Dr. Michael DiMario, Ann Hodges, Dr. Gary Mastin

2021
Annual INCOSE
international workshop
Virtual Event
January 29 - 31, 2021

SE in Early Stage R&D Working Group

www.incose.org/IW2021

Charter Overview

- **Purpose:** To provide an open forum for the development, application, and dissemination of systems engineering principles, best practices, and solutions to scaling systems engineering applications to Early Stage R&D (ESR&D) projects so that the level of systems engineering effort is commensurate with risk and the anticipated ESR&D outcomes are achieved
- **Primary Goal:** To provide knowledge, guidelines, and frameworks for the application of systems engineering in ESR&D

Charter Overview Cont'd

- **Scope:** Focus on activities at Technology Readiness Levels (TRLs) 1 – 5
- **Outcomes:**
  - An ESR&D SE framework that contains guidelines and processes for the "right" and "right-sized" tailored SE practices and products based on a TRL of 1-5 and other characteristics e.g., organizational culture and philosophies
  - Papers, articles, briefings, and tutorials
  - Support the development of additions to the INCOSE SE Handbook and standards related to ESR&D

Charter Overview Cont'd – Background

- Early Stage Research and Development (ESR&D) is one of the most crucial phases in the product development process
  - ESR&D is defined in terms of Technology Readiness Levels (TRLs) 1 – 5
  - Is a critical phase in the product development process
- Many organizations/positions/key stakeholders are unwilling to apply SE in ESR&D due to due to perceptions of SE being process/cost heavy
  - Results in technical issues with solutions, difficulty in transitioning to higher TRLs, higher R&D costs, and extended development timelines
- ESR&D differs from traditional SE in a number of important ways:
  - ESR&D addresses higher risk technologies with multiple opportunities for failure
  - ESR&D accounts for the fact that there is much about the underlying technology *and* its associated concept of operations that is poorly understood
  - ESR&D is a way to practice SE for organizations without a strong SE culture
  - ESR&D of focused on areas of high "system development risk"
- Lack of a commonly understood and accepted framework inhibits multi-disciplinary collaboration
  - A common framework that can be tailored and sustained for ESR&D, while enabling transition to TRL 5 and higher, is needed

Review WG Products, Initial Concepts

- CORE Team officially formed February 2020
- Charter affirmed March 2020
- INCOSE recognized WG April 2020
- INCOSE Connect Site IT Logistics
- Publications
  - “Implementing Systems Engineering in Early Stage Research and Development (ESR&D) Engineering Projects” IS20 30Th Annual INCOSE International Symposium July 18-23, 2020
  - “Perceived Conflicts of Systems Engineering in Early Stage Research and Development” Draft INCOSE InSight August 2021
- IS21 July 17-22, 2021 Panel Submission and Preparation
- Established suggested SE in ESR&D Frameworks

Initial Framework Concepts

ESR&D Framework for Research and Engineering Transition – Dr. Michael DiMario

- Innovation and research is noted with high failure
  - High risk and low return of investment
  - Projects fail at TRL 5-6 Valley of Death
  - Engineering transition is difficult and high risk
    - Research not appropriate for engineering transition
    - Basic research vs applied research
    - Solving the right problems for engineering transition
- Research and ESR&D is based in principles of expansionism vs reductionism
  - Continuous flow of ideas and experiment
  - Transition requires reductionism
- Framework must accommodate expansionism and reductionism
  - Example: Tailored process, tools and organization structure; Gated research artifacts transition to early engineered artifacts in a continual spiral of expansionism-reductionism-expansionism-reductionism using prescribed and tailored tools and processes; Research oriented engineer responsible for research whereby basic or applied research only performed to solve engineering problems

Framework Based on Risk, Industry Standards and Project Type – Sandia National Laboratories

- Risk-informed graded approach to the application of systems engineering (SE), project/program management (PM), and quality management (QM)
- Identified core set of practices that every project is required to follow – from the small best-effort research efforts to large pathfinder operational systems
- Implement differing level of rigor (timing, scope, formality) based on intrinsic project risk
  - Provide research-oriented projects an efficient and solid foundation for growth – either for future research efforts or further development of the research results – without stifling creativity and exploration
  - Start early in the project creation phase using a rigor-level determination template, followed by the tailoring of a project and product plan template for the determined level of rigor
- Developing project type category and subcategory templates for the risk-informed graded approach to increase efficiency and effectiveness.

SAND2020-12414C

U.S. DEPARTMENT OF ENERGY

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

National Nuclear Security Administration

Another Framework Based on Risk, Standards and Project Type – Los Alamos National Laboratory

- Risk-informed graded approach to the integrated application of systems engineering (SE), project management (PM), and quality management (QM)
  - Called this Mission Assurance
  - Quality standard for basic research is the ANSI standard, transitions to industry standard as TRL increases
- Identified core set of practices that every project is required to follow – from basic scientific research to advanced technology development
  - Provided the Mission Assurance Support Tool (MAST) as an implementation aid
- Implemented differing level of rigor (reviews, approvals, required documentation) based on project risk
  - Start early in the project initiation phase using a rigor-level determination template
  - Review risk-level determination throughout the project and adjust as needed

LA-UR-19-25567

Framework Based on Risk, Industry Standards and Project Type - Pacific Northwest National Laboratory

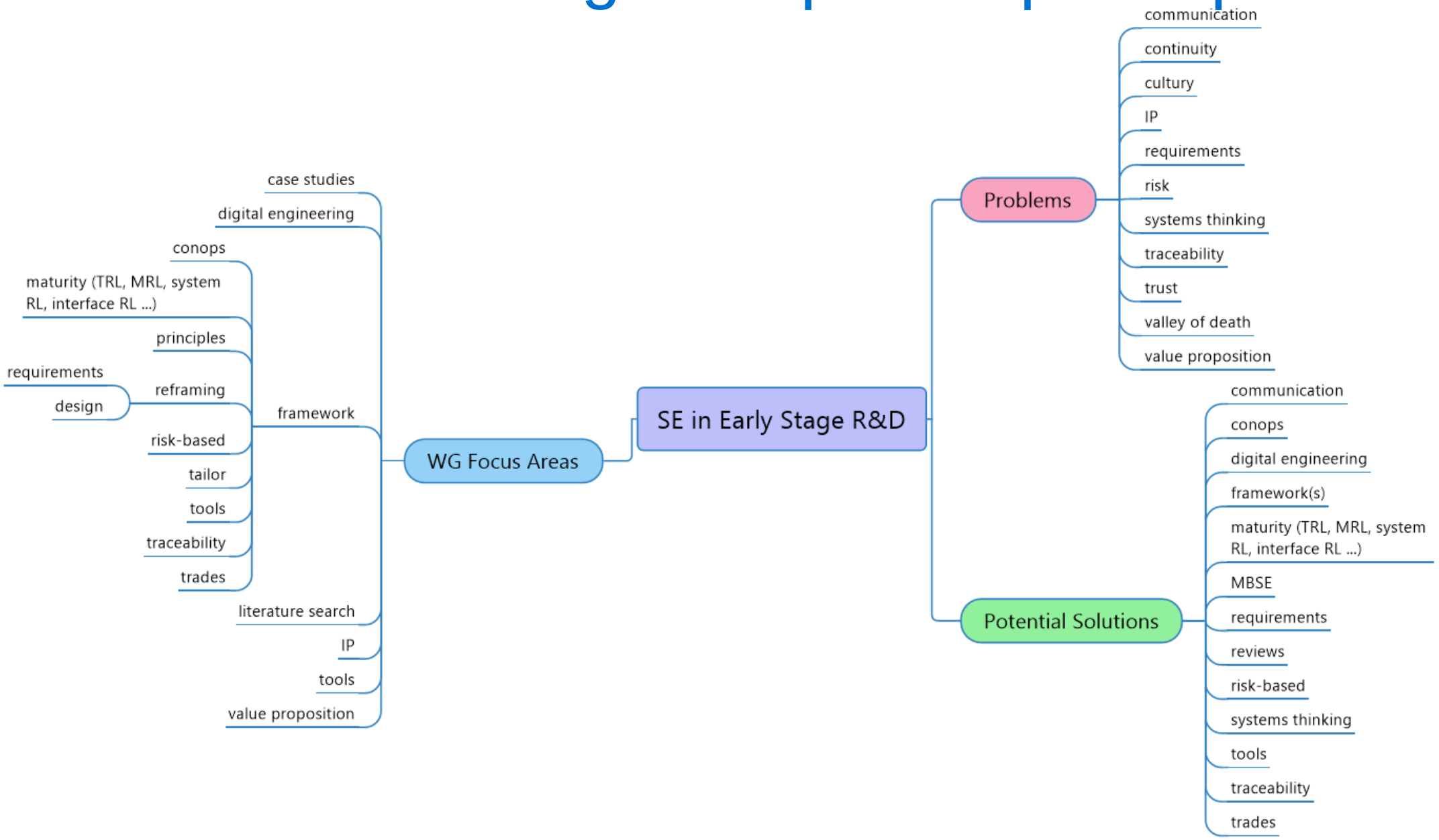
- Extend risk-informed graded approaches for project/program management (PM) and quality management (QM) to SE
- Define SE “triggers” which drive implementation of SE (informal, semi-formal, formal)
- Define SE risks
  - Across project life cycle (e.g., concept, development, utilization phase)
  - Across project types (e.g., assessments, product development, test and evaluation)
  - By TRL (TRL 3: defines KPPs; TRL 4+: define specification)

U.S. DEPARTMENT OF ENERGY

Why is ESR&D needed? - Pacific Northwest National Laboratory

- When system development risk is ignored or minimized
- For organizations without a strong SE capability/culture
- For organizations with a wide spectrum or project types, sponsors, and/or TRL levels
- When there is a high risk of technical failure
- When system requirements/ConOps are poorly defined
- Where there is a desire to institutionalize SE processes and procedures (e.g., CMMI level 3)
- ESR&D is a mechanism to transition engineering early out of engineering to iterate between research and engineering

IW21 ESR&D Working Group – 65 participants



Your thoughts?
Problems

- Thought 1

Your thoughts?
Solutions

- Thought 1

How to Get Involved

- Contact any of the core WG team to volunteer, for questions
  - Ann Hodges, alhodge@sandia.gov
  - Michael DiMario, mjdimario@outlook.com
  - Heidi Hahn, drsquirt@outlook.com
  - Nick Lombardo, nick.lombardo@pnnl.gov
  - Gary Mastin, gary.a.mastin@gmail.com

BACKUPS