EPSRC Systems Science Through to Engineering Workshop

15th February 2011
Copthorne Tara Hotel, London Kensingston

Workshop Report

Engineering and Physical Sciences Research Council

Introduction

EPSRC support for Systems Science and Engineering covers a broad range of application areas and a number of different EPSRC programmes. For example, EPSRC supports research in Control Systems, Electronic Systems, Transport Systems and underpinning work on complexity.

Background investigations and discussions with a small ‘focus group’ of UK academics and users highlighted the need to bring the Systems research community together, to exchange information, break down barriers and think about future long-term research needs and opportunities across discipline and sector boundaries.

The objectives of this workshop were to:
- showcase EPSRC’s portfolio in systems research;
- bring together researchers and users from different areas of systems to promote knowledge transfer and to identify any generic systems research needs and opportunities;
- explore where the UK is well positioned to lead and benefit from systems research in an international context.

By holding this event, EPSRC hopes to initiate some community-led activity.

Background - Messages from Pre-Workshop Discussions

As well as discussions with the focus group, we conducted a number of 1:1 interviews and surveyed a small number of research users and non-UK researchers to explore their perceptions of UK Systems Engineering. Key messages were:

- ‘Systems Engineering’ means different things to different people, and we need to take a broad view. Many people use the term ‘Systems Thinking’. We use the term ‘Systems research’ here, to indicate the broad area of relevant research including systems science and engineering, and have deliberately steered clear of a precise definition.
- The UK Systems research community is fragmented. Individuals and groups are on the whole closely aligned to sectors and understand those in great depth. However, there is often a lack of understanding of research activity outside of the immediate area and no collective understanding (either by researchers or stakeholders) of the totality of the UK research base. This is in contrast to international competitors (e.g. Germany and the US).
- While a few groups are looking at selected niche areas (e.g. there is an Aerospace and Defence KTN Systems Engineering focus group), no-one is examining research needs and opportunities across Systems, either from an industry or academic viewpoint;
- There are differing views from different stakeholders, but the overall view seems to be that much of the UK systems research base is internationally competitive and some is world leading. A UK strength is integration of hard and soft engineering;
- The UK systems research community is broad, multi-disciplinary and vibrant, but needs to develop coherence, leadership and focus to stay ahead of competition from other countries.
- Overall there is a good level of engagement between academia and industry in systems research. Collaborative training is an important element of this engagement. However, some companies and industries have been slow to recognise the importance of systems research and engage in systems thinking.
- Mobility of people between industry and academia is important for this area, but differing needs and metrics of success make this difficult.
- Systems research needs more potential future leaders (both in academia and industry). The current EPSRC investment in relevant postdoctoral training should help to rectify this.

The EPSRC Systems Portfolio

It is hard to identify the current EPSRC Systems research portfolio as it covers so many different research areas. We searched EPSRC's grant portfolio from the last five years using a number of key words and phrases which were identified with the help of our focus group. These grants were then manually checked for their relevance to systems research by EPSRC staff.

We have identified 285 grants related to Systems research. This includes:

- Complexity, transport, manufacturing, energy & healthcare systems, control systems, communications & electronic systems, infrastructure and system biology
- Underpinning theoretical work, development of application-driven approaches, examination of applications
- Single sector and multi-sector applications
- 10 systems-relevant doctoral training centres and over 200 other relevant studentships.

Much of EPSRC's Systems portfolio is focussed on single application domains. To get maximum value from this investment, the community needs to consider how to apply work in one sector to other sector(s).

The portfolio contains both research that is clearly defined as systems science and engineering, and research into systems and systems of systems where a whole systems approach is developed. Some of these later areas of research may benefit from a more formal systems thinking approach – in particular areas where the problem is difficult, complex and/or there is a risk of undesirable emergent properties.

Format of the workshop

Before the workshop, attendees were asked to send in the key research challenge that they felt should be addressed by the Systems research community in the next 10 years. These ideas were grouped into broad research themes with the help of the focus group.

There were a number of introductory presentations on state-of-the-art systems research and systems research needs. Annex 1 summarises all the user research needs in Systems brought to the workshop.

Some examples of the EPSRC Systems portfolio were displayed, and attendees were asked to discuss the following questions in groups:

- How can the Systems Community transfer knowledge and techniques between application areas?
- How can we ensure the work we've funded has the widest possible impact? What are the barriers?
- How can the study of current systems and the application of systems thinking help the systems community to identify the fundamental research challenges?
- A need for future leaders in Systems has been highlighted. How are these centres addressing this need? What else needs to be done?

Participants were then asked to discuss the broad research themes that had been identified based on the challenges submitted in advance. Discussions were based around a number of questions - summary proformas are given in Annex 2.

Messages from the workshop

There were a number of key messages that emerged from the discussions during the day:

Community/networking building
Networking was the most highly rated aspect of the event. A large number of people commented on the need to build a community, and more effective networking across different systems areas. More well-facilitated networking sessions across disciplines around needs-driven themes was suggested. Sharing best practice around statistical or maths tools was also suggested.

Dissemination of Systems Tools and Research
Enhanced dissemination was seen to be important for knowledge exchange between different areas of Systems research and between industry and academia. Suggestions included searchable web spaces for research outputs and outcomes, case studies, or an event with innovative methods for dissemination. There need to be suitable channels for industry to find out about the latest Systems ideas and engage with the right academics.

Language/taxonomy
This was highlighted by several people as an issue – in order to share techniques, ideas and what is state-of-the-art across disciplines, and standardise approaches, a common language or understanding is needed. Systems research outputs need to be communicated in plain English so that everyone can benefit.

Impact and Stakeholder Engagement
The need to think about who the end-users are, and how the results will be taken up from the start, was highlighted. The importance of clear, precise definition of the problem was emphasised, as well as a focus on needs-driven research. There is a need for full stakeholder collaboration on research, including work on real systems with live data, and broader stakeholder engagement to increase impact. Thought could be given to new applications of existing research.

Identifying generic properties/insights across different systems and commonalities across different research areas
There was general agreement that comparing and contrasting different systems and approaches can lead to new insights. Suggestions included:

- Review grants retrospectively to identify common findings.
- A domain independent model that can be used to integrate across disciplines was suggested, and this was explored further in one of the research challenge discussions
- Parallel investigation of analogous systems – see how far you get, eg. rail and aviation
- Identify generic properties of systems and approaches
- Identify generic and application-specific aspects of research projects/programmes
- Look at commonly occurring failures
- Focus parallel research threads on a single real-world problem.
- Look at a limited number of sectors (not all of them at once)
- Demonstration/assessment of approaches across widely, systematically differing application areas

Developing tools and techniques
Much systems research focuses on developing tools and techniques for decision-making. Suggestions were:

- Benchmark what we have – case studies, existing tools/methods, and match these against RCUK priorities
- Separate generic models and techniques from specific ones
- Several people suggested developing generic multi-methodology

(This was explored by one of the research challenge groups.)

Other generic challenges identified included:

- How do we understand the unpredicted emergent systems interactions in real systems?
- Even before we know what emergent behaviour will emerge, can we say when it will appear?
- How do we manage systems with incomplete information?
- How do we understand the interplay between human actors and technological components?
- How do we design, build and validate complex systems models?
- How do we deal with uncertainty?
- How do we use complexity science in engineering (problems & solutions)?

The research challenge proformas in Annex 2 contain many more ideas.

Education and training
Doctoral training is not the only career level where action is needed to develop future systems leaders - action is also needed at undergraduate level. It is a bit too early to tell how far the related EPSRC Centres for Doctoral Training will fulfil the need for future leaders – we need to track these students. Some suggested that future leaders should be identified and supported early on. Joining up related training centres and allowing students to move between them was suggested. All engineers who are successful industry will need to become systems engineers – systems thinking is seen as an important skill for all engineers.

EPSRC is not the only sponsor of this area.
Other activities/funders include:

- EU Framework programmes
- ESRC
- KTNs, including the Aerospace and defence KTN
- INCOSE
- Royal Academy of Engineering

Next steps

EPSRC will publish this report and supporting information on its website and ensure it is disseminated as widely as possible, including via KTNs and INCOSE UK.

By holding this event, EPSRC hopes to initiate some community-led activity. Outputs from the workshop and related work are also being considered as part of ongoing planning across EPSRC, particularly across the priority ‘challenge’ areas of Energy, Manufacturing, Healthcare and Digital Economy.

Annex 1
User needs for Systems research

The following talks at the workshop discussed research needs in systems:

Brian Collins, Chief Scientific Adviser of DfT and BIS and Professor of Information Systems at Cranfield University described the challenges of managing UK infrastructure, including transport and energy. This is complex due to all the interdependencies of the various components, and the need to consider numerous factors including policy, standards, demand, safety, climate and environment. He demonstrated how systems thinking can be applied. There are many outstanding research questions e.g. the systems improvements needed to achieve greenhouse gas savings, and whether we should reduce personal consumption. He asked whether we can model, analyse and make useful predictions with current methods.

Damien Culley from National Grid spoke about creating a smarter energy grid. Challenges include the fact that the system cannot be turned off, integration of new modern equipment with old, reduction in predictability of the network eg. with wind power, and massive increases in data.

David Oxenham from DSTL explained that systems engineering has been critical to defence acquisition for nearly a decade, spanning the whole life-cycle from research to disposal. The challenge is simultaneously delivering safety, security and sustainability while maintaining military capacity at lower cost. He explained the need get smarter at systems engineering to stimulate innovation in the supply chain, using open standards to allow smaller companies to contribute into complex platforms.

Jim Hall from Oxford University also spoke about national infrastructure. He highlighted the limitations of network analysis, inadequacy of the economics of change, the need for data acquistion for model parametrisation and validation, and the challenge of uncertainty and sensitivity analysis in high-dimensional models.

Janet Smart from Said Business School described the challenges of managing major programmes such as London 2012. These include evolving user requirements, the size and complexity of interactions between components, and enabling supportive cultures.

Roy Kalawsky from Loughborough University described work to develop coupled models to aid cross-discipline design of complex systems. The challenge is exposing unexpected emergent behaviour.

Richard Kitney from Imperial described potential opportunities in Healthcare Systems. These systems include the care continuum, which includes homecare, hospital care and telecare, and the biological continuum, from populations through to individuals and down to cells, proteins and genes. Advances in information technology and imaging and visualisation can be used to help manage these systems.

Other research needs submitted in advance by non-academic workshop participants included:

- Autonomous decision making in complex systems
- Control of networked systems so they are reliable, safe and efficient, as this applies to power, transportation, and communication, ecological and biological networks
- A shared network approach of industry partners and academia to deliver a key component/sub system database – look to develop standard parametric relationships to assess key output metrics vs. metric input design parameters

- Low carbon/renewable energy presents a fantastic system engineering problem -multi-variable, multi-interface
- Understanding and managing social and socio-technical system complexity, particularly as regards systems integration and organisational integration across multiple domains
- Significant research on technical aspects of systems engineering exists. Research into the more “business related” aspects may facilitate easier adoption of systems engineering best practice
- Whole system safety
- Encouraging procurers/clients in the built environment sector to make decisions on a whole system level
- Application of existing systems engineering techniques as a means of problem-solving and management in new domains previously treated by science alone, e.g. biosciences, control systems, energy, ecology
- Treatment and management of very complex projects, requiring the linking of engineering, innovation, cognitive science, behavioural psychology, economics, risk management
- Architectural representations and tool support
- Underpinning mathematical foundations for systems science, to facilitate systems integration across multiple domains. Integration within and across technical, social and natural systems in any combination

Annex 2
Challenges identified

Title of the challenge Systems management across/within multiple scales with imperfect information
What is the challenge? What are the research challenges/knowledge gaps? (Please be as specific as possible.) • Agility + learning v rule breaking • Human + technical components (+ rule breaking) • What is an appropriate 'working' compromise? - Normative V Emergent • Dynamic on many time scales • Reliance on tacit knowledge • Imperfect, limited, inaccurate information - coming from multiple and diverse sources.
Why is it important? What is the potential impact? • Reputational risks for organisations and individuals • Inefficiencies, costs, safety, failure, errors • An inter-connected world • Keeping the 'system' working • Affects all parts of the system lifecycle - planning, adaptation, maintenance, repair and extension.
Why or how is it cross-sectoral? What sectors will it impact on? • Multi-agency systems • Utilities • 'Strategic' industries } Many potential 'application' domains
Who needs to be involved? What is the first step to make this happen? • Social scientists, management scientists,........ • First step analysis + synthesis of real cases (evidence base), trials in exemplar domains – generalists • Business and economic case for solving these problems for UK plc (and the world) • Almost invariably there are multiple stakeholders.
What is the timeframe for impact? • Needed now • Progressive delivery over the next decade.

Title of the challenge

Delivering Societal Benefit Using System Methods

What is the challenge? What are the research challenges/knowledge gaps? (Please be as specific as possible.)

Can a systems approach to the development & operation of complex systems deliver societal benefit?

- Quantifying applicable benefits
- Need predictive methods & standard approach to compare cross-sector
- Need a generic multi-methodology
- How do you drive a capability
- Systems performance difficult to measure- phenomenally difficult to identify values of parameters

Why is it important? What is the potential impact?

- It will deliver high value socio-economic impact
- Improve societal trust & society will understand why/what they are paying for
- More cost effective solutions linked to value of result
- Recognising balance of cost & safety & introduce transparency/objectivity
- Give us most valuable/viable way to procure a capability

Why or how is it cross-sectoral? What sectors will it impact on?

- Solutions in Transport may provide insight in other sectors
- Delivers level playing field across industrial landscape to common method
- Needs top down & bottom up + interaction
- Needs holistic consideration & multifaceted views
- Cross over Defence & Civilian environment (esp. zero casualties on road & zero casualties on blue on bluein defence)
- Need complete range of contribution (Economics, Health, Engineering, Govt, etc)

Who needs to be involved? What is the first step to make this happen?

Everybody – full range of Academic disciplines & industry
Through life set of stakeholder representation
Need a trial project – proof of concept
Case study with government imperative to succeed (cf Beijing, CUBE)
Within project need Industry: (energy), TPT, Built environment, Manufacturing

What is the timeframe for impact?

Need demonstrable benefits within current government cycle 5yrs

Title of the challenge

Design Methods & Tools

What is the challenge? What are the research challenges/knowledge gaps? (Please be as specific as possible.)

Develop tools /methods/processes that enable systems thinking design & decision making

GAPS:

- Connecting between listed features
- Exploiting systems thinking is rare – how do we teach/develop/enable tools
- To ‘do’ systems thinking
- Enable systems thinking within each feature

Tools/requirement/properties {
Evolutionary management, customer friendly
Balance of depth & breath, processes – Throughlife – Behaviours
System, Real time data management (PLM?),Knowledge Management
(PLM?), Risk Uncertainty – Failure, Modelling Analysis, Decision Making –
Options & Evaluation, Integration of Disparate Models Disciplines (PLM?),
Whole Systems Thinking, Incorporation of Technology to Requirements,
Requirements Redevelopment & Flow down Design Space, Verification
Re-Useable, Adaptable

Why is it important? What is the potential impact?

- Avoid undesirable emergents, while creating desired behaviours
  - Sub-Optimisation
  - Lack of robustness to variation
  - Unexpected dynamic behaviours
- Improving optimality
- System problems but lack of systems solutions(UK & Global)

Why or how is it cross-sectoral? What sectors will it impact on?

Systems principals are application independent

Who needs to be involved? What is the first step to make this happen?

The Big Society, Stakeholders, Senior Business Leaders

STEPS:

- Create sense of urgency in need to understand Systems Engineering not just system/technology itself
- Benchmark what we have, case studies – existing tools/methods map these against RCUK theme priories

What is the timeframe for impact?

Emphasis on Sustainable Solutions Rather than Ad Hoc Solutions

Title of the challenge

HOW TO MAKE COMPLEXITY THEORY INTO SCIENCE

What is the challenge? What are the research challenges/knowledge gaps? (Please be as specific as possible.)

- Develop a generic framework for systems engineering , which consists of simple sub-systems and complex interactions.
- Devise controlled experiments to validate the framework
- Determine minimum data/effort for experimental validation
- Investigate how the interactions limit/enhance system performance
- How to embed other aspects, eg financial, environmental, into the framework
- How to embed uncertainty and emergent factors into the framework

Why is it important? What is the potential impact?

- Providing insightful understanding about the impact of uncertainty and emergent factors on the financial aspect etc
- Transferrable to many different industrial sectors
- Reduce the risk of making mistakes. Make risk management easier
- Make things work better

Why or how is it cross-sectoral? What sectors will it impact on?

- Generic framework abstracted from different sectors
- Applicable to systems in these sectors and others, after validation
- Sectors: energy systems, transport systems, financial systems, biological systems, political systems, …..

Who needs to be involved? What is the first step to make this happen?

- Experts from different sectors, academic and industrial
- Funding is critical to make this happen, because nobody else Can make it happen apart from EPSRC
  Eg. Sandpit event (DCDC funds(MoD))

Mathematics
Physics
Chemists
Systems
Engineers
Biologists
Control Engineers

What is the timeframe for impact?

3-10 years - ACADEMIC
10-15 years -INTO INDUSTRY
25 – 30 years – Defence review

Title of the challenge

Modelling Complex Evolving Systems

What is the challenge? What are the research challenges/knowledge gaps? (Please be as specific as possible.)

Key Areas

- Standards for validation
- How do you use the construction of the model/capture information learning?
- How do you verify/validate an estimate of the future?
- Uncertainty/sensitivity analysis, dealing with uncertainty
- Integrative modelling – how to do it?
- Modelling changing/evolving structures/networks in a dynamic system
- Not building a black box. Building something with transparency/longevity
- Modelling human behaviour
- Socio-techno-economic qualitative/quantitative

Why is it important? What is the potential impact?

- Bottleneck in many areas (for model-based methods)
  is sheer availability of models
  so ....
- Huge cost reduction if many organisations can model before implementing
- UK potential for lead in this area
- Decision makers make long-term decisions, via understanding of possible futures

Why or how is it cross-sectoral? What sectors will it impact on?

All sectors – this is generic

→ Societal, Engineering, Cross-sector

Who needs to be involved? What is the first step to make this happen?

- Representative set of domain experts with sufficiently diverse modelling needs
- Computer Scientists – Tool support
- Systems Architects – Leadership
- Modelling – Diverse set of modelling approaches

What is the timeframe for impact?

- Significant tool support in 5-10 years
- Widely available in 10 years
- Benefits perpetual (from better long-term decisions!)

Title of the challenge

Holistic Design of Sustainable Energy Systems

What is the challenge? What are the research challenges/knowledge gaps? (Please be as specific as possible.)

The overarching aim is "Bringing together what has and is being done". Specifically…

- Establishing the Architecture Framework which is holistic
- Understanding requirements and as Metrics
- Identifing Stakeholder points of view – value drivers
- Identifiying the current situation and Global Context
- Identifying the current constraints
- Identifing future options including Technological Road maps
- Developing assessment models

} Integrated thinking

A major challenge is how to deal with uncertainty within the system itself and the surrounding environment.

Other challenges: robust systems design of a smart grid, and systems modelling of energy usage

How can Systems Engineering tools from other areas be applied to the national energy system?

Why is it important? What is the potential impact?

Do nothing option is not sustainable within a generation

Addressing this issue will:

Decouple Economic growth from Non Renewable Energy use growth generating UK Industry

Avoid unintended consequences of partial approach

World class research

Why or how is it cross-sectoral? What sectors will it impact on?

Holistic: it is purpose driven not sectorial

It effects everybody

Who needs to be involved? What is the first step to make this happen?

Identifying Problem owners/stakeholder needs

Not starting from scratch

Identify existing programmes, including work done by DECC and UKERC

What is the timeframe for impact?

Urgent & longterm

Title of the challenge

EDUCATION

Creating developing/educating a Society that acts wisely in light of a better understanding of systems interconnectedness

What is the challenge? What are the research challenges/knowledge gaps? (Please be as specific as possible.)

- What is the role of education?
- Creating systems thinking leaders(How) T –shaped people (hard to get depth later in life)
- Fostering systems thinking as a core life skill
- Raising awareness of systems benefits amongst current industry leaders & policy makers
- Why do some people `get' systems thinking and some don't? Could we all get it if we learn it?
- Identifying the core system thinking skills that apply irrespective of the domain?
- Scoping which systems tools help bridge the gap between systems thinkers and non-systems thinkers and how they can be made to.
- What are the soft /transferable skills needed to ensure systems deliver full impact in a non-systems world?
- How to speed up the experiential learning + credibility process?

And much, much more!

Why is it important? What is the potential impact?

- Key societal challenges (climate change, energy security, economic transition,..) are systemic in nature
- Without the skillbase impact of other work is very limited
- To develop/educate systems –thinking-engineers capable of operating in a transdisciplinary environment (competence plus credibility)

and people to communicate this

Why or how is it cross-sectoral? What sectors will it impact on?

- *Must have educational researchers and practitioners
- Link between social, engineering & educational sciences
- Systems science is an intentionally transdisciplinary approach that will encompass multiple sectors/stakeholders

Who needs to be involved? What is the first step to make this happen?

Policy makers, industry leaders, educationalists

- Experience accelerator programmes
- All the sectors mentioned above
- Educational community doctoral centres–sponsoring organisations
- Building on existing capacity but widening expertise (hard + soft systems skills)

What is the timeframe for impact?

Immediate – 5 years - more informed current practice

Long term ----- Programmes redesigned & educational paradigms shifted

Workshop Attendees

Rob	Alexander	University of York
Shaikh Faruque	Ali	Swansea University
Marko	Bacic	Rolls-Royce
Matthew	Ball	EPSRC
Bill	Barbo	SEAS DTC
Richard	Beasley	Rolls-Royce
Joe	Butterfield	Queen's University Belfast
Kim	Christensen	Imperial College London
Mark	Claydon-Smith	EPSRC
Catherine	Coates	EPSRC
Simon	Colby	BAE Systems Maritime Missions Systems
Brian	Collins	BIS Chief Scientific Advisor
Lee	Cronin	University of Glasgow
Damien	Culley	National Grid
Paul	Davies	Thales UK Ltd
Paola	Di Maio	ISTCS.org
Zhengtao	Ding	University of Manchester
John	Dinwoodie	University of Plymouth
David	Dodd	Rolls-Royce
Alex	Duffy	University of Strathclyde
Peter	Earp	Jaguar
Tim	Embley	Costain
Neil D.	Evans	University of Warwick
Hans	Fangohr	University of Southampton
Suzanne	Farid	University College London
Seamus D	Garvey	University of Nottingham
Patrick	Godfrey	University of Bristol
Phil	Greenway	BAE Systems
Kevin	Gurney	University of Sheffield
Harald	Haas	University of Edinburgh
Jim	Hall	University of Oxford
Alan	Harding	BAE Systems
Phillipa	Hemmings	EPSRC
Jeremy	Hilton	Cranfield University
George W	Irwin	Queen's University Belfast
Ben	Jeppesen	Instron - Division of ITW Ltd
Peter	Johnson	University of Bath
Peter	Jones	University of Warwick
Visakan	Kadirkamanathan	University of Sheffield
Roy S.	Kalawsky	Loughborough University
Izzet	Kale	University of Westminster
Stephen	Kemp	EPSRC
Richard	Kemp-Harper	TSB
Richard	Kitney	Imperial College London

Martin	Lakie	University of Birmingham
Chris	Lamb	Sula Systems Ltd
Ming K	Lim	Aston University
Honghai	Liu	University of Portsmouth
Ian	Loram	Manchester Metropolitan University
Wayne	Luk	Imperial College London
Bart	MacCarthy	University of Nottingham
Jan	Maciejowski	University of Cambridge
Harris	Makatsoris	Brunel University
Ian	Marshall	Lancaster University
Gary	Montague	Newcastle University
Eva María	Navarro López	University of Manchester
David	Oxenham	DSTL
Antonis	Papachristodoulou	University of Oxford
Dolly	Parkinson	EPSRC
Gerard	Parr	University of Ulster
Rushen	Patel	Smith Institute for Industrial Mathematics and System Engineering
Ian	Philips	ARM
John	Preston	University of Southampton
Alan	Purvis	University of Durham
Samantha	Riches	EPSRC
Ges	Rosenberg	University of Bristol
Susan	Rosser	University of Glasgow
Mark	Rylatt	De Montfort University
Jim	Scanlan	University of Southampton
Alwyn	Seeds	University College London
Nilay	Shah	Imperial College London
Philip	Shering	AstraZeneca UK Ltd
Duncan	Shermer	EPSRC
Carys	Siemieniuch	Loughborough University
Hillary	Sillitto	Thales UK
Les	Sims	EPSRC
Janet	Smart	University of Oxford
Stefan Thor	Smith	De Montfort University
Tristan	Smith	University College London
Danielle	Soban	Queen's University Belfast
Nigel G	Stocks	University of Warwick
Claire	Tansley	EPSRC
Adrian	Terry	Advanced Problem-Solving Partnership Ltd
Philip	Thomas	City University, London
Antonios	Tsourdos	Cranfield University
Ravi	Vaidyanathan	University of Bristol
Gavin	Walker	University of Nottingham
Graham	Wallis	MBDA Ltd
Meihong	Wang	Cranfield University

Zoe	Webster	TSB
Robert Ian	Whitfield	University of Strathclyde
Jennifer	Wilby	University of Hull
Phil	Williams	ESP KTN
Sir Alan	Wilson	University College London
Alex	Yakovlev	Newcastle University
Kate	Young	Halcrow
Qing-Chang	Zhong	Loughborough University