KTH International RAE 2008

REPORT PANEL 2: INFORMATION and COMMUNICATION SYSTEMS

Chairperson's Summary

In performing this evaluation the following process was followed. The Expert Panel met on Tuesday June 24th, with the Coordinator of the Information and Communication Systems area; the Panel listened to presentations by the area coordinator Prof. Carl Gustaf Jansson; and by the coordinators of each UoA: Prof. Paul Johanesson on Information and Software Systems; Prof. Jens Zander on Computing and Communication Systems; Prof. Anders Askenfelt for Human Communication; Prof. Rolf Stadler on Network-Information-and Control Systems; Prof. Mikael Skoglund on Telecommunications. Following each presentation and at the end of the session the Panel engaged in discussion and a question and answer period.

In an effort to obtain focused information on certain critical concerns, the Panel asked each UoA coordinator to prepare for the follow up Interviews answers and brief descriptions to the following questions:
- Describe the three most powerful ideas that they are working on.
- Provide an assessment as to what is their standing internationally.
- Describe succinctly, what distinguishes them from other research groups.
- Provide information on inventions, patents, start-ups, and other metrics of impact.

Then on June 25, 26, the Expert Panel met with the coordinator, representative faculty and students, with each UoA, listened to presentations, and followed Lab demos and posters. Questions and answer periods were interspersed throughout each Interview. The Panel met several times to integrate opinions and recommendations. A summary debriefing of the findings was given to each coordinator on June 27.

The Panel would like to thank all faculty, students and staff for their efforts to prepare the reports, participate in the presentations, demos and posters, and in the question and answer periods. The information provided was extremely helpful.

GENERAL ASSESSMENT OF THE RESEARCH FIELD

Information and Communication Systems (ICS) is a field that increasingly permeates all aspects of life and work, and all sciences and technologies. Every technological university that aspires to have a leadership standing world-wide must have a leadership standing in ICS and must integrate its components, methods and applications in all sciences and technologies, from both a research and education perspective. KTH has excellent strengths overall in this field. Several groups are world leading. Most have excellent collaboration with industry and society. The field and its components are relatively young, some just emerging, and very heterogeneous. The field involves many disciplines. Thus it is a great challenge to organize its programmes and coherently integrate the efforts of the UoAs involved. It is precisely here that

KTH leadership and management should expand considerably their efforts and planning. Overall, the UoAs comprising this field currently are not integrated to the fullest. Achieving this integration will propel KTH to be a world leading university in this critical field.

There are several opportunities for KTH, identified via this RAE. They are:
- Opportunity to leverage media technology expertise towards new application domains – c.f. persuasive computing.
- Opportunity for KTH to lead in systems engineering by developing a broad synergy on systems view and methods of systems design, testing and validation.
- Opportunity to become a world-leader in mobile information networks by developing stronger synergies between telecomms, information systems, mobile environments, HCI.
- Opportunity to achieve research leadership in "true telepresence" synergy between telecommunications and human communications.

There are several synergies or actions that are needed, which were identified via this RAE. They are:
- Clearly the area of communication and information networks is an area of leading strength in KTH but stronger synergy should be developed between the UoAs involved in these fields.
- Need to strengthen core technical areas in information systems – c.f. databases, metadata management.
- The area of socio-techical information systems and networks is of rapidly increasing significance with many applications but substantially more resources and planning are needed to make it of strength for KTH.

The following two factors were identified as affecting KTH as a whole:
1) As user and user-to-system interactions become pervasive, the UoA on Human Communications could have much broader impact in several KTH technical areas – e.g. through Visualization Interaction Communication, built environment, Centre for Interaction Design, information systems, sustainability, systems design, …
2) It is essential for KTH to sustain world leadership in mobile information networks. This can be accomplished by stronger integration of all the relevant UoAs on themes related to mobile information networks.

The UoA on Network, Information and Control Systems, is overall excellent. Its *single strongest aspect* is the work on convergence of communication and control in networked systems under the ACCESS Centre (Autonomic Complex Communication nEtworks, Signals and Systems). Its *single weakest aspect* is the lack of integration of the industrial information/control systems group in the UoA.

The UoA on Telecommunications is overall excellent. Its *single strongest aspect* is the world leading research in communication theory and the physical layer of wireless, and the Access Linnaeus Centre programme. Its *single weakest aspect* is the lack of integration of the antenna work within the UoA.

The UoA on Computing and Communication Systems is overall excellent. Its *single strongest aspect* is the world leading research in most system aspects of wireless communication networks as seen through the Wireless@KTH centre. Its *single weakest aspect* is insufficient methods and frameworks for application development for the mobile environment, and lack of

integration with the world leading group in wireless physical layer (Telecommunications UoA).

The UoA on Information and Software Systems is overall weak and incoherent. Its *single strongest aspect* is its strong tradition in conceptual modelling. Its *single weakest aspect* is the lack of coherency as a unit and lack of technical strength in systems engineering.

Additional Information
Regarding cross-disciplinary or multi-disciplinary research, KTH should establish a 'matrix' structure to facilitate creation and support development. This can be accomplished by creating 'horizontal units' as research institutes while the columns represent the discipline-based departments. Faculty and students have 'joint' appointments in departments and these horizontal units. Examples exist like the Institutes of the University of Maryland and the Labs of MIT.

UoA: Human Communications

General Assessment
The UoA on Human Communications is overall very good. Its *single strongest aspect* is the world-leading research group in Speech and Sound. Its *single weakest aspect* is in the HCI group, due to weaknesses in communicating their most promising ideas and their potential broader applicability and succession of faculty leadership.

Performance Against Evaluation Criteria

Scientific Quality (basic research)
The activities within the Human Communications UoA are organized in five research groups at the School of Computer Science and Communication (CSC): *Human Computer Interaction Group, Media Technology Group, Speech Group, Music Acoustics Group, Language Unit*. Part of the UoA, which was created from the union of three well-established research divisions, currently performs at a world-leading standard with the main part performing at an internationally high standard. On the basis of evidence presented to the Panel, the Unit so far has some limited interaction and cooperation.

Human Computer Interaction Group (HCI)
This is a cross-disciplinary research group working on: user-centred design and system development; advanced multimodal interfaces including haptics, sound and gestures; computer-supported cooperative work; digital storytelling environments; and human-robot interaction. The group has international recognition and its publication record in journals and conferences is strong. The relationship between basic research and applied research is very strong. A discriminating factor of the research has been the emphasis on user-centred design.

The haptic feedback demos were pretty rudimentary and not well executed; the research methodology described was not very satisfactory. The digital-storytelling demonstration was of good quality but hardly unique and well behind some commercial efforts. The "main fields" seemed somewhat arbitrary in their selection. It was hard to see what the edge differentiating quality was in relation to other groups, nationally, or internationally; e.g. the work on an interactive pedagogical museum seemed very much the same as in other places. The workshop methodology seems to be the most significant contribution and one that can

play a supporting role in many projects and investigations. However, this is past work. What is in the pipeline of new ideas and future developments? What are the overarching theories that are driving the group?

Overall this is a very strong group with a long record of high-quality scientific achievements even if the impression is that production has decreased somewhat during recent years. In comparison with other leading research groups in HCI, it is at the same level as Georgia Tech, PARC, and Univ. of Nottingham, but at a lower level than MIT, Univ. of Maryland, and Stanford.

Media Technologies
This is a cross-disciplinary research group working on: technology support for mediated communication; convergence management in media industry; semantic web; media technology and performing arts; mediated social spaces and collaboration; and sustainable mediated communication. The relationship between basic research and applied research is excellent. They have a very strong international reputation, that is rising, and a strong publication record. A discriminating factor of the research is the recent project and new VINNOVA Centre on New Media Technology services to help create and maintain an ecologically, economically, and socially sustainable society. Another innovative programme is the integration of media and the performing arts; e.g. dancing and choreography in mediated space and the World Opera Project.

The work on production systems, media convergence, and knowledge management is quite relevant to industry. It is somewhat incremental, but of very high quality. A tighter collaboration with computer science, especially in regard to metadata modelling could be fruitful. The work on media technology and the performing arts is excellent; a unique feature of the work is the extent to which the students are engaged – on a par with the MIT Media Lab. Much of the work has implications for the other groups in the UoA and the Panel 2 area; c.f. their creative use of technology is exposing new uses and new needs for networks, distributed databases, etc.. It would be of impact to have routine cross-pollination with groups such as NICS and CC.

The group's positioning is excellent for the future. The future directions presented were well selected and worthy of development; e.g. the work on Sustainable Communication is an important area of growth. The Panel noted however a general lack of specifics in future plans and strategies. Overall this a very strong research group with a rising reputation in a relatively new field. It is at a level lower than the top leading research groups such as the MIT Media Lab, Microsoft Research, Univ. of Cambridge, UC Berkeley, Stanford Media X, and Google Research.

Speech Group
This is a cross-disciplinary research group working on: methods for automatic speech understanding; principles of speaker characterization; multi-modal speech synthesis; language technology in interactive dialogue systems; infrastructure for speech technology development; and applications to people with disabilities and second-language acquisition. This is a very well-known and distinguished research group internationally with very strong publication record. This standing is evidenced by the group's wide participation in EU projects (18), many invited talks at key international conferences, and editorial appointments. The relationship between basic research and applied research is outstanding as is the collaboration

with industry. A discriminating factor in their research is the development of innovative interfaces using the person-to-person metaphor, which requires deep integration of many diverse disciplines. Another discriminating characteristic is their outstanding record in bringing basic research results to applications.

The research on a new paradigm for human-computer interaction − from a desktop metaphor to a person metaphor − has several innovative characteristics. The work on resynthesis of speech including the combination with motion of capture techniques is excellent. The various dialogue systems (social, mixed initiative, multimodal) are innovative. The presentation on the CNN show was outstanding with unique results. Areas for expansion: integration with hearing models and brain functioning; brain-plasticity as a tool for learning and rehabilitation of language skills.

The future directions described were excellent with very good plans for future research. The VINNOVA Centre for Speech Technology (CTT) provides a platform for cooperation and project funding with industry. Inclusion of other areas in collaboration with UoAs in the Panel 2 area should be encouraged – assisted living, ICT for the elderly and persons with disabilities. This is an outstanding, world leading research group – among the top and most respected (a national asset).

Music Acoustics Group
This is a cross-disciplinary research group working on: sound and music computing; expressive sound; acoustics of the human voice; physics/acoustics of musical instruments; IT for music pedagogy; sonification; performance science; and music information retrieval. It is an internationally known research group with a strong publication record. The relationship between basic research and applied research is very good, as is the collaboration with industry and society. A discriminating factor of their research is the integration of uniquely deep science base in the area, with physical experiments (rather than simulation) and high-level performing artists.

Their work has an impact on music performance, but much more than that. They are actively exploring all the ways in which sound can impact on the human experience – through enhancing interface design, better tools for spatial or distance interactions, etc. Some of their research has led to international standards and roadmaps – e.g. the SMC *Manifesto*. They are a very active group internationally, collaborating with many research groups in Europe, playing a key role in many conferences and publications in leading journals. Impressive involvement in education and courses.

The future directions described to the Panel were exciting and well fitting the competences of the group. This is a very strong research group with internationally leading position in areas (such as singing voice, choir acoustics, performance science, string instruments and piano).

Language Unit
This is a new research activity focusing on: language use and language-learning needs of KTH students; speech analysis in language teaching; and a linguistically-oriented approach to language for specific purposes. The Panel found that this group covers an interesting and important set of application areas. However it was not clear how to position the work within the context of this UoA. Opportunities for much clearer integration exist and they should be exploited in the future.

Applied Research Quality

Overall this UoA has excellent current engagements with society and industry and currently performs at an internationally high standard with some parts even performing at a world-leading standard. This is indicated by their participation in several multi- and interdisciplinary activities via several centres, most having a very high standard internationally. These include: Centre for User-oriented IT-design (CID), Centre for Speech Technology, Centre for Sustainable Communications (SUS), KTH Visualization Centre, Research Centre for Opera and Technology. Another strong indicator is the number of companies founded (spin-offs) on research results from this UoA: UsersAward, Antrop, Veridict AB, Synface AB, Audeq AB, Nyvalla DSP. Several of the research groups (HCI, Media Technologies, Speech, Music Acoustics) have an outstanding record of transitioning research results to applications and products. Several of the research groups have continuous collaboration with user groups for both assessing user needs and for user evaluation of research results and prototype technologies and products.

Scholarship

Overall this UoA has a very strong record and accomplishments in scholarship, as evidenced by the establishment of new approaches and standards, particularly by the Speech, Music and Acoustics and HCI groups. This scholarship is excellent in some parts of the Unit and some individuals have been recognized internationally. Further evidence is provided by many invited talks at prestigious conferences, leadership in the organization of conferences and courses, pursuit of unique integrative research directions; e.g. Speech group, Music and Acoustics group, HCI group in their user-centric approach.

Vitality and Potential

Overall this UoA is well balanced between senior and junior faculty; 8 full professors, versus 17 associate, assistant and guest professors. Vitality and potential is excellent across the majority of the UoA. There is a very strong faculty recruitment record over the evaluation period, total of 16, with 2 women. The HCI group is currently recruiting a new professor and a senior lecturer. The Panel highly recommends that this strong record and trend should continue. This is critical for this UoA as it faces a transition in faculty leadership.

Younger faculty have been developed and included in the current research projects and future plans, as evidenced by them being the main authors of a significant part of publications (e.g. 50% in HCI, 59% in Media). Seven young faculty were awarded significant awards.

There is very strong production of PhD graduates that have gone on to academia (24) and industry and some have been involved with start-ups. Forty-three PhDs graduated from this UoA over the evaluation period. Twenty were women, i.e. 47%. Thus the gender balance in the UoA is outstanding.

Strategy

The research programme of this UoA is clearly multidisciplinary as it encompasses engineering sciences, behavioural, humanistic and design disciplines, and the strategy is good with real potential to achieve. The long-term goals of the UoA are: (a) to communicate and interact with machines in a natural manner; (b) reach a thorough understanding of the human-human communication processes; (c) develop technologies and products that support and augment human communication (between humans and with machines, locally and over distance and time).

Overall the strategic plan and coordination of the UoA was somewhat weak and needs much further development. The response to the Panel's request for identification of the most powerful ideas for the future met with mixed success. Three groups will have a major renewal in their senior faculty in coming years; a major challenge as future leadership will be critical for continued success and for sustaining high standards and performance.

The research funding of this UoA has been excellent over the period of evaluation, with the funding of the HCI and Speech groups being outstanding. Two of the groups (HCI and Speech) have had very successful centres of excellence together with industry, where the permanent funding recently has been terminated. Thus a major challenge for which a detailed and effective strategy is needed very soon is how to obtain such substantial funding in the future.

Actions for Development

Given the pervasive use and expanding role of communications in every aspect of life, this technical area is judged by this Panel as very significant for KTH. The combination of research activities within engineering and human sciences has immense potential and impact on the quality of life, sustainable growth, healthcare, working life, education, entertainment and industrial development. As user and user-to-system interactions become pervasive, this UoA could have a much broader impact in several KTH technical areas. Unique opportunities exist with the competencies within this UoA to achieve world leadership with the proper coordination and resources. This will require substantial planning and integration within this UoA as well as joint programmes with other UoAs in the Panel 2 area and in other areas such as robotics, computer science – c.f. appointments of new chairs. The Panel envisages that such integration will create many opportunities for strategic cross-disciplinary activities and engagements with industry and society. A good example is collaboration in the management and delivery of healthcare and in assisted living for the elderly – both problems of immense significance for the entire world.

The new project and activity between technology and medicine by the HCI group, especially the inclusion of multimedia technology for embedded systems in advanced medical processes is very promising and must be developed to the fullest. The new HCI activity and planned projects for an elderly and disabled population are very important. The new VIC KTH centre should be supported and developed to its fullest. In the Media Technology group there is great opportunity to develop a persuasive-computing theme. The Metadata model could be helped with stronger ties to computer science. They should develop their potential in addressing the spatial-temporal latency in Human Communications. The multi-modal work needs to be strengthened. The realism of building a strong language research group within this UoA should be carefully evaluated versus developing stronger collaboration with existing groups at KTH, SU.

UoA: Network, Information and Control Systems (NICS)

General Assessment

The UoA on Network, Information and Control Systems, is overall excellent. Its *single strongest aspect* is the work on convergence of communication and control in networked systems under the ACCESS Centre (Autonomic Complex Communication nEtworks, Signals and Systems). Its *single weakest aspect* is the lack of integration of the industrial information/control systems group in the UoA.

Performance Against Evaluation Criteria

Scientific Quality (baisc research)

The activities of the NICS UoA are organized in three research groups within the School of Electrical Engineering (EE): *Laboratory for Communication Networks (LCN); Department of Industrial Information and Control Systems (ICS); and Automatic Control Laboratory (ACL).* Part of the UoA currently performs at a world-leading standard with the main part performing at an internationally high standard. There was strong evidence of collaboration between the ACL and LCN groups (e.g. ACCESS Centre) as well as between the ACL, LCN and ICS groups (e.g. Viking project). The Panel believes that there is potential for further integration between these groups, which is essential to propel this UoA to a higher standing world-wide.

Laboratory for Communication Networks (LCN)
This is a research group working on: network and service management; internet and wireless communications; and new application areas for networking. The group has international recognition and its publication record in journals and conferences is excellent. The relationship between basic research and applied research is strong and it should be further strengthened and expanded. There are strong industrial collaboration partnerships that should be expanded. A discriminating factor of the research is the good balance between theoretical studies (distributed algorithms, stochastic processes, queuing theory) and experimental studies (simulation, prototype building, testing in the state-of-the-art network laboratory).

The research on scalable network management and real-time monitoring, as well as its implementation, prototype and demo, are innovative and well balanced between theory and practice. The work on self-configuration of wireless networks, distributed router architectures and peer-to-peer communications is of very high quality. The MS programme in Network Services and Systems is indeed attractive and innovative and should be developed further. The new applications described in SCADA systems and medical and health systems are very important and should be vigorously developed. Overall the group has a strong basis in fundamentals for measurement and analysis of networks.

The Panel found the areas for the future research presented were promising and appropriate, but the strategies and plans presented need quite a bit more development. Their future plans in software and security would benefit by interactions with the Computing and Communication Systems (CCS) and Human Communication (HC) UoAs. Attention to different models of scale would be of strategic interest. Modelling energy as one of their metrics is important but was not mentioned.

Overall this is a very strong group with solid academic presence and with some international recognition. The group has excellence in some niches (in-network management, p2p modelling, gossiping for network monitoring) as evidenced by best paper awards in prestigious conferences and IBM faculty awards. It is not among the top networking research groups internationally (MIT, Stanford, UC Berkeley, U of Illinois UC, U of Maryland CP, U of Cambridge, EPFL, UCLA, Georgia Tech, and U of Massachusetts Amherst).

Information and Control Systems (ICS)
This is a research group working on: the development of complete and cost effective IT-based operation support systems for complex industrial processes; system management process from conceptual planning to operations; system properties and performance metrics; and enterprise

architectural models and system-level R&D tools. The group has some international recognition, primarily through its leader. The group's publication record in journals and conferences is not strong. However, the relationship between basic research and applied research is very strong. A discriminating factor of the research is the emphasis on systems of systems, addressed by enterprise architecture and a systems engineering approach. Another discriminating factor is the analysis of the dependence of system quality properties on system architecture.

The research on enterprise architecture, and its consequences on system properties, is very important and promising but needs to use more quantitative, model-based methods. The work on integration of industrial control systems with other information systems in the enterprise addresses an important problem for a specific industrial sector, but it is just beginning. The research on system management processes, including system performance metrics and their characterization, lacks model-based and quantitative methods. As a general comment, the research presented lacked fundamental basic quantitative methods, while it was strong on its industrial relevance. The real strength and promise of this group is their long and outstanding record and experience with real-world industrial strength problems in industrial information technology systems (industrial IT-systems), and their close and extensive collaboration with industry in this area over time. This expertise and work provides a unique opportunity for synergy and impact through collaboration with the other groups within this UoA. It is the Panel's opinion that such collaborations have not been developed to their full potential yet, which is needed.

The strategic areas for the future presented to the Panel included: model-based design of enterprise architectures and system of systems software, integrated industrial IT systems (from design to operations), integration of control systems with other enterprise information systems, industrial control systems security, safety critical software systems. Although the Panel found these areas appropriate and important, the plans presented were very 'sketchy' and were lacking substantially in detail and planning.

Overall this is a strong group with an excellent leader, and with some international recognition. The group lacks strength in the underlying science and quantitative methods. Overall it is not among the top industrial IT-systems and systems engineering research groups in the world (i.e. CMU, MIT, UC Berkeley, U of Maryland CP, Georgia Tech, USC, ETH, and INRIA).

Automatic Control Laboratory (ACL)
This is a research group working on fundamentals of networked embedded systems, control over wireless systems, control and optimization of networks, multi-agent and hybrid systems, experiment design in system identification, identification for control and systems biology. The group has international recognition and its publication record in journals and conferences is excellent. The relationship between basic research and applied research is excellent. The collaboration with industry is also excellent. A discriminating factor of the research is the emphasis and focus on networked information and control systems (ACL is the largest partner in the ACCESS Linnaeus Centre). Another discriminating factor of the research is the work on wireless networks for control of industrial factories and processes.

The cross-disciplinary character of the work is exceptionally strong as is the balance between basic research and industrial applications. The research on the fundamentals and experimental validation of wireless networks for control is excellent and rather unique worldwide,

especially with its tight relationships with real-world applications in factories and mines. The research on identification for control is solid along established directions. The research on hybrid control systems and networked embedded systems is excellent and in an important emerging area internationally. The research on resource-efficient networking for predictable QoS is of very high quality, addresses critical open problems and should be expanded. The research on systems biology is promising but it is at its initial stage of development and needs to develop critical mass through stronger collaboration with other UoAs.

The strategic areas for the future presented to the Panel included: strengthen further research on networked information and control systems through the ACCESS Centre, develop further the research on sensor networks, develop research on systems biology, expand research on networked embedded systems, network and system security in information and control systems, real-time software. The Panel believes that the group has solid foundations in basic science, the right emphasis and new initiatives, and the right collection of industrial partners to pursue a world leading position in the emerging critical area of networked systems. Such a 'push' will most certainly require more resources from KTH for success.

Overall this is an excellent group − up-coming internationally − with solid academic credentials and is well known internationally. The group is not yet world leading or among the top automatic-control research groups internationally (MIT, Stanford, Caltech, U of Illinois UC, UC Berkeley, U of Maryland, Australian National University, and U of Cambridge), although it has strong collaborations with most of these groups. It is rising fast in its international standing and has the potential to become world leading, primarily due to some outstanding young faculty within the group.

Applied Research Quality

Overall this UoA has excellent current engagements with society and industry meaning the majority of the UoA currently performs at a world-leading standard. This is evidenced by many joint projects with industry and an excellent record of transition of research results to industry. This is indicated by their participation in several multidisciplinary activities via centres, most having very high standard internationally. These include: ACCESS Linnaeus Centre, Centre for Autonomous Systems, SICS Centre for Networked Systems, Wireless@kth and Centre of Excellence in Electric Power Engineering. Further evidence is provided by the close collaboration with many companies, some very critical for the Swedish economy, including Cisco systems, IBM, Ericsson, Nokia, TeliaSonera, ABB, Siemens, Honeywell, Ericsson, General Motors, SCANIA, Schneider Electric, SAP, Global Crossing, SAAB, FOI.

Overall the UoA encompasses excellent cross-disciplinary activities compared to international norms and standings. The excellent collaborations with industry and society are in critical and strategic emerging areas. In addition to many projects and contracts with industry, the UoA has joint think tanks with industry, and has put to broad industrial use various software systems. The Panel recommends that further plans for close collaboration between this UoA's groups will create many more opportunities for such strategic cross-disciplinary activities and engagements with industry and society.

Scholarship

Overall this UoA has an excellent record and accomplishments in scholarship, as evidenced by their publication record in parts and individuals within the Unit. This scholarship has been recognized internationally. Further evidence of very strong scholarship is provided by many invited talks, invited plenary addresses at prestigious conferences, membership in editorial boards of prestigious journals, leadership in the organization of technical conferences,

leadership in the organization of international courses, frequent appointments as expert reviewers for foreign universities and the EU Commission, and frequent appointments to strategic planning committees for the Swedish Government. Several technical areas and trends were initiated by faculty from this UoA (e.g. IP address lookup, in-network management, the KTH systems engineering method for industrial IT-systems, the prototype enterprise architecture analysis software tool, wireless networking for control, and computational stability analysis of hybrid control systems). Research papers from the UoA are highly cited. Leading participation in many European research projects and networks of excellence (RUNES, SOCRADES, RecSys, FeedNetBack, HYCON, Artist2, EuroNF, EURON, 4WARD, Sendora, Onelab", E-Next, EMANICS) is further evidence.

Vitality and Potential

Overall this UoA is well balanced between senior and junior faculty, seven full Professors versus nine associate, assistant and guest professors meaning vitality and potential is excellent across the majority of the Unit. There is an exceptionally strong faculty recruitment record over the evaluation period. For example, the rapid build-up in faculty for networked control systems was outstanding. Faculty in security and real-time software are currently being recruited. The Panel highly recommends that this record and trend should continue, given the opportunities identified for rising in international standings.

Younger faculty have been developed and included in the current research projects as well as in future research plans, as evidenced by younger faculty being the main authors of a significant number of the publications. Several of the young faculty were awarded prestigious national and international awards and recognitions (5). Indeed, several young faculty have provided the leadership for some of the recent accomplishments of this UoA (e.g. ACCESS Linnaeus Centre).

There is strong production of PhD graduates that have gone on to leading positions in academia and industry. The quality of the graduated PhDs is very high, as evidenced by the awards they have received for their work. Twenty-two PhDs graduated from this UoA over the evaluation period. Efforts should be undertaken to increase PhD production. PhD production is non-uniform between the groups. Only three were women, i.e. 14%. Efforts should be undertaken to improve the gender balance in the UoA in the future.

Strategy

Overall the strategic plan and coordination of the UoA were very strong and were considere excellent but challenging to achieve. Better coordination and integration of the ICS group with the other two is needed and highly recommended. The long-term goals of the UoA are: (a) establish a competence centre on networked information and control systems and build an internationally leading standing through strong partnerships with industry, other Universities and other leading centres internationally in this critical for the future area; (b) develop a rigorous educational programme in systems engineering, considered to be highly critical for future engineers; (c) become an internationally leading centre in research and education on critical information infrastructures.

Well thought out strategies to achieve these goals were presented. For example the response to the Panel's request for identification of the most powerful ideas for the future met with reasonable success. The research funding of this UoA has been outstanding over the period of evaluation, and is increasing. This indicates the high interests in this area and the high quality of the overall programme (competitive wins).

Actions for Development

As expected there is some heterogeneity within the groups which is very promising and critical for the future UoA. The ACL group is extremely successful with high-class research and industry relevance. The LCN group seems to have high quality but partially, with a potential which is not yet fully realized. The ICS group is, to a high degree, an area which has been built on the ideas, contacts and enthusiasm of a single leader. For the ICS group, one should consider the possibility to join forces with software engineering and information systems in order to also strengthen those areas with contacts in manufacturing and process industry and with ideas in systems engineering.

There is a world-wide increasing interest and significance in the systematic design and performance evaluation of networked systems. Examples range from intelligent transportation systems to healthcare infrastructures. These systems are characterized by the tight coupling of software/hardware cyber components with the physical processes they control. The associated product areas represent enormous and emerging markets. On the other hand the challenges these systems create are fundamental and daunting. Currently, Sweden lacks a concentrated effort in this area as compared to the USA and Germany. It is the Panel's opinion that NICS, with the ACCESS Linnaeus Centre as a base, is extremely well positioned to lead KTH and Sweden to a leading position in this critical area (networked information and control systems) worldwide. The Panel also believes that there is a unique opportunity for KTH to develop a world leading programme in systems engineering by developing a broad synergy on systems view and methods of systems design, testing and validation, including cost, risk and business aspects. This should involve much closer collaboration between NICS, and the CSS and ISS UoAs (in addition to the already strong collaboration between NICS and the TC UoA).

UoA: Telecommunications

General Assessment

The UoA on Telecommunications is overall excellent. Its *single strongest aspect* is the world leading research in communication theory and the physical layer of wireless, and the Access Linnaeus Centre programme. Its *single weakest aspect* is the lack of integration of the antenna work within the UoA.

Performance Against Evaluation Criteria

Scientific Quality (basic research)

The activities within the Telecommunications (TC) UoA are organized in five research groups at the School of Electrical Engineering (EE): *Spatial-Temporal Wireless Communication Group; Information and Communication Theory Group; Multimedia Processing Group; Antennas and Wave-propagation Group; and Radio Frequency Measurement Technology Group.* The groups within this UoA are well integrated and collaborate closely with each other, with the exception of the group on Antennas (and related *metamaterials*) that appeared to be a little disconnected with the rest. However, it was clear that the majority of the UoA currently performs at a world-leading standard.

Spatio-Temporal Wireless Communications Group
This is a cross-disciplinary research group working on: multiple antenna systems, distributed cooperative communications, transmitter and receiver design, channel modelling with input to standards bodies, resource management and system design, and multi-antenna wireless test-bed development. The group is world leading and its publication record is outstanding. The relationship between basic research and applied research is excellent. There is a great track-

record of collaboration with industry. A discriminating factor of the research is the emphasis on multimedia antenna systems, multi-node cooperative transmission and accurate and validated physical layer models.

The work in multi-antenna systems for suppressing interference in wireless communications is world leading (the widely used Spatial Division Multiple Access (SDMA) technology was developed and patented here). The work on RF channel spatio-temporal modelling is right on target, critical and of the highest quality. The work on validation of MIMO channel models in the group's test-bed is excellent. The group has developed model-based schemes for interference rejection (patented and transitioned to industry), blind identification, spatio-temporal equalization, joint estimation and detection, multi-user detection for multi-channel systems. Their research on achieving scalability in mobile wireless communications via multiple antenna systems, and the associated system level studies, is rather unique on a world-wide basis. The development of a unique-for-academia wireless multi-antenna, multi-node test-bed and associated rapid prototyping capability is outstanding and a critically valuable resource.

The future directions described were excellent, including well thought out expansion in cross-layer design, media access protocols, decentralized adaptive resource management and automatic control/optimization. The plans presented were careful and well integrated. This is an outstanding, world leading research group – among the most respected.

Information and Communication Theory Group
This is a disciplinary group working on new transmission and coding schemes, fundamental performance limits, communication signal and system theory, information theory, cooperative transmission and coding, utilization of partial channel state information (CSI) in wireless transmission, sensor networks, and applications to closed-loop control systems. There are strong collaborations with researchers from other groups. This is a world leading research group with an outstanding record of accomplishments and publications. The relationship between basic research and applied research is excellent as is the collaboration with industry. A discriminating factor of their research is the systematic characterization of fundamental performance limits in communication systems over wireless media including joint protocol optimization, adaptive schemes and realistic models.

The research on joint source-channel coding, computation of capacity bounds for links with feedback, joint coding and control is excellent and has been pace setting internationally. The work on utilizing partial CSI and the design of CSI-adaptive multiple-antenna coding schemes is excellent and at the leading edge. So is the research on the characterization of the diversity-multiplexing trade-off. The more recent work on cooperative communications in wireless media is of critical importance and among the best in the world – e.g. the results on the diversity-multiplexing trade-off of the decode-and-forward protocol with partial CSI. More recently there are exciting and very promising collaborations with NICS researchers in the ACCESS Centre – e.g. distributed compression and coding and joint coding and feedback control designs.

The future research directions, focusing on cooperative communications, wireless sensor networks, multiple communicating (wireless) nodes, and the fundamental limitations of distributed integrated control and communication systems, are timely and well planned. The ACCESS Linnaeus Centre is playing a key role in setting the agenda and in strengthening

productive collaboration with NICS. This is an excellent research group with several world leading contributions.

Multimedia Processing Group
This is a disciplinary group working on source coding, signal processing and enhancement, speech recognition, plus algorithms to compensate sensory impairments. This is a very well known and internationally recognized research group with an excellent publication record. The relationship between basic research and applied research is excellent. The collaboration with industry and transition of research to products is outstanding. A discriminating factor of the research is the emphasis on the development of source coding and signal processing to facilitate telepresence and human communication.

The work on audio coding (patented), VOIP coding and enhancement, and its application to mobile telephony was pace setting and has been included in world-wide standards. The more recent work on combined source and channel coding technologies, that allow continuous adaptation to both information rate and link robustness to losses, is excellent. The work on automatic monitoring of perceived speech quality is very good but should be expanded to include feedback adaptation of processing to improve the perceived quality. The group's research on suppression of non-stationary environmental noise is promising. The work on using physical and psycho-acoustic models for improving cochlear implants is also promising. This UoA contains one of the strongest groups in speech and audio coding and enhancement world-wide, based on independent evidences. Although video was included in the presentations and interview, there was little evidence on a real vision or a research plan in this important for the future area. Similarly, there was little evidence to suggest a real vision on "true telepresence" or the right personnel to address multimedia research topics within the UoA itself. Thus, there is an excellent opportunity to leverage and collaborate with other UoAs in the Panel 2 area (e.g. HC and CCS).

The future directions described, i.e. enhancing telepresence, technology to increase mobility and fidelity, ambient audio-visual telephony, robust 3D video coding, are interesting and fitting. The plans were somewhat vague and not well integrated, however. This is a very good research group with some world leading past contributions.

Antennas and Wave Propagation Group

This is a disciplinary group working on ultra wide-band technology (UWB), multi-purpose antennas, integrated design of reconfigurable antennas for MIMO systems, metamaterials (for future microwave devices). The group is somewhat isolated from the rest of the UoA. This is a very good group with some international recognition and an excellent publication record. The relationship between basic and applied research appeared to be weak. There was little evidence to support strong collaboration with industry. A discriminating factor of the research is the integrated design and analysis of modern complex antennae.

The work on multi-purpose wide band array antennas is very good. The work on RF and MEMS antennas is excellent. The research on metamaterials (synthetic materials with negative electric permittivity and magnetic permeability) and associated implementation is excellent. The work on electromagnetic wave propagation computations and simulations is good, but somewhat routine.

The research agenda and future directions are important and the goals worthwhile. This is a very good group with very talented and successful researchers, but an 'island' within the UoA. There should be much better synergy developed in the future with other groups within this UoA and KTH (e.g. CCS).

Radio Frequency Measurement Technology Group
This is a group working on novel measurement techniques for design and production radio communication systems, to meet the tougher requirements on hardware, power amplifiers, analogue-digital and converters and terminal antennas. The group research is a collaborative effort between this UoA and the University of Gävle, within the national graduate school of telecommunications, managed by this UoA. The relationship between basic research and applied research is excellent as is the collaboration with industry. This is a rather unique activity internationally involving academics and industry. This is a very important area to industry, which has remained unexplored from an academic research viewpoint. The research combines, creatively, techniques from signal processing and microwave engineering.

The proposed future directions are important and very much in line with the goals of the group. Better integration with the other groups should be developed in the future, and especially with the wireless MIMO and antenna laboratory test-beds of this UoA.

Applied Research Quality
Overall this UoA has excellent current engagements with society and industry which means it currently performs at an internationally high standard with some parts performing even at a world-leading standard. Evidence is provided by their strong participation in many national and international centres of excellence: ACCESS, Wireless@KTH, ACE, NEWCOM, Centre for RF Measurement Technology, HYCON, KCSE, KTH joint research centre on Photonics, antenna centre of excellence, Charmant, National Aeronautical Research Program. Other evidence is provided by the strong collaborative efforts with national and international industry including: Ericsson AB, Nokia Research Centre, ABB Corporate Research, France telecom, GN resound, Cochlear, Global IP Solutions, SAAB Microwave Systems, Volvo Aero, Thales. The inventiveness and commercialization of this UoA are outstanding. More than 50 patents exist, including SDMA, speech coding for mobiles (implemented by Nokia), ADC calibration (implemented by Ericsson), speech enhancement (implemented by Ericsson). Start-up activity has also been vigorous, the most notable being GIPS (startup in VOIP with key patents used by Skype, AOL, Yahoo and others) and ArrayComm (with more than 250,000 commercial base stations implementing SDMA).

Scholarship
Overall, the majority of this UoA has an outstanding record, and accomplishments in scholarship, as evidenced by several pace setting results and papers in communication theory, wireless communications, speech coding, physical layer modelling and experimentation, which have become international standards. Additional evidence is provided by the many publications in the most prestigious journals and conferences in the field, high citation index for several publications, IEEE paper awards, many plenary talks, IEEE Fellow faculty recognitions, Technical Programme Committee chairmanships of IEEE conferences, and participation in Editorial Boards of IEEE journals. Their strong participation, leadership, and winning of many EU projects provides further evidence including COOPCOM, WINNER, ACORNS, FLEXCODE, HEARCOM, SENDORA, FeedNetBack, AUDIS – all being risky, basic research, highly competitive awards. The leadership/management of the Graduate School of Telecommunications (involving several other partner universities) and the direction/management of the MS programmes in Wireless Systems (the most competitive

within KTH), demonstrates the trust enjoyed by this UoA in the critical area of attracting and educating future generations in the very important area of telecommunications.

Vitality and Potential

Overall this UoA is well balanced between senior and junior faculty; six full professors versus eight associate, assistant and guest professors, and vitality and potential is excellent in some parts of the UoA, good in the remainder. There is a very strong recruitment record over the evaluation period, with a total of 12. The group has notably young and vital researchers – 40% of faculty below 40 years old. There is a very competitive, post-doctoral programme with 4-6 post-doctoral scholars annually. One new professor will be recruited in autumn 2008 (Information and Communication Theory) and there are on-going recruitments for faculty positions in Communication Theory, Multimedia Communications, and Antenna Systems, adding research associate positions. There are no women faculty – a situation that needs to be corrected in the near future.

Younger faculty have been recruited, excellently mentored and developed and they are a vital part of the group. Several have received prestigious national and EU awards (5).

There is very strong production of high quality PhD graduates that have gone on to leading positions in academia (9) and industry. Thirty-three PhDs graduated from this UA over the evaluation period. One was a woman. Thus the gender balance is not satisfactory and needs to be ameliorated.

Strategy

The research programme of this UoA involves several disciplines with very good integration in most areas of the research. There are two anchors on which a common vision is based: (a) facilitation of 'true telepresence', and (b) 'everything connected'. Overall, strategy was considered excellent but challenging to achieve. The strategic plan was very strong and well integrated, addressing important questions for telecommunications, and evolving projects motivated by the common vision and contributing to it. Better integration is needed for the Antennas and Wave Propagation group. The research funding of the group has been, and continues to be excellent, with many wins in prestigious and tough competitions (both national and EU).

A major part of future plans evolves around the ACCESS Linnaeus Centre, which brings this UoA and NICS in close collaboration in many exciting and significant areas. The vision for ACCESS is to play an internationally leading role in networked systems research, education, collaboration with industry, and service to society. Thus the UoA is excellently positioned to continue its world leading research.

Actions for Development

Telecommunications will continue to be pervasive, with increasing new services and uses by society. The Stockholm region is world renowned for its research and industry concentration in the area of telecommunications. This UoA, in collaboration with others, and KTH as a whole should undertake whatever efforts are needed to maintain and strengthen their world leading programmes in Telecommunications. The ACESS Centre, the so called "Wireless Valley", and the concentration of large companies and SMEs in the Stockholm region provide a unique environment.

However, the Panel highly recommends much better integration of the efforts of this UoA with the programmes of the HC, CCS and ISS UoAs, in addition to the excellent existing

integration with NICS. There should be much better cooperation and integration with the CCS UoA, as efforts are very complementary. Only through the development and sustenance of such strong synergies between telecommunications, information systems, mobile environments, human-computer interactions, wireless communication networks can KTH capitalize on the apparent opportunity to become a world-leader in mobile information networks – an area that is affecting every aspect of life and work world-wide.

UoA: Computing and Communication Systems

General Assessment

The UoA on Computing and Communication Systems is overall excellent. Its *single strongest aspect* is the world leading research in most system aspects of wireless communication networks as seen through the Wireless@KTH centre. Its *single weakest aspect* is insufficient methods and frameworks for application development for the mobile environment, and lack of integration with the world leading group in wireless physical layer (Telecommunications UoA).

The activities within the Computing and Communication Systems (CCS) UoA are organized in eight research groups at the School of Information and Communication Technology (ICT): *Computer Architecture; Distributed Software and Computing Systems; AI and HCI; Computer Communications; Computer Security; Telecommunication Systems; IT products; and Radio Communications.* The presentations, discussions and interview were conducted along research themes (described below) driven by the overall vision of the UoA: "making the mobile revolution happen" – from exclusive to pervasive computing and communication for everyone. Their group vision (and associated grand challenges) is somewhat commonplace, but that is perfectly fine as long as they have extraordinary approaches to these problem areas.

The groups within this UoA are well integrated (the UoA composition is not an artifice) and it is clear that there is a great deal of existing synergy among the groups. The panel much appreciated this different (from the other UoAs) form and approach to the RAE. There was ample evidence presented that the groups indeed are working together combining their disciplinary expertise and methods into projects with a strong application focus and with a pervasive systems approach. The key discriminating factor of the research is precisely this systems level approach and methodology. Within this UoA's research programme, this systems approach involves on the one hand research in services and underlying technologies (for service design) and on the other business models and economic costs and constraints (for commercial deployment). In fact this was the only UoA within the Panel 2 area that included costs and economic-business considerations in its research programme – a refreshing change for a leading technical university unit.

Overall, this UoA is an applications-focused unit, but one that thinks in terms of systems. Indeed, the interest in a systems approach is what seems to unify their efforts (although they acknowledge there are some holes in their team). In addition, their focus on rapid prototyping is a real plus.

The main and driving research foci are: (a) affordable broadband access to all; (b) and bridging the technology gap between service design and commercial deployment, including co-design of software and hardware platforms, user-friendly services, and business driven technical design. The relationship between basic research and applied research is outstanding as is the collaboration with industry. Most of the research and industrial collaboration revolves around the KTH/industry consortium Wireless@KTH, the KTH Centre for Wireless Systems and industrial thesis projects. Wireless@KTH is a jewel in the crown (in its

structure, organization, management and approach). It is of strategic interest and a model from which other groups may learn. A balance of directed and seed funding is a very positive indicator.

A burning question for this Panel going into the interview was: is the co-location of this UoA at Kista being exploited sufficiently to merit the separation from the rest of the UoAs? Unequivocally, the answer is yes. While, to some degree, collaboration with other UoAs is diminished, there was ample evidence presented that all members of the unit are engaged in numerous, productive collaborations with industry and their international colleagues. That said, the challenge, organizationally and technically for KTH, is how to integrate the outstanding and complementary programmes in this UoA and the NICS, TC and HC UoAs in the main KTH campus in order to capitalize on the opportunities, environment and competencies present to become a world-leader in mobile information networks (e.g., the MIMO work in this UoA would benefit from a direct connection to TC and NCIS and TC, others with HC).

Overall, this is an excellent UoA, with excellent publication and inventiveness record, excellent research programmes and international recognition. There is an outstanding relationship between basic research and applied research as well as industrial collaboration. There is significant innovation in education and training through very successful and high demand MS programmes. Compared with other leading groups internationally, this UoA fairs very well – it is among the top. It would be ranked below MIT, Stanford, and would be competitive compared with UC Berkeley Wireless Research Centre, WINLAB at Rutgers, HyNet of the U of Maryland, UC San Diego, and Georgia Tech GCATT. It is leading all of these groups in the area of systems level research and implementation in wireless networks, mobile computing and associated services. It is at the very top with respect to industrial collaboration and commercialization in this list (at par or better with MIT and Stanford). This is facilitated by the tremendous environment in Kista Science City with its focus on wireless systems, broadband systems and mobile systems, and with 700 Companies, 250 ICT companies and 175 SMEs, the ELECTRON Foundation, the commercialization company STING, and the outstanding laboratories and centres there (e.g. Electrum Laboratory, iPACK, SICS).

Performance Against Evaluation Criteria

Scientific Quality (basic research)
Part of the UoA currently performs at a world-leading standard with the main part performing at an internationally high standard. Emanating from the UoA's unifying vision, the research is organized around six research areas (or themes): *Communication Infrastructures; Communication Security; Computer and Programming Systems; Large-scale Services and Service Science; Adaptive and Cognitive Systems; and Technoeconomics.*

Communication Infrastructures
Research is conducted on affordable wireless broadband access infrastructures, fixed (wire and fibre) access infrastructures and new internet paradigms. The programme covers a rich set of some typical and some atypical areas. Recent emphasis on cost and business aspects, as part of resource management, reflects a healthy transition to systems considerations. Also, recently, emphasis has shifted to architectures, deployment and resource management of heterogeneous mobile broadband access networks. This is a particularly challenging area and they are making important contributions. The emphasis on architectures is a discriminating

feature. Some of the research themes, such as delay-tolerant services, are the sort of non-incremental approach that will undoubtedly lead this unit to making important contributions to advancing infrastructure design. They have already demonstrated a track record in designing innovative architectures, such as cognitive radio. Overall the work is very strong with international recognition.

Communications Security
Research is conducted on security at all layers. At the protocol level the group has developed innovative security solutions for wireless networks (e.g. Wi-Fi, Bluetooth, GPRS). At the application level, interesting research results were described in security for personal communications, secure real-time communication, trusted media delivery mechanisms, and trusted payment schemes. The group is also researching several aspects of large scale security architectures including generation and distribution of security credentials, establishment and enforcement of roles and trust, and management of security policies. They are addressing the right set of problems (smart to leave TCG to others). A possible additional problem to consider is the trade-off between security and privacy, which is becoming very important internationally. No new ideas were presented, but there is significant talent and an innovation record in the unit in this area.

Computer and Programming Systems
Research is addressing important problems in design and implementations of programming systems and component-based middleware (multi-paradigm programming, concurrent and distributed computing, constraint-solving techniques), an event-driven hierarchical component model for reconfigurable distributed systems (combined threat/event-based scheduling, compositional and reconfigurable, multicore-enabled), and energy-aware computing systems. The work on the development of a software architecture and middleware, based upon a compositional event-based component model for building distributed services and its applications, is among the best in the world and truly innovative. An important application is autonomic network self-management. The excellent standing is reflected in leading positions in large EU projects in these areas. They are also investigating non-Von-Neumann architectures and their MIT Press textbook suggests that their work is well respected in the field.

Large-scale Services and Service Science
Research is conducted in structured overlay networks, gossip algorithms in the context of DHTs, super-peer overall networks, peer-to-peer real-time streaming and on-demand streaming, methods and metrics for service science. All topics are timely and the work and posters presented described excellent efforts. Some of the areas are emerging as critical (e.g. service science). Some recent award-winning work in this area suggests that they will be significant contributors to this emerging area.

Adaptive and Cognitive Systems
Research is conducted in two areas: interface and service design (technology to enable adaptivity of ubiquitous computing systems, cognitive systems capable of understanding and learning the user's behaviours and needs and able to adjust towards meeting them), access design (cognitive radio for dynamic spectrum allocation and use, self-deployment and management of infrastructures). The problems are important, are driven by significant applications and markets and the work is very good, especially from a systems perspective. The staff interviewed did not present any significant work on HCI or AI, nor was it evident in

the major publications list. Nonetheless, there are good people working in this area as part of the unit.

Teleconomics

Business models, value chains, regulatory policy, and financial models are important elements of systems research for communication and computing systems. This was the only UoA from any of the UoAs we reviewed that looked at the economy of communications systems as a subject of research. They should be commended for addressing these key systems problems. Their work is well recognized internationally as is evidenced by their leading role in the EU project "Ambient Networks' and from the impact their research results have had on regulatory and financial strategies in Europe. The research programme could be enhanced by some interaction with the field of behavioural economics – if such resources are available at KTH or Stockholm University. Overall, this is excellent and pace setting research on very important aspects of communication and computer infrastructures.

Applied Research Quality

As most of the research is applications driven, this UoA has outstanding engagements with industry and society, and the majority of the Unit is thus considered to perform at a world-leading standard. Wireless@KTH has become a world leading consortium for industry-university collaboration in wireless networks. More than 50 researchers have collaborated in such projects. Its partners include Ericsson, Huawei, TeliaSonera, SAAB Communication, the Swedish National Defence Research Establishment, and the Swedish regulator, PTS. Additional cooperation with industry occurs through the Swedish Institute of Computer Science (SICS). An additional centre through which this UoA collaborates with industry is the Mobile-Life VinnEx centre. Collaboration with industry involves joint projects, contract work, development and delivery of advanced and focused courses, education of PhD students (50) who in their majority have gone to industry, education of MS students (>100) who are involved in most of the industrial projects. Another important piece of evidence is the spin-offs that have resulted from the UoA work: Tacton, Virtutech, Jaczone, Perialism. The degree to which the research within the research of this UoA is addressing significant problems for IT industry and IT services for society is indeed quite unique and remarkable.

Scholarship

Overall, this UoA has an excellent record and accomplishments in scholarship in some parts, or in some individuals, despite its applications driven research portfolio. This is evidenced by several trendsetting results (e.g. cognitive radio, component-based distributed software, wireless protocol security) as well as trendsetting research areas (rebalancing communication and computing capabilities, innovative services, software for large scale deployment, business model driven technology design). Their systems perspective emphasis is exceptionally well timed and world leading. Additional evidence is provided by the very strong publication record, awards, invited lectures, and technical and organizational leadership of conferences and courses. Further evidence is provided by their strong participation and leadership in many highly competitive national and EU projects including Evergrow, Selfman, Grid4All, Ambient Networks, Mobilizing Internet, HDVIPER, FEDERICA, Peer2Peer, CoreGrid.

Vitality and Potential

Vitality and Potential were considered excellent in some parts of this UoA and good in the remainder. There is good balance between senior and junior faculty; eight full professors versus 17 associate, assistant and guest professors. There is a healthy number of postdoctoral fellows as well. Young faculty have been recruited and developed, and they are heavily involved in research projects in collaboration with industry. One received a prestigious award

(Marie Curie Excellence Grant). Recruitment efforts have been good (eight overall, with one being a woman), and they continue in several areas. The gender balance in faculty needs to be improved substantially.

There is very strong production of PhD graduates that have gone on to leading positions primarily in industry. Thirty-two PhDs graduated from this UoA over the evaluation period, six were women. Thus the gender balance is satisfactory but could be improved substantially.

Strategy
Excellent presentation on the needs for wireless and wireless mobility and services in the next 10 to 15 years was given and an excellent set of problems priorities and plans for the research and other activities of this UoA rendering this Unit's strategy as outstanding with real potential to achieve. The research plans evolve around four challenges: scalability and affordability, simplicity-efficiency-trust (SET), energy conservation, and new policies and business models. Wireless@KTH and SICS will continue to play a major role in this UoA. Overall this UoA was well integrated, coordinated and their strategy and plans (in research, education, attracting new faculty, going after funding resources) are well thought out and on target.

Actions for Development
Given the exploding demand of broadband wireless communications and computing this UoA, based on its competencies, has the opportunity to help KTH become a world leader in mobile information networks. This can only be accomplished with the development of better integration and collaboration with the UoAs TC, NICS, ISS and HC. For instance, a well thought out and close collaboration with the world-leading group on wireless physical layer models and systems in the TC UoA would provide immediate benefits and results. Another example of such immediate integration efforts should be stronger involvement and collaboration within the auspices of the ACCESS Linnaeus Centre with the NICS and TC UoAs. Improvement is needed in the development of methods and frameworks for application development for mobile environment.

UoA: Information and Software Systems

General Assessment
The UoA on Information and Software Systems is overall weak and incoherent. Its *single strongest aspect* is its strong tradition in conceptual modelling. Its *single weakest aspect* is the lack of coherency as a unit and lack of technical strength in systems engineering.

Performance Against Evaluation Criteria

Scientific Quality (baisc research)
The activities within the Information and Software Systems (ISS) UoA are organized in four research groups at the School of Information and Communication Technology (ICT): *Software Engineering of Distributed Systems, Information Systems Engineering, Modelling and Simulation* and *Synthetic Populations*. There does not appear to be coordination and integration between the groups. However, part of the UoA currently performs at an internationally high standard with the main part performing at a nationally high and internationally recognised standard. These are small groups, or rather individual supervisors with a handful of doctoral students. All professors perform well in their respective area of interest, but their activities are under-critical in size and not yet coordinated. This unit

includes a close collaboration with Stockholm University (i.e. some associate professors), the reason being that the Department of Computer and Systems Sciences is a joint department of KTH and Stockholm University.

Software Engineering of Distributed Systems
This is a disciplinary group (single professor) conducting research in: semantic oriented presentation and processing, logic-based methods for automated synthesis/composition for software services, autonomous computing, service oriented computing, personalization of software and service. The emphasis is on systems that have distributed components, operate in open operating environments and have decentralized control. The research is on good topics and of good quality but the group is not ranked as leading at the national level. The publication record is not strong. There is a good relationship between basic research and applied research, in the sense that most research problems are well motivated by applications and industry problems. There is reasonable collaboration with industry. The Panel could not identify discriminating factors in the research performed.

The work on service composition based on linear logic theorem proving is quite good and innovative (best paper award IEEE ICWS). The work on partial deduction for linear logic and on the development of a formalisation for symbolic negotiation is preliminary and weak compared to the international state of the art, in the opinion of the Panel. The work on modelling trust relationships and trust ontology is good on the software side but needs to be linked to the international state of the art on trust management systems (from a security perspective). The group should try to publish research on their work on trust in more prestigious journals and conferences in this field. The just initiated work on semantic web services analysis and composition addresses important problems and the approach is promising. The group has strong international collaborations (European) and a set of industrial collaborators. However it does not have strong collaborations with the best leading research groups internationally, or with the strongest companies in this area.

Information Systems Engineering
This is a disciplinary group conducting research in: enterprise modelling, modelling business processes and the business value of organizations, value driven design of services, and evaluation of business process management languages and systems. The Panel believes that information-systems engineering is emerging as an important topic – specifically, how can a world of distributed processes and service providers deal with issues of stability, sustainability, and support? But to date the approach taken towards answering these questions within the unit has been quite conventional and not seemingly convergent. The overall research quality and output (publications) is judged as weak (even at the national or local level). As all the projects are driven from specific industry problems there is good relationship between basic and applied research, but the basic research component is very weak. There is good, but narrow, collaboration with industry. The Panel could not identify any discriminating factors in the research performed.

The work of the group focuses on research to support organizations in their management of information systems at both the business and engineering levels. The research is centred on two closely related research domains: enterprise modelling and reference process models. The work on evaluation of business process management languages and systems (BPMS) is good from an applications perspective, but routine. The key technical ideas were generated elsewhere (foreign collaborators). The topics in the ongoing projects (visualization of patient centred process and business models in health and social care, SAMNET, SO business models

for enterprise systems, CMMS) are very good, but the Panel has not been able to determine what the key contributions from this UoA are, or will be, in these collaborative efforts. The research on life-cycle management process models is solid from a technical perspective, but again rather routine. Some important contributions and achievements are: Recommendation of results and systems by the ISO/IEC software engineering-life cycle processes-maintenance standard, and by the SWEBOK guide and standard of the IEEE Computer Society.

Modelling and Simulation
This is a disciplinary group (single professor) working on the development of algorithms, techniques and methods for modelling, simulation and analysis of complex systems. Some of the systems considered are computer systems, communication systems, and information systems. The overall research quality and output (publications) is judged as weak even at the national or local level. There was no evidence presented of collaboration with industry. The Panel could not identify any discriminating factors in the research performed.

The work on simulation is routine. Issues addressed are distributed simulation principles and algorithms, synchronization and data distribution, collaborative modelling and automatic model composition. The basic research component is weak, even at the national level. There is a reasonable good collaboration network, but there was no basis to judge the level, strength or quality of these collaborations (except in the joint projects cited).

Synthetic Populations
This is a disciplinary group (single professor) working on computer-generated populations of individuals. More specifically it investigates the use of such populations for simulating complex processes in real-life applications. The main application area is computational epidemiology. The work on synthetic populations described posed some interesting questions. However, the results were judged to be preliminary and/or weak, measured from an international or national standard. There was no discussion of methodologies for validation of results, and this is critical in this area. There is some collaboration with the Swedish Institute for Disease Control, the Swedish Ministry of health and Social Affairs, the Swedish Institute of Computer Science.

Applied Research Quality
Most of the projects are applications driven, thus the level of applied research is reasonably good, and the majority of the UoA currently performs at an internationally high standard. The UoA has collaborative projects with Swedish and European industry, and has extensive collaboration with SICS (Swedish Institute of Computer Science) and FOI (Swedish Defence Research Agency). The UoA manages two attractive (to students and industry) MS programmes at KTH: Software Engineering of Distributed Systems, Engineering and Management of Information Systems). There was no evidence presented for strong commercialization or transition to industry efforts or results (most probably a consequence of the small size and under-critical mass of the entire UoA).

Scholarship
The scholarship within this UoA was very heterogeneous between the groups but was seen to be emerging in some parts/individuals of the UoA. Overall the UoA is judged weak as most of the projects are specifically driven from specific applications. The overall publication record is weak, especially with respect to journal publications. There is an extensive network of international collaborators listed but in the opinion of the Panel, this does not include the leading research centres in this area internationally. Thus the international recognition of this UoA is judged as rather weak. There is reasonable participation in conference committees.

Vitality and Potential

Overall, the vitality and potential needs to be improved across the majority of the UoA. The Unit had a balance between senior and junior faculty, four full professors versus five associate, assistant and guest professors. However, from a KTH perspective, this is somewhat 'fuzzy' as faculty from Stockholm University were included. Another weakness is that most faculty are part-time – thus there is a serious critical mass and personnel question. There was no evidence of systematic processes to mentor, support and develop young faculty. No faculty awards were cited, but the gender balance is very good. The faculty resources should be increased very substantially for this UoA to attain reasonable vitality and potential.

The number of graduated PhDs is very low over the evaluation period: seven, two being women. This figure includes PhDs awarded by Stockholm University; KTH doctorates were three, two to women, so the gender ratio is very good. The PhD production should be increased very significantly for this UoA to attain reasonable vitality and potential.

Strategy

The UoA has undertaken a research planning exercise for the next 8–12 years. The research areas identified and presented are driven by the correctly perceived need, but the strategy was considered weak. These research areas are; semantic orientation, service orientated computing, automated service composition, personalization of software, autonomous software systems, model-driven architectures, synthetic populations, agent-based modelling and simulation, and symbiotic simulation. The UoA has also identified a set of applications where it intends to apply the results from the above research areas. These applications are: pandemic control, crisis management, organizational memory, citizen services, access to cultural heritage, smart environments, e-learning systems, smart robotic systems, MMOGs, and social software. There is lack of both coherency as a unit, and technical strength in systems and software engineering. The Panel concluded that as a Unit, they have identified interesting future research areas and application areas, but they failed to convey the sense that the team, as currently constituted, would be able to realize these ambitious goals.

Actions for Development

The area of this UoA is socio-technical systems; that is, systems composed of technical and social subsystems where people cooperate in order to accomplish tasks using technical artefacts in their environment. Recent developments in information and communication technologies enable novel and more complex forms of socio-technical systems where users interact with large scale, service orientated, component-based and collaborative cyber-infrastructures. There is a clear need for the development of new models, design methods, performance evaluation methods and validation-verification methods for such systems. In particular, novel methods are needed to manage the complexity in these extremely complex, distributed and dynamic systems. The panel agrees with this assessment of the area. Furthermore, these systems affect all aspects of life and work and at all scales from individuals to companies/organizations to nations to the international community.

There are many disciplines required to address this need, and it is very demanding for any university to become a technical leader in this significant, new and emerging area. This UoA is a competence and teaching resource in software engineering, information systems and databases, which are examples of such important areas. But, it is the Panel's judgment that it does not, by itself, have either the critical mass or the resources to accomplish even a small fraction of what is being described as future plans. A starting point exists but overall direction is needed. This conclusion includes the basic and applied research aspects of the programme, as well as collaboration with industry, inventiveness and innovation. The area of socio-

technical information systems and networks is of rapidly increasing significance with many applications but substantially more resources and planning are needed to make it of strength for KTH. Thus KTH leadership should examine carefully plans and investments versus priorities. A considered strategy should be developed for how these areas should be covered at KTH, both as key resource for research in many other disciplines and for undergraduate education. An important part of the plan should include integration of the collective resources of KTH, SU and industry towards developing more realistic plans that have a chance to put KTH into an internationally recognized and leadership position.