International Perceptions of the UK Research Base in Information and Communications Technologies

December 2006

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1 Executive Summary

The 2006 ICT International Review Panel has completed a week long review of ICT research throughout the United Kingdom. This document presents the perceptions and recommendations of the review. The aim of this Panel is to provide long-term, strategic recommendations that will sustain and improve the excellent ICT research that is occurring throughout the UK.

The Panel was impressed with the breadth and quality of ICT research throughout the UK. There have been significant improvements in ICT research and attitudes since the last review in 2001. Morale in the ICT community was perceived to be high and the excitement of the institutions and individuals at each of the week's events was refreshing and contagious.

The UK ICT community is doing exciting, high quality, world class research across the spectrum of CS and EEE. The Panel agreed that the UK is in the premier league in many research areas.

The UK, through its Interdisciplinary Research Collaborations (IRCs) and e-Science programmes, has made great strides in interdisciplinary research and in some areas this is attracting new talent into the ICT community. Both programmes have brought together groups that did not traditionally collaborate.

The Panel saw evidence of substantial and pervasive knowledge transfer from universities to industry. There is substantial IPR creation and numerous small company spin-outs.

Finally, EPSRC has been an agent for change over the past five years. The change in attitude and respect for EPSRC has been amazing. The Panel believes that these changes are due to a variety of new funding mechanisms, an overall increase in ICT funding and better and more frequent communication between EPSRC ICT staff and the universities. In particular, EPSRC received many positive comments regarding the Platform Grants that provide continuity between funding cycles. Some of these improvements follow recommendations of the 2001 Panel.

The Panel identified several long-term strategic recommendations that focus less on technology and more on process improvement. These along with two short-term, programmatic recommendations, represent the main contribution of this report.

2 Terms of Reference

The terms of reference of the International Review Panel were to:

- Assess and compare the quality of the UK research base in ICT against the rest of the world and prepare relevant recommendations;

- Assess the international impact of the UK's ICT research base, and its impact nationally on other disciplines, on wealth creation, and on quality of life, and prepare recommendations.

3 Background to the Review

EPSRC holds regular international reviews to inform itself and other stakeholders (industrial bodies, learned societies, academia, and government departments) about the quality and impact of the UK science base against the rest of the world and to highlight any gaps or missed opportunities. Each international review provides a broad perspective on the research activity in a particular discipline in the UK, and is undertaken with the relevant learned institutions and other research councils as appropriate; it is a rolling programme in which the research base in each discipline is reviewed approximately every five years. Nine reviews have been conducted since 1999.

The 2006 International Review of ICT is thus one in a series. The previous review in this subject area was the 2001 International Review of Computer Science, which was more narrowly focused. In contrast it should be noted that the aim of this review is not to assess ICT research activity at any specific location but across the UK as a whole; it aims to cover all aspects of the infrastructure, organisation and components that transmit, collect, process, display, store, disseminate and act on information. The review panel was selected with this in mind following an extensive consultation exercise by the Steering Committee (chaired by Professor Sir Mike Brady, Oxford), and individuals were chosen for the breadth as well as the depth of their expertise.

In 2006 EPSRC adopted a new strategic framework focusing on seven 'success features' which were defined to characterise the top-level goals of the Science and Innovation Investment Framework: 'a healthy UK science and engineering base', and 'better exploitation'. The seven 'success features' are:

- Stimulating creativity and adventure in research and research processes;
- Attracting, nurturing and supporting the most talented people at every stage of their career for the benefit of the UK;
- Building collaborations that achieve a two-way flow of knowledge between the research base and industry;
- Encouraging and supporting research that crosses the borders between disciplines, research councils and universities;

- Developing a shared vision of tomorrow's major challenges and opportunities with stakeholders, society, industry, universities and other partners;
- Building a better understanding of where we should focus our effort in order to benefit both UK society and the UK economy and increase its global competitiveness;
- Creating and sustaining research scientists and engineers in the UK so that they are recognised world-wide as leaders in their field.

The 2006 International Review of ICT is the first evaluation activity to adopt a review framework based on these seven success features. The review framework is provided in Section 6. It consists of eight top-level questions framed to reflect each of the success features (there are two questions relating to the attraction and retention of talented researchers). For each top-level question a number of more specific questions were developed, which helped to explore the issues in more detail and enabled the identification and provision of relevant evidence. The framework was developed and agreed with the Steering Committee.

This report was first presented at a Town Meeting of the ICT research community held in London on 6th February 2007.

4 Acknowledgements

The Panel would like to thank all those who made the review not only possible but also memorable – and not just for the pace at which we were shepherded from place to place throughout the week.

First, we thank the UKCRC and all the institutions and individuals who submitted statements in advance of our visits.

We thank the members of the Steering Committee who met with us in London at the beginning of the week (to remind us that we had a very difficult assignment – to assess the ICT research of the UK in a week) and in Edinburgh at the end (to hear and discuss our initial findings).

We also thank the many research departments and groups who hosted us on our visits to ten Universities, as well as those who came to see us at several specially arranged events, for the expertise and patience with which they explained their research and answered our questions. We particularly enjoyed the opportunity to talk one-on-one with graduate students and post-docs who provided objective and refreshing comments to the Panel.

Finally, we particularly thank those EPSRC personnel who planned the agenda and visits, prepared the background materials, and shepherded us on our little odyssey. Whatever real problems might have arisen were dealt with so well they were mostly invisible to us. We gratefully acknowledge their help and their good humour.

5 Panel Recommendations

The Panel used the **Review Framework** (Section 6) to identify ten issues for consideration by the UK ICT community and EPSRC. The observations and related recommendations are meant to improve ICT research over the coming years. The community and EPSRC should revisit these issues periodically to assess progress in each area. The issues are broken into long-term strategies and short-term tactics. Recommendations are suggested for the EPSRC and the ICT community where appropriate.

5.1 Long-Term

The first three recommendations address different aspects of developing and retaining human resources in ICT.

5.1.1 Eroding Pipeline of UK Students

Observations:

The number of UK PhD students enrolled in ICT programmes is low, undergraduate ICT enrolment is on the decline and elementary student enthusiasm for ICT is weak (Figure 1).

Discussion:

The lack of interest and enthusiasm in ICT for students at all levels of education is alarming. This problem is not isolated to the UK. The United States, Canada and other western countries have also seen drastic reductions in computer science enrolments. These reductions are in spite of the fact that ICT technology is ever more present in day-to-day life.

ICT was once considered a ‘hot field’, but several factors have changed the perception of the field. For one, the frenzy established during the Internet craze from 1995-2001 caused an increase in ICT student enrolment that was followed by the ‘dot com’ bubble burst. Another factor, the outsourcing of some ICT jobs to lower cost countries like India and China, presents the incorrect impression that all of ICT is ripe for outsourcing and that there is little future in ICT professions. The Panel does not have a clear view of the reasons for these perceptions, but such shifts are often related to the students’ and parents’ perception of both opportunity and attractiveness of a career in a particular field.

The current undergraduate programmes are organised so that there is far too little visibility given to mixed ICT careers. These mixed careers include the sciences as well as financial and management jobs. ICT education often focuses on the ’engine room’, and many people do not find the career, as described, sufficiently attractive. The worlds of ICT, and the career opportunities in ICT, have expanded enormously over the years as ICT has become in many cases the ‘nervous system’ of enterprises, government and social systems.

Many of the challenges in exploiting the promise of the technological advances in ICT and achieving its potential economic and social returns require individuals with deep understanding of the ‘lower layers’ of ICT, but

who also have strong ability and interest in exploiting the core technologies. This often implies a deep understanding of business and business strategies in specific areas such as healthcare, finance and management. There is a long history of failure in programmes aimed at obtaining the benefits available from proper application of ICT in such areas, largely driven by a lack of sufficient talented resources spanning the core ICT technologies and the areas of application. In presenting ICT to young students the emphasis tends to be on the lower layers, the 'engine room', and it is careers in these areas which seem to be increasingly less attractive to young people. We believe that a far better job can be done of communicating the true breadth of career potential available to those who study ICT, so that the career potential does not seem to be limited to university research laboratories and fields of cubicles with displays and keyboards.

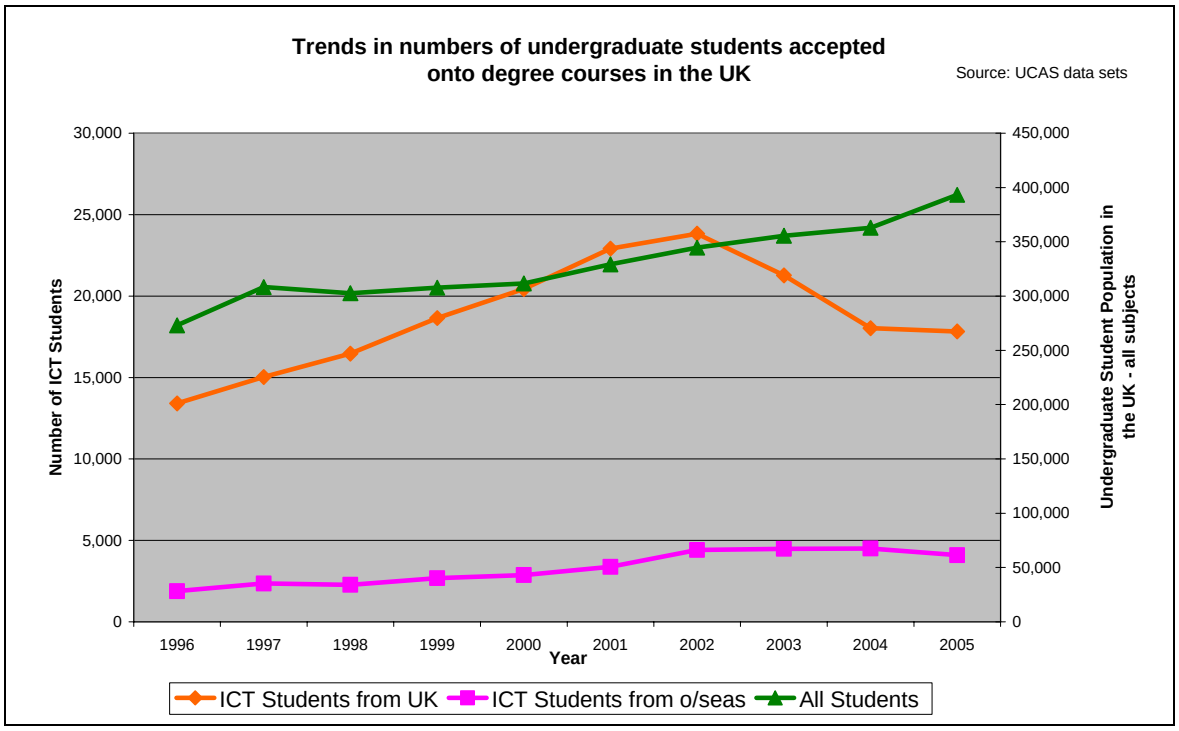

Figure 1 Undergraduate Trends.

Recommendations:

A strong undergraduate body of students must be in place if the UK is to have a good supply of excellent graduate students. The ICT community, including educational institutions, learned societies and funding agencies, should redouble their efforts to establish a strategic plan for embracing and motivating the youth of the UK to enter ICT careers.

Universities should encourage their faculty to reach out to the local communities. The Panel saw a few instances of successful outreach programmes including the Wales IT workshops[1] for elementary students

1 http://itwales.com/

and teachers, the Queen Mary College cs4fn website[2], and EPSRC's Public Engagement programme. There was also evidence of individual efforts to motivate elementary school students. However, the Panel feels that much more can and needs to be done in this area. A small investment in time by the ICT community can serve as a starting point. Universities should initiate 'Teach the Teachers' programmes by holding workshops and summer schools in ICT for teachers.

The ICT community should influence existing curricula in maths and sciences with more exposure to ICT.

Successful pilot projects should be expanded with small EPSRC grants. For example, the IT for Wales effort has matured to a state that exceeds the informal funding available thus far.

UK Universities should actively seek and encourage UK PhD applicants, as these are more likely to stay in the UK after graduation. EPSRC could perhaps create an incentive programme that favours local students (the current University system incentivises Universities to favour overseas students due to differential fees).

5.1.2 Retention of Overseas PhDs

Observation:

The UK attracts large numbers of overseas scientists and engineers into ICT programmes but many far-east students are returning home after completing their studies. Universities appear to focus on attracting foreign graduate students rather than UK students.

Discussion:

UK Universities are attractive to overseas students because of social and educational reasons. The UK offers a diverse cultural environment and outstanding education opportunities for students from abroad. The high calibre and excellent reputation of the UK University system offers an outstanding opportunity for these students. The fee structure for overseas students (approximately £5,000/pa UK, £12,000/pa overseas) also encourages UK universities to seek out and to admit overseas students. This imbalance in fee structure is a good source of income for universities. While beneficial in the short term, this is damaging in the long term.

There is at least anecdotal evidence from meetings with a number of students from Asia, China and the Far East that, in recent years, more and more students return to their home country after education and perhaps a brief stay in the UK. However, in the long term, the UK cannot afford to be producing PhDs for other countries at the expense of its own. While it is currently easy to attract overseas people, this may change over the next decade as the economies in Asia, China and the Far East continue to grow. It may be increasingly difficult to retain international students after they

2 http://www.cs4fn.co.uk/

complete their training due to visa issues and because they will increasingly find their home country an attractive place to return to work.

Recommendations:

Overseas students should be encouraged to stay in the UK once they have received their PhD's. There is more scope within the system (e.g. through project studentships) to offer support to overseas students than is perceived by the community. However, UK government regulations prevent the use of Doctoral Training Grant funds to support overseas students, and EPSRC should continue to work on getting these relaxed. EPSRC should continue to educate the ICT community to understand the actual funding rules and how to best use the various funding mechanisms. In addition, the UK government should examine and seek to remove any regulatory barriers that may make it difficult for overseas students to stay and work in the UK after earning a PhD here.

5.1.3 Career Development

Observation:

Career development for young scientists and engineers is patchy. The level and quality of mentoring of young scientists by their host institutions is variable. For instance, discussions with younger faculty members reveal that promises made for their personal development and support (e.g. as stated in supporting documentation during the application process for First Grants and Fellowships) are often not upheld in practice.

It is difficult for people to rejoin academia from industry and/or maternity leave and/or family leave. The community perceives that the EPSRC First Grant scheme is inflexible, believing that it allows a researcher only one chance to apply and discriminates against those returning from industry or a family break.

Discussion:

Compared to international norms (for example in North America), there appears to be a greater emphasis in the UK on supporting Postdocs/Research Associates over PhD students. Care should be taken in research proposals to strike a good balance between funding these two, as the training of PhD students (especially UK students) is important to create a new cadre of researchers and educators. There was little evidence that young RAs receive any career counselling. In many places, the RAs are the backbone of the research organizations and they often are major contributors to the research proposals. There was also an impression in the community that the new breed of young inter-disciplinary researchers working in-between disciplines would have less success when compared to core researchers, affecting their career path.

The First Grant scheme actually appears more accessible than many in the ICT community report. Changes to the scheme occurred in November 2006 and have added greater flexibility. The period of eligibility for the scheme has been extended from 24 to 36 months from appointment to the first academic post while the removal of the schemes' upper funding limit

(previously £250k) means that First Grant applicants now have the opportunity to request the level of funding they require for their proposal without restriction. Candidates with a non-standard pattern of academic experience, for example through working part-time or taking a career break, may still be eligible to apply and are encouraged to approach the Council on a case by case basis; this is especially true for those who have taken family breaks. Resubmissions of First Grants by Prioritisation Panels may now be invited when a proposal's research quality is high but where substantive improvements would be brought by minor revisions to other sections. These revisions to the First Grant scheme should go some way to ensuring that the most able young researchers are better supported by the funding bodies, in terms of appropriate flexibility in their funding mechanisms.

Recommendation:

EPSRC should coordinate career-planning resources. This should remain at an advisory role, since this is mainly a community responsibility. EPSRC could set up a database of best practices and engage academics and industry to contribute/feedback. The First Grant scheme is an excellent idea, however, the recent changes (November 2006) that make it more flexible may need to be better publicised to ease community concern, and we believe it could be made even more flexible by for example allowing for three applications within two or three years. The Responsive Mode funding mechanism could also take into consideration the recent experience of the principal investigator, perhaps using labels such as 'first time returning grant holder' as a method of turning young scientists into career researchers. However, the First Grant Scheme must be more flexible in terms of who can apply, e.g. the 'clock should stop' for family related issues, and people who fail in their first attempt should be allowed to reapply to this programme.

5.1.4 Infrastructure

Observation:

Many universities have established a solid infrastructure of software and hardware facilities over the past five years. Currently, there are no mechanisms to maintain infrastructure once the initial grants end.

Discussion:

The establishment of several Interdisciplinary Research Collaborations (IRCs) within the ICT community since 2000 and the ongoing support of National Facilities have allowed universities to build hardware and software infrastructure, often at considerable investment. There is concern in the ICT community that this infrastructure will deteriorate without additional funding. Even when software is successfully transferred into commercial use, the re-engineered software is not retained by the original institution and/or may not be suitable for advanced research purposes. There is still a need to maintain the original research code base. Full economic funding can help in some cases where the infrastructure becomes part of the institution overhead. However, even though new projects often leverage existing capabilities, these projects are usually not willing to invest significantly in shared infrastructure.

Recommendations;

EPSRC should establish a funding mechanism to maintain critical software and hardware infrastructure.

There are successful mechanisms in the United States for funding infrastructure. For example, the US National Institutes of Health have U24 Research Infrastructure grants that fund local infrastructure and the National Centres for Research Resources fund capabilities at individual sites that can be used throughout the country. Also, US grants often have additional 'supplements' awarded after the initial grant. This additional funding may be targeted at supporting critical software components or hardware upgrades. EPSRC should look to NIH and NSF for best practices regarding infrastructure funding.

Additionally, care should be taken not to fund duplicate infrastructure at multiple universities; there would be substantial benefit in EPSRC carrying out an audit of the existing hardware/software infrastructure. Similarly, care should be taken so that infrastructures are created in a manner that can be shared by other Universities. This is especially important regarding software.

5.1.5 Balance

Observation:

Multidisciplinary research is thriving in the UK, enabled by a strong theoretical base in ICT established over time and the establishment of IRCs and the e-Science programme. There may be an erosion of fundamental research.

Discussion:

The Panel was impressed with the advanced application of ICT research and the numerous interdisciplinary programmes. The e-Science initiative was especially impressive in the way it fostered cross-discipline ICT applications. However, the Panel perceived a larger proportion of applied research and interdisciplinary work compared to theoretical work. This may be in fact an artefact of the type of projects selected for the Review rather than an actual de-emphasis of theoretical work in ICT. The Panel feels strongly that a balance between theory and application must be maintained. Sustained, high-quality theoretical ICT work must continue to enable future multidisciplinary research and applications.

Recommendations:

The UK has been a pioneer throughout computing history and must maintain a fundamental presence in each discipline. The ICT community must continue to stimulate and nurture both cross-discipline and theoretical ICT research. Universities should always be on the lookout for new theoretical areas that may be complementary to current research (e.g. machine learning and computer vision). EPSRC should encourage high risk, theoretical ICT research, perhaps by creating new funding mechanisms. EPSRC should quantitatively track over time the proportion and absolute amount of its funding which supports theoretical research. At the same time, EPSRC must continue to encourage inter-disciplinary

programmes through its Interdisciplinary Research Collaborations and next generation e-Science programme equivalent.

5.1.6 Collaboration with the World

Observations:

The UK ICT community has a reasonable representation on EU grants but there are few significant connections to ICT research in the United States, despite evidence of formal collaborative arrangements. The Panel heard very little about collaboration with Asia, China and the Far East.

Discussion:

There is a widespread desire in the ICT community for more formal interactions between UK ICT research groups and CS/EE research in the United States. Schemes such as Overseas Travel Grants and Visiting Fellowships only partially address this need for mechanisms of collaboration. Successful experiences in establishing collaborations in the areas of energy and materials suggest that much more can be done in ICT.

The Panel noted that experience with EU projects was mixed. There was some concern that the EU projects often had too many partners and too much project overhead in the way of meetings and reporting.

The Panel recognizes that the rapid rise of economies in Asia, China and the Far East offers an opportunity for more aggressive collaboration policies.

Recommendations:

EPSRC should actively reach out to the US NSF, NIH and DARPA to establish joint funding of projects. This should include exchanges between agency programme and project managers as well as joint sponsored workshops for researchers. There are also some large US initiatives that encourage collaborations:

- The NIH National Centres for Biomedical Computing (NCBC) are building national infrastructures in bioinformatics, image analysis, ontologies and biomedical simulation. These centres are actively reaching out to biomedical researchers worldwide.
- The US National Science Foundation also has grants that encourage foreign collaboration.
- The US Defence Advanced Research Projects Agency (DARPA) is adept at funding long term, high risk, and multi-disciplinary research. DARPA is an excellent source for best practices in pursuing new, high-risk research areas and can provide guidance to EPSRC in funding strategies.

Regarding countries in Asia and the Far East, as their economies continue to grow they are more likely in future to prefer to educate their students at home rather than abroad. The Panel recommends that EPSRC and the community look for innovative approaches to collaboration. For example, the University of Liverpool has a campus in China and the University of Nottingham has campuses in China and Malaysia.

5.1.7 Continuity of funding

Observation:

Increased ICT funding over the past five years has produced positive results. In particular, the IRCs have been very successful but the community is concerned about what happens next.

Discussion:

The IRCs have been excellent in fostering large collaborations and the creation of infrastructure. The EPSRC ICT programme aspires to maintain a rolling portfolio of IRCs over future years, establishing a critical mass of activity in research areas as and when strategic need arises and subject to an adequate funding stream following future UK spending reviews; it is currently reviewing existing ICT-focussed IRCs to identify best practice and inform future activity. The initial ICT-focussed IRCs will end in 2007; plans for the sustainability and continuity of IRC-related research formed part of the initial assessment criteria for funding such projects, and it was made clear (and is well understood) that there would be no automatic renewal of funding.

There is however a general concern in the ICT community, shared by the Panel, that this means a phase-out of the IRC funding that will compromise the working relationships and projects that the IRCs had started. However there is in fact nothing to stop the existing IRCs applying for responsive mode funding and, if successful, continuing and acting like IRCs.

The Panel noted that not all existing ICT-focussed IRCs have responded to EPSRC's invitation to apply for Platform Grant funding as a means of sustaining their research capacity. The Panel also noted that EPSRC's ICT programme established in September 2006 a specific 'large grants' panel that offers a common mechanism for reviewing complex proposals from across the programme. The Panel also notes that there is benefit in staff moving into new areas from mature projects, and that gains accrue from a continual refreshment of the talent pool, and these should not be underestimated.

The Panel was assured by EPSRC that the groups established using IRC funding could remain intact using other EPSRC funding vehicles. However, the community consistently raised concerns that this would not happen in practice due to peer review biases.

Recommendations:

The Interdisciplinary Research Collaborations have been excellent in fostering the creation of infrastructure. Relevant groups should ensure strategies are in place to leverage funding from a wide variety of sources (over reliance on Research Council funding is a high risk strategy) and EPSRC should encourage the ICT community to submit large, multi-year grant proposals through the responsive mode funding mechanism. The UK ICT community must, as peer reviewers, continue to act fairly towards large bids: this will ensure that the process results in the selection of those proposals that are of the highest technical merit and consequently, successful IRC's should continue to receive funds. However, care must be

taken to ensure that the peer review process is not biased against inter-disciplinary proposals when ranked against traditional ICT proposals of similar quality (see 5.2.2). As discussed in 5.1.3 (Career Development), flagging young interdisciplinary applicants as ‘first time returning grant holder’ may also help negate biases when these grants are compared to other traditional grants. As well, EPSRC should explicitly clarify the policy to reviewers regarding the merit of inter-disciplinary work,

5.1.8 University/Industry Knowledge Transfer

Observation:

The Panel observed many instances of small business creation. There is less engagement with large multi-national businesses.

Discussion:

The Panel witnessed considerable IPR transfer from university to industry. The process of IPR transfer varied from university to university and no single approach was more successful than another. There are many instances of professors spinning out small companies, some successful, some not. Somewhat surprisingly, the Panel saw very little in the way of economic analysis relative to ICT commercial impact in the UK. The main focus of the review was to understand the quality of ICT research in the UK universities, and the health of the underlying enterprise, supported by EPSRC. However, the impact of ICT research activity on the UK economy and global competitiveness, and to a lesser degree, dealing with the knowledge exchange between the research base and industry, rightly imply a focus on the EPSRC’s university funding as an investment by the people of the UK, with an expected return to them. Looked at from this perspective questions are raised relative to whether the current investment is appropriate in size, and whether appropriate returns on the investment are achieved.

These questions are particularly relevant in the light of a view often heard that ICT-related industry in the UK is not particularly strong in spite of a historically and currently strong research base and history of knowledge creation and invention. It may well be that there is significant analysis of the sort that would underlie and facilitate the exploration of the question raised above, but the Panel saw very little of it.

The Panel did see an impressive array of programmes driven by EPSRC that clearly motivate research activities in directions that are likely to enhance returns, the movement of funding to interdisciplinary programmes and programmes involving industry and socially relevant goals such as healthcare. However, some members of the Panel feel that to the degree that economic impact is an important (by no means the only important) goal of EPSRC’s investment, a set of economic analyses deeper than anything to which we were exposed would have significant value.

Recommendations:

The Panel recommends that EPSRC initiate a study to assess the impact of ICT research on the UK economy. Some qualitative and quantitative issues can be studied and stakeholders at all levels could contribute valuable

inputs to any such studies. From the perspective of the EPSRC's ICT group these issues might include the following:

- Given the interlinked importance of each sector, how is the UK doing?
- Is the UK leading, even, or trailing what is appropriate for a country with the UK's characteristics and economic dynamics?
- Is there a relationship between the EPSRC investments and programmes and the path to UK advantaged exploitation and impact on the UK economy?
- Does the balance of the investments among ICT areas seem optimum?

Digging into these questions with somewhat quantified underpinnings together with inputs from stakeholders might drive change-stimulating conclusions.

5.2 Short-Term

5.2.1 Lengths of Grants

Observation:

EPSRC communication with the ICT community has vastly improved over the past five years. However, the ICT community has the perception that grant proposals aimed at support for more than three years are far less likely to be supported.

Discussion:

The Panel heard several groups and investigators complain about the length of grants. Many groups and individuals were under the impression that grants for longer than three years were discouraged by the EPSRC. In fact, the Panel was informed, there is no three year limit on the length of grants. This 'three year limit', to the degree that it exists, apparently has been imposed not by EPSRC but by peer review panels which appear unfavourable to longer grant periods (due to their previous expectations, experiences, and norms).

Recommendations:

This is an ICT community imposed problem. EPSRC should explicitly clarify the policy regarding grant duration. If the community continues, through the peer review process, to discriminate against proposals that do not conform to a three year norm then EPSRC should consider instituting a stratified-funding mechanism that has separate calls for 2 year, 3 year and longer term grants.

5.2.2 Peer Review

Observation:

Criticisms of the peer review process continue. These criticisms were also present during the 2001 Review. The criticisms continue to centre on reviewer selection by non-ICT trained EPSRC programme managers rather than ICT specialists or by a peer ICT panel.

Discussion:

Peer review processes in science and engineering should be under constant review and improvement, even if for no other reason than that the less transparent the review process, the more likely the process will be criticised. The EPSRC process, which was recently awarded ISO 9001 accreditation, is subject to systematic review and analysis and includes a number features to ensure that appropriate referees are used. These include: the use of at least one of three applicant-nominated referees for each proposal; the selection of referees based on their declared expertise; the freedom of anybody to refuse a request to referee an application if they feel they have insufficient expertise; the right of applicants to respond to the referee comments; the option available to peer review panels to request that additional referees be approached for comment if they feel the referees chosen for a proposal were inappropriate.

Analysis of replies on returned questionnaires from ICT-only panels between April and December 2006 shows that 98% either agreed or strongly agreed that the referees selected for the proposals were appropriate.

However, the Panel notes that perceptions regarding the review process are as important as the facts behind the process.

Recommendations:

Although there is no evidence that the current process is defective, EPSRC should engage the community to either improve the process or educate the community. The process needs to be transparent and understood by the community, and the concerns expressed by the ICT community suggest that there may well be a mismatch between perceptions of peer review and the actual views of people involved in the process.

The Panel feels that EPSRC could do more to make their process more transparent. EPSRC could also consider other reviewer selection processes, where primary decisions on referee selections are made by a peer committee rather than EPSRC staff. Options include, for example, the reviewer selection process used by Canada's NSERC grant agency for their Discovery Grants. Applicants supply a short abstract and list of potential reviewers several months ahead of their grant applications. A peer review panel reviews these choices, substituting some of their own recommendations (an NSERC-maintained database provides the panel with a large set of national and international reviewer possibilities, categorized by topic areas). The NSERC staff then use this peer review recommendation to solicit the actual reviews. There is general satisfaction with this process. An alternative could be perhaps an advisory editorial board of experts to be used as a sanity check of the process at routine intervals.

6 The Review Framework

1 To what extent is the ICT community addressing key technological/ societal challenges and engaging in new research opportunities?

1.1 What are the key challenges and research directions in ICT research?

1.2 Does the EPSRC ICT programme reflect accurately the breadth of activity of the ICT research community?

1.3 Is the research community structured to deliver solutions to current and emerging challenges?

1.4 Are there significant research pioneers and challenges to nucleate significant effort?

1.5 Is the current research portfolio robust and responsive enough to deal with any major perturbations?

2 To what extent is the ICT research base contributing to other disciplines and multidisciplinary research?

2.1 Has multidisciplinary research and approach become embedded within the community?

2.2 Is there appropriate dialogue between the ICT community and other disciplines and are there any barriers to an effective communication flow?

2.3 Are the developments to date sustainable in the future?

2.4 What evidence does EPSRC have to demonstrate the impact it has had in this area? Is there multidisciplinary within ICT?

2.5 Is the transition from main stream areas to multidisciplinary areas as expected?

3 What is the level of knowledge exchange between the research base and industry that is of benefit to both sides?

3.1 What is the flow of trained people between the industry and the research base and vice versa?

3.2 What is the relationship between UK academia and industry both nationally and internationally?

3.3 Does EPSRC enable this knowledge exchange through its different schemes?

3.4 What is the scale of industrial R&D in ICT and what is the trend?

4 To what extent is the UK ICT research activity focussed to benefit the UK economy and global competitiveness?

4.1 What are the major innovations in the ICT area?

4.2 How successful has the UK ICT community been at innovation?

5 To what extent is the UK able to attract young scientists and engineers into research, nurture and support them at every stage of their career to benefit the UK?

5.1 Are there areas of weakness - is the UK producing a steady-stream of researchers in the required areas and/or are there areas that should be declining to reflect changes in research climate?

5.2 Is the demand from undergraduates to become engaged in research as expected?

5.3 How does the career structure for researchers in the UK compare internationally?

6 To what extent is the UK able to attract and retain overseas scientists and engineers to the UK?

6.1 How is the engagement between the UK and Europe?

6.2 How is the engagement between the UK and the rest of the world?

6.3 Are there particular issues for the ICT programme area?

7 What is the impact on a global scale of the UK ICT research community both in terms of research quality and the profile of researchers?

7.1 Is the UK internationally leading in ICT?

7.2 In which areas, why?

7.3 Where are the highlights, why?

7.4 What are the trends, why?

7.5 What are the opportunities/threats in the future?

8 What evidence is there to support the existence of a creative and adventurous research base and portfolio?

8.1 Comment on the balance of adventure and safety in the ICT research base portfolio.

8.2 How do research groups foster adventurous ideas?

7 Panel Assessment of 2001 Study Recommendations

The 2001 Panel made a number of recommendations. Here, the 2006 Panel assesses progress towards the 2001 recommendations:

1. UK computer science, hitherto excellent, is in danger of decline.

   Progress: Although admittedly the 2006 Panel was exposed to some of the best ICT groups in the UK, the quality of the work was excellent and the morale of the researchers and students appeared very high. The Panel is still concerned about the risk of decline, but sees no evidence that the quality of UK ICT research has declined since the last report.

2. The talent pool for academic researchers is shrinking through poor pay and conditions.

   Progress: In general, the remuneration situation seems to have improved, but we have serious concerns about the recruitment and retention of students in ICT, both from the UK and abroad (see sections 5.1.1 and 5.1.2).

3. EPSRC funding, in quality and style, hampers effective computer science research because grants are small and inflexible; infrastructure and platforms are inadequately supported; funding discriminates against new area, high risk, interdisciplinary and large experimental proposals.

Progress: EPSRC has improved considerably in the quality and diversity of funding. The 2006 Panel did not detect any significant complaints about the current portfolio of EPSRC funding mechanisms. However, interdisciplinary researchers are concerned that they may do less well in responsive mode (section 5.1.3), with the exception of continuation of funding for IRC's, which we address in section 5.1.7 .

4. The focus on industrial connectivity of scientific research is an irrelevancy.

   Progress: Our impression was that, in general, researchers engaged in joint projects with industry were doing so willingly, and often enthusiastically. The same can be said for the much increased emphasis on multi-disciplinary research.

5. Dividing the IT/CS Programme into one programme for computer science and one for physical layer technology would allow increased visibility, better control and independent budgeting.

   Progress: The 2006 Panel disagrees with this recommendation. The unification of CS/EEE does not appear to be an issue. In fact, there are opportunities if EEE and CS work closer together. Smaller schools may benefit from close connections between the two disciplines.

6. Computer scientists should be more involved in formulation of EPSRC policy and its day-to-day management.

   Progress: Rotations of staff are less frequent than in the past. This provides some measure of continuity in the programmes. However, there remains the perception that EPSRC staff are not qualified to select reviewers. Perhaps an advisory editorial board of experts could be used as a sanity check, or a reviewer selection panel process as recommended in 5.2.2 . The community and EPSRC should work together to resolve this issue.

7. UK computer science research strengths, now at risk, are in formal methods and programming languages; software engineering and system security, architectures, artificial intelligence and human/computer interaction, and bioinformatics.

   Progress: The 2006 Panel did not investigate individual programmes.

8. Research in algorithms needs promotion. Opportunities for computer science research within the e-Science programme should be exploited.

   Progress: Algorithm research has gained support over the past five years. For example, EPSRC prioritised research in algorithms in March 2006 with a £3.8 million Science and Innovation Award to the University of Warwick. This was to set up the 'Centre for Discrete Mathematics and its Applications', which will be rooted in the departments of Computer Science, Mathematics and the Business School. It will focus on both the interface between mathematics and computer science and the fundamentals of

operational research.

The Panel saw evidence that ICT is playing an important role in the e-Science programme.

9. UK remains a world leader in some research areas, and a strong participant in many others, but its position is not assured.

   Progress: The Panel agrees. However, in the past five years, there is no indication of erosion of the UK leadership role in some areas. The Panel agrees that the position is not assured.

8 Annex 1: Supporting Evidence and Information Provided

A range of supporting evidence and information was provided to the review panel both before and during the review. This included:

- A background data document prepared by EPSRC.
- Responses, submitted during a consultation period before the review, to the questions posed in the Review Framework; these were submitted mainly by Universities.
- Data sheets describing the principal ICT research groups active within the universities visited by the review panel.
- Case studies prepared by EPSRC of knowledge transfer activity from the ICT research community to Industry
- Visits to ten leading non-London Universities to view their facilities and meet with their key ICT research staff
- A collective meeting/demonstration event with researchers from four London Universities
- A 'Knowledge Transfer' event providing opportunity to meet with businesses that directly exploit the latest results of ICT research
- A 'Multidisciplinary' event providing an opportunity to meet with researchers from other fields whose work is integrated with current research in ICT
- A series of informal dinners with invited guests from academia and industry, affording the panel the opportunity to explore a wide range of issues within the remit of the review.

The following tables list the sources of information for each of the above:

Institutional Responses the questions posed by the review framework were submitted by:

Aston	Heriot-Watt	Nottingham
Bangor	KCL	Royal Holloway
Belfast	Kent	Southampton
Bradford	Lancaster	Strathclyde
Bristol	Liverpool	Surrey
Durham	Loughborough	Sussex

Edinburgh	Manchester	UCL
Essex	Newcastle	UKCRC

Personal responses were received from:

Professor Alan Newell (Dundee)
Professor Colin Tully (Middlesex)
Professor Harold Thimbleby (Swansea)
Professor Jon Crowcroft (Cambridge)

Data sheets were received from key ICT research groups at the following Universities:

Cambridge	Nottingham	KCL
Edinburgh	Southampton	Imperial College
Glasgow	Newcastle	QMUL
Lancaster	Surrey	UCL
Manchester		

The following Universities were visited by members of the review panel during the course of the review week:

Cambridge	Nottingham
Edinburgh	Southampton
Glasgow	Newcastle
Lancaster	Surrey
Manchester	Oxford

Four Colleges of London University – King's, Imperial College, Queen Mary College, and University College –presented their research to the panel at a special 'London University' event.

Research teams engaged in multidisciplinary work at the following universities presented their research to the panel at a special event held at the National e-Science Centre, Edinburgh:

Cambridge	Nottingham	Liverpool
Southampton	St. Andrews	Bath
UCL	Sheffield	Loughborough
Edinburgh	Leeds	Imperial College
Glasgow	Newcastle	Oxford
Kent	Surrey	Institute of Education
Manchester	Aston	

Research teams and others engaged specifically in Knowledge Transfer, from the following Universities and other organisations, presented details of their work to the panel at a special ‘Knowledge Transfer event:

Agilent Technologies UK Ltd	Intense Ltd.	Toshiba
Bioscience Centre	IT Wales	UCL
British Broadcasting Corporation	Kings College London	University of Bristol
Cardiff University	Location and Timing KTN	University of Cambridge
City University	Microsoft Research Ltd	University of Leeds
Codeworks	Mobile VCE	University of Nottingham
Department of Trade and Industry	Orange Holdings (UK) Ltd	University of Oxford
e-San Ltd.	Participate	University of Southampton
E2V Technologies Ltd	Research Acquisition Organisation	University of Surrey
Hewlett-Packard Ltd	Rinicom Ltd	University of Wales Swansea
Hi Consulting	Rolls-Royce plc	York
I3S Centre for Industrial Collaboration, Leeds	Snell & Wilcox Ltd	Vodafone
Institution of Engineering and Technology	Sony Semiconductor Europe Ltd	

In addition to the above, panel members were also able to meet with representatives of the following:

British Aerospace plc.	Royal Holloway	University of Birmingham
Queen's University Belfast	University of Sussex	University of Essex

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British Aerospace plc. Royal Holloway University of Birmingham
Queen's University Belfast University of Sussex University of Essex