The Future of Systems Engineering: Realizing the Systems Engineering Vision 2035.

A Systems Community Initiative
FuSE Mini-Event: Introduction and Update, 29 March 2023

William D. Miller
Future of Systems Engineering Lead
First FuSE Mini-Event Series

MAR 29, 2023
Future of Systems Engineering (FuSE) Introduction and Update
And FuSE Foundations Overview

APR 06, 2023
Future of Systems Engineering (FuSE) Vision & Roadmaps

APR 13, 2023
FuSE Application Extensions – SE and Asset Management

APR 20, 2023
FuSE Methodologies Virtual Workshop

Visit https://www.incose.org/about-systems-engineering/fuse or https://www.incose.org/events-and-news for details and registration information
FuSE Mini-Event: Introduction and Update
29 March 2023

• Future of Systems Engineering (FuSE) Initiative Introduction and Update – William Miller
• FuSE Foundations Stream Overview and Update – Joshua Sutherland
• Q&A
FuSE Mini-Event: Introduction and Update
29 March 2023

• Future of Systems Engineering (FuSE) Initiative Introduction and Update – William Miller

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• Q&A
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
Understanding Socio-Technical Complex Systems with Human Systems Integration Methods Applied to Major Societal Challenges

• The future of systems engineering is **model-based**, leveraging next generation modeling, simulation, and visualization environments powered by the global digital transformation, to specify, analyze, design, and verify systems. High fidelity models, advanced visualization, and highly integrated, multi-disciplinary simulations will allow systems engineers to evaluate and assess an order of magnitude more alternative designs more quickly and thoroughly than can be done on a single design today.

• **Artificial Intelligence**, powered by large data sets and expert domain knowledge will drive major changes in systems engineering methods and tools, and within systems themselves, as algorithms are developed to assist the systems engineer be more efficient and effective to deliver solutions.

• **Data science** techniques will be infused into the systems engineering practice to help make sense of large-scale data sets and assess complex systems. Further, the rapidly expanding set of data science tools will be an important part of an integrated analytic framework for systems engineering.

• **Human-systems integration** practices will become essential to design smart systems that can effectively interact with humans, and account for increasing levels of systems complexity and autonomy.

• The **theoretical foundations** for systems engineering will be based on established science and mathematics that characterize systems phenomena and stakeholder value, and provide the basis for systems education and evolving methods and tools.

• Ongoing **education and training** of systems engineers and the infusion of systems thinking across a broad range of the engineering and management workforce will meet the demands for a growing number of systems engineers with the necessary technical and leadership competencies.

• **Systems engineering** will be embraced by a greater number and broader range of small and medium enterprises and will be continually adapted to manage systems complexity while also driving incremental market value.
**Systems Engineering Challenges**

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

**Practices**
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.

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

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

**Competencies**
9. Systems engineering education is part of the standard engineering curriculum, and is supported by a continuous learning environment.
Realizing the Vision: Top-Level Roadmap

The figure here is a top-level roadmap that reflects the set of Systems Engineering Challenges.

The Systems Engineering Challenges need to be addressed in an integrated and holistic manner. They are not entirely independent of each other and reflect only the most significant challenges.

Addressing these challenges will be facilitated by improving our ability and willingness to share knowledge, practices, and lessons learned. This sharing is enabled by several organizations and resources, such as the professional societies, industry associations, and academies, and in resources such as the System Engineering Body of Knowledge (SEBoK) and INCOSE product portfolio.

These are updated regularly with new practices, artifacts, and emerging technical information. Initiatives focused on progressing the necessary achievement and sharing results include the INCOSE-facilitated Future of System Engineering (FuSE), which includes over a dozen organizations; and various systems engineering research organizations.
Realizing the Vision: The Path Forward

“When the rate of change inside an institution becomes slower than the rate of change outside, the end is in sight. The only question is when.”

Jack Welch, General Electric Chairman and CEO (1981-2001)

“Our situation is not comparable to anything in the past. It is impossible, therefore, to apply methods and measures which at an earlier age might have been sufficient. We must revolutionize our thinking, revolutionize our actions ….”

Albert Einstein (1948) in “A Message to Intellectuals”

“I often say that when you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind.”

William Thomson, Lord Kelvin (1824-1907)
Program Overview
FuSE Program Mission Statement

FuSE refines and evolves the SE Vision 2035 across competencies, research, tools & environment, practices, and applications.

FuSE identifies critical gaps towards the vision realization and initiates & supports relevant actions.

FuSE fosters involvement and collaboration within and outside of INCOSE.

FuSE educates, shares success, and expands.

Engage and inspire the systems engineering community by realizing the SE Vision 2035 to sustain the future of systems engineering.
FuSE Program Charter

**Vision Statement**

*Inspire the global community to realize the Vision of SE*

**Mission**

Engage and inspire the systems community for sustaining the future of systems engineering in realizing the SE Vision 2035

FuSE refines and evolves the SE Vision 2035 across competencies, research, tools & environment, practices, and applications.

FuSE identifies critical gaps towards the vision realizations and initiates & supports relevant actions.

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FuSE educates, shares success, and expands.

**Success Factors**

**Inclusive**: From an exclusive club to inclusive initiative

**Attractive**: Engage members and non-members

**Implementation**: The degree to which the road map is realized

**Fresh**: Relevant and updated road map and context

**Close to application**: Involvement of companies and domains

**Global promotion**: Attractive global digital marketing

**Passion**: To get the working group proud to be part of it

**2023 Milestones**

1. International Workshop
2. EMEA WSEC
3. International Symposium
4. AOSEC
FuSE Journey Beginning IW 2018
The Systems Community Initiative Facilitated by INCOSE
## Engagement with INCOSE Working Groups, Initiatives, and Periodicals

### Current and potential FuSE intra INCOSE engagements

**INSIGHT Practitioners’ Magazine**

**Systems Engineering Journal**

**Systems Engineering Vision 2035**

**SE Principles Action Team**
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<tr>
<th>What</th>
<th>FuSE Streams</th>
<th>Lead(s)</th>
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<th>EOY 2022 Goals</th>
<th>EOY 2023 Goals</th>
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<td>SEV5 Draft Reviewed</td>
<td>SEV5 Published (IS2023)</td>
<td>Does not support 2025 Goals?</td>
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<td>SEBoK Heuristics Article</td>
<td>SE Heuristics → GRCSE</td>
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The FuSE program is organized in 4 streams with additional central teams

FuSE Program Executive Team
William Miller, Ralf Hartmann, David Long, Olivier Dessoude, Erika Palmer

FuSE Program Management Office
Stephan Finkel, Martina Feichtner

FuSE Stream Lead
“SE Vision & Roadmaps”
INCOSE MarCom
Paul Schreinemakers

FuSE Stream Lead
“SE Foundations”
Oli de Weck

FuSE Stream Lead
“SE Methodologies”
Chris Hoffman

FuSE Stream Lead
“SE Application Extensions”
Tom Strandberg

Related INCOSE activities
- e.g., SEV2034, REAct, FuSE Roadmap
- e.g., Bridge Team, SEHv5, SE Principles, SE Heuristics, Science Foundations for SE
- e.g., SE4AI and AI4SE, Human Systems Integration (HSI), System Security, Agility, Complex Systems, Social Systems
- e.g., Contextual Ecosystems, Smart Cities

FuSE Program
Program Lead
“FuSE Initiative”
William Miller

FuSE Com & Outreach Office
INCOSE Lead
President-Elect
Director for Strategic Integration
Technical Director
Deputy Technical Director

FuSE Stream Working Team
FuSE Stream Working Team
FuSE Stream Working Team
FuSE Stream Working Team
Sequence of SE Vision 2035 elements for 2025 goals

### 2023
- **Application**
  - Identification of different domains
  - Selection of focus domains
  - Description of different domains
- **Practices**
  - Create baseline of existing standards
  - Create a common-enough ontology / glossary
- **Tools & Environment**
  - Identification of what is already there, and evidence if it is not suitable.
- **Research**
  - Create baseline of existing foundations
  - Ensure applicability of foundations
  - Create / align research agenda
- **Competencies**
  - Baseline of current set of competencies
  - Creation of a competency map
  - Setup community

### 2024
- **Application**
  - Identify collaboration partners from domains
  - Review research of different domains
  - Create first examples & application guides
- **Practices**
  - Document SE practices & value
  - Create fist derivations of SE documentation
- **Tools & Environment**
  - Identify how to integrate SE engineering tools with SW engineering tools (together with partners)
  - Derive first guides and tools
- **Research**
  - Ensure applicability of foundations
  - Create / align research agenda
  - Make the value of SE quantifiable / measurable
  - Elaborate first awareness campaigns
- **Competencies**
  - Identify generic competencies
  - Collaborate with GRCSE 2.0
  - Generate first publications
Keynote:
The First Law of Systems Science: Conservation of Complexity

Prof. Olivier de Weck, INCOSE Fellow
Massachusetts Institute of Technology
deweck@mit.edu
# FuSE at IW 2023 overview

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**Rooms for FuSE Stream Sessions:**
- **Vision & Roadmaps Stream:** Ballroom
- **Foundations Stream:** Salon A
- **Methodologies Stream:** Salon D
- **Application Extensions Stream:** Salon C
The FuSE Setup at IW was well received.
# Systems Engineering Vision & Roadmaps Stream

**Paul Schreinemakers**  
Stream Lead “SE Vision & Roadmaps”  
e paul.schreinemakers@incose.net

The Systems Engineering Vision and Roadmaps stream continuously refines, evolves, and complements the SE Vision 2035. Furthermore, we create an integrated set of roadmaps across the four interrelated FuSE streams. The concurrently executed streams will guide and influence each other.

The IW 2023 goal is to frame the structural relationships and value models for the roadmaps’ creation.

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<td>2. Elaborate on roadmap items to address in each stream</td>
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<td>3. Elaborate on projection of the challenges on each stream</td>
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<td>4. Set up an Inventory</td>
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Key Insights Vision & Roadmaps Stream

Topics

• Get familiar with SE Vision 2035, roadmaps, and actions to be done.

• Generate first insights on what is needed to realize the SE Vision 2035

• Identify missing elements of the SE Vision 2035

• Collect means to keep the SE Vision a living document

Key Insights

• The goals stated in the SE Vision 2035 needs to be made measurable.

• It is crucial to involve a young and diverse community (within and outside) of INCOSE to realize the SE Vision 2035.

• Specific measures to do the above were conceptualized at IW
## Systems Engineering Foundations Stream

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### Oli de Weck

**Stream Lead “SE Foundations”**

E: deweck@mit.edu

In order to yield predictable results, Systems Engineering methods and tools need to be built on foundational principles that are provably true and based on laws and axioms that can be tested for falsifiability similar to those in other well-established disciplines of science and engineering like Chemical Engineering, Electrical Engineering, or Biological Engineering. This stream will formulate a set of candidates underlying Laws of Systemics, the science at the foundation of Systems Engineering.

The IW 2023 goal is to assess the foundational value of the “Conservation of System Complexity,” which parallels the Conservation of Energy in the First Law of Thermodynamics and the Conservation of Mass in continuum mechanics.
Key Insights Foundations Stream

**Topics**
- Introduced proposed 1st law "Conservation of Complexity"
- Ran experiment on complexity designing a transport system to test our hypotheses, i.e. effort increases with complexity, etc.
- Shared case study on "technical complexity" using Jet Engine evolution, did group breakout work to understand complexity drivers
- Shared case study on "organizational complexity" using SLS and Space X Falcon 9, did group breakout work to understand complexity drivers
- System Science WG shared state of their work

**Key Insights**
- Generated data via the complexity experiment, need to post process data and verify or falsify our initial assumptions
- Experiment was fun and mimics SE reality, but needs refinement to be even more realistic
- Group breakout on technical complexity did confirm our basic direction, but also revealed additional drivers we need to considered
- Involvement of SSWG highlighted what is already existing and benefits of joining forces
- Group breakout on org complexity illustrated need for more discussion and alignment on how to model org complexity
Systems Engineering Methodologies Stream

The SE Methodologies stream guides the advancement of practices, methods, and tools for the effective engineering of systems to be fit for purpose in the presence of varying scale, interrelatedness, complexity, non-determinism, and emerging technology innovations such as AI and agility.

The IW 2023 goal is to assess the adequacy of current INCOSE technical products and ongoing FuSE projects in this stream and identify gaps.

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**Chris Hoffman**
Stream Lead “SE Methodologies”

e christopher.hoffman@incose.net

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**Introduction, Activities for 2023, Initial feedback, Opt-in participation**

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Key Insights Methodologies Stream

Topics

Introduced the stream’s purpose, content and goals.

Major disrupters and obstacles for advancing systems engineering methodologies were captured.

Selected disrupters were clarified with solution proposals generated.

A needs gathering form for solution proposals was shared @ www.incose.org/needs

Key Insights

Disrupters were multi-dimensional and included:
- Lack of training
- Past failures leading to low trust of new items
- Limited resources
- Impeded development of practical SE methods
- Lack of support to change (stagnated culture)

Solution proposals were generated and initially screened. Work remains to form and select the highest potential solutions to focus upon.
# Systems Engineering Application Extensions Stream

**Tom Strandberg**  
Stream Lead “SE Application Extensions”  
[Email: tom.strandberg@incose.net](mailto:tom.strandberg@incose.net)

The SE Application Extensions stream integrates social sciences, soft systems, as well as initiatives such as Smart Cities to address grand challenges to meet human and societal needs as stated in the United Nations Sustainable Development Goals.

The IW 2023 goal is to frame the value model to justify systems engineering’s role at the policy table for these grand challenges.

<table>
<thead>
<tr>
<th>SAT</th>
<th>SUN</th>
<th>MON</th>
<th>TUE</th>
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<tbody>
<tr>
<td>08:00</td>
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<tr>
<td>08:30</td>
<td></td>
<td></td>
<td>Wrap-up FuSE (for participants)</td>
</tr>
</tbody>
</table>
| 09:00 | 1. How SE supports sustainable cities  
2. How SE supports innovation |     |     |
| 09:30 | Break |     |     |
| 10:00 | FuSE Kick-off |     |     |
| 10:30 |     | Break |     |
| 11:00 |     |     |     |
| 11:30 |     |     | Wrap-up FuSE |
| 12:00 | Lunch |     |     |
| 12:30 |     |     |     |
| 13:00 |     |     |     |
| 13:30 |     |     |     |
| 14:00 | Introduction, Activities for 2023, Initial feedback |     |     |
| 14:30 |     | Break |     |
| 15:00 | Break |     |     |
| 15:30 |     |     |     |
| 16:00 | Introduction, Activities for 2023, Initial feedback |     |     |
| 16:30 |     |     |     |
Key Insights SE Application Extensions

Topics

Validating the stream’s purpose, content and goals

Topics for extending SE applications proposed validated fit for purpose:

- Smart Cities
- Innovation
- SE and Asset Management
- Grand Challenges

Key Insights

SE Application Extensions stream purpose and topics have been validated. MoE, risks and activities have been proposed by the participants.

Smart Cities – good foundation exists for reaching out to internal & external groups. Next step is the validation by application together with mayors or alike.

Innovation – an innovation framework based on systems thinking identified to be a useful means to engage with new target groups. Good potential for collaboration between WGs.

Asset Management – Value and interest to cooperate with the Institute of Asset Management in order to align the forces. Identify the respective WGs within INCOSE.

Grand Challenges – Quite some Value Propositions identified that INCOSE could provide – Proposed next step set up a cross-WG initiative and to seek collaboration with complementary organizations with a joint message to target groups.
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
Bengalore, India
11. – 14. OCT 23

Working Sessions
Virtual
Planned for CW 8 – 11

Working Sessions
Virtual
TBD

Regular Stream Meetings
TBD
# First FuSE Mini-Event Series

<table>
<thead>
<tr>
<th>Event Title</th>
<th>Date</th>
<th>Description</th>
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<tbody>
<tr>
<td>Future of Systems Engineering (FuSE) Introduction and Update &amp; Foundations</td>
<td>MAR 29, 2023</td>
<td>Introduction to the Future of Systems Engineering (FuSE) to realize the Systems Engineering Vision 2035. FuSE started at IW2018 and has a dozen ongoing projects including participation by INCOSE working groups and engagement in the broader systems community. We announced the next phase of FuSE at IW2023 with the establishment of a program management office (PMO) and the clustering of projects into four streams: SE Vision &amp; Roadmaps, Foundations, Methodologies, and Application Extensions. We will highlight the outcomes of the stream workshops at IW2023 and our program plan moving forward. We will have virtual mini-events for each of the streams in April, followed by workshops at EMEA WSEC and AESEC, and invited content sessions at IS2023. We are also partnering with the broader systems community. We welcome the proactive engagement of individuals, working groups, and initiatives to realize the SE Vision 2035.</td>
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<tr>
<td>Future of Systems Engineering (FuSE) Vision &amp; Roadmaps</td>
<td>APR 06, 2023</td>
<td>The Future of Systems Engineering (FuSE) SE Vision &amp; Roadmaps stream is maintaining the online version of the SE Vision 2035 and populating it with valuable add-on information and white papers. Maintaining and synchronizing the SE Vision’s implementation roadmap as well as those of all four FuSE Stream’s has our focus. To prepare for this session, please read chapter 4 (Realizing the Vision) of the SE Vision 2035. (<a href="http://www.incose.org/sevision">www.incose.org/sevision</a>) After a short introduction of the Vision &amp; Roadmaps stream an overview of the results from the IW2023 activities is presented. This is followed by interactive involvement of all participants, collecting their additions to the Systems Engineering Challenges and the Roadmap as defined in the SE Vision 2035. The information gathered will be evaluated afterwards for implementation in the near future FuSE activities.</td>
</tr>
<tr>
<td>FuSE Application Extensions – SE and Asset Management</td>
<td>APR 13, 2023</td>
<td>The Future of Systems Engineering (FuSE) SE Application Extensions stream is focusing on stimulating and supporting initiatives that broadens the application of systems engineering in non-traditional domains including socio-technical systems. As a means different cross-cutting topics where SE can bring value to new applications were discussed at the International Workshop 2023. This online session will focus on physical Asset Management (AM), a topic that brings a systems and life cycle approach to in particular the infrastructure domain. The topic will be introduced by Ben Mogridge, AM expert and member of INCOSE as well as representative from organizations focusing on AM. This is followed by interactive involvement of all participants elaborating on the findings from the workshop at IW2023. The information gathered will contribute to the establishment of a joint initiative to reach out to new target groups.</td>
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<tr>
<td>FuSE Methodologies Virtual Workshop</td>
<td>APR 20, 2023</td>
<td>Following previous FuSE sessions at IW2023, how might we evolve System Engineering Methodologies to engineer solutions for a better world? After a brief introduction on FuSE and a summary from IW2023, participants will leverage the SE Vision 2035 publication, the FuSE IW2023 session outputs, and their own wisdom to elaborate on methodology gaps, share work-in-progress to close those gaps, and then propose go-ahead ideas to realize SE Vision 2035 (<a href="http://www.incose.org/sevision">www.incose.org/sevision</a>). This workshop will require active engagement in a Miro board. No prior training or Miro account is necessary, but participants are encouraged to complete a few Miro tutorials (<a href="https://miro.com/app/dashboard/#/lc/getting-started/">https://miro.com/app/dashboard/#/lc/getting-started/</a>) ahead of the event to increase their focus on the content and not the Miro tool during the workshop.</td>
</tr>
</tbody>
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Visit [https://www.incose.org/about-systems-engineering/fuse](https://www.incose.org/about-systems-engineering/fuse) or [https://www.incose.org/events-and-news](https://www.incose.org/events-and-news) for details and registration information
EMEA details

FuSE is going to be part of EMEA WSEC in Sevilla.

Planned content
• Presentation of FuSE including focus topic
• 4x2h working session for each FuSE stream
IEEE Systems Council

Technical Committees

Get in touch with us.
ieee-systems-council.org

Systems Council Technical Committee on Systems Engineering Methods

Tuesday, 11 April 2023
11 AM ET/3 PM UTC
Space is limited to the first 100 registrants
Joint SMCS- INCOSE Panel: Seeing and Building the Future of SE

After Joint FuSE panels at Bari, IT and Toronto CA IEEE Systems, Man, and Cybernetics Society conferences, this third in a series with the International Council on Systems Engineering (INCOSE) will build on the evolving relationship between SMCS and INCOSE by inviting respective insights on the future of systems engineering from both development and research points of view.

Both SMCS and INCOSE value quality in the professional practice of system engineering (SE), which continues to evolve in response to technical opportunities and political, economic, social, technological, environmental, and legal (PESTEL) factors. Anticipating what SE will and should be in the future has significant implications for research, education, training, certification, and resources. What challenges can be expected? Are our members ready to engage them?

The panel will:

- Describe how INCOSE plans for the future
- Identify development needs that INCOSE can inform, and potential needs
- Identify new SE challenges and opportunities from the SMCS perspective
- Suggest opportunities for joint collaboration
FuSE Mini-Event: Introduction and Update
29 March 2023

• Future of Systems Engineering (FuSE) Initiative Introduction and Update – William Miller

• FuSE Foundations Stream Overview and Update – Joshua Sutherland

• Q&A
FuSE Mini-Event: Introduction and Update
29 March 2023

- Future of Systems Engineering (FuSE) Initiative Introduction and Update – William Miller
- FuSE Foundations Stream Overview and Update – Joshua Sutherland
- Q&A
The FuSE Program is organized in 4 streams.

- Vision & Roadmaps
- Foundations
- Methodologies
- Application Extensions
Let’s connect.

Or find us on www.incose.org/fuse

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