Systems-NET

EPSRC
Engineering and Physical Sciences Research Council

Research Grand Challenges for Systems Engineering Workshop Report

Summary

The Research Grand Challenges for Systems Engineering workshop provided a forum to discuss the main concerns for systems engineering practice and research in the UK. The objective of the workshop was to identify what are the key challenges in the understanding and analysis of complex systems, their emergence, organisation and behaviour, and the utilisation of tools including modelling and visualisation to understand their complexity, document their evolution and access the relevant information about them. The workshop provided an opportunity to formulate, discuss and reach a consensus amongst a group of participants from industry and academia. The resultant set of Research Grand Challenges is presented in this report and is intended to signal the areas of systems engineering where breakthroughs are required. The identification of the Grand Challenges is expected to a) facilitate collaboration across research groups, b) signal the areas where research efforts should be focussed and c) influence funding organisations to support the research.

Contents

1. Introduction

Systems-NET was funded by the EPSRC with the objective of drawing on and consolidating the strengths of major systems engineering centres and research groups across the UK to share knowledge and communicate best practice between application domains. EPSRC is the main UK public funder of research in Engineering and Physical Sciences research and PhD training, investing about £800M per year. Part of EPSRC mission is to ensure that national capability in engineering is developed and sustained through a) supporting long term and ambitious research, b) mobilizing leadership in engineering related fields and c) shaping the portfolio in relation to national need. Systems-NET was created on these bases as network to bring together researchers and professionals in Systems Engineering (SE) to a) stimulate knowledge transfer between research groups by organising webinars in SE, b) promote knowledge transfer between industry and academia in the UK and internationally through several collaboration schemes, and c) organising network activities to discuss the grand challenges in SE research.

The concept of Grand Challenges has been widely used to identify global issues such as global health, sustainable agriculture, access to clean water, energy availability, and in general the world's most pressing issues that must be overcome for benefit of human kind. Systems-NET takes the view that a research Grand Challenge in SE can be loosely defined as a challenge that pursues goals that are recognised as being one or two decades in advance and its achievement is regarded as major milestone or breakthrough in the advancement of technology and engineering. Similarly EPSRC defines the features of a grand challenge as: a) they are long term, b) they require several disciplines working together to be achieved, and c) they require coordination, collaboration and investment to make a difference.

EPSRC is currently concentrating effort in developing long-term, inspiring and cross-disciplinary engineering-focused research challenges, around which the UK research community can be mobilised. In a recent EPSRC retreat [1] to identify Engineering Grand Challenges for the next decade, one of the main recognised issues was the applicability of systems engineering across scales and sectors. Particularly in the understanding, analysis and control of large networked systems, and also in the definition of frameworks applicable to different areas of decision-making. With this concept in mind Systems-NET invited members of the SE community to a workshop to find out what they consider to be the main SE Grand Challenges from two different perspectives, a) from the perspective of their own studies b) from a generic point of view through workshop discussion groups. This led to formulation of a list of Grand Challenges that are common across many areas of SE.

The workshop was attended by delegates from industry; LSC group, Thales UK, Rolls Royce, Systemic Consult Ltd, Airbus, Holistem Ltd, and Costain. There were participants from various universities including University of Strathclyde, University of Portsmouth, University of Sheffield, Loughborough University, University of Birmingham, University of Brunel, University of Leicester, University of Hull, De Montfort University, University of Warwick, University of Reading, and University of York.

There were 43 participants from academia and industry of which 22 also contributed with Quad Chart presentations and posters. The Quad Chart templates used consisted of a single PowerPoint page divided into four quadrants that summarised a Grand Challenge; the first quadrant was used to propose a grand challenge/problem statement and antecedents. The second quadrant was used to describe the approaches, plans, milestones or progress associated with the grand challenge; the third quadrant was used to give examples, evidence, results or findings, and the last quadrant was used to present the relationship of the challenge(s) discussed with other disciplines, areas of work or other grand challenges.

The Quad Chart presentations came from widely diverse areas of research and work including design, analysis, statistics, methodology, applications, health care, manufacturing etc. These diverse topics were intended to offer an insight into projects as well as into the current understanding of actual SE issues. The presentations were also envisioned to motivate ideas and debate at the workshops where the participants formulated, analysed, and discussed SE issues of more generic relevance.

2. Workshop Process

The Workshop took place during a day and a half. On the first day, the time was divided so as to dedicate the first part of the morning to hold workshop Session I, "Developing an Initial Set of Grand Challenges"; this was followed by Quad Chart presentations on Complexity, Methodology, and Modelling. On the second day there were Quad Chart presentations on topics related with Autonomous Systems, and Verification and Validation. After the final Quad Chart presentation the workshop continued with Session II "Reviewing the Grand Challenges" and Session III "Consolidating the Grand Challenges" The conference/Workshop ended at this point, see Figure 1.

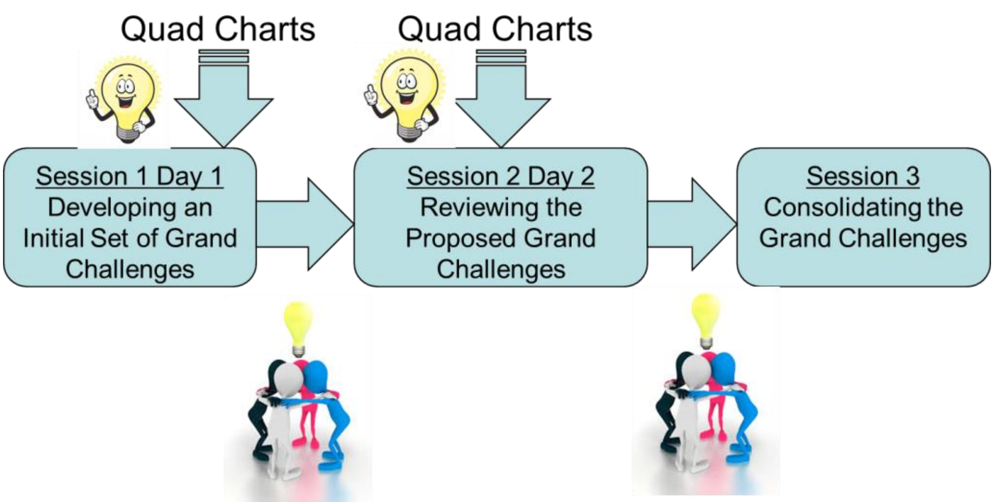


Figure 1 Workshop process to identify the Research Grand Challenges for Systems Engineering

2.1 Workshop Session I - Developing an Initial Set of Grand Challenges

This session was about polling opinions from all the participants as to what they consider to be the Grand Challenges for SE research through discussions between 6 to 7 participants in six different groups. This was a difficult task given that the area of specialisation of each participant was in most cases very different from many others; however the motivation to formulate a list of issues that are common across many areas resulted on several challenges proposed totalling 33 from all the groups together. Each challenge was written down in a template, this form included a definition of the Grand Challenge proposed, Context, Potential impact, and Perceived difficulty. The actual scanned copies of the Grand Challenges proposed in this session can be seen in Appendix B.

The challenge templates where displayed in the exhibition area for the rest of the time while the conference presentations took place. Displaying the grand challenges statements served to give all the participants an insight into the challenges discussed in other groups and were discussed informally at various points during the break times. Additionally there was also an exhibition of posters submitted by a number of participants that illustrated the main research issues that concern systems engineering in the different projects or areas of research.

2.2 Workshop Session II – Reviewing the Grand Challenges

Following the last presentation on day two, the participants were asked to join their groups from the previous day. A set of copies of all the 33 challenges from the previous workshop were supplied to each group. The participants were asked to review and refine the set and select the challenges that were most representative of real concerns for research in SE. A total of 17 Grand Challenges from the original set of 33 were selected and also 5 extra grand challenges that were proposed as a result of the groups reviewing and expanding the original set. This selection process involved discussions amongst the participants within each group. Each group then selected a spokesperson

2.3 Workshop Session III – Consolidating the Grand Challenges

The spokesperson from each group read out the group's selected list of Grand Challenges, on completion there was a general discussion on these by all the participants. The total number of Grand Challenges selected by all the groups was 22. These challenges were submitted to a voting process in which each participant could place up to six red star markers on a Grand Challenge to indicate their relevance.

The Quad Chart presentations can be seen in Appendix A, and scanned copies of all the Grand Challenges proposed at the Workshop are given in Appendix B. The resulting challenges and votes are given in the following list.

3. Research Grand Challenges List

Challenge 1

Grand Challenge Statement: **Systems engineering methodology –How systems are defined, developed and tested is well established with different models existing. Can a scientific approach be used to determine if there is a better methodology that can be defined?**	**Score** 20 stars
Context: Improving the way we develop systems and coming up with an approach that is domain agnostic	
Potential Impact: Harmony in the way SE is applied and using a scientific approach to get there.	

Challenge 2

Grand Challenge Statement: **With the increase in autonomy in systems there is a need to ensure ethics can be embedded in a system rather than solely be applied at the operational phase by humans – legal issues**	**Score** 19 stars
Context: Increase of large complex interconnected cyber physical systems with demand for greater autonomy plus self-re-configuration.	
Potential Impact: Greater trust in systems Greater uptake of systems Gives potential to expand the autonomous functionality of systems	
Perceived Difficulty: Don't know how to do this	

Challenge 3

Grand Challenge Statement: **Importance of the knowledge base to support system development (knowledge management)**	**Score** 19 stars
Context: Different Domains /transferability between different domains, Decision making, Uncertainty and risk	
-Potential Impact -Extract required/needed knowledge -Interconnectivity/dependency -Consequences of failure/ prevention of fails -Multidisciplinary collaboration -Robotic systems, big data, maintainability of systems, expert support	

Challenge 4

Grand Challenge Statement: **Modelling the next generation Model Based Systems Engineering for the industry 4.0 (IoT) to allow scalability and add end-end value**	**Score** 18 stars
Context: At the moment there is no model to support the changing business environment. In order to support the industry 4.0 plus IoT (which goes across manufacturing,	

service, etc.) to add end- to -end value. The next generation MBSE tools should be able to address product/process interactions to make physical systems (e.g. factories) smart and flexible, as industry 4.0 doesn't exist without these two.	
Potential Impact: There is no MBSE tool for the Industry 4.0 or IoT. As whole industry is moving on a full autonomous approach. Having the next generation MBSE tool will allow studying the risk generated with system of systems and make them more resilient and flexible.	
Perceived Difficulty: • Organised data management (managing the real time information) • Self-learning (organising) based on real time information and unforeseen circumstances. • Human-machine interaction in order to address the issues due to a fully autonomous system	

Challenge 5

Grand Challenge Statement:	Score
Reliability, robustness and recoverability of complex systems to support more flexible and autonomous negotiation between systems to enable/ease interoperability of different systems (including management of legacy and new systems) e.g. To develop systems for autonomous and connected transport systems.	16 stars
Context: Complex systems control critical operations like aircrafts, flying, nuclear power stations, railway system, etc. Failing of these systems might have catastrophic results that's why they should not in the first instance but if it happens they have to be recoverable – either autonomous or thanks to human intervention. Understanding these factors would be the goal of this challenge.	
Potential Impact: Increase of complex systems reliability; reduction of redundancy due to deeper understanding of these factors; reduction of losses due to systems failures.	
Perceived Difficulty: Medium – high; risk management goes into this direction but has to be combined with in depth system knowledge.	

Challenge 6

Grand Challenge Statement:	Score
Semantic conflicts and uncertainty	
Context: Complexity science, cyber-physical systems. Sources of uncertainty Physical environments Heterogeneity Agent autonomy Hazards Natural disasters	12 stars
Potential Impact: A new generation of systems, A new science	
Perceived Difficulty: Extreme-domain specific	

Challenge 7

Grand Challenge Statement: **How do we achieve sustainability with Systems Engineering?**	**Score** 12 stars
Context: Systems engineering could play central role in preserving the environment and the human race.	
Potential Impact: The impact would be enormous in terms of improving quality of life.	
Perceived Difficulty: The technology is still not advanced enough to meet this challenge.	

Challenge 8

Grand Challenge Statement: **Renewable electricity generation to reach carbon neutral state**	**Score** 10 stars
Context: Preserving a liveable environment for future generations, maintaining species diversity.	
Potential Impact: Survival of human race (and other species), not needing to colonise mars	
Perceived Difficulty: International alignment, Social acceptance – changes to lifestyle, Economic stability	

Challenge 9

Grand Challenge Statement: **Decision making and big data era**	**Score** 7 stars
Context: System coupling is increasing and thus understand information around their interconnectivity becomes essential	
Potential Impact: Improve understanding in the consequences of system failure and how information around their use can reduce risk	
Perceived Difficulty: Challenging as data increases in size and in value, and thus involved parties are not prone in sharing	

Challenge 10

Grand Challenge Statement: **Achieving multi-disciplinary model integration across the system development lifecycle ... to help deal with semantic conflicts and uncertainty**	**Score** 7 stars
Context: Understand systems interactions better	
Potential Impact: System quality improvement , Further development time	
Perceived Difficulty: Modelling tool self-integration and related standards	

Challenge 11

Grand Challenge Statement: **Understand emergent properties of complex systems using system identification of fractional order calculus; non-linearity needs to be accommodated.**	**Score** 5 stars
Context: Broad, addresses most of the existing grand challenges	

1. Characterisation of materials 2. Agriculture modelling of fresh water, conservation in plants 3. Energy/new superconducting technologies 4. Neuroscience understanding of neuronal form and function.	
Potential Impact: High, enables us to move from black box type input /output models to grey box and white box models understanding better the underlying systems	
Perceived Difficulty: High. Requires training of researchers to existing tools and mathematics control theory and systems identification.	

Challenge 12

Grand Challenge Statement: **Develop a framework for socio-technical interactions between stakeholders.**	**Score** 5 stars
Context: Being able to quantify and assess how stakeholders within a system affect each other and to what extent they affect each other.	
Potential Impact: The understanding of the implications of certain stakeholders working on projects/ programs and developing effective and efficient teams that deliver positive and beneficial outcomes allows greater resilience when forecasting issues between stakeholders.	
Perceived Difficulty: The quantifying impact of the interaction and understanding the extent to which an interaction may impact a system	

Challenge 13

Grand Challenge Statement: **Real time solution generation and update of integrated systems solution…** **And forecasting (what ifs) and predicting performance (e.g. for IoT)**	**Score** 5 stars
Context: Robotics systems require high expert knowledge to build. However, a design environment that can generate solutions based on operational lifecycle can help to highlight behaviour as well as highlight solution changes in real time.	
Potential Impact: Non-expert or semi-skilled people can use such capabilities to test their ideas plus innovate, as well as small companies can uptake manufacturing of highly technical systems.	
Perceived Difficulty: • Availability of knowledge databases from different domains • Technical challenges to developing intelligent solution • Modelling real time systems in uncertain environments	

Challenge 14

Grand Challenge Statement:	**Score**

Systems of autonomous and connected transport systems	5 stars
Context: Integration of autonomous vehicles into existing infrastructure meeting safety plus legal constraints building support infrastructure Driverless taxis => Google's/amazon automated delivery Handling unexpected events	
Potential Impact: Improved mobility, safety, efficiency, energy consumption, reduced emissions, allowing elderly people on the road safely.	
Perceived Difficulty: Varying => many technical, legal and public perception challenges	

Challenge 15

Grand Challenge Statement: **Proof and communicate the benefits of SE to increase its attractiveness to a wider audience**	**Score** 4 stars
Context: In order to increase levels of training, number of positions and funding for SE activities, political, economic and social entities have to inform and convince of its benefits	
Potential Impact: Increase of funding, use of SE methodology throughout, as well as public awareness of SE effects.	
Perceived Difficulty: Medium – high; biggest part is to actually start to do this and allocate money to it	

Challenge 16

Grand Challenge Statement: **Driven from context of a specific end solution ("go to Mars", solve power generation"…) develop and mature the set of techniques for defining and analysing verification and validation systems solutions with characteristics required.**	**Score** 3 stars
Context: Techniques need to cope with Complexity Multi-disciplinary aspects SoS Interactions (interfaces/negotiation Semantics/underpinning science / Optimisation New and or incremental level of Ethics/legislation Full lifecycle aspects Large scale/ scalability Autonomous aspects Integration of models Within coherent process framework Balancing Social technical aspects	

Challenge 17

Grand Challenge Statement: **Management of legacy plus integration of new**	**Score**

Context: How does this apply to developing nations were legacy is not always so restrictive?	3 stars
Potential Impact: Legacy infrastructure is prevalent in many countries, and in many industrialised countries legacy infrastructure is reaching capacity constraints. Building resilience into connections between legacy and new systems	

Challenge 18

Grand Challenge Statement: **How do we actually engineer complex systems?**	**Score** 2 stars
Context: Complex systems exhibit emergent characteristics. How do we characterise these properties and provide systems engineering tools to support their construction (and verification and validation)?	
Potential Impact: Very significant – especially given internet of things/mobile technology	
Perceived Difficulty: Very difficult – the innate unpredictability of such systems makes them difficult to verify and validate.	

Challenge 19

Grand Challenge Statement: **Balancing V.S. optimising systems (and sub-optimal systems) and understanding roles of competition and collaboration, (negotiation of boundaries) including the constraints of networks of contracts**	**Score** 1 star
Context: Against architectural, legal requirements, organisational, people's expectations. Working towards good enough? May depend on the level of abstraction	

Challenge 20

Grand Challenge Statement: **The ability of humans to "interrogate" systems to understand, question, maintain or extract required data/ information /knowledge**	**Score** 1 star
Context: CPS (Cyber Physical Systems) etc., are all pervasive and geographically spread and in most cases are designed to be operated by a range of engineers, commercial/government organisations.	
Potential Impact: Improved use of systems, Improved transparency of systems, Improved maintainability of systems	

Challenge 21

Grand Challenge Statement: **Automated electricity demand management**	**Score** 1 star
Context: Balancing	

Challenge 22

Grand Challenge Statement:	**Score**

More flexible and automated negotiation between systems to enable/ease inter-operability of different systems	1 star
Context: Where multiple computer systems are used in "an environment" – e.g. organisation	
Potential Impact: Ability to address /solve problems not solvable by one system alone. "Modularity" of systems purchases. Extended lifetime of systems?	
Perceived Difficulty: Requirement for knowledge/ terminology/ agreed languages to enable negotiation - Artificial intelligence - Ontologies - Knowledge representation	

4. Discussion

At the end of workshop session III a list of 22 Grand Challenges was gathered, and voting took place to decide which were considered most important by the majority of participants. A total of 176 votes were casted. The results are illustrated in Figure 2.

The five most voted for Grand Challenges have the highest scores from 16 to 20 votes each and together they took some 50% of the total vote (Figure 3). These Grand Challenges are:

- Develop Better Methodologies for SE Based on Systems Science see Challenge 1.
- Ethics in Autonomous Systems (Challenge 2),
- Knowledge Base to Support Systems Development (Challenge 3)
- MBSE for Industry 4.0 and IoT (Challenge 4)
- Reliability, Robustness and Recoverability of Complex Systems (Challenge 5).

Challenges 6, 7 and 8, received scores from 12 to 10 gathering some 20% of the total vote, these are:

- Semantic, Conflicts and Uncertainty (Challenge 6),
- Sustainability with Systems Engineering (Challenge 7)
- Renewable Electricity Generation to Reach Carbon Neutral State (Challenge 8)

Of less concern amongst the SE community gathered at the workshop were the challenges represented by numbers 9 to 14 which all together received some 20% of the votes and scores from 5 to 7 stars:

- Decision Making and Big Data Era (Challenge 9)
- Multi-disciplinary Model Integration (Challenge 10)
- Emergent Properties of Complex Systems Using System Identification of Fractional Order Calculus (Challenge 11)
- Framework for Socio-Technical Interactions between Stakeholders (Challenge 12)

- Real Time Solution Generation and Update of Integrated Systems Solution (Challenge 13)
- Systems of Autonomous and Connected Transport Systems (Challenge 14)

The Grand Challenges 16 to 22 raised little support with a score from 1 to 4 stars which correspond to less than 10% of the total votes. This does not necessarily mean that they are of less validity and in some cases their importance is implicated in the area of application of the other more popular Grand Challenges.

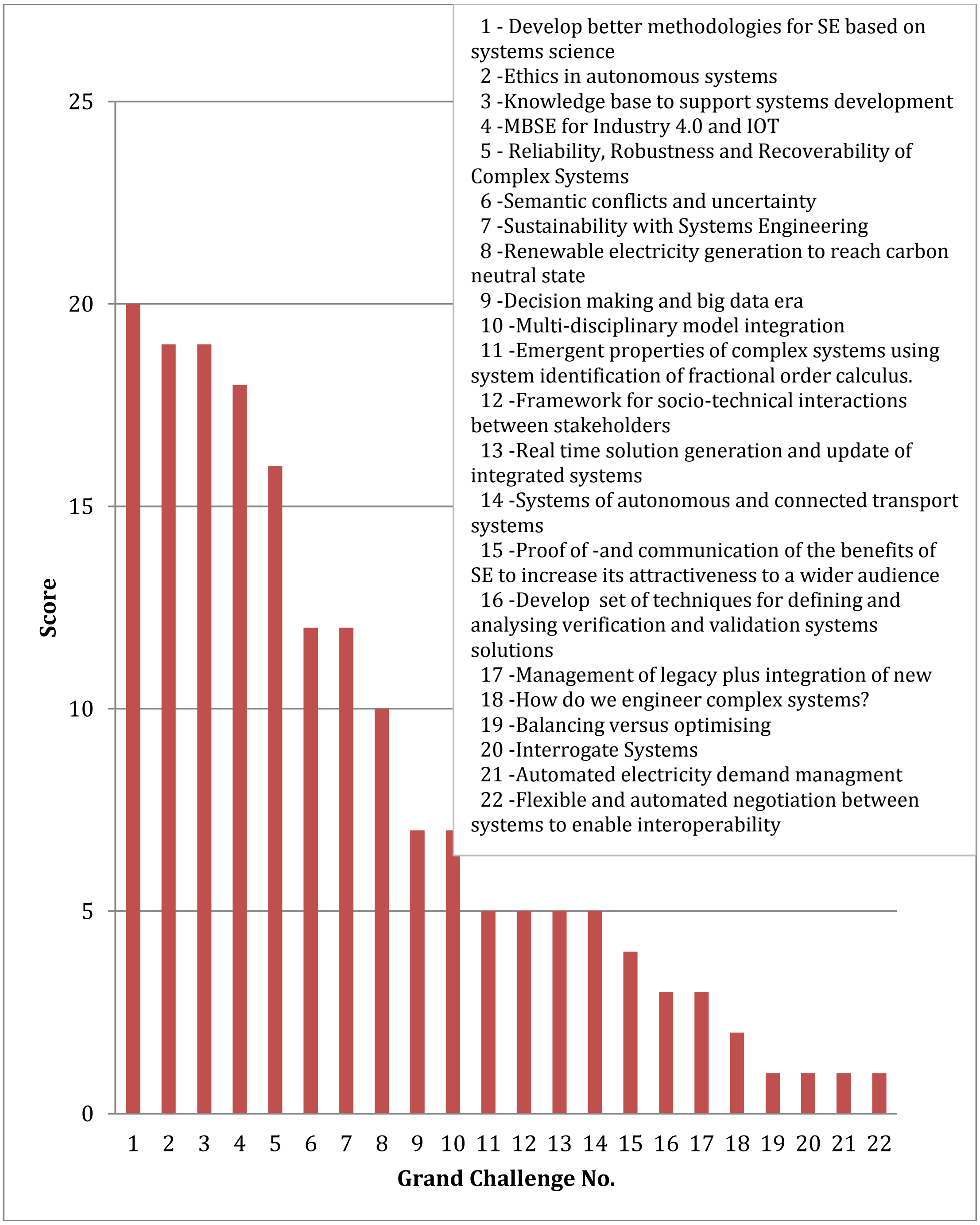


Figure 2 Grand Challenges Consensus Chart showing the number of votes for each Grand challenge.

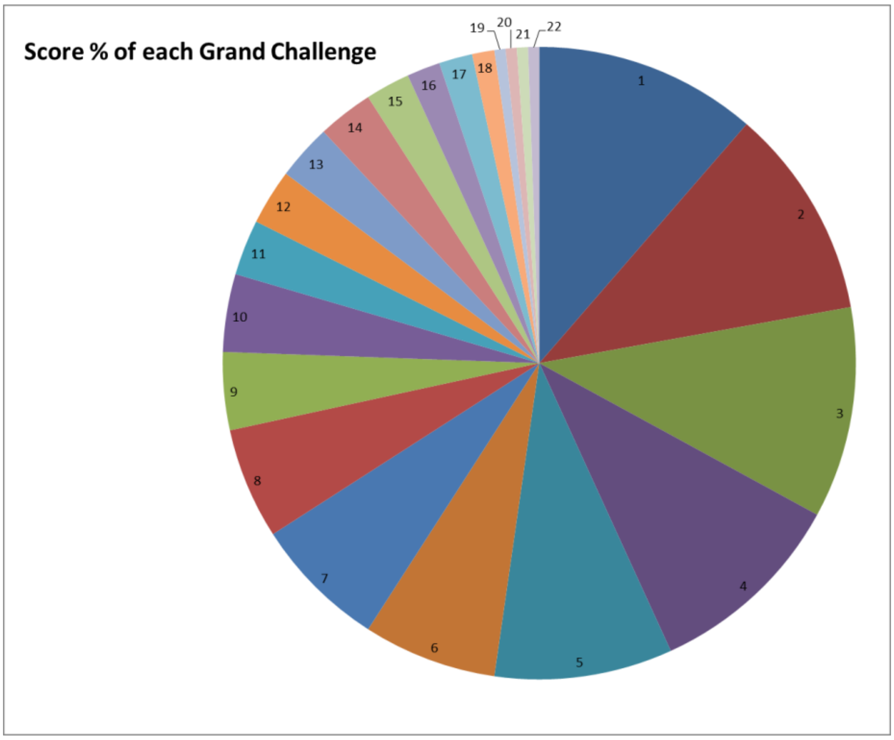


Figure 3 Vote Percentages for each Grand Challenge

5. Conclusions/Recommendations

A total of 38 Grand Challenges were identified during the workshops, the interpretation and analysis of each of them will be carried out independently from this report, as each one of them requires detailed and careful considerations. The objective of this report is to present the results of the workshop so that each contributor and participant has access to this information and is able to pursue further research in the Grand Challenge areas they consider most significant

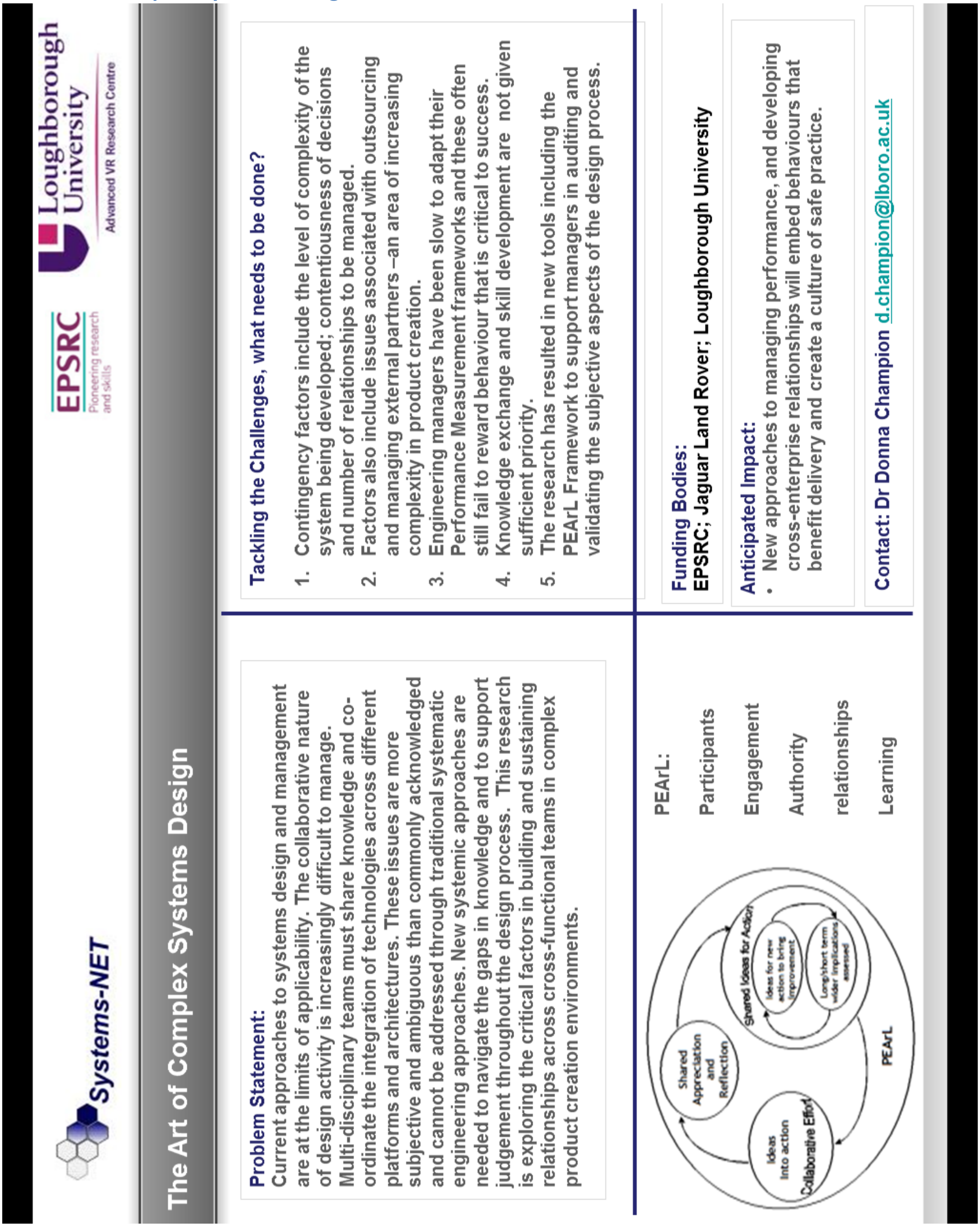
The set of proposed Grand Challenges reflects the concerns of the gathered community in this event, but although the background and experiences of the participants in this workshop was diverse, it would be expected that a different group of people could propose a different set of research Grand Challenges.

The identified top Grand Challenges will be the subject of follow up workshops.

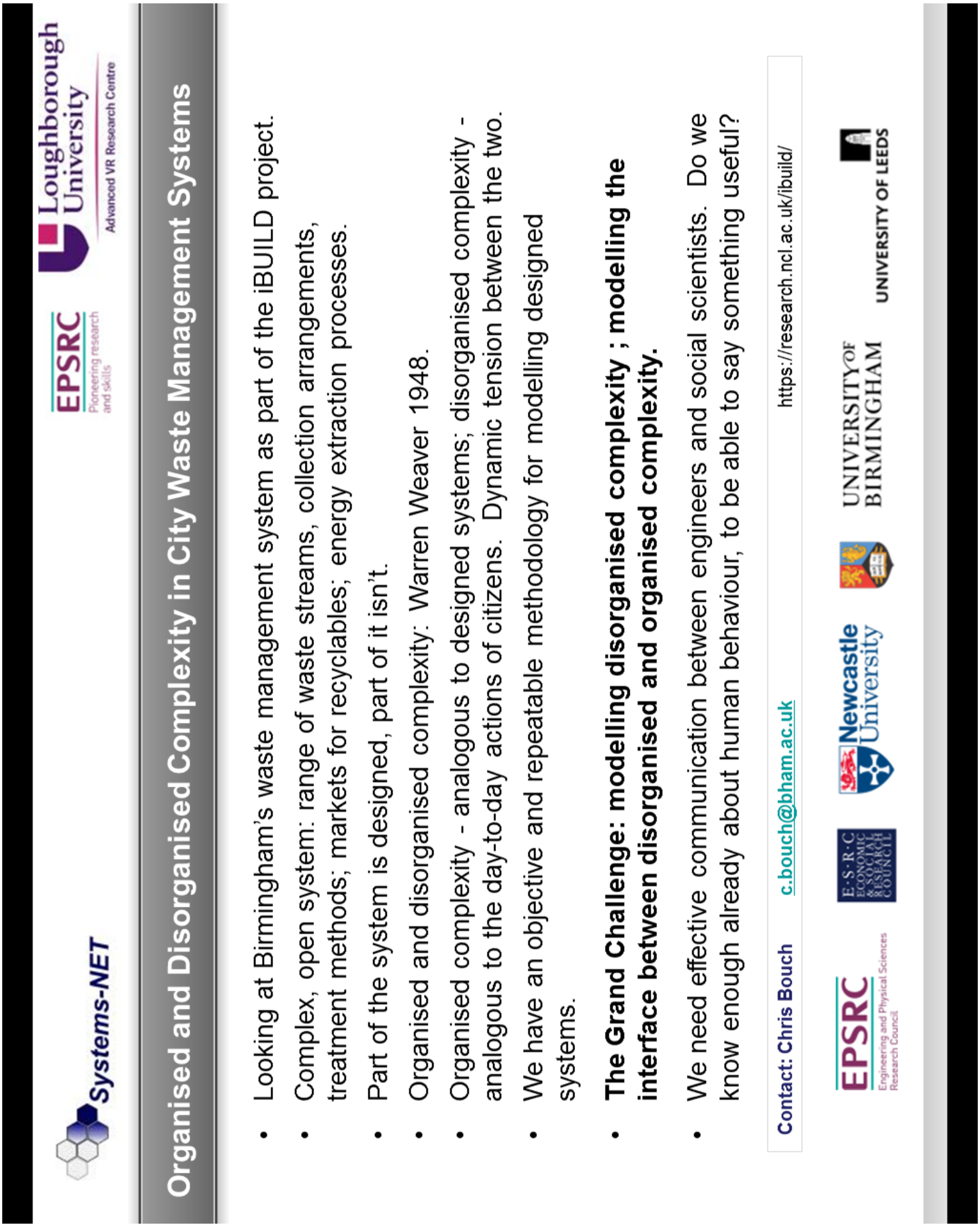
References
[1] Engineering Grand Challenges Report on outcomes of a retreat – 07 and 08 May 2014 Ettington Chase, Stratford-upon-Avon

Appendix A - Grand Challenges Presentations Quad Charts

The Art of Complex Systems Design



Organised and Disorganised Complexity in City Waste Management Systems



Projects as Complex Systems: A Network Perspective

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Projects as Complex Systems: A Network's Perspective, by Christos Ellinas

1.Why care?

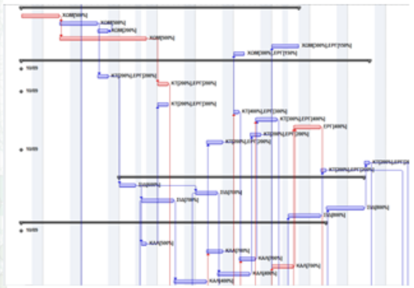
"We live in a projectified world, where change, revenue earnings and many other activities take place through project-based processes"[1]

"The industry is currently struggling from too-consistent failure of programs created to develop large systems-of–systems, or complex systems"[2]

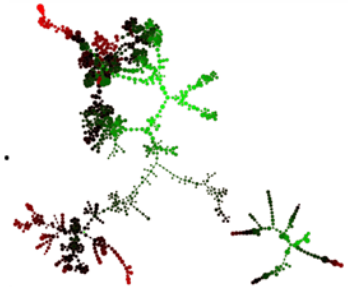
Advanced Logistics System – Air Force [38]	1968-1975 (scrapped)	$250M
Taurus Share trading system – British Stock Exchange [16]	1990-1993 (scrapped)	$100–$600M
IRS Tax Systems Modernization projects [34]	1989-1997 (scrapped)	$4B
FAA Advanced Automation System [35]	**1982-1994 (scrapped)**	**$3–$6B**
London Ambulance Service Computer Aided Dispatch System [30]	1991-1992 (scrapped)	$2.5M, 20 lives

Examples of project failures

2. Projects: Process or a System ?



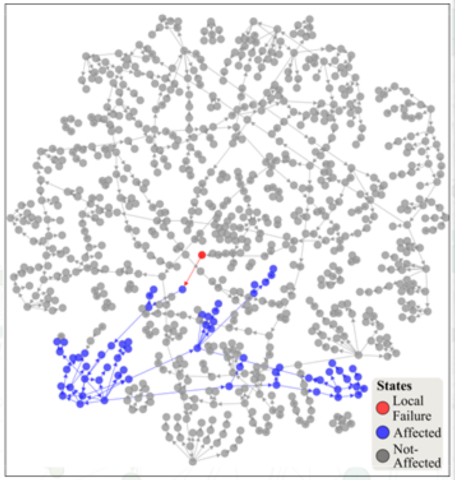
Vs.



Large-scale, systemic failures appear to be the *a posteriori* definition of **complex** projects. Can we equate this complexity with underlying properties of other **complex systems** (e.g. Internet, the brain)?

3. Embrace Complexity

- Identifying **Aspects of** (Project) **Complexity** – how about measuring them?
- **Consequences of complexity** – Project Systemic Risk (e.g. Piper Alpha)



4. Challenges

- Scientists have revealed common organisation principles in systems that **we** design and manage – how have **we** responded?
- Big Data and increased computation capabilities – fancy; **so what**? (hint: quality vs. quantity)
- **Knowledge generation** – case study vs. universality (or management/engineering vs. science)
- The role of **Professional Associations** and Best Practice – useful or cliques ?

References
[1]"Now, let's make it really complex (complicated)"
[2]"Principles of Complex Systems for Systems Engineering"

Contact: Christos Ellinas ce12183@bristol.ac.uk

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Control of Statistical Behaviour

Title: Control of Statistical Behaviour

Problem Statement:
For a large complex system, it may be infeasible to install enough sensors and actuators to control the trajectory of the system. But a lesser goal might suffice: to control the statistical behaviour of the system. How can this be achieved?

L-M Bujorianu, MacKay RS, Complex Systems Techniques for Cyber-Physical Systems, in Proceedings of 4th ACM SIGBED International Workshop on Design, Modeling & Evaluation of Cyber-Physical Systems, eds R Laemmel, W Taha (ACM Digital Library, 2014) 27-30

L-M Bujorianu, RS MacKay, Perturbation and Sensitivity of Inhomogeneous Markov Chains in Dynamic Environments, IEEE Proceedings of 21st International Symposium on Mathematical Theory of Networks and Systems, University of Groningen, The Netherlands, 7-11 July 2014, pp 184-191

Proposed challenges for systems engineering

1. Collect examples of engineering systems where control of statistical behaviour makes sense as a goal (e.g. electricity demand management, geo-engineering climate, examples of Hong Wang).
2. Deepen understanding of the statistical behaviour of large complex systems.

Tackling the Challenges, what needs to be done?

1. Design control so that the statistical behaviour is uniquely determined.
2. Understand how the statistical state depends on the controls.
3. Determine how much can be achieved by decentralised control.

Funding Body: EPSRC

Anticipated Impact:

- Uptake of probabilistic point of view in engineering design.

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The Purpose of Change is Problem Solving

THE PURPOSE OF CHANGE IS PROBLEM SOLVING

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'We cannot solve our problems with the same thinking we used when we created them'. [Quotation from A. Einstein]

Subject of inquiry : The 'systemic' or 'structural' view of parts of the world, its analysis and design

Current state of 'systems thinking', 'systemic view', 'structural view' and so on including 'systems engineering' may be characterised by :

Speculative thinking [generating ideas is **essential**], difficult to relate to parts of the world because operates in abstract terms, without agreement of meaning of basic concepts [meaning of system, for example], without fundamentals unlike mechanics, electricity etc,
Fragmented [technical control systems, information systems, social systems, systems science, administrative systems, transport systems ..... anything that looks complex and appears to do something],
Out of context of human intellectual endeavour [without roots in accepted branches of knowledge,
Unrelated to conventional science and engineering and problem solving/design

There is an <u>immense variety and diversity</u> of parts of the world in static or dynamic state [natural, artificial, living (at individual and social level)]

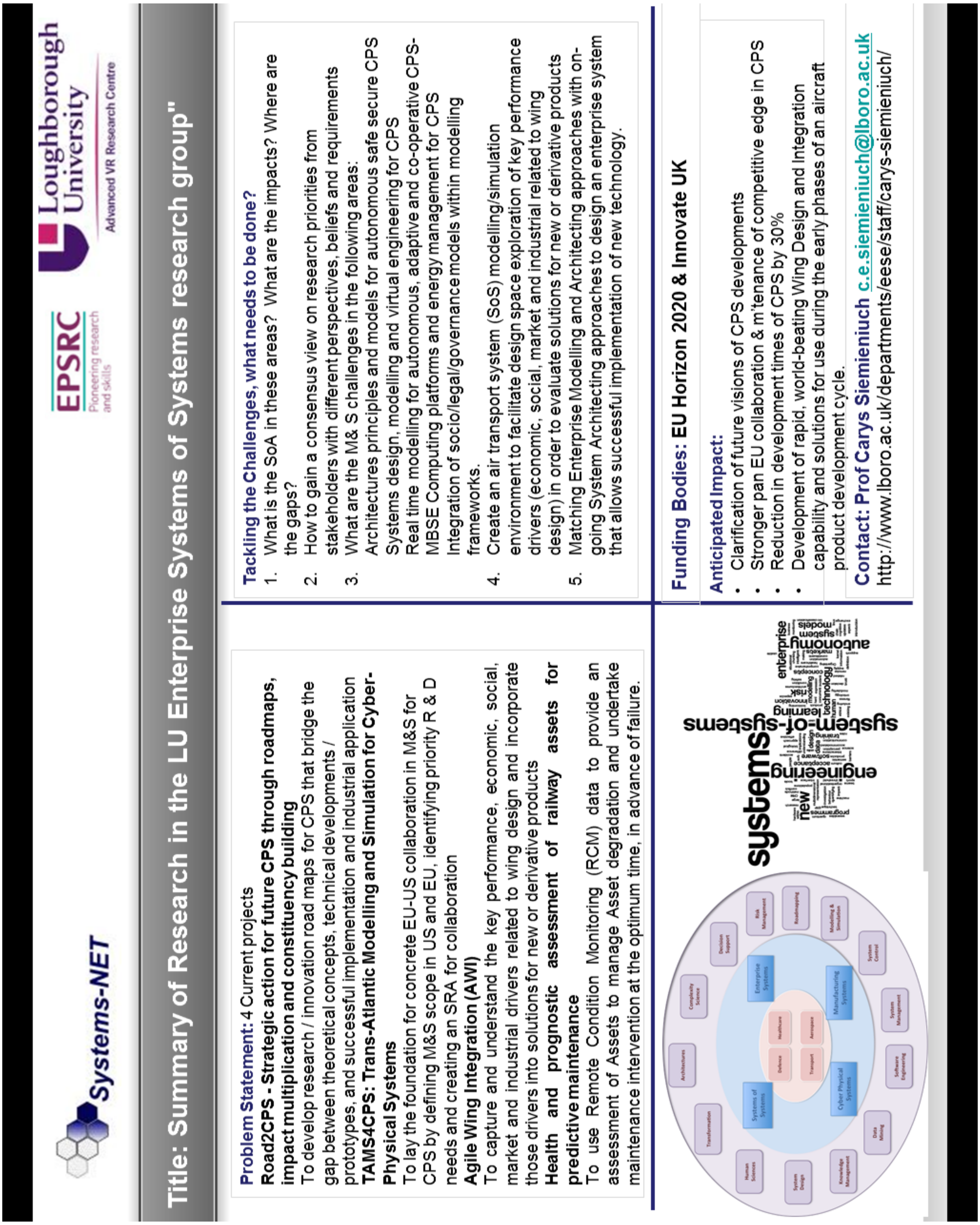
QUESTION : How to handle this immense variety and diversity to bring **intellectual order** towards enhanced **informative** [precision] and **cognitive** [knowledge] **content** into the 'systemic view' to be achieved through **empirical** research ????????

ANSWER : <u>Paradigm change from 'systemic view' to 'systems science'</u> [which is to play a role in 'systems and product' design] !!!!!!!!
[unlike the misfit connection between conventional science and conventional engineering]

Anything can be seen in terms of its structure [pervasive, single domain]
Invariants [which are (classes of theoretical objects, relations, interactions, qualifiers {adjectival and adverbial phrases})] to exploit isomorphism with **natural language 'Elementary constituents'** of natural language of which complex structures can be constructed **[linguistic modelling], BRICKS** in buildings, **reductionism**
Their analytical content is expressed by mathematics of **ordered pairs** [static state] and **predicate logic** statements [dynamic state] carrying uncertainties and the appropriate mathematics [differential equations, for example....]

WHAT IS THE POINT ?????
<u>PRODUCER – PRODUCT- USER/CONSUMER</u>

Summary of Research in the LU Enterprise Systems of Systems research Group



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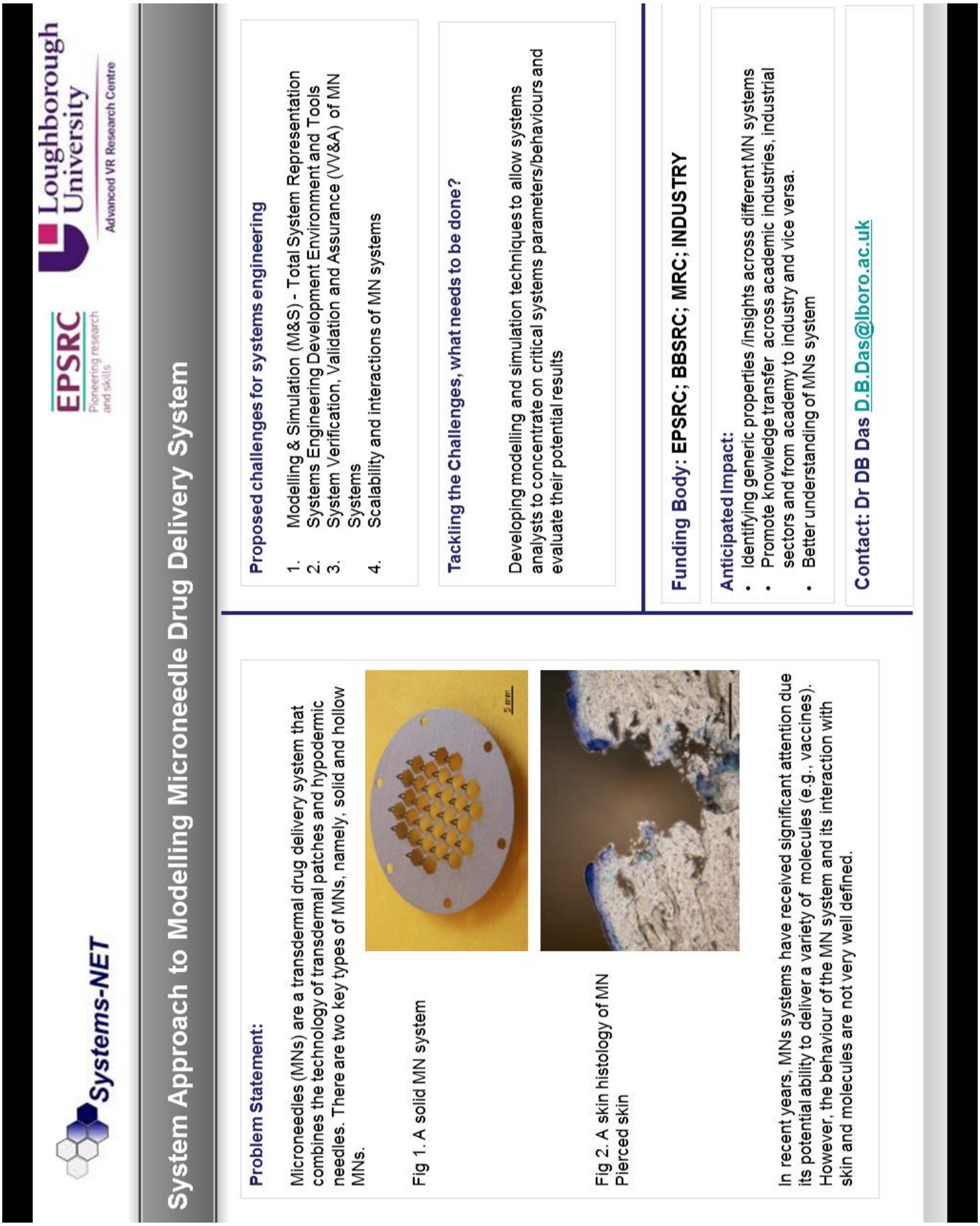
Systems Approach to Modelling Micro-needle Drug Delivery system



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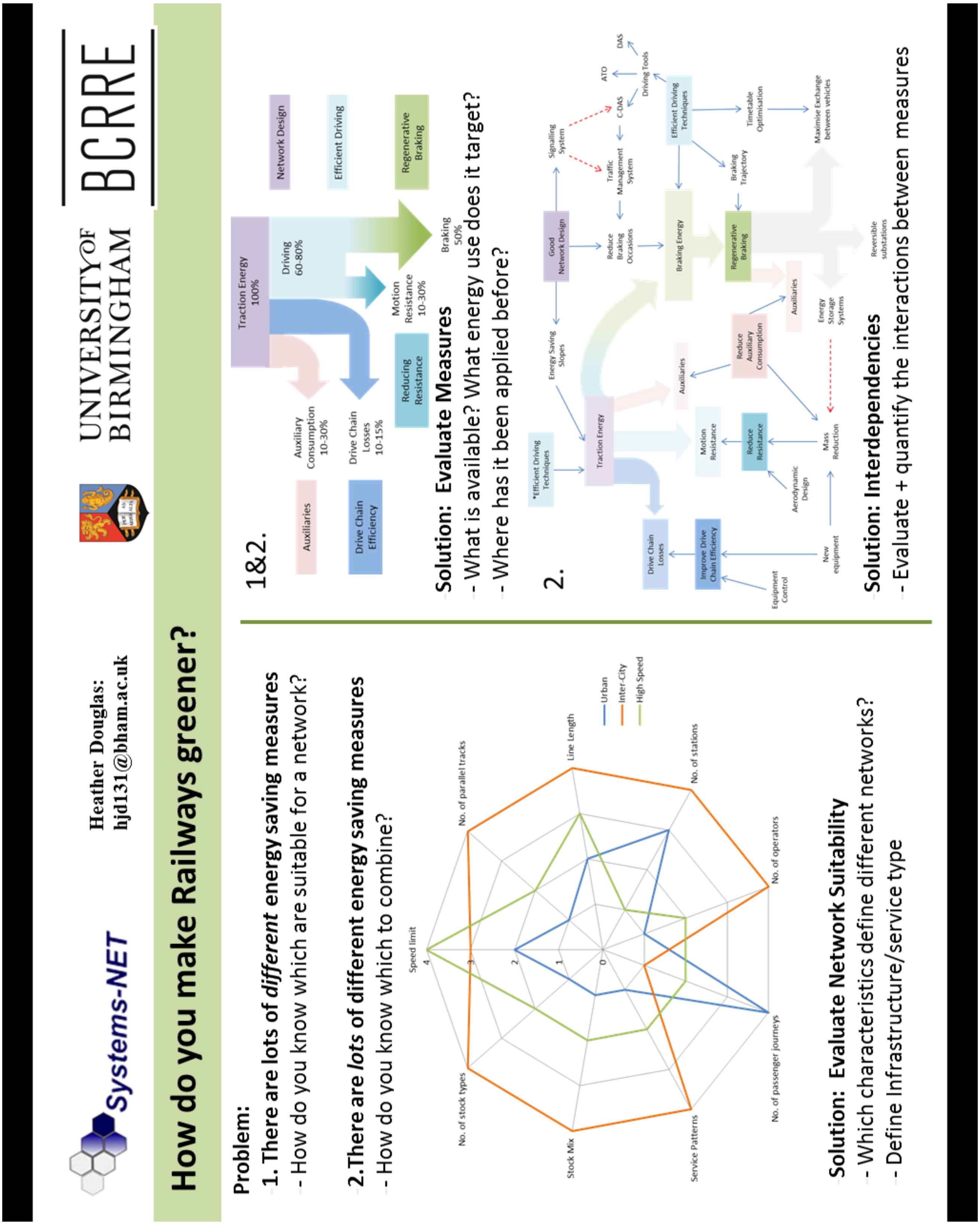
How do you make Railways Greener?



Steps Towards Next Generation Model Based Systems Engineering

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Steps towards Next Generation Model Based Systems Engineering

Problem Statement:

- Despite the recognition of the benefits of MBSE, its uptake often requires a steep learning curve necessary to reach the proficiency required, in addition to the costly purchase of software and hardware tools
- The low level of adoption within the industry, particularly SMEs, was mainly due to financial and manpower constraints, while facing pressure from the market to remain competitive.
- Within the educational sector, where students were tasked to apply MBSE in the design and development of their engineering systems, they often failed to come up with quality work within the time frame. The approach was considered new to them, and they often cite the lack of time, plus difficulties in learning and applying the approach in their work.
- The Research Grand Challenges for Systems Engineering highlights the need for next generation system engineering development, environment and tools.
- These observations and demand from the system engineering community galvanise an inherent need to increase the ease of use and capability of the MBSE tools available, to make it much more learners and users friendly, for widespread adoption by the design engineers, students and non-experts.

Tackling the Challenges, what needs to be done?

- This calls for a design development with the much-craved features of lesser human decision, self-organisation, context-aware, able to provide design suggestions, and fine-tuning of the final design.
- The aim is to research and create next generation MBSE design environment that provides a high level of autonomy during the design, modelling, and simulation of various systems to be designed.
- A semi-autonomous system would be a sensible way forward, which significantly reduces human dependency during the design phase to key design decisions, and managing the whole life cycle of the model based design and development.
- An architectural framework for such semi-autonomous MBSE design environment will be developed, which include a methodology for the automatic model and component selection, modification, integration and simulation.
- Traceability of the design decision is vital to this approach, it is necessary to have a clear catalogue of the design decision taken, where designers can monitor the steps taken, and make necessary changes to arrive at the final design.

Proposed challenges for systems engineering

- **Semi-Autonomous Model Based System Engineering Design Environment**

Funding body: De Montfort University

Anticipated Impact:

The research will have a great impact on the way future systems will be designed, as systems are becoming increasingly more complex and interconnected. Not only quicker and better design can be achieved, the designers will feel that an expert is guiding them throughout the design process. The design environment proposed is not only a design tool, but an educational tool at the same time.

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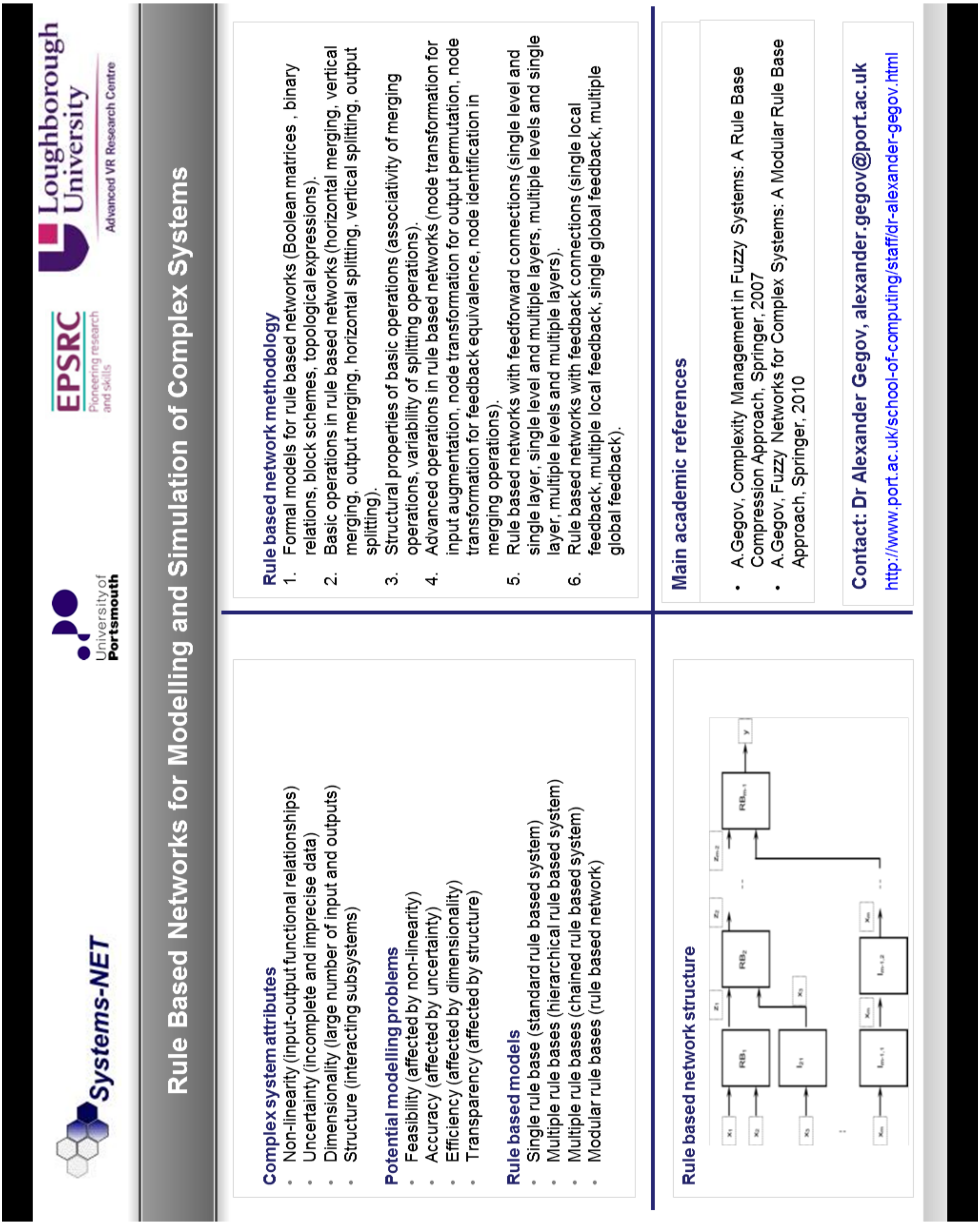
Rule Based Networks for Modelling and simulation of Complex Systems



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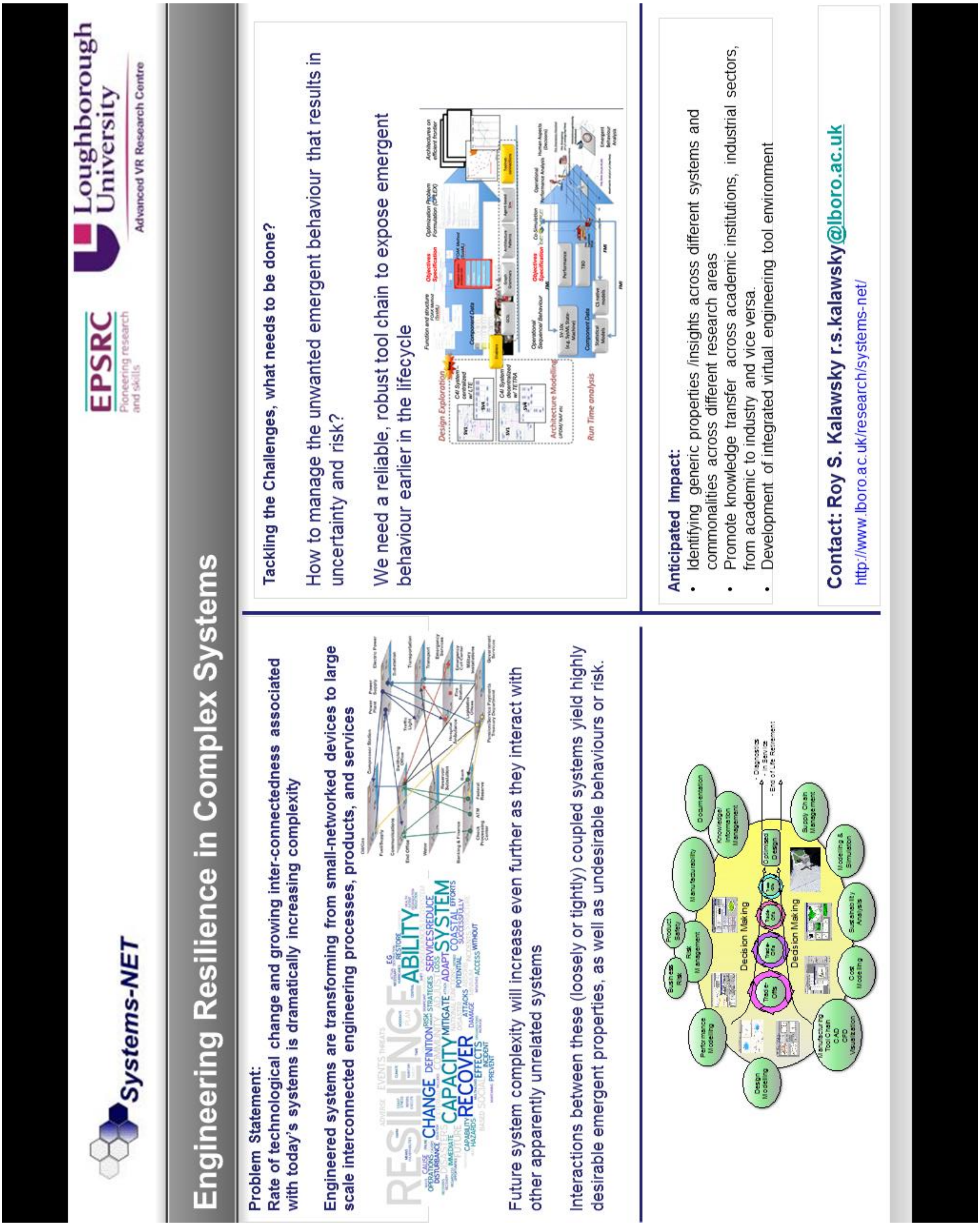
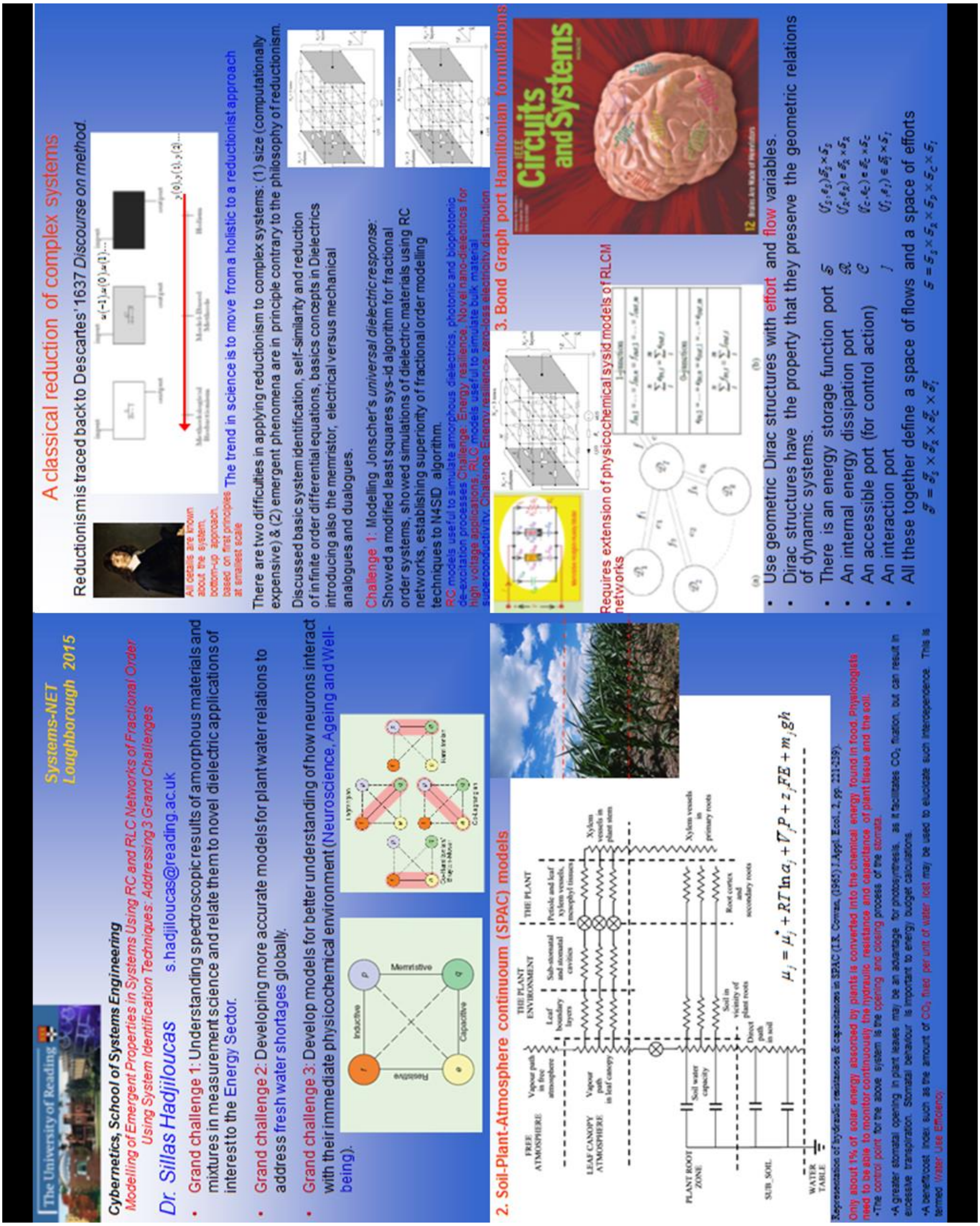
Engineering Resilience in Complex Systems



Modelling Emergent Properties in Systems using RC and RLC Networks of Fractional Order using Systems Identification Techniques Addressing Three Grand Challenges



SE Challenges to Support Autonomous Systems and their Validation

Title: SE Challenges to Support Autonomous Systems and their Validation

Problem Statement:

The future vision for the System Engineering of Complex Systems will deliver an environment that allows the designers and users to interact with the simulated environment with immersive detail of their system and its interactions with the environment.

This will allow ideas and concepts to be explored, designs to be honed and verified and new methods of operating the system to be explored and validated without the requirement to build the entire system itself. It will lead the system design through test, validation and certification allow the users to understand the risks and benefits of particular designs and their artefacts in the evolving environment in a rapid and effective manner.

Tackling the Challenges, what needs to be done?

1. Understand the full scope of Complex Systems challenge to be addressed and the current landscape of Machine Intelligence and Complex Environments
2. Develop Systems Models and Architecture Options and select Machine Intelligence, Complex Environment Models and initial framework for the initial SE test system. Produce an extensible, fieldable functioning demonstrator under SE Framework
3. Understand and Influence Validation / Certification processes and drive "sensible" agenda based on human integrity and SE Validation.
4. Identify Key System Challenges and new SE methods to design systems to mitigate the risks of Machine Intelligence in the Complex Environment
5. Explore the Machine Intelligence baseline models in the Complex Environment using the initial framework for the integrated SE test system.
6. Identify Gaps in the Machine Intelligence responses from the baseline and provide input to design and develop both System Engineering issues and Technology issues.

Proposed challenges for systems engineering

1. Understand the current State of the Art Architecture Frameworks Complex Environments and Machine Intelligence
2. Develop System Engineering and System Architecture approaches to the Complex System Problem
3. Evaluate State of the Art Machine Intelligence Models in the context of the Complex Environment and assess emergent behaviours.
4. Develop Systems Assessment of machine intelligence methods and techniques to allow successful and sustained operation in complex and evolving environments

Funding Body: EPSRC

Anticipated Impact:

- Rapid and effective de-risking of autonomous systems
- Proving of those systems in new, simulated, environments
- Prediction of system performance
- Acceptance testing and design validation where the circumstances of use would preclude full field testing from the variety or the effect PoVs.

Contact: Angus Johnson angus.johnson@uk.thalesgroup.com

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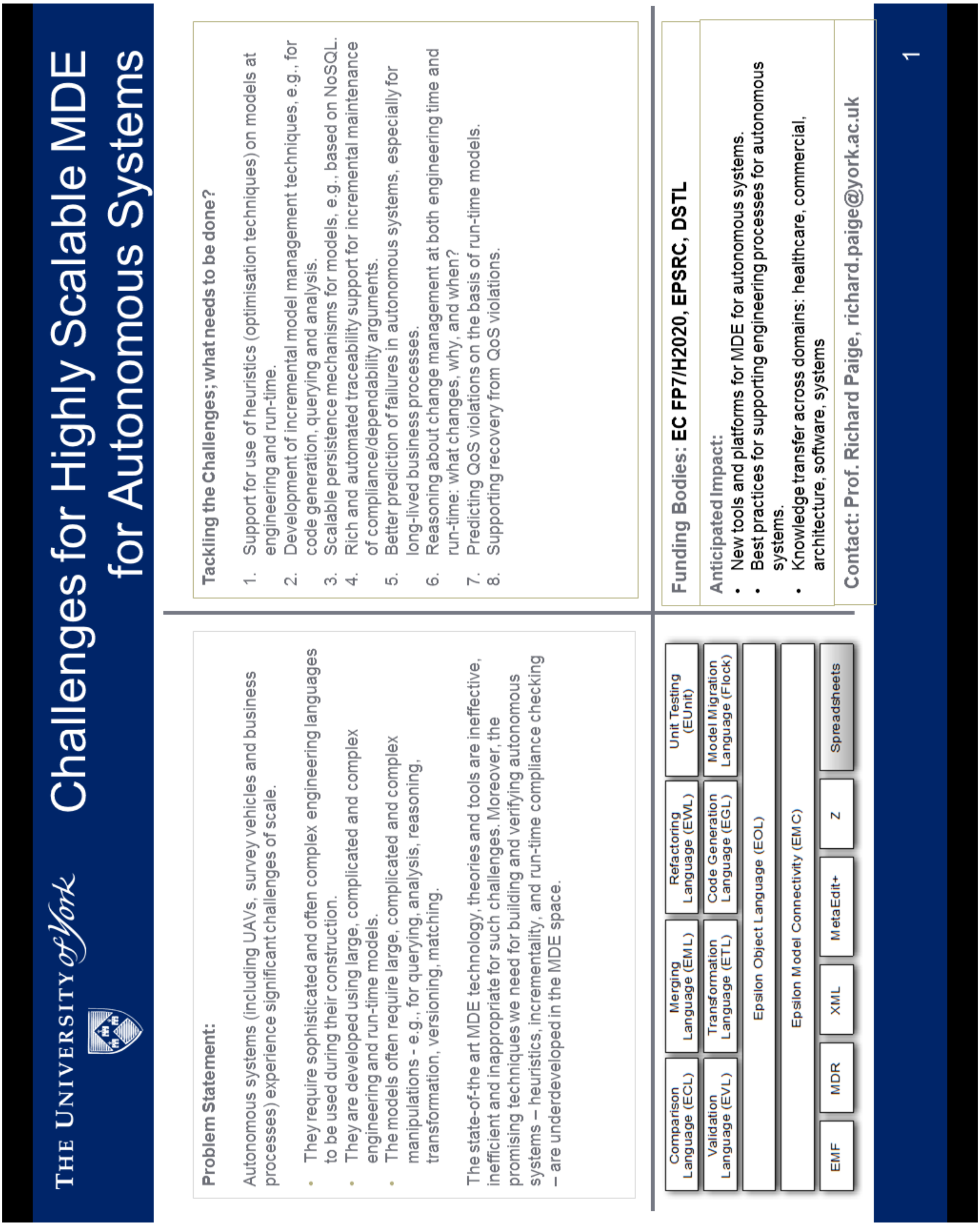
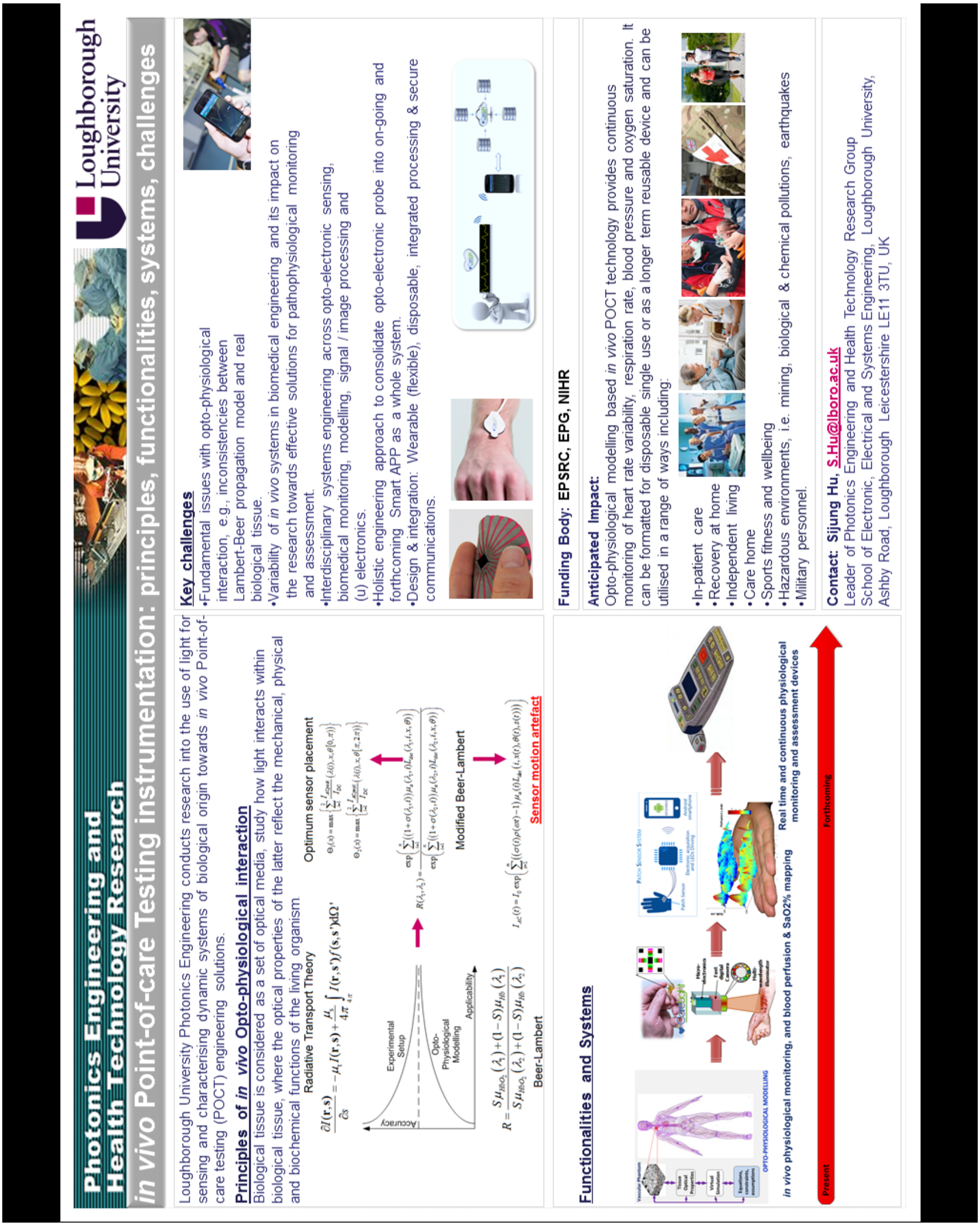
Challenges for Highly Scalable MDE for Autonomous Systems



In Vivo Point of Care Testing Instrumentation: Principles, Functionalities, Systems, Challenges



Maintaining systems of Systems Fit for Purpose

Title: Maintaining Systems-of-Systems (SoS) Fit-For-Purpose (FFP)

Problem Statement:

"How to design for the Unforeseeable?"

New and ever more complex societal challenges constantly appear that require timely and effective solutions, and this trend is likely to continue as both challenges and the systems developed to address them become more interconnected and dynamic. Furthermore, both the challenges and the response to them are affected by external influences such as the economy and political decisions, and all interact and affect each other.

Financial constraints and environmental concerns increasingly influence us in both our professional and domestic lives to "do more with less"; repair, reuse, recycle …

In complex socio-technical systems, it is often the human elements that have to bridge gaps between problems and capabilities available for solutions: the aim of this work is to help them!

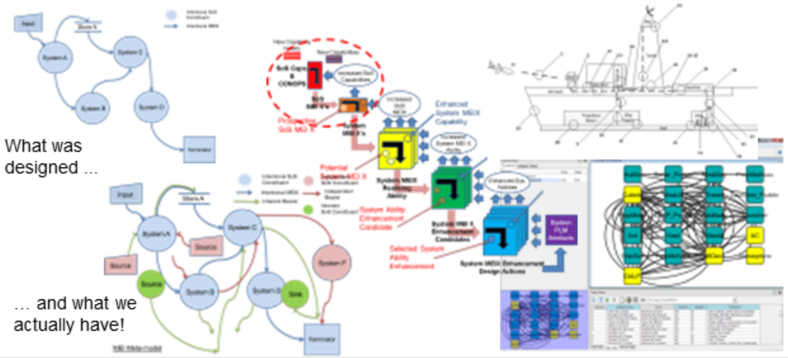
This research asserts that SoS' do not maintain FFP because they cannot implement the correct, timely and complete transfers of Material, Energy and Information (MEI) between the SoS constituents and externally necessary to achieve a particular result.

Tackling the Challenges, what needs to be done?

The problem situation means that capability-providing SoS' will have constituents that are needed to operate in ways that they were not originally designed to do, will have their service lives extended, and new constituents will have to integrate into an active brownfield environment.

Designers are able to design for agility, robustness and resilience against specified or foreseeable uncertainty, but any benefit these provisions have against "unknown-unknown" factors is largely due to luck. Suppliers of SoS constituent systems need to be able to provide some means for people to address the effects of these "unknown-unknown" factors.

This research has created a method with processes that can be integrated into industrial Product Lifecycle Management (PLM) systems that capture the "Designed-for", inherent and independent Sources, Sinks and Bearers of MEI that affect the SoS of interest. This novel holistic viewpoint of all the MEI transfers reveals prospective MEI transfer enhancement enablers to expand capability to meet unforeseeable needs, and also exposes hidden potential causes of undesirable emergent properties.



Funding Body: LU Graduate School and THALES

Anticipated Impact:

- Scalable enhancements to created products / services, and also to the creating PLM engineering processes to suit available resources.
- Reduction in system rework and undesirable emergent properties.
- System-of-Systems maintained as Fit For Purpose to address new unforeseeable tasks and/or changes throughout the lifecycle.

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http://www.lboro.ac.uk/departments/eese/phd/steve-hinsley

FFP GC for SE quad chart issue 2.pptx

Appendix B - Grand Challenges (Scanned copies)

A blue star indicates the challenge was chosen from the list of 33 proposed challenges.
A red star represents a vote.

C 1

Research Grand Challenges for Systems Engineering

Grand Challenge Statement

System engineering methodology - how systems are defined, developed and tested is well established with different models existing. Can a scientific approach be used to determine if there is a better methodology that can be defined?

Context

Improving the way we develop systems and coming up with an approach that is domain agnostic.

Potential impact

Harmony in the way SE is applied and using a scientific approach to get there.

Perceived difficulty

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A 2

Research Grand Challenges for Systems Engineering

Grand Challenge Statement

With the increase in autonomy in systems there is a need to ensure ethics can be embedded in a system rather than solely be applied at the operational phase by humans - legal issues

Context

increase of large complex interconnected cyber physical systems with demand for greater autonomy + self configuration.

Potential impact

~~has to be controlled by~~
Greater trust in systems
" uptake of "
Gives potential to expand the autonomous functionality of systems

Perceived difficulty

Don't know how to do this.

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3 Research Grand Challenges for Systems Engineering

Grand Challenge Statement
Importance of the knowledge base ~~[illegible]~~ to support system development (knowledge management)

RGC

Context – Different domains / transferability between dif. domains
– Decision making
– Uncertainty + Risk

Potential impact
– Extract required / needed knowledge
– Interconnectivity / dependencies
– Consequences of failure / prevention of fail
– Multidisciplinary collaboration
– Robotic systems, big data, maintainability of systems / Expert support

Perceived difficulty

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E 4 Research Grand Challenges for Systems Engineering

Grand Challenge Statement: modelling the Next Gen ~~Systems~~ Model based Systems engineering for the Industry 4.0 (IOT) to allow scalability and add end-end value.

Context: At the moment there is no model to support the changing business environment. In order to support the Industry 4.0 + IOT (which goes across manufacturing, service, etc.) to add end-to-end value. The next gen MBSE Tools should be able to address product / process interactions to make physical systems (e.g. factories) ~~[illegible]~~ smarter and flexible as Industry 4.0 concept doesn't exist without them

Potential impact – There is no MBSE Tool for the I4.0 or IOT. As whole Industry (system, service, etc.) is moving on a full autonomous approach. ~~being~~ Having the next gen MBSE Tool will allow to study the risk associated with system of systems ~~[illegible]~~ make them more resilient & flexible

Perceived difficulty ① Big data management (managing the real time data)
② Self-learning (organising) based on real time information and unforeseen circumstances.
③ ~~[illegible]~~ Human-Machine Interaction in order to address the issues due to a fully autonomous system.

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B 5

Research Grand Challenges for Systems Engineering

Grand Challenge Statement

Reliability, Robustness & Recoverability of Complex Systems. to support more flexible & automated negotiation between systems to enable/ease interoperability of different systems (including mgmt of legacy & new systems). Eg. to develop systems of autonomous connected ~~transport systems.~~

Context

Complex Systems control critical operations like ~~[illegible]~~ aircraft flying, nuclear power stations, railway system etc.
Failing of these systems might have catastrophic results that's why they should not in the first instance BUT if it happens

Potential impact they have to be recoverable - either autonomous or through / human intervention. Understanding these factors would be the goal of this challenge

Increase of complex system reliability; reduction of redundancy due to deeper understand of these factors; reduction of losses due to System failure

Perceived difficulty

- Medium - High: Risk Mgt goes into this direction but has to be combined with in depth system knowledge

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C 6

Research Grand Challenges for Systems Engineering

Grand Challenge Statement

SEMANTIC CONFLICTS
AND
UNCERTAINTY

Context

COMPLEXITY SCIENCE
CYBER-PHYSICAL SYSTEMS

Potential impact

- A NEW GENERATION OF SYSTEMS
- A NEW SCIENCE

Perceived difficulty

EXTREME
DOMAIN SPECIFIC

SOURCES OF UNCERTAINTY:

- PHYSICAL ENVIRONMENTS
- HETEROGENEITY
- AGENT AUTONOMY
- HAZARDS
- NATURAL DISASTERS

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7 Research Grand Challenges for Systems Engineering

RGC 1

Grand Challenge Statement

HOW DO WE ACHIEVE SUSTAINABILITY USING SYSTEMS ENGINEERING.

Context

SYSTEMS ENGINEERING COULD PLAY CENTRAL ROLE IN PRESERVING THE ENVIRONMENT AND THE HUMAN RACE.

Potential impact

THE IMPACT WOULD BE ENORMOUS IN TERMS OF IMPROVING QUALITY OF LIFE.

Perceived difficulty

THE TECHNOLOGY IS STILL NOT ADVANCED ~~[illegible]~~ ENOUGH TO MEET ~~ACHIEVE~~ THIS CHALLENGE.

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B. 8 Research Grand Challenges for Systems Engineering

Grand Challenge Statement #1

~~HOW~~. RENEWABLE ELECTRICITY GENERATION TO REACH CARBON NEUTRAL STATE.

Context

PRESERVING A LIVEABLE ENVIRONMENT FOR FUTURE GENERATIONS, MAINTAINING SPECIES DIVERSITY.

Potential impact

SURVIVAL OF HUMAN RACE (AND OTHER SPECIES) NOT NEEDING TO COLONISE MARS

Perceived difficulty

INTERNATIONAL ALIGNMENT
SOCIAL ACCEPTANCE - CHANGES TO LIFESTYLE.
ECONOMIC STABILITY

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A G 9

Research Grand Challenges for Systems Engineering

Grand Challenge Statement

Decision Making in a Big Data Era (

Context

System Coupling is increasing, and thus, understand information around ~~their~~ their interconnectivity becomes essential

Potential impact

~~Ried~~ Improve understanding in the consequences of system failure and how information around their use can reduce risk

Perceived difficulty

Challenging as data increases in size, and in value, and thus involved parties are not prone in sharing

Well established!

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C 10

Research Grand Challenges for Systems Engineering

Grand Challenge Statement

Achieving multi-disciplinary model integration across the system development lifecycle to help deal with semantic conflicts & uncertainty

Context

Understand system interdependencies better

Potential impact

System quality improvement

Faster development time

Perceived difficulty

Modelling toolset integration and related standards

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13 11

Research Grand Challenges for Systems Engineering

Grand Challenge Statement
Understand emergent properties of complex systems using system identification of fractional order calculus
Non linearity needs to be accomodated.

Context Broad, addresses ~~all~~ ~~or~~ most of the existing grand challenges: 1. Characterization of materials
2. Agriculture modelling of fresh water conservation in plants
3. Energy / new superconducting technologies
4. Neuroscience Understanding of neuronal form and function

Potential impact High ~~Large~~. Enables us to move from black box type input/output models to grey box and white box models understanding better the underlying systems.

Perceived difficulty High. Requires training of researchers to existing tools and Mathematics Control theory and System Identification

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E 6 12

Research Grand Challenges for Systems Engineering

Grand Challenge Statement
Develop a frame work for Socio-technical interactions between Stake holders.

Context
- Being able to quantify and assess how stakeholders within a system ~~and to what extent they~~ affect each other and to what extent they affect each other

Potential impact
The understanding of the implications of certain stakeholders working on projects/programs and developing effective and efficient frame that deliver positive and beneficial outcomes
Allows greater resilience when forecasting issues between stakeholders

Perceived difficulty
The quantifying impact of the interaction and understanding the extent to which an interaction may impact a system.

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E 13

Research Grand Challenges for Systems Engineering

Grand Challenge Statement

Real time solution generation + update of integrated systems solution. and forecasting (what ifs) & predicting performance (eg. for IoT)

Context Robotic systems require high ~~complex~~ expert knowledge to build. However, a design environment that can generate solution based on operational lifecycle can help to highlight ~~b.~~ behaviour as well as highlight solution changes in real time.

Potential impact – Non-expert or semi-skilled people can use, such capabilities to test their idea + innovate as well as small companies can uptake manufacturing of highly technical systems.

Perceived difficulty

- Availability of knowledge databases from different domains.
- Technical challenge to developing intelligent solution.
- Modelling & real time systems in uncertain environments.

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D 14

Research Grand Challenges for Systems Engineering

Grand Challenge Statement

SYSTEMS OF AUTONOMOUS + CONNECTED TRANSPORT SYSTEMS

Context INTEGRATION OF AUTONOMOUS VEHICLES INTO EXISTING INFRASTRUCTURE, MEETING SAFETY + LEGAL CONSTRAINTS, BUILDING SUPPORT INFRASTRUCTURE

DRIVERLESS TAXIS → GOOGLE'S /AMAZON AUTOMATED DELIVERY SYSTEM

HANDLING UNEXPECTED EVENTS

Potential impact IMPROVED MOBILITY, SAFETY, EFFICIENCY, ENERGY CONSUMPTION, REDUCED EMISSIONS, ALLOWING ELDERLY PEOPLE ON THE ROAD SAFELY,

Perceived difficulty VARYING → MANY TECHNICAL, LEGAL, AND PUBLIC PERCEPTION CHALLENGES

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15

Research Grand Challenges for Systems Engineering

Grand Challenge Statement

Proof & Communicate the benefits of SE to increase its attractivity to a wider audience

RGC1

Context

In order to increase levels of training, number of positions and funding for SE activities, political, economic and social entities have to informed & convinced of its benefits

Potential impact

Increase of funding, use of SE methodology throughout, as well as public awareness of SE efforts.

Perceived difficulty

Med - High : Biggest part is to actually start to do this & allocate money to it.

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16

cluster 1 = C1

Research Grand Challenges for Systems Engineering

Grand Challenge Statement

Driven from context of a specific grand solution ("go to MARS, solve power gen..") develop and mature the set of techniques for defining, analysing, V+V system solutions with characteristics reqd.

RGC5

Context Techniques need to cope with:-

- complexity
- multi disciplinary aspects
- SoS
- interactions (interfaces/negotiation
- scenarios/underpinning science
- large scale/scalability
- autonomous aspects
- integration of models
- within educated process frameworks

Potential impact

- optimisation
- balancing
- new and/or incremental development
- ethics/legislation...
- full lifecycle aspects
- social technical aspects

Perceived difficulty

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D 17

Research Grand Challenges for Systems Engineering

Grand Challenge Statement MANAGEMENT OF LEGACY + INTEGRATION OF NEW.

Context HOW DOES THIS APPLY TO DEVELOPING NATIONS WHERE LEGACY IS NOT ALWAYS SO RESTRICTIVE?

Potential impact LEGACY INFRASTRUCTURE IS PREVALENT IN MANY COUNTRIES, AND IN MANY INDUSTRIALISED COUNTRIES, LEGACY INFRASTRUCTURE IS REACHING CAPACITY CONSTRAINTS.
→ BUILDING RESILIENCE INTO CONNECTIONS BETWEEN LEGACY + NEW SYSTEMS

Perceived difficulty

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IAN

18

Research Grand Challenges for Systems Engineering

Grand Challenge Statement How do we actually ENGINEER complex systems?

RGC3

Context Complex systems exhibit emergent characteristics. How do we characterise these properties & provide systems engineering tools to support their construction (and verification & validation)

Potential impact Very significant - especially given Internet of Things / mobile technology

Perceived difficulty Very difficult - the innate unpredictability of such systems makes them difficult to verify & validate.

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Research Council

D 19

Research Grand Challenges for Systems Engineering

Grand Challenge Statement

BALANCING VS. OPTIMISING SYSTEMS (AND SUB-OPTIMAL SYSTEMS)

and understanding roles of competition & collaboration, ~~the~~ (negotiation of boundaries) including the constraints of networks of contacts

Context Against Architectural, Legal requirements, Organisational, People's expectations

working towards good enough?
may depend on level of abstraction

Potential impact

Perceived difficulty

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3

A 20

Research Grand Challenges for Systems Engineering

Sorted

Grand Challenge Statement

The ability for humans to be able to "interrogate" systems to understand, question, maintain or extract required data/information/knowledge.

Not quit in the right place!

Wht? Possibly

Context

CPS etc are all pervasive/ and geographically spread and in most cases are designed etc operated by a range of engineers, commercial/govt organisations

Potential impact

improved use of systems
improved transparency of systems
" maintainability of systems

Perceived difficulty

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D 21

Research Grand Challenges for Systems Engineering

Grand Challenge Statement AUTOMATED ELECTRICITY DEMAND MANAGEMENT	
Context Balancing	
Potential impact	
Perceived difficulty	

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E 22

Research Grand Challenges for Systems Engineering

Grand Challenge Statement More flexible and automated negotiation between systems to enable /ease inter-operability of different systems	
Context where multiple computer systems are used in 'an environment' – e.g organisation	
Potential impact ability to address /solve problems not solveable by one system alone. 'Modularity' of system purchases. Extended lifetime of systems?	
Perceived difficulty Requirement for knowledge / terminology / agreed languages to enable negotiation – Artificial Intelligence	

EPSRC – Ontologies – Knowledge Representation.

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B 23

Research Grand Challenges for Systems Engineering

Grand Challenge Statement

Knowledge Based Semi-Autonomous MBSE
"Expert-~~Led~~Assisting"

Knowledge
Expert.

Context

Integration of knowledge base
and expert system into MBSE
Allow customisation - expert knowledge

Potential impact

~~Ease of use~~
Improved adoption.
Improved efficiency, performance,
etc

Perceived difficulty

Life cycle support
Openness - allow inhouse expertise
Integration - Strategy Traceability
- Architecture

Expert System - Thinking Process
- Decision Making
- Judgement

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Seng Chong

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B 24

JJ.

Research Grand Challenges for Systems Engineering

Grand Challenge Statement

~~ACHIEVE~~ COMPREHENSIVE INTELLIGENT ENVIRONMENT (TOOLS, STANDARDS, METHODOLOGIES) THAT CAN SUPPORT SYS ENG TO ENABLE/ENHANCE:
- REUSE/DOMAIN KNOWLEDGE
- PATTERNS
- ANALYSIS FOR NF PROPERTIES
- DEPENDENCIES
- EVOLUTIONARY DEVELOPMENT
- HIGH INTEGRITY
- ASSURED PROPS

Context

- OPEN
- HARD + SOFT ASPECTS
- HUMAN FACTORS ASPECTS
- KNOWLEDGE SUPPORT.
- FULL LIFECYCLE.

~~INCREASING~~ GROWING DEMAND FOR COMPLEX, ADAPTABLE, CONNECTED MULTI-DISCIPLINARY SYSTEMS SOLUTIONS

Potential impact

- REDUCE TIMESCALE TO MARKET
- INCREASE POSSIBLE SOLUTION VARIANTS
- REDUCED DEVELOPMENT, MAINTENANCE, AND UPGRADE COSTS.
- INCREASE SOLUTION INTEGRITY, ROBUSTNESS

Perceived difficulty

- THIS REMAINS A DIFFICULT VISION TO ACHIEVE, IN PART BECAUSE OF LARGE NUMBER OF ASPECTS, AND NON-TECHNICAL ISSUES (LIKE TOOL VENDOR MARKET).

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D 25

Research Grand Challenges for Systems Engineering

Grand Challenge Statement TRANSFERABILITY → BENEFITS FROM ONE DOMAIN / FIELD TO ANOTHER	
Context	
Potential impact	
Perceived difficulty	

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26

Research Grand Challenges for Systems Engineering

Grand Challenge Statement Understanding, modelling & managing, using SE techniques, the dynamic tension between organised & disorganised complexity.	
Context The introduction of expensive, complex new urban infrastructure systems	
Potential impact More effective urban infrastructure systems embraced by urban population	
Perceived difficulty Very difficult. New effective dialogue between engineers & social scientists (psychologists, ethnographers, anthropologists, behavioural economists etc) required.	

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A 27 Research Grand Challenges for Systems Engineering 9

Grand Challenge Statement	
Large scale systems have many interconnections. There is a high potential for failure + hence this will propagate into system. = brittleness.	Connections
Context	
Currently humans are main agents to deal with this it is not really considered by engineer - cannot predict brittleness in system.	
Potential impact	
More robust systems	
Perceived difficulty	
Education, knowledge, tools predicting the future, hypo-visors	

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D 28 Research Grand Challenges for Systems Engineering 9

Grand Challenge Statement	
SYSTEMS THINKING VS. SYSTEMS ENGINEERING	Solution
Context	
Potential impact	
Perceived difficulty	

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D 29 (a)

Research Grand Challenges for Systems Engineering

Grand Challenge Statement Roles of competition + collaboration (Negotiation of boundaries)	
Context	
Potential impact	
Perceived difficulty	

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C 30

Research Grand Challenges for Systems Engineering

Grand Challenge Statement Develop Systems Engineering as a skill that is attractive and valued	
Context Systems engineering is a discipline that is not widely understood and not defined well. This leads to a lack of importance and a lack of entrants into the discipline in industry.	
Potential impact A skills gap is on the horizon and not filling this will impact an industry's ability to develop solutions for customers	
Perceived difficulty This problem has been prevalent for several years and is on the increase. The problem has not been solved thus far.	

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C 31

Research Grand Challenges for Systems Engineering

Grand Challenge Statement

The ability to make the business case to management for application of ~~SE~~ ~~math~~ model-based systems engineering methods

The inability to make the business case for MBSE is a topic frequently raised at INCOSE UK MBSE WG.

Context

Adoption of MBSE is slower than it should be, even in industries familiar with SE, because it is difficult to make the business case

Potential impact

Greater adoption of MBSE leading to large productivity improvements

Perceived difficulty

Difficult to get hold of the case study data necessary to make the business case

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E 32

Research Grand Challenges for Systems Engineering

Grand Challenge Statement

INCREASE INTELLECTUAL RIGOUR OF SYSTEMS ENGINEERING

I understand the background and I think this could be said as "introduce science to SE." Is it a grand challenge?

Context

PROVIDE DEMONSTRABLE BENEFITS OF SYE, & MAKE SYE MORE CREDIBLE FROM VIEWPOINT OF TRADITIONAL SCIENCES.

Potential impact

MORE FIDELITY IN MODELS & SIMULATIONS –
– MORE VALIDATION & CERTIFICATION OF PHYSICAL SYSTEMS

Perceived difficulty

"POLITICAL" IMPLICATIONS & ACCEPTABILITY
NON-DETERMINISTIC NATURE OF ~~SE~~ SOCIO-TECHNICAL SYSTEMS

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D 33

Research Grand Challenges for Systems Engineering

Grand Challenge Statement
THE WHAT-IFS OF INTERNET-OF-THINGS.

Context Predicting performance.
forecasting
Scalability

Potential impact

Perceived difficulty

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D 34

Research Grand Challenges for Systems Engineering

Grand Challenge Statement
Thinking through the "whole-life" of all new complex systems/product/technology + obsolescence → upgradeability/strategic engineering

Context

Potential impact

Perceived difficulty

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B 35

Research Grand Challenges for Systems Engineering

Grand Challenge Statement #2

COLONISING MARS

Context

IF WE EITHER DESTROY OR OUTGROW OUR PLANET WE NEED SOMEWHERE TO LIVE.

Potential impact - SURVIVAL.

INCREASED AND NEW RESOURCES.

TECHNOLOGICAL AND SCIENTIFIC ADVANCES TO ACHEIVE COLONISATION

Perceived difficulty

PREPARING MARS TO ACCEPT PEOPLE, AND MAKING IT HABITABLE LONG TERM

POLITICAL CHALLENGE - WHO OWNS MARS? THE RIGHTS OF THE MARTIANS.

ESTABLISHING SOCIETY AND CULTURE.

Goal

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A 36

Research Grand Challenges for Systems Engineering

Grand Challenge Statement

There is a requirement for "theoretical foundations" for SE to provide a knowledge base + understanding to facilitate comm. between S. Engineers + S. Scientists.

Context

The need for multi-disciplinary collaboration between Engineers / Scientist + contribution to and dev. of complex systems.

Potential impact

wider [illegible] applied to dev. of systems.

Successful delivery of system!

Perceived difficulty

No common language or perceptions

Education

A bit fuzzy!

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E 37

Research Grand Challenges for Systems Engineering

Grand Challenge Statement TO ESTABLISH MBSE USING NOVEL, BESPOKE SYSTEMS METHODS THAT PROVIDES INTEGRATED SOLUTIONS	
Context Replace software engineering lifecycle tools with a re-thought systems lifecycle; as well as tools for systems architecture, systems design, + verification + validation.	
Potential impact Huge – as would affect how systems engineers approach problem – solving.	
Perceived difficulty Needs academic lead that can provide the rigour demanded	

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38

Research Grand Challenges for Systems Engineering

Grand Challenge Statement How can systems engineering methods and techniques be applied to transitioning the UK from being a country reliant on fossil fuels to one that is reliant on renewable energy sources.	
Context Fossil fuels are limited and will run out one day. At present the UK is not set up to be a "green" society. To make this transition soon + smoothly would be a grand challenge	
Potential impact No more reliance on fossil fuels, environmental benefits	
Perceived difficulty High. Every individual is reliant on fossil fuels now and this would need to change.	

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