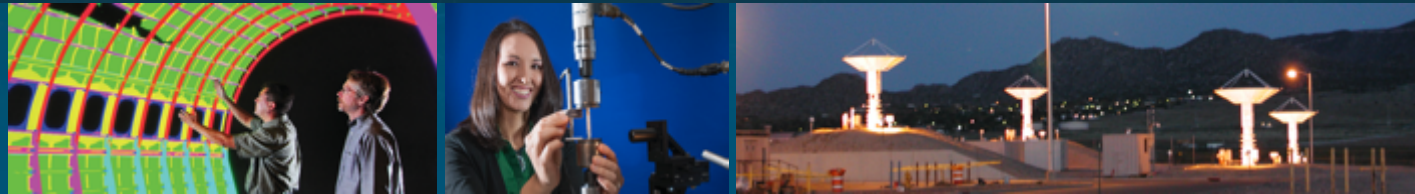




How MBSE is Reducing the Duration of the Nuclear Weapon Development Lifecycle



PRESENTED BY

Anthony Matta – Manager, Model Based Systems Engineering

- Casey Noll
- Erik Olson
- Ryan Coleman



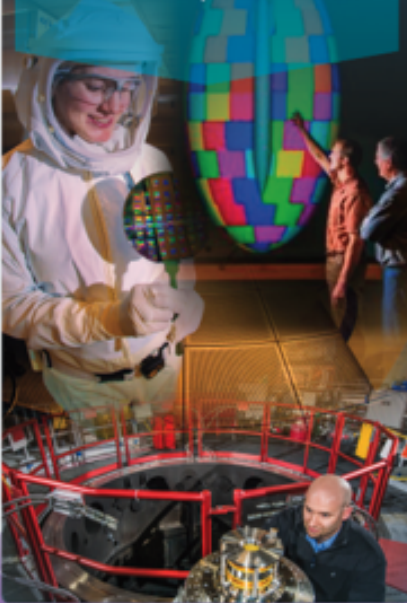
Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

Sandia National Laboratories (SNL) Enterprise Pillars



The Foundation

Nurture and advance our capability-based science and engineering foundation through innovation to enable more agile and effective fulfillment of Sandia's nuclear weapons mission



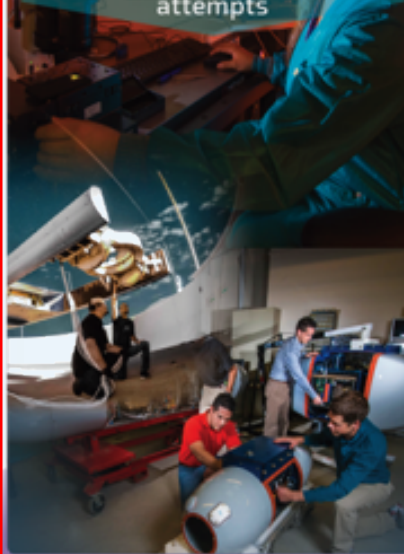
Flexible and Responsive (Sustained) Deterrence

Strengthen the U.S. nuclear deterrence posture in an uncertain and rapidly changing global environment



Nuclear Enterprise Assurance

Ensure research, design, development, production, testing, storage, packaging, transportation, maintenance, surveillance, dismantlement, and disposal for all current and future weapons are resilient to subversion attempts



Integrated Weapon and Physical Security

Create system solutions based on intelligence-informed threat assessments that provide security for U.S. nuclear weapons throughout their lifecycle



Stockpile Evaluation and Assessment

Drive agile, sustainable, forward looking assessment of U.S. nuclear weapons safety, security, and effectiveness through engagement and application of Sandia's broad capabilities



PEOPLE, FACILITIES, AND TECHNICAL CROSS-CUTS

Current Stockpile, Nuclear Triad, & Design



Principles



ALWAYS perform when intended



NEVER at any other
unapproved time



Unique Nuclear Weapon Activities

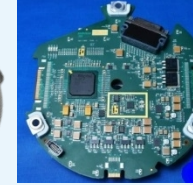


Warhead systems engineering & integration



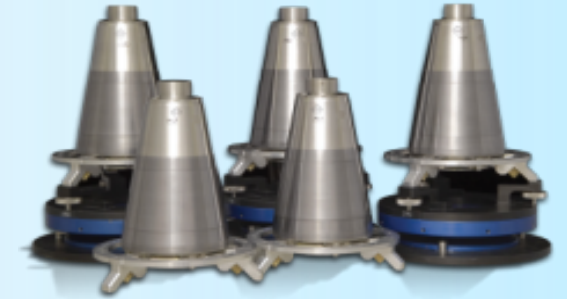
Design agency for Non-nuclear components

Gas transfer systems



Radar

Safety systems



Arming, fuzing & firing systems

Multi-disciplinary capabilities required for design, qualification, production, surveillance, experimentation/computation

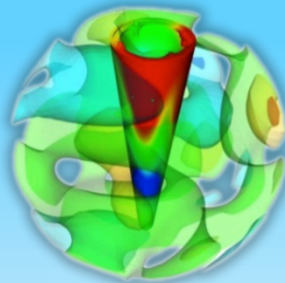
Major environmental test facilities & diagnostics



Materials Science



Light initiated high explosive



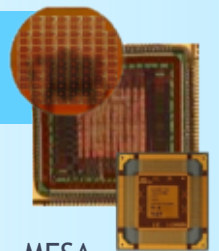
Computational analytics

Production agency

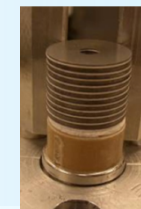
Sandia External Production



Neutron generators



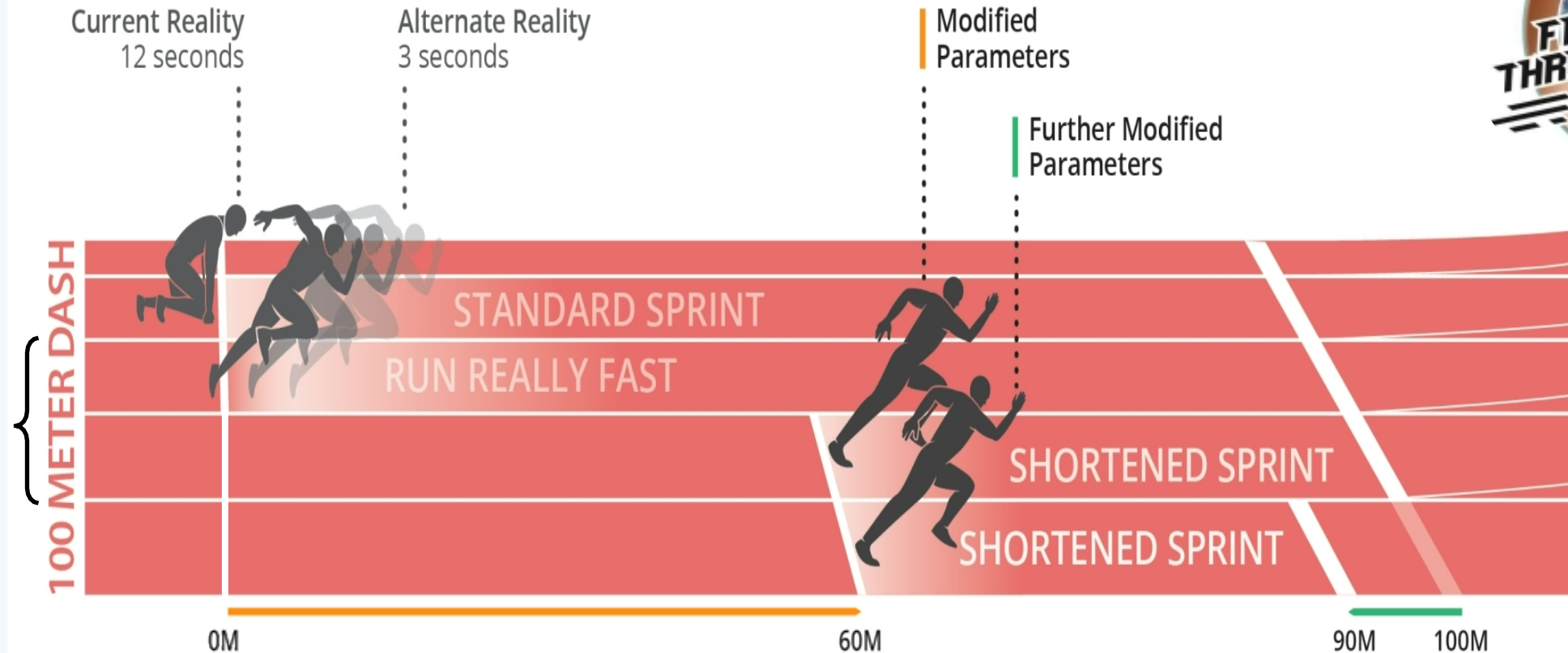
MESA microelectronics



Thermal battery back up



Review												
Reviews	RR	FSG	IPR1-Sys	CDR	BDR	IPR2-Sys	PDDR	FDR	IPR3-Sys	ASA	PR-Sys	
					VANov02				PRR	SPR		
Gates	SRF		FSG	CFG		BRG			PPNG-Cmn	VA Nov17	PSGL-Cmn	IOC

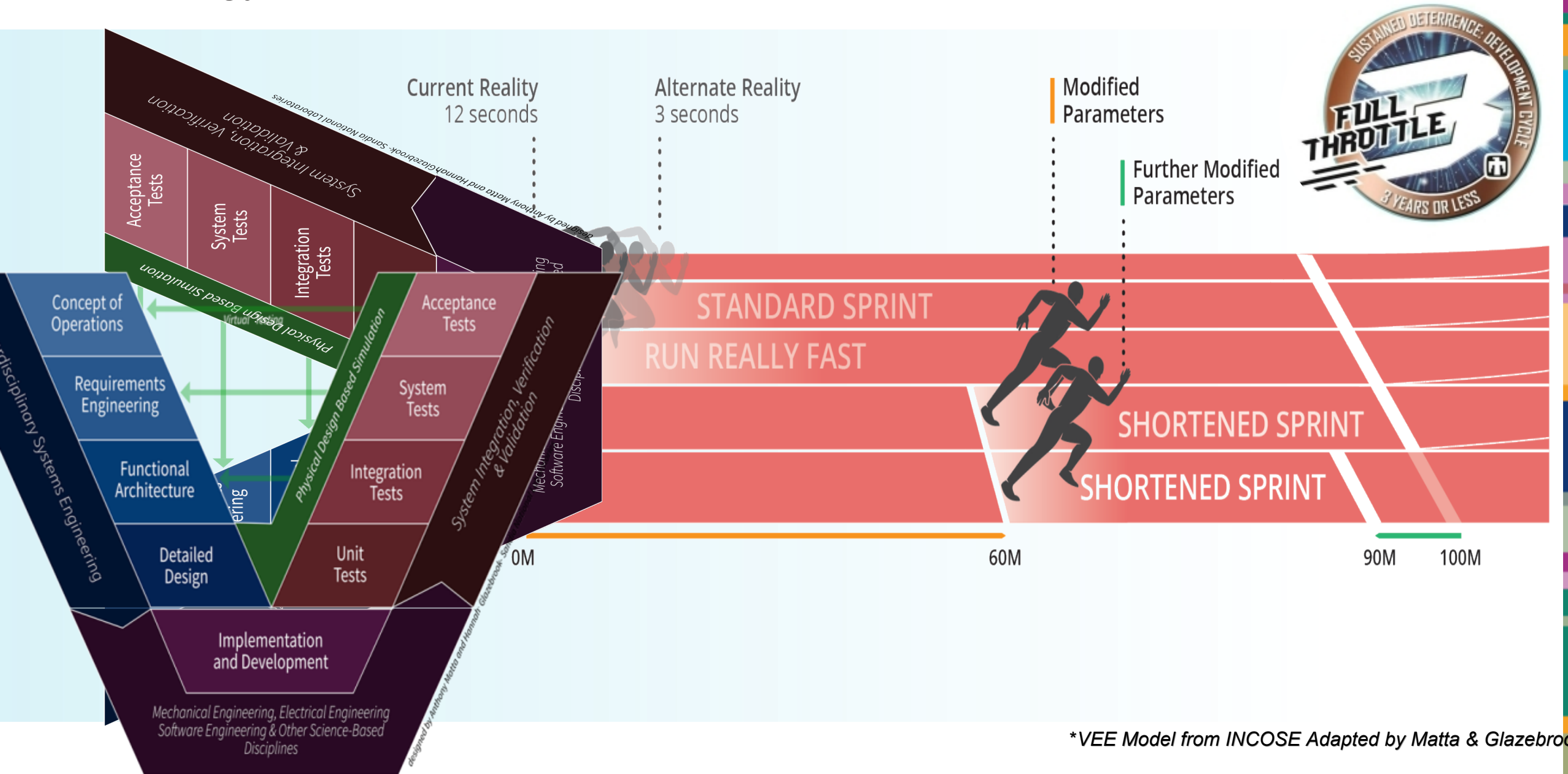


Two methods toward achieving the dramatic speed up:

Move the starting line by building infrastructure

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

May shorten the required distance by possibly performing some qualification after FPU





NW DESIGN LIFECYCLE FOCUS AREAS

Current Cycle
Time
~12 Years

AND



Casey Noll

- Verification & Validation activities
- Complex testing and environment reference architectures



Erik Olson

- Reduced order modeling
- Interrelating high fidelity physics codes for early design engineering



Ryan Coleman

- Digital Twin Data Strategy for Integrated Models
- Ontologically based integrated data sets

AND

Objective Cycle
Time
<3 Years

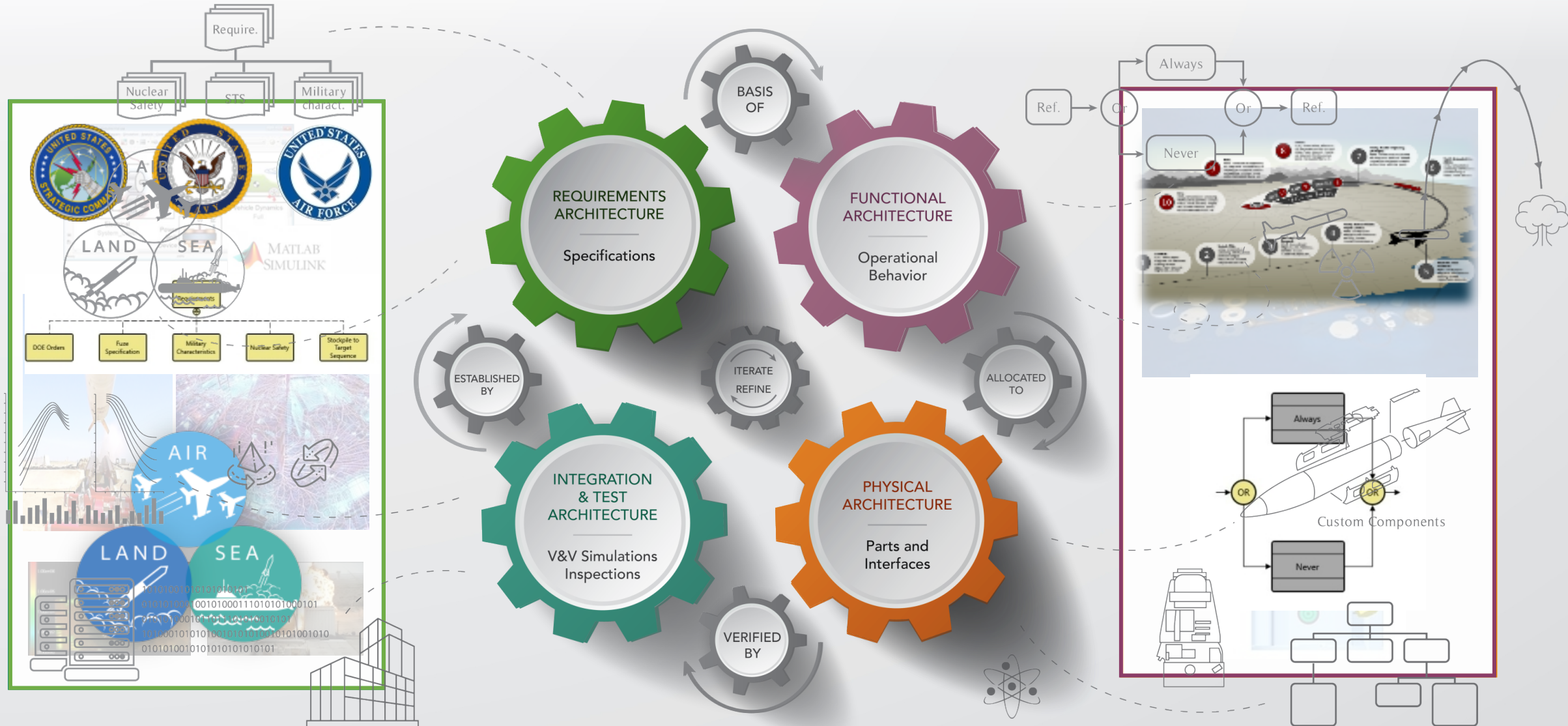


Casey Noll
R&D Systems Engineering

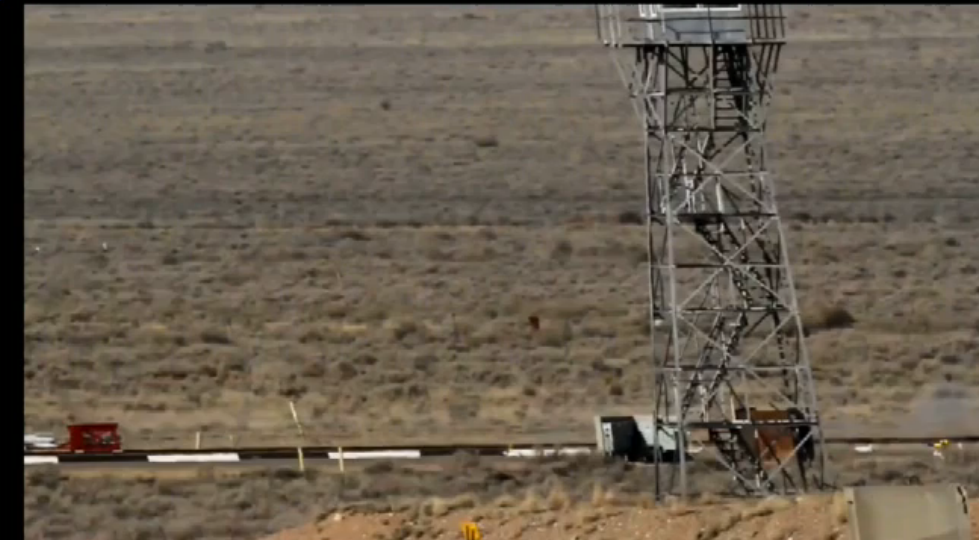
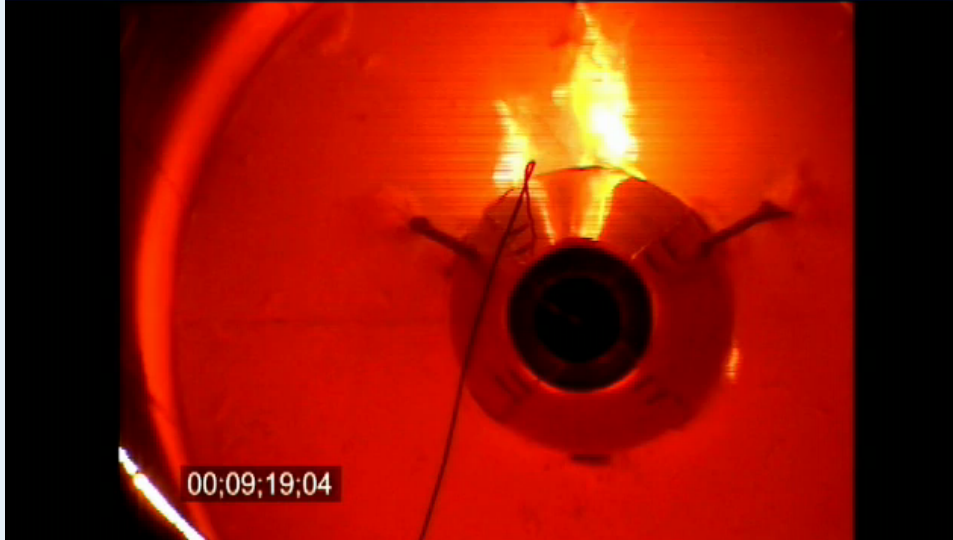
How Modeling Verification and Validation Activities Reduce the NW Development Time

Served as a Nuclear Weapon (NW) component Product Realization Team (PRT) Lead responsible for the development and transition to production of custom high reliability components supporting multiple programs impacting the NW stockpile. Casey has his BS/MS in Engineering Management, from Missouri University of Science and Technology and is currently pursuing his Master in Systems Engineering from Stevens Institute of Technology.

MBSE for Nuclear Deterrence

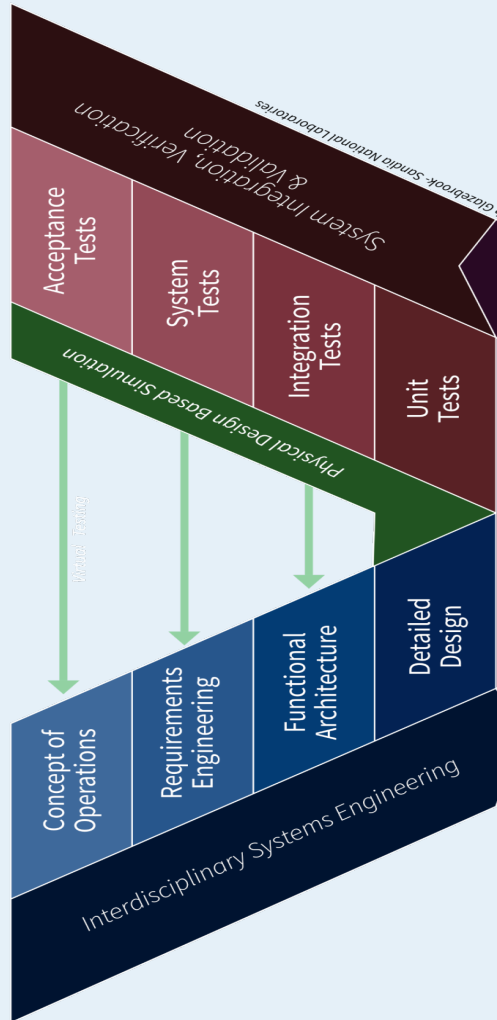


Verification & Validation



How can V&V modeling contribute to reducing the lifecycle for NW?

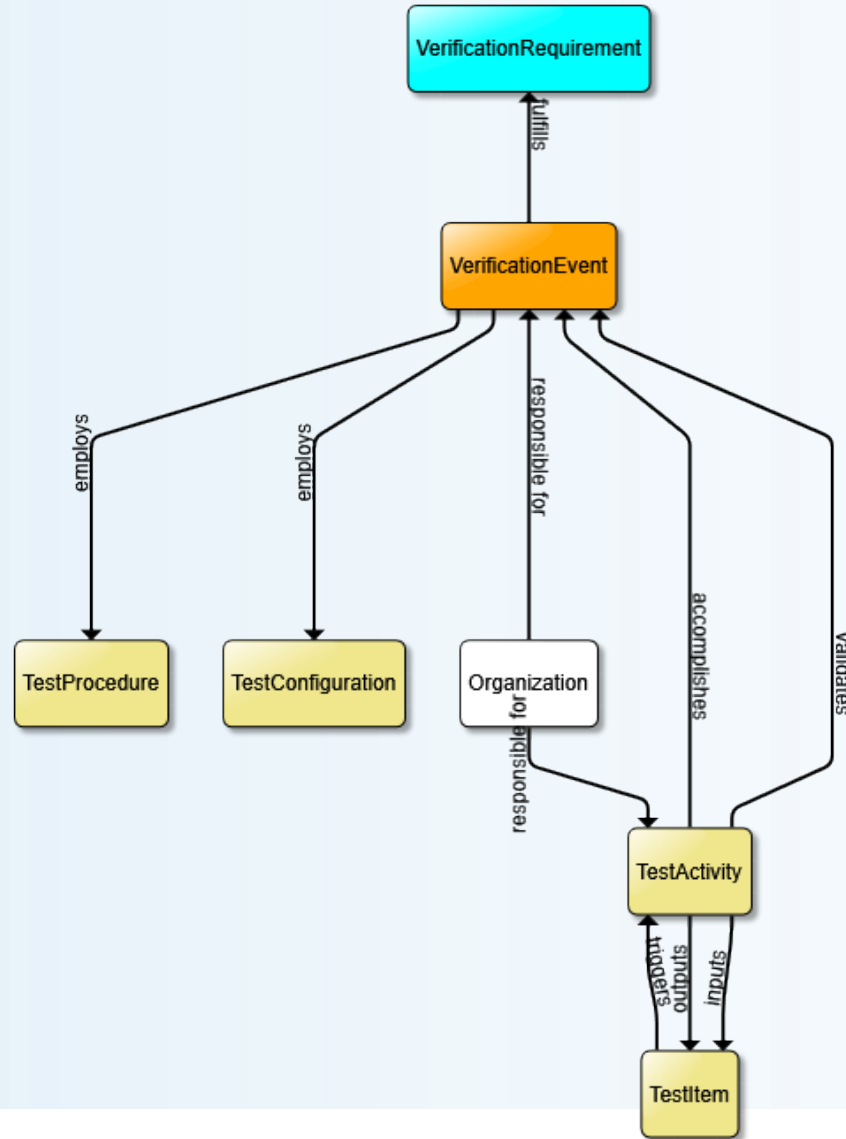
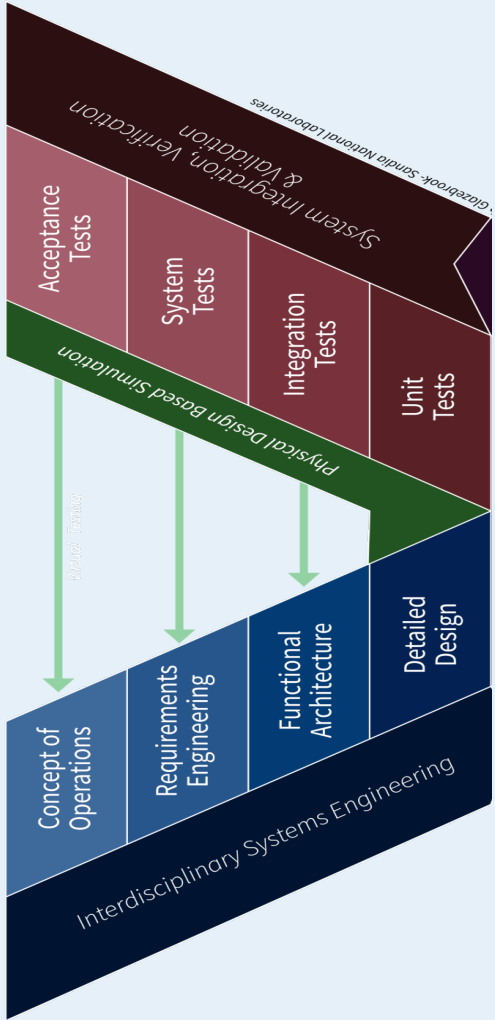
Verification & Validation



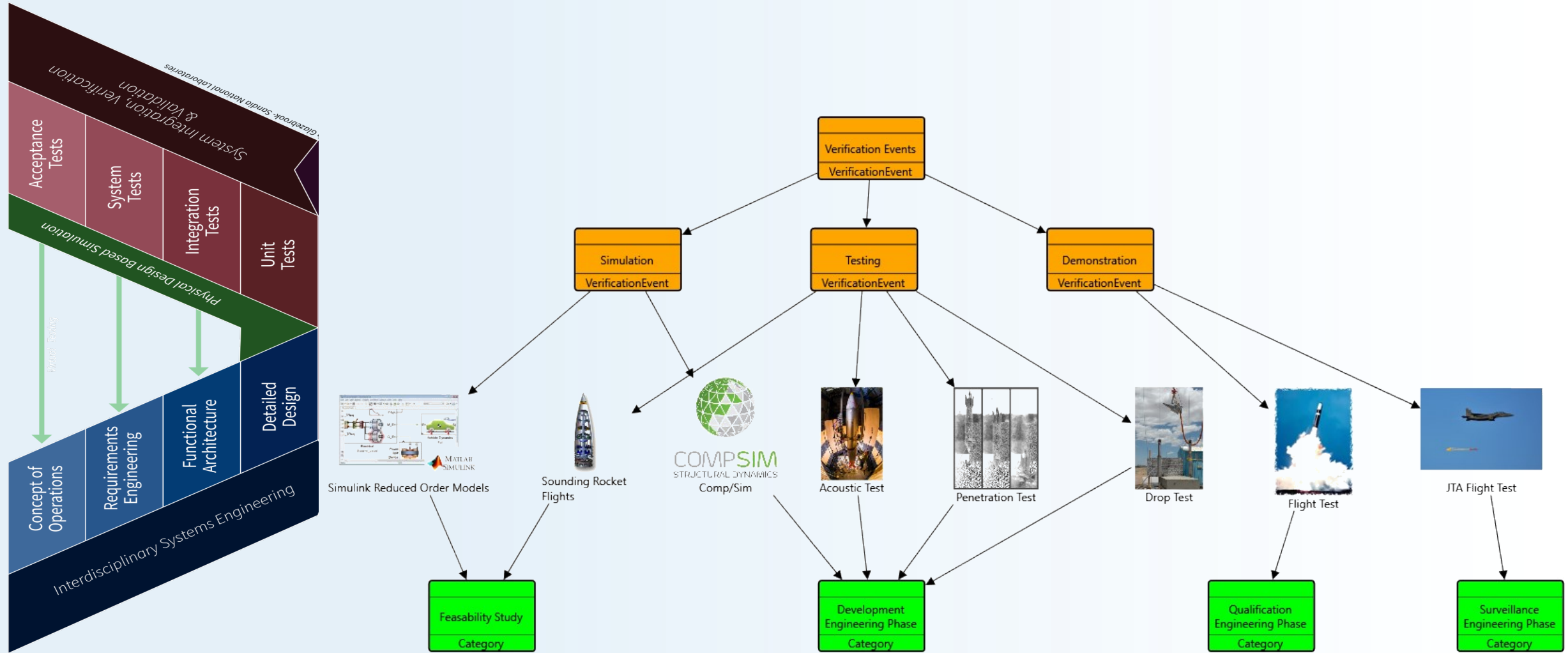
Requirement No.	Document	Paragraph	Shall Statement	Verification Success Criteria	Verification Method	Facility or Lab	Phase ^a	Acceptance Requirement?	Preflight Acceptance?	Performing Organization	Results
<i>Unique identifier or each requirement</i>	<i>Document number the requirement is contained within</i>	<i>Paragraph number of the requirement</i>	<i>Text (within reason) of the requirement, i.e., the "shall"</i>	<i>Success criteria for the requirement</i>	<i>Verification method for the requirement (analysis, inspection, demonstration, test)</i>	<i>Facility or laboratory used to perform the verification and validation.</i>	<i>Phase in which the verification and validation will be performed.</i>	<i>Indicate whether this requirement is also verified during initial acceptance testing of each unit.</i>	<i>Indicate whether this requirement is also verified during any pre-flight or recurring acceptance testing of each unit</i>	<i>Organization responsible for performing the verification</i>	<i>Indicate documents that contain the objective evidence that requirement was satisfied</i>
P-1	xxx	3.2.1.1 Capability: Support Uplinked Data (LDR)	System X shall provide a max. ground-to-station uplink of...	1. System X locks to forward link at the min and max data rate tolerances 2. System X locks to the forward link at the min and max operating frequency tolerances	Test	xxx	5	Yes	No	xxx	TPS xxxx
P-i	xxx	Other paragraphs	Other "shalls" in PTRS	Other criteria	xxx	xxx	xxx	Yes/No	Yes/No	xxx	Memo xxx
S-i or other unique designator	xxxxx (other specs, ICDs, etc.)	Other paragraphs	Other "shalls" in specs, ICDs, etc.	Other criteria	xxx	xxx	xxx	Yes/No	Yes/No	xxx	Report xxx

Source: NASA Systems Engineering Handbook

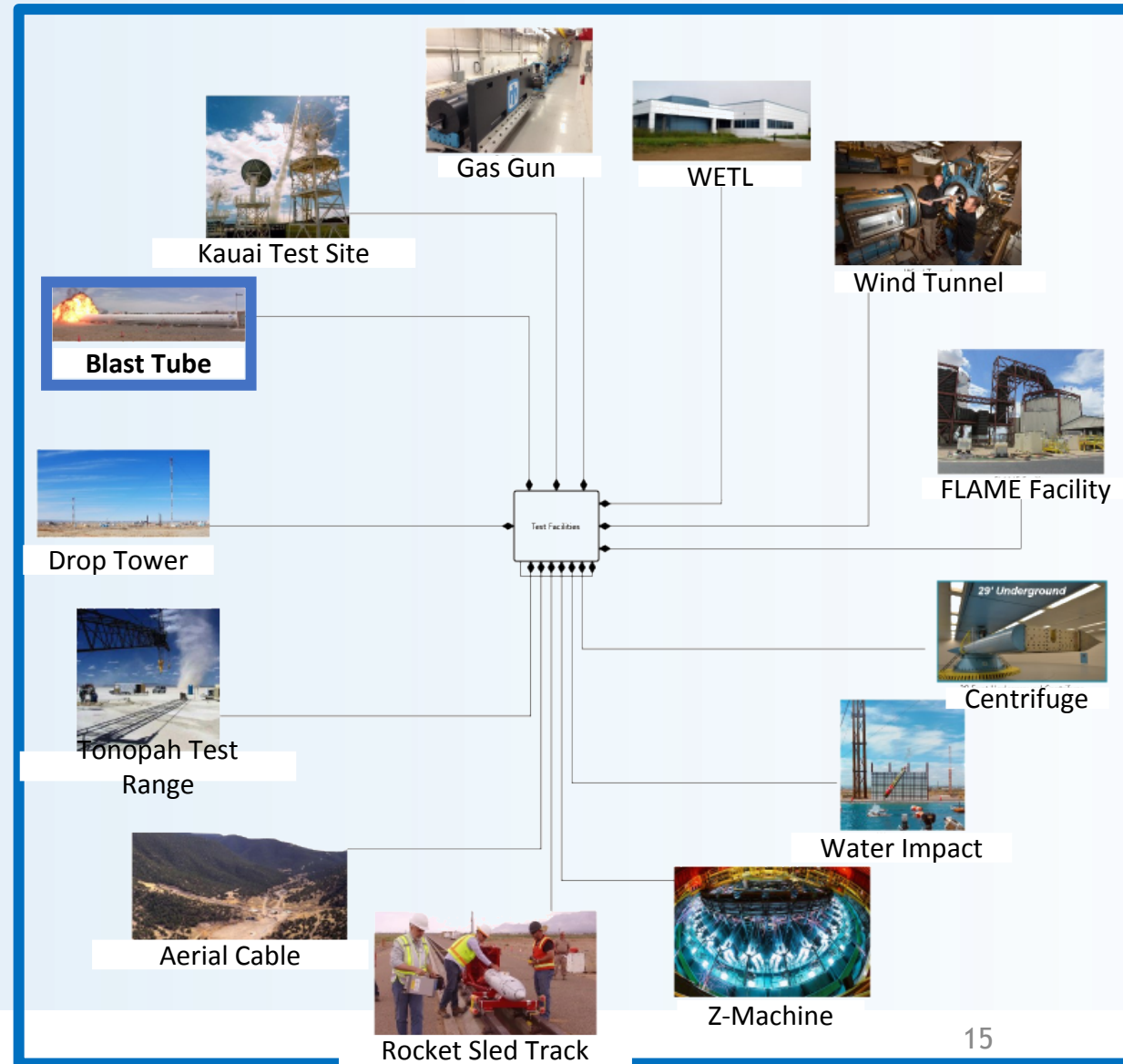
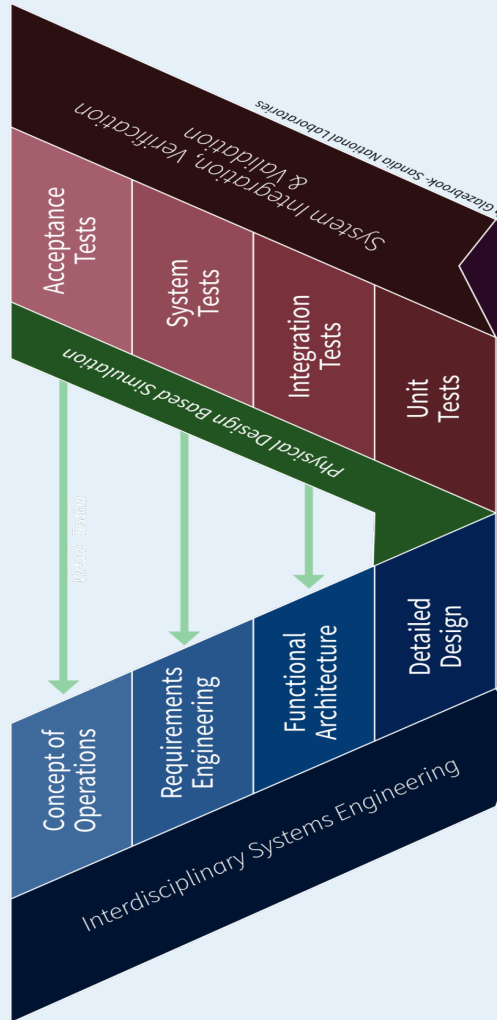
Verification & Validation



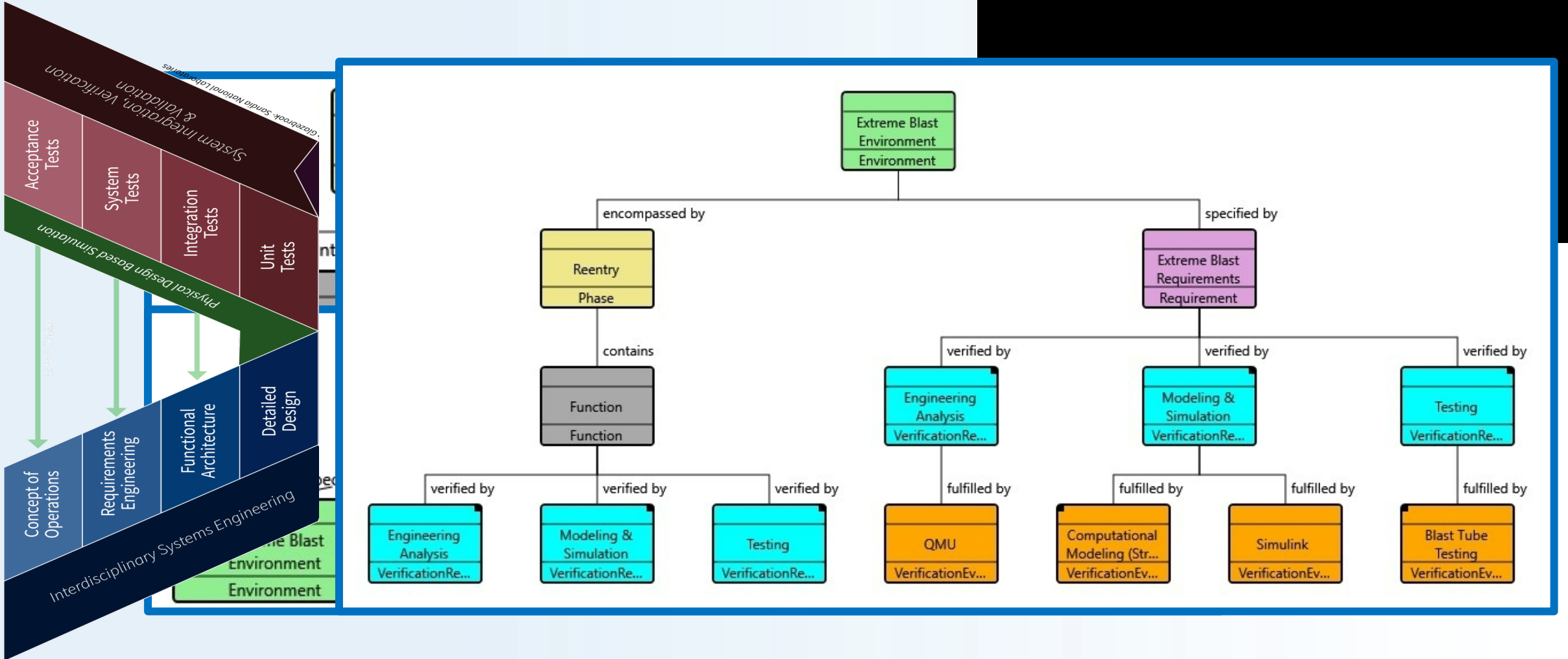
Verification & Validation



Verification & Validation



Verification & Validation



V&V modeling moves the “starting line” to shorten the lifecycle of NW

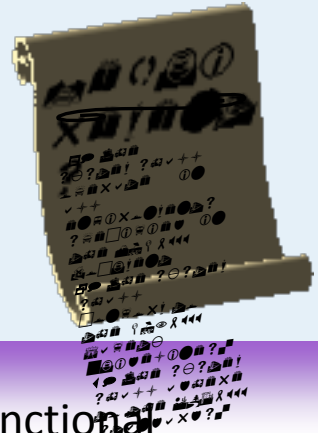


Erik Olson
R&D Electrical Engineering

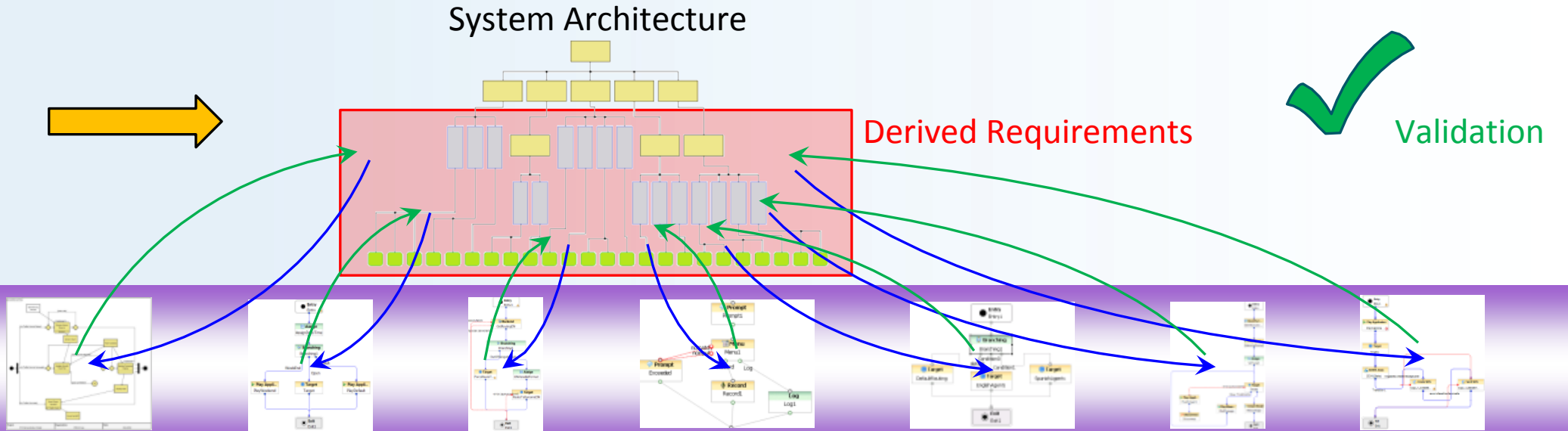
How Bridging MBSE with Reduced Order Modeling Reduces Development Time

Erik Olson has a background in both Electrical and Mechanical Engineering. He has his PhD in Electrical Engineering from University of Wisconsin. He spent the last ten years working in Sandia's satellite programs, and spent two years as an R&D engineer at Tyco thermal Controls in Menlo Park, California.

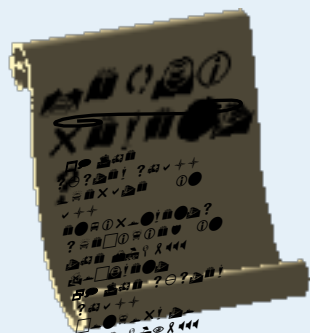
The Role of MBSE and Reduced Order Modeling



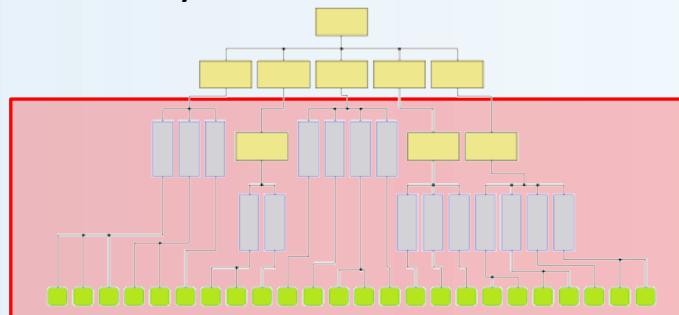
Functional
Models



The Role of MBSE and Reduced Order Modeling



System Architecture

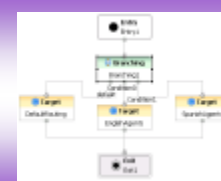


Derived Requirements



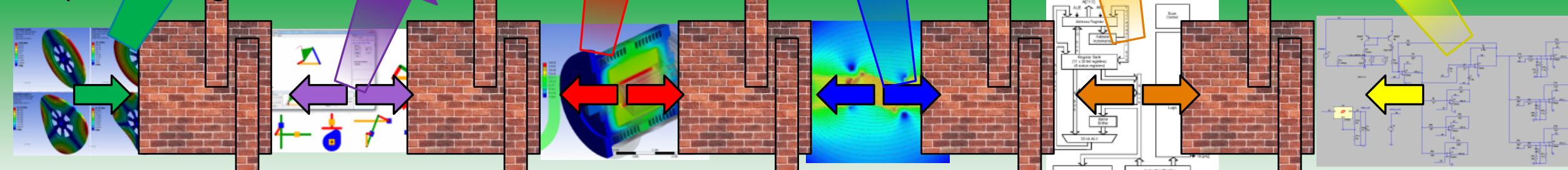
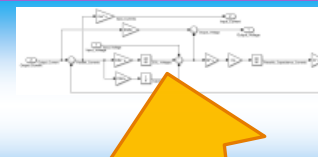
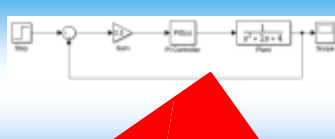
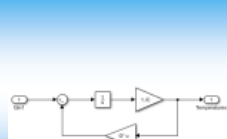
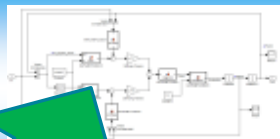
Validation

Functional Models



Reduced Order Models

Component Designs



Mechanical Modeling - Vibration



Mechanical Modeling - Kinematics



Thermal Modeling - Conduction



Electro-magnetics

RAMSES

Circuit Modeling - Digital

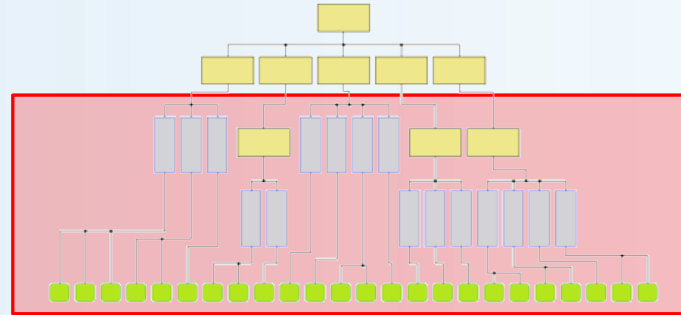


Circuit Modeling - Analog / Power

The Role of MBSE and Reduced Order Modeling



System Architecture



Derived Requirements



Validation



Verification

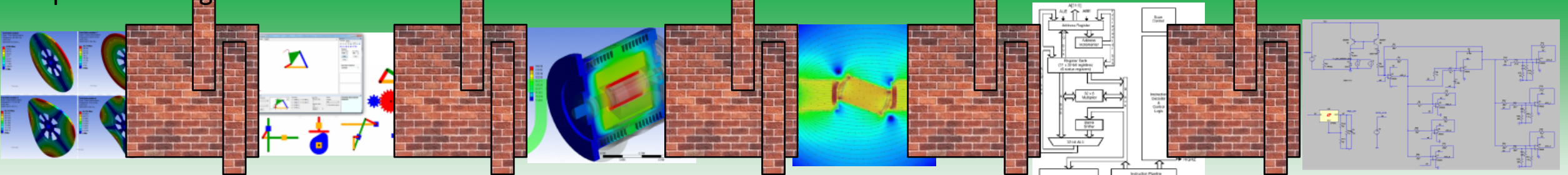
Function Models



Reduced Order Models



Component Designs



Mechanical
Modeling -
Vibration



Mechanical
Modeling -
Kinematics



Thermal
Modeling -
Conduction



Electro-
magnetics

RAMSES

Circuit
Modeling -
Digital



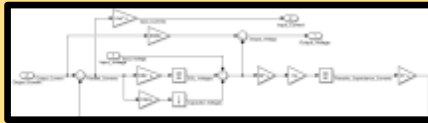
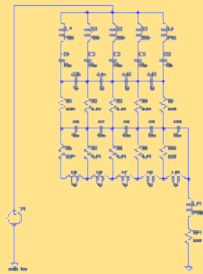
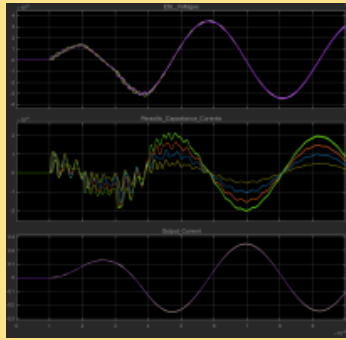
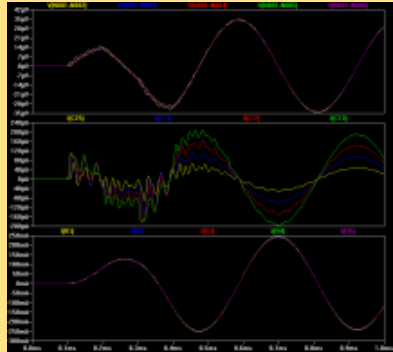
Circuit
Modeling -
Analog / Power



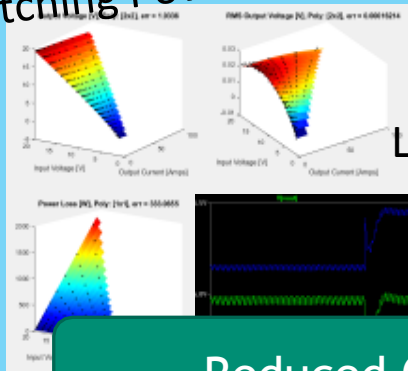


Passive Coupled Networks

LTSpice SIMULINK



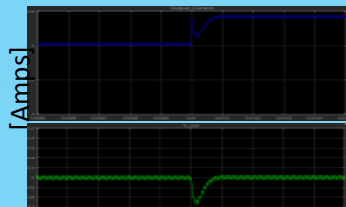
Switching Power Converter Models



LTSpice

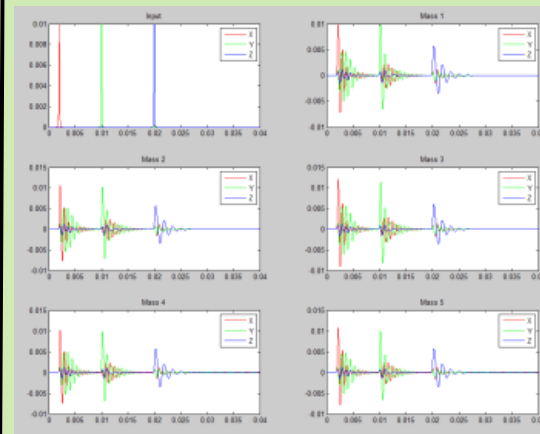
Input Voltage [V]
Output Current [Amps]

SIMULINK

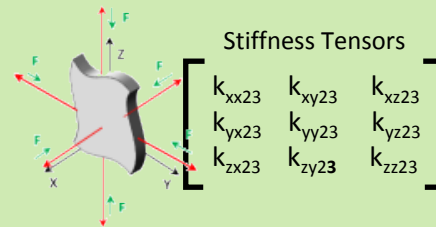


Reduced Order Modeling allows for virtual cycle verification with combined environments

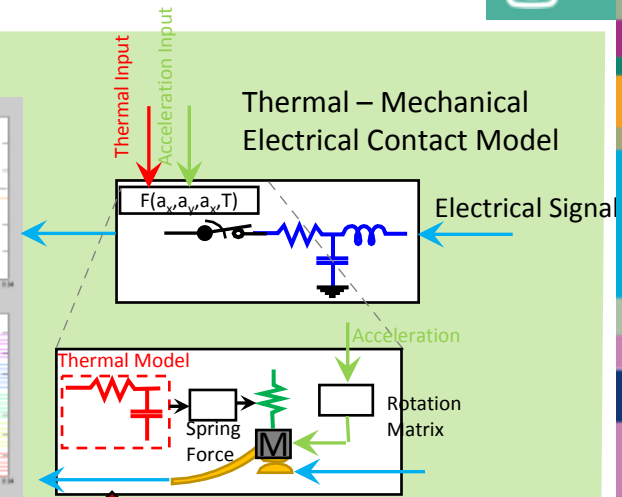
Mechanical Vibration / Electrical



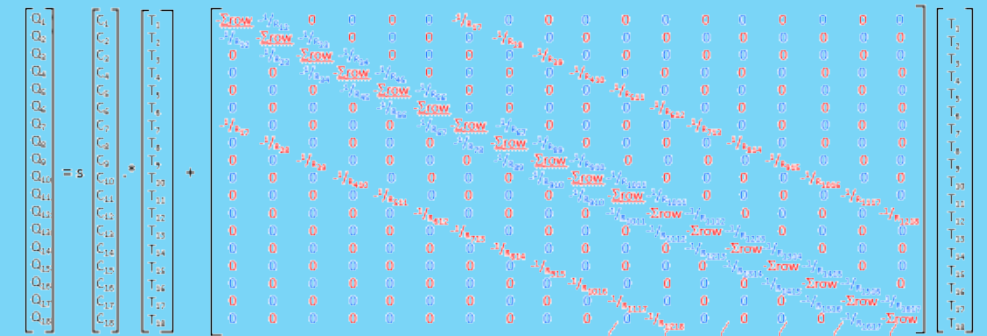
Mechanical Vibe



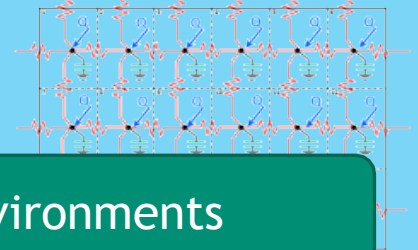
Electrical Contact Chatter



Thermal Conduction Models



Thermal Radiation Models

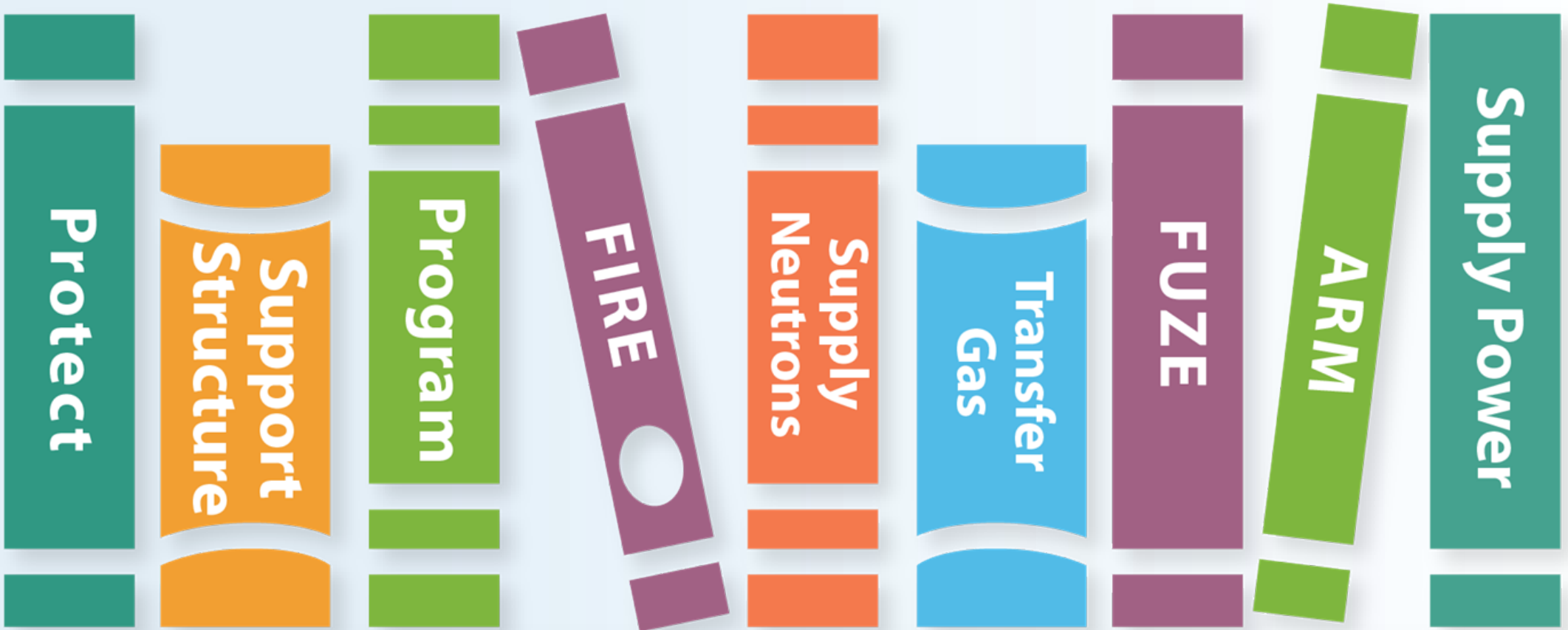
(T₁ - T₂)



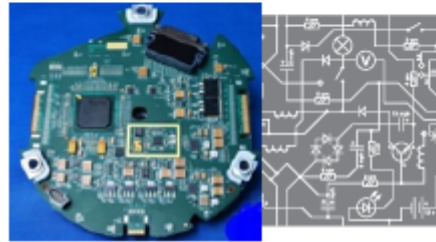
Ryan Coleman
R&D Computer Scientist

How Data Strategy For The Digital Twin Reduces NW Development Time

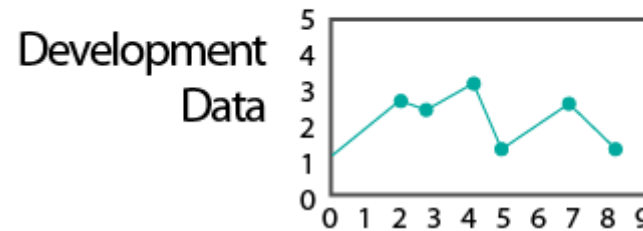
Ryan has experience in abnormal environments and detonator modeling, and many of the advanced simulation and computing analyses for nuclear weapons qualification. Immediately prior to joining Sandia, Ryan was an academic postdoc in Pharmaceutical Chemistry at University of California San Francisco, where he built and used software systems for drug discovery. Ryan has degrees in Computer Science, Philosophy, and his PhD in Computational Biology.



Library of Functions; Books of Components

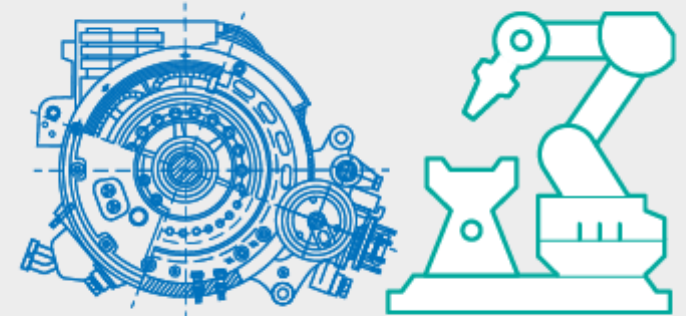
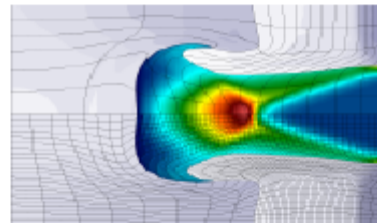


Mk2017
Design



Environment
& Margins

Simulation
Models



Manufacturing Plan

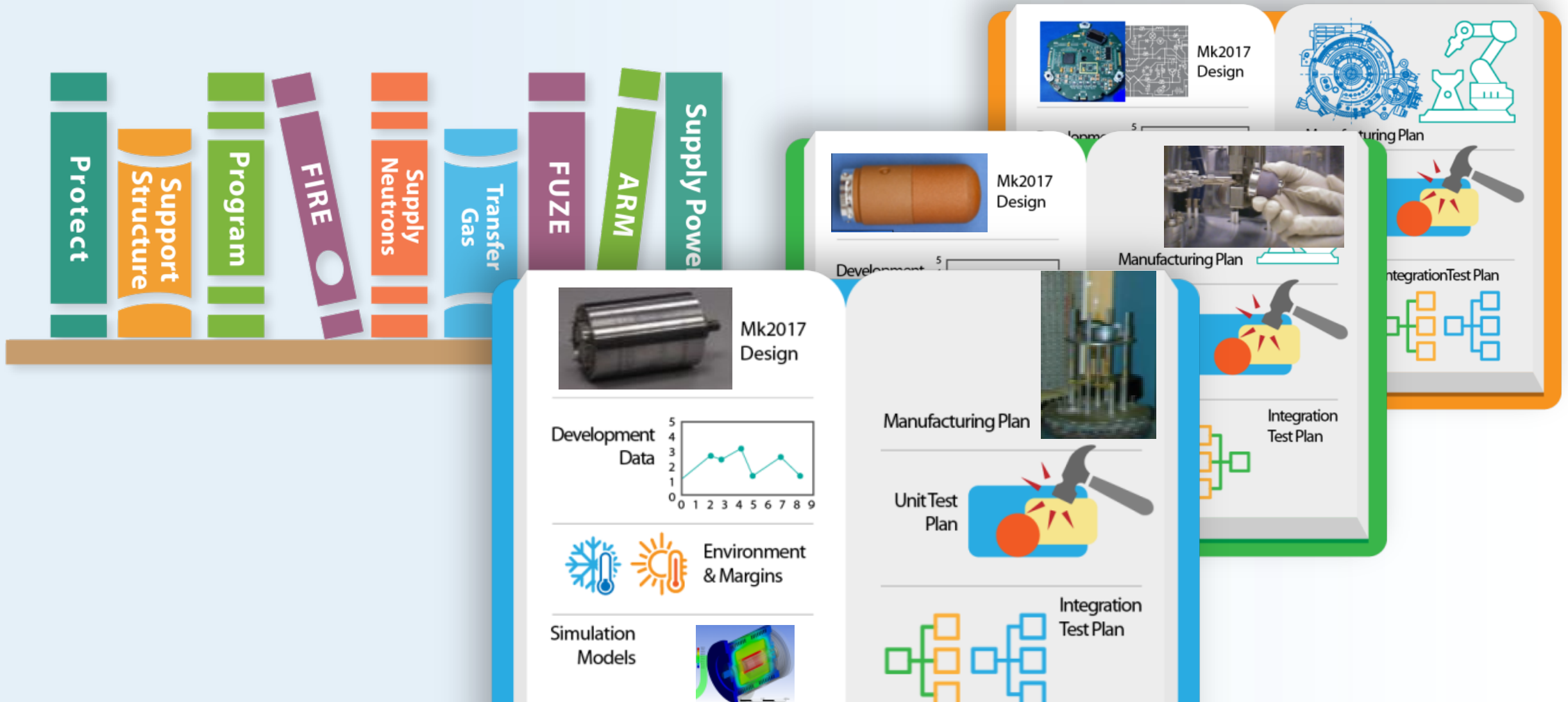
Unit Test
Plan



Integration Test Plan

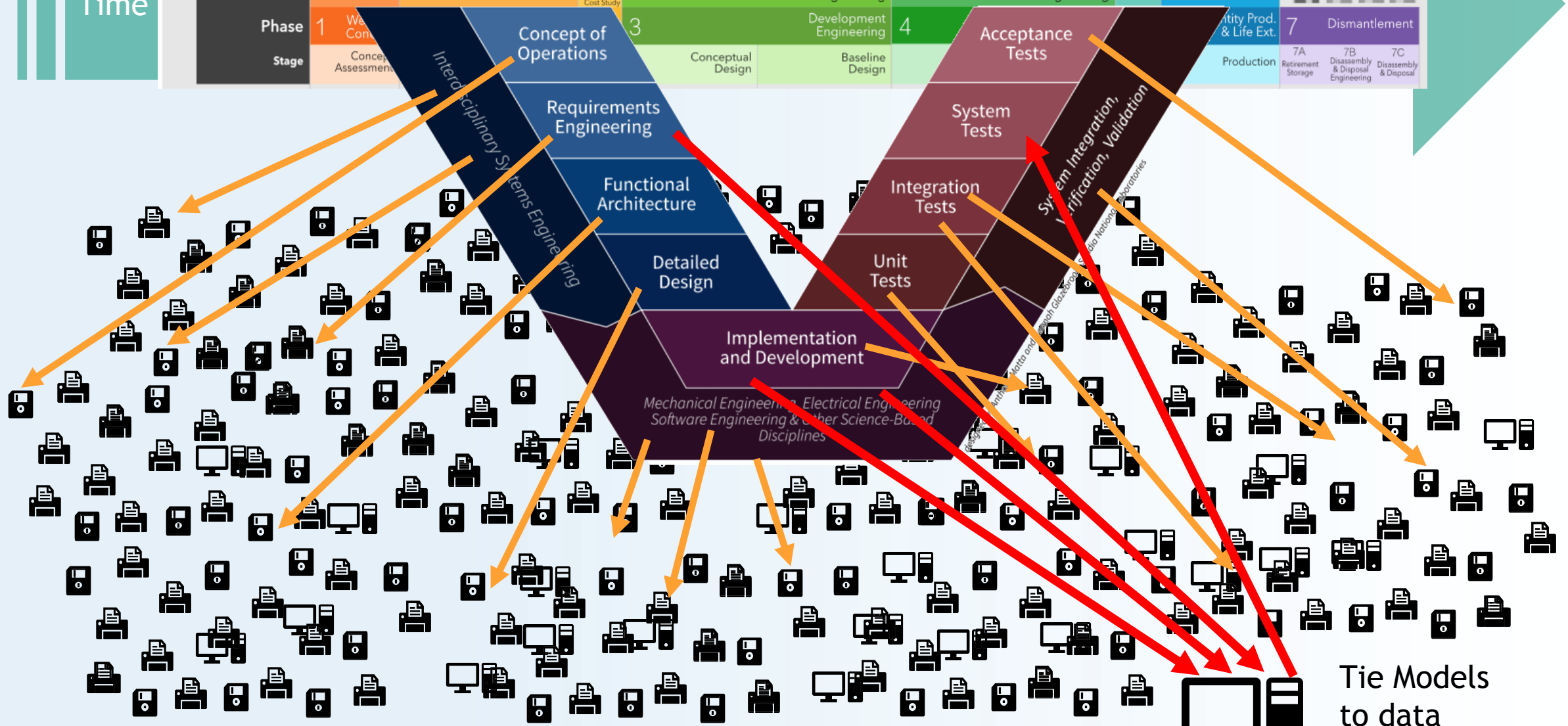
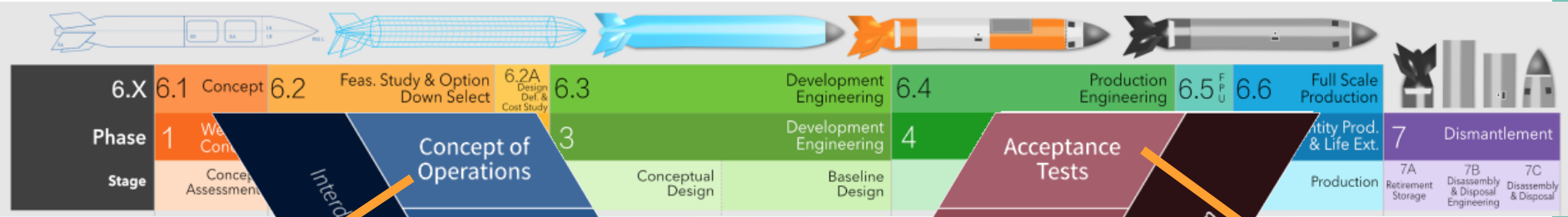


A Digital Twin for Components allows them to be reused to shorten development time



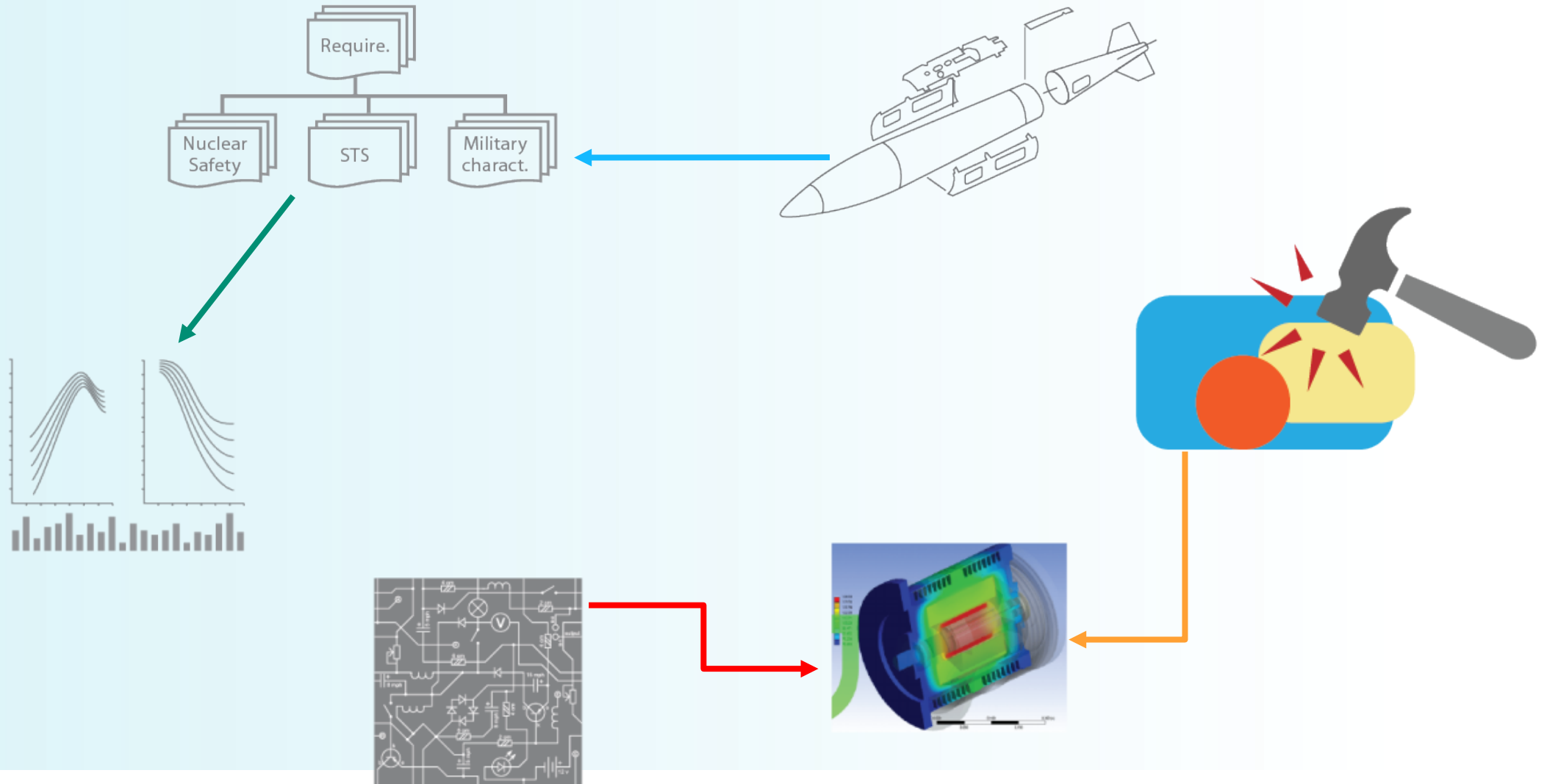
Infrastructure to reuse components will reduce development time

Time

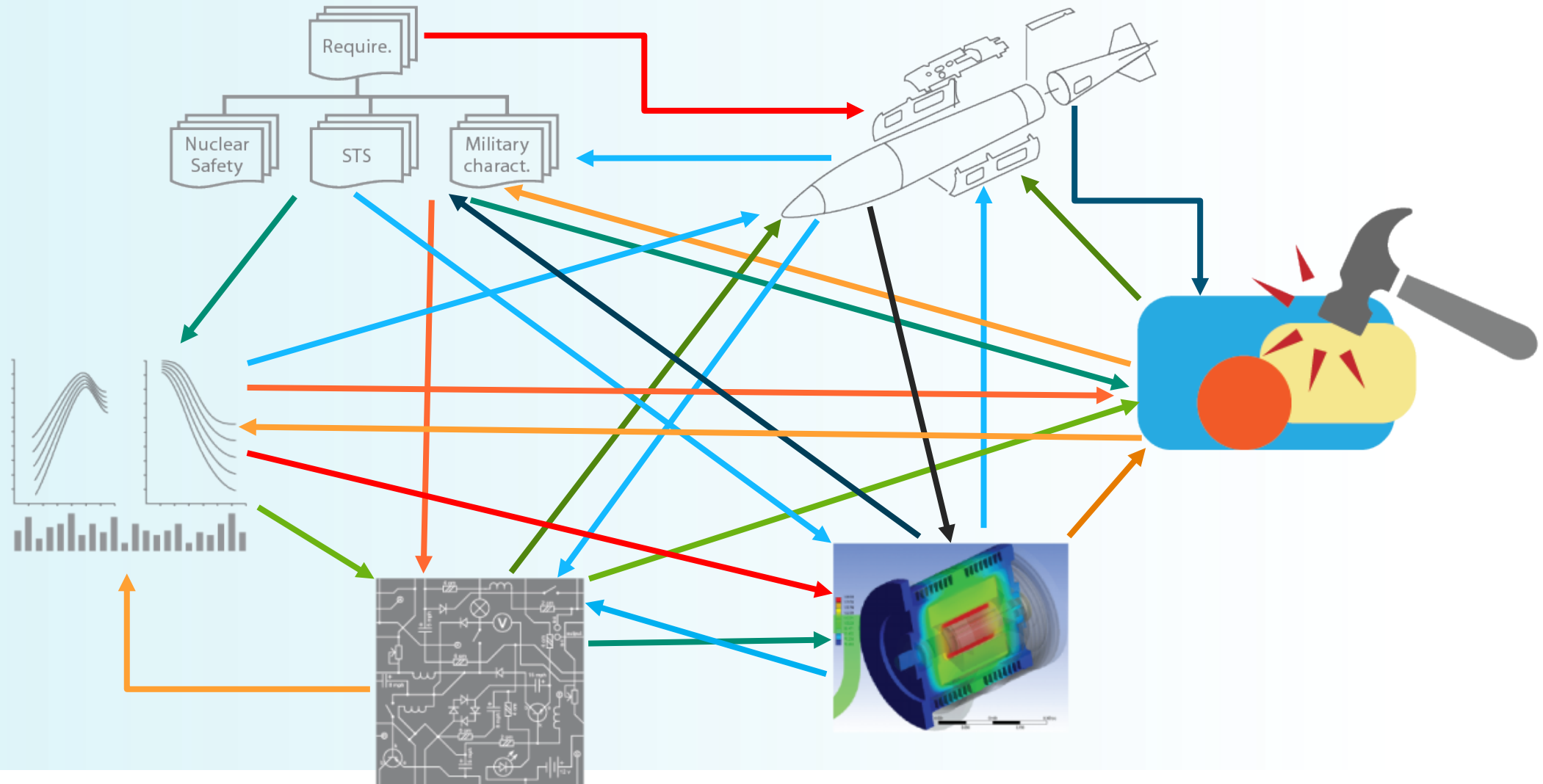


Digital Twin of Each Weapon System will reduce development time

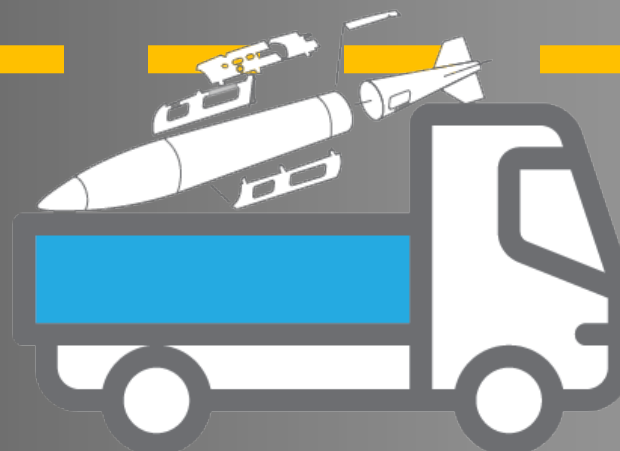
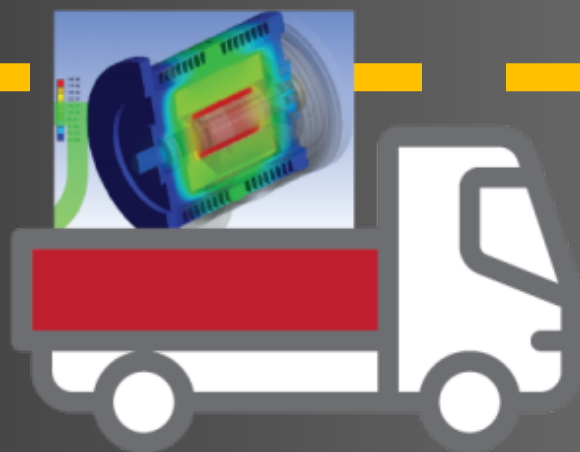
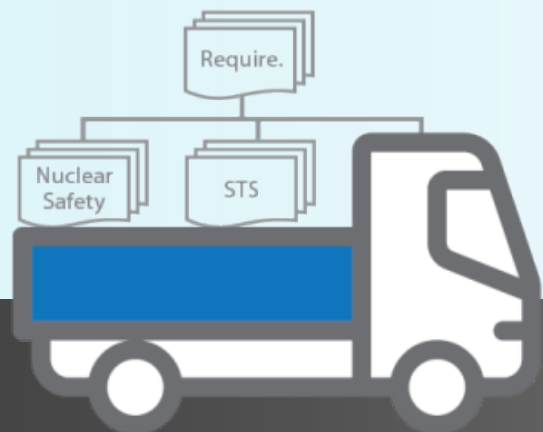
Architecting the Connections Between Diverse and Disparate Sources

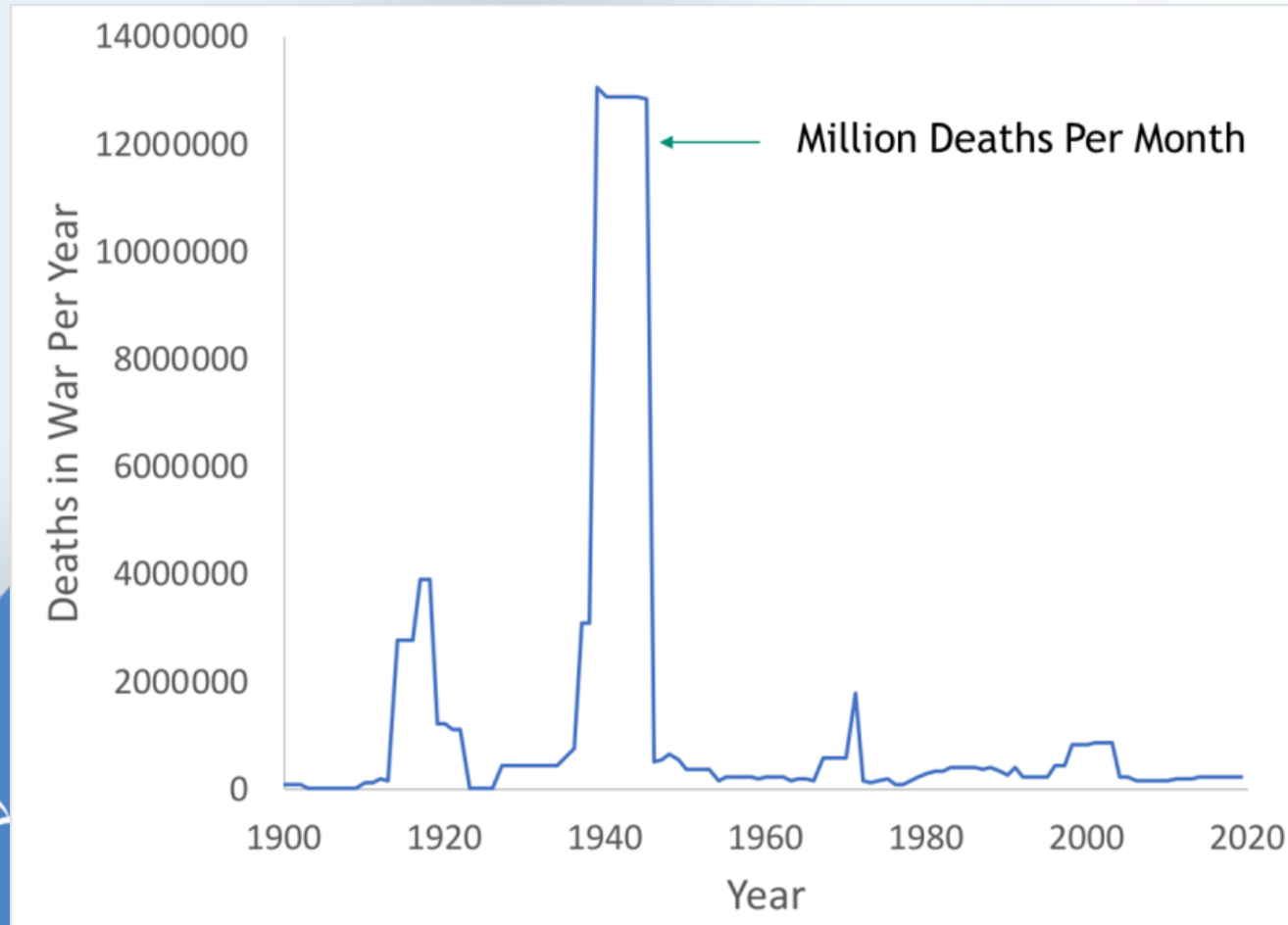


Architecting the Connections Between Diverse and Disparate Sources



Merging Complex Data Sources





Nuclear Deterrence Works

Respond to Threats, Sustained
Deterrence