STC RESEARCH STRATEGY

INDUSTRIAL IT – TECHNOLOGY THAT ENABLES SENSOR SYSTEMS AND SERVICES

stc Sensible Things that Communicate

PART OF MID SWEDEN UNIVERSITY

STC Research Strategy: Industrial IT – Technology that Enables Sensor Systems and Services

1. Introduction

STC@MIUN is a research centre at Mid Sweden University with a vision to enable future sensor-based systems and services by conducting innovative and multidisciplinary technology research in electronics and computer science. Sensor-based systems and services is a general technology area that can be applied in all parts of society. The research within STC@MIUN is focused on applications in the field of Industrial IT, supported with a strong industrial cooperation – both regional and national. STC produces high quality research in all research groups and demonstrates the potential of the whole area. The overall goal is to facilitate remote presence that can be a base technology for new business models.

2. Motivation

Analogue technology has dominated development from the discovery of the telegraph to the development of analogue TV. Right now, we are in a digital technology revolution (see MDNMC in Figure 1), where analogue technology is replaced by digital. In practice this means that all telecommunication speaks the same language, namely a universal digital language in which television, telephone, fax, email, video conferencing, etc. can be distributed over the same physical network. The limitations today are not in the digital technology of the communication channel; instead competition occurs at the interface between the digital communication channel and the user [18]. The contents of the digital services become more important and the communication channel is becoming more standardized and therefore not a competitive factor. Of course, the communication channel develops continuously but the focus will be at the interface development in the coming years.

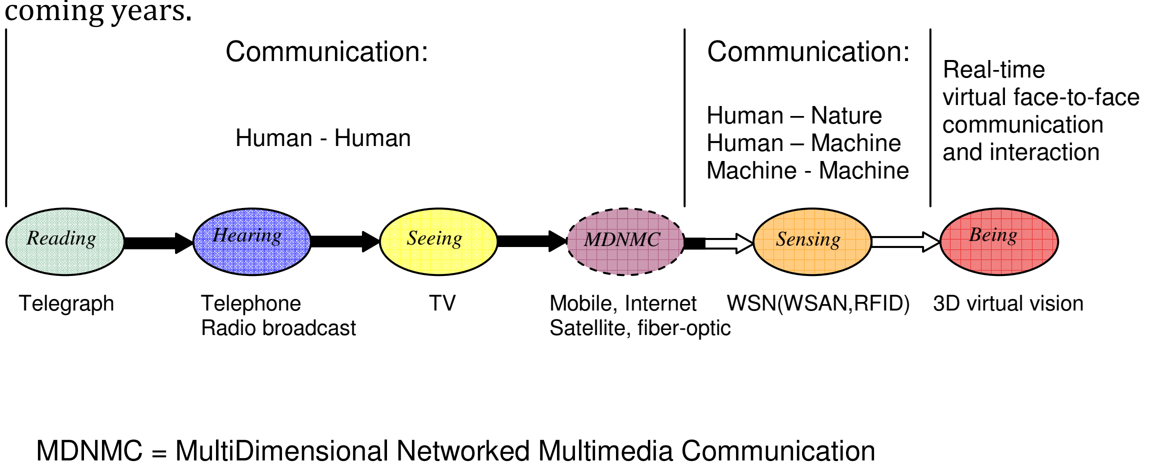

Figure 1. The development of telecommunication.

The progression of communication has also driven the development of how communication can be used to build new services and new business models. Both Google and Facebook are good examples of this, where both build their revenue on information generated by users – in Google's case search patterns whereas Facebook monitors how users socially interact as well as their interests. We will probably see much more of this utilization of the possibilities of today's technology [1,10,11,18].

The evolution of technology in the future will focus on bridging the gap between the real world and the digital world, the Internet of Things [1,7,11]. The goal is for these worlds to merge as much as possible. A great deal of the technical development will be focused on the interface between these worlds by the development of sensor technology [1,2,3,4,5,7,8]. Sensors enables us to sense and interact over distance with the ultimate goal and be able to fully interact with a remote environment – "remote presence", as shown in Figure 1.

A common trend is that new technologies are initiated and shaped in a niched area linked to industrial applications, and then further developed into public art with a big impact on our society. The cost of the initial product development is often motivated by an industrial application in a closed system with great value to the industry players using the technology. As a result, the technology most likely to be used in next-generation audience technology is already developed in the industry. We can even now see how such technology is implemented, for instance, in Apple's iPhone with motion sensors and multi-touch screen. Another example is the digital camera. It was developed mainly for industrial monitoring and measurement technologies, but today its use has spread throughout the community. This particular example shows how sensor technology solutions, developed in an industrial context, are becoming key technology in the digital society [3,4,7]. Opposite to this, there is also a movement of technology that becomes being sold for consumer/automotive industry enables new applications in the industrial sector. Both these trends are important in the development of research in the area. The technology affects the way the media and advertising sector develops, how organizations can communicate with their customers and employees [14], how we communicate with each other and how society organizations can provide services to citizens.

The path towards enabling "remote presence" will require extensive research worldwide and will generate changes to business and sociality that is hard to see. There are several examples of technology drivers such as remote robots - in areas such as agriculture/forestry [9], medicine [12] and mining [13], smart grids [6], environmental monitoring [8] and industrial systems [5]. Common for all these is the generic and common technology composed of sensor technology, embedded system technology, network technology and service technology [18]. Below are examples of two application challenges extracted from real projects within STC. These involve all the technology areas within STC, described later in this strategy.

Physical products become services [15]: For software solutions there is already a great momentum towards business models where the software is sold as a service rather than as software that customers can install locally. This is enabled by high-speed Internet connections and the customer gets added value. The added value comes from the fact that the customer does not need to maintain the software. To move this model to physical products requires more work than is required for the software. First of all, the product needs to be connected [16] and it needs to be able to sense [1,2,3,4,5,7,8] its status and its environment in order to communicate its condition and to allow remote control of itself. New sensor technologies, wireless systems and robust communication methods are key technologies [4,5] that must be developed to enable products to become services. The benefits for the end-user are the same for software as a service: lower maintenance and less need for expert knowledge in the specific product.

Examples of activities that have been addressed in this area within STC are; (1) fibre optical [26], optical [19] and radiation [21] based sensor solutions for remote surveillance of industrial equipment, (2) wireless vision [22] and MEMS [23] based sensor nodes for measurement and navigation in places that was not possible before, (3) energy harvesting [24] and power conversion [25] (4) sensor network protocols [32] and security issues [33] and finally (5) collection and aggregation of sensor data [31].

The "Google" of the physical world [7]: If all physical objects can sense their own status and environment and can communicate this information to others [1,7,11], they will present us with the same potential that the social networks and other Internet services offer today: machines will produce information about themselves and their environment, similar to what users of Facebook do for the Facebook system. This information can be generated through sensor technology, communicated and then aggregated in such a way that it is possible to build new services around this massive amount of information [10].

Example of activities that has been addressed in this area within STC are; radiation measurement for security application [27] and printed sensors [20] for low cost measurement, wireless visual [29] and environmental sensor [28] for large area measurements, handling of privacy [30], aggregation and development of mobile service technology [31], 3D visualization and communication techniques [34].

3. Related research initiatives

The research field addressed by STC is a multidisciplinary field that includes many different research fields, represented by different research groups in STC, where each group has been formulated and developed with respect to the best research in each field. As for the STC research area, there are no other single research groups that can address the same whole area although there are clusters, nationally and internationally, that address parts of it. Nationally, there are a few initiatives such as CERES (Halmstad University College), EISLAB (Luleå Technical University) and WiseNet (Uppsala University), and they all have similar ambitions as STC, but with a more software/communication oriented focus instead of addressing the entire challenge including the sensor interfaces. Mälardalen University College's Real-Time Research Centre (MRTC) has even more of a software focus. iPAC at KTH addresses a sub-set of the STC area with an emphasis on low-cost surveillance of logistics chains. A uniqueness that distinguishes STC from other national research initiatives is the close integration and cooperation between the different research groups within the centre.

The Swedish research institutes Acreo and SICS have together a similar focus as STC, but these institutes are not collaborating and, since they are institutes, they concentrate on applied research problems.

Internationally, there are a lot of different research clusters within the STC area. To mention a few of them: Berkeley University has a few initiatives, for example, Berkeley Sensor & Actuator Centre. SENSEable City is an initiative from MIT that applies the technology within an urban living context. A European initiative is SensLAB Testbeds (Grenoble INRIA / University of Strasbourg). SensLAB focuses on demonstrating large-scale sensor networks.

4. Priority research areas

The priority research area is technology research concentrating on sensor systems and services within the area of Industrial IT. STC has a holistic view on the selected focus area, which include the full spectra from sensing to aggregation of sensor data into visualization and services. The connection is supported with sensor network technologies composed of embedded system technology and network technology.

The technology research is carried out within nine research groups - see Figure 2, where the responsibility of the technology area is to address the research challenges in the targeted fields. The STC focus is research on Industrial IT applications with an aim to develop technology in a scope that can be further developed into consumer market solutions. The previous results of the STC research can be found in Appendix B.

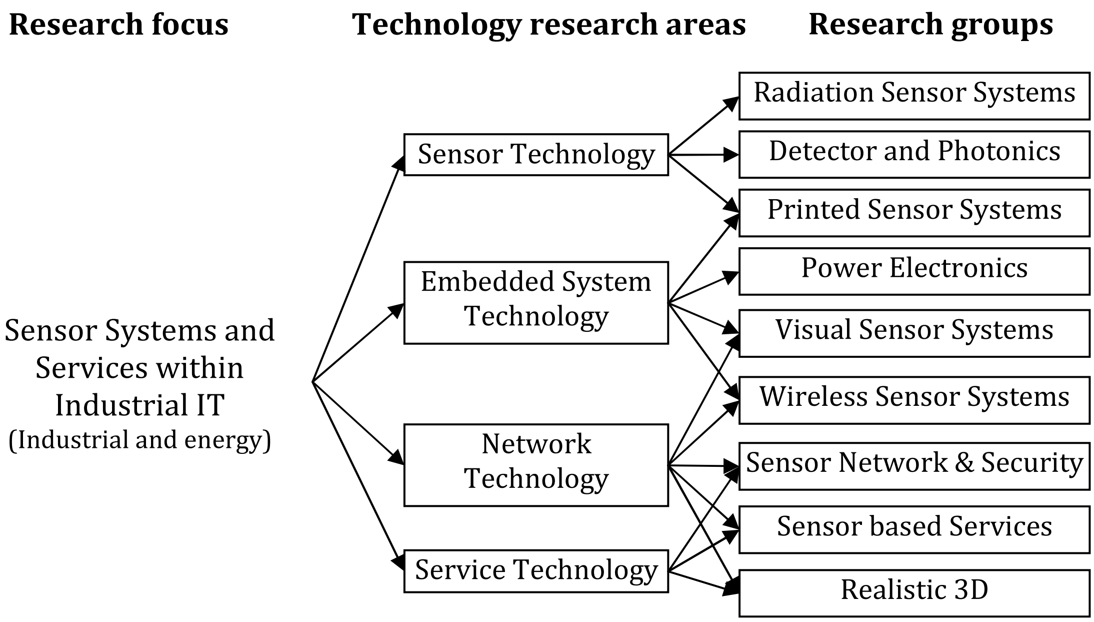

Figure 2. Defined research groups and targeted research areas in STC.

Summary of research groups:

Radiation Sensor Systems: The group has activities in X-ray imaging- and sensors and particle detectors. Research is focused on both simulation - processing in own clean room, and characterization. Apart from the challenges addressed in this strategy, the

research group also has research in detectors to support particle physics research in CERN and other international research centers.
Detector and Photonics: The group has activities in low cost IR/NIR sensors, UV-sensors, and low cost fibre optic sensors. Apart from the challenges addressed in this strategy, the research group has research in fibre lasers.

Printed Sensor Systems: The group has activities in low cost printed sensor systems and detectors. The research target issues on integrating antennas, detectors and electronic functions on paper. This involves study of printing material, substrate characteristics effects and robustness. The drivers for the technology are the possibility of flexible form factor, low cost and large structures that enables a new and wide area of applications.

Power Electronics: The group has activities in HF switched power supplies compact applications. The target applications are energy generation (e.g. small scale energy production), energy transformation (e.g. electrical/hybrid vehicles and welding) or for electronics systems. Technology challenges addressed is focused on transformation and control in high frequencies.

Visual Sensor Systems: The research group focuses its research on the new challenges that arises with the introduction of embedded visual sensor systems. The addressed challenges within embedded vision systems are real-time and low-power implementations of imaging systems. Additionally challenges addressed are the algorithmic challenges that are faced in new embedded applications that the new technology enables.

Wireless Sensor Systems: The group has two focus areas - wireless measurement nodes, targeting mostly industrial measurement applications, and surveillance of large areas, such as environmental monitoring. This research involves activities on embedded implementation technology, signal processing and the implication of the measurement system and energy supply on the network system.

Sensor Network & Security: The research group addresses communication-related challenges within sensor networks. That is, activities on transportation of data such as sensor network architecture and efficient routing algorithms and also activities on the identity and security of nodes and data. All these challenges have relevance for both industrial measurement and large area surveillance applications.

Sensor based Services: The group focus on research issues on technology that enables open distribution and sharing of sensor/user information. Further, the process on how to study the aggregation of sensor data is done and how this technology can be used to build services in both mobile and wired applications.

Realistic 3D: The group has research activities on coding and capturing of 3D visual information. Apart from the challenges addressed in this strategy, the research group also has research in presentation and play back of 3D material.

5. Analysis of the profile area/research centre research profiles

The research profile in Industrial IT is conducted as multidisciplinary research jointly in nine research groups. The size of each group is 6–10 researchers with overlapping competences. It is important to have overlapping competences in order to be able to interact between the research groups and to address the multidisciplinary challenges. Apart from excellent research results, the wide composition of researchers that actually interact across boundaries is one of the main strength of STC. The table below shows a summarized analysis of the senior researchers' competence and Appendix A collects curriculum vitae for the research leaders.

Research group	Title	Area of research represented by the research groups								
Researcher		1	2	3	4	5	6	7	8	9
Radiation Sensor Systems										
Christer Fröjdh	Professor	X	X							
Heinz Graafsma	Adj. Professor (DESY, Deutsches Elektronen-Synchrotron)									
Börje Norlin	Ass. Professor	X	X							
Sture Petersson	Prof. emeritus	X	X							
Detector and Photonics										
Göran Thungström	Assoc. Professor	X	X							
Jan Andersson	Adj. Professor (Acreo)	X	X							
Lars Norin	Adj. Professor (Acreo)		X							
Clas Mattson	PhD	X	X	X	X					
Magnus Engholm	PhD		X							
Printed Sensor Systems										
Hans-Erik Nilsson	Professor	X	X	X						
Ulf Lindefelt	Professor		X	X						
Johan Sidén	Ass. Professor			X			X			
Henrik Andersson	PhD	X	X	X						
Anatoliy Manuilskiy	PhD		X	X		X				
Power Electronics										
Kent Bertilsson	Assoc. Professor		X		X					
Visual Sensor Systems										
Mattias O'Nils	Professor		X			X	X	X		
Benny Thörnberg	Ass. Professor		X			X				
Jan Thim	Ass. Professor	X	X			X				
Najeem Lawal	PhD					X	X			
Wireless Sensor Systems										
Bengt Oelmann	Professor					X	X	X		
Cheng Peng	PhD						X	X		
Sensor Network & Security										
Tingting Zhang	Professor							X	X	
Mikael Gidlund	Adj. Professor						X	X	X	
Stefan Pettersson	Ass. Professor							X	X	
Sensor based Services										
Theo Kanter	Professor							X	X	
Youzhi Xu	Professor							X	X	X
Ulf Jennehag	Ass. Professor							X	X	X
Patrik Österberg	Ass. Professor							X	X	
Rahim Rahmani	Ass. Professor								X	
Realistic 3D										
Mårten Sjöström	Assoc. Professor									X
Kjell Brunnström	Adj. Professor									X
Roger Olsson	PhD								X	X

6. Vision for the profile

The long-term vision for STC@MIUN is to enable future sensor-based systems and services by conducting innovative technology research in electronics and computer technology. Although sensor-based systems and services is general technology, which can be applied in all areas, the research within STC@MIUN is focused on the application area of Industrial IT.

7. Goals for the profile

The main goal for the STC research centre is to become the national centre for sensor systems and services. As a national centre, STC would be the natural partner for application challenges within this area. The research should be of high quality, published in reputable journals and presented at conferences and have an emphasis on educating doctors to be able to both lead development in industry and become successful researchers. Additionally, the research should be useful in terms of generating new knowledge to industry (specifically our partners) and generating innovations that are transferred to new companies. To meet these general goals some sub-goals needs to be fulfilled:

- Ensure up-to-date lab facilities to be able to carry out verification of results and ensure that the results are useful.
- Ensure at least nine technology areas.
- Ensure a strong connection to the best and strategic competence in industry through adjunct professors.
- Have a high throughput of produced doctors (PhD).
- Ensure a larger profiling funding similar to a KK-profile.
- Have a tight integration between Master students and the research.

8. Goal indicators

STC has actively worked with the goal indicators since the establishment of the profile. These have been targeted towards a) financing amount and distribution, b) staff amount and competence, c) scientific publications, d) industry collaboration, e) research education throughput, f) academic networking, g) positioning of the research centre and h) close connection to education.

The goal indicators will be reviewed within STC on a yearly basis and be revised from a strategic point of view every three years. However, the initial indicators in this first version will be revised after one year through a bottom-up analysis.

Ad a) ***Financing amount and distribution***: This is described in Section 9.

Ad b) ***Staff expansion***: Target for 2020: 50 PhD students, 35 post-docs and senior lecturers, and 15 professors.

Ad c) ***Scientific publications***: The base line (i.e. 2011) is 30 journal publications and 50 conference proceedings publications per year; the target is to double this figure until

2020. Specific journals are not identified for the whole research centre, but the strategy for publication is further described in Section 10.

Ad d) ***Industry collaboration***: As indicated in Section 11, we should have a strong cooperation with the national research institute Acreo and large industries in the area (ABB, SCA, Holmen and Ericsson). Each research group should identify a consortium for future EU framework programmes and identify key cooperation partners within their respective field.

Ad e) ***Research education throughput***: A high production of PhDs has been a prioritized area within STC from the beginning, since we believe that this is the most efficient and robust way to increase the competence in industry partners. From start to finish, a PhD student has four years of full-time studies, which with the 30 PhD students active today, would result in a throughput of 5–6 doctoral dissertations per year on average.

Ad f) ***Academic Networking***: Each research group should have identified international academic cooperation partners and describe how this increases the quality of the research group.

Ad g) ***Positioning of the research centre***: Each year STC should organize a positioning conference (STC Expo) and be active in regional and national media.

Ad h) ***Close connection to education***: Make sure that Master students are involved in research tasks, addressing both academic research and industrial partner problems.

9. What it takes to reach the goals: financial plan

Since the start of the research within STC@MIUN, the KK-foundation has been an important funding partner, enabling the establishment of the STC profile in 2005. From the start of the profile funding, the KK-foundation was the major financer of the research within the STC area. One constraint for the profile project was to attract more funding resources to STC, and during the six years of the profile research funding became much more diversified. At the end of the profile, STC had considerably increased funding from the university and from other funding sources.

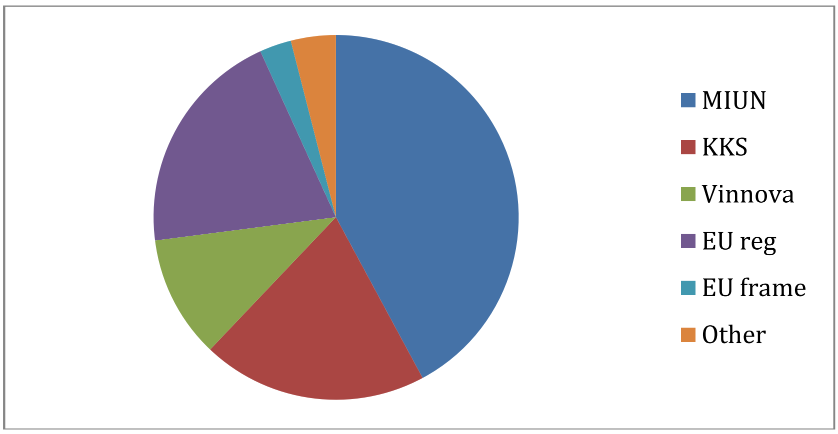

Figure 3. STC funding distribution 2011.

An important part of this success is that an increased number of researchers have started applying and formulating research projects, which was a strategy during the profile project. The identified sources of funding for the moment are: *the KK-foundation, Vinnova, the Energy Agency (Energimyndigheten), EU Regional Funds, Objective 2, EU framework programme* and *the Mid Sweden University*. As seen in Figure 3, there is today a good composition of funding. Sources in which we foresee potential growth of research funding are the EU Framework programme, Vinnova and KK-stiftelsen. A missing piece that will be addressed in the coming years is to attract funding from the Swedish Research Council (Vetenskapsrådet). These values can vary between years, to meet variations in financing, such as between periods in EU-funding.

Funding needs – million SEK	Total	Miun	KK	Vinnova	Energy Agency	EU reg	EU frame	Nat RC	Other
Annual short-term funding needs	42	17	10	3	0	10	1	0	1
Annual long-term funding needs	62	18	15	6	2	12	5	3	1

10. Publication strategy

The research outcome is measured by publications in the form of monographs/edited volumes, working papers, anthologies, peer-reviewed articles in journals, as well as presentations at national and international conferences. The aim is to disseminate the information as widely as possible. It is important to collaborate with international partners on edited volumes and publish in prestigious journals. Finally, several *international conferences* would be the venues for distributing the outcome of the STC research. They include the international conferences and workshops organized by IEEE, ACM and SPIE. Specific conferences and journals need to be addressed by each research group.

11. Cooperation strategy

STC@MIUN interacts with partners in a regional, national and international context. The role of the centre and the level of cooperation differ with the context.

Regional: At a regional level, STC has an important role to play in the regional innovation system. One aim is to be useful for regional industry and generate growth through innovative research – either through generating new knowledge in existing companies or by the spin-off of ideas into new companies. For regional cooperation, innovation systems such as Fiber Optic Valley and Åkroken Science Park perform an important part.

National: At a national level, STC has the role of acting as a national resource in sensor based systems and services. Here, STC has established strong connections to key partners, such as Acreo, through establishing adjunct professorships and working towards common strategic projects. Industry cooperation is directed to a few large companies (ABB, SCA, Holmen and Ericsson) and smaller innovative companies whose competences match the identified technology challenges focused upon within STC.

International: Internationally, each research group should have identified international strong partners with a goal to increase the quality of their research. Each research group should also work actively to build a strong consortium to peruse the EU's framework programme.

12. Working process and management of the profile

The core of STC@MIUN was developed within the profile funding from the KK-foundation during 2005–2011. From the end of the profile funding, the restructuring of STC has concentrated on integrating the technology areas that were not a part of the initial profile and to develop a robust organization and vision for the coming period regardless of sources of financing. The organization has been influenced by the KK-environment process at Mid Sweden University, with an added quality process.

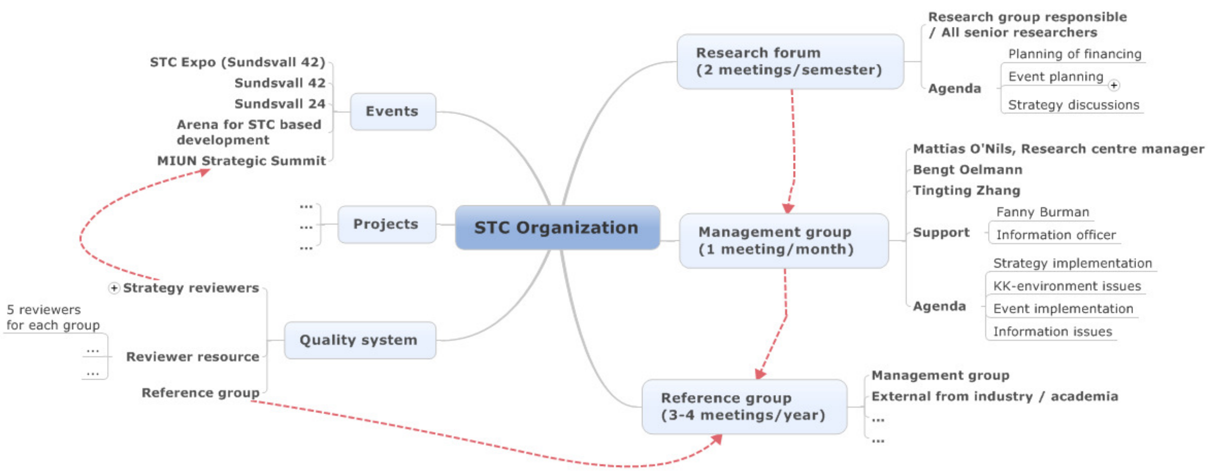

Figure 4. Organization of STC@MIUN.

The STC organization, shown in Figure 4, has several entities that together build the management and development process of the research centre. Some parts of this can be affected by the new organization of research centres at Mid Sweden University.

Reference group: The reference group is composed of the research centre's management group, external experts from key industrial partners and researchers from academia. The reference group has the role of assisting and guiding the research centre in its work with quality assurance, strategic development, positioning of STC and the construction of the brand STC@MIUN. The reference group is responsible for prioritizing the project proposals within the KK-environment.

Management group: The management group is the executive leadership of the research centre, and is responsible for implementing the research strategy and KK-environment. Furthermore, the management group will be in charge of event and information issues.

Research centre manager: Leading the work within the whole research centre.

Research forum: Discussion forum that includes all senior researchers within STC. Issues that are handled in the research forum are strategy development, planning of financing and event preparation.

Quality system: The quality system of STC has the purpose of ensuring quality in the project initiation, funding allocation within the KK-environment and project review. The quality system also consists, apart from the internal STC structures described above, of external resources for the review of project proposals (one set of reviewers for each research group) and reviewers for the strategy of the research centre (two reviewers for the whole centre).

Projects: The research within STC is either conducted in projects financed by different funding sources or internal money. All research done within STC will be followed and analysed by the research centre. For projects funded by the KK-foundation, STC will have a more active role in assuring the quality of the projects.

Events: Events are an important part of positioning the research centre, building new cooperation and creating the research environment. The main events are the conferences STC Expo (information and exhibition that targets positioning of STC towards researchers and industry), Sundsvall 42 (marketing of research for industry) and Arena (discussion and inspiration of ideas to start new cooperation with industry partners).

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Appendices

- Appendix A, CV for research leaders
- Appendix B, Final report for STC profile funding from KK-foundation.