EPSRC

Pioneering research and skills

EPSRC Workshop Report

ICT Research – The Next Decade Workshop

20 – 21 October 2010

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EPSRC

Contents

Background

Motivation for the workshop

As EPSRC seeks to achieve its strategic goals of Delivering Impact, Shaping Capability and Developing Leaders, the ICT Programme would like to engage with the research community on how we maximise our alignment with these objectives and implement our new Delivery Plan. Our aim is to draw together representatives from across the ICT community and involve them in the development of strategy for the ICT programme, in the context of our new Delivery Plan, and explore the direction and shape this should take.

This continuing engagement with the ICT community follows on from the recent successes of the ICT Theme Days and Photonic Systems Workshop where a number of common and specific issues were identified across the ICT portfolio. These resulted in a number of positive steps being taken by the ICT Programme and the ICT research community. Amongst these are the ExICTe workshop held in February, the starting of an early career campaign and formation of an early career focus group, more engagement in the development of European funding opportunities, and the formation of networks between researchers.

Outcomes of this workshop will feed into programme strategy, may influence programme funding streams, and will influence how the programme contributes to the success of EPSRC's Strategic Plan. Research funding will be attached to this workshop to enable the follow up of any outcomes.

Objectives

- To involve the ICT research community in considering the future strategy for the ICT Programme
- To reach community agreement on what the ICT Programme should prioritise when implementing the delivery plan.
- For the ICT community to consider and answer the following questions:
    - What does the strategic plan mean for the ICT Programme?
    - What should the priorities be for ICT research going into the next decade?
    - How can ICT research contribute to future research challenges?

Delegate selection

An open call was issued on the EPSRC website in July 2010 inviting expressions of interest to attend the workshop. We received over 100 applications and were able to invite 44 delegates to the event, held on the 20th and 21st October 2010 in Manchester. Selection was based on the application form, which asked the candidates to provide a brief biography and a statement detailing their interest in attending this event. An important selection criterion was the ability to think strategically about the whole ICT portfolio and delegates were chosen to cover a range of research areas, career stages and institutions. A full list of the attendees can found in Appendix A of this report.

Agenda

The workshop was held on the 20 and 21 of October 2010 at the Hilton Deansgate Hotel in Manchester.

Day One

10:30 Introduction – Liam Blackwell

10:50 Strategic Thinking – Muffy Calder

11:10 Mapping the ICT Portfolio

13:00 Lunch

14:00 Opportunities for ICT

15:00 Break

15:30 Where do we start?

16:30 Implications and Considerations for ICT Research

17:45 Close

19:00 Pre-dinner drinks

19:30 Dinner

Day Two

9:00 Introduction to Day Two – Liam Blackwell

9:15 How would we like the shape of the ICT Portfolio to evolve (1)?

10:45 Break

11:00 How would we like the shape of the ICT Portfolio to evolve (2)?

12:00 ICT Research – The Next Decade

12:30 Lunch

13:30 Achieving our Vision

14:30 Next Steps

15:15 Round up

15:30 Close

Workshop Outputs

Strategic Thinking

Professor Muffy Calder (University of Glasgow) gave an introductory talk on thinking strategically highlighting some current tensions such as personal discipline/institutions versus greater good, core research versus multidisciplinary research and infrastructure versus basic science. She also advised the need to think about the direction in which to travel, how to get there and how to know when you have arrived.

Session 1 – Mapping the Portfolio

In order for us to consider shaping the portfolio, we first need to think about what the research landscape looks like now. During the first session delegates were asked to map the ICT portfolio and identify any important challenges that will need to be overcome as we begin to shape the portfolio. Objectives of the session were to gain a view of what the ICT community feels the ICT landscape looks like and to identify important challenges present now, both across ICT and within individual portfolios.

It was noted by some delegates that mapping the research portfolio is a difficult task and one which EPSRC is probably best placed to lead. The ICT team will continue to work on formulating this picture of the landscape in consultation with the community.

During the feedback session of “Mapping the ICT Portfolio” the following key challenges across the ICT portfolio emerged:

- Industrial interaction
- Scale
- Security, resilience, privacy
- Challenge-led research
- Systems approach
- Adventurous research
- Centres of critical mass
- People pipeline
- Cross-disciplinarity

Many of these challenges were identified as being relevant to all portfolios within ICT (**Communications, Computer Science, Electronic Materials and Devices, People and Interactivity and Photonic Materials and Devices**). It was interesting to expose this commonality and demonstrate synergies between the themes within the ICT portfolio. A full list of challenges listed in each area as well as across ICT has been collated and can be found in Appendix B.

Session 2 - Opportunities for ICT

Taking forward the key challenges from the Mapping the Portfolio session, the next session looked at Opportunities for ICT. The aim was to put these challenges into a political, economical, societal and technical context. In order to do this, delegates were asked to comment on each of these headings for the

challenges identified. It was felt that by encouraging delegates to consider these challenges more broadly we could identify the ways in which ICT research could tackle and overcome these challenges.

The following pages contain the ideas and thoughts posted throughout this session. Where an opportunity was noted to be relevant to multiple headings, it has been grouped as being “relevant to more than one heading”.

Industrial Interaction	
Political • Broader constituency • Retention of skills in the UK • Perception of relevance • Risk of short termism	**Economical** • Inward investment • Benefit to UK companies • Technology transfer • Let industry suggest challenges **not** projects • Commercial exploitation of research • Research with impact • Input from UK plc • Technical/base equipment • Now lack of industrial research labs in UK • Research development gap – how to cross/fund
Societal • **Training** and employment industry. PhDs and Postdocs • Energy efficient solutions and safety • Training of skilled people	**Technical** • Technical/base equipment • Now lack of industrial research labs in UK • Research development gap – how to cross/fund • Research leading to **knowledge exchange** between academia and industry • Knowledge transfer both ways • Application driven research • Problem definition and motivation
Relevant to more than one heading • Satisfies politicians of shorter term impact and economic gain • Avoid agendas driven by short term and political topicality in EPSRC • SMEs • Who pays? • Real problems! • Less can be more • More can be less	

<table>
<tr><th colspan="2">Scale</th></tr>
<tr><td>Political
Critical ICT Information in the UK (self reliance)
Wood for the trees
Nanotechnology – public education</td><td>Economical
Long tail micro-payments
Data storage
cost
resilience
Stability of data driven applications
Energy Consumption – low energy computing</td></tr>
<tr><td>Societal
Complexity (managing) social engineering usability
User tools
Social implications on multiple scales
Large-scale social-technical systems (e.g. NHS computer system and people)
Scalable intelligent infrastructure</td><td>Technical
Toolsets for next generation nanotechnologies
Nano
Massive data exploitation
Parallelism many core + language support
Modular verification
Communication – centric computation
Data mining – multiple levels of scale
More info available. Tools needed to search
Computing scales and programming models
Sifting the chaff
Verification of scale?
Coping with complexity of large scale
Data centric computation</td></tr>
<tr><td colspan="2">Relevant to more than one heading
Very large (e.g. datasets) AND very small (e.g. devices)
Bandwidth
Emergent Structures
Heterogeneity</td></tr>
</table>

<table>
<tr><th colspan="2">Security, Resilience, Privacy</th></tr>
<tr><td>Political
Develop new legal ethical frameworks
Engage lawmakers
What happens when power goes out?
Surveillance and intelligence
Safe, secure lifestyle and infrastructure</td><td>Economical
Business models rewarding privacy conscious technology
Fully digital economy
What influences privacy? or otherwise?
Prevention of e-crime</td></tr>
<tr><td>Societal
Risk awareness
Terrorism prevention
Social network mining
Well-being</td><td>Technical
Security and privacy by design
Extreme environment technologies
Privacy preserving data mining (urgent)
Foundational and applied research (tool support) into producing secure systems</td></tr>
<tr><td colspan="2">Relevant to more than one heading
Critical National infrastructure
UK presence in emerging specialisation
Verifiable security, how?
Robustness by self-motivation
Intelligent infrastructure
Robustness of ICT
Usable secure systems
Collective intelligence
Multicomponent complex systems
Robust intelligence (large scale systems)</td></tr>
</table>

Challenge Led Research

Political

- Bridging digital divide
- Easier to sell due to headline potential
- Who sets the challenge and how?
- Cyber security
- Public payoff justification
- Privacy preserving data mining

Economical

- How do we predict the economic consequences of solving the challenge?
- Creates new markets
- Cheap fast broadband, universal

Societal

- Bringing the 3rd world to our level in shorter time (i.e. skipping steps/mistakes)
- Waste Public money
- Failure is very public?
- What are the social challenges?
- Big society
- Control e-mail
- Large scale intelligent systems
- Social/business networking
- Energy generation/harvesting
- Technologies for healthcare
- Ability/empowerment to switch it off

Technical

- Science automation (the automation of scientific discovery)
- Future CMOS solutions
- Large scale nanotech integration
- Implantable technologies for bio applications
- Integration of photonics with electronics
- Low power devices/systems
- Human-centric robotics
- Vast quantity of information available - exploitation of ….
- Reliable systems from unreliable components
- Verified software
- Grand challenges

Relevant to more than one heading

- Does it win Nobel prizes?
- Climate change/limited fossil fuels
- Management of energy
- Splitting winners
- Spotting winners
- Reliable secure web
- Measurement of appearance
- Often becomes the application of known technologies rather than the new
- Achieving performance of biological system

Systems Approach	
Political • Mixture of leading edge R&D and COTs. Need to make mix work • Easier to describe benefits (political – social) • Can we learn from other science systems approaches • Resilience - build on proven • Grand challenges • Theme based	**Economical** • Scalability • Need business models to experiment with scale • Re-use • Critical mass • More effective solutions – can be personalised/customised at no great cost • Less waste/shorter time to market trade-off with bigger mistakes – bigger problems
Societal • Intelligent web • Bigger problems • **New** and emerging behaviours • Unbalance between incremental and adventurous aspects • Research vs. consultancy • Relevance • Inclusivity • Superficiality vs. depth	**Technical** • Integration (a collection of pieces does not make a system) • Multidisciplinary/collaborative • Unexpected outcomes • Robust intelligence • A systems challenge • Iteration between system-design-tech to improve efficiency of application/product • Pull technologies through to applications
Relevant to more than one heading • Complexity • Boundary problems • Co-creation • Emergence • Common vision • Public services integration/admin/engagement (NHS, Council, Gov, etc)	

Adventurous Research	
Political • Impact? • Inspirational • Fighting • Mixed portfolio • Risk vs. outcome • Engage popular media • Digital identity • Comprehensive security • Is courageous adventurous? • Assisted living debate ad vs. incremental	**Economical** • Size of funding pot determines how much adventurous research you can fund • High risk⟶(High gain) ^{2} • Managing failure
Societal • Social computation (and bringing society into systems engineering) • Getting a social life • Quality of life issues – technology interface • Serendipity – how to engineer it happening • Natural conservatism of peer review – stifles adventure • Robot companion	**Technical** • Adventure in depth as well as breaking new ground • Post Moore's law circuits • Provably reliable computer infrastructure • Semiconductor lasers on silicon • Human computation • Fundamental advances with wide impacts • Cognitive systems • Multicore systems
Relevant to more than one heading • Security issues • Simplicity is adventurous too • Brains • Synthetic biology	

Centres of Critical Mass	
Political • Visibility • Engagement on equal terms with other centres Internationally • Who decides topic? • Influence • Robotics	**Economical** • Infrastructure sharing • Risk: loss if diversity • Virtual centres • Efficiency of scale? • Cheaper to fund than distributed research centres (?) • Sustainability • Inward investment • Sharing of expensive facilities • Pros: can afford larger projects
Societal • Excluding? • Less **intra** institution competition • More **inter** institution competition • Excellent training/development (if you are in it?)	**Technical** • Translation of research • Multidisciplinary research • Rapid progress • Attract world experts to UK • Tech depth • New areas of opportunity • Boost for existing centres of excellence
Relevant to more than one heading • How to assess viability and death?	

People Pipeline

Political

- Funding for continuity
- Assurance of high quality UK research and next generation of high quality researchers
- Influence at highest level
- Convince paymasters
- Fund ICT
- Developing advocacy
- ICT v computing curriculum (schools)
- Retention of skills base in UK

Economical

- KTP good for pipeline to industry
- Fellowship funding gap: young academics (yes serious)
- Job prospects?
- Jobs outside academia – strong pull out
- Entrepreneurship → stimulate company formation
- Influencing investors (VCs). Need to keep UK-trained PhDs in UK
- Stipends too low for UK students?
- Continuity of funding
- Pay maintenance for EU students

Societal

- Uni/PhDs – social mobility
- Getting rid of research dinosaurs
- Reputation
- Meet social needs
- Raise awareness of ICT issues in society and vice versa
- Platform grants excellent mechanism
- Universities providing support to schools in fostering interest in ICT cf IT ambassadors
- Don't stop research project PhD studentships
- PhDs encourages → industry
- Transferable skills funded easier

Technical

- Technical skills
- Engineering spinout
- Develop underpinning skills for whole range of jobs
- finance
- business
- Not just ICT
- Baseline support for internationally leading groups – essential to maintain

Relevant to more than one heading

- Avoid "brain drain" (keep smart scientists in UK)
- Fellowships are **best thing** keeping **talent** in this country. Do not shrink!
- Forge international people pipelines (don't worry about UK PhD) – Newton Fellowships

Cross Disciplinarity

Political

- Institutional support beyond lip service
- Security governance
- Makes you more attractive for funding partnering
- Willingness to do it
- Cross-disciplinary
- bad at both
- “new”
- New/changed reviewing process
- Hitting ref targets in this world

Economical

- New economic/financial/rate e.g. deliverables
- Costs more – but higher return on investment
- Cost of initiating new thinking
- New business models e.g. YouTube
- Need critical mass
- Funding robustness to create and sustain multidisciplinary groups

Societal

- Cross-disciplinary reputation and reward
- User/engagement
- Business
- User generated content
- Sheltering young researchers to do cross disciplinary research
- Societal/need
- Reluctance to engage – need confidence/support to overcome

Technical

- Formal languages and reasoning techniques
- An example of new core computer science
- Large scale problems can be tackled that can’t be solved by single discipline
- Problem/application pull
- Big data theme as a link across disciplines
- Computer vision ⟷ computer science gain
- Creative industry
- Heritage
- Cultural
- Application-driven user focused

Relevant to more than one heading

- All permutations
- Societal **pull**: problems vs. technological **push**: methods
- Learning new ways of working
- Overcoming silo-thinking
- Lots of scope for ICT cross-disciplinary

Clearly, each challenge holds a number of opportunities in different contexts and these should be considered by EPSRC and ICT researchers as the next delivery plan is implemented. It was recognised that there are opportunities for ICT within all of these challenges.

Our perception is that the delegates found this a useful exercise in thinking about the context of the challenges posed and we would urge the reader to consider the content of the last few pages when formulating research proposals, particularly when considering their pathways to impact.

Session 3 - Where do we start?

At this point, delegates had considered the current landscape of the ICT Portfolio and had listed a number of important challenges that would need to be overcome to shape the portfolio effectively. These challenges had been put into a political, economical, societal and technical context and delegates had used the sessions to discuss these.

Although challenges and opportunities had been identified, delegates had not yet discussed the direction in which they needed to go in order to realise and maximise these. Therefore, the objectives of this next session were to identify key directions the community needs to head in order to realise the challenges and opportunities raised in the previous sessions. Delegates were asked to form an initial picture of the direction the community needs to travel and the toolkit they need to realise this vision.

EPSRC were encouraged by the depth of discussion surrounding this question. A particular topic of note was that of early career researchers and ideas to ensure the people pipeline remains healthy. Ideas on this theme will be fed through into the ICT programme's Early Careers Focus Group, two members of which were present at this workshop.

There was also a large amount of discussion surrounding various strategies to shape capability within ICT such as avoiding too much focus on short term results and impact, defining islands that can be bridged to provide a whole and determining social need. It was useful to have had the Mapping the Portfolio exercise earlier in the day to feed into these more strategic discussions as it had exposed the whole ICT portfolio to the attendees.

In addition to this, EPSRC noted a lot of discussion about the benefits of different funding models. Specifically, while it was noted by delegates that responsive mode has its advantages, there was also discussion about ICT running a more managed programme where grand challenges would be defined. It was also felt by some that there should be some common research themes across and within programmes.

In Appendix C is a list of the key themes which emerged from discussions within the groups grouped under the headings early career researchers, international, industry, funding modes, strategy and technical.

Implications and Considerations for ICT Research

To end day one and to develop thinking further, this session was designed to expose some issues ICT researchers may want to consider when proposing

research and the implications their work can have. Recent consultation with the ICT Strategic Advisory Team identified the need for ICT researchers to think about the implications of their research. Dr Marina Jirotka (University of Oxford) gave a short presentation detailing the need for an ethical framework within ICT and highlighting some key examples and models. Key points covered were:

- Accountability of research
- Scale and breadth of teams
- Formal ethical approval committees
- New media and audiences
- New sources of data and aggregation

Examples relevant to ICT research such as automation, data deluge and digital self harm and rationing resources. Dr Jirotka spoke about looking at ethics from a computer scientist's perspective and in particular the question of who has ethical responsibility. The ICT Programme is continuing discussions in this area with the aim to engage with researchers to explore the ethical approach to take in ICT.

The presentation from Dr Jirotka was followed by a discussion session which continued in some groups over dinner.

From feedback provided by delegates, our perception of this session is that it was well received and provoked some interesting discussions between delegates and the wider community.

Session 4 - How would we like the shape of the ICT Portfolio to Evolve?

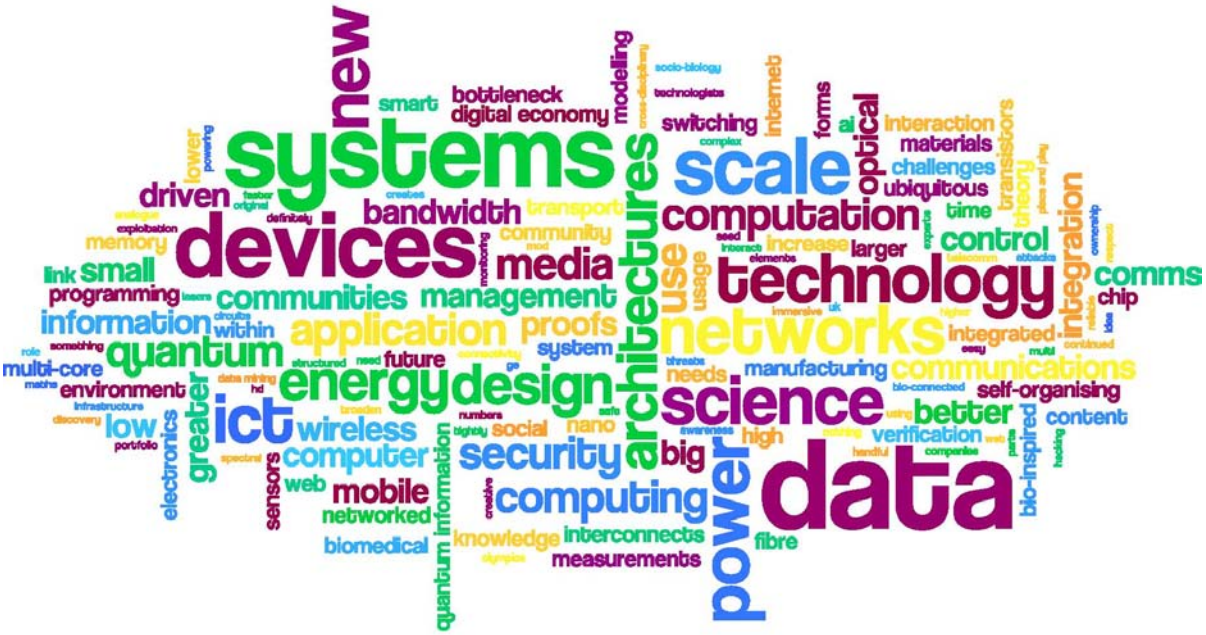
The morning of day two concentrated on looking at how the shape of the ICT portfolio might evolve over the next decade. The objectives of this session were to put together a timeline illustrating how the portfolio may evolve over the next decade and to think about how the shape of the portfolio might change during this time. It was important that these views were displayed as an evolving picture as EPSRC recognises that Shaping Capability will represent an ever changing portfolio. It was felt that ten years from now is the length of time the community should ideally be thinking about as it represents what they might be proposing two or three research grants from now and could inform the direction current research might take. Although each group took a different approach to this, with some looking at research areas and others looking at research challenges, some key themes did emerge such as

- taking a systems approach
- parallelism and many-core
- coping with large amounts of data
- more working across the themes covered by ICT

The delegates in general rose to the challenge of this session and the points raised provoked some interesting conversations. Whilst the outputs of it will not set the agenda firmly for ICT, it does give us some steer on how we implement the next delivery plan and a basis for further engagement and discussion with the community.

These timelines were also shown to the ICT Strategic Advisory Team (SAT) during their last meeting in November. There was further discussion surrounding parallelism and many-core and in particular that both the hardware and software communities will need to work together in this area. Further areas were mentioned such as green data and social HCI. The SAT noted that cross-disciplinary areas such as computer science with biology were not proposed.

The timelines are available to view in full in Appendix D. In addition to these, a Wordle has been produced to highlight the key areas that arose in the discussions. The Wordle was constructed from the combined timelines of all 5 groups and displays words such that the size is proportional to the number of times a word or phrase appears on the timelines.



Session 5 Achieving our Vision and Next Steps

As these sessions focussed on informal discussion and networking to take forward ideas that had come up over the previous day and a half, they naturally combined into one longer session. During the first half of the session delegates were asked to discuss the tools, expertise, capability etc that they would need to shape themselves over the next decade. Delegates had the opportunity to look at the timelines they had made in the previous session and use this as a basis to their discussions.

During the second half of the session, groups came to common views about what needed to be done and delegates started to form groups which might work together. Delegates were asked to advertise their ideas in a “shop window” so they could be viewed by everyone and interested parties would know who to contact if they were interested.

The “shop window” with the “adverts” from the people present is displayed as a list below. As delegates added their ideas to the “window”, a lot of proactive discussion began to take place.

SHOP WINDOW

- THz freq electronic/photonic device design, verification (A Davies)
- THz super b/w wireless (A Seeds)
- Wired-wireless interface (A Seeds)
- Wireless friendly protocols (M Beach)
- Router designer (A Seeds)
- Data deluge software processor (A Seeds)
- Analogue/mixed signal verification (George C)
- Sensor systems designer (A Seeds)
- Ethnography of comms (A Seeds)
- Privacy/security analyst (A Seeds)
- IP comms designer (A Seeds)
- Obtaining algorithms for infinitive data (M Seisenberger)
- Mathematical logic and TCs (Peter O)
- Verifying algorithms and extracting algorithms (M Seisenberger)
- Interactive theorem proving and verification (M Seisenberger)
- Automotive program analysis and debugging (Peter O)
- Verification of parallel hardware systems (George C)
- Scalable security (Siraj)
- Reliable secure heterogeneous systems (Kevin J)
- Holistic network in
- To promote cross-community with ICT
- To form multi-scale consortia
- To potentially lead to broad programme projects (D Hutchings)
- The network as the sensor (B Mulgrew)
- Hierarchy of community networks – grand challenges and societal needs (S Furber)
- Low power wired/wireless systems and networks (J Elmirghani)
- Multi spectral and multi photon imaging and display (D Foster)
- Energy optimal software (A Seeds)
- Efficient flexible (multi band) RF components (M Beach)
- Robust low energy high band identify wired/wireless connectivity (M Beach/R Penty)
- Energy harvesting devices (A Seeds)
- Reliability and resilience in low power systems/networks (J Elmirghani)
- Could you use Diamond to make your research better? (D Moran)
- Quantum systems engineering (G Buller, R Hadfield, M Dawson, D Moran)
- Science and technology for entertainment, culture, media, heritage, fashion (M Sandler)
- Try to avoid harming the patient (Hippocrates)
- Ethics for security privacy research (Siraj)
- Towards a framework for ethics and ICT (M Bloj)
- Nello Cristianini (B Stahl, M Sandler)
- Gallium nitride communications (M Dawson)

- Bio nano/molecular devices (G Davis)
- Collective intelligence in machine/human communities (Nello)
- Nano feature capability – want small things made? (D Mason)
- Data driven intelligent systems (Neil)
- Skype on steroids
- Programmable hardware for parallel computation (George C)
- Sensory coding as optimisation (D Foster)
- Scalable data interpretation and search analysis of giga samples and more in high dem spaces (N Kingsbury)
- Human grain project – modelling neuroscience to understand brain function (S Furber)
- Bio inspired computing (Andy T)
- Bits to usage (M Bloj)
- Usage patterns expectations (M Chantler)
- Future internet of people/things Control/management band width size (J Elmirghani)
- Addressing the telecoms future bottlenecks (D Hutchings)

One group did a lot of work together within the session and started expanding on an idea they had for a Skype Holodeck. EPSRC understand that the group intend to take this forward along with other members of the community, not present on the day, who they have contacted since the workshop. This serves as a useful example of the sorts of discussions many groups have been having since the workshop. The initial scoping for the Skype Holodeck is shown below.

SKYPE – HOLODECK

PARTICIPANTS PRESENT: A O'Neill

D Foster

M Chantler

J Bagshaw

M Bloj

A Fitzgerald

WHAT WILL IT DO

- Fully intensive interaction
- Real time – fast
- Trust – verification (retina glasses)
- Multi sensory
- Medical monitoring
- 3D artefacts vs. abstract representation

WHAT IT CAN BE USED FOR

- Virtual conferencing – real telepresence

- Nuclear decommissioning
- Security
- Co-designing
- Shopping
- Conferencing
- Talk to granny
- Medical exams
- Task? People expectations
- Deep sea manipulation
- Military – counter IED UXB
- Social life
- Haptics 3D vision interaction
- Healthy aging

WHAT DO WE NEED

- Rich perception of materials and things and people
- Ethics
- Gyros screen processor/sensors?
- n-filter display camera systems
- Configuration
- Secure links
- Trustworthy predictable software components
- Image and data fusion
- Large flexible screen
- Efficient and robust wired and wireless connectivity
- Radio cognitive systems
- Network architectures will move towards smaller cells
- Higher frequencies for specific communication applications
- Wet connectivity
- Ultra fast networks – 3D and HD media

EPSRC hopes that the ideas discussed throughout this session and the conversations had will be shared by members of the community who were not present at the workshop.

Delegates were also asked to write down one thing they would do when they go back to the office (these can be found in Appendix E).

Summary and Conclusions

A number of outcomes arose from the workshop that specifically aligned with the objectives for the workshop (highlighted in bold below). These outputs, as perceived by EPSRC are described below each objective.

To involve the ICT research community in considering the future strategy for the ICT Programme

- The community was involved in considering future strategy by presenting to EPSRC and other delegates their views for how the portfolio should evolve over the next decade
- All outputs are being considered by the ICT Programme and will be used to inform our strategic decisions in consultation with the SAT
- The attendees actively engaged in discussion on strategy

To reach community agreement on what the ICT Programme should prioritise when implementing the delivery plan.

- The workshop brought together a broad range of people from across the ICT community who took the opportunity to engage in proactive discussions
- Discussions during the workshop exposed a number of key challenges which are important across the whole ICT portfolio

For the ICT community to consider and answer the following questions:

What does the strategic plan mean for the ICT Programme?

What should the priorities be for ICT research going into the next decade?

How can ICT research contribute to future research challenges?

- There was discussion about the strategic plan and what it meant for ICT
- The session on how the portfolio should evolve over the next 10 years highlighted priorities for ICT research and the contribution ICT can make to societal challenges
- Delegates took advantage networking opportunity to discuss how ICT researchers can begin to shape the portfolio.

Further discussion involving the ICT SAT draws the conclusion that the workshop highlighted that there were various areas where EPSRC could encourage more cross-area working and that EPSRC should also be considering the challenges of far reaching questions such as pervasiveness, implications of technology and ICT as an enabler.

Since the workshop, EPSRC has had numerous dialogues with attendees regarding the topics discussed and steps the community is going to take. EPSRC has received a number of applications for funding to pursue projects intended to help shape capability which will be considered at a panel in March. There are also

a number of applications pending from delegates who were unable to meet the deadline; however we would not want people to abandon these proposals.

EPSRC noted that during the last session (next steps) small groups formed to take projects forward and that the groups that emerged were not confined to narrow subject areas. As a result of the workshop, EPSRC feel that our relationship with the community has improved. Certainly we have had a lot more dialogue with a wide range of researchers about how we can shape the ICT landscape. Further to this we have had dialogues about how the community can get involved in helping us shape capability and how we go about it. Informal feedback to EPSRC staff gave the impression of a strong community atmosphere at the workshop and a greater understanding of how the various areas within the programme can work together.

Appendix A – Delegate List

First name	Surname	Organisation
John	Bagshaw	BAE Systems
Mark	Beach	University of Bristol
Marina	Bloj	University of Bradford
Gerald	Buller	Heriot-Watt University
Muffy	Calder	University of Glasgow
Mike	Chantler	Heriot-Watt University
George	Constantinides	Imperial College London
Tom	Crick	University of Wales Institute, Cardiff (UWIC)
Nello	Cristianini	University of Bristol
Giles	Davies	University of Leeds
Anuj	Dawar	University of Cambridge
Martin	Dawson	University of Strathclyde
Peter	Demian	Loughborough University
Jaafar	Elmirghani	University of Leeds
Andrew	Fitzgibbon	Microsoft Research
David	Foster	University of Manchester
Steve	Furber	University of Manchester
Philippa	Gardner	Imperial College London
Carole	Goble	University of Manchester
Robert	Hadfield	Heriot-Watt University
Wendy	Hall	University of Southampton
Ian	Henning	University of Essex
Ian	Horrocks	University of Oxford
David	Hutchings	University of Glasgow
Marina	Jirotka	Oxford e-Research Centre
Kevin	Jones	City University London
Karol	Kalna	Swansea University
Nick	Kingsbury.	University of Cambridge
Mark	Leeson	University of Warwick
Jonathan	Legh-Smith	BT Innovate & Design
John	McAllister	Queen's University Belfast

First name	Surname	Organisation
Derek	McAuley	University of Nottingham
Dave	Moran	University of Glasgow
Bernie	Mulgrew	University of Edinburgh
Peter	O'Hearn	Queen Mary University of London
Anthony	O'Neill	Newcastle University
Richard	Penty	University of Cambridge
David	Robertson	University of Edinburgh
Mark	Sandler	Queen Mary University of London
Alwyn	Seeds	University College London
Monika	Seisenberger	Swansea University
Siraj	Shaikh	Coventry University
Bernd	Stahl	De Montfort University
Andrew	Tyrrell	University of York
Liam	Blackwell	EPSRC
Katie	Blaney	EPSRC
Clive	Hayter	EPSRC
Thomas	Headen	EPSRC
Phillipa	Knight	EPSRC
Dave	Martin	EPSRC
Andrew	Rose	EPSRC
Christina	Turner	EPSRC

Appendix B – Outputs from Session 1 (Mapping the portfolio)

ICT

- Grand challenges
- Industrial collaborations/links
- Doctoral training
- Collaborative research projects
- Early stage researcher career development, early career researchers support to become 'established'
- Community building workshops
- Building centres of research expertise
- ICT
    - Quantum physics
    - New materials
    - Chemistry
    - Coding
    - Semiconductors
    - Devices/human interface
- Recruitment of UK students (poached by industry)
- Single panel
- Research grants
    - A lot on track record of PI and trust
    - Impact on EC academics
    - How assess true industrial involvement (lots is informal- SMEs)
    - Support of hardware incremental though very important
    - Attribution, how truly assess given arbitrary 'areas'
    - Retention of PhD students (OK now but likely to get harder)
- Sustainability and resilience
- Joining all the bits together early to give strong early linkage to applications
- How can we understand and deal with social consequences of the technologies
- How much theoretical user and applied can we afford
- Core fundamental research
- Systems needed for many solutions/ systems approach
- Control of distributed power network. PV, WiD, Wne. Photonics/Comms/Electronics computing
- Legal and ethical issues
- Reliable, secure computer infrastructure
- What's hot
    - Scruffy information at scale (from sensors)
- Visualisation – people – tools to aid decision making in real time – what we can do we all defer

- Core – techniques for dealing with massive areas of heterogeneous data – navigation/image analysis/context analysis making combinations of data meaningful
- Optimisation
- Foundational: sustainability in and using ICT lowering carbon impact of ICT
- Foundational: customer experience
- Force communications between machine and biological vision
- Interaction with TSB?

Computer Science

- Theoretical computer science and all is sub disciplines
- Category theory
- Domain theory
- Complexity theory
- Specification and **verification**/formal methods
- Logic and computation
- Computer graphics/vision
- Hybrid systems, dynamic systems CS- Maths
- Multicore computing
    - Architecture
    - Design
    - Software
    - Experiments
- Machine understanding (listening/seeing/sensing)
- E-science, cloud, grid, middleware
- Semantic web and web science
- Software engineering
- Building brains
    - Neuromorphic
    - Computational
    - Neuroscience
- Interaction to non-technical computing respond
- Information systems
- Building complex systems with provable properties
- Secure systems
- Low power networking
- Fundamentals in forever storage
- Fundamentals of social computing
    - Machine learning, network analysis, evolvable info systems, HCI
    - Important: societal and economic covert: industry/USA?/FET areas

  Links to; Machine learning for very large scale systems and data stochastic techniques for this
- Software system verification and analysis. Proofs for everybody
- System/operating systems, in light of changing infrastructure – multicore, cloud network

- Security/cryptography hostile computing
- Parallelism models/architecture
- Foundational ‘big data’
- Computational thinking in the traditional science (outside ICT)
- Distributed and parallel systems (and communications)
- Data intensive computation (and communications)
- Foundational ‘big data’
- Computational thinking in the traditional science (outside ICT)
- Distributed and parallel systems (and communications)
- Data intensive computation (and communications)

Communications

- Air interfaces (3G, 4G...)
- Wireless systems
- Ubiquitous computing
- Secure communications
- Optical networks
- Comms. Network
- Signal processing
- Wireless free space, high bandwidth 100% availability
- Robust, reliable including safety critical monitoring and control
- Efficient power and spectrum interconnectivity
- Shift from vertical integration (economics)
- Security, trust, privacy
- Interworking of optical and wireless
- New fundamentals of communications
    - Ultra fast wireless
    - Step improvements in spectral efficiency
- Network as a sensor
- Electronic/photonic comms
- Coherent applications of computational intelligence to communications systems ((and computer science)
- Business objective:
    - Future TU
    - Content and communications (and computer science)
- Emergence of quantum communications/computation. How to handle in ICT? (also People, Electronics, Computer science and outside of ICT)
- Challenge of competence in management of multidisciplinary research
- Nano networks
    - Emerging at present
    - Fundamentals
    - Link to nano and DE chem.
- Information theory and coding (building capacity)
- Business objective: internet of things (aka ‘Smart Britain’) (also people)

Electronic Materials and Devices

- Electronic design automation
    - CAD
    - Asynchronous design algorithms…
- Embedded systems
    - Systems-on-chip
    - Real time systems
    - Power management
- New computer /electronic methodologies e.g. bio nano devices
- New electronic materials e.g. grapheme
- Device technologies
    - Advanced CMOS, III-IV
    - Graphene
    - Carbon nanotubes
- Smart interfacing of electronics and humans
- Material research
- Design tools for faster, cheaper, TTM chips
- Flexible RF components
- Industrial drive
- Efficient power and spectrum interconnectivity
- Systems integration
- Fabrication/manufacturing capability
- Reliable, secure computer infrastructure
- Foundational security
- Sensors based on new materials/concepts
- Digital systems for mobile applications. Why? UK Fabless Group (and ICT)

People and Interactivity

- Media computing
- Ethnography/user centric design
- Haptic/visual/audio interfaces
- Human computer interaction
- Smart interfacing of electronics and humans
- Security, trust, privacy
- Useable systems that work
- Core fundamental research
- Cyber securities – CS
- Robust, reliable including safety critical monitoring and control
- Legal and ethical issues
- Citizen of programmes Death of the lay board. Death of the box
- Machine learning for very large scale systems and data stochastic techniques for this links to ; Fundamentals of social computing
    - Machine learning, network analysis, evolvable info systems, HCI
    - Important: societal and economic covert: industry/USA?/FET areas

- Design capturing debugging
- Social/business network
- Computer vision – vision science opportunities e.g. measurement of appearance
- Social computation (also computer science and outside ICT)

Photonic Materials and Devices

- Exploiting new regions of the E/M spectrum e.g. terahertz
- Lasers and integration photonic circuits
- Optical systems
- Light sources (lasers/LEDs)
- Optical detectors
- Integrated photonics fibre, waveguides, plasmonics
- Optical
- Materials research
- Ultra high bandwidth to support high definition applications
- Interworking of optical and wireless
- Low power networking
- Secure systems
- Sensing technologies and smart systems (photonics/electronics)
- Electronic/photonic comms
- Opportunity to apply photonics to multiple applications areas (systems approach) to include bioscience, comms, manufacturing …..
- Fables technologies (new devices, sub-systems can be made in foundries) (and electronics)
- New forms of optical comms e.g. visible light comms, ultraviolet comms (also communications)

Appendix C – Outputs from Session 2 (Where Do We Start?)

Early Career Researchers

- Skills pipeline (school through to academic positions)
- Large pressure on young researchers
- Concentration of funding on leaders contradicts aspirations of academic pipeline. How do younger people engage with this?
- Allow early stage researchers to re-submit responsive mode proposals once
- Support the young middle aged
- 1-2 year postdoctoral fellowships for the brightest young researchers. Give freedom to support the best younger people as well as the best older people
- More focussed early career support e.g. ring-fenced funding, bridging the fellowship/first grant to large scale grant gap, incentive for large grant PIs to include Early Career Researchers as co-PIs.
- Broken things - EPSRC young fellowships

International

- EPSRC involvement n FP7, FP8 agenda
- Fund a pilot programme funding EU overseas students.
- If impact is important then invest in international collaboration
- Broaden funding to include for international partners

Industry

- TSB – EPSRC relationship
- Identify areas with UK industrial potential
- TRL 3-5 is valley of death

Funding Modes

- Mechanisms too skewed towards large grants
- Responsive mode allows agility and reactivity – big advantage
- 5 grand challenges cross cutting ICT and touching other research councils - utilise opportunity from existing programme and create cross linking projects
- Platform grants
- Change balance of funding (need reasonable level of responsive mode)
- Problem of continuity of funding – how to bridge gaps between grants
- Promote networks to focus research themes and centres (also cross disciplinary)
- Appropriate level of responsive mode is vital
- Networks bottom up – focus
- Selection/encouragement of proposal/programs
- Even working peer review doesn't make the right decisions
- Efficiency in peer review – outlines do not decrease workload

Strategies

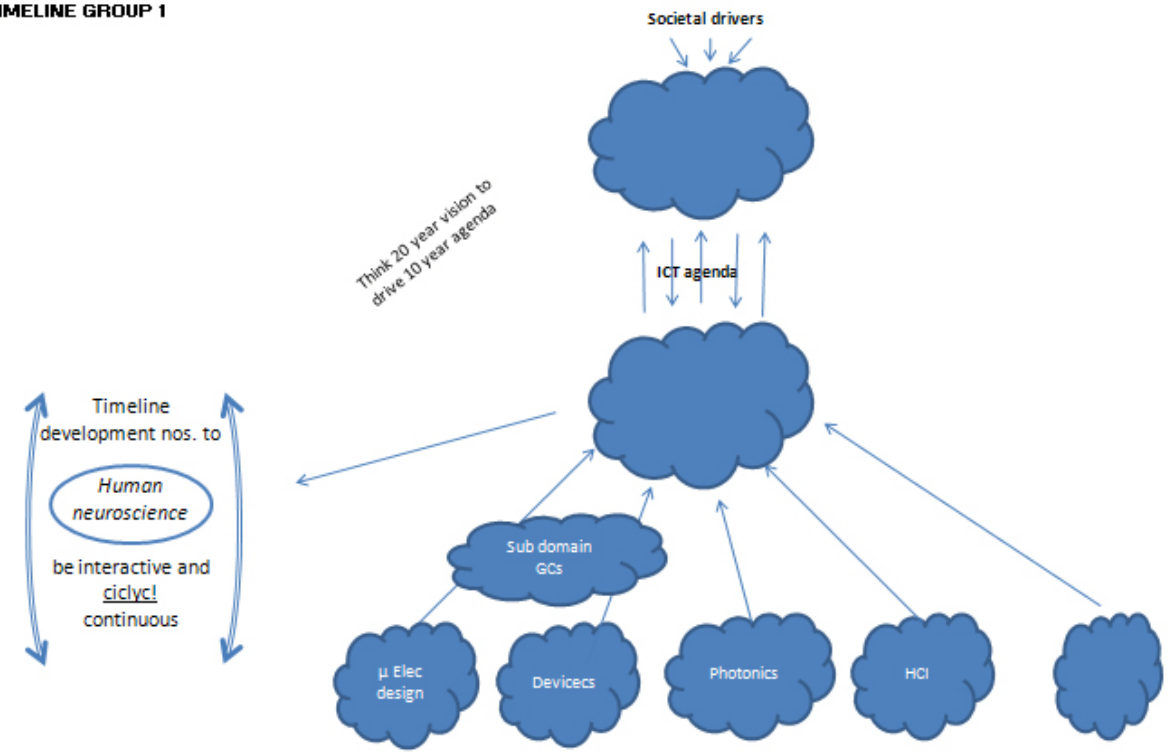
- Gap analysis
- Sustainability and reliance embedded in all areas of ICT
- Determine social needs, UK Plc, business supply chain, public/business input, portfolio development
- Across and within programmes research council should force common research themes. Players to work together upstream and downstream (sandpit series)
- Beware of short term results/impact, privacy preserving technology, system level, data centric paradigm of computation, call for UK consortia integrating upstream and downstream
- What's the business case for each area (is that feasible)?
- "open data" concrete quantitative discussion on balance of portfolio – industry presence
- Economic models for large scale research
- Define islands that can be bridged to provide a whole, reduce areas but have a full picture
- Funding at appropriate level, trickle fund until reaches threshold
- Second academics into EPSRC and vice versa
- Community building networks to identify challenges with industry input (in terms of problems, not to dictate solutions).
- Reject the losers (areas not people)
- Society needs – technology competence
- Inter/cross/multi disciplinary approach, challenge led societal issues
- Societal relevant challenges
- High risk = high payback
- Grand challenges
- Societal pull

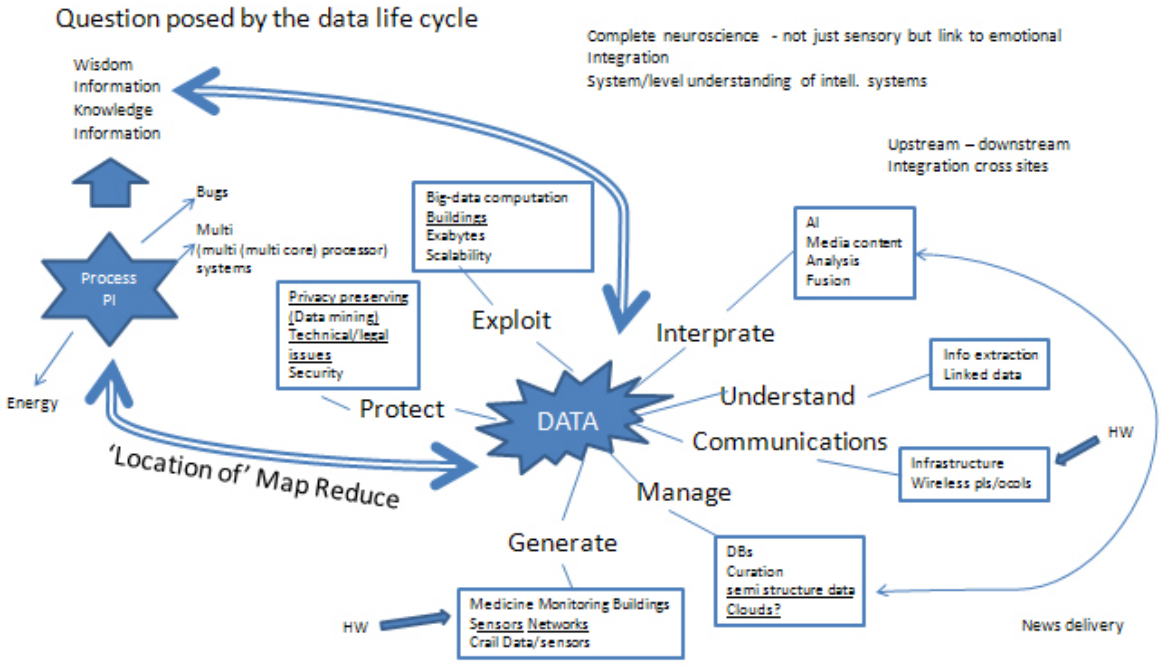
Technical Challenges

- How do we record/cope/interact with very large datasets and what do we do with them
- Safe preservation (forever storage, forever software, forever access)
- Parallel hardware has made development ingenuity – limited rather than manufacturing limited – golden opportunity for the UK
- Wouldn't it be nice if all software were correct – verification, if we could efficiently deal with large set of data
- How to grow communications bandwidth to meet future application demand
- How do we have access to huge platforms e.g. Google for ICT research at credible scales
- Better trend prediction, better understanding, political/economic decision making, importance of understanding (applying what we know about how the human brain works).

Appendix D – Outputs from Session 4 (How would we like the shape of the ICT Portfolio to Evolve?)

TIMELINE GROUP 1





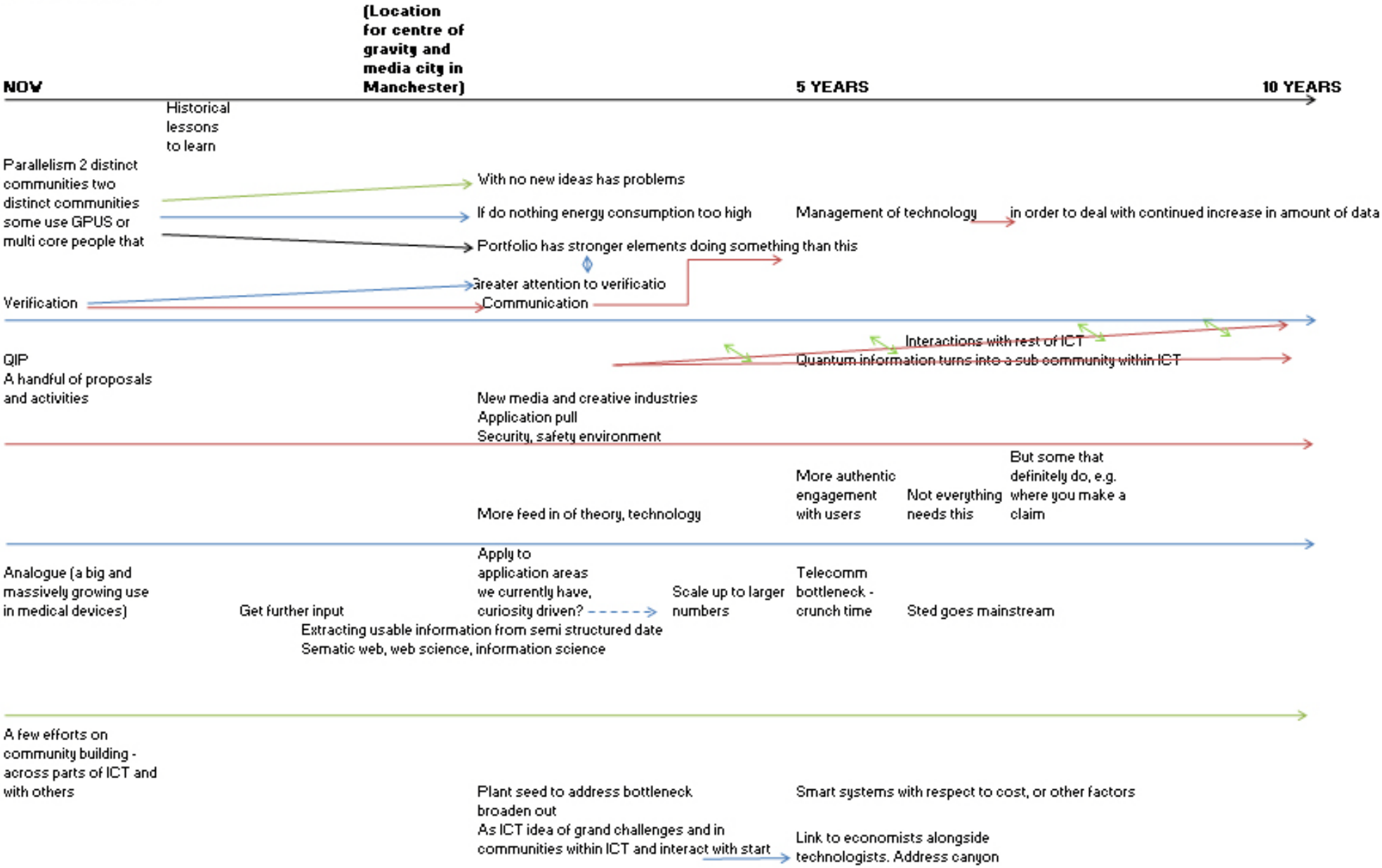
Data centre computation
All issues deriving from big data exploitation – system level integration and resilience
Human computer/process/data interaction
Hardware bottlenecks ⟷ Quantum inform systems technology
$ IG

Fund data-centric research

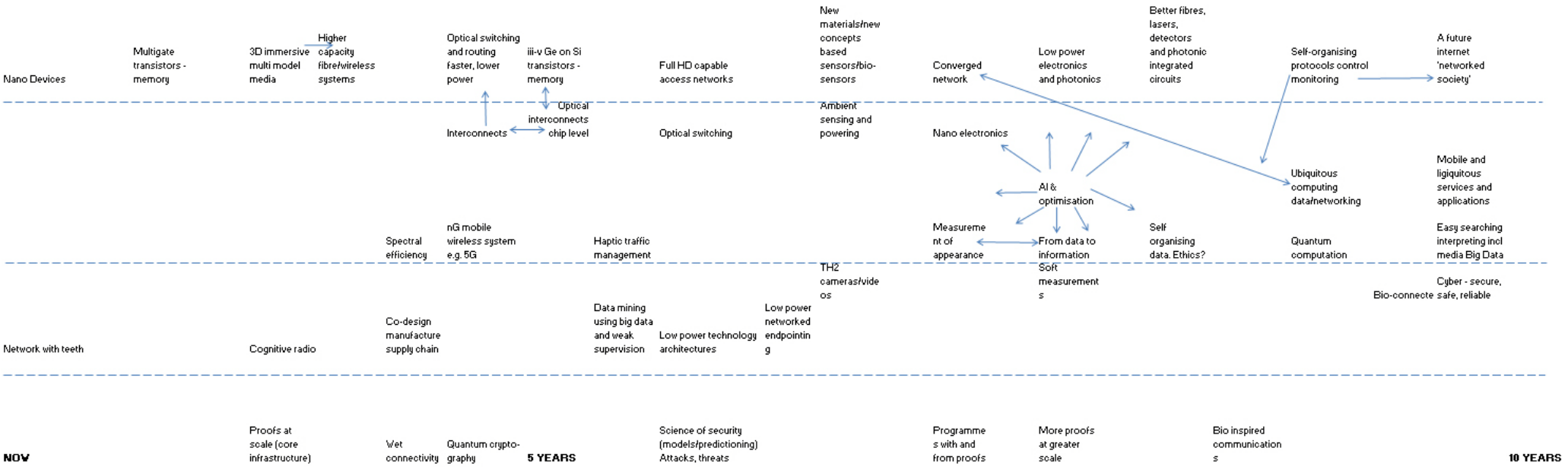
10	15	20
2010		2020

sensor networks web of things
Systems Data Massive scale Integration
Centric Privacy
Content Computing Resilience
Understanding

TIMELINE GROUP 2



TIMELINE GROUP 3



GROUP 4 TIMELINE

NOW						5 YEARS				10 YEARS	BEYOND
		Chip comms at >BW				Ever high bandwidth 10mms at micro to megre metre scales	Bits to usage greater integration and consideration from theory-application usage Original DE cluster type activity			Holistic interaction with systems	
	Post Moores law computation	Integrated cross-disciplinary networks			Systems that operate on real-world knowledge	Heterogeneous distributed systems	Comms that don't use IP - router architects comms experts knowledge of larger comms systems	System design and operation at very small scale			
Content driven design User communities link to Digital Economy	Effective design and use of parallel and multicore architectures			Data visualisation context driven real time		New forms of sensor devices and architectures Media beyond broadcast			Social computation (involving social scientists		
Security and resilience of complex systems		Bio-medical systems modelling and devices	Content rich data environments								
				Energy storage / transfer		Bio inspired computation	Data bandwidth - tension Energy		New forms of device architecture e.g. quantum		
wireless architectures			Green ICT Data ownership, management and control								
Materials science transition from small scale to large scale manufacturing											

NOTES:
Holistic socio- technical systems
Bits to usage
Energy

Physical router
Comms
Sig proc/systems architects
Software designers
Ethnographer
Users

High quality

'Holistic network' ?
- to promote cross community building with ICT
- to address ICT grand challenge
- multi-scale
-large gilmos
network consequences
large fuzzy data
- to form consortia
- potentially lead to broad programme project

TIMELINE
GROUP 5

SOCIETY (PULL)				Transport - self drive car	Entertainment		Energy	Climate		
				Understanding evolving systems. 'Socio-biology of computer networks'					Future challenge. MoD & Treasury booklets	
				Switch from inventive mind set to discovery (invent the internet but it creates lots that needs discovering)						
NOW			Increase in spam, hacking and nastiness. Need better control of this	**TIME 2020 ONWARDS**		Awareness				
		Death of PCs			Death of Paper			Death of Transport for business?		Death of Bugs Death of Computer science - computing is embedded (engineering & maths)
		Place and play New role for PCs. More tightly linked with 'what is' rather than 'what we want'								
	Programming multi core devices	Next generation of programming language Lower power technology. Energy harvesting			UK Exploitation e.g. Fabless R&D companies etc					Fusion
	Integration more than Moore agenda	Design technology group			Better computing power	Biomedical technology, electrodes, sensors	smart dust' small area devices			Quantum computing (way out)
TECHNOLOGY (PUSH)			Mobile devices						AI	

Appendix E – Outputs from Session 5 (Achieving our Vision and Next Steps)

- Think about cross community challenges
- Email colleagues re Holo…!
- Talk further to Peter O'Hearn re verification and to Swansea crew re exact numerical algebra
- Update colleagues regarding scope of meeting
- Email several attendees to follow up networking/development of part of field
- Explore more formal network in engineered quantum systems
- Eagerly await feedback from the event for tangible opportunities for funding and collaboration
- Email new contacts
- I will eagerly await feedback from EPSRC on what you have got from the meeting
- Try to get a scoping project started for bits usage
- Think about broadening the e-futures remit to cover strategy across neighbouring areas
- Arrange to meet Carol Goble
- Go back to people in computer science to identify 'hot topics'
- Check whether my methods could solve some of the problems (in hardware) about alternatives for parallel issues
- Pass on information relating to long and short term thinking to others within the school
- Follow up with Siraj Shaikh
- Explore the possibility of a community building workshop or similar activity to follow up on some of these ideas