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Sensor Technology Foresight in Denmark - 2015

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Type:	A national technology foresight aiming at strengthening industry's, organisations' and policy maker's strategic outlook on sensor technology		
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Duration:	2000-2001	**Budget:** €114,000	**Time Horizon:** 2000-2015

Purpose

The overall goal of this foresight on sensor technologies was to provide scenarios for future developments in sensor technology in terms of the technology itself, its application and relevant markets for the period 2000–2015. This was to provide a decision support tool to prioritise research and development and to guide the commercialisation of sensor technology in the near future. It was also intended to develop and maintain networks of expertise within the sensor technology community and to test elements of technology foresight methodology applied to a narrow technology domain.

Sensors for Future Technologies and Markets

Sensor technology is one of the technologies that will play a major role in the future. It can be used in all sectors of industry to give products added value that make them more competitive. Sensor technology is a rapidly growing area of research. Many products incorporating sensor technology are already on the market and it promises to continue to play a critical role in technologies of the future.

Sensors and sensor systems perform a wide range of sensing functions. They enable products and systems to capture process and communicate information about the status of the system in which it is placed. Sensors are able to capturing information on the chemical composition, texture and morphology, large-scale structure, position and motion of systems in which they are applied. It is a characteristic feature of a sensor that the device is tailored to the environment in which it is to operate.

The Danish government established a dedicated sensor programme in 1999 and provided approximately €14M over a 3 year period to support research and development of sensor technology. This foresight project was an important early part of that initiative. The target group for the foresight study was the Danish sensor technology community. This included manufacturers and users of sensors, the R&D community, public authorities and the Sensor Technology Center - a consultancy centre for the industrial sector.

Project structure

The project comprised six main tasks:

- **Technology Mapping:** This involved desk research to identify the boundaries and categories of the technological landscape to be analysed.

The EFMN is financed by the European Commission DG Research. It is part of a series of initiatives intended to provide a 'Knowledge Sharing Platform' for policy makers in the European Union. More information on the EFMN and on the Knowledge Sharing Platform is provided at WWW.EFMN.INFO

- **Technology Premises:** An expert panel was set up to establish the state-of-the-art in sensor technology and to define boundary conditions for sensor technology over the next 15 years.
- **Case Studies:** These were used to analyse important mechanisms for sensor technology breakthroughs.
- **Technology and Market:** An expert panel was set up to develop a future oriented discussion on trends in the development of sensor technology and the interaction between the market and technology over the next 15 years.
- **Survey:** This was performed to improve validity and reliability of the preliminary conclusions of the foresight.
- **Conclusion:** Discussion and processing of the various elements of the previous tasks employing technology mapping and scanning, case studies, expert panels and the survey.

Data Collection

The collection of data and information for the synthesis of possible future developments of sensor technologies were structured along three axes:

- Sensor physics and sensor systems,
- The generation and transfer of expertise and skills,
- Technology users and areas of application.

The study analysed six categories of sensors:

- Electromagnetic,
- Mechanical,
- Electrical,
- Magnetic,
- Chemical,
- Nuclear.

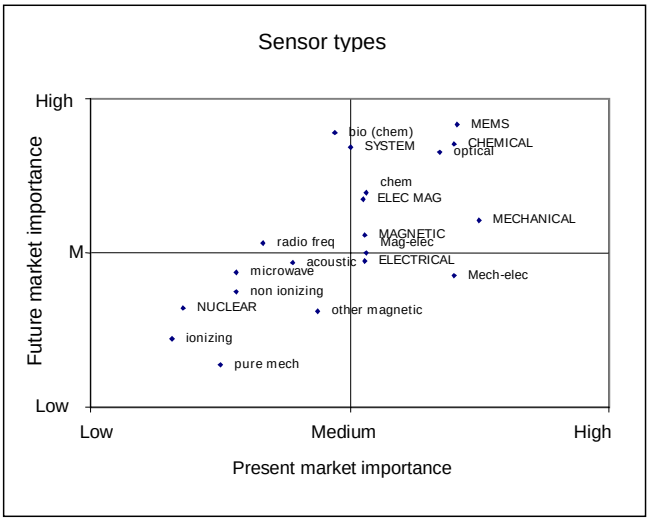
These covered 13 sub-categories in addition to a number of systemic issues. The scanning process was concerned with 'looking ahead' and was followed by detailed technology mapping. Scanning was performed by examining topics in the available literature and through four thematic expert workshops. Two of these were Danish workshops and two international workshops one on 'Technological Premises' and the other on 'Technology and the Market'. In structured brainstorming sessions experts were asked to formulate statements and visions about trends in sensor development. It was intended that these statements should reflect issues identified during the technology mapping. The experts were therefore asked to follow a syntax that referred to the following elements:

- Development stage,
- Sensor type,
- Basic technology,
- Area of application.

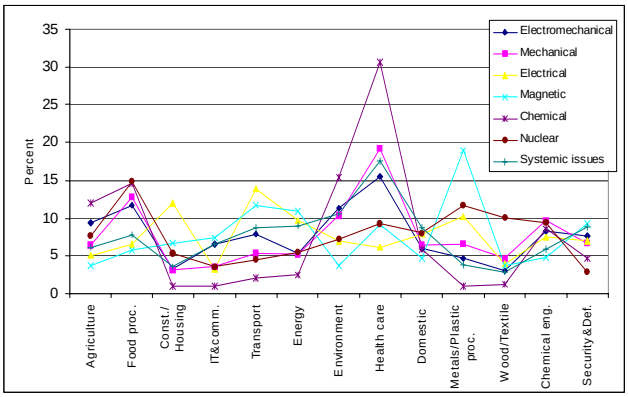
This scanning process resulted in a list of 217 topics and statements central to the future development and use of sensors.

The Delphi Survey on Sensors

A Delphi survey was performed in order to improve the validity and reliability of the preliminary results. The questionnaire cannot be too long or burdensome to complete and the number of statements should therefore be limited to about 50. The Delphi survey asked experts to respond to each statement in terms such as the time horizon or barriers for realization and the potential market volume. 130 statements were formulated on basis of the 217 topics arising from the data collection process and these were narrowed down to a final 50 used as the basis for the Delphi questionnaire. The following diagram summarizes the results of the survey in terms of the present and future market potential of different sensor types.



The next diagram summarizes the results of the survey in terms of the expected impact of different sensor technologies on markets linked to specific application domains.



Approximately 1000 sensor experts received the questionnaire and 174 responded. Comparing with other international experience the response rate of about 17% is neither high nor low. Half of the respondents came from academia and more than one third came from industry. 90% of the respondents

came from Europe, of which the largest group came from Denmark (38%).

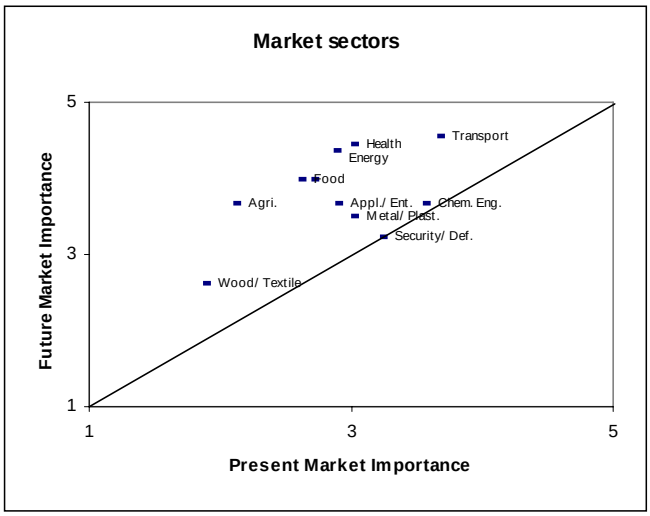
The Strongest Market Prospect is Health Care

One of the questions in the Delphi questionnaire concerned 'Market sectors most heavily impacted by the statement'. For each sensor type the number of respondents has been normalised resulting in a market impact index.

A general conclusion is that the market sector most heavily impacted by new sensor technology will be healthcare. It also appears that new sensor technology will affect food processing and the environment. It will have less impact in sectors such as construction and housing, wood or textiles. All sources of information - literature, workshops and questionnaires indicate the same pattern regarding the future attractiveness of sensor types. MEMS (Micro-Electro-Mechanical Systems), optical sensors, and biochemical or biological sensors together with sensor systems are all expected to be the most interesting sensor types over the next 10 years in terms of market volume.

Increased Use Expected in All Sectors

The issue of how the expected future market importance compares to current market importance was evaluated in an expert workshop. In the figure below, market sectors above the diagonal line correspond to rising sensor markets. Markets on the line are expected to remain for a while at the status quo. As can been seen from this diagram the prognosis is for increased use of sensors in nearly all markets of application.



The Future of MEMS and Integrated Systems

It is possible to rank survey results according to different variables with a view to identifying lists of 'top-ten' technologies.

A top-ten list of technologies was prepared on the basis of the combined index of technological feasibility and potential market volume among expert and knowledgeable respondents. This list comprises refers to all types of sensors, except electrical and nuclear sensors.

MEMS in particular stand out together with sensors that are small, low cost, and flexible. MEMS refer to Micro-Electro-Mechanical-Systems, in particular to physical sensing devices that are of the order of a micrometer in size and are integrated with signal processing technologies using silicon fabrication techniques. It is also expected that sensors will be developed as integrated systems that can be used for multiple applications.

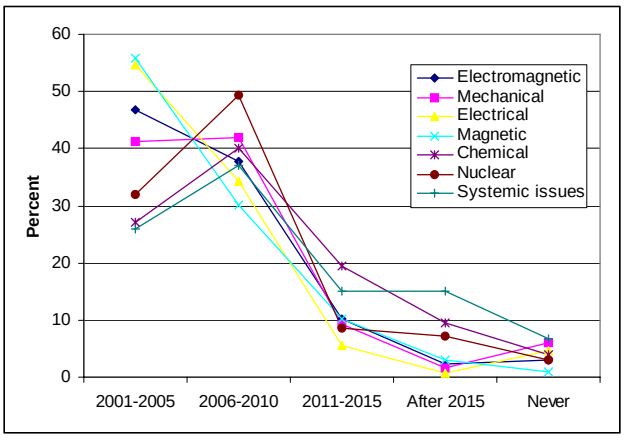
The markets most influenced by the future development of sensors vary as a function of sensor type. Biosensors for example will have a significant impact on the food and health markets. These markets will also be affected by developments in MEMS.

The study revealed that the most important barriers to realizing expected technological developments in sensor technology are limited cross-disciplinary collaboration, limited cross-sectoral collaboration, and a lack of qualified human resources. For the topics on sensor communication and motion control, the lack of standardization is also highlighted as a barrier. Limited cross-sectoral collaboration is especially emphasized as a barrier in topics on MEMS and measurement of water quality.

The study also revealed conflicting assessments of the future for biosensors. On the one hand the widespread use of biosensors, in particular DNA sensors, is considered likely. On the other hand however the use of implanted bio- sensors and human-like sensors was considered unlikely and ranked at the bottom of a technological feasibility list. This at least partly contradicts the positive assessment of their potential market impact.

When Will All This Happen?

The diagram below indicates results from the Delphi study on when experts expect specific sensor types to become available for application.

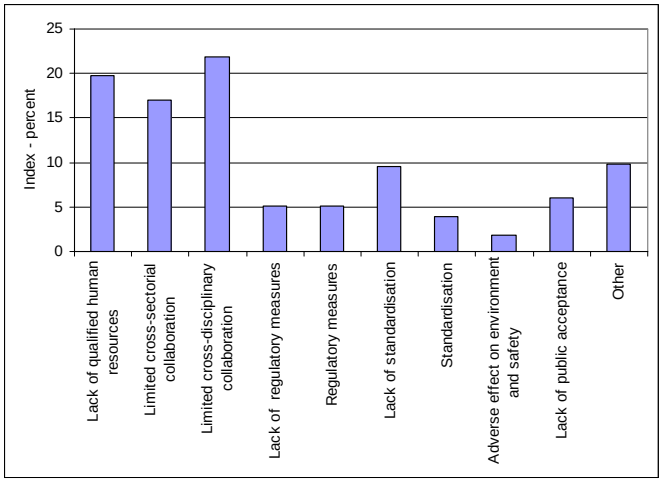


The general opinion is that most of these sensor types will have been developed by about 2011.

This is not surprising given the focus on practical and widespread use in many of the Delphi statements. Respondents felt that 39% of the topics would be realized between 2006 and 2010, 37% between 2001 and 2005, and the remaining topics after 2010. 4% of the technology developments were expected never to occur. An analysis of developments that 10% of knowledgeable responses considered would 'never' occur three stand out as particularly unlikely. All of these events concerned biosensors in stages of development that ranged from development to practical use. Comparing the 'never' responses with those at the bottom of the list for technological feasibility and potential market volume, revealed some conformity with results for implants and the use of sensors for human perception.

Limited Collaboration is Seen as a Major Constraint

The realisation of stated events can be constrained by a variety of framework conditions central to the development of the technology and its markets. The study revealed that the most important barriers to realising the expected developments in sensor technology are limited cross-disciplinary collaboration, limited cross-sectoral collaboration, and lack of qualified human resources. On the topic of sensor communication and motion control, the lack of standardisation was highlighted as a barrier. Limited cross-sectoral collaboration was given special emphasis as a barrier to development of technologies such as MEMS and the application of sensor technology to measurement of water quality. Some attention was paid to the lack of regulation. In particular this was seen as a barrier for the development of automotive and optical gas sensors, as well as implants and biosensors. Public acceptance was deemed a factor in the case of implanted sensors and the use of X-ray sources for sensing in industrial processes. The following diagram gives an overview of expert response on barriers.



Discussion and Lessons Learned

The results of the project and its final report were presented to an invited group of stakeholders and their comments typically fell into three categories.

- Marketing people and professionals from firms importing and distributing sensors felt that the survey gave them a good overview of current technological trends in the area. They indicated that the study provided a foundation for change in their sensor-type portfolio. This group consisted primarily of small and medium-size firms with limited resources to carry our larger foresight and strategy processes of their own.
- People from research and industry with a deep knowledge of sensor technology typically said that they learned nothing new in their own area of expertise. This indicates at least that the final result does not contain any major large flaws or misinterpretations. It also indicates that technology foresight projects at this level of focus do not target the needs of sensor experts but a more user.
- Several representatives from larger firms with a tradition or experience in strategic thinking found the methodology was interesting and requested more information on the process.

Sources and References

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