Report of the Medical Imaging Technology Working Group

March 2012

Contents

1 Introduction

The Working Group met on three occasions (29 September 2011, 14 November 2011 and 19 January 2012). The aim of the first meeting was to agree the scope of the review and to develop the academic, institutional and industrial questionnaires. The second meeting discussed the EPSRC and MRC data relating to this area and the results of the academic survey including, in particular, the international standing of medical imaging technology in the UK and the hot topics emerging areas. The final meeting discussed the institutional and industrial surveys, and looked at the hot topics emerging areas as highlighted by the surveys.

1.2 Medical Imaging Working Group membership

Chairs:

Dr Rachel Bishop – Theme Lead for Healthcare Technology, EPSRC

Dr Kedar Pandya – Theme Lead for Engineering Capability Delivery, EPSRC

Members:

Professor Paul French, Imperial College London

Professor David Hawkes, University College London

Professor Paul Matthews, GlaxoSmithKline and Imperial College London

Professor Peter Sharp, University of Aberdeen

Professor Irene Tracey, University of Oxford

Professor Peter Wells, Cardiff University

Research Council staff attending:

Dr Chloe Heywood, Engineering Theme, EPSRC

Dr Helen Hunt, Healthcare Technologies Theme, EPSRC

Dr Joanna Jenkinson, MRC

Miss Susan Soulsby, Engineering Theme, EPSRC

1.3 Medical Imaging Working Group scope

EPSRC in partnership with MRC undertook a review of current and future research opportunities in medical imaging technology. The objectives of the review were to produce: a joint EPSRC/MRC stocktake; a vision for research investment in medical imaging; and specific recommendations for EPSRC's activities and interventions in medical imaging from 2012 to April 2015; and to do this in synergy with other funders in the area, e.g., Cancer Research UK, Wellcome Trust, STFC and NIHR.

1.4 Strands of input

Academic, institutional and industrial surveys; infrastructure survey; EPSRC and MRC portfolio data for medical imaging technology; NIHR portfolio data; Wellcome Trust data and Imaging Report; and the Web of Science.

1.5 EPSRC Medical Imaging portfolio

The EPSRC medical imaging portfolio has a value of £79.2 million based on number and value of current grants (excluding training grants) on 1 April 2011. The research funding in medical imaging is concentrated within a few key institutions. However, there is a healthy range of projects throughout all career stages, reflecting the quality of the research community in this area. The grant portfolio includes 1 Programme Grant, 5 Platform Grants and 12 First Grants.

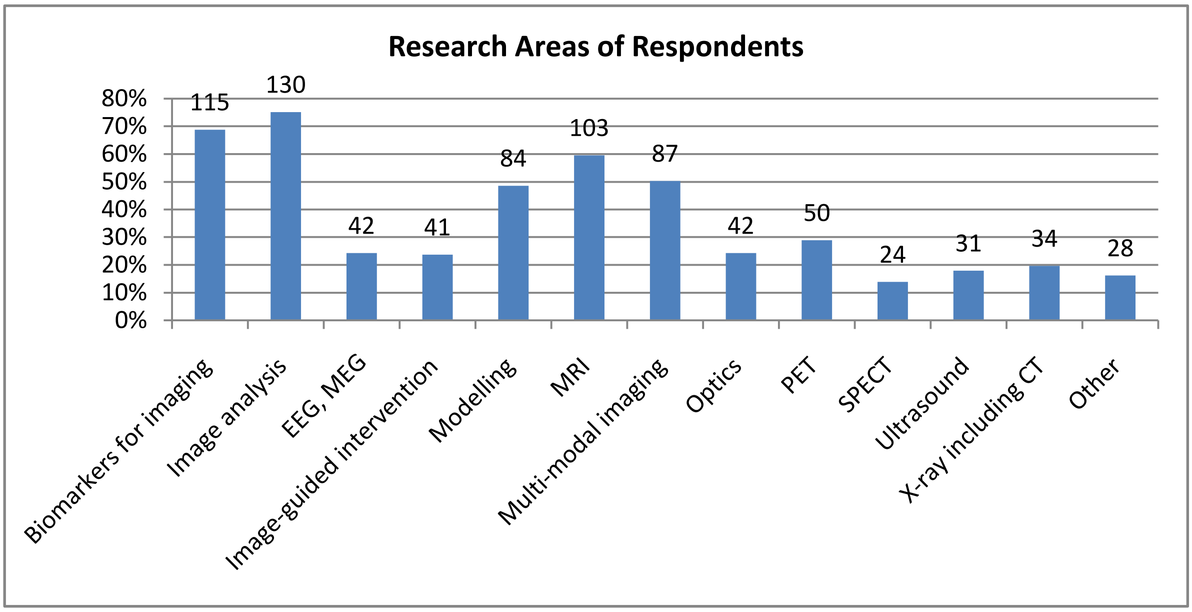
The EPSRC portfolio also includes the 4 Cancer Research UK/EPSRC Imaging Centres and the imaging research at one of the Wellcome Trust/EPSRC Medical Engineering Centres.

This is a similar size to the portfolios of research funded by MRC and NIHR in medical imaging technology.

2 Outputs from the surveys

2.1 Academic survey

The survey was completed by 173 respondents from UK academia, NHS and overseas universities. The chart below shows the percentage and number of respondents who selected each of the research areas listed as an area of their expertise.



The UK's world-leading excellence in medical imaging is evidenced by:

- Web of Science bibliometric data are shown in Appendix 1, which place the UK first for relative world impact in the neuroimaging field, third for relative world impact in radiology, nuclear medicine and medical imaging (closely behind Germany and the USA) and third for relative world impact in imaging science and photographic technology (behind the USA and France).

- Other reports that highlight the UK's excellence in medical imaging include

  The Wellcome Trust Human Functional Brain Imaging 1990-2009: Portfolio Review Report.

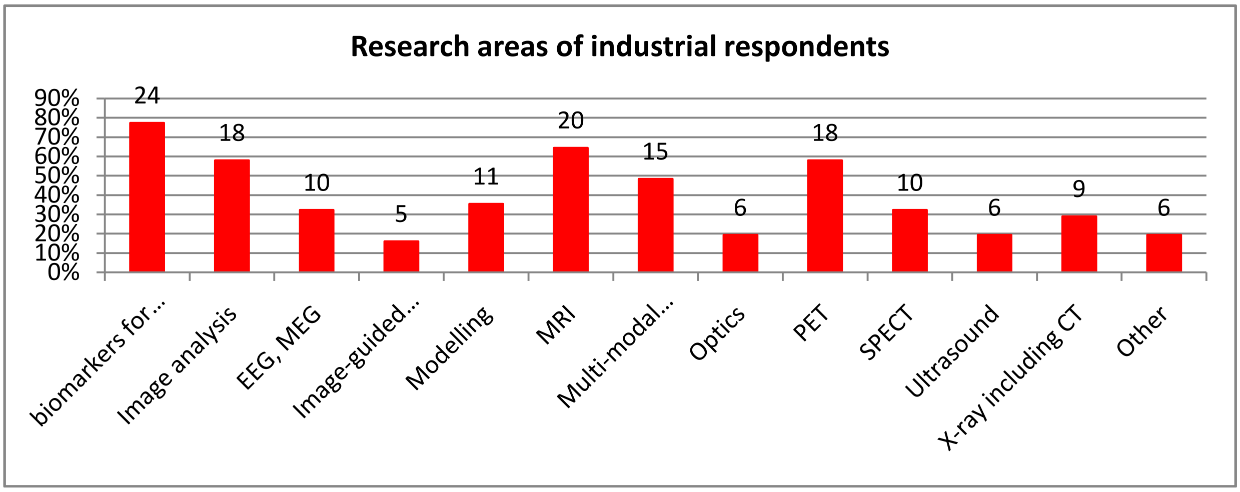
- The EPSRC Healthcare Themes Futures Forum Report (2011) and the Engineering for Health Royal Academy of Engineering Briefing Paper (March 2011) highlight the importance of medical imaging.

- The results from the academic survey of research quality can be seen in Appendix 2.

Medical imaging has the potential to enable earlier and more precise diagnosis of disease and its use during therapy can improve patient outcomes. Imaging can also be used in planning and during surgery to increase its effectiveness. “Point of care” imaging technologies that are suited to clinical environments across the world are needed to improve the patient experience and reduce costs. Public investment in biomedical imaging research is essential for the UK to remain competitive in an area currently characterised by UK leadership.

2.2 Industrial survey

The industrial survey was completed by 31 respondents. The chart below shows the percentage and number of respondents who selected each of the research areas listed as an area of their expertise.



There are strong links between researchers in this area and industry. From a company perspective, collaboration with the UK academic partners in the field of medical imaging enables access to leading researchers and novel ideas, provides access to people trained in the specific techniques of interest and helps to identify new uses of technologies/new markets. The advantages and barriers to industry working with academia can be seen in Appendix 3.

The survey highlighted the following issues for medical imaging technology in the UK:

- Emerging markets are providing options for hosting research with their increasingly competitive academic centres.
- The UK must be aware of this since the rest of Europe, Japan and the USA are no longer the only other locations that are capable of this type of research.
- There is perceived to be a need to find ways to share risk and reward between academia and industry and for recognition that industrial

partnerships are not just a source of funding but also provide expertise to academia.

- The Knowledge Transfer Networks have been valuable mechanisms of coordination for small companies. There is perceived to be a need for follow-up funding for UK industry after initial grants and funding streams, such as the Technology Strategy Board (TSB) and the MRC Developmental Pathway Funding Scheme/Developmental Clinical Studies Scheme (DPFS/DCS) targeted at medical imaging technology and applications of novel technology. The NIHR i4i programme also supports projects through prototype and commercial development to introduction and adoption in the NHS.

- The big three multinational imaging companies (GE, Philips and Siemens) dominate the market for imaging equipment internationally. The high quality research base in imaging attracts significant inward investment to the UK, but there is some inertia within these large organisations and, to counteract this, a vibrant community of UK SMEs is expanding in this sector.

- The main UK weakness is a lack of agility and extended timelines (contracts, staff recruitment, clinical trial approvals, patient recruitment, and write-up). Strong collaborative links that do not rely on new appointments of key staff for each agreement are needed.

3 Conclusions

The academic, institutional and industrial surveys were used to prompt the Working Group discussions. The medical imaging research drivers and opportunities selected by the academic survey can be seen in Appendix 4.

3.1 Challenges for medical imaging technology

3.1.1 Probes and biomarkers

- The information available from medical imaging needs to become both more specific and applicable to a broader range of medical problems, many of which still rely on expensive, invasive and limited diagnostic or monitoring methods.

- New probes able to provide additional information are needed. These could be based on either endogenous contrast mechanisms (such as intrinsic tissue signal differences, including autofluorescence, stiffness, elasticity and vascular markers), or targeted (e.g., molecularly specific) or “smart” probe designs (e.g., using nano constructs). In specific applications (e.g., oncology), this could include development of agents with combined diagnostic and therapeutic uses (“theragnostics”).

- Advances in technology and discovery research and are interdependent. However, the range of biomedical imaging sensors or contrast mechanisms has expanded only slowly. New concepts in sensors, particularly the development of “smart” sensors able dynamically to integrate information on physiology or molecular interactions *in vivo* and new approaches to sensor development that could accelerate the rate of their discovery and validation are needed.

- Additionally, computational approaches that enable the integration of large complex datasets and bioinformatics methods to interrogate them more efficiently and with greater precision provide a promising approach to the identification of new biomarkers.

3.1.2 Safer, lower cost, and higher throughput systems

- Medical imaging methods do not always meet all the needs of the increasingly diverse global healthcare environment.

- Imaging methods in current use range from those that are moderately (e.g., ultrasound) to very (e.g., MRI, PET) expensive to establish and may involve ionising radiation (e.g., CT, PET). Although scanners are expensive items of equipment, per scan costs are relatively modest in well-run facilities compared with many other investigations and treatments.

- Researchers should seek to involve clinically based individuals at an early stage to ensure the appropriate incorporation of imaging technology during patient diagnosis and ensuring the most cost-efficient and effective care is provided.

- Imaging technologies demand expert use and interpretation, some more than others.

- There are many opportunities for advances. For instance, higher sensitivity detection technologies could lower radiation exposure, analytical advances could enhance information available from sparser (more rapidly acquired) datasets, and technology could be adapted in more specific ways for lower cost with more specialised applications. Acquisition or analysis technology improvements for ”real time” information direct to doctors or patients could also reduce costs, enhance the patient experience and increase the range of applications.

- Optics potentially has a big role to play in the future. For example, sensors in the home could measure waking person’s movements to assess the risk of a medical episode, such as a seizure. This is another example of how imaging for healthcare can be preventative and move closer to the patient while enhancing the quality of care.

3.1.3 Improving the value of current medical imaging technologies

- Incorporation of prior information in analysis, multimodal imaging methods and computationally intensive iterative reconstruction methods are all ways in which image quality could be improved for existing technology, either through new technology or post-processing “add ons”.

- Diagnostic scanning outcomes can be limited by artifacts, e.g, arising from patient motion during scanning, patient prosthetics (e.g., metal implants), or truncated scanning times. Research to address common artifacts and enhance image quality will have high impact, as it will enhance the value of imaging methods and could improve health outcomes.

- There is a need to make high quality information from complex technologies accessible outside of the research environment, e.g., with magnetoencephalography (MEG), which poses considerable analytical challenges, although it could make substantial contributions to clinical neurosciences.

- Another example of enhanced imaging capability is via endoscopes. Narrow-band imaging (NBI) is a new endoscopic technique designed for detection of pathologically-altered submucosal and mucosal microvascular patterns. The combination of magnification videobronchoscopy and NBI shows great potential in the detection of precancerous and cancerous lesions of the bronchial mucosa. More sophisticated optical techniques could obtain further useful diagnostic information from endoscopy.

3.1.4 Improved precision of diagnosis, therapy monitoring and application of imaging biomarkers to get the right medicine to the right patient

- Improvements in integration of relevant population-based information for contextualisation of individual images, quantitative imaging analysis and artifact removal, and efforts to standardise acquisitions could all build new value on existing technologies.

- This could support the concept of a “one-stop shop” for efficiency in healthcare facility use and help to shift the model away from reliance on highly trained specialist interpretation to facilitate the diffusion of technology to a broader range of healthcare environments.

3.1.5 Lowering costs and barriers to use of medical imaging technologies

- One driver of cost is an emphasis on imaging systems designed for maximum flexibility and high-end performance for the most demanding applications.

- While these technologies may be particularly valuable for patients with chronic or end-stage diseases, technology innovation is needed. There are opportunities to exploit additional sources of medical imaging signals, improvements in technology to create a new generation of lower cost, more application-specific imaging systems, greater standardisation of current approaches minimising unit costs, and automated and more intelligent analysis pipelines, which all offer opportunities for cost reductions and greater diffusion of imaging methods.

- The development of less expensive (or even cheap) devices (including devices such as niche MRI breast- and knee-scanners, which have low cost-per-scan when the throughput is high) would facilitate their more routine and widespread use to identify diseases and other conditions before they become more difficult and expensive to treat.

- Such devices could even be directly employed by the patient. For example, diagnostic devices such as retinal scanners that could be extensions of patients’ existing consumer electronics products, such as the digital cameras on mobile phones, could provide additional diagnostic and treatment options and make information available to the appropriate medical personnel.

- “Point of care” diagnostic technologies are needed for key applications that are suited to clinical environments across the world.

3.2 Skills / gaps

- Multidisciplinary collaboration is essential for medical imaging research and teams with a critical mass of the type rarely available in single departments are needed for international competitiveness in this fast-moving area.

- Staff retention can be a problem as competition comes from pharmaceutical companies, medical equipment industry and attractive opportunities overseas, where a better-defined career path can often be found.

- Areas specifically highlighted by the surveys as to where there are shortages of research leaders include academic radiology, MR physics (in short supply internationally), clinical nuclear medicine, clinical and preclinical imaging.

- There is a lack of leaders in radiochemistry and a need to establish more Principal Investigator level researchers. Radiochemistry research that can develop new chemistry and probes is key.

- Shortages of early stage career researchers in molecular imaging, PET physics and imaging physics were also identified.

- For instance, there are problems in recruiting to post-doctoral positions in MR physics, where an understanding of the fundamental physics of MRI and direct experience of scanner hardware and software are needed.

3.3 Other issues

3.3.1 Preclinical imaging

- More preclinical imaging on small animal models is needed and reverse translation of animal models that are representative of clinical conditions is an increasingly important issue for drug discovery and in clinical settings.

- The challenge of translational research requires a significant shift in the utilisation of the available infrastructure for preclinical imaging.

- Imaging provides a broad range of tools allowing integration between preclinical and clinical studies.

3.3.2 Career structure

- The development of a career structure for the highest quality career scientists who are not on an academic track is needed.
- The infrastructure staff who form the backbone of the leading laboratories are difficult to retain and have an uncertain career structure in the UK compared with their equivalents in our main competitor nations.

- Academic career development in medical imaging physics and engineering is limited, as few UK institutions have medical imaging as a theme in its own right and medical imaging is often embedded within medical schools where the focus is on clinician researchers.

- The growing potential and need for medical imaging can only be sustained by a larger commitment to training, particularly emphasising development of a cadre of clinician-engineers, who can see application needs for imaging and have a mind-set for creative solutions.

- In medical imaging, there is a need for nonmedical scientists to work with clinical research fellows on grants, fellows (e.g., those on the CRTF scheme) and academic clinical researchers. The MRC has identified biomedical imaging as a strategic skills priority area.

- New work visa limitations are having an impact on the number of overseas students able to join Masters courses and at a post-doctoral level. This Masters' funding was viewed by the Working Group as an important route into PhDs for the best students.

- In an NHS setting, postdoctoral researchers may struggle to find a role but in academic and industrial environment this is a skills gap.

3.3.3 Infrastructure

- As medical imaging equipment becomes increasing expensive, mechanisms are needed to finance, upgrade and maintain kit in order to keep cutting-edge physicists and mathematicians in this country and to maintain UK scientists as international leaders in this research field.

- There was a pragmatic acceptance by the Working Group that there will need to be foci of large equipment and that the research hotel approach at Diamond is a useful and appropriate model to facilitate access to large infrastructure for a short period of time. The new environment at Imanova was agreed to be interesting and it was hoped that this would provide a model for the future. The ESFRI Euro-BioImaging approach was noted as intended to facilitate wide access to a limited number of advanced resources and capabilities.

- The community may therefore need to accept some concentration of expertise. Equipment sharing currently tends to be by collaboration with academics responsible for the instrumentation or by collaboration with the NHS.

- Collaborative clinical research with the NHS is critically dependent on continued investment in NHS imaging equipment and continued research access to these facilities. Increasing workload on clinics and increasing use of private-sector-managed imaging services are real threats. Shared investment from Higher Education to "buy time" on clinical scanners is a proven solution, but needs sustained infrastructure funding.

- The lack of secure national data storage facility similar to NHS PACS but available to research institutions makes it difficult to store and share large data sets between researchers, limiting the research use of images. There is a lack of data mining projects relative to the potential for this activity. A coordination of compatible platforms is needed, rather than diversity due to software constraints. This can also impact the ability to undertake multicentre trials.

- The Research Councils have had a reduction in their capital budget and the changes in the way equipment is funded can be found here.

3.3.4 Instrument development

Certain areas have matured outside EPSRC's remit: for example, a lot of major large-scale MR instrument development has shifted into the instrument industry base. However, there is a need for research skills and activity in certain Cinderella areas, such as low-field-strength MR and the general area of ultrasound.

3.3.5 Access to patient data

- Clinical trials is an area where companies want to work in the UK because of the quality outcome that will be delivered, but access to patients makes this difficult.

- Access to large numbers of patients can be challenging, because the current opt-in arrangement with patients and trials causes issues and requires closer working with NIHR and ethics committees.

- Blanket ethics approval with some provisos to exclude certain patients and volunteers could transform the speed of development and significantly reduce bureaucracy.

3.3.6 Translation

- Currently, incentives for commercialisation of imaging technology research and development are low because regulatory pathways are uncertain, long and expensive.

- Expected investment returns are typically modest and high risk, particularly in the UK, where the NHS has been a slow adopter of new technologies.

- A more risk-based approach to regulation, greater clarity regarding criteria for new technology assessment and a more explicitly innovation-for-value focused healthcare delivery environment would be transformative.

Appendix 1 – Bibliometic Web of Science data[1]

Bibliometric analysis of the WoS neuroimaging field

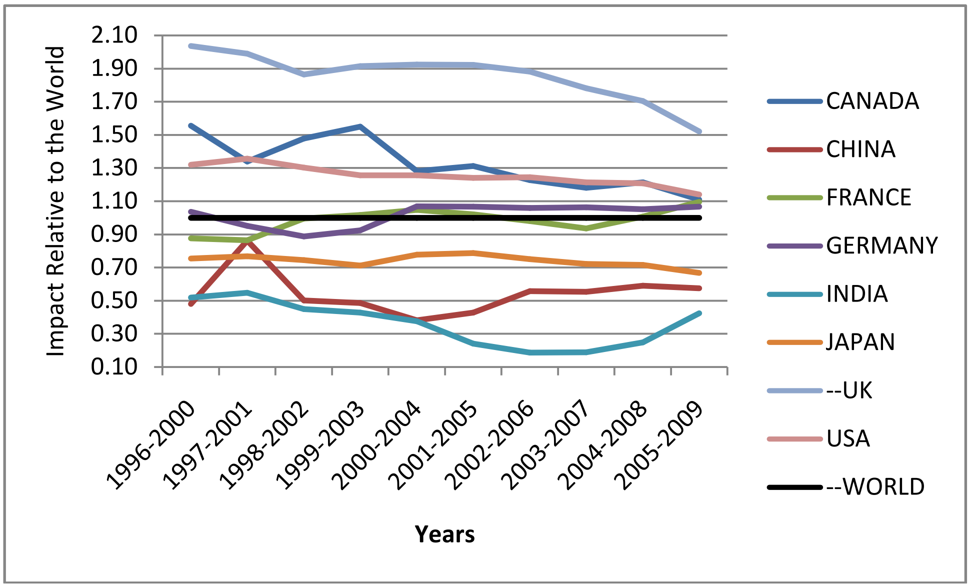


Figure 1: Relative world impact of the UK in the field, displayed alongside comparator countries

Bibliometric analysis of the WoS radiology, nuclear medicine and medical imaging field

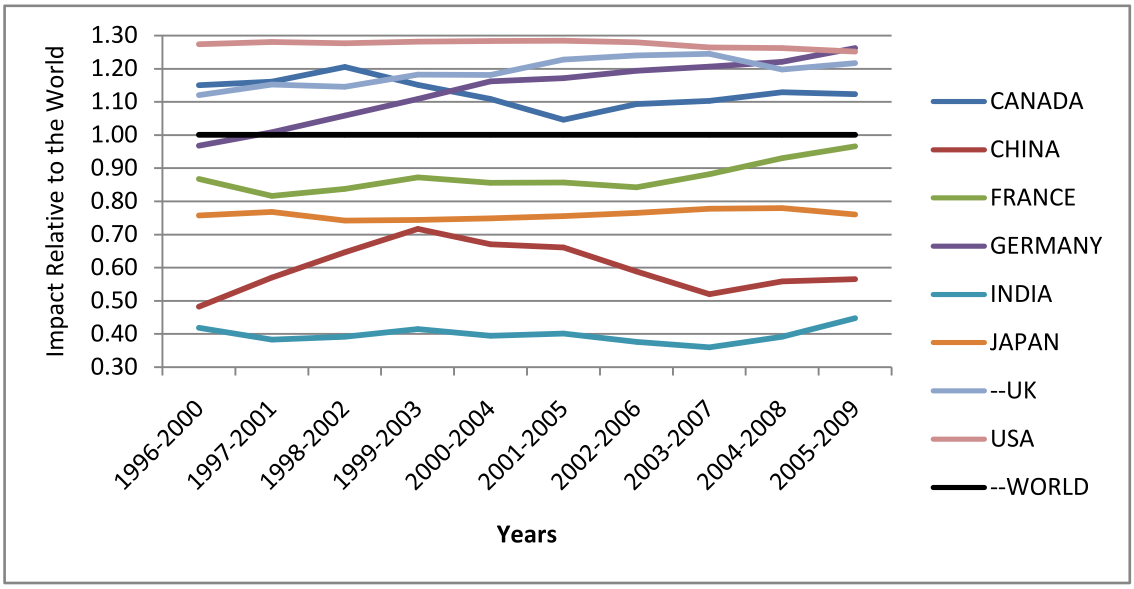


Figure 2: Relative world impact of the UK in the field, displayed alongside comparator countries

Bibliometric analysis of the WoS imaging science and photographic technology

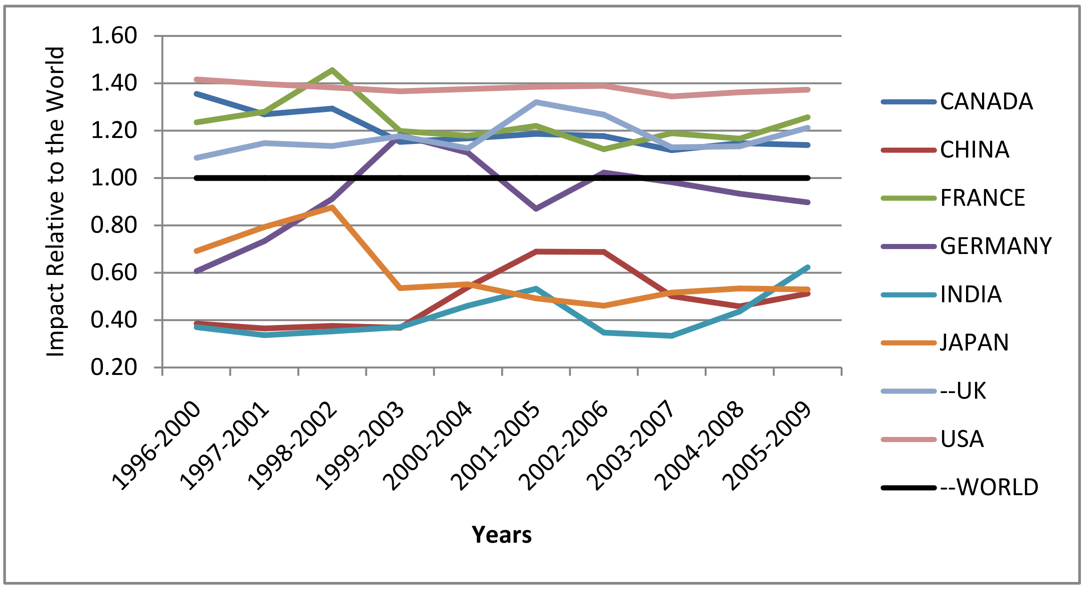
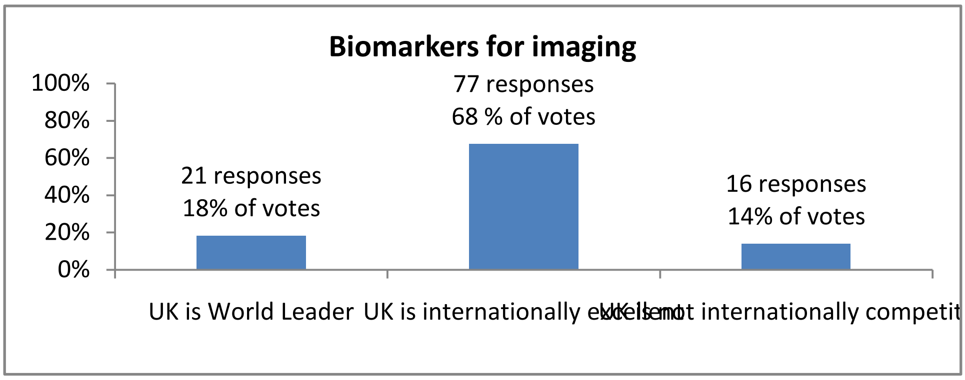


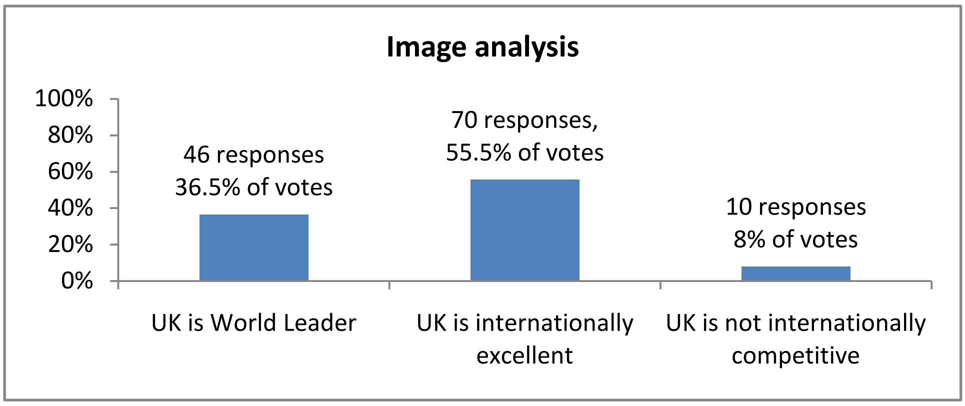
Figure 3: Relative world impact of the UK in the field, displayed alongside comparator countries

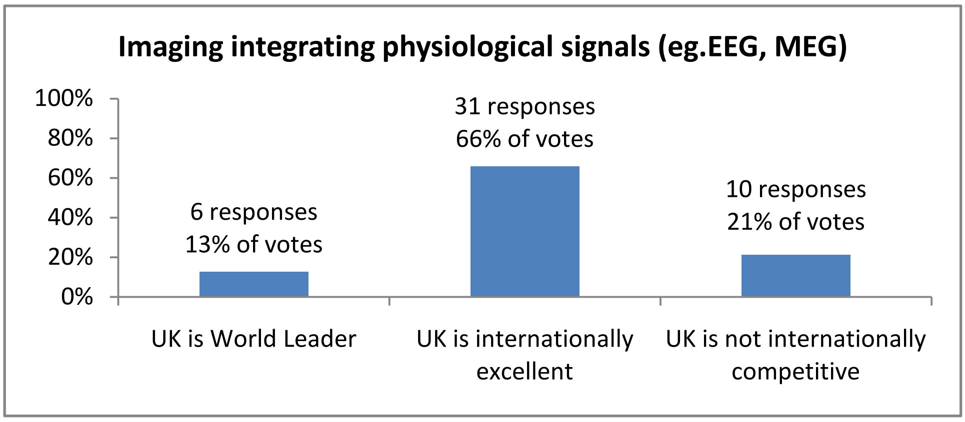
[1] All data in this report are from InCitesTM, Thomson Reuters (2011). Report created: 27 July 2011. Data processed: 31 December 2009. Data Source: Web of Science ® These data are reproduced under a license from Thomson Reuters.

Appendix 2 – Academic survey: research quality

The REF definition of "world leading" meaning that "to be world leading you are the world leader" was used in this survey.







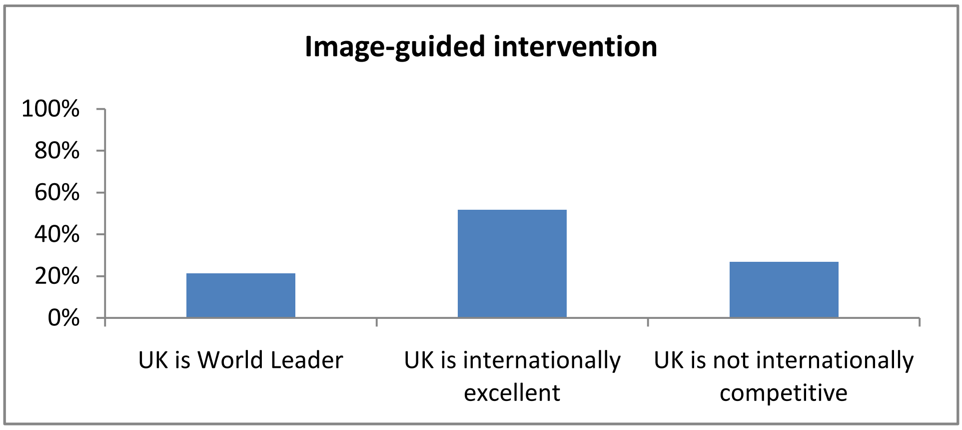
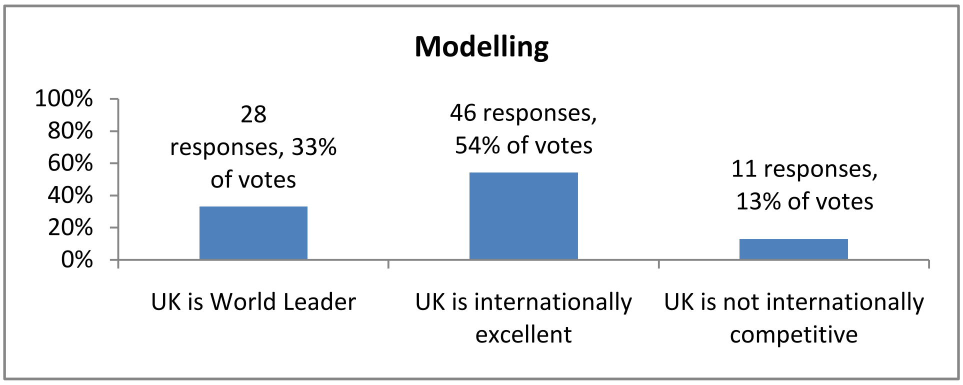
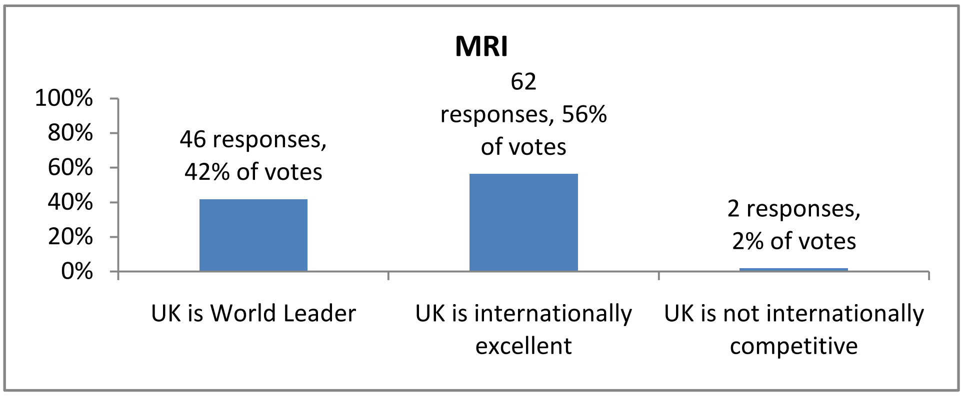
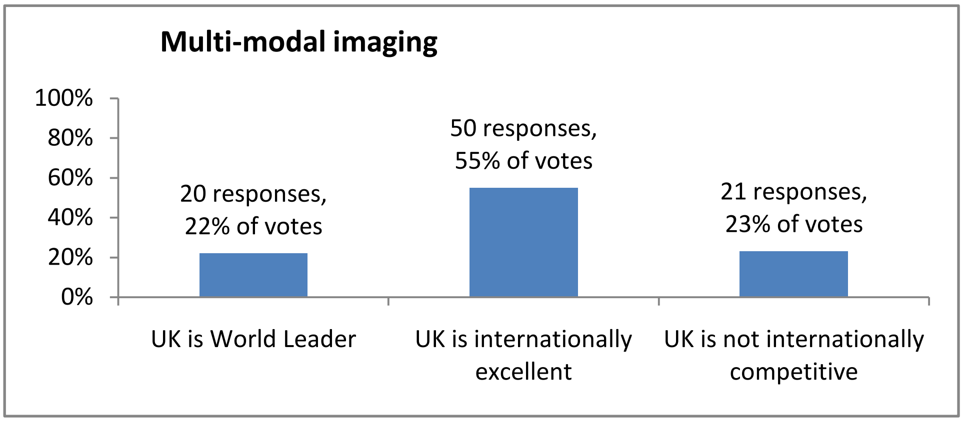
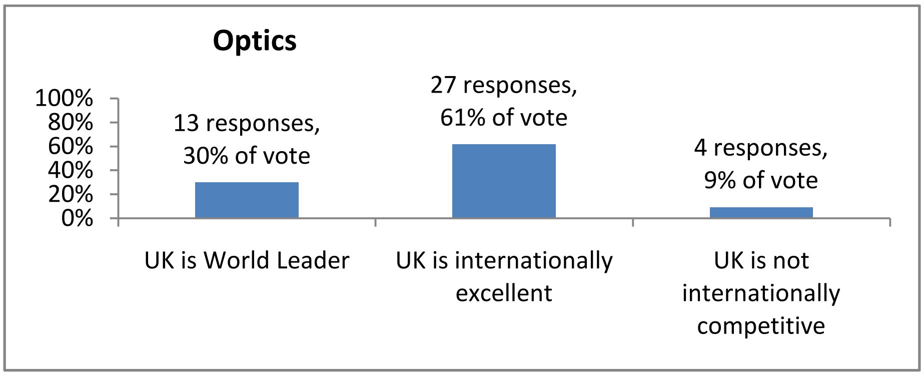


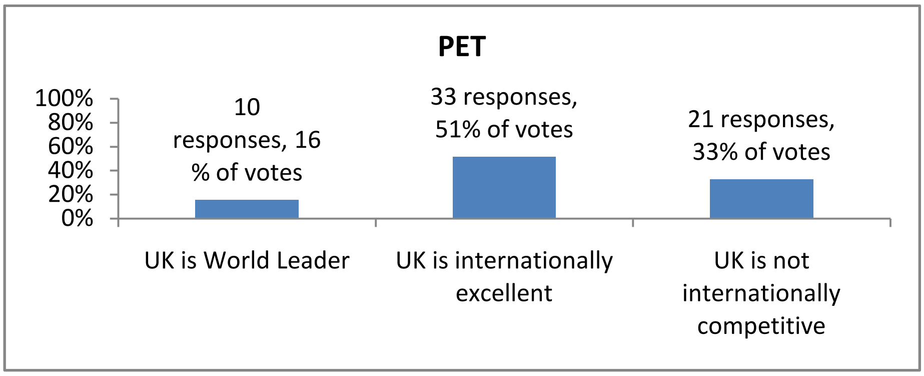
Image-guided intervention
100%
80%
60%
40%
20%
0%
UK is World Leader
UK is internationally excellent
UK is not internationally competitive

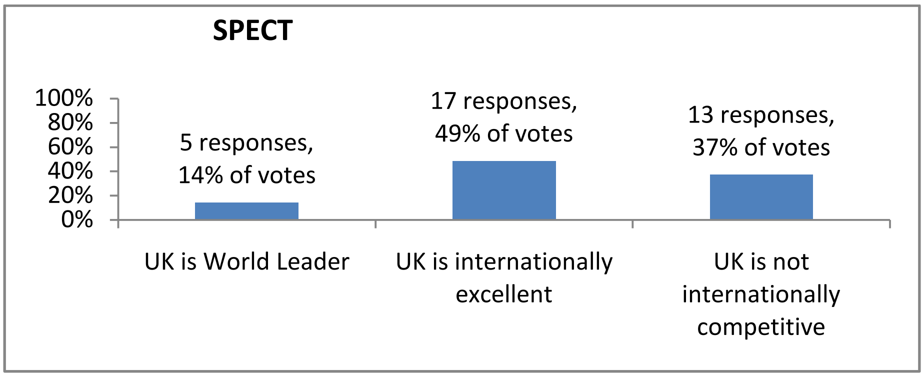

Modelling
100%
80%
60%
40%
20%
0%
28 responses, 33% of votes
46 responses, 54% of votes
11 responses, 13% of votes
UK is World Leader
UK is internationally excellent
UK is not internationally competitive

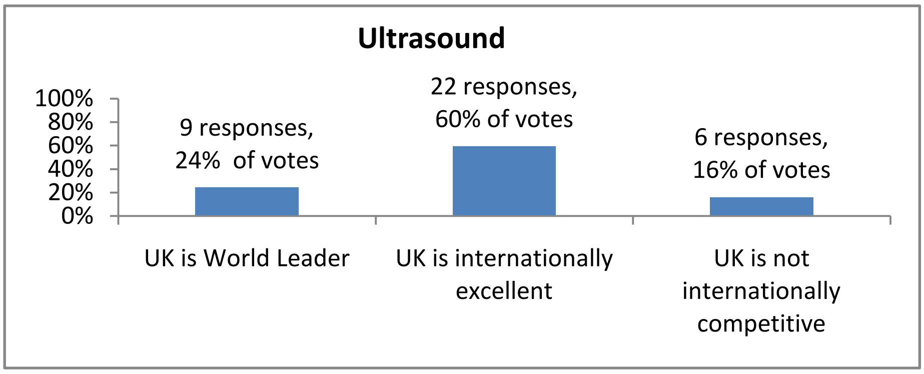

MRI
100%
80%
60%
40%
20%
0%
46 responses, 42% of votes
62 responses, 56% of votes
2 responses, 2% of votes
UK is World Leader
UK is internationally excellent
UK is not internationally competitive

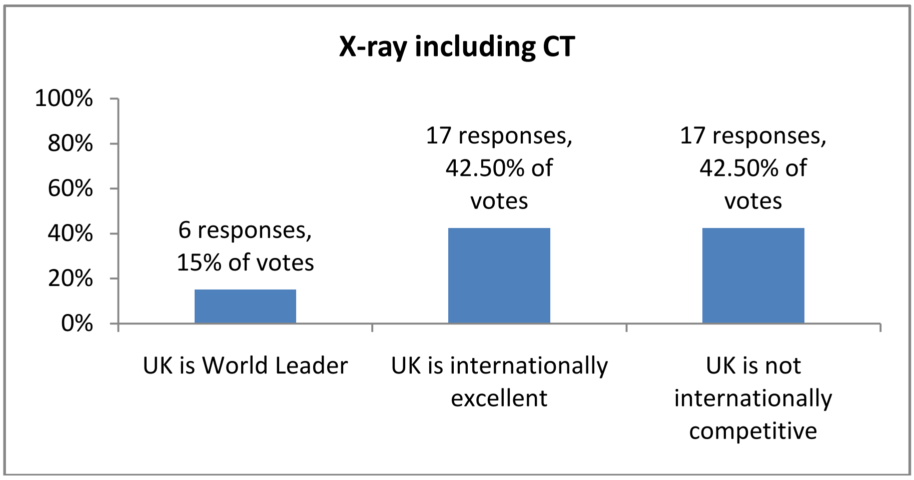

Multi-modal imaging
100%
80%
60%
40%
20%
0%
20 responses, 22% of votes
50 responses, 55% of votes
21 responses, 23% of votes
UK is World Leader
UK is internationally excellent
UK is not internationally competitive


Optics
100%
80%
60%
40%
20%
0%
13 responses, 30% of vote
27 responses, 61% of vote
4 responses, 9% of vote
UK is World Leader
UK is internationally excellent
UK is not internationally competitive


PET
100%
80%
60%
40%
20%
0%
10 responses, 16 % of votes
33 responses, 51% of votes
21 responses, 33% of votes
UK is World Leader
UK is internationally excellent
UK is not internationally competitive


SPECT
100%
80%
60%
40%
20%
0%
5 responses, 14% of votes
17 responses, 49% of votes
13 responses, 37% of votes
UK is World Leader
UK is internationally excellent
UK is not internationally competitive


Ultrasound
100%
80%
60%
40%
20%
0%
9 responses, 24% of votes
22 responses, 60% of votes
6 responses, 16% of votes
UK is World Leader
UK is internationally excellent
UK is not internationally competitive


X-ray including CT
100%
80%
60%
40%
20%
0%
6 responses, 15% of votes
17 responses, 42.50% of votes
17 responses, 42.50% of votes
UK is World Leader
UK is internationally excellent
UK is not internationally competitive

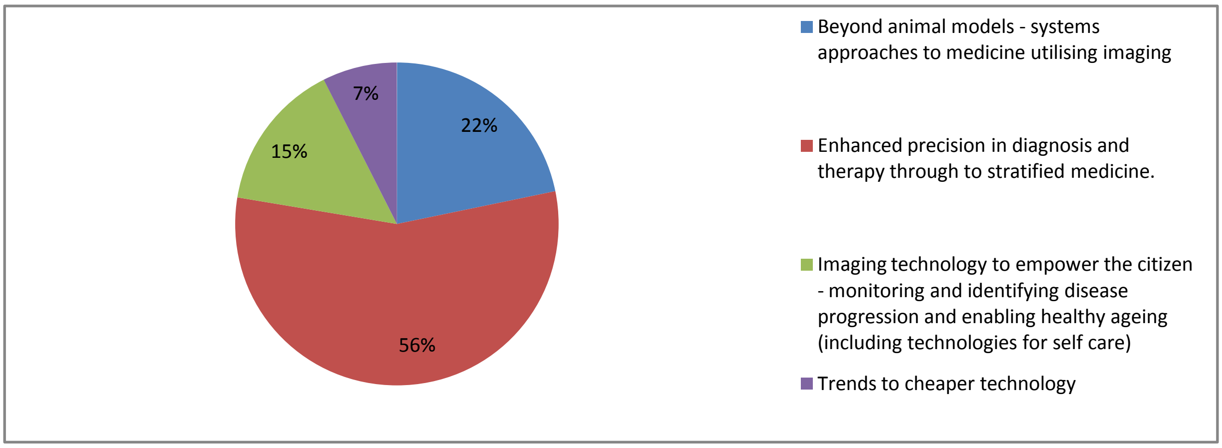
Appendix 3 – Industrial survey: summary

From a company perspective, collaboration with the UK academic partners in the field of medical imaging...	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
enables access to leading researchers and novel ideas	52%	48%	0%	0%	0%
provides access to people trained in the specific techniques of interest	41%	45%	10%	3%	0%
helps identify new uses of technologies/new markets	35%	45%	7%	7%	3%
provides access to facilities and unique technologies	30%	50%	10%	10%	0%
facilitates recruitment of staff (e.g. students)	17%	47%	23%	10%	0%
provides potential access to further funding	3%	63%	17%	10%	7%
raises the company's profile and/or helps marketing company products	20%	33%	27%	10%	10%
results in cost saving	0%	37%	40%	17%	7%

The main barriers to collaboration with UK academic partners in the field of medical imaging are...	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
negotiating contracts	43%	27%	17%	10%	3%
how to deal with intellectual property/confidentiality/publication policies	40%	27%	17%	17%	0%
overhead rates/costs in general	31%	35%	24%	10%	0%
accessing or maintaining funding	14%	48%	28%	7%	3%
different cultures (e.g. in terms of project management)	24%	24%	24%	24%	3%
sudden changes of company strategies and staff	7%	35%	28%	14%	14%
working with multiple parties	7%	28%	41%	14%	10%
identifying the right people to work with	0%	33%	37%	20%	10%

Appendix 4 – Academic survey: research drivers and opportunites

Medical imaging research drivers



Medical imaging technology opportunities