EPSRC Systems Engineering Workshop

16th February 2017

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1.0 Introduction

The Engineering theme at EPSRC wanted to engage with a cross-section of the systems engineering community in order to establish a perspective on the research themes which sit within EPSRC remit and how these might relate to the future landscape. It had been noted that there has been little work done in this area for around five years and with the development of the Prosperity Outcomes and the launch of the new Industrial Strategy Challenge Fund, now was seen as a timely opportunity to facilitate a discussion around how this area can contribute to EPSRC's overall Engineering strategy.

The workshop was held on Thursday 16th February and was a successful event enabling academics and industrialists who work in the discipline to engage around this area and explore potential avenues for further research.

The results of the workshop, comprising this report and any notes taken during the day or prior to the workshop through conversations with members of the community will be used to help EPSRC understand the underlying research challenges for systems engineering and the direction EPSRC support should take to address these challenges.

1.1 Aims and Objectives

- Explore the novel Engineering and Physical Sciences challenges in systems engineering
- Understand the contribution this area of research makes to the Engineering and Physical Sciences portfolio
- Identify next steps

1.2 Attendance

A call for Expressions of Interest was publicised on EPSRC's website and attendees were selected from submissions made. Selection aimed to generate a balance of academia/industry, research areas, career stage, strategic awareness and equality and diversity characteristics.

A full list of attendees is available in Annex 4.1.

1.3 Well Sorted survey

In order to include as many views as possible, all applicants were sent a link to a survey using the Well Sorted tool. The question asked was, 'what do you think are the two main systems engineering research challenges, within EPSRC's remit, over the next five to ten years?'

The tool collated all the answers and a subsequent link was sent to applicants asking them to cluster all submitted answers. From this, a number of visualisations were generated showing the highest incidences of clustering and so separating the answers into categories. These were taken forward into the sessions at the workshop and used to frame discussions.

A full copy of the Well Sorted report can be reached by following the link provided in Annex 4.3. It is advised that this document is read in conjunction with the Well Sorted report.

2.0 Workshop Outputs

An introductory presentation was provided to highlight the purpose of the day. Following this, delegates were led through a series of exercises in small groups and time was made for plenary discussions.

2.1 Session 1 – Novel Engineering and Physical Sciences Challenges

The key aim of this session was to discover what drives engineering and physical sciences research in systems engineering and what we actually mean by it when thinking about engineering and physical sciences challenges. Delegates were asked to form five groups and to each look at a cluster from the Well Sorted report. Using the information provided, they had a discussion around the topics within each cluster and gave them a title as well as adding in anything they felt was missing from the cluster.

The raw output of these sessions can be found in Annex 4.4.1. The titles that delegates attached to each area were:

1. Understanding and Managing Emergent Properties and Behaviours
2. Integrated System Modelling Design
3. Confidence (Merited Trust) in Systems Capability
4. Integrated Socio-Technical Aspects of Systems Lifecycles
5. Applications

Delegates were also asked to comment on the types of approach which might be needed to achieve these goals. Key points raised were:

- Systems engineering requires systems engineers able to use systems thinking in practice
- Some areas need to be systems engineering led
- Skills training should include understanding and implementing specialist engineering in the context of national and global strategies
- Multidisciplinary and cuts across many themes
- There is no benchmark for what makes good systems engineering research

- Graduates need both a deep understanding of the core discipline as well as a broad understanding
- There are limited places where systems engineering research can be published
- Linking systems engineers to applications projects will speed up impact

2.2 Session Two – What contribution does systems engineering make to the EPSRC Portfolio

Delegates were asked to do a SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis of each of the identified areas below. The raw outputs can be found in Annex 4.4.2. A summary of the main points raised for each aspect have been combined and are provided below:

Strengths

- There needs to be an increase in the appreciation of the significance of this area in industry and government organisations
- There is potential for significant impact provided industry is engaged
- UK leadership exists in some areas and there is strong expertise in individual communities
- There are many different, diverse application areas where systems engineering is absolutely necessary to achieve outcomes.

Weaknesses

- Limited or lack of science, systems engineering aspect is not fundamental research and is it systems science or systems engineering?
- This area needs lots of people
- Lack of understanding for example between systems engineering and systems theory, why modelling and design needs to be integrated or what the unknown unknowns are in order to understand challenges

Opportunities

- There are opportunities for real impact and could be transformative in new sectors for examples on policy and practice in many domains
- Areas such as 'Big Data' are a direct example of where systems engineering opportunities can be utilied
- This is an area where there needs to be integrated multi-disciplinary working where holistic and joint problem solving is used
- There is a greater public demand for more confidence because of awareness of autonomous systems
- The formation of UKRI
- Large numbers of industry and government partners could be engaged including EPSRC who could locate systems engineering on a high impact, integrating function

Threats

- Work funded that does not have a systems engineering focus
- Many different and diverse communities need to be involved and they all have different cultures, languages etc
- Systems engineering should not become purely a service
- A failure to consider the influence of human factors in systems engineering
- This area spans multiple research councils and there is a fear that peer review would not support socio-techincal work particularly well
- Perception that there is no science in systems engineering and this is a high-TRL activity

Within this session, delegates were also asked to list what systems engineering does well and what it could do better. The full list can be found in Annex 4.4.2.

2.3 Session Three – Next Steps

This session was an opportunity to do some horizon scanning. Delegates formed small groups and were asked to identify what they thoughts the main challenges for systems engineering will be in the next 10, 20 and 50 years. A full list of outputs can be found in Annex 4.4.3.

- Key thoughts for the near future could be interpreted as being:
- Systems engineering method to evaluate social threats and mitigate against crime
- Designing differently for new manufacturing techniques
- A continued need for the STEM pipleline and more systems engineers and to have embedded skills from early childhood. This should include defining what it means to be a systems engineer
- For systems thinking/systems engineering to be our natural approach
- For systems engineering to be recognised as a vital discipline in addressing global grand challenges

Finally, delegates were asked what the UK could do in this area. The full list is available in Annex 4.4.4 and will be used alongside the rest of the material collected from this workshop as well as discussions had with the community to feed into thinking at EPSRC about what can be done to help support systems engineering research.

3.0 Conclusions

The workshop proved to be a successful event and a large volume of information was generated on the day. It was interesting to see the cross-cutting themes that emerged from the clustering tool and it would be worth looking at these in further detail to see if they could be used to address the needs of the community.

There was a strong sense that there are novel systems engineering challenges within the engineering and physical sciences remit and that these need to be recognised more. It was also noted that this area is inherently multidisciplinary so despite there being clear challenges which sit within EPSRC remit, other research councils will need to be involved in discussion.

Training as well as impact was raised and the workshop gave the impression that more could be done in both these areas. Regarding training it was clear that there is a need for engineers who can think in a systems way and around impact the message received was that there is a lot of potential for this area to really make a difference.

Overall this is a strong area with a potential to drive the engineering portfolio forward if applied in the best areas. As a next step EPSRC proposed to form a small focus group to help use the outputs of this event to steer a strategy in this area.

Finally, EPSRC welcomes any further inputs either to this report or thoughts on tools that would be useful in supporting this area of research.

4. Annexes

4.1 Workshop Attendees

Alan Harding	BAE
Alex Duffy	University of Strathclyde
Alison McKay	University of Leeds
Andrew Lawrence	EPSRC
Andrew Plummer	University of Bath
Cliff Cheesman	AWE
Clive Roberts	University of Birmingham
David Oxenham	DSTL
Dimitrios Pezaros	University of Glasgow
Emma Sparks	Cranfield University
Harvey Arellano-Garcia	University of Surrey
Herve Borrion	UCL
I. Felician Campean	Bradford
Jakob Sprickerhof	EPSRC
Jennifer Whyte	Imperial
Joana Fonseca	City University
John Clarkson	University of Cambridge
John Fitzgerald	Newcastle University
Katie Blaney	EPSRC
Martin Mayfield	University of Sheffield
Michael Butler	University of Southampton
Michael Henshaw	Loughborough University
Michele Erat	EPSRC
Narakorn Srinil	Newcastle University
Niall MacDowell	Imperial
Paul Casely	DSTL
Pavel Loskot	Swansea University
Phil Longhurst	Cranfield University
Pia Sartor	University of Bristol
Ray Ison	Open University
Roy Kalawsky	Loughborough University
William Holderbaum	Manchester Metropolitan University

4.2 Workshop Agenda

10:00	**Welcome and introductions (All)**
10:10	**Theme overview (Andrew Lawrence, Theme Lead)**
10:40	**Session One – Novel Engineering and Physical Sciences Challenges**
11:15	**Tea/Coffee**
11:30	**Session One – continued**
12:00	**Session Two - What contribution does Systems Engineering make to the EPSRC portfolio?**
13:00	**Lunch and networking**
13:45	**Session Two – Feedback**
14:00	**Session Three – Next Steps**
15:00	**Tea/Coffee**
15:15	**Session Three – continued**
15:45	**Feedback**
16:00	**Close**

4.3 Well sorted output

A full delegate document can be found here:
https://www.epsrc.ac.uk/files/funding/calls/2017/sysengworkshop2017wellsortedmaterials/

4.4 Raw output

4.4.1 Novel Engineering and Physical Sciences Challenges

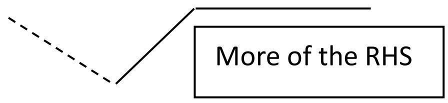
Understanding and managing emergent properties and behaviours

- Security Resilience
  Safety
- Digital Complex → Boundaries? Systems as noun? OR
  Systemic/Systematic
- V&V
- Delivering systems → production systems
- 'Partially grown' systems
- Operating systems e.g. situational awareness
- Managing the Red Queen Effect
- Systems engineering requires systems engineers able to use systems thinking in practice
- This area benefits from domain specific examples but needs to be systems engineering. led
- Self-adaptive systems
- Environmental-technical interdependence
- System of systems
- Long term emergence…
- Skills – understanding and implementing specialist engineering in the context of national and global strategies e.g. national infrastructure protection

Integrated System Modelling Design

- Implementation
- Empathy – understanding perspectives and view points
- Impact outcome
- Training: abstract systems dynamics
- Both
- Transformation
- Operational/s systems engineering
- Effects of multiscale!
- These are skills models, training is patchy, training is not enough (SEMAP? TLAE?)
- Skills – leadership, transformational leadership
- Optimal network design, modelling, optimisation

- Training – emergence as a science – how to manage?
- Must be multidisciplinary context depend
- Business case?
- Exploitation
- System evaluation



Confidence (Merited Trust) in Systems Capability

- Context (trust and robustness)
- New approached for greater uncertainty
- Training – research methodology
- Training – what makes good SYSTEMS ENGINEERING research (methodology), what's the PhD curriculum (versus EngD)
- Training – students would learn to design for things they can't control
- In presence of uncertainty
- Training – learning from other mulit-disc. Areas e.g. make up of multi-disc teams in health and social care systems
- Training – systems science
- Autonomy and Resilience
- Reasoning
- Many existing projects in this area are diluted by not having enough systems engineers
- Evolutions – v – vvvv
- Work on visualisation exists but needs adapting/transfer to systems engineering e.g. role in data/model based design
- Systems engineering requires systems engineers able to use systems thinking in practice
- SoS – true multidisciplinary multi – domain (e.g.technical/social…)
- Systems engineering 'science' – systems behaviour, SoS emergence, uncertainty/confidence/trust, resilience, system design synthesis and V&V
- Systems engineering – ~~Deng~~ – DPhil!
- Novel challenges – changing engineers mindsets and ways of thinking without losing their engineering capabilities
- Autonomy, cyber, quantum, human – cutting across all 5 themes

Integrating Socio-Technical Aspects of Systems Lifecycles

- Verification of dynamic systems with too many systems started
- Important for graduates to have deep understanding of core discipline as well as broad understanding

- There are a limited number of places to publish systems engineering academic research (and hence inform the field)
- Skills and training - those working in this field in academic and industry generally have realised the importance and are self-taught
- To govern/redesign/design in the Anthropocene requires systems thinking engineers
- Systems engineering ≠ multidisciplinarity
- Systems engineering requires systems engineers able to use systems thinking in practice
- Skills – we do not start early enough, to encourage and promote breadth
- Need for shared testbeds for integration for experimentations
- Complex supply chaings
- Add 13, 22, 48, 59 (respond to social issue) (from well sorted report)
- Add allocation of function
- Human – AS
- Challenge of exposing students to realistic integration problems
- CDTs in systems engineering needed bringing disciplines together
- Integrating distributed systems
- Difficulty of publishing 'real' systems papers
- Evolving systems (no clean sheets)
- Integration appreciated at 'real' systems level – hard to do in academic
- Integration of disciplines

<u>Applications</u>

1. Energy
2. Health
3. Manufcaturing
4. Infrastructure
5. Space

- Systems engineering requires systems engineers to use systems thinking in practice
- Linking systems engineers to applications projects will speed up impact
- Training – radically cross-disciplinary systems CDTs (e.g. medicine and energy)
- Skills – development of SYSTEMS ENGINEERING approach and systems thinking out of non-traditional domains
- Design against crime
- Skills: strongly encourage discipline diversity across broad domains
- Skills in applying systems engineering approached
- Chemical and energy conversion systems

Enablers (common language)

- Robotics and autonomous systems
- Cyber physical systems and understanding
- Systems modelling across scales

- Systems resilience and performance

4.4.2 What contribution does Systems Engineering make to the EPS Portfolio?

Understanding and managing emergent properties and behaviours

Strengths	**Weaknesses**
• Strong expertise in individual communities • Computer power to deal with faster than real time modelling (also a weakness)	• Difficulty in imagining unknown unknowns in order to understand challenges • No science • The science behind modelling emergent behaviours • Integration of networks in system of systems • Lack of data
Opportunities	**Threats**
• Design closed-loop measurement and control systems • Opportunities for real impact • Would improve ability to manage and improve systems • Manage user expectations • Cyber solutions • Better predictability (quality, reliability) • Computational data-driven approaches • Cross-disciplinary research • 'Big Data' – is a direct example of systems engineering opportunities where resource savings and resilience benefits can be gained	• Work funded that does not have systems engineering focus • Different communities, culture, language etc not working together • Lack of data in certain application domains inhibits progress • Failure to advance methods to dynamically validate systems • Different domains create varying/conflicting approaches • Increased reliance on software • To become purely a <u>service</u> • Intelligent systems achieve world domination

Integrated systems modelling and design

Strengths • Holistic views/approach enabler • Predictability – better operation and design • Evidence that modelling adds value to engineering • Can assist in the identification of emergent behaviours • UK leadership in area • Reduces time to market – more rapid convergence on performant systems • Deals in reality • Reduces development cost by managing risk e.g. in prototyping • Optimum uses of resources and infrastructure accelerate system evolution	**Weaknesses** • Insufficient scalability and integration of modelling approaches • Mission analysis (pre-gate O) • ISM&D could be perceived as disciplinary • Uncertainty in models, verifying/validating models • Explaining why modelling and design needs to be integrated • Funding opportunity • V+ → Underpinning Maths • Uncertainties, Sensitivities, Probabilities/reliability • Lack of open framework for international • Miss key emergent behaviours • Translation theory → application
Opportunities • Proper research or agile vs waterfall • Formal foundation for impact • Could be transformative in new sectors • Model based design/sysnthesis • Model – based systems engineering in the profession (e.g. INCOSE) • Model validation methods • Reduction in time + costs • To provide clarity across proliferation of systems engineering tools/life cycle tools/ERP systems • Manage growing complexity • Identify key emergent behaviours • Innovative physics-based design • Integrated multi-disciplinary working • Interface with complex modelling community (e.g. ML) (Turing) • Rapidly improving analytic tools for models • Virtual engineering	**Threats** • No full lifecycle tool integration • Paradigm software ≠research • Disparate work/initiatives • Cost of developing high quality tools • Not enough quality systems engagement • Computational robustness for simulations for modelling/design • Validation of research results • Data privacy and availability • High profile avoidable project (HS2, HS3, Crossrail,…) failures e.g. feature interactions

Confidence (merited trust) in systems capability

Strengths	**Weaknesses**
• Mature technology for verification of closed/known systems exist • UK a world leader in verification tech in some domains (cyber/software) • Growing body of work of integration of verification techniques • Guaranteed performance	• Limited science • Don't know what it is • Needs lots of people • Measurement of trust • Verification of systems with uncertainty not understood
Opportunities	**Threats**
• Multidisciplinarity creates an opportunity to reduce bias in V+V • Creates the ability to predict and plan for outcomes before implementation • Rigorously assessed examples • Model validation methods • Systems uncertainty modelling is a hard science • Trust can be understood as an emergent property of social processes mediated by technology • Greater public demand for more confidence because of awareness of autonomous systems • Numerous engaging application areas – creates public interest	• Problem is viewed as too difficult to tackle at all • Failure to address individual aspects • Failure to consider influence of human factors in systems engineering • Great ideas/systems fail because they cannot give confidence, trust (people walk away from it) • Failure to understand loss of human/democratic control over systems • Unknown threats/security issues • Lack of understanding of the effects of uncertainty • Discipline barriers to systems research

Integrating Socio-Technical Aspects of Systems Lifecycles

Strengths	**Weaknesses**
• Increasing appreciation of significance in industry and government organisations • Services oriented – user centric • This is really important to problem owners • Potential for significant impact if industry engaged – improvement in efficiencies • It can make existing and new systems work better • Integrated systems are fundamental to securing resource savings/efficiencies • Fundamental property of smart (systems) cities/living	• Links between systems engineering and systems theory are rarely discussed/understood • Lack of data • Leaves out socio-ecological, fails to appreciate the mediatory role of technology between social/biophysical • Fluffy science • Flakey engineering • Mutual misunderstanding, hostility even between engineering and social methodologies • Credibility • Title doesn't mean anything to problem owners • It is still part of something bigger
Opportunities	**Threats**
• 'Merging' of research councils • Integration of techniques from different disciplines • Address the interaction of various issues • Cross-industry product/services development • UKRI • …in a language they understand • GCRF where linking supply chains can deliver net gains for developing communities • Holistic, joint/better problem solving • Potential positive impact on policy and practice in many domains • Opportunity to engage a large number of industry and government partners • Autonomy and human behaviour • An opportunity for EPSRC to locate systems engineering on a high impact, integrating functions – can be built on national priority challenges e.g. health/social care challenge	• Peer review process does not tend to support socio-tech very well • To think systems engineering only applies to building 'stuff' • Analysis without solutions • Spans EPSRC, ESRC plus others • A need to ensure outputs are relevant and practical. Clear link to application. • Involves many and very diverse communities • Perception that systems engineering is inherently high-TRL with no opportunity for science • Significant risk of not understanding failure of integrated infrastructure e.g. energy, transport, comms, emergency response…

Applications

<table>
<tr>
<td>Strengths

Small interventions in large systems
Many different, diverse application areas
Applications are essential to doing meaningful systems research
Plenty of natural energy resources
SYSTEMS ENGINEERING absolutely necessary to achieve outcomes
Understanding the real world
Provides foundation of challenges and potential impact
Some good foot-holds already but is this recognised? (also a weakness)
</td>
<td>Weaknesses

Focussed in applications not outcomes
SYSTEMS ENGINEERING aspect not fundamental research
Systems science not systems engineering? (more easily adapted across disciplines)
Lack of test beds – accessible to research teams, at scale
What is the real meaning of systems engineering? Fundamental vs applied research?
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<td>Opportunities

Learning between application domains, knowledge transfer
Large civil engineering projects
Unconventional applications at sea or underwater
Applications support impact
Failing health systems
Internet, ICT, Digital Economy, Shared/Network Economy
Cross-sector learning and best practice/results sharing
Need for indepth domain knowledge to re-apply between domains (also a threat)
Cross-sector resource benefits – impact (theory to understand vulnerability and resilience of integrations)
</td>
<td>Threats

Not having a unified body of SYSTEMS ENGINEERING knowledge
Not really research as just ‘doing stuff’
Lack of data on system structure behaviours
Lack of funding on the development of approaches
Only interested in application and not generic underlying issues
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What is done well?

- Look at INCOSE and higher level apprenticeship standard for some of the evidence
- RAEng activity (including visiting Professor programmes)

What could be done better?

- Strengthen the systems thinking in practice elements through increased investment and research which examines cognitive and behavioural and institutional constraints to enacting systems thinking in practice (STiP)
- More collaboration with industry on low TRL research
- We have talked enough about ‘services’

4.4.3 Next steps - challenges over the next 20-50 years

- Augmented intelligence
- All day to day decisions driven by data driven algorithms
- Systems engineering will need to be aware of implication ethically of their design
- High capacity small power
- Systems engineering will have to respond to what people value
- Machines in the human
- Radically different responsibility and ethics
- Systems engineer method to evaluating social threats and mitigating crime
- Systems engineering used design new society or meet societies needs
- Enduring challenges safety, crime, security, sustainablity
- Reverse engineering diagnostic/'forensic systems engineering' How does this system work?
- Systems Engineering for colonising the moon
- The systems engineering of anarchy (a world where every systems property is an emergent property) (and there is no governance)
- Systems Engineering in biology
- Retro engineering to the 1950s (creating a less connected world)
- Design differently for new manufacturing techniques
- Service-led systems engineering and systems engineering of services
- Systems engineering by machines. Why do systems engineers have to be people?
- Operational models driving design (reversing the engineering paradigm)
- Systems engineering for 'open' (really open!) systems
- Systems engineering for quantum technologies
- Integrated systems – culture, business, technical, social, law etc
- Plugging new systems into existing or legacy systems
- Challenges 20+ $\longrightarrow$ 50 None should be embedded in what we do
- Bionics
- Environmental Engineering e.g. carbon capture
- Understanding human control of the wider environment (weather, pollution etc)
- Sustainable systems
- Integrated energy systems
- Ability to apply systems engineering for global sustainability
- Weather engineering
- Systems for living in extremely hostile environments (space, underwater, arctic)
- 50 yrs - systems engineering done by computers!
- Handling chaos – coping with critical systems too complex to validate
- Self evolution of product design
- Self learning for self design
- Tools and processed for automatic optimisation, V+V for all systems (inc. mission critical)
- Adaptive/reconfigurable autonomy
- Continued need for STEM pipeline and more systems engineers
- Personal/professional accountability

- Handling chaos
- V+V of additive manufacturing + 3D printing revolutionising the logistic supply chain
- De-skilling via automation
- Systems engineering to act in the framing of problems to appreciate the implications
- Application at scale. Taking on much larger systems of systems
- How we respond to rapid and unpredictable changes in infrastructure
- For systems thinking/systems engineering to be our natural approach
- To have embedded the skills from early childhood
- Facilitating, negotiating, influencing
- Defining what it means to be a systems engineer
- To have a coherent theoretical basis for systems engineering
- To enhance working practices to influence lifecycle timelines
- Machine learning across applications
- Augmenting human capabilities
- Knowledge management providing the feedback and audit trail for projects and programmes
- To focus on attainable challenges
- Controlling and responding to the effects of human decisions/actions from now
- For systems engineering to be recognised as vital discipline in addressing global grand challenges
- Modelling and design in face of uncertainty
- Increased complexity of cyber-physical systems
- More instances of multiple overlapping shocks to systems under greater stress
- Greater need for resilience in the UK and threats are getting bigger – higher impact as we depend more on interconnected technology
- Design traceability and provenance as standard (built into tools)
- Resource constraints increase need for whole system (not sub-system) robots optimisations
- Validation of models used to predict and respond to systems failures
- Greater range in system age and rate of evolution
- Diversity is an important property of resilient system. But which legacy systems do we retain and which are allowed to die?
- ‘DevOps’ processes routine and reliable
- Increasing use of flexible compute resources make model-based design affordable for small businesses
- Ubiquitous autonomous systems
- Leverage massive growth in data
- Ubiquitous compositional resilience
- Food productions
- Space travel, farming,… (volume production of space machines)

4.4.4 What should the UK do in this area?

- Be more collaborative to address the challenges in EPSRC calls, workshop
- Increase the funding and resources available for research and education
- Better relationship and understanding between industries and universities regarding the forthcoming challenges in systems engineering
- Embed engineering thinking in government
- EPSRC: ask for systems angle in calls for proposals
- Systems engineering should cut acorss research councils
- Establish/create forum where systems research is tested in multiple contexts
- Link systems engineering research agenda to specific development plans e.g. next infrastructure plan
- Support thematic systems engineering centres (joint institute) of excellence – linked to cross-centre impact accelerations
- EPSRC could help by…targeted systems engineering calls/sandpits with a thematic focus and systems engineering challenge
- Unified activities on systems engineering across RCUK
- Promote multidisciplinary discussions around systems engineering to promote research and involve industry
- Promote international visibility in systems engineering + more funding for systems engineering regardless of application field
- Create systems engineering hub with many institution involvement
- Link systems engineering to impact in all engineering proposals
- Work closely between academic and industry on systems engineering research
- Much more prevasice and proactive promotion of systems engineering
- Appoint a Chief Engineering Advisor
- Employ Chief Systems Engineers towards non-traditional/social problems
- Embed systems approach in decision making for all government departments
- Set a clear agenda for systems engineering research in the UK
- Stay globally connected on systems engineering and engineering
- Create a link with US systems engineering community (NSF had a workshop in Jan 2017)
- Learn from other communities (applications and underlying science)
- Form partnerships with international research communities
- Co-creation with stakeholders, value-proposition for SE
- Provide mechanisms to allow systems engineers to work alongside large research programmes
- Use systems engineering more to understand the impact of policy, governance, KPIs etc
- Make sure systems engineering research has a prominent place in the RCUK agenda, and it is delivered by systems engineers
- Identify the benefits of using a systems approach for policy making and use a systems approach within other communities (security, healthcare etc)
- Providing policy industry decision maker evidence based systems engineering
- More systems engineering research (reflect on workshop outputs)

- More systems engineering research
- Deliver impact from systems engineering research
- UKRI to be lobbied for funding for systems engineering
- Invest more in understanding and improving resilience
- Educate children about systems
- Stop treating systems engineering, sytems science and systems thinking as separate disciplines and research domains
- Research toward broader view of systems – beyond 'closed systems' to understand wider interdependencies
- Facilitate Health + Care. Transformation through introduction of systems engineering
- Convene a cross-domain systems engineering strategy advisory panel
- 'Systems Engineering for Dummies'
- Establish national systems engineering research hub (involving other areas, social, law, business etc) and covering low to mid TRLs (RCUK and Innovate UK) with industry
- As I-A systems engineering training programme
- Operating systems as starting point for design of new interventions
- Build portfolio of research and support to raise profie/impact of systems engineering
- Leverage investment across UKRI for systems thinking in practice capability and research benefits and contraints
- Form communities across disciplines
- Identify the unique systems engineering theoretical research vs the multi-disciplinry applied systems engineering research
- Identify the unique contributions the UK can make internationally
- Identify 3-5 areas of engineering applications which rely on systems engineering and are of national importance
- Determine whether and how much 'systems engineering' overlaps with other themes such as energy systems and publish this report
- Get feedback from industry on whether they have the same/different ideas regarding systems engineering
- Develop a joined up research – innovation chain (post merge with Innovate UK) for SE
- Work with e.g. learned societies to define 'good' SE research e.g. methodology (prior to establishing CDTs)
- Promote systems engineering as a route to impact now (invite integrative projects)
- Identify the grounds for a 4* review
- Develop a clear UKRI narrative/vision for systems science and engineering
- Focus on resilience and performance in an increasingly uncertain and competitive world
- Drive systems thinking/dynamics/science into secondary education