30th Annual INCOSE international symposium

Virtual Event
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Implementing Systems Engineering in Early Stage Research and Development (ESR&D) Engineering Projects

Presenter: Heidi Ann Hahn

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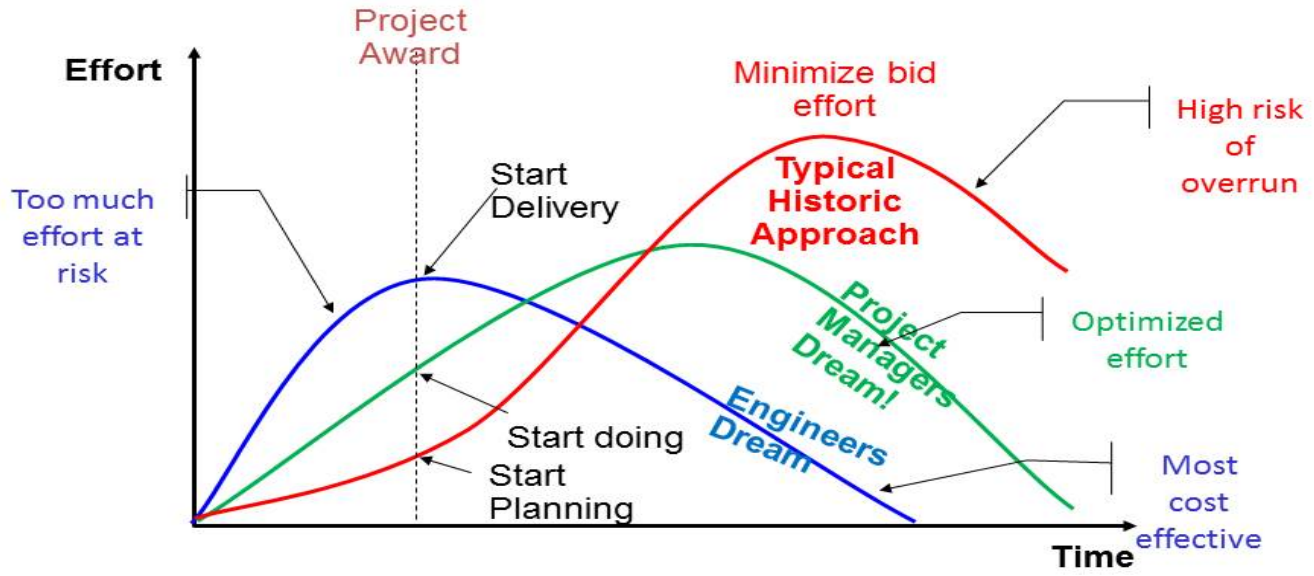
Acknowledgements

- This presentation is based on the *Proceedings* paper which has the following authors:
  - Frederic Autran, Airbus Defense & Space
  - Ann Hodges, Sandia National Laboratories
  - Nick Lombardo, Pacific Northwest National Laboratory
  - Mitchell Kerman, Idaho National Laboratory

The Problem

- ESR&D is a crucial phase of the design process
- But many executives, program/project managers, researchers, and clients don't understand the value of SE
- Application of formal SE processes may not be warranted or affordable
- Result is that SE is often not applied
  - This results in R&D efforts that solved the wrong problem, solved the problem incorrectly, could not be transitioned to higher maturity levels, and/or had cost or schedule overruns

Tradeoffs in Applying SE in ESR&D Projects



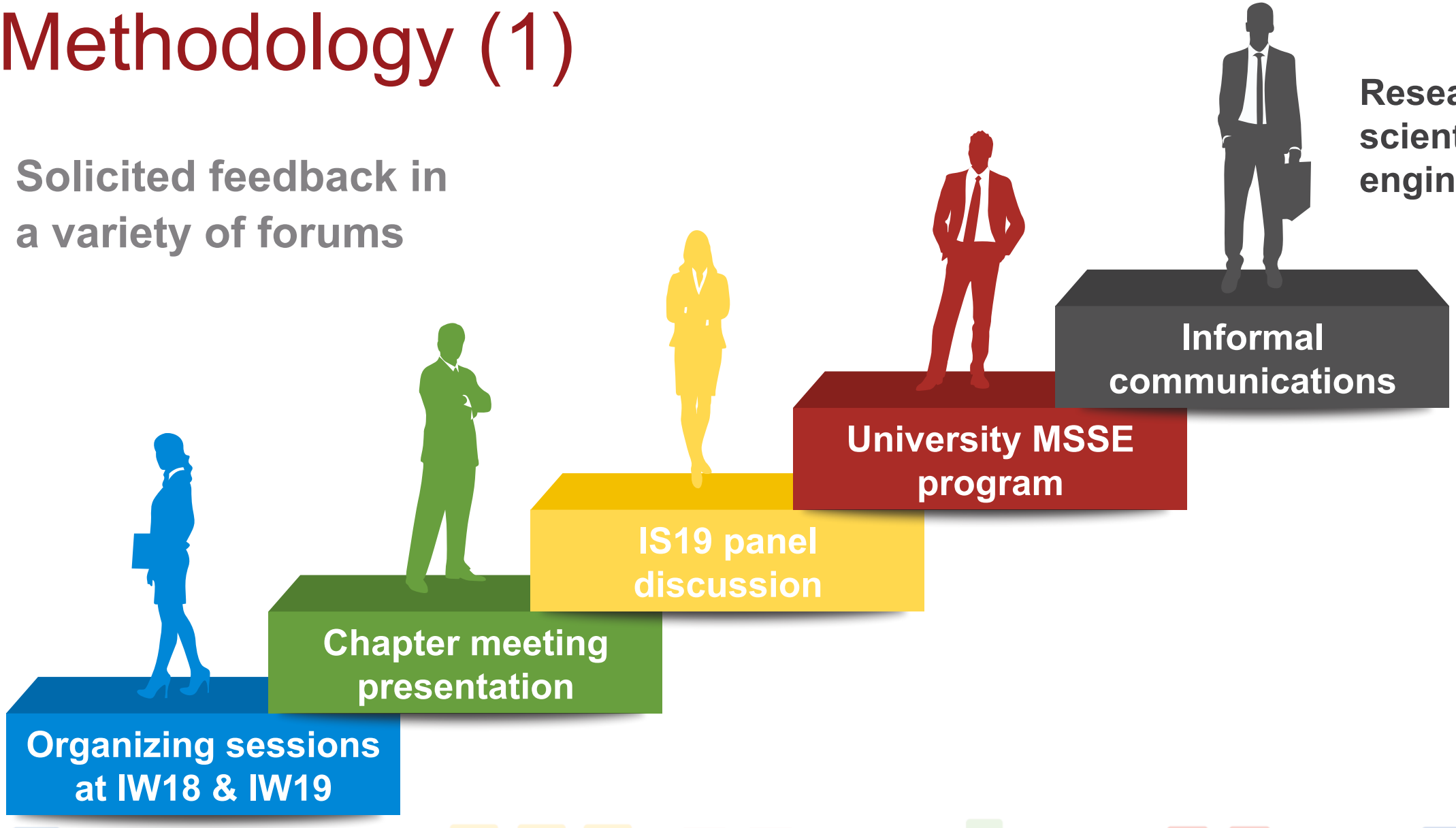
Trade-offs in Applying Systems Engineering in the Early Stages of R&D Projects (adapted by Autran, 2019, from Smith, 2011)

Emergence of Interest in the Topic

- Started with a subset of US Federally Funded Research and Development Centers
- Attendance at organizing meetings at subsequent IS and IWs showed that there was much broader interest
  - Government laboratories, university-affiliated research centers, S&T and R&D organizations, including public and private commercial entities, all represented
- Issues common to all of these organizations drive their interest

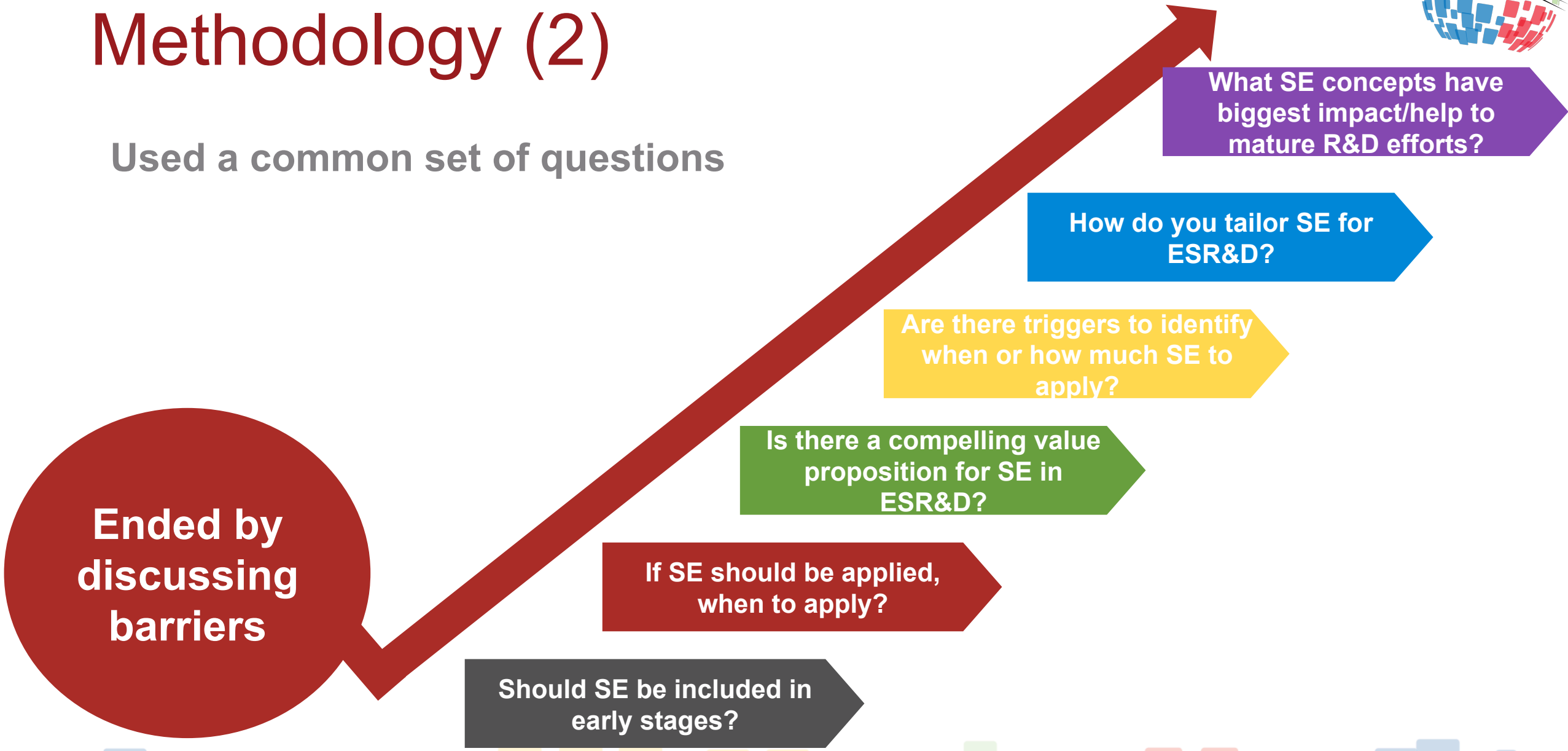
Methodology (1)

Solicited feedback in a variety of forums



Methodology (2)

Used a common set of questions



Results

- Compiled from authors' IS19 panel presentations and feedback from the participants at the various forums

Whether and When to Apply SE

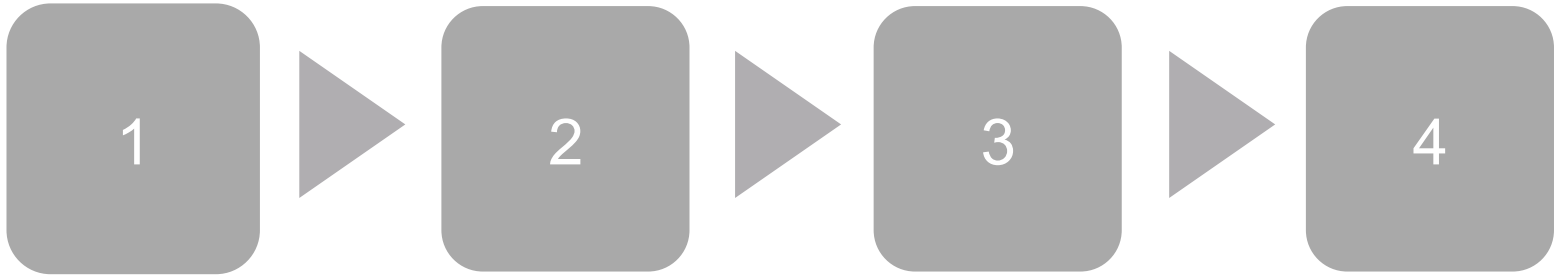
- Nearly unanimous agreement that SE should be applied to ESR&D
- And that SE should be applied as early as possible

Overall Value Proposition for SE (1)

- From Kerman (2019):
  - The application of SE principles, practices and tools helps projects clearly define goals, requirements, and system boundaries and understand and manage complexity and risk

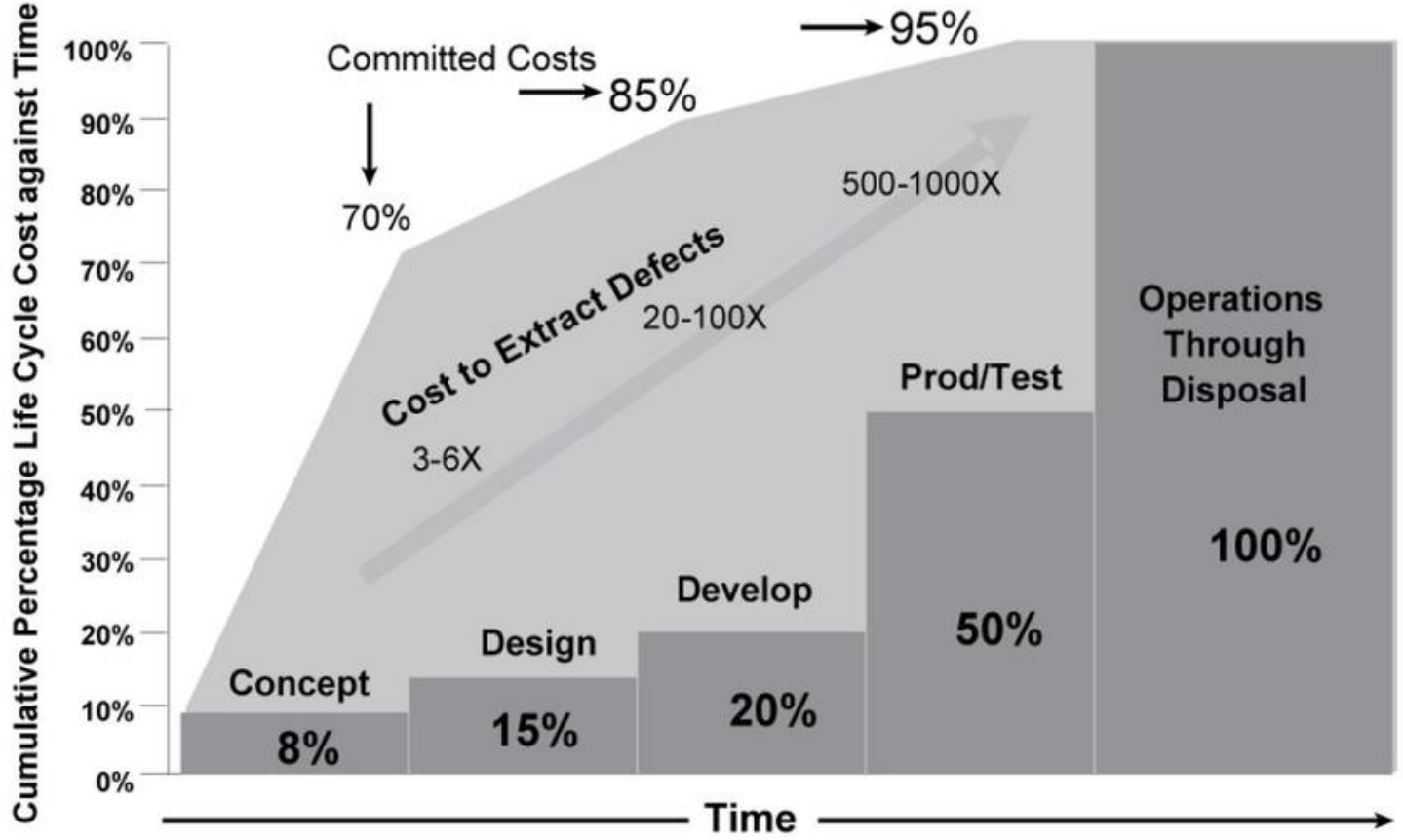
Overall Value Proposition for SE (2)

Said another way, application of SE helps ensure:



1	2	3	4
A single, consistent, clear project target	Application of structured DM processes	Accurate engineering estimates	Realization of optimal solutions

Value Proposition for Applying SE Early



Lifecycle Costs and Cost to Extract Defects Through-out a Project (INCOSE, 2015)

Triggers for Including SE in ESR&D Projects

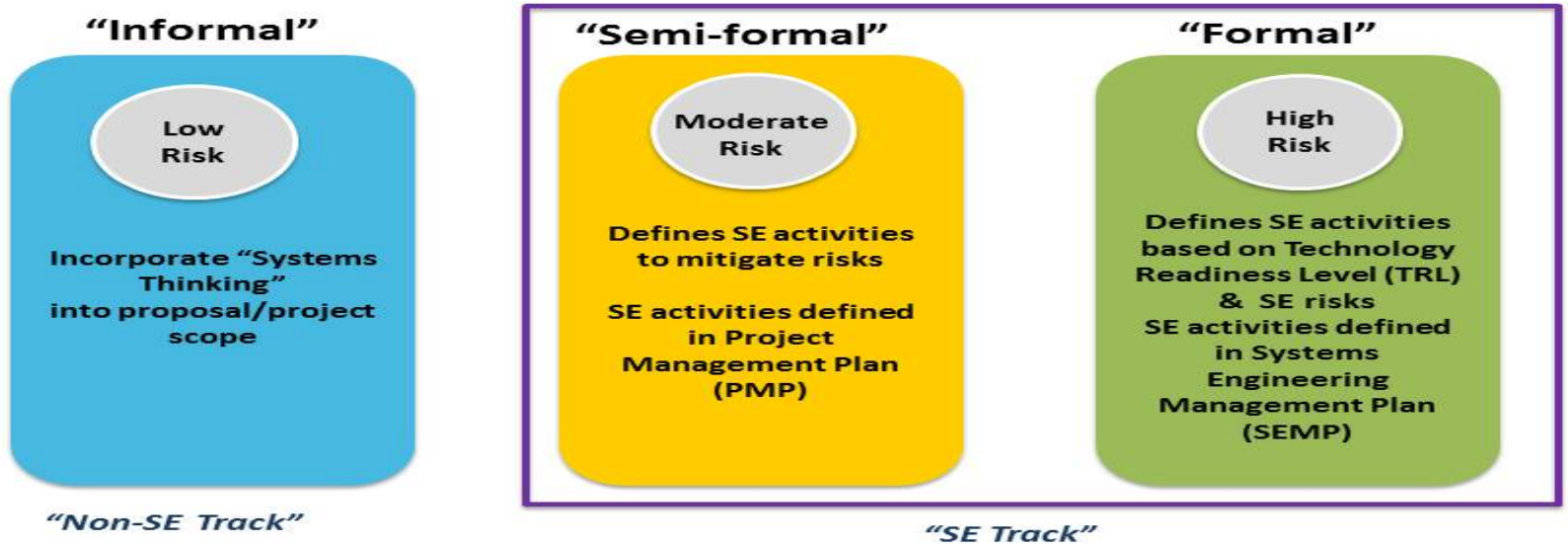
- Triggers guiding the degree of SE rigor should be risk-based

Hahn (2019)	Hodges	Lombardo (2019)
Technical risks	Consequence of failure	Client factors
Resource risks	Product-related characteristics	Multiple stakeholders/ execution partners
Cost and funding risks	Organizational/project-related characteristics	Multi-disciplinary/multiple life cycle stages
Schedule risks		Projects with testing requirements
Transition risks		Safety- or mission-critical projects, highly regulated environments
		Potential commercialization

Tailoring (1)

- All agree that tailoring is needed, but there are organizational differences in what tailoring is permissible
  - Is there a *de minimus* threshold below which no formal SE processes are required?
  - How much formal project management is needed?
- Tailoring must account not only for how much SE to apply but also for how SE concepts are presented
  - "Stealth" SE (Hahn, 2016)

Tailoring (2)



Three Classes of Systems Engineering Based on SE Risk (Lombardo, 2019)

Tailoring (3)

- Lombardo (2019) describes four dimensions of tailoring:
  - What is the project's system development risk level?
  - Does SE apply?
  - What SE activities should be performed to manage system development risk?
  - What technical procedures apply?

Bang for the Buck/Support for Future Growth

- Analysis activities typically performed in the SE concept phase have the greatest bang for the buck
  - Mission and business analysis
  - Stakeholder needs analysis
  - Lifecycle analysis
  - Requirements development
- These same activities support future growth

Barriers/Challenges (compiled from Hahn's, Hodges', and Lombardo's 2019 presentations)

- Stakeholders may perceive SE as being heavily process oriented, adding unnecessary costs, and being applicable only to mature technologies
  - The PM/PI may not understand what SE is or what value it may add
  - The PM/PI may not think it is important to apply SE in the early stages of the project because the benefits won't be derived until later in the development process
  - Researchers may want a *de minimus* standard at which there would be no required action
  - The PM/PI may be reluctant to invest in SE because the project is underfunded or because SE is considered added scope for which funding has not been allocated
  - The customer may be unwilling to fund SE scope – again because of the lack of perceived value and the timeframe in which benefits accrue
- There may not be corporate capability in SE
- There is little guidance on how to "scale down" SE practices to fit ESR&D projects
- There may be a lack of enforcement of corporate systematic processes that would ensure implementation of SE on all projects

Implementation Recommendations

- View early stage implementation of SE as an investment
- Closely couple the organization's SE and PM processes
- Use risk-based trigger questions/criteria to determine "how much" SE to apply
- Avoid using SE jargon
- Base the implementation on standards
- Use stage gates to manage the transition from research focus to development focus
- Demonstrate and build advocacy with all types of stakeholders

Discussion

- Whether to leverage successes and failures as a way of demonstrating SE value
- How much SE resource to invest early in the project
- Lack of good guidance on tailoring
  - Balance of right-sizing SE for early stages of the project while supporting future scale-up
- Language barriers

Summary and Conclusions

- ESR&D requires a risk-based, disciplined and graded approach to effectively manage scope, cost, and complexity
- SEs role is to analyze the problem and solution space and to focus early effort on the risky parts of the development stages of the project
- Overcoming the barriers to SE implementation requires a concerted change management effort
  - Stakeholders need to recognize that they have common goals: preserve research quality while managing risk to ensure project success

INCOSE SE in ESR&D WG

- WG chartered in early 2020
- Goal is to expand the SE body of knowledge to include ESR&D processes, standards, best practices, and approaches to tailoring
- Have an ongoing project aimed toward this goal

Questions/Comments?

- Post questions or comments on the presentation dashboard
- I will check the dashboard at least 2X/day
- If you have a question for an author other than myself, include to whom it is addressed

References Used in this Presentation

- Autran, F 2019, 'An Industrial Viewpoint on SE in Early Stage Product Development', Presented as part of a panel discussion titled *Implementing Systems Engineering in Early Stage Research and Development Projects* at the *INCOSE 29th Annual International Symposium*, Orlando, FL (US) July 20-25.
- Hahn, H. A 2019, 'Perspectives on Implementing Systems Engineering in Early Stage R&D Projects', Presented as part of a panel discussion titled *Implementing Systems Engineering in Early Stage Research and Development Projects* at the *INCOSE 29th Annual International Symposium*, Orlando, FL (US) July 20-25.
- -- 2016, 'A Mission Assurance Framework for R&D Organizations', *Proceedings of the 26th Annual INCOSE International Symposium* 26 (1), 2070-2084, Edinburg, Scotland (UK) July 18-21.
- Hodges, A. L 2019, 'A Federally Funded Research and Development Center Perspective on Systems Engineering in Early Stage R&D', Presented as part of a panel discussion titled *Implementing Systems Engineering in Early Stage Research and Development Projects* at the *INCOSE 29th Annual International Symposium*, Orlando, FL (US) July 20-25.
- *INCOSE Systems Engineering Handbook: A Guide for System Life Cycle Processes and Activities,* Fourth Edition 2015. Edited by David D. Walden, Garry J. Roedler, Kevin J. Forsberg, R. Douglas Hamelin and Thomas M. Shortell. John Wiley & Sons, Inc. Hoboken, NJ (US).
- ISO/IEC 29110 – *Systems and Software Lifecycle Profiles and Guidelines for Very Small Entities (VSEs)*, 2015.
- Kerman, M 2019, 'A Digital Engineering Ecosystem for Future Nuclear Power Plants', Presentation to the Virginia Tech Northern Virginia Center's Systems Engineering Master's Program, August 5.
- Kerzner, H 2017, *Project Management: A Systems Approach to Planning, Scheduling, and Controlling*, John Wiley & Sons, Hoboken, NJ (US).
- Lombardo, N. J 2020, 'SE 101 for Project Managers', Training course presented at Pacific Northwest National Laboratory, Richland, WA (US), various dates
- --- 2019, 'SE in Early Stage R&D', Presented as part of a panel discussion titled *Implementing Systems Engineering in Early Stage Research and Development Projects* at the *INCOSE 29th Annual International Symposium*, Orlando, FL (US) July 20-25.
- Lombardo, N., Millard, D., and Sturges M 2015, 'A Systems Engineering Framework for R&D Organizations', *Proceedings of the INCOSE 24th Annual International*
- Rebentisch, E (ed.) 2017, *Integrating Program Management and Systems Engineering*, John Wiley & Sons, Inc., Hoboken, NJ (US).
- Smith G 2011, 'Trade-offs in Applying Systems Engineering in the Early Stages of R&D Projects', personal communication with Autran, February 2011.

Thank You!

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