Engineering X

Safer Complex Systems strategy

Royal Academy of Engineering

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EngineeringX

Engineering X is a new international collaboration founded by the Royal Academy of Engineering and Lloyd's Register Foundation that brings together some of the world's leading problem-solvers to address the great challenges of our age.

Our global network of expert engineers in academia and industry are working in partnership with leaders in business, government and civil society to share knowledge and best practice, explore new approaches and technologies, and educate and train the next generation of engineers to improve safety and deliver impact.

The Engineering X community will bring together partners from around the world, building on a network of global alliances to tackle the most pressing safety and sustainability challenges, and developing practical and inclusive solutions for the engineering profession worldwide.

You can find more information about Engineering X and its other Missions on our website.

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Lloyd's Register Foundation

Lloyd's Register Foundation (LRF) is an independent global charity that helps to protect life and property at sea, on land, and in the air. The Foundation has partnered with the Academy to tackle the most pressing engineering safety and sustainability problems, and to develop these into practical and accessible outputs for the engineering profession and affected communities.

Royal Academy of Engineering
Prince Philip House
3 Carlton House Terrace
London SW1Y 5DG
Tel: 020 7766 0600
www.raeng.org.uk
@RAEngNews

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Contents

Introduction to Safer Complex Systems

All around the world people rely on critical infrastructures to survive, stay safe and maintain a good quality of life. Much of this infrastructure, for example food and water supply, healthcare, education, housing, transportation and communications, is made up of complex systems that are highly interconnected and interdependent on one another. As the devastating COVID-19 pandemic has demonstrated, when one complex infrastructure system fails, many other complex systems are also affected, which can have catastrophic consequences for people's lives.

Complex systems play an increasingly important role in people's lives and the list of complex systems is long and continually growing, including:

- supply chains that provide fresh food from around the world to local supermarkets
- energy systems that extract energy from wind, sunshine, tides, biomass, and fossil fuels and make it available in our homes
- health and social care systems that link frontline staff with pharmaceutical research, Personal Protective Equipment (PPE) providers, and professional training
- autonomous ships navigating busy shipping lanes to transport goods internationally
- international data networks that connect phones, computers and media
- the financial system allowing international credit card usage and providing access to money for business and industry.

The world's climate is an important example of a complex system – air temperatures, concentrations of CO^2 and other 'greenhouse gases', hurricanes, droughts, forest fires, ocean temperatures and circulation, polar ice cover, ocean acidity, survival of coral reefs, species migrations, melting of permafrost and many other natural phenomena are all interlinked. Changes in one can impact many others via complex feedback loops, many of which are not well understood.

Most complex systems are socio-technical – there are humans in the loop - either in their design or during their operation. Some complex systems are *engineered* – there is a plan, the participants are known in advance, and there are protocols and regulations in place for successful operation. A city metro system may be complex, but there is little ambiguity over its geographical extent, assets, operations or responsibility for the safety of the network. Other complex systems can be *ad hoc* systems that emerged without any planning and with no-one being accountable – there is no central authority, players join and leave at will, and regulation covers multiple jurisdictions. Supply chain management during the COVID-19 crisis has revealed how the global PPE supply chain is an ad hoc system with many places around the world needing to innovate and repurpose local production to manufacture PPE as international supply chains failed.

Often people find themselves in a complex system-of-systems that, until one system fails and there is a cascading effect on lots of other systems, no-one had previously thought as interconnected. Flooding in the UK in 2015 demonstrated the unplanned interdependence between the UK electricity system and many essential services including communications, banking, food supply, mobility, the health service and many other aspects of life we often take for granted. With more areas of life becoming subsumed into complex technological systems, this is an area that engineers will increasingly be expected to understand and take a lead in resolving problems and instabilities.

With this in mind, in 2019 Engineering X launched a £5 million five-year mission, Safer Complex Systems, to enhance the safety of complex infrastructure systems globally. Safer Complex Systems is governed through a Board chaired by Dame Judith Hackitt DBE FREng, former Chair of the UK's Health and Safety Executive and leader of the UK government's Independent Review of Building Regulations and Fire Safety conducted after the tragic Grenfell Tower fire in London, UK.

A message from the Chair

Dame Judith Hackitt DBE FREng
Chair of Safer Complex Systems

The world is a different place from when we started the Safer Complex Systems mission. In early 2020 the COVID-19 pandemic shifted the frame of reference for us all and demonstrated how the increasing complexity and interconnectedness of the world we live in has made us all more vulnerable to systemic shocks of this nature. A major global safety challenge, therefore, is to develop our understanding of the root causes of systemic failure and to take collective action to prevent or mitigate against future events with a similar potential to harm.

Our experience of the COVID-19 pandemic tells us that our work to enhance safety in complex infrastructure systems is more important and urgent than ever. As we begin to rebuild we need to ask ourselves three questions: how can we manage complexity more effectively? How can we find ways to simplify and share knowledge and good practice? And how do we raise awareness and increase competency across engineering disciplines and beyond?

This strategy document is based on our current understanding of this subject area and the priority needs outlined by the Safer Complex Systems community. This mission is a complex system in itself, we are learning by doing and there is always the need to adapt our plan as new learnings arise. As we engage with a wider global community and our understanding of the subject develops, we may need to revise or reprioritise our strategy to meet the needs of our global complex systems community. As we navigate through future phases of the Safer Complex Systems mission, we will closely monitor and evaluate our work and our success with be determined by our demonstrable impact.

We hope that this short summary of the Safer Complex Systems mission's journey so far, which includes links to the publications that have informed our new strategy, will help you to think further about these issues and consider how we can all work together to engineer safer outcomes in an increasingly complex world. **Join us.**

The Safer Complex Systems journey

2019 to 2021

PHASE 1: LEARN

Listen to a diverse expert community to develop an understanding of the landscape of safer complex systems, to identify what practical change is needed and who can help make it happen

2021 to 2023

PHASE 2: BUILD

Build a diverse community and equip them with educational resources and mechanisms to support knowledge sharing and collaboration so they can advocate for and effect change

2023 ONWARDS

PHASE 3: LEAD

Engineering profession recognised as thought leaders on safety in complex systems, and play a significant role in supporting other professions and helping to shape global agenda

Figure 1: A five-year plan for Safer Complex Systems

Fire in an informal settlement in Cape Town, South Africa.

Phase one: Learn (2019 to 2021)

LEARN → BUILD → LEAD

Phase one: Learn (2019 to 2021)

In 2018, LRF commissioned an insight report on global safety challenges, which made numerous references to complex systems and how failure of such systems can threaten safety. With this and many other independent sources pointing at complex systems as a risk to safety, LRF and the Academy partnered to explore the topic further and founded the Engineering X Safer Complex Systems mission in June 2019.

The Safer Complex Systems mission began with an initial scoping workshop held in July 2019, where Engineering X brought together around 40 experts from different sectors and disciplines to share thoughts on complex systems safety. Workshop participants agreed that the rapidly-changing and increasingly complex nature of the world we live in means that systems operate at ever greater levels of uncertainty and unpredictability. In this context, participants confirmed our views that the safety management tools of the past are no longer appropriate for the complexity of the issues we are currently facing. Participants suggested that we commission a piece of research to help understand what we already know about safety and complex systems, what tools exist, and how relevant knowledge is currently being shared across different sectors, disciplines and international contexts.

In December 2019 Safer Complex Systems commissioned the University of York to undertake this research. The resulting *Safer Complex Systems: An Initial Framework* report is an important first step in our journey to support society to better manage complexity. Through powerful case studies, it highlights the need to systematically understand all of the elements of a system, their interconnectedness, and the non-linearity whereby a simple failure in one place can lead to a surprising and disproportionate effect elsewhere. The report generated the following six recommendations for the Safer Complex Systems mission:

i. Develop approaches for better communicating risk, increasing trust and forming consensus on acceptable levels of safety.

ii. Acknowledge and address complexity in oversight, regulatory structures, legal accountability, and policymaking.

iii. Develop methods to address equality, diversity and inclusion during risk management and promote heterogeneity of thought.

iv. Integrate simulation, model-based analysis and digital twins into design and operational-time controls.

v. Develop an integrated and complementary set of methods for analysing risks in complex systems.

vi. Identify design-time and operation-time controls for increasing system resilience.

Importantly, the report also made a start on creating a framework (see Figure 2) to enable people in different sectors and disciplines to analyse systemic failure and discuss how to manage safety in their different contexts.

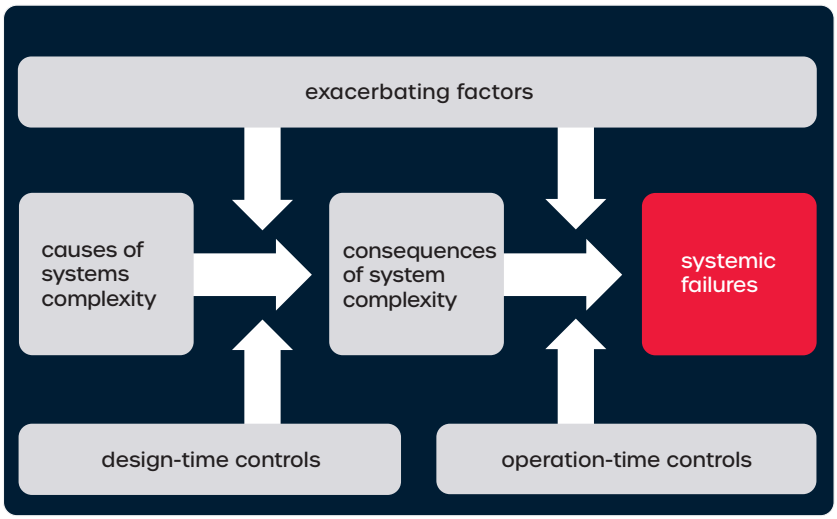

Figure 2: An initial framework for analysing systemic failure and managing complexity safely

The University of York report, which includes the above recommendations and framework, was one of two key inputs into the Safer Complex Systems workshop held virtually in September 2020 for 131 participants from 20 countries across six continents. In addition to the University of York report, workshop participants also discussed the findings of the *Exploring the safety of super-sized structures* workshop, which focused on the fact that few large structures exist simply as engineering structures, most form part of complex socio-technical systems. The workshop made the following recommendations, which are primarily aimed at a UK audience but the principles also apply internationally:

- **Outcomes-based regulation** – placing responsibility with the owner/risk creators is most effective, but we must recognise that with complexity comes the significant challenge in identifying a single point of responsibility and maintaining a clear sightline of accountability.
- **Competency** – the Engineering Council and the professional engineering institutions need to consider competencies required of registrants for CEng. They need to be fit for contemporary purpose, including the practical considerations around cross-disciplinary working, systems thinking and a sound appreciation of ethics in engineering practice so that professionals deliver work with honesty and commitment.
- **Research** – understanding low occurrence, high consequence 'Black Swan' events that impose risks on engineered structures, particularly high occupancy buildings and geotechnical and bridge constructions. We need to understand how to quantify and articulate this for people deciding budgets so that the correct safety engineering can be built in.

Professor Roger Kemp MBE FREng, Workshop Convenor, summarised the Safer Complex Systems September 2020 workshop discussion and recommendations in this *Safer Complex Systems workshop 2020* report.

The majority of workshop participants found both reports to be interesting and the framework to be useful. While participants affirmed the value of our efforts, it was clear that there is still much more work to be done. For example, it was suggested that we should test the relevance and applicability of the framework in new global contexts and in non-engineered, ad hoc systems (for example, humanitarian supply chains or fire safety in informal settlements). The testing and validation process by our community is ongoing and we plan to publish an evidenced report on this later. We have included some initial observations from the community below:

- It would be helpful to present the framework in a way that supports iteration of the model.
- There is a need to expand the scope of the framework to cover anthropological and sociological aspects, and for more social, behavioural and cultural issues to be taken into account when framing the risk. Combining this framework with other behavioural frameworks that already exist may be a way of achieving this.
- Adding granularity within the layers of the framework may help to capture the interdependencies and interfaces between different levels of the system.
- The framework is a useful tool that prompts people to ask the right questions.
- The framework lacks a conception or early planning stage ahead of the design phase where the seeds of problems can be sown.

We will explore this valuable feedback in more detail in the next stage of the mission. Aside from commenting on the usefulness of the framework, workshop participants collectively recommended the following focuses for Safer Complex Systems:

- **A lexicon of safety** - There was confusion over definitions and the relationships between safety, resilience, robustness, efficiency, and antifragility for example, which are terms that have different meanings in different sectors. There are also questions, such as how to measure resilience or robustness and how to factor in security associated with external malicious intent. Engineering X could support the production of a lexicon that analyses the various definitions, their usage in different environments and how they can be translated across disciplines, from domain to domain, between academic study and public usage and internationally. There is also still confusion over the differences between complex and complicated.
- **Acceptable levels of risk** - None of the groups came up with a formulation of the acceptability of risk. Defining acceptable risk in an ad hoc complex system that affects a spectrum of communities is particularly difficult. Engineering X could support a study to investigate the way in which people view and assess risks, including differences between regulators and the public. What does 'safety' mean in, for example, a humanitarian system where a failed outcome is destitution, stunted development and ill-health? There is also a need to factor in the risk of the system versus the risk of 'doing nothing'

– particularly important when the system is designed to counter pre-existing hazards. For many systems, quantitative measures of safety may not even be possible. If this is the case, should trust be the objective?

- **Regulating the safety of complex systems** - Internationally, there are many different regimes for regulating the safety of hazardous situations. Most work adequately for well understood hazards but can produce anomalous decisions for complex or unusual hazards and are poor at regulating low-probability, high-impact events. Are existing laws adequate and, if not, what changes are needed and how might complex systems be regulated?
- **Support for case studies** - Good case studies of successes and failures could make a major difference to the understanding of the safety of complex systems. A challenge with complex systems is the long feedback loops and the interactions with humans in the system. A classic narrative form often doesn't capture it and so we might need a new style of case study and a new way of teaching them. Perhaps we need to redesign the concept of a case study or at least recraft the structure to enable maximum learning? In studies funded by Engineering X, it would be useful if authors could align the case study with the University of York framework and comment on the appropriateness of the framework for that study.
- **Diversity and inclusion** - To ensure all aspects of a complex system are considered, a multidisciplinary team is needed. It is important to include people from different backgrounds and viewpoints – for example, giving a voice to occupants and users of a building, not only the owners and architects. Some of these groups will be uncomfortable with the terminology of risk analysis or expressing themselves in the erudite language often used by safety professionals. Organisations, and the professionals employed by them, need to develop means of communication that can be widely understood by diverse groups of people. Could Engineering X commission work on diverse team building and communication?
- **Education** - Engineering and business degree courses are generally deficient in teaching complex systems: the courses have not kept up with the way the world has changed. It was suggested that Engineering X could set up a Safer Complex Systems Education and Training Group to work towards an international programme of education. An understanding of complex systems is particularly important for policymakers who may determine the governance layer.

As shown above, Safer Complex Systems workshop participants identified a lack of case studies for engineering education and professional development relevant to complex systems. In response to this, Safer Complex Systems has now commissioned 19 case studies (see Figure 3) to examine complex system successes and failures (past or present) and explore how a specific approach to the design, management or governance of a complex system has resulted in safe or unsafe outcomes. Each case study is capturing the underlying principles for success or failure, and we will share these important learnings across sectors and disciplines to help create safer practices in complex systems globally.

Written case studies will continue to be developed in the next stage of the mission – the 'Build' phase - and will be finalised by November 2021 and launched at a global workshop shortly afterwards.

Project lead name	Project lead organisation	Project lead country	Project title
Matías René Rojas De Luca	Socialab	Chile	Social innovators as a human sensing network solving humanitarian challenges of the 21st century
Dr Giuliano Punzo	University of Sheffield	UK	Cyber-physical system shortfalls in the 2011 Brisbane flood
Dr Jonathan Gosling	Cardiff University	UK	Complex systemic failures in the Edinburgh schools case
Professor Richard Taylor	University of Bristol	UK	Improving resilience to major safety events in industry
Professor Chengi Kuo	University of Strathclyde	UK	Ferry disaster provides vital global safety lessons
Dr Chris Elliott MBE FREng	Pitchill Consulting	Switzerland	Bexley train crash – a system failure
Dr Richard Judge	Bartlett Judge Associates	UK	Planned adaptive regulation – as applied to the Dutch 'Delta Programme'
Professor Roger Kemp MBE FREng	Lancaster University	UK	The Hatfield derailment – a problem of governance?
Brian Tomlinson	Network Rail	UK	A systems approach to reducing train accident risk
Danielle Antonellis	Kindling	USA	A comparative study of fire risk emergence in informal settlements in Dhaka and Cape Town
Dr Yin Jin Janin	TWI	UK	Structural integrity management of energy infrastructure
Professor Steve Gwynne	Movement Strategies	UK	Vulnerability and evacuation strategies of rural communities threatened by wildfire
Dr Kristen MacAskill	University of Cambridge	UK	Australian climate extremes and building transport network resilience
Professor Andrés Medaglia	Universidad de Los Andes	Colombia	Understanding the dynamics of an emergent cycling transport system during the COVID-19 pandemic
Dr Richard Judge	Bartlett Judge Associates	UK	Beyond the limits of knowledge – navigating uncertainty in complex systems
Claire Travers	Field Ready	Sweden	Analysing humanitarian supply chain crashes, recovery and alternatives during COVID-19
Professor Dr Joachim Sturmberg	University of Newcastle	Australia	Systemic failures in nursing home care
Dr Brian Haddock	Network Rail	UK	Delivering a seasonally agnostic railway
Professor Francis Livens	University of Manchester	UK	Towards a simpler and safer nuclear sector

Figure 3: Details of 2021 case study awardees and projects

Phase two: Build (2021 to 2023)

LEARN → **BUILD** → LEAD

Phase two: Build (2021 to 2023)

After two years of evidence gathering, building an expert community and listening carefully to the challenges they are facing, we have refined the scope of Safer Complex Systems to focus on four key areas for the 'Build' phase over the next two years:

GOVERN

Supporting innovative collaborations and experimental mechanisms to test new ideas for complexity-appropriate policy and regulation

EDUCATE

Develop written case studies and innovative, educational tools to support engineering education and professional development

ADVOCATE

Supporting researchers to spot emerging safety challenges and supporting professional engineers to spot systemic risk and advocate within their organisations and beyond for measures that mitigate against it

CONVENE

Build and convene an active, diverse community of complex systems experts and build mechanisms to facilitate knowledge sharing across sectors and disciplines globally and the application of academic knowledge into practice to enact change

Figure 4: Four focuses for Safer Complex Systems 'Build' phase (2021 to 2023)

Structural engineers in disaster relief training in earthquake ruins in Sicily, Italy.

Educate

What we believe

As the world becomes increasingly complex and unpredictable we must not allow it to get any less safe. We therefore need to better understand how to safely interact with our changing world.

To achieve this we need a radical rethink of what is and is not in an engineer's education and we need to better understand how to train engineers so they have the necessary competencies to understand and manage issues arising out of complexity in a safe way. We need to develop new educational resources to support this process.

We believe that complex systems and complexity thinking, cross-disciplinary working, systems thinking, ethics and sustainability should sit at the core of engineering education and professional development to keep society safe. It is also vital to enhance the understanding and skills of people outside of engineering who also play a role in upholding safety in complex systems. For example, policymakers, social scientists, professionals working in finance, insurance and risk management sectors, and many others.

As our world becomes increasingly complex, things get more difficult to predict as we can no longer base our understanding and our approach to safety management on things that have happened in the past. Existing tools that have previously worked for us are no longer suited to the new context we are working in and we cannot keep using old tools for new problems. We need to develop new tools to help us manage safety and we need greater visibility and sharing of new safety management tools that have already been developed amongst the global community.

What we will do

We will support a global discussion on the changes required in engineering education and professional development to better understand how we can equip engineers and non-engineers to manage safety in an increasingly complex and unpredictable world.

We will continue to develop a portfolio of written case studies that examine systemic successes and failures arising out of complexity. Information about our case study awardees can be viewed on the Academy website. This case study work shows us what we can learn from things that have worked well or gone wrong in the past and anticipates what we will need to stay safe in the future so that we can all live in a complex society in a safe way. Case study awardees will continue to test the applicability and usefulness of the University of York framework (see Figure 2) as part of their work. To create impact, we will share the case study learnings with our target audiences – for example, engineers in academia and industry, policymakers and senior business leaders - across a range of different communication channels to educate them on the subject. In the next stage of the case study work we will develop a suite of innovative, educational tools to support the education and professional development of engineers and other stakeholders who play a significant role in the safety of complex systems.

As our world becomes increasingly complex, things get more difficult to predict as we can no longer base our understanding and our approach to safety management on things that have happened in the past.

Govern

What we believe

Governance of complex systems includes the laws and regulations that govern its design and operation, and the management structure that is put in place to design, engineer and operate the system as well as the norms, cultural understandings and assumptions by those who operate within and around it. It often consists of a heterogenous group of players including national governments, international bodies, shareholders, regulators, standards organisations, the criminal justice system, professional and accountancy bodies, and trade unions and the larger institutional structures, frameworks and norms in which they are embedded.

Governance creates the environment in which a complex system is built and operates. In some cases, it can be a catalyst for contributing towards, rather than helping to prevent, systemic failure. As systems evolve to increasing complexity, traditional forms of regulation become impossibly complicated and there is a need for reform to develop a legal or regulatory system that recognises complexity and responds appropriately. Furthermore, we need to listen to diverse voices and set up the structure of a project so that managers take into account the views of everyone who might be affected or who has a useful contribution to make.

What we will do

We will shortly hold a *Governance of complex systems* roundtable on the subject to better define the scope of this workstream and to decide on the types of activity we will support. We anticipate supporting innovative collaborations between different governance stakeholders and provide seed funding for experimental mechanisms to test new ideas for complexity-appropriate policy and regulation. Our work will build on the Lloyd's Register Foundation Foresight Review of The Future of Regulatory Systems.

We welcome suggestions of organisations or other programmes of work that we should be aware of or partnering with in this area. If you are interested in attending the *Governance of complex systems* roundtable or if you have recommendations of organisations (in the UK or overseas) for us to invite along we would love to hear from you.

Governance creates the environment in which a complex system is built and operates. It can be a catalyst for contributing towards, rather than helping to prevent, systemic failure.

Advocate

What we believe

When catastrophic systemic failures occur, there is nearly always someone who has predicted it and raised concern yet no one has taken preventative action. We want to prevent this from happening by proactively changing culture, mindsets and behaviour within the communities that develop, operate and use complex systems to help engineers mitigate against longer-term threats to safety.

Senior leaders make better, safer decisions when they draw on diverse perspectives. We believe that senior leaders in evidence-based organisations can too readily dismiss safety concerns based on intuition, however gut feeling can often identify an arising issue before the evidence catches up. We believe stronger communication between engineers exposed to risk and senior leaders accountable for safety will improve safety in complex systems and help to save lives. We also believe that inclusive organisational cultures will encourage engineers who spot risks to raise concerns about safety and make it easier for senior decision-makers to ask for help when making safety-critical decisions.

What we will do

We want to support the engineering community to spot systemic risk and advocate within their organisations and beyond for measures that mitigate against it to make the changes needed to engineer a safer world.

Through this workstream, we plan to explore approaches that spot emerging safety challenges and we will deliver a programme of work that develops safety advocates at all levels to engineer safer outcomes for us all.

We will shortly hold a roundtable to better scope this workstream. We welcome suggestions of organisations or other programmes of work that we should be aware of or partnering with in this area. If you are interested in attending the roundtable or if you have recommendations of organisations (in the UK or overseas) for us to invite along we would love to hear from you.

We believe stronger communication between engineers exposed to risk and senior leaders accountable for safety will improve safety in complex systems and help to save lives.

Convene

What we believe

Safety professionals working in safety-critical environments across different sectors and disciplines globally use different context-specific terminology when talking about safety in complex systems. This difference in vocabulary inhibits communication and collaboration between people working in different contexts who are tackling the same safety issues arising out of complexity. This, in turn, stops much-needed knowledge sharing across sectors and disciplines globally and stops us from reaching our collective potential to design, manage and govern complex systems safely.

We need to better connect the thinking of academics with safety professionals in industry to create safer practices and policies that practically address issues that make complex infrastructure systems unsafe.

Different cultures internationally approach safety and risk management in very different ways and we can all learn from each other. To safely manage complex systems that span international boundaries and operate in different safety cultures, we need to foster knowledge sharing across international contexts where safety cultures differ.

Building a diverse community of people with different professional backgrounds, personal characteristics and lived experiences will lead to the creation of more useful, creative, and inclusive safety solutions that are applicable to a wider range of contexts and serve a broader spectrum of people.

What we will do

We will build global partnerships to address shared safety challenges and we will continue to convene an active, diverse community of complex systems experts across sectors and disciplines globally to input into our strategy and enact change.

To date, we have built a diverse community of engineers and non-engineers internationally. As we expand we will seek to make our community even more interdisciplinary and truly global. We will coordinate locally led in-country workshops in different parts of the world to support this. We will shortly commission stakeholder research to determine who we need to partner with globally to collectively and efficiently create the most impact.

We will build new mechanisms to facilitate networking, knowledge sharing, and the application of academic knowledge into industrial practice.

We will ensure young voices have a say in the direction and implementation of Safer Complex Systems to ensure we meet the needs of future generations.

Finally, as mentioned above, we have developed an initial framework that enables people in different sectors and disciplines to talk about, analyse, and manage safety in different contexts (see Figure 2). We will support our community to test this framework in new contexts and build on this work as appropriate.

Different cultures internationally approach safety and risk management in very different ways and we can all learn from each other.

The interdependency and interconnectedness of the Safer Complex Systems workstreams

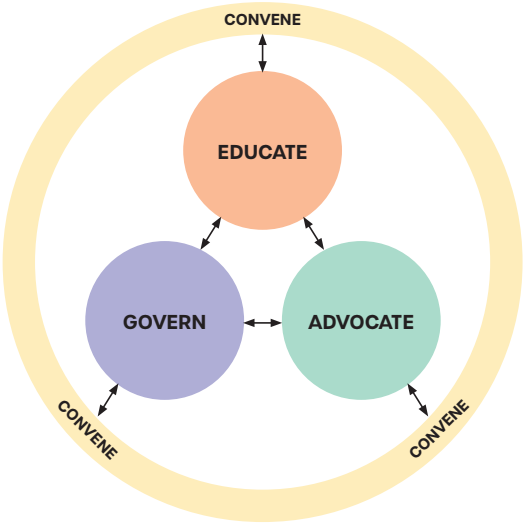

Figure 5: The iterative nature of the Safer Complex Systems mission

Figure 5 shows the interdependent nature of the different workstreams within Safer Complex Systems. Our Convene activities (for example, workshops and other events) support all other aspects of the mission. Our Educate, Govern and Advocate workstreams are guided by the expertise of our diverse, global community of engineers and non-engineers, including the members of our advisory and governance boards. We listen carefully to our community and try to respond to their needs wherever possible. At regular intervals, we consult with our community to assure ourselves on the quality and usefulness of Safer Complex Systems outputs and, together with our research awardees, keep up-to-date with the most pressing emerging safety challenges we should be addressing.

Outputs that emerge from one workstream will input into the others to ensure the activities are interlinked, aligned and supportive of one another. For example, written case studies that emerge from the Educate workstream will inform the strategy of our Govern workstream and will also support any initiatives we deliver through the Advocate workstream.

As this mission is a complex adaptive system in itself, each activity will inform the next and we expect to regularly adapt our strategy and direction as new learnings arise.

We listen carefully to our community and try to respond to their needs wherever possible.

Phase three: Lead (2023 onwards)

LEARN → BUILD → LEAD

Phase three: Lead (2023 onwards)

Of course, we expect to continue to learn and build far beyond our two initial phases, however as we progress into our 'Lead' phase from mid-2023 onwards, we hope that the engineering profession will begin to be recognised as a thought leader on safety in complex systems.

In this phase, we will continue to work towards our overall aim of safer design, management and governance of complex infrastructure systems globally. We will have built resources and relationships that have helped translate key learnings into improved practice and policies for the sectors and regions have much to gain. We will leverage these resources and our diverse network of experts around the world to share learnings as widely as possible and to maximise our global impact.

At this stage of the mission, we hope to play a significant role in helping to shape the global agenda. We hope to reach the point where the engineering profession leads in the prevention of systemic failure in engineered infrastructure systems and supports other professions to prevent systemic failure in non-engineered infrastructure systems globally.

Safer Complex Systems aims to support the global community in its safe transition to operating increasingly complex systems. We expect this change will take longer to achieve than the timescale of this five-year mission. If the value that this mission brings to the global complex systems community continues to be needed beyond the timescale of this mission then we will explore how best to enable this important work to be continued.

Engineering X lecture on 'wicked problems' delivered by Guru Madhavan in 2020.

Are you interested in joining the Safer Complex Systems community?

The Safer Complex Systems mission is now firmly established and we are seeking to expand our community to engineers and non-engineers working in academia, industry, government, non-profit and elsewhere where there is an interest in making complex systems safer globally.

Globally we have much to learn from each other and we share the belief that nobody has all of the answers. For this reason we want to engage with as broad a range of experiences, perceptions and cultures as possible in the spirit of learning from each other and to build up a fuller picture of what safety means in different parts of the world.

The main route for involvement is through funding opportunities or participation in annual international workshops but there are also opportunities for closer involvement with the steering groups overseeing the Safer Complex Systems strategy and activities.

If you are interested in Safer Complex Systems and would like us to keep you updated with information about future workshops, reports and funding opportunities, please contact Shelley Stromdale, Programme Manager (Safer Complex Systems) at Shelley.Stromdale@raeng.org.uk to join the Safer Complex Systems community.

If you are expressing an interest in closer involvement, it would be helpful if you could please include some brief information about yourself and your professional experience, or link us to your online profile, as well as highlighting any particular part of the mission you are especially interested in engaging with. We look forward to welcoming you into the community.

Network of social innovators in South America.

Governance

As Safer Complex Systems has developed over the last two years, the mission's governance has grown to meet the needs of the mission. In order to input necessary breadth of expertise into the mission's strategy, we have formed several layers of fit-for-purpose governance to oversee each area of activity as shown below:

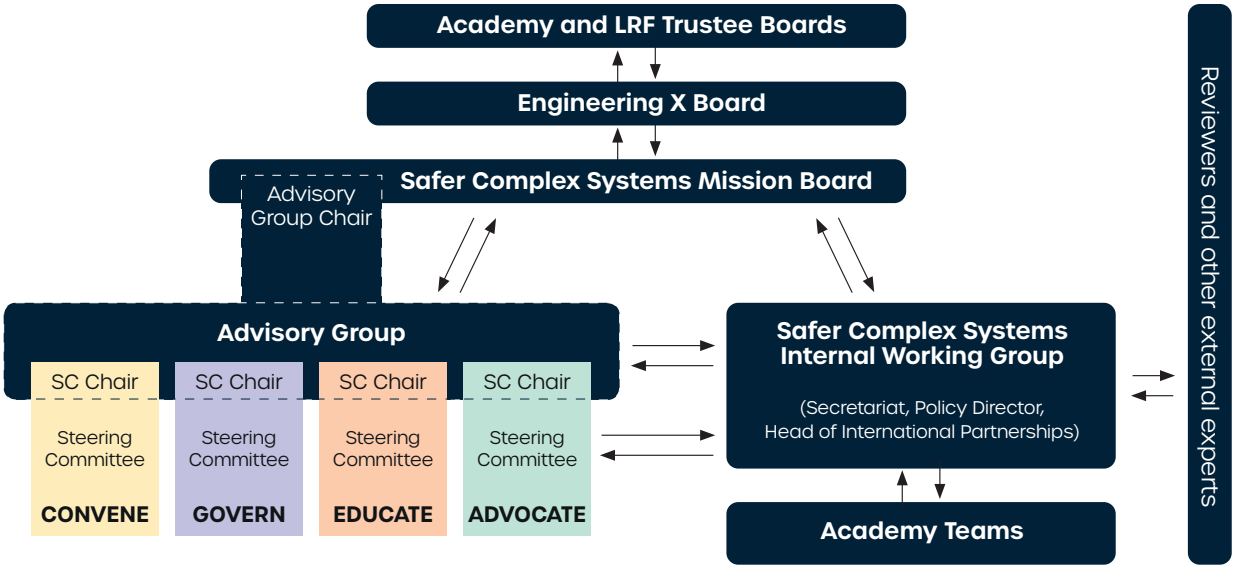

Figure 6: Safer Complex Systems governance

As a first step, please contact: Shelley.Stromdale@raeng.org.uk with your query, and Shelley can connect you with other members of the team.

Safer Complex System Team

Secretariat
Shelley Stromdale
Programme Manager,
Safer Complex Systems (Engineering X)
Royal Academy of Engineering

Board
Dame Judith Hackitt DBE FREng (Chair)
Chair, Make UK

Dr Jan Przydatek
Director of Technologies,
Lloyd's Register Foundation

Edward Fort
Global Head of Engineering Systems,
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Dr Nick Starkey
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Appendix of Acknowledgements

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The below table lists the individuals who have voluntarily contributed their time to support the governance of the Safer Complex Systems mission to date. The Safer Complex Systems Board would also like to pass on their sincere thanks to everyone who has attended our workshops, supported our review processes, or joined the community as an awardee – your generous contributions have been extremely valuable to the development of the Safer Complex Systems mission.

Name	Position	Organisation
Professor Robin Bloomfield FREng	Professor of Software and System Dependability	Adelard LLP and City, University of London
Steve Yianni FREng	Vice President	AIRTO
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Professor Philip John FREng	Emeritus Professor	Cranfield University
Michael Macdonnell	Director of Global Deployment	Google Health
Professor Nilay Shah FREng	Head of Chemical Engineering	Imperial College London
Dr Zsuzsanna Gyenes	Deputy to the Director	Institution of Chemical Engineers Safety Centre
Kerry Lunney	President / Chief Engineer	International Council on Systems Engineering (INCOSE) / Thales Australia
Dr Chris White	Senior Programme Manager	Lloyd's Register Foundation
Dr Joanna Boehnert	Lecturer in Communication Design	Loughborough University
Dr Thomas Jun	Senior Lecturer in Design School	Loughborough University
Duncan Kemp	Visiting Professor of Systems Thinking	Loughborough University
Howard Mathers CBE FREng	Former Technical Director	Ministry of Defence
Hideyuki Ando	Senior General Manager	Monohakobi Technology Institute

Name	Position	Organisation
Monika Szczyrba	Senior Technical Advisor - Water, Floods and Waste	National Infrastructure Commission
Professor Chan Ghee Koh	Director of Lloyd's Register Foundation Institute for the Public Understanding of Risk	National University of Singapore
Benjamin Kumpf	Head of Development Innovation Team	OECD
Dr Tingting Zhu	Royal Academy of Engineering Research Fellow	University of Oxford
Dr Chris Elliott MBE FREng	Director	Pitchill Consulting
Dr Juliet Mian	Technical Director	Resilience Shift
Shane McHugh	Head of International Partnerships	Royal Academy of Engineering
Shaarad Sharma	Head of Stakeholder Engagement	UK Government Office for Science
Professor Richard Parker CBE FREng	Chairman	Singapore Aerospace Programme
Diana Torres	Director	Suava Fundación
Shahana Buchanan	Global Head of Environment, Safety & Health	Sulzer
Dr Dougal Goodman OBE FREng	Vice President	The Foundation for Science and Technology
Professor Seth Blumsack	Professor of Energy Policy, Economics and International Affairs	The Pennsylvania State University and Santa Fe Institute
Matt Crossman	Deputy Director for Infrastructure	UK Department for International Trade
Professor Liz Varga	Professor of Complex Systems	University College London
Professor Jonathan Dawes	Professor of Applied Mathematics	University of Bath
Dr Rainer Groh	Royal Academy of Engineering Research Fellow	University of Bristol
Professor John Clarkson FREng	Director of the Cambridge Engineering Design Centre	University of Cambridge
Professor Ilaria Capua	Director of the One Health Center of Excellence	University of Florida
Professor C.C. Chan FREng	Honorary Professor and the former Head of the Department of Electrical and Electronic Engineering	University of Hong Kong
Professor Gary Burnett	Professor of Transport Human Factors	University of Nottingham
Dr Guru Madhavan	Senior Director of Programs	US National Academy of Engineering
Dr Mikela Chatzimichailidou	Associate, Directorate of Systems Engineering and Assurance	WSP