Evaluation of Research in ICT in Estonia 2009–2014

Evaluation Report 5/2015

Eesti Teadusagentuur
Estonian Research Council

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EVALUATION OF RESEARCH IN ICT IN ESTONIA 2009–2014

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Table of Contents

1. Preface

The Estonian Ministry of Education and Research commissioned in 2014 an international evaluation of research in information and communication technology (ICT) in Estonia. The goal set for the international evaluation by the Steering Committee was to assess the scientific quality of research, interaction between research and society, research environment and organization, quality and relevance of PhD education and to make recommendations for the future. The institutional assessments involved three public universities (Tallinn University, Tallinn University of Technology and University of Tartu), two technology competence centres (ELIKO and STACC), one state research institute (KBFI), and one private company (Cybernetica). Site visits took place during November 24-28, 2014.

In Europe universities and public research institutions are faced with demands for greater accountability and the consequences of diminished funding. The number of researchers has grown but expectations towards research have grown even faster. Research funding, on the other hand, has not grown significantly. These pressures have made research evaluation essential.

The objective of the research evaluation is to measure the qualitative and quantitative outputs of any given research unit. To compare it with the international level and to give recommendations. In the field of ICT the scientific impact cannot be measured only by counting the number of publications and citations in high-impact journals. The research output here is much more varied, including also books, proceedings, computer programs, designs and prototypes, etc. And very importantly, the societal relevance has to be taken into account as well.

It is very good to get a confirmation that many Estonian ICT research groups are internationally outstanding. Many PIs are very active in research, they are recognized internationally and are coordinators of large international research projects. However, the report outlines also some visible weaknesses. Most importantly, problems stemming from the current short-term project-based funding system and weaknesses related to the limited funding of the PhD students.

On behalf of the Steering Committee I would like to thank all evaluation panel members for their great effort of visiting and evaluating all 32 research groups. Their comments and recommendations are certainly beneficial and should be considered by all involved parties: policy makers and funding agencies, industry partners, and research performers.

Professor Gert Jervan
Chairman of the Steering Committee
Tallinn, April 2015

2. Summary

The following are the recommendations of the panel of the Estonian 2014 ICT research evaluation. They are discussed, justified and elaborated in the remainder of the report.

Estonian ICT research is on a good level, with several strong researchers and research groups. The strongest groups in each of the universities can certainly be called internationally outstanding, but there is yet no ERC grant awarded for ICT research in Estonia. Universities are recommended to continue efforts to obtain a few such grants. Also, many groups have not yet experienced sufficient renewal of management and research themes, although they are still performing well on their traditional topics. Attending to the renewal and/or successful succession of leadership for these groups is an important task for the universities.

There can be stronger focus on basic research in many areas, in particular, the areas of Machine Learning and Signals and Systems are less active than in many other countries, where they significantly strengthen and are strengthened by the research in information systems, computer communications, robotics, computer vision, bioinformatics and physiology. The panel recommends strengthening of the two former areas.

Research in Estonia, besides the small volume bundled together with university teaching, is mostly built on short-term research projects and this can have negative long-term effects. It is recommended to have continuous development of the funding system, thus encouraging long-term research commitment for competitive and promising groups.

The PhD education is organized according to international conventions and is mostly working well. In several units the PhD students are, however, not financed to a level that ensures full-time commitment to the completion of PhD theses and selective recruitment of candidates. In others, there seems to be too many PhD students for effective supervision. A national development of rules ensuring uniform and adequate financing based on progress, and ensuring adequate supervision of academic and industrial based PhD studies is recommended.

The interaction between research and society is generally good but can be strengthened in a few groups.

University managements have a realistic view of their institutions' strengths and weaknesses and have shown ways forward that the panel supports. The biggest change being planned is the reorganization of research at TLU, which can result in important new research on effects of ICT on society, both descriptive and prescriptive.

The separate ICT Research Institutes perform well within their given bounds, and are open to developing their business models and interaction with Estonian and international industry, according to promising plans discussed during site visits.

3. Introduction

3.1. Methodology

This is the final report of the assessment panel of the 2014 targeted evaluation of ICT research in Estonia. The evaluation is based on directive 396 (September 2014) of the Ministry of Education and Research. Information used by the panel contains: presentations of the Estonian Research and Education system given by the Estonian Research Council and the Ministry of Education and Research; reports from previous research assessments in Estonia; self-assessments, statistics and publications submitted by the participating units to the ETIS system for the present evaluation; site visits to all assessed institutions in the last week of November 2014; and the panel's familiarity with the international research and research management system.

Institutions Evaluated

1 Tallinn University (TLU)

- Digital Learning EcoSystems
- Human Computer Interaction

2 ELIKO

3 Cybernetica

4 Tallinn University of Technology (TUT)

- Optical Fiber Communication Group
- Department of Biomedical Engineering
- Institute of Cybernetics (IoC): Software Engineering Group
- Institute of Cybernetics (IoC): Lab for Phonetics & Speech Technology
- Institute of Cybernetics (IoC): Control Systems Laboratory
- Institute of Cybernetics (IoC): Logic and Semantics Group, Lab. of Software Science
- Centre for Biorobotics
- Department of Electrical Engineering: Electric Drives, Industry Automation & Robotics
- Department of Electrical Engineering: Power Electronics Group
- Cyber Security
- Thomas Johann Seebeck institute of Electronics: Impedance spectroscopy and instrumentation group
- Research Laboratory for Proactive Technologies
- Department of Computer Engineering: Dependable Computing Systems Design (DCSD)
- Department of Computer Science: Formal method-based analysis, verification and planning
- Sociotechnical Systems and e-Governance Group

5 National Institute of Chemical Physics and Biophysics

6 University of Tartu (UT)

- Institute of Computer Science: Bioinformatics and IT
- Institute of Computer Science: Software Engineering
- Institute of Computer Science: Distributed Systems
- Institute of Computer Science: Computational Neuroscience
- Institute of Computer Science: Cryptography and Theoretical Computer Science

- Institute of Computer Science: Language Technology
- Institute of Computer Science: Programming Languages
- Institute of Technology
- Department of Geography, Ecology & Earth Sciences
- Institute Molecular and Cell Biology: Bioinformatics
- Natural History Museum & Botanical Gardens, Institute of Ecology & Earth Sciences

7 Software Technology and Applications Competence Centre (STACC)

Site visits: 24–28 November, 2014

International Panel:

- Stefan Arnborg, Professor Emeritus, Royal Institute of Technology (KTH), Chairman
- Barbara Pernici, Professor at Politecnico di Milano, Italy
- Sasu Tarkoma, Professor at University of Helsinki, Finland
- Sethu Vijayakumar, Professor at University of Edinburgh, UK
- Olli Yli-Harja, Professor at Tampere University of Technology, Finland

Grading

Where sufficient evidence was available, the Evaluation Panel generally applied the following five-level grading system to assess the Scientific Quality of Research (national and international), Interaction between Research and Society, Research Environment and Organization of Research, Quality and Relevance of PhD Education: **Unsatisfactory, Satisfactory, Good**, and **Excellent**. Occasionally the grading **good to excellent** is used. For international level, the Panel used the terms **High, Good** and **Fair** for the gradation. Where insufficient evidence was available, the assessment is recorded as **Non-applicable**.

The steering group, after reading the first report draft, felt that there were many groups assessed as excellent and asked for a smaller field of outstanding groups. Indeed, about one third of the university based units are assessed as excellent. The panel felt that an arbitrary restriction, like imposing quantitative thresholds for excellence or distinction would be inappropriate. Instead, the report points out some clearly visible weaknesses in industry targeting, publication strategy, PhD output, and international recruiting and financing in each university group, including the excellent ones. The only ERC grant visible in the evaluation was awarded mainly for activities outside Estonia.

3.2. Importance of ICT for the Estonian Economy

The ICT sector is, in Estonia as in most countries, considered an important factor for economic growth. Owing to the rapid rate of technical innovation, the sector has to get support from publicly or philanthropically funded education, research and pre-development. Likewise, at the universities where education and research takes place, the more applied work must be supported by more basic dissemination and creation of knowledge, which is also needed for the universities' educational mission (not evaluated here). Estonian research in ICT has been targeted for research funding on a relatively large scale. The panel has visited universities and research institutes and developed an overview of how ideas are created and developed for export to society and private initiatives. The panel has no direct information on how these activities are appreciated by the receivers, who obviously also obtain the benefits of international activities of the same kind and of individual entrepreneurial initiatives. With this in mind, the panel has seen a research and innovation system that is strongly geared to application in industry and society, and with relatively small emphasis on basic research. On the whole, the effort to build this system has been successful. A number of remaining problems will be pointed out.

3.3. Short-term research funding

Most groups have mainly project-based funding that causes instability in the directions of research and uncertainty along the years. While competitive funding is generally beneficial to research output, relying too much on short-term project funding can cause unwanted focus on short-term and light-weight research results, to the extent that some PhD students feel they are given carte blanche in publishing whatever can be accepted in a journal of the right Scopus designation. Several of those journals are not quite competitive.

There is certainly a good point with competitive funding, but even strong research units would often benefit from sources of funding with a somewhat longer time horizon.

3.4. Education of PhD Students

All Universities have reported serious problems originated by the current basic stipend level. It is quite low in comparison with other countries, even considering the low cost of living in Estonia, and is an impediment for recruitment of the most promising candidates. PhD students have to look for additional sources of income and the consequence is often that only a limited time can be devoted to research due to other internal or external commitments to integrate the stipend, and studies are very often delayed. In the ICT sector this problem could be alleviated by guaranteeing that each PhD candidate receives a basic stipend of at least € 1000, derived from project or university funds (e.g., in form of overhead paid from grants). It is desirable that the economic compensation to PhD students is determined by student progress and is uniform over at least the institute or the department and preferably over the institution, and that the compensation is adequate to ensure full-time commitment to degree achievement and international recruitment of students. Several assessed units have accomplished this on the unit level. Departments have the authority to implement it over departments, as they should do, while awaiting rules implemented on national level.

The position of industrial doctorates should be clarified and formalized. The potential of integrating research within a company with supervision at the university can and should be better exploited.

4. Unit Assessments

4.1. Tallinn University

Tallinn University was established in 2005 by a merger of a number of higher education and research institutions in Tallinn, mainly focusing on educational science, social science and humanities. It has approximately 10,000 students of which 600 are international and 1,100 faculty and researchers. The Institute of Informatics was established in 2008, but the origin of research in ICT-supported education is somewhat older. The self-assessment identifies two units within ICT, Digital learning ecosystems and Human-computer interaction. Other ICT activities exist, but they are small and were not submitted for assessment.

4.1.1. Scientific Quality of Research

The ICT research has a narrow and niche focus in TLU. The scientific output in the domain of ICT that is related to education is at an **excellent** level, especially in the larger DLE group.

4.1.2. Interaction between Research and Society: Public and Professional Activities

The institution's professors have been active in developing Estonia's ICT and education strategies, several of them are members of national policy-making bodies and have had considerable influence on deployment of new methodologies and learning environments in educational institutions. Tutorials and courses for practitioners on HCI-related methods have been organized**.**

Assessment: We rate the societal engagement and relevance as **excellent.**

4.1.3. Research Environment and Organization of Research

The University is undergoing a restructuring based on problem-based areas. One planned area focuses on Digital and Media Culture, and all areas are planning a support in digital technologies within the area.

4.1.4. Quality and Relevance of PhD Education

PhD education was established fairly recently, in 2010, so it is still developing its activities.

29 PhD students have been admitted since the program started. The program is accredited by the Estonian Higher Education Council and has the standard components of course work, study plans, progress monitoring and financing international travel and exchange.

The panel met a group of PhD candidates and discussed with them the structure of PhD education and the issues related to PhD studies.

As in other universities, PhD candidates have to find additional support to complement the basic stipend, often with external teaching activities in schools or working in companies. As a result, research activities may progress more slowly than expected due to other commitments, and talented students simply disappear to positions where they feel they are more appreciated. Some PhD students indicated that they must themselves hunt for research topics and effective supervision.

Recommendation:

1. PhD supervision should be more structured and student guidance, including career planning, should be improved.

2. In general, it appears that the choice of research subjects is not always related to the group's mainstream research.

4.1.5. Recommendations and Future Potential

Given the TUT and UT focus on developing new ICT, the strategy of focusing on new deployments of ICT and effects on society at TLU appears an appropriate division of responsibilities for ICT research within Estonia. The groups assessed by the panel would have to be complemented by new recruits in order to accomplish a reasonable coverage of ICT expertise, enabling digital and media culture studies.

Recommendations:

1. The ICT research focuses on the traditional strengths of the university in education and pedagogical research. This is both a strength and a weakness. If they sustain world class outputs in this niche domain, this will serve as an important centre in Estonia for ICT-led paradigm shifts in educational technologies.
2. The new planned area in Digital and Media Culture seems like an exciting prospect; however, it is unclear if the current personnel will be sufficient to fulfil the plans on both the teaching and research front.
3. Equal conditions should be provided for PhD students, guaranteeing each of them a higher salary to work in the research group, even if this might imply a reduction in the number of PhD candidates. It would make sense to increase the stipend size to 1000€ per month.

4.1.6. Research Group: Digital Learning EcoSystems

The group is led by Prof. Tobias Ley and consists of 22 researchers, including 5 lecturers and 1 docent. The research focuses on conceptualizing, modelling and designing new forms of technology-enhanced learning systems: distributed adaptive socio-technical systems consisting of learners and digital learning artefacts. The research presented in the group investigates a variety of topics, using a design-based approach and practical work in interdisciplinary areas. The group is planning to move away from applied research to a more research-oriented focus. The group is very active and covers different aspects of digital learning.

The group is truly interdisciplinary, including specialists from the traditional strengths in educational technologies, pedagogical strategies, with research applied in schools (e.g., e-textbooks), in university education, professional communities and workplace practice.

Assessment: The panel judges the research to be **high international level.** The overall evaluation of the group is **excellent**.

4.1.7. Research Group: Human-Computer Interaction

The group is led by Prof. David Ribeiro Lamas. The group was formed during the evaluation period.

It is a very small group with a large number of PhD candidates (14 and ongoing).

The research topics are rather diverse, and the theme in PhD research is often derived from negotiations based on the original proposal of the candidate.

The group has been recently established, so it has yet to organize, however the panel feels that in order to become a stronger group, more focus on research themes is needed. It is recommended to strengthen the group so the breadth of the research areas corresponds to the breadth of the research topics either acquiring new researchers or a merge with other groups. Otherwise, more focus is suggested.

Assessment: The panel judges the research to be of **fair international level.** The overall evaluation of the group is **satisfactory**.

4.2. ELIKO

ELIKO Competence Centre in Electronics-, Info- and Communication Technologies was established in 2004 as a competence centre (an independent state supported research organization) and is led by Professor Mart Min. The group focuses on developing competences based on four core areas—sensing and signal processing, wireless communication in smart environments, software applications for smart environments and software and hardware testing, with significant technologies derived out of basic research in impedance spectroscopy. It currently employs 68 researchers.

In the ten years of existence, ELIKO has successfully managed to translate several ideas from the research labs in TUT (especially the Thomas Seebeck Department of Electronics) to proven concept ideas that are capable of exploitation by partner companies.

4.2.1. Scientific Quality of Research

The research activities are closely linked with the Department of Electronics as well as the biomedical engineering group at TUT, since there is a significant overlap of key personnel. Innovative techniques and signal analysis methodology has been used to exploit impedance spectroscopy in various materials and domains ranging from healthcare, emergency response, interpretation of biosignals to domains such as intelligent streetlamp control and contactless RFID payments for the transportation network.

The numbers of publications are high, but the number of high quality publications is more modest. Given the close ties with the university and the number of personnel (across the university and ELIKO) involved, there is a scope to aim higher— although several top level publications in health monitoring and biomedical engineering are acknowledged.

Assessment: The panel judges the research to be at **good to excellent** international level.

4.2.2. Interaction between Research and Society: Public and Professional Activities

Several of the research themes are of direct societal relevance. There is excellent cooperation initiated with several companies like St Jude's Medical Guidant, Boston Scientific as well as public bodies such as the North Estonia Medical Centre (PERH) and East Tallinn Central Hospital (ITK)— although during the site visit it was unclear (not sufficient evidence) how tight knit these interactions were or what is the level of translation that has been achieved.

ELIKO has also worked with the tourism board to analyse real time data and develop recommendation systems that can be exploited further.

There are several outreach channels mentioned in the report including hosting of visits by dignitaries. ELIKO has also contributed to several standardization panels in Estonia and internationally.

Assessment: The panel judges the interaction between the research and the societal relevance of activities as **good to excellen**t.

4.2.3. Research Environment and Organization of Research

The research environment strategy seemed to be to bootstrap significant infrastructure facilities based at the Electronics department at TUT and to create proof of concept demonstrators—a conscious decision based on the cost of these large test rigs. This seems to be working well, especially since the projects are closely tied in with the research interest and PhD supervision topics of many students and supervisors in the department.

Assessment: The panel judges the research infrastructure and organization to be **excellent.**

4.2.4. Quality and Relevance of PhD Education

ELIKO has close ties with the TUT Department of Electronics and there is a strong participation of students undertaking PhD research on topics of interest to either side. As an example, in 2009—2010, as many as 9 students defended their doctoral thesis on topics closely tied to ELIKO research.

Assessment: **Good** ongoing collaboration with universities involving PhD students.

4.2.5. Recommendations and Future Potential

The panel finds that ELIKO has been successful in achieving its goals to act as a bridge between the academia and the industry. Because of it being more or less fully state-financed, then judging by the discussions some limitations in capability to build full-fledged products and operate as a 'for profit' organization seem too limited. However, ELIKO is providing a good conduit of interesting proof of concept ideas and demonstrators to affiliated companies.

Assessment: The panel judges the research to be **of good international level.** The overall evaluation of the unit is **good**.

Recommendations:

1. ELIKO is providing a valuable bridge between academia and companies; they need to continue investigating and implementing sustainable funding models, since their model of not being able to directly sell products may be an impediment.

2. The panel also recommends that ELIKO quickly identifies a few niche directions that they want to focus on, since the current portfolio seems quite diverse. This will enable them to do more thorough testing of proof of concept ideas and perform the last mile for real-world feasibility in a much more efficient way.

3. ELIKO has great potential in motion tracking, bio-signal interpretation and health monitoring domains by combining the expertise they possess—a much closer interaction with stakeholders (like the hospitals) may pave the way for increased impact.

4.3. Cybernetica

4.3.1. Scientific Quality of Research

Cybernetica focuses on IT security research, reflecting the needs of Estonian society, as well as future application areas of information security solutions. The current research directions include privacy-preserving computations, structured risk assessment, Internet voting, security properties of hash functions and time-stamping systems, language-based security, and federated databases. The publication record is relatively scarce in terms of high level

journals and conference publications, but there are good publications in more specialized venues. The number of PhD graduations is good.

Assessment: The panel assesses the overall scientific quality of the research to be **good**.

4.3.2. Interaction between Research and Society: Public and Professional Activities

Cybernetica's research and development activities are vertically integrated. Good examples of this are the X-road governmental middleware, the Estonian Internet voting system, the privacy-preserving computation platform Sharemind, and marine security. Here the identified business needs are guiding both the research directions and the development activities.

Assessment: The panel assesses the interaction between research and society within Cybernetica to be **excellent**.

4.3.3. Research Environment and Organization of Research

Cybernetica's research is financed from Estonian basic and applied research funding, European Commission's Framework Programmes and DARPA, from the income of Cybernetica's business activities, and other sources. The established national and international collaboration is at a high level.

Assessment: The panel assesses the research environment and organization of the research to be at an **excellent** level.

4.3.4. Quality and Relevance of PhD Education

Cybernetica does not have PhD programmes. However, 15 of Cybernetica's young researchers are enrolled in the Computer Science PhD studies in either University of Tartu or Tallinn University of Technology, receiving their primary supervision from senior researchers in Cybernetica. During the evaluation period, 6 students obtained PhD degree based on their work in Cybernetica.

Assessment: The PhD education (at TUT and UT) benefits from the vertical integration implemented at Cybernetica. The panel assesses the ongoing collaboration involving PhD students to be **excellent**.

4.3.5. Recommendations and Future Potential

Assessment: The panel judges the research to be of **good international level.** The overall evaluation of the unit is **excellent**.

Recommendations:

The panel encourages Cybernetica to aim for a higher level in publications. This would be in line with the aims of joint PhD education with TUT and UT.

4.4. Tallinn University of Technology

Tallinn University of Technology (TUT) is the second largest university in Estonia with 14,000 students. The university has three main cores that are organized in 8 faculties. Almost 20% of the students at TUT are studying in the field of ICT. ICT-related research is conducted in several faculties and research institutes of TUT. Most ICT research is done in the Faculty of Information Technology and the semi-autonomous Institute of Cybernetics (with no teaching duties). There are also significant activities in the Faculties of Mechanical Engineering, Power Engineering, and in the Technomedicum of TUT.

4.4.1. Scientific Quality of Research

Since the evaluation made in 2000, TUT has developed a strong international profile in ICT. It shows internationally excellent research units in fibre communication, biomedical engineering, non-linear control, logic and semantics, dependable computing systems and biorobotics, besides a fair number of good and internationally recognized units. EU research projects and internationally funded research has increased significantly (410,000 and 711,730 Euros, respectively, in 2014). At least 5 FP7 or H2020 ICT projects were coordinated by TUT.

According to the self-assessment, the most important achievements have been the establishment and very successful operation of two of Estonia's seven national centres of excellence (CoE), both in the ICT area. TUT researchers are increasingly participating in various EU research projects (FP7, H2020) and at least 5 of such projects have been coordinated by or are under coordination of TUT researchers (including one H2020 project, coordinated by TUT). TUT has been also very active on commercialization of the research activities as well as internationalization.

Many groups have published at excellent international venues. The PIs have been very active in research and this is evidenced by the high levels of bibliometric indicators for a significant number of group leaders and faculty members.

In addition to core scientific research, there are good examples of translational research that takes ideas to products.

Assessment: The panel found the scientific quality to be **excellent** and the TUT has several highly cited researchers, for example Kruusmaa, Andrekson, and Uustalu, in the ICT areas. The research environment and the international collaborations are **excellent**.

4.4.2. Interaction between Research and Society: Public and Professional Activities

TUT staff has been involved in many roles in national and European policy-making bodies, and in technology transfers to society and industry. They have been visible in the public debate on the future of ICT and its promises and threats. Among specific achievements, audit and publishing of Estonia's e-voting system, implementation of the data exchange framework for Estonia's state information system, organization of NATO cyber-defence exercises, establishment (with University of Tartu) of the IT Academy aimed to promote ICT education by raising its quality and competitiveness deserve a mention.

Most ICT units at TUT work on problems of obvious relevance for society and industry.

Assessment: TUT has demonstrated, through its choice of research themes and extra-mural initiatives, strong engagement with the societal aspects of research. We rate the societal engagement and relevance to industry as **excellent**

4.4.3. Research Environment and Organization of Research

The ICT research is primarily based in the Faculty of Information Technology and the semi-autonomous Institute of Cybernetics. The former is responsible for both teaching and research and the latter is a research institute, although staff of its stronger units teaches in order to reach talented students. No problems were aired at this division, but there is some overlap of research areas and the current division seems to be a historical circumstance more than a consequence of current needs. Some areas required for education at TUT seem to have a significant research base only in the Institute of Cybernetics. The faculties handle administration pertaining to education whereas departments under faculties facilitate the operation of the research groups. The research funding is primarily obtained by PIs from competitive funding sources.

The Faculty of Information Technology has 6 departments, ca. 150 academic staff members, ca. 150 PhD students and ca. 2400 students. The Institute of Cybernetics has ca. 40 research staff members in the field of ICT. In addition to the two above research units, ICT research is also carried out in other faculties, namely Power Engineering and Technomedicum.

The ICT research groups evaluated at TUT cover the ranges from large to small and from basic research to applied research. Some of the groups are well beyond the state of the art state and have momentum to achieve breakthroughs. Other groups are still small and need to grow to establish themselves. Some groups would benefit from newer research themes and better integration with their respective international scientific communities.

4.4.4. Quality and Relevance of PhD Education

TUT has 10 PhD programs. Majority of the ICT related PhD students are in the Information and Communication Technology program (IKT). The number of state-sponsored PhD positions is limited (in the IKT program it has usually been 16 new positions per year). Although the state scholarship is rather modest, there are several other scholarship opportunities available for the ICT students. Each year the IT Academy program hands out up to 13 scholarships, the national Tiger University program 10 scholarships and national Doctoral School in Information and Communication Technologies (IKTDK) also hands out up to 10 scholarships (each around 400 EUR per month). Majority of the ICT PhD students are associated with the IKTDK doctoral school project (http://iktdk.dcc.ttu.ee). The main focus of the IKTDK project (joint with University of Tartu) is to organize guest lectures, support PhD students' mobility (short- and long-term), joint supervision and to organize annual conferences. In addition there are several other mobility support programs (conference, workshop and course participation, trainings, internships).

At the end of each academic year, all PhD students are evaluated. Each student has to write a report and it is complemented with a statement from the supervisor. One of the weaknesses of our PhD education is the low efficiency. Typically it takes 5-6 years to complete a PhD thesis and the dropout rate is also rather high. One of the main reasons for that is the low national funding of PhD studies. Therefore the PhD studies are also efficient primarily in those groups that have rather stable external funding. Many PhD students are also actively contributing to the teaching process, consequently delaying their defence. Annually FIT has around 10 PhD defences and the objective is to raise this number to over 15.

The PhD students interviewed at TUT reported that in general the advice that they have received regarding the PhD process is adequate and that they have good possibilities for international networking. Funding for PhD research was seen as challenging due to the small stipend that is in many cases augmented with work on a research project, at a company, or by teaching. The students reported that in some cases the teaching load can be quite high. It is advised that PhD supervisors monitor and coordinate the teaching load and responsibility of the students with respect to the PhD plan. The students reported that there is information available regarding startups; however, only startups were emphasised in the discussion. In general, there was a lack of clear future prospects and pathways (career plans) to achieve goals after completion of studies.

Assessment: We found that many of the students whom the panel interacted with somewhat frustrated because of their economic situation, which varied greatly. Those solely dependent on the stipend cannot fully commit themselves to PhD studies, and most likely recruitment is affected negatively.

4.4.5. Recommendations and Future Potential

Recommendations:

1. TUT has a strong position as the leading technology university in the Baltic States, with a strong international outlook. They are encouraged to maintain this international focus and aim to increase their global standings further. Measures such as an MSc program in English (with waived tuition fees) are an excellent step towards this.
2. The University enjoys a good location, both when it comes to academic supervisor links and the presence of the Tallinn science park nearby to commercially exploit several research outputs. They have a good history of doing this and are encouraged to further strengthen this.
3. Some of the research groups could benefit from restructuring in order to re-balance the research topics (e.g., incorporate newer methods) and better exploit synergies while maintaining the traditional strengths.
4. The groups could be reorganized in a more focused departmental structure, grouping the units working in closely related research areas.
5. The PhD student support structure could be enhanced to facilitate broader exposure to opportunities after their graduation.
6. Equal conditions should be provided for PhD students, guaranteeing to each of them a higher salary to work in the research group, even if this might imply a reduction of the number of PhD candidates. It would make sense to increase the stipend value to 1000€ per month.

4.4.6. Research Group: Faculty of Information Technology: Optical Fiber Communication Group

This group is led by Prof. Avo Andrekson, an internationally outstanding researcher with an important connection to the ICT field. He holds an ERC grant for his international activities. His plan is to start up a small group or research at TUT initially based on non-experimental work, but later establishing a laboratory. The relation with Chalmers University in Göteborg, Sweden (as well as partners world-wide), will be essential in this respect. Research focuses on noiseless optical amplifiers that may find many applications that should be pursued.

Assessment: The panel must **defer** judgment since the group is not yet fully established**.** The overall prospects of the group are clearly **excellent**.

4.4.7. Research Group: Technomedicum: Department of Biomedical Engineering

Biomedical Engineering (DBME) is a relatively new research unit led by Prof. Ivo Fridolin that combines ICT and medical research. The unit has important collaboration with the e-Medicine laboratory at the Technomedicum. The unit consists of 2 professors and has a staff size of 22. The key topics include advanced algorithms for pulse wave analysis for early diagnosis of cardiovascular diseases, EEG signal processing for detection of brain disorders, and bio-optical signal analysis to estimate dialysis adequacy and quality.

The unit moved to new premises in 2010 and has access to state of the art research facilities. The research is conducted in collaboration with hospitals.

The unit has published 58 ETIS 1.1 and a total of 179 articles during the evaluation period. The scientific publications are published in adequate forums, but the ambition level could be increased. The unit is active in technology transfer and reports 7 patents/patent applications. The unit also reports 5 completed PhD degrees and 11 PHD students.

The funding level of the group appears to be stable with several different funding sources. The unit is recommended to be active in EU Horizon framework.

Assessment: The panel judges the research to be **high international level.** The overall evaluation of the group is **excellent**.

4.4.8. Research Group: Institute of Cybernetics (IoC): Software Engineering Group

The Software engineering research group (SEG) is part of the Laboratory of Software Science. The group is led by Prof. Ahto Kalja. The research of the group covers a variety of topics: e-government, model-based software design, cyber-defence, ontology engineering, and customized manufacturing.

Notwithstanding the number of topics, the number of publications is rather limited, including only 3 ETIS level 1.1 papers and few high-level conference presentations.

SEG has paid much attention to applied research that fulfils some industrial or societal needs, in particular with public administration (within the X-Road project and cyber-defence).

Members of the group have been the main organizers of the series of conferences *Baltic Conference on DB and IS* for twenty years.

The international research activity is limited to collaborations with other institutions at personal level. The self-assessment report does not specify any international projects.

Assessment: The panel judges the research to be of **fair international level.** The overall evaluation of the group is **satisfactory**.

4.4.9. Research Group: Institute of Cybernetics (IoC): Lab for Phonetics & Speech Technology

The group is led by Dr. Einar Meister. The group includes 4 researchers and employs two PhD students.

The focus of the research is the study of the spoken Estonian language. Specifically, the research carried out at the lab covers the following subtopics: Estonian text-to-speech synthesis, automatic speech recognition, acoustics and perception of Estonian vowels and quantity oppositions, microprosodic variations, acoustic and perceptual characteristics of non-native speech, acoustic-phonetic characteristics of adolescent speech, articulatory features of Estonian sounds. A large annotated corpus has been collected, including L2 language and adolescent language. Empirical work has been developed, including the analysis of electrical signals in the mouth and face movements.

Free smartphone applications based on Estonian speech recognition have been developed.

The publications include 9 ETIS level 1.1 papers and also locally published articles to disseminate the results of the research.

The group is involved in co-operations with Institute of Estonian Language and corresponding groups at University of Tartu. It is recommended that a close cooperation with the other research groups working on the Estonian language is maintained, constantly sharing the results and coordinating corpora collections.

Assessment: The panel judges the research to be of **good international level.** The overall evaluation of the group is **good**.

4.4.10. Research Group: Institute of Cybernetics (IoC): Control Systems Laboratory

The group is led by Dr. Maris Tõnso. The group is composed of 1 leading researcher, 2 senior researchers and 1 researcher. The research focus is on algebraic non-linear control systems. The theoretical work is excellent and published in top level journals, including *IEEE Transactions on Automatic Control* and *Automatica*. A tool has been developed to support the theoretical work by transforming between representations, finding state spaces, etc. The research has been applied in limited cases.

The international research activity is based on collaborations with other institutions at personal level, including some incoming visiting PhD students and post-docs. There are no internationally funded projects.

Seen from an ICT perspective, the group would benefit from a bit closer contact with one or two selected and truly challenging applications, possibly through some applied group at a university.

Assessment: The panel judges the research to be of **high international level.** The overall evaluation of the group is **excellent**.

4.4.11. Research Group: Institute of Cybernetics (IoC): Logic and Semantics Group, Lab. of Software Science

This unit is led by leading researcher Tarmo Uustalu. The group is extremely international, and almost all members got their PhD in other countries and have significant international experience. The group is today well-funded, with participation in Center of Excellence and FP6-7 grants and COST actions. The group has hosted several international events (international conferences, summer/winter schools). There have been significant variations in funding levels over the evaluation period.

The research topics are in logic and semantics as the group name suggests, with emphasis on program optimization and transformation, big-step semantics, functional programming theory, theory of átomata and conservation laws for discrete and continuous cellular automata. The above results have not yet reached industry in the form of clear application. The group is active in promoting the most promising tools of their trade, Haskell and Coq/Agda proof-checking and proof-generation.

The group participates in PhD education, but no PhDs graduated during the evaluation period because of an earlier gap in recruitment. Of the current five PhD students, one is a part-time industry PhD student (soon to complete), two left for industry but intend to complete, and two are regular PhD students who are employed in the group to do their research.

The group is recommended to significantly strengthen its PhD education and to develop concrete industrial collaborations.

Assessment: The panel judges the research to be of **high international level.** The overall evaluation of the group is **excellent**.

4.4.12. Research Group: Faculty of Information Technology: Centre for Biorobotics

The group is led by Prof. Maarja Kruusmaa, an internationally highly distinguished researcher in her domain, with strong leadership abilities. The robotics lab investigates flow modelling and flow model usage for underwater robots. The lab has an impressive scientific output and it has succeeded in obtaining a significant amount of EU project funding. The lab also develops test organs for medical

doctors to train on. The PI co-organizes several international conferences and events, is well networked internationally and is active on public outreach platforms as well.

The PI has supervised 7 PhD students to completion, with 6 under completion at the moment. The group has a good ethos and excellent working conditions, with open plan lab setups as well as good hardware support. In addition, they have ensured that all PhD studentships are fully funded through projects, an excellent model that prevents having the students to work on topics unrelated to theirPhD. The group recruits internationally and this has been their strength in terms of their visibility.

They have several globally leading contributions in terms of underwater line sensors, electro-active polymer-based actuation and biomimetic actuation systems— this is a slightly broad and diverse topics compared to the group size (led by a single PI), and perhaps it might be wise to narrow the focus slightly.

The group is encouraged to continue their excellent spin-off activities and is commended for taking the initiative to look at societal relevance of several core research topics.

Assessment: The panel judges the research to be of **high international level.** The overall evaluation of the group is **excellent**.

4.4.13. Research Group: Faculty of Power Engineering: Department of Electrical Engineering: Electric Drives, Industry Automation & Robotics

This group is led by Prof. Tõnu Lehtla with a faculty size of six teaching staff. The group conducts research and technology development for industrial and energy applications. The research topics are multidisciplinary and include mechanical and material issues, energy conversion, power electronics, and control-related issues. The group focuses in energy conversion, motion control and energy flow control.

The current projects include smart grid substation research, automation of a multi-drive pump station, and drives for drones. The group has very good infrastructure support for the research and teaching activities, including scale models of power transmission devices and robotics platforms. The research group has an applied focus that is visible in the scientific output. The group has 5 ETIS 1.1. and a total of more than 100 publications. The panel felt that the number of high quality publications is low and that the target forums could be more ambitious. The group reports 9 completed PhD students by the end of 2014 and 3 PhD theses in progress.

The sustainability plans and the scientific vision are quite vague. The level of funding, in spite of good industrial contacts, is not sufficient to sustain a nationally leading and internationally competitive group. The publication venues and numbers need a significant boost.

The panel judges the research to be at **fair international level.** The overall evaluation of the group is **satisfactory**.

4.4.14. Research Group: Faculty of Power Engineering. Department of Electrical Engineering: Power Electronics Group

This group is led by senior researcher Dmitri Vinnikov. This is a relatively young independent group.-

This group reports 30 ETIS 1.1 and a total of over 90 publications over the evaluation period. The number and quality of publications is on a good international level, especially given the young age of the group. They also have good international links, as evidenced by a number of visiting researchers currently working in their group. They were also a part of the ECPE, co-organized several international conferences/workshops and had strong networking links as a result of this. The group reports 6 completed PhD degrees and 2 current PhD students.

The group has a strong industrial focus and they have been able to address important research problems with industrial relevance. This is evident in the significant revenue generated through industry-led research projects. The group is also in a good position to license the research results to companies. Seen from an ICT perspective, the group would benefit from a stronger emphasis on software systems and data analytics thus bridging the deep hardware knowledge with software expertise.

Assessment: The panel judges the research to be of **good international level.** The overall evaluation of the group is **good**.

4.4.15. Research Group: Faculty of Information Technology: Cyber Security

The group is led by Prof. Olaf Maennel. It is a very young and active group, started around 2013. The main interests of the group are in intrusion detection, testing security policies, and security simulation exercises. They have gained a European FP7 project on E-Crime. The group is still establishing itself in research and its activities are promising. The number and quality of publications is still limited and should be increased. This can be done since the leader of the group is well cited.

Assessment: The panel judges the research to be of **high international level.** The overall evaluation of the group is **good**.

4.4.16. Research Group: Faculty of Information Technology: Thomas Johann Seebeck institute of Electronics: Impedance spectroscopy and instrumentation group

The Impedance Spectroscopy Group led by Prof. Toomas Rang and Prof. Mart Min carries research in measurement and characterization of impedance in various environments with emphasis on medical and biotech applications. The key highlights include new methods for cardiac pacemakers and thermal spectroscopy. The group's basic research is supported by the CEBE centre of excellence and the business development by the Eliko competence centre.

This group reports 32 ETIS 1.1 and a total number of 147 publications for the reporting period. They have been very active in patenting with 55 patents/patent applications. The number and quality of publications is generally on a good level; however, the panel felt that the group should aim for more high impact international publications given the size of the group. The group has 10 completed PhD degrees in the evaluation period and 28 current PhD students.

This group has a strong industry support and has had success in technology transfer. The overall funding situation of the group appears to be on a stable basis with many different funding sources. They have strong ties with ELIKO and several members of the staff have dual appointments in the department and in the institute. The group is emphasizing applied research and would benefit from being led towards more focus on basic research questions. Given the high number of PhD students, the group is encouraged to systematically develop scientific publishing, in order to target the key international forums of the area.

Assessment: The panel judges the research to be of **good international level.** The overall evaluation of the group is **good to excellent**.

4.4.17. Research Group: Faculty of Information Technology: Research Laboratory for Proactive Technologies

The Prolab group is led by senior research scientist Jurgen Preden and focuses on Cyber-Physical Systems (CPS) for dynamic environments, developing a CPS middleware platform. The research combines control systems, sensing and sense-making for dynamic runtime solutions for various application domains, such as border patrol and smart street lights.

The group consists of two professors and a total of 28 research positions. The funding level is modest, given the size of the group. The group has a good spread in the funding sources that include Artemis and European Defence Agency. The group has 5 completed PhD degrees for the period and 11 current PhD students.

Overall, the group has a solid output in terms of scientific articles, software and technology transfers. The group reports 29 ETIS 1.1 and a total of 487 publications for the evaluation period. Given the large number of publications, the panel felt that the group would benefit from having more ambition regarding the forums and perhaps even have fewer publications in more prestigious forums. To boost the basic research component, the group would benefit from identification of the relevant unsolved challenges for the next five to ten years and also focusing their research interests on a smaller set of promising directions.

The panel judges the research to be of **good international level.** The overall evaluation of the group is **good**.

4.4.18. Research Group: Faculty of Information Technology: Department of Computer Engineering: Dependable Computing Systems Design (DCSD)

The Dependable Computing System Design Group led by Prof. Jan Raik is a large research group consisting of 8 PIs that has a long history. The group has a solid basis in the past work of the PIs with new research directions pertaining to dependability in multicore systems. The group is addressing the new challenges by combining the expertise of the participating PIs. The level of synergy within the group appears to be good.

The group has a stable funding situation with many different funding sources that include institutional, personal, and national grants and both national and EU framework projects. 13 PhD degrees have been completed and the group has 18 PhD students. The number of PhD students does not appear to be high, given the number of PIs.

The group reports 19 ETIS 1.1 and a total of 323 publications for the evaluation period. The overall quality of the publications is good; however, the panel recommends more emphasis to be put on high impact forums.

They have excellent plans for international collaborations including using the EU funding for 'teaming', especially with other leading groups in Europe.

The group has renewed its organizational structure in a successful way. It has a dynamic leadership which is supported by established researchers representing the traditional strengths of the group. This serves as a positive example that could be followed elsewhere.

Assessment: The panel judges the research to be of **high international level.** The overall evaluation of the group is **excellent**.

4.4.19. Research Group: Faculty of Information Technology: Department of Computer Science: Formal methods based analysis, verification and planning

The group is led by Dr. Jüri Vain. The group is composed of 12 members.

The group presents a number of collaborations with other groups and the research covers a wide variety of topics: planning, fault diagnosis, software development methods, aspect-oriented modelling and testing, simulation modelling and analysis of emerging behaviour of multi-agent and swarm systems, cognitive robotics, tourism popularity analysis, automatic rule- and semantic-based impact analysis in DB systems for Business Intelligence and Data Warehouse services.

The impact of the research is limited, with only 6 ETIS level 1.1 publications (including a theory paper on non-linear control in the high impact IEEE Transactions on Automatic Control) and few high level conference papers.

The number of graduated PhD students in the period is 5, with 11 PhD students currently.

The panel judges, from the self-assessment and the presentation given, that the group is working on too many unrelated topics and this may have as a consequence a low level of publications, especially in quality. More focus is recommended in future activities and stronger international connections.

Assessment: The panel judges the research to be **fair international level.** The overall evaluation of the group is **satisfactory.**

4.4.20. Research Group: Faculty of Information Technology: Sociotechnical Systems and e-Governance Group

The group is led by Prof. Kuldar Taveter and it is a large group including 42 members, with 10 lecturers. Research has focused on information systems for e-governance, data mining, and interoperability. The group has a FP7 European Project on crisis management. The group presents some very good international publications, including papers in IEEE Transactions on Software Engineering and IEEE Transactions on Service Computing. Considering the size of the group the number of publications is rather low.

Assessment: The panel judges the research to be of **high international level.** The overall evaluation of the group is **good**.

4.5. National Institute of Chemical Physics and Biophysics

The KFBI unit is led by Prof. Mario Kadastik and has 8 senior researchers, 8 researchers, and 3 technical staff members. The unit is developing a large-scale scientific research infrastructure for scientific computing. The unit is part of the Estonian national research infrastructure (ETAIS) supporting both internal and external users. The main focus of the scientific computing pertains to physics, namely High Energy Physics (HEP) and the CMS project at CERN.

The KFBI datacentre consists of 5000 compute cores and 2PB of storage space with 10 GbE interconnect to the Geant global research network. The unit is a pioneer in using virtualisation and cloud computing in scientific computing. The cloud computing facilities are state of the art and the unit actively develops new software solutions for scientific computing.

4.5.1. Scientific Quality of Research

The submitted research publications of the unit are only in high energy physics, involving heavy computations on data from experiments at CERN and similar facilities. Bibliometric indicators suggest that the physics research is excellent. There are no publications in ICT venues, but the infrastructure usage and site visits indicate that ICT development and deployment are quite advanced. The computer facilities are mainly intended for processing the data from physics experiments, but there are several examples of significant spin-offs in organizing cloud facilities and data intensive computations for other applications.

4.5.2. Interaction between Research and Society: Public and Professional Activities

Not applicable.

4.5.3. Research Environment and Organization of Research

The research environment is mainly intended to advance high energy physics research. The overall funding of the unit relies on national R&D programs, targeted projects, and EU framework projects. The overall funding structure appears to be on a good basis with many funding sources.

4.5.4. Quality and Relevance of PhD Education

Not applicable.

4.5.5. Recommendations and Future Potential

The supportive role of the unit is visible in the publications and they are in other areas of science than ICT, mainly physics. The unit is encouraged to publish articles on the results of the operational research in ICT forums.

Assessment: The panel judged that the major research outputs of the unit are not in the ICT domain; however, they provide valuable knowhow and ICT infrastructure for large research endeavours. The advanced computer facilities are clearly a key factor for the unit's success in its basic natural science research. With this reservation, the panel judges the research to be of **high international level.** The overall evaluation of the unit is **excellent**.

4.6. University of Tartu

University of Tartu (est. 1632) is a multi-disciplinary classical university, the largest in Estonia. ICT research and development at the university can be divided to two parts. The Institute of Computer Science is responsible for the core computer science, software engineering, and cyber-security topics and the mainly interdisciplinary research that is carried out at the Faculty of Science and Technology.

4.6.1. Scientific Quality of Research

According to the self-assessment, the most significant achievements pertain to business process modelling, cryptography, and bioinformatics. As examples, the self-assessment report mentions the synergies in bioinformatics and cryptography, and the interdisciplinary research in mobile positioning.

The Institute of Computer Science has been involved as a partner in half a dozen FP7 projects, several COST actions, two IMI-funded projects (IMI-PREDECT and IMI-EMIF) and coordinates in Estonia two international ESFRI research infrastructures (CLARIN and ELIXIR) and Estonian High-Performance Computing infrastructure. The institute is also partner in the ERDF-funded Estonian Centre of Excellence in Computer Science (EXCS) and in the Software Technology and Applications Competence Centre – an R&D centre that involves 10 industry partners and conducts industry-driven research projects in the fields of services engineering and data mining. The Natural History Museum & Botanical Gardens, Institute of Ecology & Earth Sciences has also European projects involving ICT activities. The Institute of Technology is also involved in EU projects and will coordinate a Marie Curie Action. Funding has increased from € 1,741,854 in 2009 to € 4,445,197 in 2014, with a significant increase in institutional funding, other public funding, and international research grants and contracts.

All the groups have published at excellent international venues. The PIs have been very active in research and this is evidenced by the high levels of bibliometric indicators for a significant number of group leaders and faculty members. In addition to core scientific research, there are good examples of translational research that takes ideas to products— especially in collaboration with Competence Centres and private companies.

Assessment: The panel found the scientific quality to be **excellent** and the University of Tartu has several highly cited researchers, namely Dumas, Vilo and Remm, in the ICT areas. The research environment and the international collaborations are **excellent**.

4.6.2. Interaction between Research and Society: Public and Professional Activities

Based on their self-assessment reports, researchers at University of Tartu have been involved in several societal knowledge transfer initiatives. One of them is the “Estonian Business Process Management Roundtable”, which currently has around 90 members representing 40 Estonian organizations, including banks, telcos, insurance companies, utilities and transportation companies and several government agencies. Others include the ELIXIR - the European Bioinformatics infrastructure that aims to create interoperable data, tools, standards, computer and training infrastructure, including to the pharmaceutical and biotech industry. On the outreach front, efforts include organizing ICT teacher and student education: courses like “Make your own computer games”, teaching school teachers to manage interest groups for programming; creating web portals for kids of various ages for programming materials, and starting and running Estonian School Robotics programme and the FLL league, where more than 150 schools are involved. There have been several initiatives in OpenCourseWare with strong benefits to the society.

Tartu has also built strong industrial collaborations and resulted in several spin-offs; e.g. including active collaborations through EU framework programmes (FP7, H2020), Innovative Medicines Initiative, as well as STACC industrial research competence centre in Software Technologies and Applications. Joint industrial PhD supervision, e.g. Cybernetica, Quretec, Regio, Positium, ZeroTurnaround, etc., further strengthens this perspective.

Assessment: University of Tartu has demonstrated through various forms strong engagement with the societal aspects of research. They have looked at relevant issues (mobile localization, genome analysis, language technology) and have contributed in both educational programs and industrial settings. We rate the societal engagement and relevance to industrial needs as **excellent**.

4.6.3. Research Environment and Organization of Research

Research in the ICT area is organized around two units. The Institute of Computer Science (ICS) has a clear focus on ICT. It has over 800 students, 50 PhD students, and 80 academic and research staff. The institute conducts research in software engineering, cryptography, distributed systems, bioinformatics, data mining, programming languages, and language technology. Research at ICS is broadly split between six areas according to six professorships conducting research.

Faculty of Science and Technology is the second unit where ICT research is conducted. Computer Engineering research and education covers areas such as robotics and intelligent materials, as well as activities related to the first Estonian student satellite EstCube. Human geography research is heavily based on analysing mobile use trajectories; geographic information systems (GIS) complement the research in geography. Bioinformatics research groups are involved in a broad range of human genetics and other molecular biology related research, developing new methods and software. Similarly, the biodiversity research group has created novel data management and analysis solutions for maintaining the biodiversity data sets.

Assessment: ICT research in UT is well-organized, and the relevant infrastructure serves the activities reasonably well. The overall ICT activity in the University has been seeing a significant growth during the past years and space and infrastructure facilities are starting to feel a strain.

4.6.4 Quality and Relevance of PhD Education

Nominal period of PhD studies at University of Tartu is four years. However, only about 18% graduate in that time at the entire university, average time being 5.4 years. According to the PIs, there are many reasons for slow graduations, including far too low government scholarships (384€/month) that need to be complemented by extra-curricular activities, for example. All PhD students undergo the nominal coursework program for PhD students, and conduct research under the supervision of the research and academic staff members of the respective groups. For the PhD degree, at least three international peer reviewed publications, one in journals, at least one “first or primary author”, are required. Many students include international stay in other countries in their studies. And many have more than one supervisor, often from abroad.

Main ICT PhD studies are performed at Institute of Computer Science. At the ICS, since 2007 a boost to the institute PhD studies and research happened by appointing new professors and applying active international recruitment. ICS PhD degrees show the following dynamics—during 1999-2009 in eleven years, ten PhDs in computer science were awarded; while during the first five years of this decade (2010-2014), there were twenty. Intakes have meanwhile increased from 3-4 (until 2008) to 9 in 2010, and 12 in 2014. Of the new admissions, half are international students. And half of the graduates work in industry after completing their PhD degrees.

About half of PhD graduates work in industry, creating new core technologies for start-ups like ZeroTurnaround (Java dynamic recompiled class reloading after changes in code), Plumbr (memory leak detection), Cybernetica (Sharemind multi-party secret-sharing), for example. Of those continuing their academic careers, several have found top placements for post-docs—at Harvard, Geneva, Bristol, and Toronto universities, and Technical University of Munich, for example. They have been encouraged and given opportunities to attend summer schools and to pursue international student exchanges.

Some groups (and in particular the Software Engineering group) have experimented with a systematic employment of PhD candidates in projects directly related to their research. This practice should be encouraged and ways to provide PhD candidates with a regular sufficient income during their studies should be investigated further, as this appears beneficial to the groups and research activities as a whole.

Assessment: PhD education has been developing well in the last period and is expected to grow further. We found the cohort of students the panel interacted with extremely motivated and satisfied with the supervision they were afforded. They were more satisfied about their economic situation based on additional support received from the institution or industry, in comparison to other evaluated institutions.

4.6.5. Recommendations and Future Potential

University of Tartu has excellent potential in strengthening its already established position in ICT by leveraging the synergies of the research groups, developing the international networks, and actively developing international recruitment of top talents. The success of the University in attracting 2 ERC grants is excellent—it is encouraged to attempt such ambitious world leading applications in the ICT domain as well.

Recommendation:

1. The University of Tartu should continue developing the ICT research by emphasizing international recruitment and collaborations across the research groups.
2. They should encourage systematic practices in PhD education, especially with respect to funding practices (fairness) and monitoring of milestones
3. The panel commends the move to develop an English-taught Master's programme in Computer Science to broaden the intake base of the students as well as serving internationalization goals.
4. Developing the infrastructure necessary for supporting the growth in the ICT area.
5. There is potential in combining the research efforts of several groups for achieving more significant international impact.
6. There may be areas such as Machine Learning that the department could consider having a presence in, given the cross cutting nature and relevance of such a field to many of the research that is ongoing at the department.

4.6.6. Research Group: Institute of Computer Science: Bioinformatics and IT

The group is led by Prof. Jaak Vilo, a well-established leader in his field, who also heads the Computer Science Department. Their research involves developing and applying cutting edge computer science techniques and tools for bioinformatics. Their excellent impact in bioinformatics is evidenced by the substantial number of publications in high impact journals as well as citation counts. The group has found a good balance between basic research and development, with nice connections with local industry as well as funding from medical and gene bank initiatives in Europe. The research highlights include functional profiling of gene lists from large-scale experiments with the g:Profiler tool, the MEM+RRA robust rank aggregation and mining very large data collections, research on stem cell regulation as well as secure and privacy-aware data processing for bioinformatics. The group is funded by several financing sources, including European Framework Programme projects, European Innovative Medicines Initiative projects EMIF and PREDECT, an ERA-Net, and participation in the Elixir European bioinformatics research initiative.

The group has a solid approach to PhD education evidenced by the quality of the dissertations and the placement of the PhD graduates. PhD graduates of the group have fared well in academia with post-doctoral positions at Toronto, Bristol and Harvard to give some examples.

Based on the evidence, panel judges the research to be of **high international level.** The evaluation of the group is **excellent**.

4.6.7. Research Group: Institute of Computer Science: Software Engineering

This group is led by Prof. Marlon Dumas, an internationally recognised and highly cited researcher in the field of Information Systems. The group is extremely international in its membership and has been very successful with recruiting globally. The group has attracted significant funding, including two European Framework Programme projects and a Eureka project.

The key research topics of the group pertain to business process management and business and software process analytics. The group has outstanding results in these areas with scientific articles in top forums and several best paper awards. The group is also active in commercialization of the research results and the work has resulted in a number of patent applications and several start-up companies. The technology transfer of research results with the help of the STACC competence centre is exemplary. The results of the research are not only published in excellent journals and conferences and highly cited, but they also result in tools integrated in international software initiatives for research and teaching in the area of Process Model management, such as Signavio and Prom, and in a book on process modelling which is widely used internationally.

The group has 9 PhD students and has produced three PhD graduates since 2011. They have a good timely completion rate statistics amongst the PhD students and a proactive management style with appropriate feedback to the PhD students, which is to be commended.

Based on the evidence, panel judges the research to be of **high international level.** The evaluation of the group is **excellent**.

4.6.8. Research Group: Institute of Computer Science: Distributed Systems

The group is led by Prof. Eero Vainikko, with the leadership of the recently (2012) established mobile and cloud lab being handled by Assoc. Prof. Satish Narayana Srirama. The Distributed Systems research group covers High Performance Computing (HPC) and distributed systems. The group has more recently in 2012 expanded to cloud and mobile computing, which seems to be on a promising track as they mature. Cloud computing is a very relevant research theme to complement the HPC research. They have attracted funding from EU FP7 project REMICS and participation in a EUREKA Project SITIO. The research results of the group include an efficient linear system solver for supercomputers, applying MapReduce for iterative scientific computing, and resource-intensive task delegation from mobiles to the cloud. Publications include some good journals, the majority are in international conferences—the panel felt that the quality of output could be improved, to be more precise, they are encouraged to aim for higher impact venues.

The group has several international collaborations with international research groups, resulting in joint publications.

The group would benefit from a clearer strategy for leveraging synergies between HPC, cloud computing, and new data analytics solutions inspired by MapReduce and related developments.

Based on the evidence, the panel judges the research to be of **good international level.** The overall evaluation of the group is **good**.

4.6.9. Research Group: Institute of Computer Science: Computational Neuroscience

This is a newly established group (2013) led by a senior researcher Raul Vicente, supported through institute funding and some BIIT-led funding. The group consists of 2 postdoctoral researchers and 4 PhD students as well as M.Sc. students. The group is interdisciplinary and the group members have some background in subjects such as physics, psychology and bioinformatics in addition to computer science.

The publication record of the lead PI is excellent—this bodes well for the future. However, in order to sustain and improve this, they are likely to face a challenge to educate and bring up to speed the basic levels of neuroscience, given that there is no wet neuroscience being researched in the university. The panel recommends strengthening international links in order to accommodate this.

During the first year, the group has focused on the research strategy, building the team by active recruitment, and developing the necessary infrastructure.

Given that the group is relatively young, the panel will **defer** judgment on the final assessment. The panel sees **excellent** potential in the group.

4.6.10. Research Group: Institute of Computer Science: Cryptography and Theoretical Computer Science

This group represents a number of subunits, with 6 topics led by 5 lead PIs (Sven Laur,Helger Lipmaa, Vitaly Skachek, Dirk Oliver Theis, Dominique Unruh). The group was restructured in 2011 with the recruitment of Unruh and Lipmaa. The group addresses six key research topics, namely classical cryptography, quantum cryptography, coding theory, combinatorics and algorithms, security, and verification of cryptography. All topics are related to computer security.

The research highlights include quantum proofs of knowledge, privacy-preserving data-mining, efficient non-interactive zero-knowledge proofs, communication complexity and the rank of matrices, and permutation codes. The group claims 8 level 1.1 publications, which seems a bit low. However, it is also a bit misleading since their list of 30 best papers includes 11 articles in top or at least internationally well recognized journals (*J Cryptology, European J Combinatorics, IEEE Tr Information Theory, IEEE J selected areas in communication, Theoretical Computer Science, Journal of Computer Security, Bioinformatics, European J. Operations Research*), besides 7 papers in the very best conferences (FOCS, Crypto, Eurocrypt, ICALP). Remaining top 30 items are papers in more specialized cryptography and security venues like ACM CCS, PKC, SCN, CSF, Eurocomb. Publication rate of top level papers has increased significantly over the evaluation period.

Many of the students (10+) are working in related industrial SMEs such as Cybernetica. They are contributing to several practical applications such as e-voting.

The group is recommended to keep its current high quality and volume of output, and to develop some additional internationally financed projects.

Based on the evidence, panel judges the research to be of **high international level.** Because of the strong upward trend the overall evaluation of the group is **excellent**.

4.6.11. Research Group: Institute of Computer Science: Language Technology

The group is led by senior researcher Heiki- Jaan Kaalep and is genuinely multidisciplinary including linguistic expertise in the group. This topic was described of national importance and the aim was to introduce a paradigm shift in Estonian linguistics.

The group has a healthy funding portfolio ranging from IUT, FP7, Estonian Norwegian grants, COST action, ESF and ELT grants. They have published two books at an international level.

The new directions of the group include understanding non-standard language, application of the results in multimodal interaction and robotics, and statistical machine translation. The panel felt that these directions combine the expertise and background of the group with fresh themes.

The group has 6 PhD students and 3 PhD students have graduated since 2009. The current PhD topics are application-oriented.

It is recommended that a close cooperation with the other research groups working on the Estonian language is maintained, constantly sharing the results and coordinating corpora collections.

The panel judges the research to be of **good international level.** The overall evaluation of the group is **good**.

4.6.12. Research Group: Institute of Computer Science: Programming Languages

The group is led by Prof. Varmo Vene. The group focused on teaching up to 2013 and have since been reconsidering their research goals and ambitions. Their publication records reflect this phase. Their research focus has been on static code analysis of Java and SQL. Some applied research using this technology has been developed for fast re-deployment of dynamic changes in the Java EE ecosystem. Results from this has been utilised in collaboration with STACC , especially as ZeroTurnaround start-up.

The group has 3 PhD students and 2 PhD students have graduated since 2009.

The group has published three ETIS 1.1 articles during the evaluation period. The panel felt that to be a small number.

The panel recommends that the group increases the efforts to further rethink their research vision and publication strategies.

The panel judges the research to be of **fair international level.** The overall evaluation of the group is **satisfactory**.

4.6.13. Research Group: Institute of Technology: Intelligent Material and Systems Laboratory

This group is led by Prof. Alvo Aabloo, with a total of 9 teaching and 6 research staff. The focus of the research is based on ion-conducting polymers and several applications of that to soft robotics, sensing and mechatronics. There is also a relatively young group focusing on computer vision, mini-humanoid research (robocup) as well as educational robotics and outreach.

One notable research result is the robotic mannequin body that has been commercialized by the fits. me company.

The group has a strong interdisciplinary focus that includes computational material science, material science, robotics, chemistry, computer science and electronics. There is also excellent potential to collaborate with educational researchers as part of the outreach and STEM education—one group has implemented this in collaboration with the Estonian schools.

The group reported 75 ETIS 1.1 and a total of 135 publications for the evaluation period. The Institute of Technology is also involved in EU projects and will coordinate a Marie Curie Action on micro-actuators (2015-2018).

The group has 9 PhD students, 5 of which are in the ICT area. 7 PhD degrees have been completed since 2009.

The panel commends the strong publication record of the group as a whole, funding portfolio as well as applied elements of the research. There is a recommendation to renew/reconsider the way to move the research that is being carried out on the purely IEMS elements as well as the one on the robot vision and to plan moving them towards more cutting edge research.

The panel judges the research to be of **high international level.** The overall evaluation of the group is **good to excellent**.

4.6.14. Research Group: Department of Geography, Ecology & Earth Sciences: Geo-informatics & Cartography

The group is led by Prof. Rein Ahas. The research focuses on using computer science techniques to interpret and visualize large-scale data related to active position system, mobile tracking and localization.

The group has produced 42 ETIS 1.1. and a total of 88 publications during the evaluation period. The number and quality of the publications is on a very good international level, albeit in urban planning, cultural geography.

The main research results include software for calculating landscape indices for predictive mapping, mobile positioning solutions for tourism geography and everyday mobility, and big mobile data for urban and social studies. The group has a unique opportunity to explore large mobility datasets for new discoveries pertaining to human mobility and behaviour. They have a good relationship with the Estonian Tourism department and have utilized this expertise for applications related to tourism. The research has resulted in a spinoff company called Positium LBS.

While the research carried out by this group is predominantly in the Geosciences area, the panel recognizes the impact that the ICT related research done by the group has created in their domain. With this caveat in context, the panel judges the research to be of **high international level.** The overall evaluation of the group is **good to excellent**.

4.6.15. Research Group: Institute Molecular and Cell Biology: Bioinformatics

This group is headed by Prof. Maido Remm, who also leads the Centre for Excellence in Genomics. Their research interests and topics include DNA based diagnostic tests, Genome sequence assembly analysis and phylogenetic analysis of protein sequences.

One of their key contributions is the improvement of the Primer3 -- where they added the thermodynamics elements of the DNA-DNA interactions, and the Primer3 website is heavily accessed and used over a 1000 times a day around the world.

The group is has published 38 ETIS 1.1. publications in high quality scientific forums and one patent. Their main funding comes from the Centre of Excellence (Archimedes) and the Estonian Ministry of Research and Education.

The group has 3 PhD students and 6 PhD students have completed their dissertations. The PhD graduates have continued on the academic career path with post-doctoral positions at the University of Illinois, Oxford University, and University of Bergen.

The research carried out by this group has focused on large scale biological sequence analysis, which uses the ICT techniques as a tool for creating impact in their domain.

Although the direct impact of the research lies outside the pure ICT domains, the panel judges the research to be of **high international level.** The overall evaluation of the group is **excellent**.

4.6.16. Research Group: Natural History Museum & Botanical Gardens, Institute of Ecology & Earth Sciences

The group is led by Prof. Urmas Kõljalg and the group develops IT solutions for the creation, management, analysing, and publishing of biodiversity datasets.

Their PlutoF cloud solutions to delimit, identify, communicate and work with DNA-based species hypotheses is one of their major **research** achievements in the ICT domain and has more than 1400 users over 40 countries.

The group participates in the European project EU BON on building the European diversity observational network and to an INTERREG project Balticdiversity.

The panel found the research and publication list provided to be only peripherally connected to the ICT domain. However, the current model of collaboration seems to be fruitful, we encourage the group to strengthen this further. The research carried out by this group has a focus significantly outside the core ICT domain and the panel found it difficult to evaluate the original research to the ICT domain. Therefore, the panel assessment is **Not Applicable**.

4.7. Software Technology and Applications Competence Centre

The Software Technology and Applications Competence Centre (STACC) is a research and development organization established in 2009 to conduct industrial research in the software department. STACC is a joint initiative between the University of Tartu and Tallinn Technical University, and leading IT companies and users, i.e., Cybernetica AS, Regio AS, Nortal AS, Quretec OÜ, Browserbite OÜ, eHealth Foundation, Skype Technologies OÜ, ZeroTurnaround OÜ and Massi Miliano OÜ.

STACC main focus on industrial research is data mining and software engineering projects.

STACC is one of the competence centres financed by Enterprise Estonia.

4.7.1. Scientific Quality of Research

STACC has been very active in research and applied research. Many publications at international level have originated from the cooperation with universities. Eight patents have been filed. PhD students have been involved in applied research on themes linked to their research. Several research themes are in the Areas of Software and Services Engineering and of Data integration and Mining, organized in twelve research streams.

Assessment: STACC presents an **excellent** research level and very good collaboration with universities in the development of applied research.

4.7.2. Interaction between Research and Society: Public and Professional Activities

The research developed at STACC has tight links with industry and a focus on applied research. Projects in the software area have also resulted in the creation of new companies in web user interface testing (Browserbite), backend monitoring (Plumbr), and to improve software development productivity (ZeroTurnAround). Ongoing research focuses on data mining, in particular social network analysis and service usage prediction, data visualization for biomedical data and security in data mining and on mobile phones.

Assessment: STACC is active in applied research on several research themes and some of the research has resulted in promising results which are being developed in new companies originated from the research. Ongoing research is focusing on innovative themes with a very good potential growth.

4.7.3. Research Environment and Organization of Research

The Competence Centre is funded by a special government fund for Competence Centres. The research activities are well-organized and characterized by a special focus on applied research. The collaboration with universities is mainly based on a consultancy model, where university professors help the development of new ideas and PhD students contribute to the development of ideas.

In the future, a challenge for the Centre is going to be the ability to find instruments for its continuation. It will be a challenge is to find a business model for interacting with companies and start-ups and generating revenue from projects.

Assessment: The Centre is well established and it has very good potential for development in the future, provided the appropriate development model to make it progressively independent from national funds is provided.

4.7.4. Quality and Relevance of PhD Education

STACC, as a research institution, does not have PhD programmes. However STACC hires PhD students within applied research projects. In most cases, the research results are included as a part of the PhD thesis. The first 4 PhD theses have been defended in 2013/2014.

Assessment: **Good** collaboration with universities involving PhD students is ongoing.

4.7.5. Recommendations and Future Potential

Recommendations:

STACC has a good potential for further development. In the future, a clear model for interacting with industry and start-ups has to be identified in order to manage IPR and to generate revenues from ideas to further sustain research initiatives. Participation to calls for funding at international level should also be further pursued to identify possible additional resources.

Assessment: The panel judges the research to be of **high international level.** The overall evaluation of the unit is **excellent**.

5. Appendices

Appendix 1.
Terms of Reference for the Evaluation Panel

ANNEX II TO THE CONTRACT FOR SERVICES
Ministry of Education and Research

Directive of the Minister (non-official translation)
Tartu *04 September 2014 No. 369*

Approval of subject, participants, personnel and detailed organisation of the 2014 targeted evaluation of research in information and communication technologies

On the basis of Subsection 20^2(3) of the Organisation of Research and Development Act:

1. To organise the 2014 targeted evaluation in the field of research in information and communication technologies (hereinafter ICT), sub-field of natural sciences and engineering field (hereinafter evaluation).

2. I assign research in ICT and related fields as the subject of the evaluation:
- Computer science;
- Computing systems;
- Electronics and communication.

3. I assign the following institutions as participants in the targeted evaluation:
- Tallinn University of Technology;
- Tallinn University;
- University of Tartu;
- Cybernetica;
- ELIKO Technology Competence Centre in Electronics-, Info- and Communication Technologies;
- Software Technology and Applications Competence Centre;
- National Institute of Chemical Physics and Biophysics.

4. I appoint the following people as members of the international panel (hereinafter evaluation panel) responsible for carrying out the evaluation:
- Stefan Arnborg, professor emeritus at KTH Royal Institute of Technology, panel chairman;
- Sasu Tarkoma, professor at University of Helsinki;
- Barbara Pernici, professor at Polytechnic University of Milan;
- Sethu Vijayakumar, professor at University of Edinburgh;
- Olli Yli-Harja, professor at Tampere University of Technology.

5. I approve the detailed procedure for executing the evaluation (appended).

6. This directive may be challenged within 30 days of publication by filing a complaint with the Tartu Administrative Court in accordance with the Code of Administrative Court Procedure.

/Signature/
Jevgeni Ossinovski
Minister

Annex
APPROVED
by Minister of Education and Research directive No. 369 from 04 September 2014

Detailed procedure for performing the targeted evaluation

1. The evaluation is carried out to provide information on research in ICT and the level, productiveness and influence of research fields related to ICT to the research community, research and development institutions, research funding organisations, research policy planners and society at large. The results of the evaluation serve as an input for preparing research policy decisions and measures pertaining to research in ICT and related fields, further development of the field, preparation of development plans and introduction of necessary changes.

2. Before assuming their positions the members of the evaluation panel carrying out the evaluation shall sign a declaration of independence and confidentiality in a format approved by the authority organising the evaluation, and also undertake not to use or disclose to third parties any public or non-public information, such as data, documents and other information they learned or to which they were referred in the course of the evaluation after the end of the evaluation process.

3. For carrying out the evaluation, the institutions participating in the evaluation shall submit, through the corresponding environment of the Estonian Research Information System, by 17 October 2014:

- a self-evaluation report (including general information on the institution, overview of research and development activities, self-evaluation, overview of cooperation and activities aimed at the public during 2009-2014) in a format approved and published by the institution carrying out the evaluation;
- data which serve as a basis for the evaluation (including information on personnel, research results, doctorate studies, infrastructure, research projects and financing during 2009-2014).

4. The evaluation panel retains the right to:

- receive additional information necessary for the evaluation from participants in the evaluation, the authority organising the evaluation, and the committee preparing the evaluation, formed on the basis of the Minister of Education and Research directive No. 235 of 30 May 2014, “Formation of the committee for preparing the 2014 targeted evaluation of research in ICT” (hereinafter Steering Group);
- visit the institutions participating in the evaluation for the purpose of obtaining additional information necessary for evaluation, providing at least 10 working days advance notice.

5. Based on the information specified in clauses 3 and 4 of this directive’s annex the evaluation panel shall analyse the quality of research and PhD studies in the field of ICT, the research environment and organisational structure of the institutions participating in the evaluation, as well as the public influence and pertinence of their research and development activities related to ICT.

6. The evaluation panel may use meetings or other formats as a working format pursuant to the decision of the evaluation panel and involve experts who possess the information necessary for carrying out the evaluation, if necessary.

7. As a result of the analysis specified in clause 5 of this directive’s annex the evaluation panel shall compile a report on the target evaluation of research in ICT in the extent specified in clause 2 of this directive, i.e., in the report, the panel shall:

7.1. evaluate the quality of research in ICT (hereinafter field) in Estonia compared to the international level, including:

- identify, evaluate and analyse the strengths and weaknesses of the research and development activities in the field in institutions evaluated and in Estonia generally;
- assess the output and quality of the performed research;
- assess the collaboration with key academic partners at home and abroad;

7.2. evaluate the societal and professional activities undertaken in the field by institutions evaluated, including:

- assess the links between research and development, and the requirements of industry and different policies;
- assess the collaboration with key stakeholders in the Estonian society;

7.3. assess the organisation of research in the institutions evaluated, including:

- assess the national organisation of research in the field and the links between the research and national strategies as well as development plans;
- assess the general organisation of research in the institution and the links between the research and institutional as well as national strategies and development plans;
- assess the condition of the infrastructure of an institution for the purpose of guaranteeing the sustainable development of research;

7.4. assess the quality and relevance of the doctoral studies in the field, including:

- assess the quality and volume of doctoral studies compared to the international level based on the need to ensure the sustainability of research and development;
- assess the links between doctoral studies with research and societal needs;
- assess the supervision and level of efficiency of doctoral studies;

7.5. assess the future potential of the institution evaluated;

7.6. give recommendations and make proposals with regard to the further development and financing of research and development activities and doctoral studies in the field and the performance of necessary changes in Estonia, including providing suggestions and recommendations:

- for the further development of research policy in Estonia;
- for the further development of research and development activities in institutions evaluated;
- for the further development of doctoral studies;
- for ensuring the further sustainable development of research and development in the field.

8. The research, societal, state-oriented and professional activities and PhD studies should be assessed according to the following:

8.1. Assessed units should be rated according to the following scale:

- Excellent: The majority of the submitted works are at a high international level and virtually all others at a good international level.
- Good: The majority of the submitted works are at least at a good international level and virtually all others at a fair international level.
- Satisfactory: The majority of the submitted works are at least at a fair international level.
- Unsatisfactory: None, or virtually none, of the submitted works are at a fair international level.

8.2. International level should be rated according to the following scale:

- High international level means work which is apt to arouse serious interest within international academic communities and which in principle, if offered, could be published by the leading international publishers or in the leading international journals with the most rigorous editorial standard.
- Good international level means work which is of undisputed relevance for international academic communities and which could be published by well-known international publishers or in well-known international journals.
- Fair international level means work which is of possible relevance for international academic communities and which has been published abroad or by well-known national publishers or in well-known national journals.

8.3. Assessments should be given in international and national comparison.

8.4. National comparison should be based on comparison of assessed institutions.

9. In their assessments the evaluation panel shall take into account the following specific topics and conditions throughout all the subsections of the field:

9.1. Are there topics important for Estonia but do not receive the necessary attention?

9.2. Are there unsubstantiated overlaps in research between institutions?

10. The evaluation panel shall submit the targeted evaluation report and other materials compiled during the activity of the evaluation panel to the authority organising the evaluation by 1 March 2015.

11. The authority organising the targeted evaluation shall forward the report to the Steering Committee for an opinion. The Steering Committee shall submit its opinion on the evaluation report to the authority organising the targeted evaluation within 10 working days.

12. The authority organising the targeted evaluation shall forward the evaluation report with the opinion of the Steering Committee to the Ministry of Education and Research and to the Ministry of Justice within 5 working days. The authority organising the evaluation shall organise a public presentation and further discussion of the evaluation report as well as the compilation of an action plan in cooperation with the aforementioned Ministries.

/Signature/
Taivo Raud
Head of department of research policy

Appendix 2.
Classification of ICT research

Computer Science
Computer science, numerical analysis, systems, control;
Informatics, systems theory;
Artificial intelligence;

Computing systems
Systems engineering, computer technology;
Automation, robotics, control engineering;

Electronics and communication
Signal processing;
Electronics;
Microelectronics;
Telecommunication engineering.

Appendix 3.
Evaluation panel members

Professor emeritus Stefan Arnborg, chairman of the panel

Stefan Arnborg is a professor emeritus of the Royal Institute of Technology. He has served as professor of Computer Science at the department of Numerical Analysis and Computer Science of the Royal Institute of Technology for 30 years. He is also a former scientific Advisor of the Swedish Institute of Computer Science.

He has published in areas of theoretical computer science, data engineering and reasoning with uncertainty, human brain informatics, command and control, gaming as uncertainty management tool.

Professor Arnborg is a member of Editorial Board of the Nordic Journal of Computing and a reviewer for many major computer science journals and conferences. He has supervised ca 20 PhD theses.

He has served as an evaluator for different universities and research councils in Sweden, Denmark, Finland, Ireland and Estonia. He is also a former chairman of expert panel on Computer Science of Swedish Research Council.

Professor Arnborg is a foreign member of Finnish Academy of Science and Letters.

Professor Barbara Pernici

Barbara Pernici is a full professor of Computer Engineering at the Politecnico di Milano. She graduated in Electrical engineering at Politecnico di Milano and has a MS in Computer Science from Stanford University. Previously she was a full professor at the University of Udine (1990-1993) and associate professor at the Politecnico di Milano (1987-1990). Her research interests include process and service design, adaptive information systems, data quality, and energy efficiency in information systems.

She has published more than 50 papers in international journals, co-edited 26 books, and published about 350 papers at international level. She was a scientific leader in the European project GAMES (Green Active Management of Energy in Service Centers). She has also participated in many ESPRIT and IST European projects and has been chair or member of the program committee in several international conferences. She is chairing the Steering Committee of the CAiSE Conference. She was chair of the IFIP TC8 Information Systems Technical Committee and of IFIP Working group 8.1.

She has been involved in the editorial boards *of Requirements Engineering Journal, Journal on Cooperative Information Systems,* and the *ACM Journal of Data and Information Quality*. She is currently member of the editorial board of *ACM Transactions on the Web* and of the *Journal of Cooperative Information Systems.*

Professor Pernici is the Dean of the PhD School of the Politecnico di Milano and a member of the Academic Senate of the university.

Professor Sasu Tarkoma

Sasu Tarkoma is professor of Computer Science and Deputy Head of the Department of Computer Science at the University of Helsinki. He has received his PhD in Computer Science in 2006 from the University of Helsinki. He is also affiliated with the Helsinki Institute for Information Technology HIIT and Aalto University.

Professor Tarkoma has supervised 6 PhD students. He has authored 4 textbooks and has published over 50 journal articles and book chapters. He has 5 granted US Patents and over 25 patent applications. His research interests are Internet technology, Internet of Things, and mobile and ubiquitous computing.

He is a member of the Finnish Union of University Professors, Senior Member of the Institute of Electrical and Electronics Engineers (IEEE), Professional Member of the Association for Computing

Machinery (ACM), and member of the COST Information and Communication Technologies Domain Committee for the period 2010-2014.

He is a member of the editorial board of the Computer Networks Journal and member of organizing and scientific committees of many international conferences.

Professor Sethu Vijayakumar (OK)

Sethu Vijayakumar is the Professor of Robotics and the Director of the Edinburgh Centre for Robotics (ECR) in the School of Informatics at the University of Edinburgh. He also holds additional appointments as an Adjunct Faculty of the University of Southern California (USC), Los Angeles and a Visiting Research Scientist at the RIKEN Brain Science Institute, Japan. He has a PhD ('88) in Computer Science and Engineering from the Tokyo Institute of Technology.

His research interest spans the fields of statistical machine learning, robotics, sensorimotor control, and computational neuroscience. He is the author of over 150 highly cited publications in these fields and has pioneered the use of large scale machine learning techniques for real-time, online adaptive control of anthropomorphic robotic systems. He is the winner of the IEEE Vincent Bendix award, the Japanese Monbusho fellowship, the NEC C&C Student award and most recently the 2013 IEEE Transaction on Robotics Best Paper Award. He has served on numerous EU, NSF and DFG grant review panels and program committees of leading international machine learning and robotics conferences. He had led several national and international research projects funded through research councils as well as the industrial partners. Since August 2007, he holds the prestigious Senior Research Fellowship of the Royal Academy of Engineering, co-funded by Microsoft Research.

Professor Vijayakumar is a keen science communicator and in recent years, has been active in conceptualising, producing and presenting several public outreach events to engage with the general public and children on all things science and engineering. He is a Fellow of the Royal Society of Edinburgh.

Professor Olli Yli-Harja

Olli Yli-Harja is the Professor of signal processing in the Department of Signal Processing at the Tampere University of Technology and leads the Computational Systems Biology research group. He is also an Affiliate Professor in the Institute for Systems Biology, Seattle.

During the years 1988-1992 Olli Yli-Harja was a research scientist at the Technical Research Centre of Finland, in 1993-1996 he was a lecturer in computer science in Helsinki University of Technology, and in 1997-1998 an Assistant Professor in University of Helsinki. In 1998 he was a research fellow at East Anglia University, Norwich, UK. In 1998-2001 he was a senior researcher at the Institute of Signal Processing in Tampere University of Technology. In 2005, he was a visiting scientist in the University of Texas M. D. Anderson Cancer Centre, Houston.

He is an author of more than 170 publications in the areas of computational systems biology, including development of computational tools and software for systems biology utilizing advanced methods of signal processing and statistics.

Appendix 4.
Self-assessment Form

Self-assessment Form of the research group
Evaluation of Research in info and communication technologies (ICT) in Estonia (2009–2014)

A.1.**GENERAL REMARKS**

All data in this self-assessment form should represent research in ICT and should cover only R&D activities and R&D related personnel.

A.2. GENERAL INFORMATION
Institution:
Address:
Phone:
Internet home page:

Unit/Group:
Internet home page:
Contact person:
Phone:
Email:

A.3. Unit's/group's research profile within research in ICT (give estimate of the percentage)
(Calculations should be based on proportions of research financing. The percentages should add up to 100.)

Research field (see annex 1)	**(%)**
Computer science	
Computing systems	
Electronics and communication	
Other (please specify)	
Total	**100%**

A.4. Research-involved personnel (positions).

Staff / year	2009	2010	2011	2012	2013	2014
Teaching staff (if relevant):						
Professors						
Docents						
Lecturers						
Assistants						
Research staff:						
Research Professors						
Leading Researchers						
Senior Researchers						
Researchers						
Technical personnel						
Administrative personnel						
Total						

More detailed information about research personnel is in annex 2.

A.5. Research funding (ETIS-based).

Source of funding / year	2009	2010	2011	2012	2013	2014
Institutional research grants						
Targeted financing projects						
Personal research grants						
Estonian Science Foundation grants						
National R&D programs (also from different Ministries)						
Other national public financing (e.g. Core Infrastructure support, Enterprise Estonia, other Ministries, Environmental Investment Centre, local authorities, etc.)						
EU Framework Programme projects						
Estonian research contracts						
Foreign research grants and contracts (excl EU FP)						
Total						

More detailed information about research funding and projects is in Annex 3.

A.6. Research output.

Total number of publications and patents (2009-2014)	Number
1. Scholarly articles indexed by Thomson Reuters Web of Science (excluding articles indexed in Thomson Reuters Conference Proceedings Citation Index) and/or published in journals indexed by ERIH (European Reference Index of the Humanities) categories INT1 and INT2 and/or indexed by Scopus (excluding chapters in books) (ETIS 1.1)	
2. Scholarly monographs (ETIS 2.1 and 2.2)	
3. Articles/chapters in books published by the publishers listed in Annex (including collections indexed by the Thomson Reuters Book Citation Index, Thomson Reuters Conference Proceedings Citation Index, Scopus) (ETIS 3.1)	
4. All publications in total (including publications described above).	
Patents / patent applications	

List of the best publications (max 30) with links to full text.

A.7. PhD Studies *(if applicable)*
More detailed information about PhD studies is in annex 4.

THE UNIT'S/GROUP'S SELF-ASSESSMENT

B.1. Short description of R&D activities and organisation.
(Max 1 page)

B.2. Short description of PhD studies
(Max 1 page, if applicable)

B.3. Summarise your most significant scientific achievements for the period 2009-2014.
(Max 1 page, max 5 achievements)

B.4. Summarise your most significant societal and professional achievements/impact for the period 2009-2014.
(Max 1 page, max 5 achievements considering norms, standards, guidelines and other professional activities, industry contacts, collaboration with different professional unions, TV or radio shows, regular seminars etc.)

B.5. What are the future plans for your unit/group in terms of …
a) … direction of the research?
b) … direction of the national and international cooperation?
(Max 1 page in total)

B.6. Most important national collaboration.
(List max 5 most important national research partners (incl. your institution), max 1 page)

B.7. Most important international collaboration.
(List max 5 most important international research partners, max 1 page)

B.8. Please discuss what Strengths, Weaknesses, *Opportunities and Threats* that you see at your unit/group.
(Max 1 page)

Appendix 5.
Data provided by the Estonian Research Information System ETIS

R&D activities:
- List and description (incl. project number, title, description, project leader, senior personnel, duration, financing) of R&D projects;
- Summarized data tables.

Personnel:
- Names, positions and CVs;
- Summarized data tables by positions held;
- Age structure table;
- Defence of doctoral dissertations;
- Implementation of doctoral studies;
- Awards and recognitions.

Outcomes of R&D activities:
- List and description of publications by classification;
- List and description of other R&D based activities;
- List of most important publications (up to 30) with full text.

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