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Applying Model Based Systems Engineering to Reduce Nuclear Weapons Development Cycle Time

INCOSE International Workshop - January 2019

PRESENTED BY

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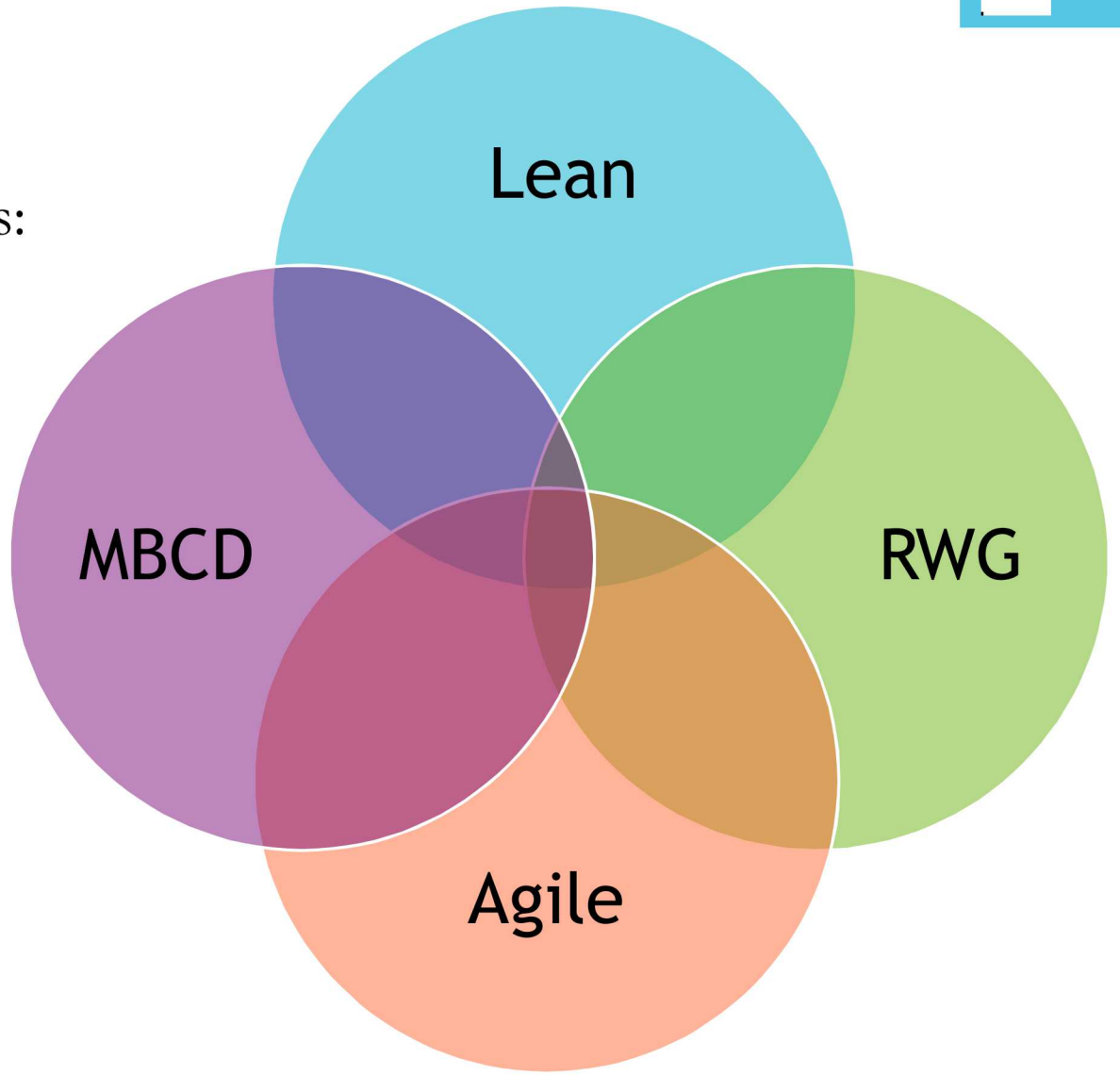
Purpose of our Presentation

We are presenting to the following working groups:

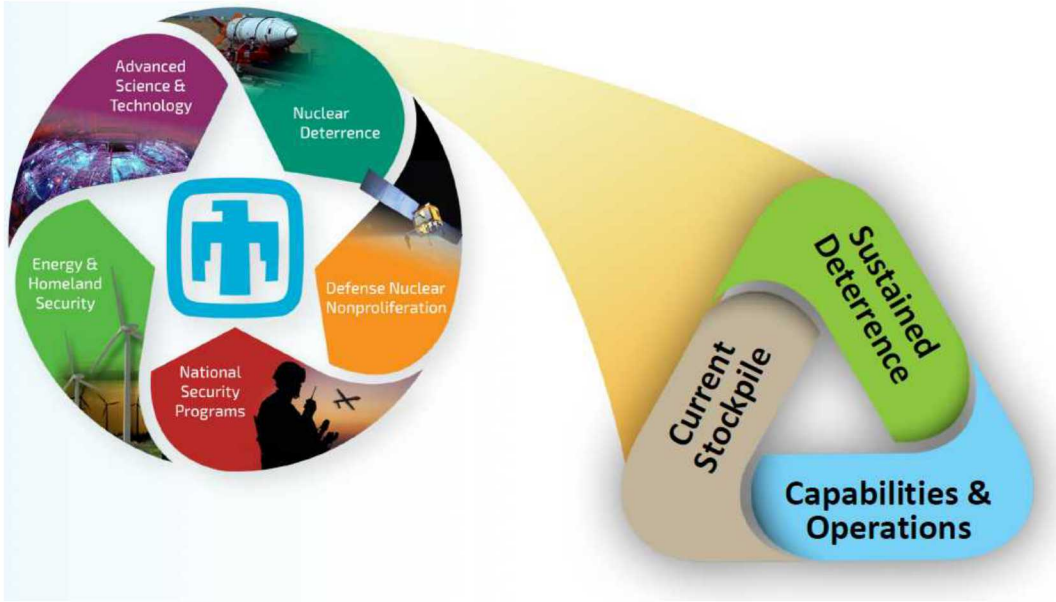
- Lean
- Requirements
- Agile
- Model Based Conceptual Design

We hope to gain feedback and information on how each of these focus areas help us achieve our goal!



Overview

- SNL Nuclear Deterrence Mission
- Reducing the Nuclear Weapons Development Cycle
- How MBSE fits and objectives
- Life Extension Programs (LEPs)
- How MBSE Benefits NW Development
- Descriptive Modeling Activities
- Obstacles and Challenges
- MBSE Intersection Points



Sandia National Laboratories (SNL) Enterprise Pillars

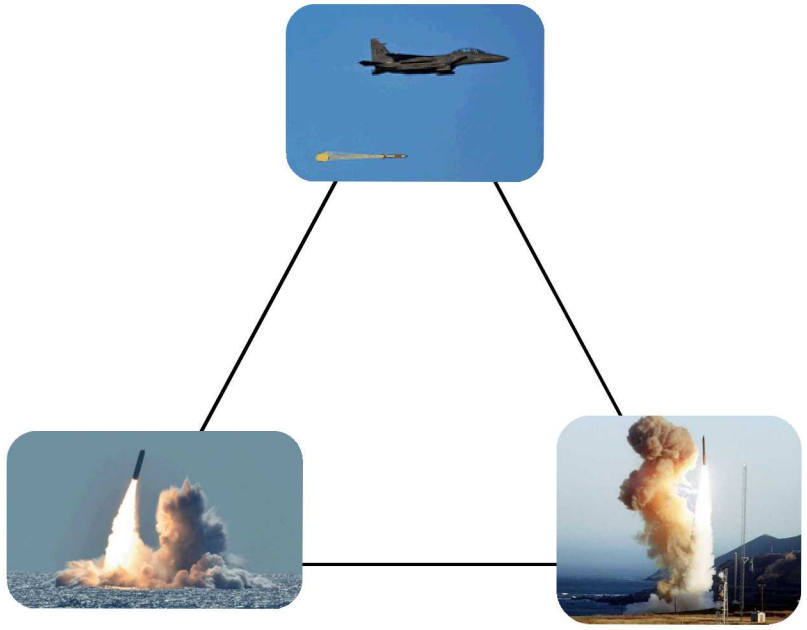
Sandia's Nuclear Deterrence (ND) Mission

National & Global Security
- Safe, Secure, effective U.S. Nuclear Deterrent

Today and in the Future
- Flexibility
- Responsiveness

Provide Systems Engineering
- R&D
- Development
- Production
- Surveillance
- Retirement

MBSE



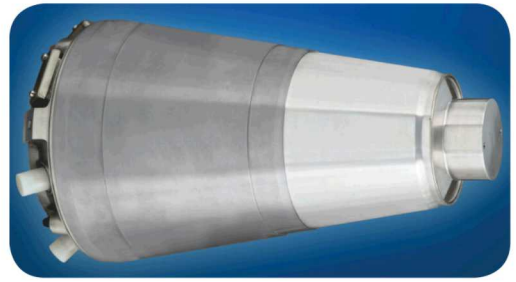
Committed to MBSE as a means to reduce NW Cycle Time

What is a Life Extension Program?

As weapons systems age sustainment activities may warrant a life extension program (LEP) to address material aging or performance issues, enhance safety features, and improve security.

An LEP is intended to evaluate an entire weapon system and refurbish, reuse, or replace components to extend the service life of a warhead while increasing safety and improving security.

- Our work will focus on two LEPs to showcase MBSE implementation efforts:
  - W80-4: Thermonuclear Warhead selected for the Air Force's new nuclear cruise missile, Long-Range Standoff (LRSO)
  - W76-2: Low Yield Ballistic Missile mentioned in the 2018 Nuclear Posture Review



Necessity for Development Cycle Reduction Activities

- Uncertainty in threat evolution drives a need for **rapid, responsive reaction** to non-U.S. "surprise" capabilities.
- Advances in **computer simulation accelerate innovation** and can offer ways to combat the increasingly long and expensive weapon-system development cycles.
- Industry is evolving toward flexible manufacturing approaches, such as additive manufacturing, that enable **rapid design evolution** and can lead to surprising advances, but also to new threats.

WHY	HOW	OUTCOME
Reduce NW development cycle time to be responsive to rapidly emerging national security threats.	Reach across the laboratory to enable and leverage industry and best in class architectures, technologies, tools, and processes tailored for NW applications.	Reduce the NW Development cycle from 12 years to 3 years with no compromise to quality, safety or surety.

NNSA Stockpile Goals for the NSE

Draft Goals and Ends for the Nuclear Security Enterprise (NSE)

1. Reduce Time to Perform a Life Extension Program.
2. Field an Inherently Safe and Secure Stockpile.
3. Improve Stockpile Affordability.
4. Improve NSE Agility and Resiliency.
5. Improve NSE's Ability to Respond to Anticipated Mission Requirements.

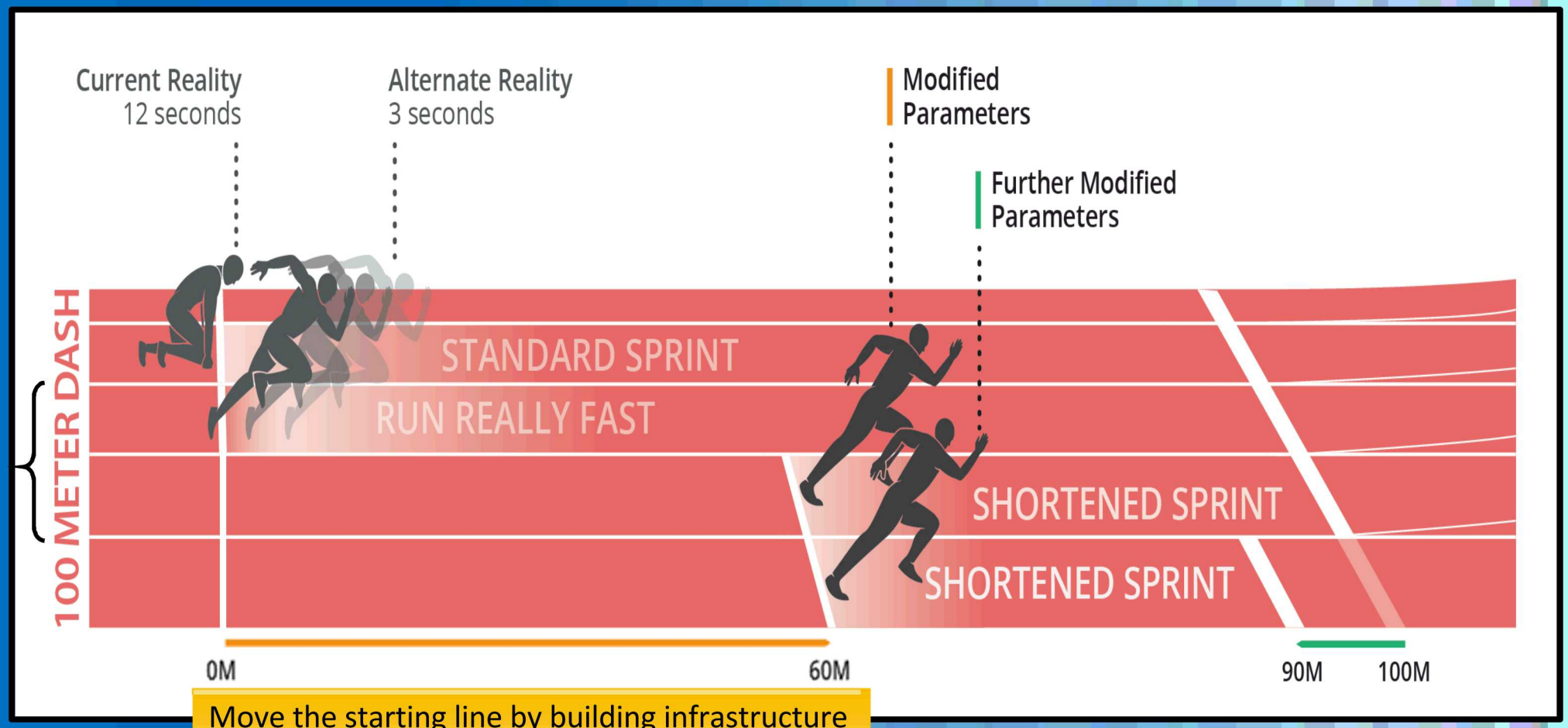
Phases 2 through 5 (Phase 6.2 – 6.5 for LEP)

Phase 2 – Program Feasibility Study
Phase 2A – Design Definition and Cost Study
Phase 3 – Development Engineering
Phase 4 – Production Engineering
Phase 5 – First Production

Rapidly respond to emerging deterrence needs	**3.1** Field an appropriate response to a high-confidence assessed threat before Initial Operating Capability of that threat.
	3.2 Agree upon the appropriate response to a technological surprise within **three months** of discovery.
	3.3 Perform Phases 2 through 5 within **three years** of a new weapon authorization from the Nuclear Weapons Council.
	3.4 Complete full production cycle for each new weapon within **two years**.

Strategy

Two methods toward achieving the dramatic speed up:



Move the starting line by building infrastructure

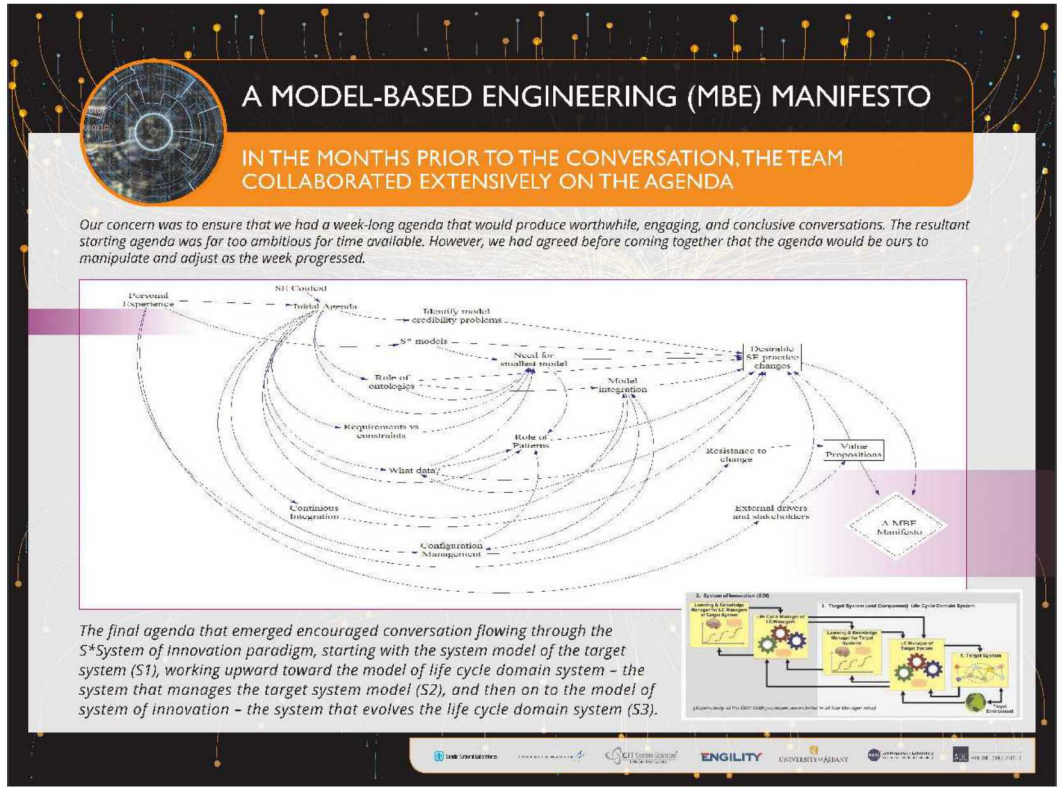
- Model-based design
- Common testers
- Design libraries
- Component reuse
- Modular architectures
- etc

May shorten the required distance by possibly performing some qualification after First Production Unit (FPU)

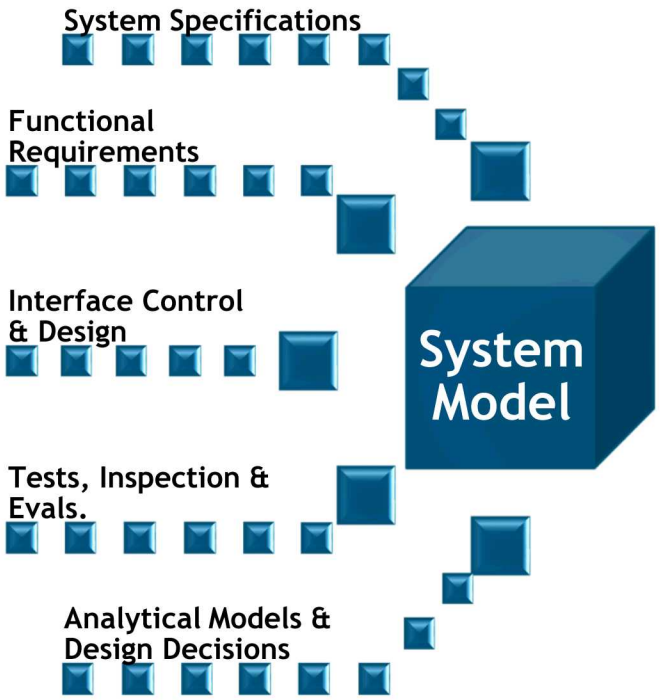
Formation of the MBSE Department

- **Functional Objective 1**-Conduct engineering activities using systems engineering models and simulations to support the realization of current and upcoming NW Programs, systems, components, and other ND related projects.
- **Functional Objective 2**-Populate and develop a NW digital environment for integrated models to be leveraged throughout the ND stakeholder community and establish a foundation for the NW digital twin.

➢ Previous efforts helped provide the basis for the MBSE department



Why Use MBSE for Nuclear Weapon Development?



A Model Based approach can protect you from the challenges of your predecessors:

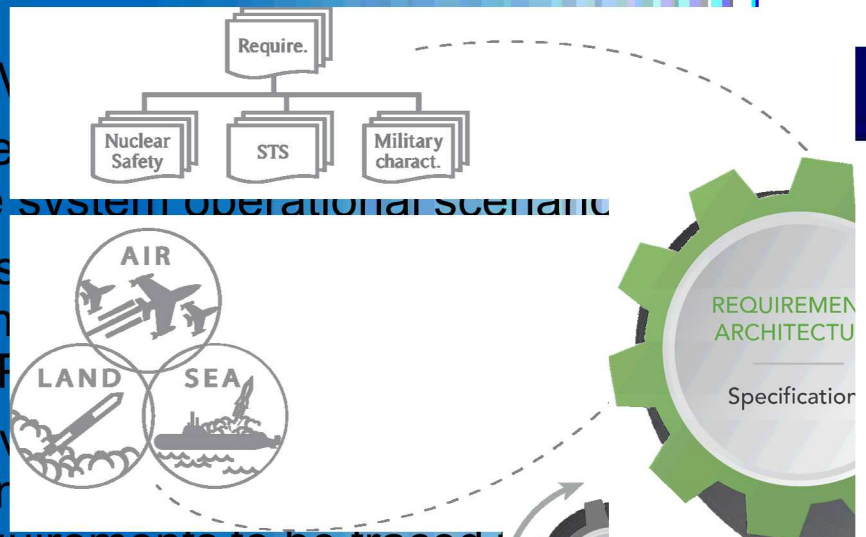
- Aides in cost impacts of requirements changes
- Traces info throughout development and reduces data loss
- Manages information complexities across documents
- Prevents defects from arising late in the development lifecycle

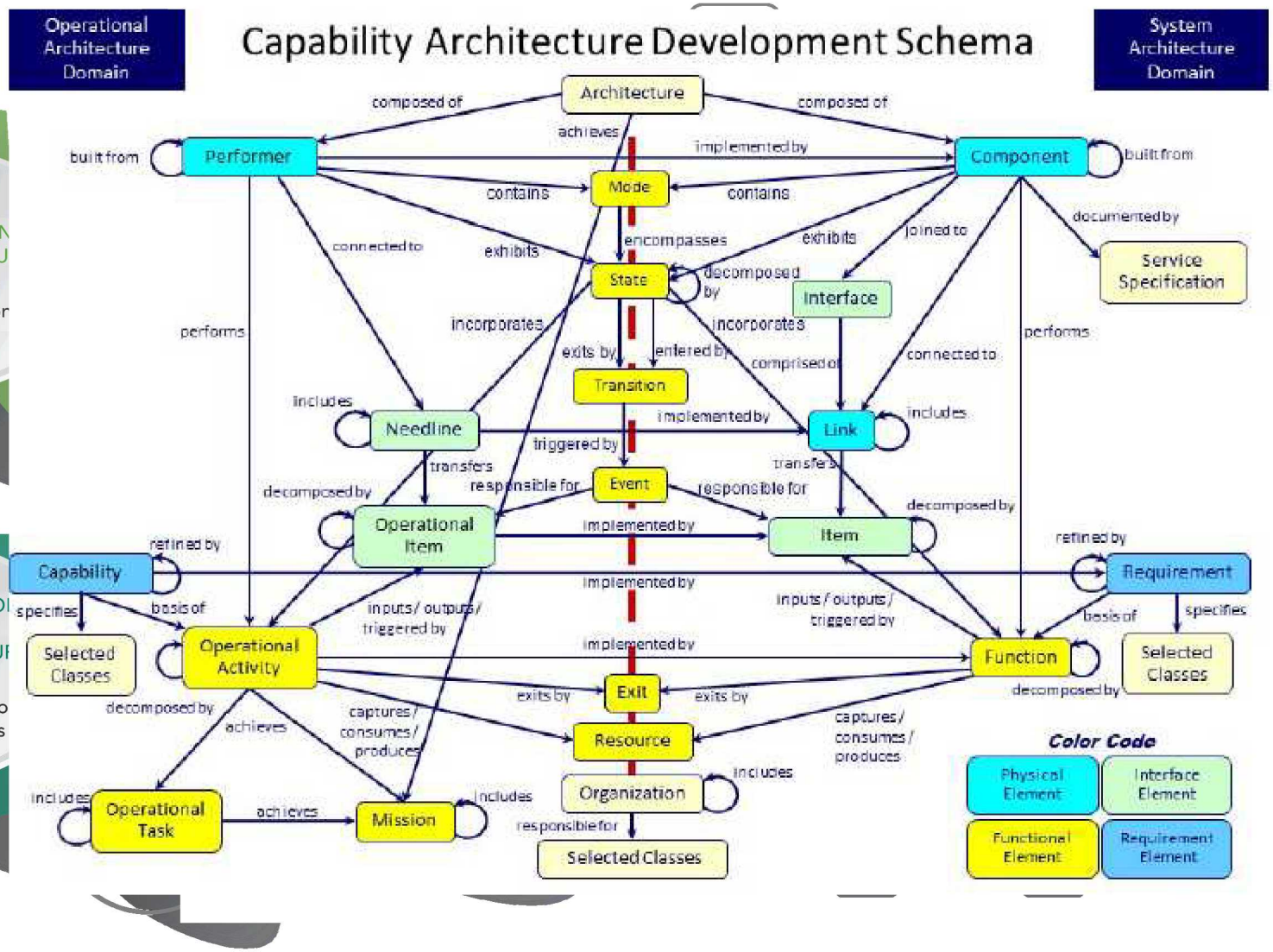
Models clarify system complexities; Model-Based Systems Engineering (MBSE) enables complex systems engineering comprehension through:

- Improved Communication & Quality
- Design Patterns and Architecture Analysis

What activities are currently being applied on LEPs?

LEP M
- Cre
the system operational scenario
- Ass
con
LEP
- Dev
Fur
requirements to be traced
- Cause communication acr
are identified and their inputs
managed



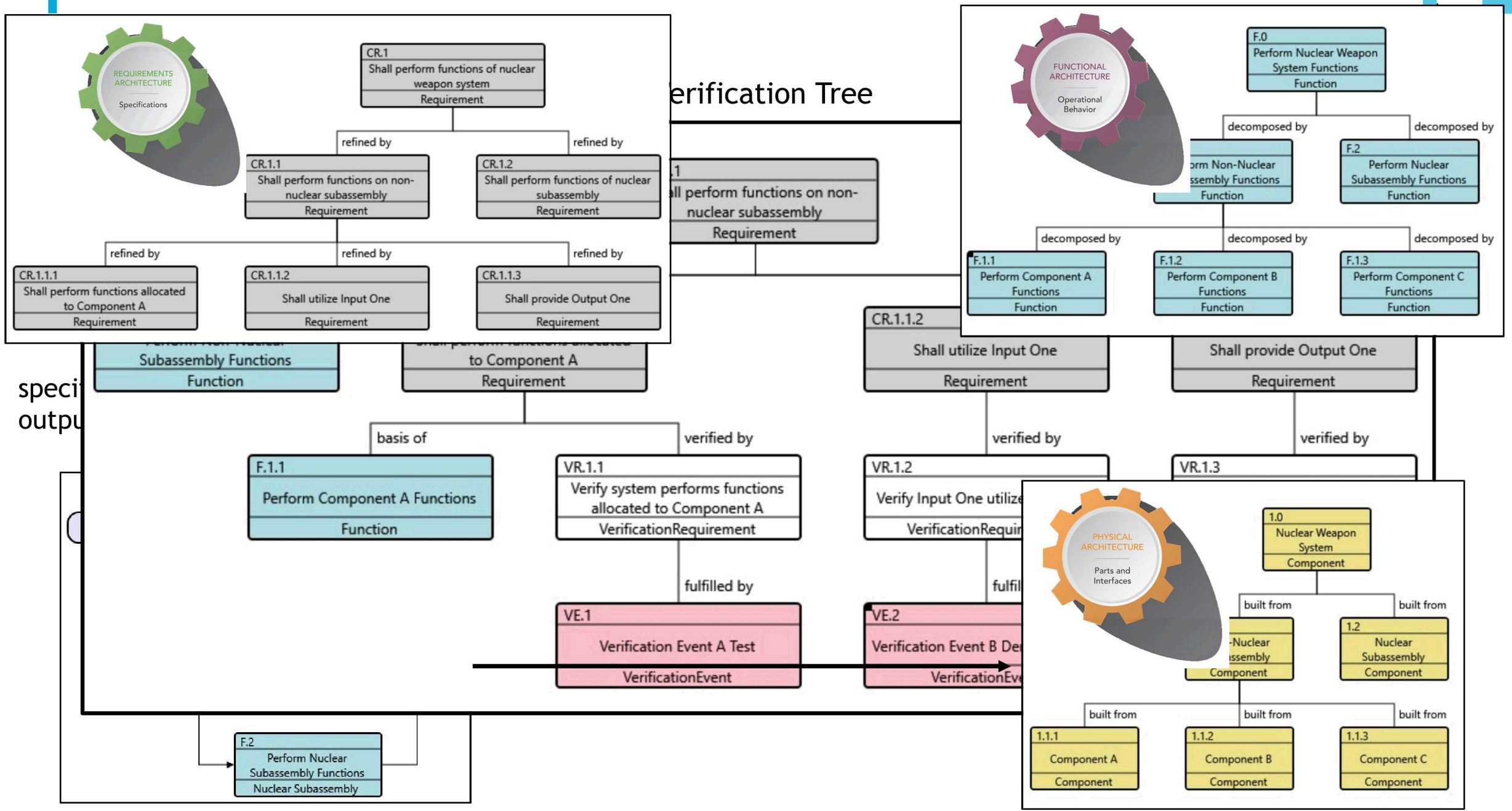


MBSE Efforts at Sandia: Past, Present, & Future

Traditional Verification Matrix

MC·Source,·Section,·and/or·Paragraph·ID¤	Requirement·/Agency¤	Requirement·Passed·to·System·Component¤	Qualification·Activity(ies)¤	Compliance·Documentation¤	Comments¤
MC·3.1.2--Gas·Transfer¤	Yes/LANL¤	¤	¤	¤	¤
MC·3.1.3--Automatic·Disarming·Provisions¤	Yes/SNL¤	AF&F·→·CD414280·Secs.·4.4.2.1,·5.3.2[12]¤	JT4A-17D1¤	JT4A-17D1·TR[110]↵ ↵ AF&F·QER[98]¤	¤
MC·3.1.4--Fuzing·Options¤	Yes/SNL¤	AF&F·→·CD414280·Secs.·5.4.4.1[12]¤	FCET-32,·FCET-35,·FCET-36,·JT4A-17B2,·JT4A-17C2,·JT4A-17D2·¤	FCET-32·TR[70],·FCET-35·TR[96],·FCET-36·TR[97],·JT4A-17B2·TR[52],·JT4A-17C2·TR[53],·JT4A-17D2·TR[54]↵ ↵ AF&F·QER[98]¤	¤
MC·3.2--Environmental·and·Survivability·Considerations¤	No¤	¤	¤	¤	Heading¤

Descriptive Modeling: Entities and Relationships



Obstacles to and Challenges for MBSE Still Exist

- MBSE initiation (beginning vs. later stages)
- Model acceptance as integral part of nuclear weapon development by project teams at Sandia
- Cultural acceptance of modeling as discipline at Sandia
- Model utilization beyond V&V

Topic	Description
MBSE Initiation	Transitioning from MBSE as an add-on late in the program to at the initialization of the program
Model Acceptance	Single source of truth across all internal program interfaces
Cultural Acceptance	Gaining participation to build the model accurately and keep it current as changes are introduced
Model Utilization	Training and awareness for users and receivers of information provided in the model

How can we apply MBSE to reduce cycle time for LEPs?

- **Lean** – streamline SE Processes
- **Requirements** – develop and manage requirements, and tie to V&V
- **Agile** – respond to changing requirements
- **MB Conceptual Design** – use requirements architecture to create/validate conceptual design