Expert report, panel 4

KTH's Research Assessment Exercise (RAE) 2021

Panel chair:
Professor Virgil Gligor

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Introduction

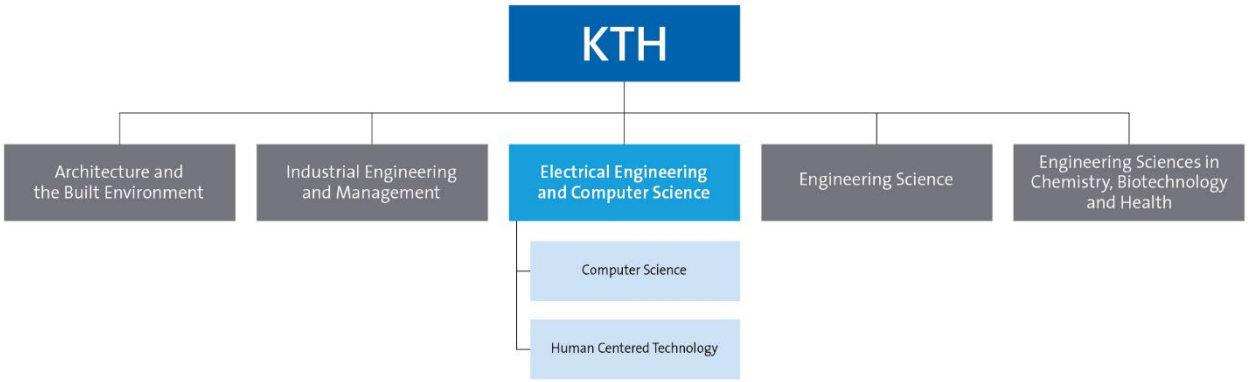
This expert panel report is part of the Research Assessment Exercise (RAE) 2021 at KTH Royal Institute of Technology. The report is based on the self-evaluation on panel 4 and aims to provide recommendations and feedback to the involved departments and KTH.

Expert panellists:

- Professor David Basin, ETH Zurich, Switzerland
- Professor Steve Benford, University of Nottingham, United Kingdom
- Professor Raouf Boutaba, University of Waterloo, Waterloo, Canada
- Professor Anthony Ephremides, University of Maryland, College Park, United States
- Professor Jodi Forlizzi, Carnegie Mellon University, Pittsburgh, United States
- Professor Virgil Gligor, Carnegie Mellon University, Pittsburgh, United States, Panel chair
- Professor Anne-Marie Kermarrec, EPF, Lausanne, Switzerland
- Professor Ahmad-Reza Sadeghi, Technical University, Darmstadt, Germany
- Professor Gene Tsudik, University of California, Irvine, United States
- Professor Ellen Zegura, Georgia Institute of Technology, Atlanta, United States
- Professor Lixia Zhang, University of California, Los Angeles, United States

Panel 4

Coordinator: Prof. Panagiotis Papadimitratos, KTH Royal Institute of Technology
Vice-coordinators: Prof. Kristina Höök, and Associate Professor Elena Troubitsyna, KTH Royal Institute of Technology,



KTH's Research Assessment Exercise (RAE) 2021

Panel 4: Computer Science and Human Centered Technologies Departments

Final Report

Professor Virgil Gligor (editor)

September 27, 2021
October 13, 2021 (update)

Executive Summary

This report contains the findings and recommendation of a panel of experts during a research assessment exercise of the Computer Science and Human Centered Technologies departments at KTH Stockholm, as observed during approximately twenty hours of on-line meetings comprising faculty presentations and discussions with teaching staff, faculty, and graduate students. It notes significant positive aspects and strengths of the research presented and points out a few visible shortcomings, mostly related to research environment and administration. It also presents specific, per-research area and general department-level, recommendations, which reflect the consensus reached by the panel members.

On the positive side, the two departments have high quality, energetic researchers and graduate students who are poised to achieve future research success. Faculty and staff uniformly praised the excellent academic life at KTH, expressed loyalty to the university, and pride in being associated with it. This should bode well for future success in research. Much of the research is at the forefront of technology. There is clear evidence of significant impact including broader societal impact on medicine, industry, government, and business. The cross-division centers of excellence display critical mass in selected research areas and enable substantial external funding. The two departments have a flexible hiring policy within given salary scales. This can enable them to hire the best and the brightest researchers in the future.

On the negative side, there is little evidence of a strategic research vision. There is no plan for new initiatives, no funding for blue-sky research, not much room for change of direction. Some topics are thinly spread across several areas, without achieving critical mass in any area, whereas some popular topics are duplicated across divisions. Internal university funding for research is minimal. While external funding is high, there are some clear challenges in obtaining it, e.g., the direct and overhead costs are high at all personnel ranks and there is no university help to faculty for proposal writing. The teaching burden for faculty is high and the number of adjunct faculty is low. However, if the adjunct faculty pool is increased, the limited internal budget for research decreases further – a real dilemma. Hiring delays, non-competitive start-up packages for new faculty, and cumbersome procedures detract from attracting first-class personnel. There is a very small number of female faculty and the clear effort to achieve gender parity is adversely affected by sluggish hiring procedures. There is an uncertain career trajectory for adjunct faculty, which could further diminish retention of high-quality personnel.

Despite shortcomings noted above, many of which are administrative matters, the panel believes that these departments are faring well in research quality. The panel also believes that its recommendations provide sufficient focus for research advances at KTH in the future.

1 Introduction

Background. A panel comprising eleven faculty members of prominent North American and European universities performed an assessment of the Computer Science and Human Centered Technologies departments of the EECS school at KTH Stockholm between 23rd and 26th of August 2021. The assessment exercise was conducted over roughly twenty hours of on-line meetings and relied primarily on faculty presentations of six departmental divisions and eight research areas, and discussions with teaching staff, junior faculty, and graduate students.

While the assessment time was somewhat shorter than similar in-person meetings, it was sufficiently detailed to enable the panel to identify positive aspects and strengths of the research presented and point out a few visible shortcomings, which form the basis for recommendations made to the KTH administration. It is important to note that the assessment exercise was *not* an evaluation of the two departments based on *specific objectives* and did *not* aim to suggest strategies to achieve them, which might help improve the university's worldwide ranking. Instead, the panel's findings and recommendations are based on each member's judgment and experience and intra-panel discussions during the assessment exercise. This report reflects the consensus reached by the panel members.

Panel membership, departmental divisions, and research areas. The faculty members of the external panel were selected by KTH and are listed below in alphabetical order:

- Professor David Basin, ETH Zurich, Switzerland (https://people.inf.ethz.ch/basin)
- Professor Steve Benford, University of Nottingham, United Kingdom (https://www.nottingham.ac.uk/computerscience/people/steve.benford)
- Professor Raouf Boutaba, University of Waterloo, Waterloo, Canada (http://rboutaba.cs.uwaterloo.ca/)
- Professor Anthony Ephremides, University of Maryland, College Park, United States (https://ece.umd.edu/clark/faculty/389/Anthony-Ephremides)
- Professor Jodi Forlizzi, Carnegie Mellon University, Pittsburgh, United States (https://www.hcii.cmu.edu/people/jodi-forlizzi)
- Professor Virgil Gligor, Chair, Carnegie Mellon University, Pittsburgh, United States (https://www.ece.cmu.edu/directory/bios/gligor-virgil.html)
- Professor Anne-Marie Kermarrec, EPF, Lausanne, Switzerland (https://people.epfl.ch/anne-marie.kermarrec)
- Professor Ahmad-Reza Sadeghi, Technical University, Darmstadt, Germany (https://www.informatik.tu-darmstadt.de/systemsecurity/people_sys/people_details_sys_45184.en.jsp)
- Professor Gene Tsudik, University of California, Irvine, United States (https://www.ics.uci.edu/~gts)
- Professor Ellen Zegura, Georgia Institute of Technology, Atlanta, United States (https://www.cc.gatech.edu/~ewz/Welcome.html)

- Professor Lixia Zhang, University of California, Los Angeles, United States (https://web.cs.ucla.edu/~lixia/)

Process. The Research Assessment Exercise (RAE) included presentations by KTH faculty on six departmental divisions and eight research areas selected by the Computer Science and the Human Centered Technologies departments of the school of Electrical Engineering and Computer Science at KTH. Presentations of the departmental divisions were attended by the entire panel whereas those for specific research areas were attended by a subset of the panel members with specific expertise in an area.

Departmental Divisions:

- *Communication Systems*. This division includes physical networking and wireless systems.

- *Computational Science and Technology*. This division includes modeling physical and biological systems, high-performance algorithms, adaptive methods, partial differential equations, networks, machine learning, visual data analysis, and parallel computing environments.

- *Media Technology and Interaction Design*. This division includes digital and physical space design, interaction design, visual technology and humanistic AI, sound and music computing, sustainability, and technology-enhanced learning.

- *Network Systems Engineering*. This division includes network protocols, wireless communication protocols, enterprise IT modeling, security, project and technology management.

- *Software and Computer Systems*. This division includes software engineering, analysis and development methods, model-based software engineering, distributed and parallel systems, data science and applied AI, computer engineering and computer systems, mobileservices, security, and privacy.

- *Theoretical Computer Science*. This division includes formal aspects of software engineering, computer security and privacy, cryptography, verification and SAT solving, and natural language processing.

Research areas. Eight research areas covered by the six departmental divisions were selected for presentation by the Computer Science and Human Centered Technologies at KTH and the purposes of RAE 2021. The panel believes that these areas provide the best representation of the research performed in the two KTH departments under consideration.

Each member of the panel was assigned to at least two research areas by the panel chair, Professor Virgil Gligor, in collaboration with the KTH coordinators, Professors Panos Papadimitratos, Kristina Höök, and Elena Troubitsyna. These assignments were made on a “best fit” basis aiming to balance the research panel members’ expertise with the eight areas selected for presentation by KTH. The research areas and panel-membership assignments are listed below. The italicized names denote the research area leads. The area leads initiated the assessment discussions amongst the panel members and provided the findings for each of the research areas after coordination with the other research-area members.

- *Research Area 1* – Software Construction and Analysis
  Professors Basin, Boutaba, *Sadeghi, Tsudik*

- *Research Area 2* - Networked Systems
  Professors Boutaba, *Ephremides,* Zegura, *Zhang*

- *Research Area 3* – Data Science
  Professors *Boutaba*, Ephremides, *Zegura*, Zhang

- *Research Area 4* – Security
  Professors *Basin*, Gligor, Sadeghi, *Tsudik*

- *Research Area 5* – Distributed Systems and Computational Complexity
  Professors Basin, Gligor, *Kermarrec*, *Zhang*

- *Research Area 6* – Scientific Computation and Visualization
  Professors *Ephremides*, *Benford*, Kermarrec, Gligor

- *Research Area 7* – Media Technology
  Professors Benford, *Forlizzi*, *Sadeghi*, Zegura

- *Research Area 8* – HCI/Interaction Design and Sustainability
  Professors *Benford*, *Forlizzi***,** Tsudik

Two additional areas covered meetings with junior personnel and cross-panel discussions. The membership assignments were:

- Cross-Panel Discussion: Research Impact
  Professors Boutaba, Forlizzi, Zegura

- Personnel Meeting (with PhD students, Staff, and Assistant Professors)
  Professors: Boutaba, Forlizzi, Zegura

***Content*.** The report reflects the consensus reached by the panel members. However, it is not intended to follow the table of contents handed to the panel by KTH administration *ad litteram* nor does it include items for which the panel found little or no basis for assessment. That is, a single set of major findings refer to *both* CS and HCT departments since these departments share many characteristics. Separate per-department reports would contain redundant sections, as they would duplicate content for two departments for which the findings are not very different. Also, findings in several areas could not be reasonably supported by the evidence presented by KTH faculty discussion, e.g., potential links and synergies with other parts of the university, recommendations for the whole university, international (social, industry) community engagement. Nevertheless, the panel believes that its Final Report reflects the broad aims of a desired assessment exercise at a major university.

In addition to the *Executive Summary* and *Introduction*, this report includes five additional sections, as follows. *Section 2* contains the panel's main findings for each research area, namely the area strengths and weaknesses, and offers specific recommendations. *Section 3* describes specific issues related to research environment and organization, and research impact on teaching. Based on the findings of the prior sections, Section 4 provides an assessment of the main departmental research strength and weaknesses and identifies areas of high-quality research and future potential development. Section 5 concludes the report.

2 Main research-area findings

In this section, we summarize the main panel findings, namely significant strengths, and noticeable weaknesses, for each of the eight research areas. Recommendations for future improvement are included. The broad criteria used for these finding refer to generally accepted characteristics of research impact, as presented in the ***Cross-Panel Discussion*** section below.

2.1 Software construction and analysis

This area encompasses research in software engineering and programming languages. Areas of focus include programming systems, software virtualization, testing/reliability, formal verification, and automatic repair. Some faculty members cross over to other areas and divisions, e.g., Security and Theoretical Computer Science.

Strengths: This group is large and has significant impact on certain subfields, such as formal methods and verification, software repair and testing, web design, concurrent programming, as well as embedded-system software. Software-security publications have been visible in top-tier security conferences. The recent ACM programming languages software award for Scala, software-tool releases, and industry collaborations are noteworthy successes.

Weaknesses. The publications record is mixed: some faculty publish in top-tier venues, whereas others favor lower-ranked, less selective, and more specialized (e.g., workshop) venues with relatively low visibility. There are few projects that offer international (e.g., EU) visibility.

Recommendations. There is a need for a strategic plan that emphasizes scientific excellence, particularly in term of publication quality, and added impact. Faculty should be encouraged to submit more EU (especially, ERC) proposals and extend international collaborations (to Asia, North America) in strategically chosen areas beyond security, e.g., AI and machine learning, embedded systems.

2.2 Networking

This area includes research on the physical layers of radio systems, wireless design and optimization, network protocols and management, and on software-defined networking. The radio systems emphasis on antennas and MIMO and on energy efficiency has been sound and successful. Research in wireless network design and optimization subarea continue a long and successful tradition of KTH's collaboration with Ericsson and addresses current and topical subjects of broad interest. The envisioned research direction on data-driven network design, security and management is timely and promising and so is the convergence of communications and computing; e.g., new research opportunities arise in the area of mobile edge computing.

Strengths. The new faculty are very talented and energetic, and well-integrated into the research community, i.e., they address important research problems and publish in top-tier conferences and journals. Funding sources seem to be well diversified across government and industry.

Weaknesses. Research appears to be spread too thin among three divisions and two campuses, and the subarea coverage is too broad to inspire confidence. The planned 5G testbed is expensive and not compelling as a few testbeds already exist, e.g., the PAWR started three years ago, Miramar 5G Testbed by *usignite*, more recently. Physical-network management is not as strong as the other subareas as it

seems to address older and less novel problems, whereas software-defined networking appears to follow current trends as opposed to offering innovative ideas.

Recommendations. There is a clear need for a strategic plan to narrow down and focus on fewer research directions and offer incentives to collaborate across subareas, e.g., to explore integrated development of radio, wireless, and network protocol layers to realize joint communication, localization, and sensing. The CS department should also investigate the cause for the weakened collaboration with industry (i.e., Ericsson) and attempt to reinvigorate it.

2.3 Data Science

As is common worldwide, research in data science and machine learning takes place in multiple parts of the CS department as well as in the IS department. The research presented spanned a variety of topics in three divisions: software and computer systems, theoretical computer science, computational science, and technology, which includes computational biology and brain science. As expected, there is substantial research interest in this area from both students and a variety of outside collaborators.

Strengths. There is a good mix of applied and theoretical work and publications are in top venues. The compelling research focus on computational brain science is noteworthy. Gender mix at faculty level is better in this area than in others.

Weaknesses. The computational biology research is small in scope and lacks administrative support. Research in machine learning is spread among (at least) three divisions, which make it difficult to avoid redundancy and integrate into a coherent computer science curriculum.

Recommendations. There is a clear need for a strategic plan to unify and integrate currently disparate research directions, and potentially create a research institute in data science. Such an institute would have both a unique focus and broader coverage in artificial intelligence, machine learning, and as well as underlying data management challenges. It would also allow better integration of research with teaching and support a unique degree program.

Future potential: Research in multiple CS divisions should be coordinated possibly by expanding the current research area in different departments into a university-wide institute. This would be one of the first such institutes in EU.

2.4 Security

Research in security covers a broad set of topics across the hardware and software stack and different application domains; e.g., networking, the web, and internet-of-things. We noted a strong security focus on networks, wireless systems, trustworthy execution platforms, and mobile security.

Strengths. There is a strong faculty presence in the research and professional community, including leadership roles, such as memberships on editorial boards of journals and program committees of international conferences. CS faculty have been successful at bringing in large-scale research projects, establishing strong collaborations with both government and local industry, and pursuing community outreach.

Weaknesses. Few of the CS faculty have a well-established research track in security and consequently many of the publications are in specialized, rather than top-tier venues, or even in non-security venues. Many security researchers have recently come to security and only spend part of their time in this

community. This leads to lack of research integration across the CS divisions and other departments. Some subareas, such as cryptography, have limited scope and need to expand.

Recommendations. The faculty should aim at higher research impact, with publications in top-tier, rather than specialized, venues. The CS department should hire additional and retain existing faculty and expand its research presence in cryptography, preferably in applied cryptography. These faculty can serve as a bridge to system- and network-focused security people.

Future potential: Research in multiple CS divisions should be coordinated possibly by expanding the current research center into a university-wide institute. While such an institute would not be unique in EU, it could have a significant impact on both the Swedish defense and industry organizations which perceive a growing need for research excellence in this area.

2.5 Distributed Systems and Computational Complexity

Research in distributed systems has integrated two seemingly separate areas, end-to-end cloud computing and continuous deep analytics, to support processing systems in real-time continuous machine learning and decision making. The scope of research in computational complexity has been recently diminished due to loss of faculty and expanded teaching duties. However, we noted that progress in this field established a strong connection between distributed and dynamic environments.

Strengths. Research in distributed systems has had excellent impact on both academia and industry. The research publications have been in top-tier venues recognized by awards. Research has been successfully commercialized (e.g., via a startup company) and distributed via an open-source project. The integration of research and teaching is impressive. The publications in the complexity area have been in top-tier venues.

Weaknesses. Collaborations with the international distributed system community are insufficiently developed for even bigger technical contributions. The computational complexity area lacks critical mass now and, unless this problem is addressed, its research impact will continue to diminish.

Recommendations. A strategic plan is necessary for both distributed systems and complexity to address future research, particularly after senior faculty have left the CS department. Younger faculty should be encouraged (e.g., given enough time) to pursue lofty future goals before reaching tenure, and enhance their international collaborations. New faculty should be hired to address the visible weakness of the complexity area.

2.6 Scientific Computation and Visualization

This area established connections across science and engineering and real-world applications. As such it supports other science and engineering disciplines, which in turn inform development of underlying techniques. This is one of the strongest research area in CS with strong industry partnerships, international open-source projects, and public engagements through participation in a network of science museums.

Strengths. The faculty has a very impressive publication record in top-tier venues such as IEEE Transactions on Computer Graphics. A well-equipped visualization studio supports both faculty research and wide industry and public engagements.

Weaknesses. The panel has not identified any significant weakness. The faculty expressed some degree of frustration with being unable to expand this research area into new directions primarily caused by lack of internal funding and a significant teaching load.

Recommendations. The panel suggests that the faculty explore deeper connections to Media Technologies and Interactive Design in area of interactive visualization. The panel also suggests that research into visualization will enhance climate change research at KTH and could address wider sustainable development goals.

2.7 Media Technology

This area encompasses several broad disciplines and strengthens collaboration with other research units within KTH, outside universities, and public institutions such as museums and public arts projects. Its learning science component has been a very fruitful research discipline which will continue to be a world-wide focus, given increased interest in online learning.

Strengths. This area has a diverse funding profile and a variety of publication venues comprising a broad spectrum of academic conferences. Collaborations with other arts-oriented Universities strengthen their multidisciplinary capability.

Weaknesses. This area exhibits growing pains: it needs additional space, which comes at a high premium in most research universities, and possibly a new organizational structure. Lack of internal funding for new and novel research directions, coupled with a significant teaching load appear to be the main causes of slow growth in this research area.

Recommendations. Media technology has disparate research areas and needs to develop a strategic plan to increase funding and raise awareness of its importance in all branches of science and engineering. It needs to create scaffolding to promote a new type of research community. Appropriate “maker spaces” and studios are needed to do cutting edge research. The university should make sure that faculty are not overburdened and have sufficient time to do research.

2.8 Interaction Design and Sustainability

This area comprises two largely separate subareas that address distinct research problems. The interaction design area of the HCT department comprises a small but world-renowned group of well-established faculty members working at the leading edge of design-led research in human-computer interaction. This group developed the notion of the *somaesthetic* design and addressed new and important challenges to women’s health. Sustainability research addresses environmental concerns both through, and in, computer science research and related fields. This includes projects on “green” AI, reducing CO_2 footprint of massive computations, and clean energy production.

Strengths. The interaction design research has had high impact both via top-tier publications in ACM and the CHI conference. Awards at the CHI conference cements this group’s recognized standing in the HCI area. New design tools and materials for industry, and influence on government and business, contribute to this group’s significant impact. Sustainability is a newer field of research, which could have great impact on society, and it could open the way to a new industrial revolution.

Weaknesses. Faculty presentation and discussion pointed to lack of studio space and room to expand “maker spaces” and other design facilities. The research appears to be somewhat bimodal: some areas have high visibility and impact whereas others are more limited.

Recommendations. A strategic plan for CS and HCT research would help in "strengthening the strong" and aim to make KTH the "go-to" place in sustainability and interaction design. To this end, internal funding or new and bold initiatives would be a first step. Addressing the lack of sufficient space for these areas' expansion should be a priority.

Cross-panel discussion: research impact

To provide a relatively uniform view of the research assessment exercise conducted by the panel, we summarize the panel's view of the research impact focusing on two aspects: 1) a common view of what impact is and how to achieve it, and 2) institutional support for and barriers to impactful research. We stress that quantitative measures of impact have not been used as they can be misleading. For instance, a flawed publication result may increase one's citation count and H-index, whereas a publication that closes an area of research may yield very few references, and a decreased citation count, despite saving significant research effort universally. Unfortunately, few presentations explicitly described what faculty consider impactful research. We summarize the panel views below.

1. Research impact and how to achieve it

In a broad sense, research impact refers to the value added by solving problems considered to be significant in both academic/intellectual life, and society in general. As such, the following examples have generally been considered to provide useful routes to impact: 1) solving long-standing problems in an area and opening and exploring new avenues of research; 2) publishing results in generally recognized top-tier conferences and journals; 3) transfer of technologies to industry, business, government, and entrepreneurship; and 4) evidence of improved social life.

2. Institutional support/barriers

Institutions have traditionally provided support and encouraged impactful research is different ways. While support modalities and their outcomes vary, there are a few examples of missing support that almost always guarantee absence of successful research. These include, in no particular order: 1) absence of internal funding for "blue-sky" curiosity-driven research that enables faculty to open new research areas; 2) inability to attract and retain outstanding faculty; 3) lack of recognition of high achievement in research (e.g., honors and awards/prizes, prestigious fellowships, chaired positions, salary incentives, faculty nominations for international honors); 4) failure to support transfer of technology (e.g., via industry, business, and government partnerships); 5) intellectual property rewards to inventors; 6) administrative support for research-proposal writing.

Personnel Discussion

CS and HCT personnel, including graduate students, staff, and junior faculty, answered the following broad questions: what works well, and what needs improvement? The answer to the first question included 1) high quality of life at KTH; 2) effective collaborations among research groups across divisions and departments; and 3) good alignment between research, teaching, and industry experience (e.g., internships).

The personnel discussion also identified several areas for improvement. The primary areas include: 1) slowness in hiring personnel at all levels; 2) lack of career paths for research staff and teaching faculty; and 3) KTH overhead is very high making externally funded proposals expensive.

3 Specific Issues

In this section, we review specific aspects of the research environment and administration at KTH, and whenever evidence of research impact on teaching is available, we comment on it. Other aspects, such as international-community (e.g., social, industrial) engagement, are not addressed as the division and research presentations offered insufficient evidence for rendering informed judgement.

3.1 Research environment and administration

Division and faculty presentations as well as personnel discussion centered around a few key research environment and administration characteristics. These included: internal funding, research distribution across department divisions, space, and technical support availability, hiring processes, and gender parity.

1. *Internal funding*. As a university KTH relies almost exclusively on external research funding from a variety of government, industry, and foundation sources. While this is laudable, since it points to research relevance, it biases work towards current topics of interest with typically short-term horizons, e.g., a few years. In contrast, internal funding is rather limited and insufficient to enable blue-sky, curiosity driven research that enables talented faculty to discover and open new areas. This also suggests that strategic planning, which is necessary in competitive academic disciplines, cannot be properly executed due to unavailability of relatively small amounts of unrestricted funding**.**

2. *Research distribution across academic units*. Excessive reliance on external funding has an additional effect: popular research that attracts current funding tends to proliferate and spread thinly across multiple academic units, lacking critical mass, coordination, and vision. Duplication of effort and hiring increases.

3. *Laboratory/studio/office space and technical support*. These are among the most common issues that arise in academic environments where internal funding is limited. External funding sources do not typically cover space and technical support costs in university settings. Hence, these two items are very hard to obtain and require internal university support. While this is not specific to KTH, it is a common characteristic of most state funded universities.

4. *Hiring and retention*. Perhaps one of the most glaring challenges of KTH, sluggishness in hiring detracts from attracting first-rate researchers, particularly if start-up packages are not competitive. In addition, certain research staff positions and adjunct teaching positions have no trajectory for career development and promotion and end up being career dead ends. This does not encourage research expansion when tenure-track positions are not available due to government budget constraints. Chair professorships, which almost guarantee retention of highly productive faculty, are too few.

5. *Gender parity*. The goal of achieving gender parity is not only a social necessity. It is a research imperative since many undergraduates – often a majority -- and an increasing number of graduate students are now female. Hence, not achieving gender parity ends up depleting the talent pool to the detriment of academic accomplishment.

All the above issues were noted during the assessment exercise and should be addressed by KTH administration.

3.2 Research Impact on teaching

A significant measure of broader impact of research is its impact on teaching. However, some areas are better suited to teaching than others, and those presented during the assessment exercise were no exception. For instance, more established areas, such as software construction and analysis, networking, and security, are amenable to teaching as undergraduate student backgrounds are usually sufficiently strong. In contrast, newer areas such as data sciences and machine learning cannot typically rely on a strong specialized undergraduate education. Furthermore, some research areas that require substantial laboratory and/or studio space and technical support are also less amenable to classroom education.

Another aspect of research impact on teaching is the need to decrease the teaching burden of research faculty since faculty is hired to fulfill teaching needs but are evaluated and promoted based on research output and impact. Consequently, hiring adjunct teaching faculty tends to proliferate at the expense of internal funding that would otherwise be dedicated to exploring new directions. This less-than-virtuous cycle causes university tension at KTH and detracts from both adjunct teaching staff's productivity, who lack career paths, and research faculty, who have no/little internal funding to open and pursue new research directions. Nevertheless, the panel noted the significant effort made to address this issue at KTH. We believe that external-foundation funding offers a way to ease the apparent research-versus-teaching tension that was repeatedly raised by faculty during the assessment exercise.

4 Overall departmental findings and recommendations

Based on the finding of the two prior sections, we summarize the overall CS and HCT department strength and weaknesses and point out of areas of high research quality and future potential. For the areas of high potential, we recommend the creation of two new university-wide units, namely two research centers/institutes (as opposed to departmental centers of excellence), which would foster cross-cutting activities and enhance KTH standing.

The CS and HCT faculty presentations, junior personnel, and individual faculty discussions enabled the panel to identify five main areas of strength and five areas of weakness.

4.1 Departmental strengths

1. The two departments have high quality, energetic researchers and graduate students who are poised to achieve further research success.

2. Faculty and staff uniformly praised the excellent academic life at KTH, expressed loyalty to the university, and pride in being associated with it. This should bode well for future success in research.

3. Much of the research is at the forefront of technology. There is clear evidence of significant impact including broader societal impact on medicine, industry, government, and business.

4. The cross-division centers of excellence display critical mass in selected research areas and enable substantial external funding.

5. The two departments have a flexible hiring policy within given salary scales. This can enable them to hire the best and the brightest researchers in the future.

4.2 Departmental weaknesses

1. There is little evidence of strategic vision. There is no plan for new initiatives, no funding for blue-sky (aka., “moonshot”) research, not much room for change of research direction.

2. Some research topics are thinly spread across several areas, without achieving critical mass in any area. Popular research topics are duplicated across divisions.

3. Internal university research funding is minimal. While external research funding is high, there are some clear challenges in obtaining it. The direct and overhead research costs are high at all personnel ranks. There is no university help to faculty for proposal writing.

4. The teaching burden for research faculty is high and the number of adjunct faculty is low. However, if the adjunct faculty pool is increased, the internal research budget decreases – a clear dilemma.

5. Hiring delays, non-competitive start-up packages for new faculty, and cumbersome procedures detract from attracting first-class researchers. There is a very small number of female faculty and the clear effort to achieve gender parity is adversely affected by sluggish hiring procedures. There is an uncertain career trajectory for research staff and adjunct faculty, which could diminish retention of high-quality personnel.

4.3 Recommendations

The panel recommendation to KTH is to address, to the extent possible, the weaknesses identified above, recognizing that some (i.e., the first two) could be addressed at the departmental and school level whereas the remaining ones require university-level intervention. The panel also suggests that older research areas that present less interest be phased out to free university resources for new directions and new faculty.

It is admittedly impractical for a research assessment exercise to recommend specific ways to address the identified weaknesses, as that would require an in-depth review of departments and university’s finances, organization structure, and priorities. Such an activity was not this panel’s charge.

4.4 High Quality Research

- Based on the panel criteria of research impact (see *Cross-panel discussion*), we identified four areas where nearly all criteria are met. In the order of research-area presentations, these are:

- Networking

- Distributed Systems

- Scientific Computing and Visualization, and

- Interaction Design

4.5 Areas of High Potential

We identified two areas where new university-wide units, like research centers/institutes (as opposed to departmental centers of excellence), would foster cross-cutting activities and enhance KTH standing. In the order of research-area presentations, these are:

- Security, and
- Data Science

The panel believes that university-wide institutes/centers (as opposed to departmental centers of excellence) would coordinate and foster cross-cutting research activity, avoid duplication, and enhance KTH standing. While institutes/centers with a more limited scope exist in Scandinavia (i.e., in Denmark and Norway), the university-wide institutes/centers we recommend also offer an opportunity to become the go-to place for faculty, with clear potential to hire and retain talented researchers.

5 Conclusions

The assessment exercise offered two pleasant surprises to the panel members. The first is that, despite current sluggishness in "out-of-the-box" thinking and excessive reliance on government and industry funding, KTH's Computer Science and Human Centered Technology departments are faring well in research. The second is that, unlike most universities, KTH grants exclusive ownership rights to intellectual property creators, whether faculty or students. This enlightened decision bodes well for technology transfer to industry in Sweden and beyond.

The panel believes that, although limited in scope, the assessment outcome reported herein offers a snapshot view of the research posture of the CS and HCT departments at KTH in 2021. The panel also believes that its recommendations provide sufficient clarity for improving this posture in the future. In short, the panel believes that this exercise has achieved its aims.

Acknowledgements

The panel is grateful to the KTH faculty for its efforts to provide a clear and accurate picture of the research posture of CS and HCT departments. Whatever clarity this report has is due in no small measure to the faculty presentations. The panel is also grateful to panel's KTH coordinator, Professor Panos Papadimitratos, and vice-coordinators, Professors Kia Höök and Elena Troubitsyna for their support during the assessment exercise. Professor Papadimitratos' effort in organizing and coordinating faculty presentations, scheduling the assessment activities, and panel-membership assignments to research areas has contributed to the assessment-exercise success immeasurably.