Ambassador:	Gustav Kjellin	

PANEL 4:
APPLIED PHYSICS AND MEDICAL TECHNOLOGY

Expert Panel Members:

Chair:	Wolfgang Eberhardt	Director of BESSY (Berlin Synchrotron) Technical University of Berlin
	Ingolf Lindau	Professor of Semiconductor Surfaces/Interfaces University of Lund/Stanford University
	Tore Lindmo	Professor of Medical Technology Norwegian University of Science and Technology
	Markus Pessa	Director of the Opto-Electronics Research Centre Tampere University of Technology
	Horst Vogel	Professor of Physical Chemistry EPFL
	Ingrid Reineck	Manager Coating Technologies Sandvik

KTH Panel Coordinators:

Research Field Co-ordinator:	Hans Hertz	
Unit of Assessment Co-ordinators:	Hans Hertz Lars-Åke Brodin Ulf Karlsson	Applied Physics and Medical Imaging Medical Technology Materials Physics
Student Ambassador:	Aref Abedi	

PANEL 5:
ENERGY TECHNOLOGY AND ELECTRICAL ENGINEERING

Expert Panel Members:

Chair:	Tuija Pulkkinen	Professor, Director Finnish Meteorological Institute
	Erkki Lakervi	Professor, Power Systems Helsinki University of Technology
Participating via tele-conference	Yassin A. Hassan	Professor and Associate Head of Department of Nuclear Engineering Texas A&M University
	Jens Juul Rasmussen	Professor, Optics and Plasma Research Department Risø National Laboratory for Sustainable Energy, Technical University of Denmark
	Lars G Larsson	Dr of Technology (Nuclear Safety) SiP Consulting
	Alberto Cavallini	Professor, Dipartimento di Fisica Tecnica, University of Padova

KTH Panel Coordinators:

Research Field Co-ordinator:	Stefan Östlund	
Unit of Assessment Co-ordinators:	Jan Wallenius Lars Nordstöm James Drake Björn Palm	Nuclear Power Safety; Reactor Physics and Reactor Technology Electrical Power Engineering Fusion and Space Plasma Physics Energy Transformation
Student Ambassador:	Rickard Andersson	

PANEL 6:
ELECTRONICS AND PHOTONICS

Expert Panel Members:

Chair:	Patrick Dewilde	Director of the ICT Delft Reserch Centre University of Technology Delft
	Thomas Lewin	Microwave and High Speed Electronics Research Centre, Ericsson
	LluisTorner	Institute Director Institute of Photonic Studies, Barcelona
	Ingrid Verbauwhede	Professor, Department of Electrical Engineering, KU Leuven
	Gehan Amaratunga	Head of Electronics, Power and Energy Conversion Research Group University of Cambridge
Deputy Chair:	Richard Syms	Head of the Optics and Semiconductor Devices Group, Imperial College London

KTH Panel Coordinators:

Research Field Co-ordinator:	Mikael Östling	Head of School
Unit of Assessment Co-ordinators:	Göran Stemme Gunnar Björk Mikael Östling Axel Jantsch	MEMS Optics and Photonics Semiconductor Components Embedded Electronics and Computer Systems
Student Ambassador:	Ann-Sofie Åhn	

PANEL 7:
APPLIED MECHANICS

Expert Panel Members:

Chair:	Peter Olsson	Professor, Dean of the School of Engineering, Jönköping University
	Niels Olhoff	Professor, Computer-Aided Engineering Design, Aalborg University
	Viggo Tvergaard	Professor, Materials Mechanics Technical University of Denmark
	Hans Fernholz	Professor, Fluid Mechanics Technical University of Berlin
	Geert-Jan van Heijst	Professor, Vortex Dynamics and Turbulence Eindhoven University of Technology
	Ajit Shenoi	Professor, Lightweight Structures University of Southhampton
	Billy Fredriksson	Professor, Solid Mechanics, SAAB

KTH Panel Coordinators:

Research Field Co-ordinator:	Anders Eriksson Dan Henningson	
Unit of Assessment Co-ordinators:	Peter Göransson Fred Nilsson Henrik Alfredsson Anders Eriksson	Vehicle Engineering Solid Mechanics Fluid Mechanics Mechanics, Biomechanics
Student Ambassador:	Tomas Nilsson	

PANEL 8:
INDUSTRIAL TECHNOLOGY AND MATERIALS SCIENCE

Expert Panel Members:

Joint Chair:	Fritz Fahrni	Professor, Department of Technology Management and Entrepreneurship ETH Zurich
Joint Chair:	Torsten Ericsson	Professor Emeritus, Department of Engineering Materials Linköping University
	Elisabeth Nilsson	President, Jernkontoret
	Rob Parkin	Professor, Head of Wolfson School of Mechanics and Manufacturing Engineering Loughborough University
	Leonardo De Chiffre	Professor, Department of Mechanical Engineering Technical University of Denmark
	Frank-L Krause	Professor Emeritus, Mechanical Engineering Department, Technical University of Berlin
	Lauri Holappa	Professor, Laboratory of Metallurgy Helsinki University of Technology

KTH Panel Coordinators:

Research Field Co-ordinator:	Bengt Lindberg	Head of School
Unit of Assessment Co-ordinators:	Pär Jönsson Jan Wikander Lars Mattssson	Materials Science and Engineering Industrial Product Development Production Engineering
Student Ambassador:	Kushink Bazaz	

PANEL 9: CHEMISTRY

Expert Panel Members:

Chair:	Erik W. Thulstrup	Professor, Department of Science, Systems and Models, University of Roskilde
Participating via tele-conference	Pia Kilpinen	Docent, Combustion Chemistry Åbo Akademi University
	Yngve Öhrn	Professor Emeritus of Chemistry and Physics, University of Florida
	Terence Cosgrove	Professor of Physical Chemistry, Head of Colloid Group University of Bristol
	Stanislaw Slomkowski	Head of the Department of Engineering of Polymer Materials Polish Academy of Sciencs
	Torbjörn Frejd	Professor, Organic Chemistry University of Lund
	Lars Gädda	Senior Vice President, R&D M-Real Corporation

KTH Panel Coordinators:

Research Field Co-ordinator:	Christofer Leygraf	Head of School
Unit of Assessment Co-ordinators:	Per Claesson Göran Lindbergh Mikael Lindström Hans Ågren	Chemistry Chemical Engineering Fibre and Polymer Technology Theoretical Chemistry
Student Ambassador:	Mariam Tazaly	

PANEL 10: BIOTECHNOLOGY

Expert Panel Members:

Chair:	Gregory Winter	Joint Director, MRC Laboratory of Molecular Biology, Cambridge
	Bauke Dijkstra	Professor of Biophysical Chemistry Groningen University
	John Villadsen	Professor, Chemical Engineering Technical University of Denmark
	Howard Bussey	Professor Emeritus McGill University
	Claes Wahlestedt	Professor of Biomedical Studies and Director of Pharmagenomics The Scripps Research Institute

KTH Panel Coordinators:

Research Field Co-ordinator:	Stefan Ståhl	Head of School
Unit of Assessment Co-ordinators:	Joakim Lundeberg Vincent Bulone Sophia Hober	Medical Biotechnology Industrial Biotechnology Protein Atlas
Student Ambassador:	Zeinab Tazaly	

PANEL 11:
TECHNOLOGY FOR THE BUILT ENVIRONMENT

Expert Panel Members:

Chair:	Andrew Collop	Head of the School of Civil Engineering and Professor of Civil Engineering University of Nottingham
	Måns Collin	Swedish Foundation for Strategic Research (SSF), SSF Committee Chairman, and former Managing Director of Nynäs Petroleum
	Hazim Awbi	Professor of Building Environmental Science University of Reading
	John Gulliver	Joseph T. and Rose S. Ling Professor University of Minnesota
	Roland Clift	Distinguished Professor of Environmental Technology and Founding Director of the Centre for Environmental Strategy (CES) University of Surrey
Participating via teleconference	Laura Punnett	Professor of Work Environment University of Massachusetts Lowell

KTH Panel Coordinators:

Research Field Co-ordinator:	Bengt Ljungqvist	
Unit of Assessment Co-ordinators:	Björn Birgisson Berit Balfors Sture Holmberg Ronald Wennersten	Civil and Architectural Engineering Land and Water Resources Health Industrial Ecology
Student Ambassador:	Mikael Palm	

PANEL 12:
ARCHITECTURE, BUILT ENVIRONMENT AND MANAGEMENT

Expert Panel Members:

Chair:	Klaus Kunzman	Jean Monnet Professorship of European Spatial Planning, University of Dortmund
	Eva Nygren	CEO SWECO Sweden
	Peggy Deamer	Professor, Yale School of Architecture Yale University
	John Polak	Professor, Head of the Centre for Transport Studies, Imperial College London
	Peter Kroes	Professor of Philosophy in Technology Technical University of Delft
	Kauko Viitanen	Professor, Real Estate Economics and Evaluation and Head of Surveying Department Helsinki University of Technology
	Ulrich Dolata	Senior Scientist, Max Planck Institute for the Study of Societies
	Ulrich Blum	Professor, President, Halle Institute for Economic Research, Berlin
	Alex Anas	Professor, Department of Economics University at Buffalo, State University of New York

KTH Panel Coordinators

Research Field Co-ordinator:	Björn Hårsman	Head of School
Unit of Assessment Co-ordinators:	Katja Grillner	Architecture
	Stellan Lundström	Real Estate and Construction Management
	Sven Ove Hansson	Philosophy and History of Technology
	Göran Cars	Urban Planning and Environment
	Lars Göran Mattsson	Transport and Economics
	Staffan Leastadius	Industrial Management
Student Ambassador:	Josefin Edvardsson	

Appendix 3: Biographies of the Chairpersons

Olavi Nevanlinna

Chair, Panel 1: Mathematics and Computer Science

Olavi Nevanlinna is Professor and Head of the Institute of Mathematics at the Helsinki University of Technology, and former Vice President of the University.

The Institute is responsible for teaching essentially all the mathematics needed in engineering. Profesor Nevanlinna's current research interests range from numerical analysis to operator theory and complex analysis. Recently he has created a low-rank perturbation theory for operators, which generalizes classical value distribution theory of meromorphic scalar functions for operator valued functions. Currently he is interested in computing the spectrum of an operator or Banach algebra element. Profesor Nevanlinna currently teaches on three courses as well as occasionally presenting a mini-course on the theory of meromorphic matrix valued functions.

He is a former president of ICIAM, the International Council for Industrial and Applied Mathematics which boasts the world's largest congress on applied mathematics.

John Baras

Chair, Panel 2: Information and Communication Systems

John S Baras holds a permanent joint appointment as Professor in the Department of Electrical and Computer Engineering and the Institute for Systems Research (ISR) at the University of Maryland. He was the founding director of ISR, which is one of the first six National Science Foundation engineering research centres. Professor Baras is the Lockheed Martin Chair in Systems Engineering and is the founding and current director of the Maryland Center for Hybrid Networks (HyNet), an university-industry-government centre of excellence.

Professor Baras' research interests include: systems and controls; communications and signal processing; networked control systems; network security and information assurance; wireless and hybrid communication networks; optimization and trade-off analysis; software and systems engineering; formal methods;

performance evaluation; distributed and asynchronous systems; applied mathematics.

Professor Baras received the 1980 George S. Axelby Prize from the IEEE Control Systems Society and the 2007 Leonard G. Abraham Prize from the IEEE Communications Society. In 2006, Professor Baras was elected as a Foreign Member of the Royal Swedish Academy of Engineering Science (IVA). IVA is the world's oldest engineering academy. Its mission is to promote the engineering and economic sciences and the development of industry for the benefit of society.

Michael Albrow

Chair, Panel 3: Physics and Theoretical Physics

Michael Albrow was born and raised in England and attended Birmingham University and Manchester University, gaining a PhD in 1969. He conducted experimental research in fundamental particle physics at CERN (European Laboratory for Particle Physics) for 22 years, holding positions at CERN, Rutherford Appleton Laboratory (UK) and Stockholm University where he was a professor. Since 1991, Professor Albrow has been at Fermi National Accelerator Laboratory (Fermilab) in the US, working at the Tevatron, the highest energy particle accelerator in the world, and is preparing for research at the Large Hadron Collider (LHC) at CERN. He is a former Head of the Experimental Physics Projects Department, chair of the CERN PS and SC Committee, and chair of the Colloquium Committee at Fermilab.

Though not a professional astronomer or cosmologist, Michael Albrow has always kept a close eye on developments in those fields. He enjoys explaining physics to non-physicists and, in 2005, he received Fermilab's Director's Award for exceptional volunteer service to educational programmes, which recognised his effort in bringing the World Year of Physics to 10,000 students at local schools.

Professor Albrow's research interests include very high precision proton spectrometers and also working on other "diffractive" processes in CMS to better understand QCD, and perhaps measure Higgs boson properties. He has designed and built several types of track chambers, Cerenkov counters, precision timing detectors and calorimeters (including the first tile-fibre calorimeter).

Wolfgang Eberhardt

Chair, Panel 4: Applied Physics and Medical Technology

Wolfgang Eberhardt was born in 1950 and studied at the Justus Liebig University , Giessen, and Hamburg University. In 1980 he took up a position as Assistant Professor of Physics at the University of Pennsylvania, and later moved on to Exxon Research and Engineering in New Jersey. He returned to Germany in 1990 to take up the position of Director of IFF (Institute of Solid State Research) at the Jülich Research Centre with a joint professorship in Physics at the University of Cologne.

Professor Eberhardt is a member of Scientific Advisory Committee's of major synchrotron radiation centers worldwide and, in 2002, he received an honorary doctorate from Uppsala University.

Since 2001, Wolfgang Eberhardt has been Scientific Director at BESSY, the Berlin Electron Storage Ring Company for Synchrotron Radiation. He combines this role with one of Professor of Physics at the Technical University Berlin. His research interests include the electronic structure of atoms, molecules and solids determined by photoemission and synchrotron radiation related techniques; development of angle resolved photoemission to study the band structure of solids, surfaces and interfaces; as well as scattering and holography with coherent synchrotron radiation.

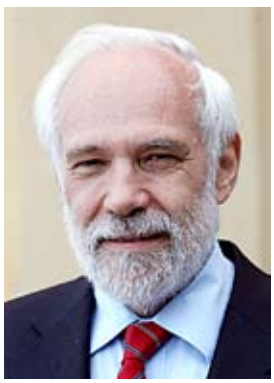
Tuija Pulkkinen

Chair, Panel 5: Energy Technology and Electrical Engineering

Tuija Pulkkinen received her PhD degree from the University of Helsinki in 1992. Early in her career, she was granted the James B Macelwane Medal and an American Geophysical Union fellowship. She is currently Professor in Space Physics at the Finnish Meteorological Institute (FMI) where she has worked since her graduate studies with the exception of extended visits to the US: Goddard Space Flight Center in Maryland, the University of Colorado, and the Los Alamos National Laboratory in New Mexico. At FMI, she is the Head of the Earth Obersvation Unit and has taught numerous students within the national graduate school for Astronomy and Space Physics. She is also Vice-President of the European Geosciences Union.

Professor Pulkkinen's research interests concern the entire chain of processes that starts from the solar surface, propagated with the solar wind through the interplanetary space to the Earth's space environment, the magnetosphere, ionosphere, and middle atmosphere. She has especially concentrated on energy flow from the solar wind to the near-Earth space environment and the energy dissipation processes in the magnetosphere. She has worked with data from multiple international space missions as well as from ground-based instrument networks monitoring the ionosphere. In recent years, she has been active in developing global space environment simulation tools especially concentrating on quantitative analysis of the simulation results.

Tuija Pulkkinen has been a member of the European Space Agency Solar System Working Group, and is currently a member of the Space Research Advisory Committee of the Swedish National Space Board, and the Research Council for Natural Sciences and Engineering of the Academy of Finland.



Patrick Dewilde

Chair, Panel 6: Electronics and Photonics

Patrick Dewilde was born in 1943 and was educated at the Catholic University of Leuven. He gained his PhD in Electrical Engineering at Stanford University in 1970 and then became an ONR Research Fellow at the University of California at Berkeley (1971–72). From 1971 to 1973 he was a lecturer in Electrical Engineering at the University of Lagos in Nigeria and from 1973 to 1975 a full time researcher with the Belgian National Fund for Scientific Research at the Catholic University of Leuven where he became an Associate Professor in Numerical Analysis in 1975. In 1977 he was appointed full Professor in Electrical Engineering at Delft University of Technology.

From 1995 to 2004, Professor Dewilde was chairman of the Dutch Technology Foundation STW, which is the main agency funding technological research in the Netherlands, and chairman of the Freeband consortium, a large Dutch research programme in 4G technology in which some 20 companies cooperate with university research groups and institutes to achieve a new generation of telecommunication hardware, networks and services. He has been an advisor to the Dutch Government on a

succession of industrial projects and, in 1981, was awarded the IEEE Fellowship for his work on scattering theory; work that has found its way into GSM speech coding technology. In 2000, Professor Dewilde was awarded the IEEE Circuits and System Society Golden Jubilee Medal, and he also received the Humboldt Research Prize in 2003. In 2006, he received the Royal decoration of "Ridder in de orde van de Nederlandse Leeuw" (Knight of the Order of the Dutch Lion) for the contributions of his scientific accomplishments and the importance of his research to widely applied scientific research and innovation in the Netherlands. Also in 2006, Professor Dewilde was appointed Chair of the Scientific Committee of the European Nanoelectronics Initiative Advisory Council, Eniac.

Since 2005, Patrick Dewilde has been Scientific Director of DIMES (the Delft Institute of Micro Electronics and Submicron Technology), a position he also held between 1993 and 2001. In 2008 he was appointed Director of the Institute for Advanced Studies of the Technical University of Munich, a position he is holding presently.

Peter Olsson

Chair, Panel 7: Applied Mechanics

Peter Olsson was born in Gothenburg in 1956 into a non-academic family. He enrolled at Chalmers University of Technology, from where he received a Master of Science degree in Engineering Physics in 1980 and, at the same time, he received the John Ericsson Medal for Outstanding Academic Achievement. In 1985, Professor Olsson received his PhD in Mathematical Physics from Chalmers University of Technology. After switching to the Department of Theoretical and Applied Mechanics, he was appointed Professor in Mechanics at Chalmers in 2000.

Professor Olsson's ambition to pursue concentrated research was thwarted in 2001 by his appointment as Vice-President of Chalmers University of Technology with responsibility for the education at the Bachelor and Masters levels. In 2007, he accepted his current job as Dean of the School of Engineering, and Professor of Mechanics, at Jönköping University.

In parallel with these developments, Peter Olsson has served in various capacities in the world of academia, with research

interests lying mainly in the field of scattering theory for classical waves: working with direct and inverse scattering of waves in solids and fluids. Tools employed in his research include invariant imbedding, the Wiener-Hopf technique, and early on the null field approach. Other work has dealt with applications of non-integer order derivatives and non-integer order integrals to the modelling of certain types of materials.

Fritz Fahrni

Joint Chair, Panel 8: Industrial Technology and Materials Science

Fritz Fahrni was born in Winterthur in 1942. In 1966 he graduated in Mechanical Engineering from the Swiss Federal Institute of Technology (ETH), Zurich. He got his PhD from the Illinois Institute of Technology, Chicago, in 1970 and, in 1980, completed the Senior Management Program at the Harvard Business School.

Professor Fahrni worked as a scientific collaborator for NASA in the USA and for Ciba-Geigy-Photochemistry in Fribourg and the UK. In November 1976 he joined the Sulzer Corporation where he held managerial positions in the gas turbine department as well as in the textile machinery division. From 1988 until 1999 he was President and Chief Executive Officer of the Sulzer Corporation. Under his leadership, Sulzer changed from a traditional machinery manufacturer into an internationally successful technology corporation with a new focus in medical engineering. Fritz Fahrni's research activities have focused on technology management, especially in quality- and innovation management, as well as in entrepreneurship and venturing.

Before his retirement in September 2007, Fritz Fahrni was Professor for Technology Management and Entrepreneurship jointly at ETH and at the University of St Gallen (HSG) since October 1999. He also chaired the Institute of Technology Management at the University of St Gallen (ITEM-HSG). Furthermore, he has served on the boards of several professional and public organisations in Europe and the US, among them the Swiss National Council for Science and Technology.

Torsten Ericsson

Joint Chair, Panel 8: Industrial Technology and Materials Science

Torsten Ericsson was born in Avesta in 1938. In 1962 he graduated in Technical Physics from KTH. He then joined AB Atomenergi working in the department for non-radioactive materials. He spent 14 months leave of absence in 1965–66 as research assistant at Northwestern University, Evanston, Illinois. In 1970 he earned his PhD at KTH in metallography and shortly afterwards became docent.. The thesis dealt with high temperature oxidation and X-ray diffraction studies of ordering in alloys.

1970 to 1972 Torsten Ericsson worked for AB Volvo, Gothenburg, as group leader in a department for materials technology. From 1972 to retirement in 2003 he has been professor in engineering materials at Linköping University. His research interest has covered heat treatment of steels, fatigue, the origin, effect and measurements of residual stresses in metallic materials. During the last 10 years the interest has also included powder metallurgy processing before sintering. Under his supervision 27 students have got their PhD. He continues doing research and acting as external examiner as professor emeritus.

Torsten Ericsson has served as vice dean 1977–1980 and head of the mechanical engineering department 1980–1987 at Linköping University. During 1992–1994 he was scientific attaché at the Swedish embassy in Paris. 1988–2005 he was scientific editor of Scandinavian Journal of Metallurgy and after that the journal merged with Steel research International he is a member of the editorial board of this journal. He is member of the Royal Swedish Academy of Engineering Sciences since 1985.

Erik Thulstrup

Chair, Panel 9: Chemistry

Erik W Thulstrup was born in 1941 and was educated at Aarhus University where he received the Gold Medal in 1969. He was accepted for a research position at the University of Florida based solely on his master's thesis work. His PhD was awarded at Aarhus in 1970. Since then, he has held various visiting professorships (Universities of Florida, Utah, Darmstadt, Bologna, Ljubljana and California, Berkeley) as well as being Senior Science and Technology Specialist for the World Bank. He has been Professor of Chemistry at the Department of Science, Systems and Models at Roskilde University since 1993.

Professor Thulstrup has been a member of the Danish Natural Science Research Council, a member of an EU Task Force on Research Evaluation, as well as President of The Danish National Commission for UNESCO. He presently serves on both the membership and Finance Committees for TWAS, the Academy of Sciences for the Developing World and is Vice-president and Treasurer of the organization Molecular Frontiers.

Erik Thulstrup's research has focused on polarisation spectroscopy. He is also an active figure in the area of scientific capacity strengthening and keenly interested in the role played by scientific research and education in economic development.

Sir Gregory Winter

Chair, Panel 10: Biotechnology

Dr Winter graduated from Cambridge University in 1973. In the 1970s, his PhD work and postdoctoral work included protein sequencing (aminoacyl tRNA synthetases) and nucleic acid sequencing (influenza virus). In the early 1980s, he became one of the pioneers of protein engineering, working initially on the engineering of an enzyme (tyrosyl tRNA synthetase) in a major collaboration with Alan Fersht, and subsequently on the engineering of antibodies. In particular, he developed technologies for making humanised antibodies (by grafting hyper-variable regions from rodent antibodies to human antibodies) and also for making human antibodies in bacteria (by use of antibody repertories and phage display technologies). Professor Winter is Deputy Director of the Medical Research Council funded Laboratory of Molecular Biology (LMB) Cambridge. A Founder and Director of both Cambridge Antibody Technology and Domantis Ltd. Dr Winter is a Commander of the Order of the British Empire, and in 2004 was knighted for his breakthrough achievements in the field of monoclonal antibodies.

Andrew Collop

Chair, Panel 11: Technology for the Built Environment

Professor Collop is currently Head of the Department of Civil Engineering at the University of Nottingham where he has responsibility for over 100 members of staff, 350 undergraduate students on accredited B/MEng courses, 90 students on a range of MSc courses and 60 students studying for research degrees. He is also Director of the Nottingham Transportation Engineering Centre and a past Director of Scott Wilson Pavement Engineering Ltd.

In 2004 Professor Collop was promoted to a personal Chair in Civil Engineering and in 2006 was awarded a DSc from the University of Nottingham. His research interests are in most aspects of pavement engineering and he has been an investigator on research grants and contracts with a total value in excess of £13 million. Professor Collop has published over 160 journal and conference papers and is Editor-in-Chief of Road Materials and Pavement Design and Chairman of the Editorial Board & Honorary Editor of ICE Transport. Andrew is a member of many technical committees and is regularly invited to chair sessions at international conferences.

Klaus R. Kunzmann

Chair, Panel 12: Architecture, Built Environment and Management

Klaus R Kunzmann was born 1942, studied architecture and urban planning at the Technical University of Munich, and completed his PhD in Planning at the Technical University of Vienna in 1971. He moved to Bangkok to work as a consultant engineer, but returned to Europe in 1974 to take up an appointment as Professor for Spatial Planning at the Technical University of Dortmund and Director of the Institute of Spatial Planning of the Dortmund School of Planning. For two election periods (1977 and 1997), he was Dean of the School. Until his retirement in 2006, Klaus R. Kunzmann held the Jean Monnet Professorship for Spatial Planning in Europe at the Technical University of Dortmund.

Professor Kunzmann was the founding president of the Association of European Schools of Planning. As policy advisor and consultant he has worked for local, regional and federal institutions in Germany, for the European Commission, for the Council of Europe and OECD, and for the German Development Cooperation (GTZ), advising Governments among others in Yemen, Nepal, Jordan, Brazil and Malawi.

He was member of the Scientific Advisory Councils of the French Délégation à l'Aménagement de Territoire (DATAR), and the Peugeot/Citroen Institut Ville et Mouvement in Paris.

Professor Kunzmann's present research interests are in innovative urban policy and European spatial planning, in regional restructuring and the learning region, in urban policy in China, and on the role of creativity and the arts for spatial and endogenous economic development. In 1996, Professor Kunzmann received an honorary doctorate from the University of Newcastle-upon-Tyne. At present he is an Honorary Professor of the University of Cardiff, the Bartlett School of Planning at University College London, and of Chung Hua University, Hsinchu, Taiwan.

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