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Agility in the Future of Systems Engineering A Roadmap of Foundational Topics

By Dr. Keith D. Willett (presenting for the FuSE Agility Team)

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INCOSE FuSE

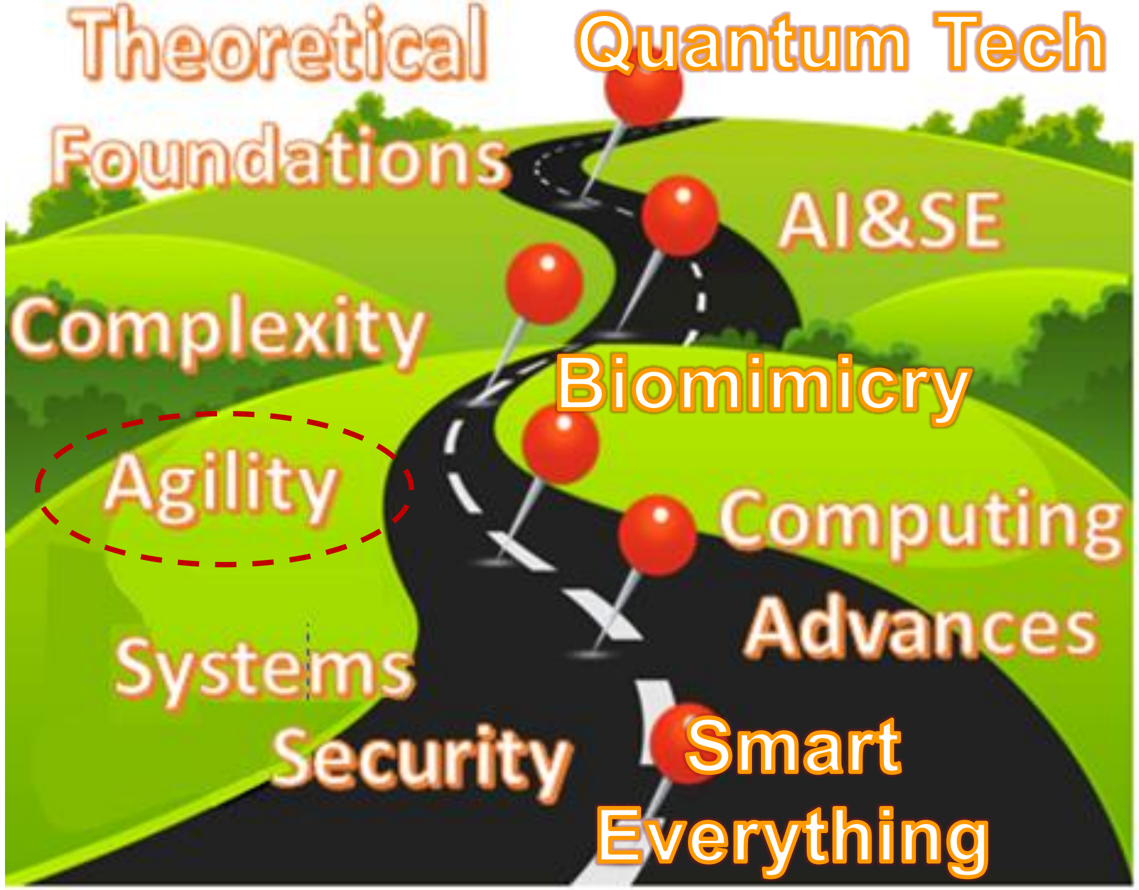
Future of Systems Engineering

FuSE Collaborative Community

Collaborating Organizations

- INCOSE – International Council on Systems Engineering
- IEEE – Advancing Technology for Humanity
- ITEA
- Johns Hopkins Applied Physics Laboratory (APL)
- ISSS
- NDIA – National Defense Industrial Association
- SAE International
- Software Engineering Institute – Carnegie Mellon University
- Systems Engineering Research Center
- MORS
- Department of Defense – United States of America

FuSE Road Map



FuSE Agility Charter for 2021

Title: Agility in the Future of Systems Engineering
(a FuSE initiative topic project)

Lead: Keith Willett (U.S. DoD)**;**
Team: INCOSE: Rick Dove; Catalyst Campus: Robin Yeman; NASA: Chris Carlson, Jennifer Stevens; NGC: Alan Chudnow , Rusty Eckman; Raytheon: Larri Rosser, Mike Yokell; LMC: Carlos Ramirez; IBM (retired): Rock Angier

What good will look like:

1. *Agile systems-engineering* [**process**]: apply agile tactics, techniques, and procedures (TTP's) throughout system lifecycle.
2. *Agile-systems engineering* [**technology**]: operational systems adaptable to predictable and unpredictable change.
3. *Agile-operations* [**environment**]: achieve composable workflows to sustain value-delivery under adverse conditions.
4. *Agile-workforce* [**people**]: achieve dynamic adaptability; skills, knowledge, and efficacy.

What good will look like in 2023-2025:

1. Some degree of *agility in SE* influences system development and ongoing evolution.
2. Applying and evolving *agility patterns* spanning process, technology, environment, and people.
3. Applying and evolving *agility* for continual dynamic adaptation in operations; toward autonomous operations.
4. Advancing / realizing Vision 2025 for agility.

What good will look like by end of 2021:

1. Solid movement toward *practical realization* of topics.
2. Extend topic *depth* and *breadth* in support of realization.
3. Expand multi-organization collaboration.

What is stopping us from doing this now:

1. Narrow *agility perception* as software development practice.
2. Lack of a *codified approach* for multi-discipline agile systems engineering; e.g., standards, SE methods/guides.
3. Insufficient *stakeholder engagement* in the SE process; agile is iterative and prompts attention to hard problems.
4. Current *acquisition process*, contracts, and projects prompt for features and requirements up front rather than evolution of the solution that coincides with evolution of the problem.

Action plan:

1. **IW2021**: introduce topics, goals, and recruit participation.
2. **IS2021**: publish FuSE Agility multi-topic cohesion paper; publish individual topic papers as able.
3. **INSIGHT**: publish topic articles as able.
4. **Ongoing**: facilitate topic realization; seek collaboration.

Criteria for FuSE Agility Foundation Topics

- Relevance to SE considerations.
- Provide new and useful value to the state of the practice.
- Can articulate concept value proposition in SE terms.
- Referenceable knowledge base that supports concept.
- Not yet sufficient published exposure for actionable SE consideration.
- Is implementable now.
- Has sufficient ecosystem/infrastructure to support implementation.
- Principally about what to do and why (strategic intent), rather than how (prescriptive tactics); examples of how can augment understanding.

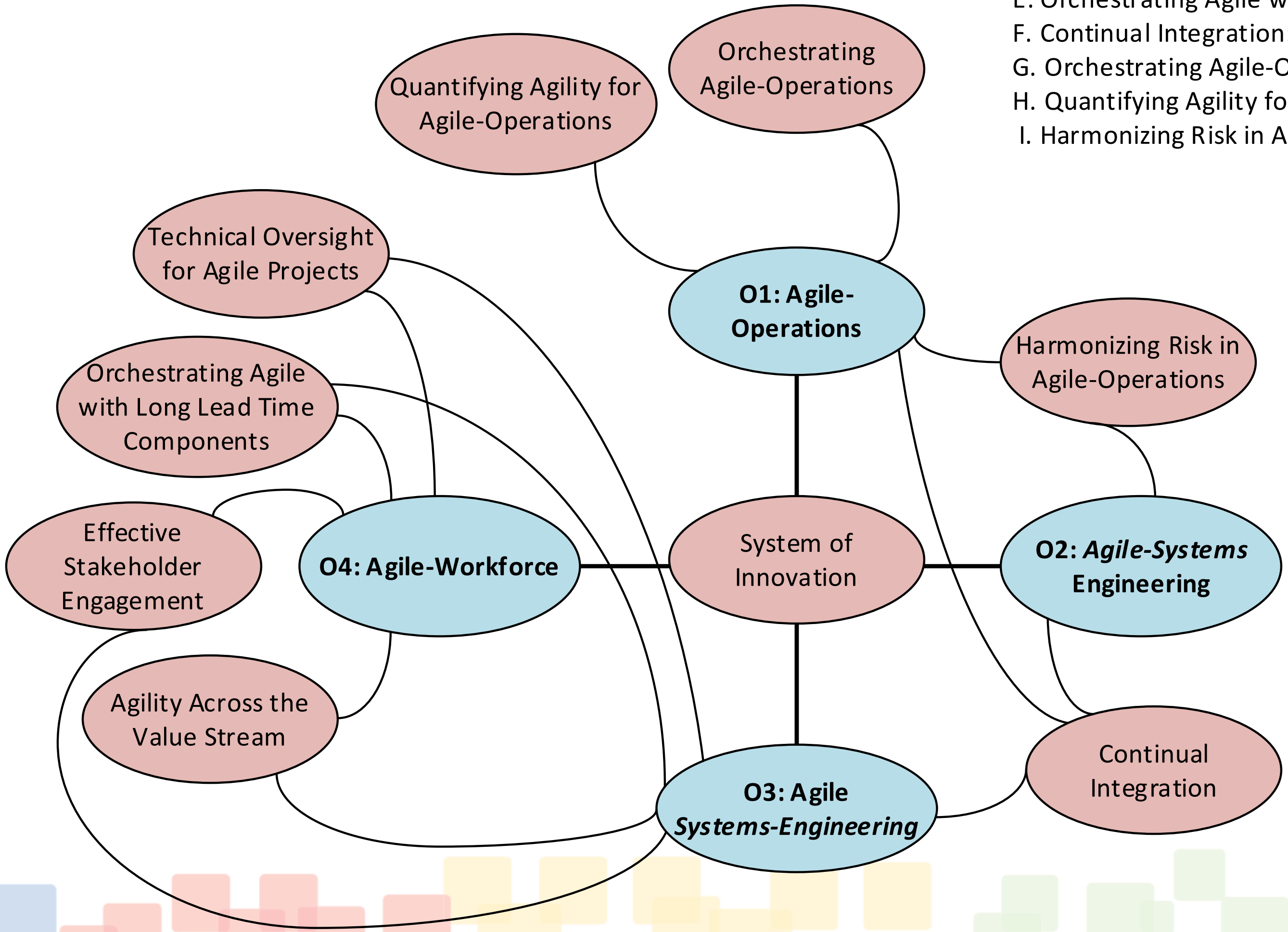
General Topic Points

Problem	Problem addressed by the concept
Need	Need to solve the problem
Barriers	Description of that which stops us from achieving the concept
Intent	Strategies to address the need
Value	Values to realize using the strategies
Metrics	Metrics for measuring effectiveness of strategies
Notions	Example references to inspire strategy development

Activity Web

Objectives:
1. Agile-Operations (adaptable workflows)
2. Agile Systems-Engineering (adaptable processes)
3. Agile-Systems Engineering (adaptable solutions)
4. Agile-Workforce (adaptable people)

Topics to Objectives:
A. System of Innovation: O1, O2, O3, O4
B. Technical Oversight for Agile Projects: O3, O4
C. Effective Stakeholder Engagement: O3, O4
D. Agility Across the Value Stream: O3, O4
E. Orchestrating Agile with Long Lead Time Components: O3, O4
F. Continual Integration: O1, O2, O3
G. Orchestrating Agile-Operations: O1
H. Quantifying Agility for Agile-Operations: O1
I. Harmonizing Risk in Agile-Operations: O1, O2



FuSE Agility Topics Summary

Topic Title	General Problem to Address
System of Innovation (Dynamic Learning)	Insufficient learning and knowledge management processes; barriers to learned-knowledge applications.
Technical Oversight	Traditional technical oversight methods are counterproductive in agile programs.
Stakeholder Engagement	Timeliness and depth of stakeholder collaborative engagement.
Agility Across Organizational Boundaries	Incompatible siloed cultures and languages.
Agility with Long Lead Components and Dependencies	Components and external dependencies with long lead times complicate schedule coordination and disrupt technical performance.
Continual Integration	Late discovery of integration and requirements issues.
Orchestrating Agile Operations	Coherence among loosely coupled multi-actor outcomes.
Situational Response Automation	Decision and action too slow.
Harmonizing Risk in Agile Operations	Agility focus is principally loss avoidance.

System of Innovation (Dynamic Learning)

Problem	**Insufficient learning activity and knowledge management; barriers to knowledge application.**
Need	Situational awareness and learning embedded in lifecycle processes; timely/affordable learning-application enabled; knowledge management.
Barriers	Unclear what to do or where to do it beyond learning ceremonies and contract obligation satisfaction. Comfort in static view of requirements and environment.
Intent	Explore the application of three core principles: sense, respond, and evolve.
Value	Less rework (cost/time); higher customer/user satisfaction; competency growth.
Metrics	Relevance of knowledge; impact of applied learning.
Notions	(Schindel and Dove 2016), (Schindel 2017), (Dove 2020).

Technical Oversight for Agile Projects

Problem	**Current technical oversight approaches (e.g., Stage-Gates reviews) are not agile. They take too much calendar time, too much team effort, are not adequately responsive to continuous unpredictable change, and do not provide insight into gaps and risk on agile programs. The Waterfall model has a long lag between design reviews at the beginning and test reviews near the end.**
Need	A light weight, interactive approach to technical oversight that provides insight in the form of good predictive feedback to agile programs with minimal burden of labor on the agile team. Balance reviews costs vs. schedule vs. benefits.
Barriers	Fixed expectations of the oversight process; contractual constraints; and the incorrect assumption that agile programs don’t need technical oversight.
Intent	Make technical oversight agile; i.e., frequent, quick, useful feedback that provides insight into project performance against commitments, environmental change vs planned capabilities and schedule, and recommendations.
Value	Insight at the speed of relevance.
Metrics	Feedback relevance; feedback accuracy; feedback cycle time; oversight labor; ROI (OS labor: cost avoidance from oversight).
Notions	Current technical oversight approaches (e.g., Stage-Gates reviews) are not agile. They take too much calendar time, too much team effort, are not adequately responsive to continuous unpredictable change, and do not provide insight into gaps and risk on agile programs. The Waterfall model has a long lag between design reviews at the beginning and test reviews near the end.

Effective Stakeholder Engagement

Problem	**Timeliness, frequency, and depth of stakeholder collaborative engagement.**
Need	Discovery of integration conflicts and true requirements as they evolve over time.
Barriers	Time involved; travel cost; inconvenient scheduling; lack of motivation.
Intent	Enable and facilitate compelling collaboration, cooperation, and teaming among all relevant stakeholders.
Value	Less rework (cost/time); higher customer and user satisfaction.
Metrics	Breadth and depth of stakeholder engagement; time and cost of rework. Lead time, cycle time, defect density.
Notions	(Dove, Schindel, Scrapper 2016); (Dove. Schindel, Garlington 2018).

Agility Across Value Streams

Problem	**Multiple handoffs across organizational boundaries lead to slower and lower quality products.**
Need	Common language; minimize handoffs, product-based teams; common metrics
Barriers	Organizational silos
Intent	Enable customer -centric product-based delivery with low complexity and higher speed
Value	Adaptability to increase quality and speed, lower cost, and reduced risk
Metrics	Lead time, cycle time, defect density
Notions	Flow-based delivery; industrial DevOps

Orchestrating Agile with Long Lead Time Components

Problem	**System under development needs to address components that can be developed quickly, components that take longer, and external dependencies. Components and external dependencies with long lead times complicate schedule coordination and disrupt technical performance.**
Need	Scheduling and acquisition techniques that better align with agile-SE principles.
Barriers	[False] justification that long-lead items prohibit the use of agile-SE.
Intent	Clarify how agile-SE can accommodate long-lead time acquisition.
Value	Reduce long-term cost and risk; quicker time to market.
Metrics	Reduce non-productive wait time, integration effort, and rework.
Notions	Integrated master scheduling, giver/receivers, minimum viable product (MVPs), minimum viable capability delivery (MVCD) workarounds, trade studies, invest in alternatives.

Continual Integration

Problem	**Late discovery of integration and requirements issues.**
Need	Minimize risk and rework; maximize stakeholder engagement.
Barriers	Development effort and expense. Technologies for integrating/testing software prior to hardware being ready.
Intent	A Live-Virtual-Constructive platform for early and continual integrated testing and work-in-progress demonstrations.
Value	Less rework (cost/time); effective stakeholder engagement.
Metrics	Rework reduction; stakeholder value statements.
Notions	(Dove, Schindel, Garlington 2018); (Dove et al. 2020).

Orchestrating Agile-Operations

Problem	**Disparate solutions operate independently.**
Need	Tightly coupled coordinated dynamic operations in real-time.
Barriers	Ability to encode self-learning, adaptive logic as decision-support to people and for autonomous decision making.
Intent	Elaborate orchestration as command and control for a system; and advance thinking on *command*.
Value	Fast adaptable system operation.
Metrics	Increase in autonomous system defense. Less people in-the-loop.
Notions	Integrated Adaptive Cyberspace Defense (IACD) – JHU Applied Physics Laboratory.

Quantifying Agility for Agile-Operations

Problem	**Lack of autonomy in orchestration; dependency on people in-the-loop.**
Need	Continual dynamic adaptation within *cyber-relevant time* or *time-of-relevance*.
Barriers	Complicatedness of encoding autonomous governance and adjudication logic and rules; situational awareness that provides necessary inputs.
Intent	A foundation of technology and mathematical disciplines to quantify agility.
Value	Contribute to realization of continual dynamic adaptation in operations.
Metrics	Orchestration performance metrics.
Notions	Many patterns throughout the mathematical disciplines, per discussion below.

Approach for Orchestrating Agile-Operations

- ***Develop*** workflow modules
- ***Compose*** workflow modules into operations
- Orchestration includes:
  - Module invocation; order of execution is dynamically adjustable
  - Module substitution according to context
  - Add modules
  - Modify modules; dynamic updates
- Group modules according to workflow phases
- Modules are elements in sets
  - Set management facilitates dynamic adaptability

Orchestration Includes Set Management

- Algorithmic design research for **continual dynamic adaptation**
  - **Set-Based Design** (enumerate sets of options readily available; defer decision to time of need)
  - **Category Theory** (manage set relationships)
  - **Compositionality Theory** (compose vs. develop)
  - **Combinatorics** (manage compositional options/variations)
  - **Bayesian Belief Networks** (quantifying dependency & causality)
  - **Uncertainty Quantification** (quantifying degrees of accuracy)
  - **Portfolio Theory** (maximize return for given level of risk)
  - **Network Theory** (safeguarding against weaponizing interconnectedness)
  - **Viable Systems Theory** (evolution of dynamic systems)

Harmonizing Risk in Agile-Operations

Problem	**Operational risk predominantly focuses on potential loss.**
Need	Expand awareness and operational realization of both the negative side of risk (loss) and the positive side of risk (opportunity, seek gain, optimize).
Barriers	Silo-thinking and predominance of looking at risk only in terms of loss.
Intent	Establish agility's role in sustaining system viability and relevance including proactive contingency planning, continual optimization, and seeking gain.
Value	Holistic approach to risk; dynamic adaptation in explore / exploit.
Metrics	Mean Time Between Failure (MTBF), Mean Time Between Repair (MTBR); uptime, value-delivery quantity and quality (time, accuracy, efficiency); consistency (dependability).
Notions	INCOSE INSIGHT December 2020 on loss-driven systems engineering (LDSE); opportunity-driven systems engineering (ODSE), and System Dynamics Modeling archetypes relevant to explore, exploit.

FuSE Agility Roadmap Topics Summary

Concept Title	General Problem to Address	General Needs to Fill	General Barriers to Overcome
Dynamic Learning and Evolution	Insufficient learning and knowledge management processes; barriers to learned-knowledge applications.	Situational awareness and learning embedded in lifecycle processes; timely/affordable learning-application; knowledge management.	Unclear what to do or where to do it beyond learning ceremonies and contract obligation satisfaction.
Technical Oversight	Traditional technical oversight methods are counterproductive in agile programs.	An interactive approach that reveals relevant knowledge for guidance and decision making.	Oversight traditions; standard contract wording; disrespect for oversight.
Stakeholder Engagement	Timeliness and depth of stakeholder collaborative engagement.	Discovery of true requirements and integration conflicts.	Time involved; travel costs; inconvenient scheduling; lack of motivation.
Agility Across Organizational Boundaries	Incompatible siloed cultures and languages.	Common language; less handoffs; product-based teams; common metrics.	Functional organizational silos.
Agility with Long Lead Components and Dependencies	Components and external dependencies with long lead times complicate schedule coordination and disrupt technical performance.	Scheduling and acquisition techniques that better align with agile-SE principles.	[False] justification that long lead times prohibit the use of agile-SE.
Continual Integration	Late discovery of integration and requirements issues.	Minimize risk and rework with fast learning; maximize stakeholder engagement.	Development effort and expense; technologies for integrating/ testing software prior to hardware being ready.
Orchestrating Agile Operations	Coherence among loosely coupled multi-actor outcomes.	Dynamic operational coordination in real-time.	Ability to encode self-learning; adaptive logic as decision-support for people and for autonomous decision making.
Situational Response Automation	Decision and action too slow.	Continual dynamic adaptation within cyber-relevant time and/or time-of-relevance.	Complications of encoding autonomous governance and adjudication logic and rules; situational awareness that provides necessary inputs.
Harmonizing Risk in Agile Operations	Agility focus is principally loss avoidance.	Expand awareness and operational realization of both negative side of risk (loss) and positive side of risk (opportunity, seek gain, continual optimization).	Silo-thinking and predominance of looking at risk only terms of loss.

Conclusion

- Introduced 4 objectives & 9 foundational topics
- Begins roadmap for improving the integration of agility into systems thinking and systems engineering
- Vision 2025 and Beyond
  - SE produces and operates systems as software platforms
  - SE facilitates autonomous systems
    - Dynamic adaptation: 1) sustain value-delivery & 2) sustain relevance
- The future depends on formalizing agility in SE

Next Steps

- Help continue the journey!
  - Realize/refine the vision
  - Further the topics
  - Introduce new topics
  - Expand the roadmap

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Questions
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