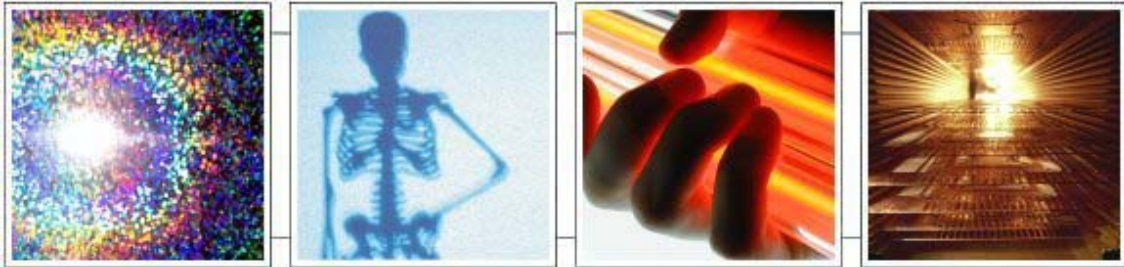


Foresight **Exploiting the Electromagnetic Spectrum Project**



One Year Review

April 2004 – May 2005

September 2005

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1 Aim

This paper reviews the outcomes of Foresight's Exploiting the Electromagnetic Spectrum project (EEMS) over the 12 month period since the launch of the project's findings. It seeks to determine its successes, learn from the process in order to inform future Foresight projects and identify potential next steps.

1.1 Key findings

The aims of the project were to:

- identify areas of rapidly moving science which presented a significant potential future commercial opportunity for the UK; and
- agree a plan of action to ensure that the UK captured a share of those emerging markets.

The project delivered on the first of these objectives in April 2004 and set out the steps which the UK would need to take to remain in a position to exploit these opportunities.

1.2 Activity since the launch

- The messages from the project were effectively communicated and responsibility to take forward the work was passed to Department of Trade and Industry (DTI) Innovation Group.
- There has been continuing investment in the science in these areas which confirms that they are rapidly moving and likely to be commercially important in the next 5-10 years.
- There has been small scale investment in the creation of networks. These could create a community which would seek to capture a share of some of the market opportunities identified.
- However, there are no plans of action or significant investments in any of the areas identified.

1.3 Conclusions on UK ability to exploit these areas

- There are important Government mechanisms in place which support the creation of new networks between academia and business to underpin the development of new areas of science and technology.
- There do not appear to be any Government mechanisms which could be approached and quickly mobilised to make significant investment in long-term speculative science and technology-driven market opportunities.
- The investment community in the UK does not appear to be geared up to take advantage of these opportunities.

1.4 Key issues for consideration

- Have we missed the opportunity to capture a share of these markets?
- What mechanisms should the UK have in place to allow swift and significant investment in important long term investment opportunities?

- What steps should we take to ensure that the investment community supports such activity?

2 Introduction

2.1 Background

The EEMS project began in March 2003 and its findings and action plan were launched in April 2004. The project focussed on a specific area of broadly-applicable underpinning science of interest to DTI Innovation Group, where the potential for future innovation seemed great and in which the UK already had a history of world-leading research. The combination of priorities in science, engineering and technology, with those in wealth creation was a particular feature.

The aims of EEMS, as set out at the start of the project, were to:

- identify key areas of long-term commercial opportunity across the electromagnetic spectrum;
- assess these against UK capabilities; and
- agree a plan of action to help the UK exploit these areas.

2.2 Resources

The project was planned to take 12 months from its start until launch with a budget of £350k and a team of 3.5 people. It launched after 13 months, when Foresight passed responsibility for the project to DTI Innovation Group. Foresight continued to provide support on completing action plan commitments, through organisation and funding of events. The total project spend was £346k, of which £36k was spent after the launch.

2.3 Project outputs

The project selected four 'growth point' topics that combined scientific excitement and promise with the potential to have a major impact on wealth creation. Topics needed to be relatively 'far-out' (10-20 years), innovative, of major potential economic significance, able to be exploited by the UK and, when taken together, form a balanced portfolio within the project. Those selected were:

- All-optical data handling
- Photonics at the molecular level
- Electromagnetics in the near field
- Non-intrusive imaging

The following table indicates the initial investment costs and a best guess of the UK market share of five of the EEMS subject areas. These figures were published in the EEMS Findings and Analysis document.

EEMS topic area	Phase 1: Initial investment (duration)	Total investment cost (total duration)	Value of UK share of market
Optical switches	\$15 million (5 years)	\$215 million (8.5 years)	\$0.5 billion
Diagnostic lab on a chip	\$15 million (3 years)	\$570 million (9 years)	\$5.0 billion
Low cost security imaging	\$50 million (2 years)	\$145 million (6 years)	\$0.4 billion
Laser machining	\$100 million (4 years)	\$580 million (12 years)	\$2.0 billion
Smart contrast agents	\$160 million (5 years)	\$1,500 million (16 years)	\$6.0 billion

The project concluded that significant amounts would need to be spent in these science areas in order to benefit from the potential returns from related technologies. The time scale for this development was seen as short in some cases, for example, six years for low cost security imaging.

Secondary topics identified as significant and on which actions were taken, but for various reasons did not merit a detailed review were:

- Pervasive bandwidth: managing next generation wireless communications;
- Coherent x-rays: bringing wave effects to x-ray imaging; and
- Checking for health: compact personal sensors.

2.4 Analysis and reports

The project produced a review of the current state of the science for each of the four primary topic areas chosen. Over 60 experts participated in the action groups set up to produce them. Alongside the science, the groups created a number of one-page 'roadmaps' for key areas within each topic, which illustrated the steps that would need to be taken over the next 15 years to develop the technology for the identified applications. The science reviews were condensed into overviews and published with the project findings, analysis and an executive summary. This is still available, with other outputs, on the Foresight website: www.foresight.gov.uk.

Foresight commissioned two science writers to write *Tales from the Future*, a set of science-fiction stories taking the project topics as their inspiration. This was a novel way of communicating the future visions from the project to non-experts in a more easily-accessible way.

The project also developed a novel, simple, real options tool which allows a broad comparison of potential returns from investment in different areas of research. The tool was used to help assess potential market opportunities for key areas and to assess the stages of investment to achieve those returns.

2.5 Action plan

The action plan provided a detailed framework for work after the project's launch. A copy of it can be found at Appendix A, annotated with progress that has been made on individual points.

3 Project Outcomes

This section looks at the actions that have taken place since the launch under the headings used in the action plan.

3.1 Informing research and development

DTI Innovation Group

In April 2004, the second competition of the DTI Technology Programme for collaborative R&D funded 56 projects with support totalling £58m. Of these projects, two were directly relevant to the EEMS project, with a combined value of £1.6m. They both proposed to develop terahertz (THz) sensor imaging technology to detect concealed plastic explosives, firearms, drugs and other objects. The transfer of this technology to real-world environments, for example in airports, is the next step to commercial exploitation in this field.

Foresight has worked closely with DTI Innovation group on how best to assist the competitiveness of UK industry through exploitation of technologies identified by EEMS. The project's findings influenced the choice of bids submitted to the new Technology Strategy Board, with the November 2004 competition of the Technology Programme supporting:

- Opto-electronics and disruptive electronics: approximately £7m
- Imaging technologies: approximately £7m

These areas received many project applications relevant to the three of the four areas identified by EEMS (all-optical data handling; photonics at the molecular level; non-intrusive imaging) and support for projects relevant to these areas is estimated to be approximately £8m.

The April 2005 competition of the DTI Technology Programme has supported a further EEMS relevant topic, covering next generation lasers in manufacturing, healthcare and security with £5m available to support successful proposals.

Research Councils

The findings were presented to the council of the Engineering and Physical Sciences Research Council (EPSRC) in 2004 and EPSRC has supported over 100 research proposals in the field covered by EEMS in excess of £37m. In April 2005, a further

£2m was awarded in research grants and further proposals to the value of £9.5m are currently under consideration.

Photonics is especially well represented, with two portfolio partnerships in Nanophotonics and Photonics (£3.5m and £7.5m respectively) awarded to Southampton University and £2.6m awarded to Bath University for research into photonic crystal fibres. EEMS has informed the EPSRC 'Electrophotonics' £6M programme, with a presentation being given at the recent workshop review of this.

3.2 *Establishing links between business, investors and researchers*

Venture capital events

Library House is a company that forges links between venture capitalists and innovation-based companies. They were employed by Foresight to help take the EEMS project findings to the venture capital community. EEMS project findings were presented to 17 venture capitalists and 15 industry representatives, with a total of 53 people attending all the events.

They organised an initial communications event on 14 September 2004 at the Institute of Physics, followed by three interactive dinners, looking at all optical data handling, photonics at the molecular level and non-invasive imaging.

The feedback received from those who attended was very positive and the events provided an excellent forum for discussion. However, in the words of the event organiser, "while the [EEMS] scenario is intrinsically of interest to the venture investing community, their interest really picks up once the science is proven, technology development is underway and companies exist which have the potential to benefit from the step-change in technology and hence financial performance."

'Opticks' conference

Foresight contributed £15k to co-sponsor a conference at the Royal Society in December 2004. The event marked the three hundredth anniversary of the publication of Newton's 'Opticks'. It reviewed the most exciting areas of current and prospective optics and photonics, and the UK's important role in the field. The day was opened by Lord Sainsbury and consisted of lectures by 11 scientists on science areas such as fibre optics and quantum photonics. It was covered on the BBC Radio 4 science programme Material World and the talks are available on the EEMS website.

Publications

In addition to the various reports and invited papers presented there will be an article in the Royal Academy of Engineering's journal 'Ingenia' describing the project and its conclusions (in proof).

Media coverage

EEMS was the top story on the BBC Online Science and Technology pages and the project also had articles in New Scientist and Physics World, and a number of general and specialist online publications.

3.3 Strengthening communities of interest

Network on coherent x-rays

Coherent x-rays was one of the six topics identified as important and included on the shortlist for EEMS, but it was not chosen for the final report. The National Physical Laboratory (NPL) took this area forward at a seminar on 2 June 2004. Presentations on the work of the EEMS project were discussed by a group including most of the UK experts in the field. Attendees identified collaboration between accelerator-based physicists and those who use table-top lasers as a key area to take forward from this meeting.

Metrology Conference

NPL also hosted a conference on Precision Electromagnetic Measurements in London from 27 June – 2 July 2004, with over 500 international delegates, at which the EEMS findings were reported. This encouraged the formation of a project on attosecond laser technology at NPL as part of the 2004-07 Quantum Programme.

The impact of ICT on Healthcare

The Royal Society has used the findings of the medical imaging component of the EEMS project to inform their new study into pervasive healthcare in the future.

Medical Imaging Network

NPL, Department of Health, EPSRC, BBSRC and Medical Research Councils all strongly supported the creation of a medical imaging network. DTI is taking this forward through the Faraday Review process.

3.4 Informing government and other agencies

Ministry of Defence

MoD has offered support for collaborative work in the field of metamaterials. It remains engaged and is considering taking up further activity through the Joint Grant Scheme. The Defence Scientific Advisory Council technology board has also identified the compact personal health monitoring topic as a top priority for future research.

OfCom

The pervasive radio frequency area of EEMS is a key topic for OfCom and their Spectrum Advisory Board (OSAB). There have been several meetings and workshops to consider the long-term implications for regulation of developments in this technology. It is likely that this work will lead to a series of research and development projects.

Regional Development Agencies (RDAs)

Foresight EEMS findings were fed into the RDA's long-term research strategies through the joint steering committee of the RDA and Research Councils UK in July 2004.

As a result, for example, SEEDA's Science and Industry Council has identified security as a priority technology area and will be promoting and supporting greater knowledge transfer in related technologies, such as terahertz security imaging and photonics.

SEEDA commented that their involvement demonstrated to them the value of science futures work. As a result, their Chief Executive is now actively involved in Foresight's Intelligent Infrastructure Systems project.

Real options model

The real options model has generated considerable interest in DTI and in the DTI Economists' network in the use of tools of this type to support long-term strategic investment decisions.

Council for Science and Technology has as a consequence, reviewed the use of such approaches and has made recommendations to DTI about their use.

4 Review of the project process

The project tried to look across a whole area of science and identify commercial opportunities, the first time this had been done by Foresight. One aspect of the process which worked very well was to ask a group of leading scientists to identify very fast moving areas of science and then write two pages on it. This work became the cornerstone of the science evidence. We were then able to use this to seek users' views of how they might take advantage of those new capabilities and to identify areas of potential commercial opportunity. 'Two-pagers' on key science have become a key part of subsequent Foresight projects.

The state of science reviews, which normally just cover current science capabilities, were developed for this project to look at the strength of the UK science and commerce base and comparative international strengths in these areas. A number of people in the project considered these so useful that they suggested that they should only be made available to UK businesses.

The action groups, which were set up to develop the roadmaps, were a success. The groups comprised a third each from business, science and government. The key benefit was to bring people with the need together with the scientists. A number of ideas were generated in these discussions which were considered novel by the group, such that copyright issues had to be considered.

By the end of the project, we had developed strong support from all those involved. However, although it was possible to deliver the project to the shorter timetable of 13 months, rather than the usual 18, this did not allow sufficient time to generate self-sustaining networks. The shorter timescale also put considerable pressure on the

team. For future projects of this time duration, it will be important that action is taken to ensure self-sustaining networks are developed.

5 Next steps

5.1 Continued monitoring of project impacts

Continued monitoring of the project outcomes will be necessary to determine the long term impact of the EEMS project. Foresight proposes reviewing the impact of the project in a further two years' time. Meanwhile, it is commissioning an external evaluation of all Foresight projects completed in the last three years, to be carried out in Autumn 2005.

6 Appendix A: Action Plan

ACTIVITY as set out at project launch Apr 2004	OWNER	PROGRESS as of May 2005
<i>Informing R&D</i>		
Innovation Group, KBT would consider whether to support any of the areas identified under the DTI's new Technology Programme in 2004/05.	DTI Innovation Group, KBT	Calls were made in 'Applications of Imaging Technologies' and Photonics
The MoD would now monitor the metamaterials area and consider opportunities to fund research in metamaterials under the Joint Grant Scheme.	MoD	MoD remains engaged in the findings of the EEMS project and is considering taking up activity through the Joint Grant Scheme..
Foresight would presenting the findings of the project to the RDA/RCUK steering committee on 26 July, to help inform their strategies for investment in research.	Foresight	Completed, RDAs using the EEMS project as source for R&D investment strategies
Foresight would meet EU Commission officials responsible for EU FP6 and FP7 on 15 July 2004 to brief them on the project's findings.	Foresight	EU officials briefed on project findings. Considerable interest from EU officials. Foresight since asked to provide advice on priorities for FP7 as a result.
<i>Establishing links between business, investors and researchers</i>		
Foresight would seek to find a route to foster connection between investment community, EEMS scientists and technology communities.	Foresight	Completed. 53 people attended an introductory event and 3 interactive dinners were held at the Institute of Physics and Library House
The project's findings and actions would be communicated to the wider business community through the Institute of Physics' 'Opticks 2004' conference on 9 December	Foresight	Completed, with more than 200 attendees from business and academia.
<i>Strengthening communities of interest</i>		

ACTIVITY as set out at project launch Apr 2004	OWNER	PROGRESS as of May 2005
The DTI Electronics team would initiate a Photonics Strategy Group drawing from EEMS findings.	DTI KBT/BR	This is being taken forward through the Faraday Review process.
Foresight would foster the creation of a medical imaging network.	Foresight	EEMS has informed the Royal Society's 'Healthcare Everywhere' project and Foresight's own project on Infectious Diseases. Meeting held which won support of key stakeholder. Proposals now being considered by TSB.
NPL would support development of a network in Coherent x-rays (one of the non-selected topics from the EEMS shortlist) through supporting a network and running workshops. For further details see http://www.npl.co.uk/quantum/foresight.html	Jeff Flowers, NPL	A meeting on coherent x-rays was held at NPL on 2 June 2004
<i>Informing government and other agencies</i>		
Foresight would take steps to communicate trials of work on real options analysis	Foresight	Series of presentations were given, including to Investment Committee and CST. CST as a result undertook a review and made recommendations to DTI.
<i>Establishing best practice</i>		
Foresight would incorporate the learning from the project into Foresight's best practice guide, and ensure that relevant information is made available to others.	Foresight	Lessons learned were incorporated into the Foresight Project Toolkit to be used in future Foresight projects
<i>Evaluation</i>		
Stephen Timms would chair a Stakeholder Group meeting in Q1 2005/6 to review progress.	DTI Innovation Group	6 June 2005

ACTIVITY as set out at project launch Apr 2004	OWNER	PROGRESS as of May 2005
Foresight will track the impact of the project after one year (2005) and three years (2007).	Karl Cunion, Foresight	One year review complete