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A Systems Engineering Framework for R&D Organizations

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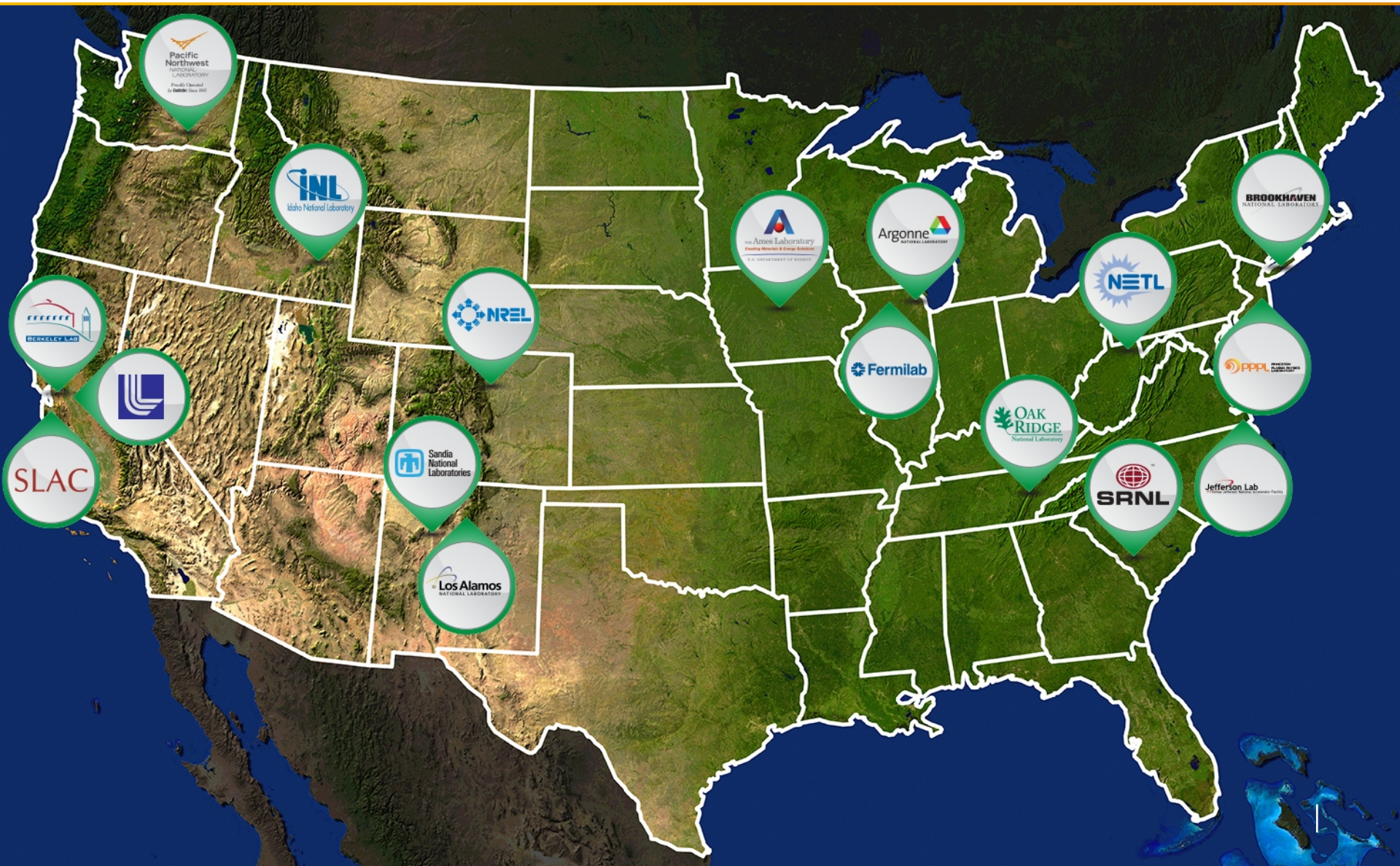
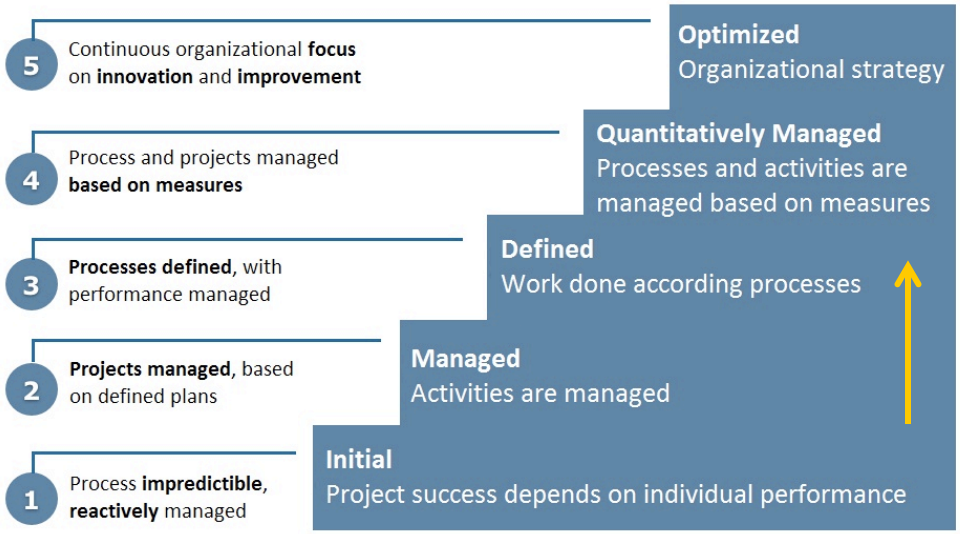


Why Make Investments in SE?

- While a core competency, SE was practiced on an ad hoc basis
- Enhance our “expert delivery” of projects
- Help create exceptional products
- Improve our record of transitioning technologies
- Client expectations of SE
- Competitiveness



Initial/target CMMI Levels

SE supports PNNL’s mission, expert delivery, and staff and business development

The Challenges

- 1000+ projects annually
- Projects span basic research to support
- Multiple project “types”
- Lab culture span “academics” to “industrial” focus
- Clients span spectrum of systems engineering awareness

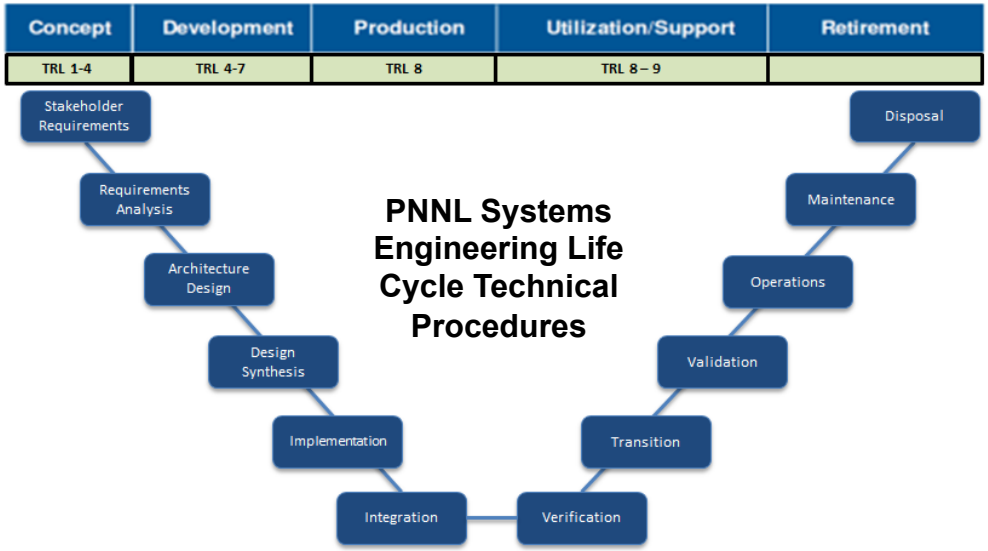
Systems Engineering Framework Elements

Lifecycle Selection

- Evaluated wide range of standards, lifecycle processes, and approaches
- Selected candidates that met key requirements
- Developed downselect decision criteria
- Peer review of downselect process and selected lifecycle

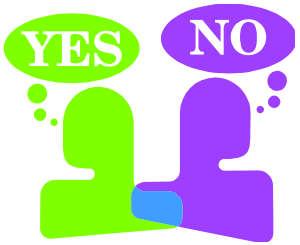
Systems Engineering Life Cycle Process (SELCP)

- Defines 5 management and 12 technical procedures
  - MPs guide its use, technology transition, & continuous process improvement
  - TPs define “good SE practices“ for realization of systems
- Accommodates wide range of project types, TRLs
- Tied to ISO/IEC 15288
- Defines 3 levels of SE based on *system development risk*
- Multiple built-in tailoring opportunities
- Key risk mitigation resource



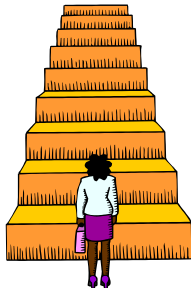
PNNL Systems Engineering Life Cycle Management Procedures

Dimensions of SE Tailoring

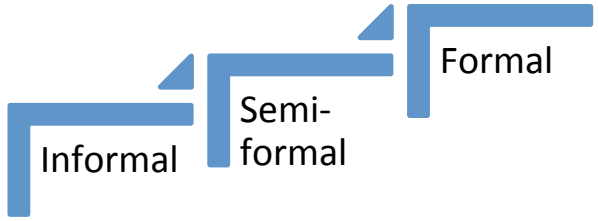


Does SE apply?

Procedure M1



What are my risks?



What level of SE do I need?

Procedure M2

Concept	Development	Production	Utilization/Support	Retirement
TRL 1-4	TRL 4-7	TRL 8	TRL 8 – 9	

What technical procedures (TPs) apply?

Which technical activities apply?

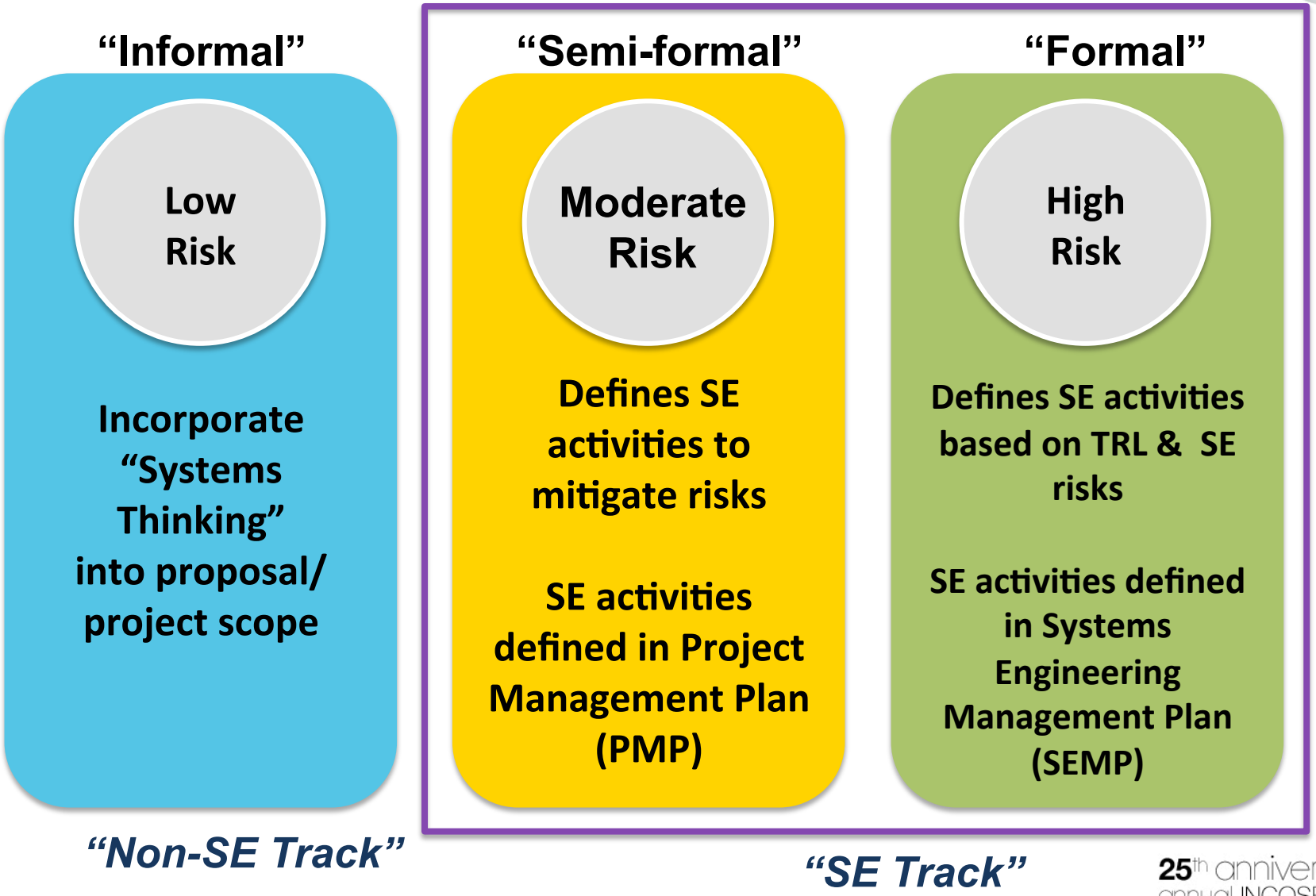
Procedure M3

Project Planning Documents

SE Applicability Trigger Questions

- Delivery of product or service
- Safety-critical or mission-critical application
- Multiple stakeholders, contract execution partners, technical disciplines
- Validation/verification testing, field tests
- High degree of technical risks/uncertainty
- Regulatory issues
- Potential for technology transition/transfer

SE Levels & Documentation



SE Risk Register Facilitates Right-Sizing of SE Activities

- System development risk are assessed across all lifecycle stages
  - Assesses 9 major risk categories addressing ~ 20 risk areas
- Presents risk mitigation options and relevant TPs for development of actionable risk mitigation strategies
- Risk profile is primary factor in determining SE level
  - Client requirements, funding level, or other factors may override

SE Risk Register Elements

System Risk
- SoS complexity
- Integration complexity
- Transition barriers

Interface Risk
- Stakeholder complexity
- Interface complexity

Requirements Risk
- Strength of requirements
- Definition of key metrics
- Requirements verification traceability complexity

Technology Risk
- Alternative architectures
- Technical risk
- Specialty engineering

Execution Risk
- Tech reviews
- Implementation complexity

V&V Risk
- V&V complexity

Production Risk
- Acquisition level
- Production complexity

Transition-to-Disposal Risk
- Transition complexity
- Supportability complexity
- Disposal complexity

Customer Risk
- SE posture

Example Risk Register Element

Risk Element 4	Risk Definition	Level	Risk Assessment	Risk Mitigation Strategy
Strength of Requirements	Requirements should be documented, actionable, measurable, testable, traceable, related to operational scenarios, defined to a level of detail sufficient for system design, and approved by stakeholders and users. Requirements can be defined as TBD as long as there is a plan to generate the requirement details later. Projects without well-defined operational scenarios or with poorly-defined and/or changing requirements carry a greater level of risk. Note: the requirements *belong* to the stakeholders and users, not PNNL or the system developer. PNNL may lead or support requirements development.	N/A Low	Requirements are well understood and are grounded in a concept of operations. Customer and stakeholders have a unified view of the system requirements. Requirements documentation exists or is being prepared. The number of requirements TBD does not present a development risk.	Track TBD requirements and develop a strategy to close gaps if appropriate. Review requirements documents to ensure that sufficient granularity exists to design and verify the system. Document any additional requirements activities in PMP Section 2.1, *Technical Activities* and reference existing source and/or requirements documents in PMP Section 2.6, *Reference Documents*.
	For additional insights, see SELCP Procedures T1, Stakeholder Requirements Definition and T2, Requirements Analysis.	Med	Loosely defined concept of operation. Sources of requirements exist, e.g., concept documents, but have not been formalized. If requirements documents exist, key requirements may be TBD. Stakeholders may have limited understanding of requirements and/or may have conflicting	Consider an effort to formalize requirements in the proposal. Work with the client to define the appropriate level of requirements document (e.g., operational requirements vs. functional requirements document). Consider a Requirements IPT to facilitate requirements development and concurrence. Develop a strategy and timeline to address TBD requirements. Define the strategy to strengthen requirements in PMP Section 2.1, *Technical Activities and Approach* and reference existing requirements in PMP Section 2.6, *Reference Documents* or in a SEMP.
		High	Poorly defined concept of operations; formal requirements do not exist and there is a limited number of source documents to generate requirements. Many key requirements are TBD. Stakeholders have little experience in defining requirements and/or have conflicting requirements.	Consider an effort to formalize requirements in the proposal. Work with the client to define the appropriate level of requirements document (e.g., operational vs. functional requirements document). Consider a Requirements IPT to facilitate requirements development and concurrence among stakeholders. Develop a strategy and timeline to address TBD requirements and track the number of open requirements as a function of time. Define the strategy to strengthen requirements in PMP Section 2.1, *Technical Activities and Approach* and reference existing requirements in PMP Section 2.6, *Reference Documents* or in a SEMP.

Input to M3: SE Planning

Life Cycle/TRL Mapping to Technical Procedures

	Concept			Development				Production	Utilization & Support	Disposal
	TRL 1	TRL 2	TRL 3	TRL 4	TRL 5	TRL 6	TRL 7	TRL 8	TRL 9	
	Basic principles observed and reported	Technoclogy concept and/or application formulated	Analytical and experimental critical function and/or characteristic proof-of-concept	Component and/or breadboard validation in laboratory environment	Component and/or breadboard validation in a relevant environment	System/sub-system model or prototype demonstration in a relevant envrionment	System prototype demonstration in an operational environment	Actual system completed and qualified through test and demonstration	Actual system proven through successful mission operations	
T1 - Stakeholder Requirements Defn	A	P	I	I	I	I	I	M/R	M/R	M/R
T2 - Requirements Analysis	A	P	I	I	I	I	I	M/R	M/R	M/R
T3 - Architectural Design	A	P	I	I	I	M/R	M/R	M/R		
T4 - Design Synthesis		A	P,I	I	I	I	i	M/R		
T5 - Implementation		A	P	I	I	I	I	M/R		
T6 - Integration			A	P	I	I	I	M/R		
T7 -Verification			A	P	I	I	I	I	M/R	
T8 - Transition					A	P	I	I	M/R	
T9 - Validation					A	P	I	I	M/R	
T10 - Operations						A	P	I	I	
T11 - Maintenance						A	P	I	I	
T12 - Disposal								A	P	I

A=Awareness
P=Planning
P,I=Planning, Implementation
I=Implementation
M/R=Monitoring Refinement

Entry

Exit

Who are Key Players in SE?

Technical Group Managers
- Create awareness
- Develop SMEs
- Assist in identifying SE-track projects

Project Managers
- Understand and mitigate SE risks
- Right-size SE effort
- Engage clients
- Implement SE scope
- Process feedback

Sector
- Identify SE-track proposals
- Market PNNL's unique approach
- Market awareness and feedback

PMODs
- Implement framework
- Assess SE risks
- Drive lexicon
- Mentor PMs
- Process feedback

Results to Date

- 36 risk assessments competed
  - 16 proposal, 20 ongoing projects
- All in semi-formal track
- Half had appropriately addressed risks
- Half had not clearly articulated risk mitigation strategies or were in early stages of their implementation
- Predominant risk: stakeholder complexity, lack of requirements, evaluation of alternatives, and complexity of verification activities

Implementation Challenges

- Last minute proposals
- Demonstrating value add
- Consistency of implementation
- Organizational perceptions/differences
- Sustainability of process

SE Framework Is the Catalyst For Creating A SE Culture At PNNL

- Formalizes SE in the execution of projects
- Increases the awareness of the importance of SE
- Serves as the basis of SE project tailoring, training, and products
- Brings a risk and technical maturity approach to right-sizing SE
- Provides an extensive set of tools, templates, and guidelines
- Provides traceability for key decisions made
- Will help realize SE's value proposition

Questions?