The Future of Systems Engineering: Systems Engineering Application Extensions

A Systems Community Initiative

EMEA WSEC workshop: SE and Climate Change, 26 April 2023

Tom Strandberg
Systems Engineering Application Extensions Stream Lead
FuSE Workshop: Extending SE to address climate change

- FuSE Application Extensions
- Introduction to the Topic: Gerhard Krinner
- Workshop
- Next steps
Systems Engineering Vision 2035

Executive Summary
• The Global Context for Systems Engineering
• The Current State of Systems Engineering
• The Future State of Systems Engineering
• Realizing the Vision

5 Categories:
- Competencies
- Research
- Tools & Environment
- Practices
- Applications

https://www.incose.org/about-systems-engineering/se-vision-2035
The world is coming to a conclusion that we need to take a systems approach to solve our challenges.

A better world through a systems approach

However, the world’s recognition of Systems Engineering and INCOSE is still very limited.
Industry adoption of SE

2. Systems engineering demonstrates value for projects and enterprises of all scales, and applies across an increasing number of domains.

3. Systems engineering anticipates and effectively responds to an increasingly dynamic and uncertain environment.

4. Model-based systems engineering, integrated with simulation, multi-disciplinary analysis, and immersive visualization environments is standard practice.

5. Systems engineering provides the analytic framework to define, realize, and sustain increasingly complex systems.

6. Systems engineering has widely adopted reuse practices such as product-line engineering, patterns, and composable design practices.

7. Systems engineering tools and environments enable seamless, trusted collaboration and interactions as part of the digital ecosystem.

8. Systems engineering practices are based on accepted theoretical foundations and taught as part of the systems engineering curriculum.

9. Systems engineering education is part of the standard engineering curriculum, and is supported by a continuous learning environment.
The FuSE program is organized in 4 streams with additional central teams.
**2025**


**2030**

Goal: Impactful application across domains underpinned by SE foundations and best practices supported by education and research.

**2035**

Goal: SE is the ‘go to’ discipline across domains to solve engineering and societal grand challenges. Synthesizing cross disciplinary practices, models and tools.

**VISION 2035**

Goal: Integration of practice across domains with majority adoption and institutionalization of tools and practices.

Goal: Evidence of wide reuse with system generative design underpinned by standardized libraries.

Goal: Broad implementation of SE theoretical foundations across domains guiding future research and applications.

Goal: SE embedded at all educational levels and across disciplines supported by innovative education and training approaches.

Goal: SE theoretical foundations taught at multiple institutions.

Goal: Democratized systems language widely used and supporting multi domain application. Working towards standardized libraries.

Goal: Formalize and standardize approaches underpinned by SE foundations across domains. Collaborate with academia and industry to embed knowledge further enhancing knowledge management.

Goal: Normalize community of practice with common SE foundations, definitions, and ontologies. Underpin knowledge management strategies to provide real time reuse of SE assets.

Goal: Moving toward standardization with agreed language and tools.
• Identify topics that can mobilize initiatives that can contribute to the realization of the SE Vision 2035 Roadmap.

  • Existing, e.g. Smart Cities Initiative
  • Potential new ones, e.g. Sustainability

• Stimula and support to initiatives
  • Typically, cross-WG, cross-organization

• Coordination and collaboration
  • products, papers, workshops, lobbying
How?

Define topics that can support extending the application of SE

Define target groups and the message required

Define how to approach the target group

Identify the resources required, internal and external to INCOSE

Stimulate and support joint initiatives
Initial Selection of Topics.

- Smart Cities
- Innovation
- Asset Management
- Grand Challenges
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A look at systems transitions in the IPCC AR6

Gerhard Krinner, IGE Grenoble
gerhard.krinner@cnrs.fr
A look at the very long term

Strong correlation between CO$_2$ concentration and global temperature
The current Andalusian heatwave

Record hot temperatures (for April) will likely be exceeded on Thursday
The global ocean

60°S-60°N average temperature above 21°C for the first time

>4σ above the 1982-2011 mean

Ocean is currently transitioning from La Niña to El Niño state – 2024 will likely be a new record year
Humanity is not on a trajectory towards 1.5 or 2°C warming by 2100.
Mitigation and adaptation options depend on the sector

**Reductions in GHG emissions in industry, transport, buildings, and urban areas:**
Combination of energy efficiency and conservation and a transition to low-GHG technologies and energy carriers

**End-use sectors:**
- Socio-cultural options and behavioural change
- Most of the potential in developed countries (if combined with improved infrastructure design and access)

**Energy:**
- Transitioning from fossil fuels without carbon capture and storage (CCS) to very low- or zero-carbon energy sources
- Demand-side measures and improving efficiency
- CDR
Urban sector:
Deep emissions reductions and integrated adaptation actions are advanced by:
• integrated, inclusive land use planning and decision-making
• compact urban form by co-locating jobs and housing
• reducing or changing urban energy and material consumption
• electrification in combination with low emissions sources
• improved water and waste management infrastructure
• enhancing carbon uptake and storage in the urban environment

AFOLU mitigation options:
• Can deliver large-scale GHG emission reductions and enhanced CO₂ removal if sustainably implemented
• Reduced deforestation in tropical regions: highest total mitigation potential
• Many barriers to implementation and trade-offs: impacts of climate change, competing demands on land, conflicts with food security and livelihoods, complexity of land ownership and management systems, cultural aspects
Many options exist for scaling up climate action quickly.

**There are multiple opportunities for scaling up climate action**

Feasibility of climate responses and adaptation, and potential of mitigation options in the near-term

<table>
<thead>
<tr>
<th>Climate responses and adaptation options</th>
<th>Mitigation options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy reliability (e.g., diversification, access, stability)</td>
<td>Solar</td>
</tr>
<tr>
<td>Resilient power systems</td>
<td>Wind</td>
</tr>
<tr>
<td>Improve water use efficiency</td>
<td>Reduce methane from coal, oil and gas</td>
</tr>
<tr>
<td><strong>Feasibility level and synergies with mitigation</strong></td>
<td>Bioelectricity (includes BECCS)</td>
</tr>
<tr>
<td>High</td>
<td>Geothermal and hydropower</td>
</tr>
<tr>
<td>Medium</td>
<td>Nuclear</td>
</tr>
<tr>
<td>Low</td>
<td>Fossil Carbon Capture and Storage (CCS)</td>
</tr>
<tr>
<td><strong>Confidence level in potential feasibility and in synergies with mitigation</strong></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td><strong>Net lifetime cost of options:</strong></td>
</tr>
<tr>
<td>Medium</td>
<td>Costs are lower than the reference</td>
</tr>
<tr>
<td>Low</td>
<td>0–20 (USD per tCO₂-eq)</td>
</tr>
<tr>
<td>Insufficient evidence</td>
<td>50–100 (USD per tCO₂-eq)</td>
</tr>
<tr>
<td><strong>Land Water Food</strong></td>
<td>100–200 (USD per tCO₂-eq)</td>
</tr>
<tr>
<td>Efficient livestock systems</td>
<td>Not allocated due to high variability or lack of data</td>
</tr>
<tr>
<td>Improved cropland management</td>
<td>Shift to sustainable healthy diets</td>
</tr>
<tr>
<td>Water use efficiency and water resource management</td>
<td>Improved sustainable forest management</td>
</tr>
<tr>
<td>Biodiversity management and ecosystem connectivity</td>
<td>Reduce methane and N₂O in agriculture</td>
</tr>
<tr>
<td>Agroforestry</td>
<td>Reduce food loss and food waste</td>
</tr>
<tr>
<td>Sustainable aquaculture and fisheries</td>
<td>Carbon sequestration in agriculture</td>
</tr>
<tr>
<td>Forest-based adaptation</td>
<td>Ecosystem restoration, afforestation, reforestation</td>
</tr>
<tr>
<td>Integrated coastal zone management</td>
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There are multiple opportunities for scaling up climate action

Feasibility of climate responses and adaptation, and potential of mitigation options in the near-term

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<tr>
<td>Sustainable urban water management</td>
<td>Efficient buildings</td>
</tr>
<tr>
<td>Sustainable land use and urban planning</td>
<td>Fuel efficient vehicles</td>
</tr>
<tr>
<td>Green infrastructure and ecosystem services</td>
<td>Electric vehicles</td>
</tr>
<tr>
<td>Enhanced health services (e.g. WASH, nutrition and diets)</td>
<td>Efficient lighting, appliances and equipment</td>
</tr>
<tr>
<td>Risk spreading and sharing</td>
<td>Public transport and bicycling</td>
</tr>
<tr>
<td>Social safety nets</td>
<td>Biofuels for transport</td>
</tr>
<tr>
<td>Climate services, including Early Warning Systems</td>
<td>Efficient shipping and aviation</td>
</tr>
<tr>
<td>Disaster risk management</td>
<td>Avoid demand for energy services</td>
</tr>
<tr>
<td>Human migration</td>
<td>Onsite renewables</td>
</tr>
<tr>
<td>Planned relocation and resettlement</td>
<td></td>
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<tr>
<td>Livelihood diversification</td>
<td></td>
</tr>
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Feasibility level and synergies with mitigation

- High
- Medium
- Low
- Insufficient evidence

Confidence level in potential feasibility and in synergies with mitigation

- High
- Medium
- Low

Net lifetime cost of options:

- Costs are lower than the reference
- 50–100 (USD per tCO₂-eq)
- 100–200 (USD per tCO₂-eq)
- 20–50 (USD per tCO₂-eq)
- Cost not allocated due to high variability or lack of data
The pace of the transition to net zero CO$_2$ depends on the sector.

Technology transfers allow to accelerate transitions (leapfrogging).
Strong and rapid action is possible, including demand-side mitigation

Demand-side mitigation can be achieved through changes in socio-cultural factors, infrastructure design and use, and end-use technology adoption by 2050.

### a. Nutrition

- **Food**
  - **Socio-cultural factors**
    - Dietary shift (shifting to balanced, sustainable healthy diets), avoidance of food waste and over-consumption
  - **Infrastructure use**
  - **Choice architecture and information to guide dietary choices; financial incentives; waste management; recycling infrastructure**
  - **End-use technology adoption**

### b. Manufactured products, mobility, shelter

- **Industry**
  - **Socio-cultural factors**
    - Shift in demand towards sustainable consumption, such as intensive use of longer-lived, repairable products
  - **Infrastructure use**
  - **Networks established for recycling, repurposing, remanufacturing and reuse of metals, plastics and glass; labelling low emissions materials and products**
  - **End-use technology adoption**

- **Land transport**
  - **Public transport; shared mobility; compact cities; spatial planning**

- **Buildings**
  - **Electric vehicles; shift to more efficient vehicles**
  - **Energy efficient building envelopes and appliances; shift to renewables**

### c. Electricity: indicative impacts of change in service demand

- **Industry**
- **Land transport**
- **Buildings**
- **Load management**

Reduced emissions through demand-side mitigation options (in end-use sectors: buildings, industry and land transport) which has potential to reduce electricity demand.

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1. The presentation of choices to consumers, and the impact of that presentation on consumer decision-making.
2. Load management refers to demand-side flexibility that can be achieved through incentive design like time of use pricing/monitoring by artificial intelligence, diversification of storage facilities, etc.
3. The impact of demand-side mitigation on electricity sector emissions depends on the baseline carbon intensity of electricity supply, which is scenario dependent.
FuSE Workshop: Extending SE to address climate change

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Extending SE to address climate change

The Challenge

SE state of application

Insights from EMEA WSEC

WHY should SE applied?

WHAT keeps SE from being applied?

HOW do we extend the application of SE? Who to approach? Who to work with?

Actions

Roadmaps
FuSE Workshop Summary

Extending SE application to address climate change

The Challenge

SE state of application

Insights from EMEA WSEC

WHY should SE applied?

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HOW do we extend the application of SE? Who to approach? Who to work with?

Actions

Roadmaps

Holistic approach to problem solving

Communication

Educate! Collaborate! Language
Photo Documentation

Team 1
Workshop: Extending SE to address climate change

Team 2 (1/2)

**Holism**
- BECAUSE WE MAKE CONNECTIONS ACROSS STAKEHOLDERS
- IT'S A SYSTEMIC PROBLEM
- HOLISTIC VIEW OF ALL FACTORS

**Lifecycle Approach**
- Integration and Continuous V / V is Important
- TO UNDERSTAND MEASURES OF SUCCESS / EFFECTIVENESS

**Skills**
- we draw the Best diagrams? Visualization experts
- Good Communicators
- BECAUSE WE ARE HUMBLE LEADERS

**Complexity**
- BECAUSE WE ARE ABLE TO APPRECIATE COMPLEXITY
- SE is the (practical) application of Systems Thinking to generate a number of (sustainable) solutions to complex challenges
- SE roots are in complexity it's what we do
- SE is a means to manage complexity

**Awareness**
- not universally taught / known
- LACK OF AWARENESS OF SE
- Exposure and Understanding OF what we do
- People / Decision makers want simpler approaches / answers
- VALUE NOT UNDERSTOOD
- COMPLEXITY OF PROBLEM NOT RECOGNISED
- 1. Lack of Knowledge; 2. Politics; 3. Economy - EXT
- Processes not always unique to us – understanding value add

**OUTWARD PERCEPTION**
- Perceived as “slow”
- PERCEIVED BURDEN OF PROCESS / DOCS
- PERCEIVED AS PART OF THE ONES WHO CREATED THE PROBLEM IN THE FIRST PLACE
- "ENGINEERING" SEEN AS A PHYSICAL / SOFTWARE THING
- ENGINEERING TURNS OFF A LOT OF STAKEHOLDERS

**Why**
- Why should SE be applied?

**What**
- What keeps SE from being applied?

**How**
- How do we extend the application of SE?
- Who to approach? Who to work with?

- COMMON (MODELLING LANGUAGE / SEMANTIC ONTOLOGY)
- Be prepared to change our own Structure to the desired function APPLY SE to SE
- Better SML more wow factor

**Training**
- TRAINING BE THE SYSTEM you WANT BE
- TARGET EARLY Learning (LATEST: 1st semester) BROADER ACCEPTANCE
- K-12 education – primary "same"
- TURN YOUR GARDEN INTO A PERMACULTURE
- DUTY OF CARE DEFINITION FOR SE WITH Respect To CLIMATE CHANGE / SDGS
- 1- Promotion; 2- increasing knowledge; 3 – Dialog; 4- Involving decision makers; 5 - Understanding the need / Req
## Workshop: Extending SE to address climate change

Team 2 (2/2)

<table>
<thead>
<tr>
<th>WHY should SE be applied? (2/2)</th>
<th>WHAT keeps SE from being applied?</th>
<th>HOW do we extend the application of SE? Who to approach? Who to work with?</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Soft / Justification</strong></td>
<td><strong>Lack of Collaboration</strong></td>
<td><strong>Marketing</strong></td>
</tr>
<tr>
<td>• CC presents the greatest disruptive force to SE Systems</td>
<td>• COMPETITION FOR &quot;OWNERSHIP&quot; OF ANYTHING 'SYSTEMS RELATED' (e.g., Engineering, Thinking)</td>
<td>• DEMONSTRATION OF VALUE</td>
</tr>
<tr>
<td>• ITS VERY REWARDING TO MAKE A REAL DIFFERENCE</td>
<td>• SE is its own silo</td>
<td>• GET INVOLVED EVERYWHERE - POLITICS – COMMUNITIES – ORGANISATIONS – SOCIAL GROUPS – EDUCATION</td>
</tr>
<tr>
<td>• 1 - for a better world; 2 - Reducing Co2; 3 - Save Lives; 4 - Save The Planet</td>
<td>• WE ARE NOT COLLABORATING WITH A MASSIVE DIVERSITY OF SYSTEM ORGANISATIONS</td>
<td>• OTHER INSTITUTES (WHO TO APPROACH)</td>
</tr>
<tr>
<td>• BECAUSE IT IS A GOOD IDEA !</td>
<td><strong>INWARD Perception</strong></td>
<td>• HOW ABOUT A TARGET OPERATING MODEL FOR HOW INSTITUTES WORK TOGETHER AND WHEN? e.g WHAT WOULD INCOSE BE RESPONSIBLE FOR?</td>
</tr>
<tr>
<td>• Unique Perspective</td>
<td>• Systems Engineers not positioned to help politicians</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• LACK OF UNIFIED DEFINITION OF OUR PURPOSE WITH RESPECTS TO &quot;NON-ENGINEERING&quot; PROBLEMS AS CLIMATE CHANGE</td>
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<tr>
<td></td>
<td><strong>OPPOSING FORCES</strong></td>
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<tr>
<td></td>
<td>• THE DARK SIDE OF THE FORCE</td>
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<td></td>
<td>• SHORT TERM OVERRIDES LONG TERM THINKING + ACTING</td>
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<tr>
<td></td>
<td>• OUR CULTURE REWARDS THE GREEDY / CORRUPT</td>
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<tr>
<td></td>
<td>• OUR EDUCATION SYSTEMS REINFORCES FACTS NOT THINKING</td>
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<tr>
<td></td>
<td><strong>Maturity</strong></td>
<td></td>
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<td></td>
<td>• WOULD 2 SEs EVER AGREE ON THE 5 Ws</td>
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<td></td>
<td>• Different Definitions of SE</td>
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<td></td>
<td>• Competition of Ideas</td>
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<tr>
<td></td>
<td>• WE HAVEN'T TRIED</td>
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<tr>
<td></td>
<td>• Takes time and training to use Systems thinking and to understand</td>
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<tr>
<td></td>
<td>• Lack of Competences</td>
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</table>
**Workshop: Extending SE to address climate change**

**Team 2**

**Stuff we bring to help**
- EXPERIENCE IN DEALING WITH MULTIPLE STAKEHOLDERS
- REUSE can only be address effectively using SE techniques (NFR.)
- KEEP FOCUS IN SYSTEMIC INSTEAD OF THE SYSTEMATIC
- ABILITY TO DO INTERNATIONAL COLABORATION
- Big picture problem solving
- THINK IN LONG-TERM USE RATHER THAN SHORT-TERM
- SE is good at addressing Complexity

**Demand**
- IT'S A HOT TOPIC

**Responsibility**
- MAN MADE SYSTEMS CREATE THE PROBLEM NEED TO MODIFY THEM TO SOLVE THE PROBLEM

**Why should SE be applied?**
- Less than 10% of MPs have an Engineering (or similar) Background!
- THE LANGUAGE IS DIFFICULT TO EXPLAIN TO "OUTSIDERS" WHAT SE IS.
- FINANCIAL INCENTIVES / METRICS REGULATION BE AWARE OF THOSE IN PIPELINE
- DECISION MAKERS ARE NOT ENGINEERING / SCIENCE PEOPLE
- Engineering Credibility
- HAVE A BETTER BIZ CASE SE
- OVER PROMISE UNDER DELIVER e.g., LATE OVER BUDGET etc.
- Lack of Climate related SE Tools available!

**What keeps SE from being applied?**
- Responsibility
- Promoting education on SE
- BE THE REPRESENTATIVE OF POLLUTING SYSTEMS. AND HOW THEY CAN BE ADAPTED
- Produce a "Street Language " Dictionary.
- SOCIAL MEDIA INFLUENCE
- JUST START WORKING ON THE PROBLEM. EVEN ON A SMALL SCALE
- Create SE/Climate change mitigation Tools
- UPDATE INFORMATION ABOUT HOW BENEFITS (BUDGET) GET INCREASED BY APPLYING SE

**How do we extend the application of SE?**
- Whom to approach
- Regulatory organizations
- MANY "SMALL" ORGS / GOV NEED HELP. REACH OUT & HELP

**What to do**
- Update information about how benefits (budget) get increased by applying SE
Photo Documentation

Team 3
**Workshop: Extending SE to address climate change**

**Team 3**

**WHY should SE be applied?**
- Because solutions need to be integrated and cross-cutting to harness synergies and prevent trade-offs between adaption, mitigation, and other SDGS.
- Because the world is a set of interconnected systems that need to be addressed holistically.
- I think we need a common language on how to approach the challenges posed by climate change. It is systems lingo I don't know.
- It's a complex problem that needs lots of SME's to work together.
- Because it is a problem coped as complex Project.
- Because standard Systems Operation affect CC => CC is a new affecting system stakeholder.
- Because SE guided by CC reduction can help.
- Because Politicians NEED to understand the means SE can provide for than to cope with the problem.

**WHAT keeps SE from being applied?**
- How can we ensure that we appear credible in the eyes and ears of the listeners.
- Not able to make it (SE) simple enough to talk / convinced to others communicate.
- SE considered as to technical and climate chance is "not a technical problem".
- NO DIDACTIC OF SE IS EXISTING.
- SE doesn't know the whole picture and life cycle.
- SE's can be too introspective &seems to talk a different language.
- Just about right amount of SE - How can we identity that.

**HOW do we extend the application of SE? Who to approach? Who to work with?**
- Adapt our language to suit the audience.
- Can we find friendly organization willing to listen to us while we learn to communicate.
- We will stop climate change. The Kennedy speech!
- Educate Decision Makers on system Principles.
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Follow up

Documentation will be sent to all the registered for the event with notes on how to stay in touch
FuSE Targeted Events in 2023

Where to engage

**International Workshop**
Torrance, CA USA
28. – 31. JAN 23

**EMEA WSEC**
Sevilla, Spain
24. – 26. APR 23

**International Symposium**
Honolulu, HI USA
15. – 20. JUL 23

**AOSEC**
Bangalore, India
11. – 14. OCT 23

**Working Sessions**
Virtual
Planned for CW 8 – 11

**Working Sessions**
Virtual
TBD

Regular Stream Meetings
TBD
Let’s connect.

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