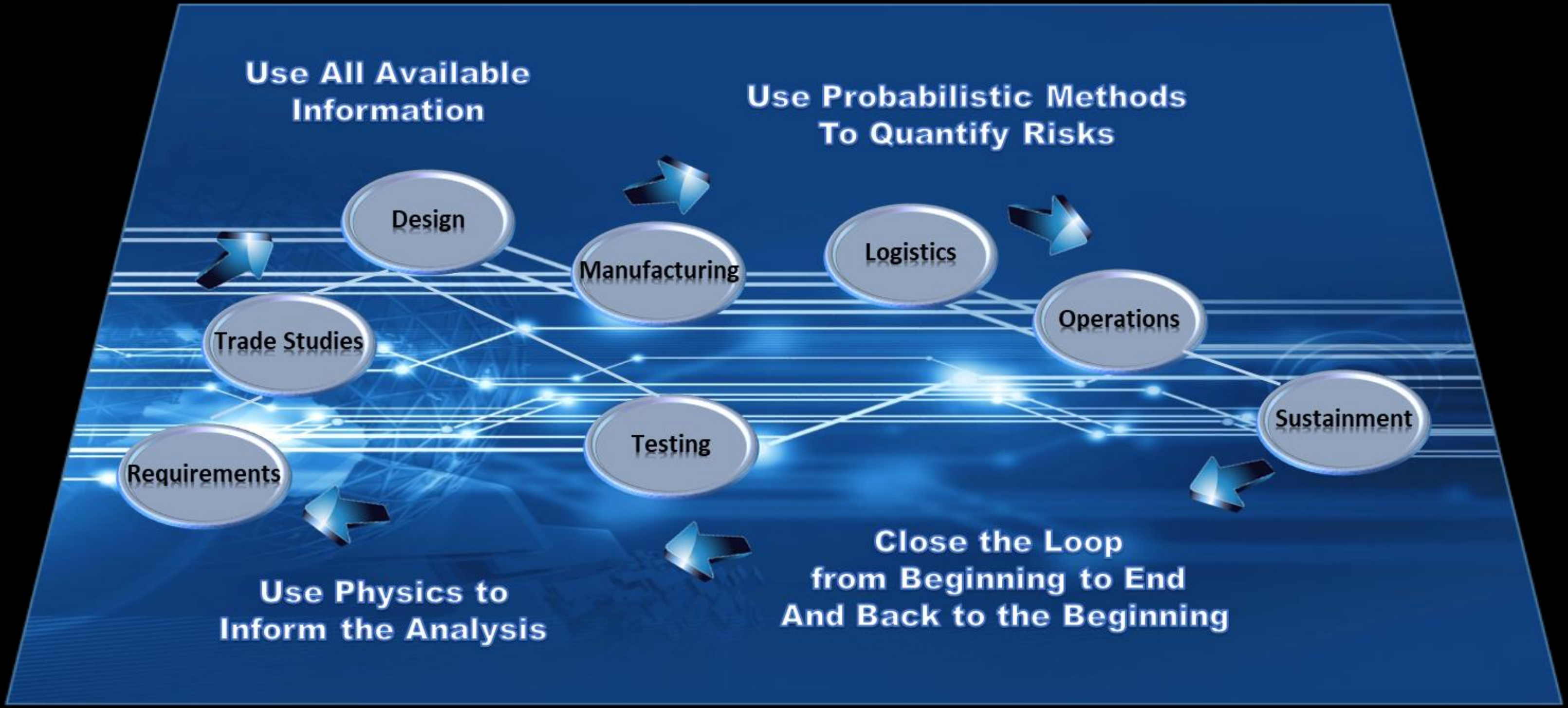
Challenges and Innovations in Digital Systems Engineering



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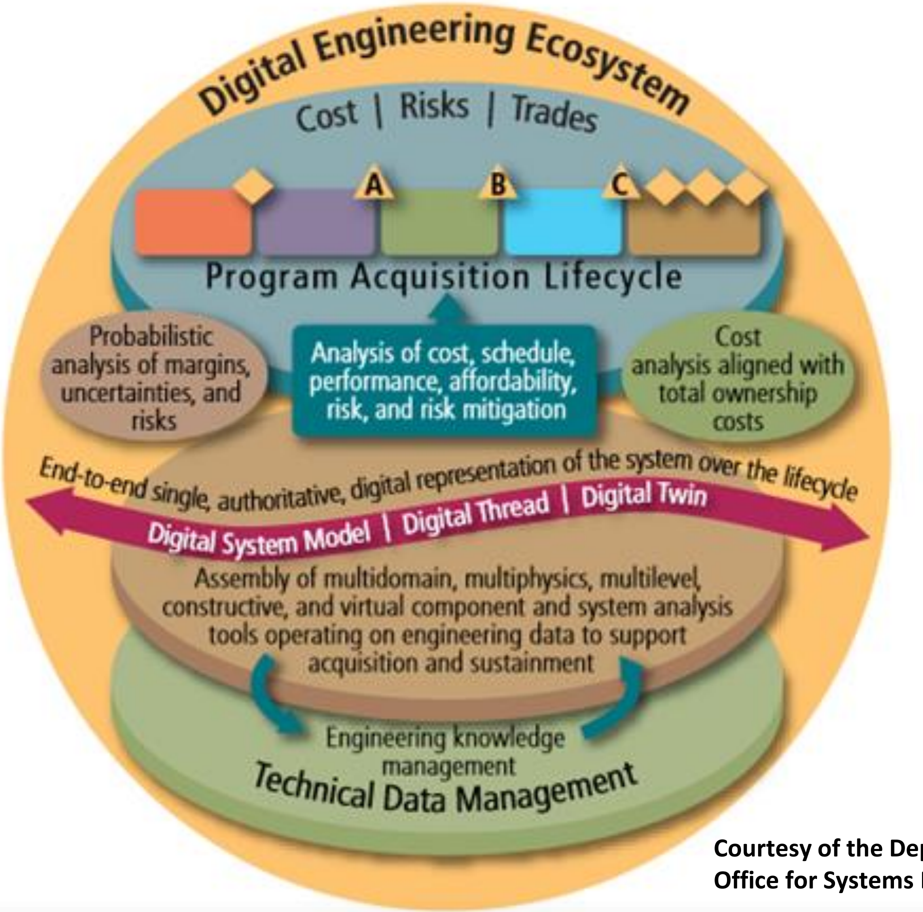
Introduction

- The Aerospace & Defense Industry is investing heavily in Industry 4.0 for their commercial opportunities
- The AF in particular, and the DoD in general, are at the threshold of developing Digital Engineering Ecosystems in collaboration with Industry to take advantage of the Digital Revolution for defense programs
- Challenges to developing a Government / Industry Digital Environment for Defense Systems include:
  - Technologies and Tools for a cyber-physical world
  - Policies – data rights, intellectual property
  - Processes – moving from document-centric to fully digital model-based processes
  - Culture – education and training in Systems Engineering and Program Management consistent with the Digital Revolution

It is Time to Move From Abstraction to Realization in the Integration of Modeling into Digital Engineering Ecosystems

Digital Engineering Ecosystem



Courtesy of the Deputy Assistant Secretary of Defense
Office for Systems Engineering

The interconnected infrastructure, environment, and methodology (process, methods, and tools) used to store, access, analyze, and visualize evolving systems' data and models to address the needs of the stakeholders.

Defense Acquisition Guide

Connected and Integrated Data
Digital Thread / Digital Twin

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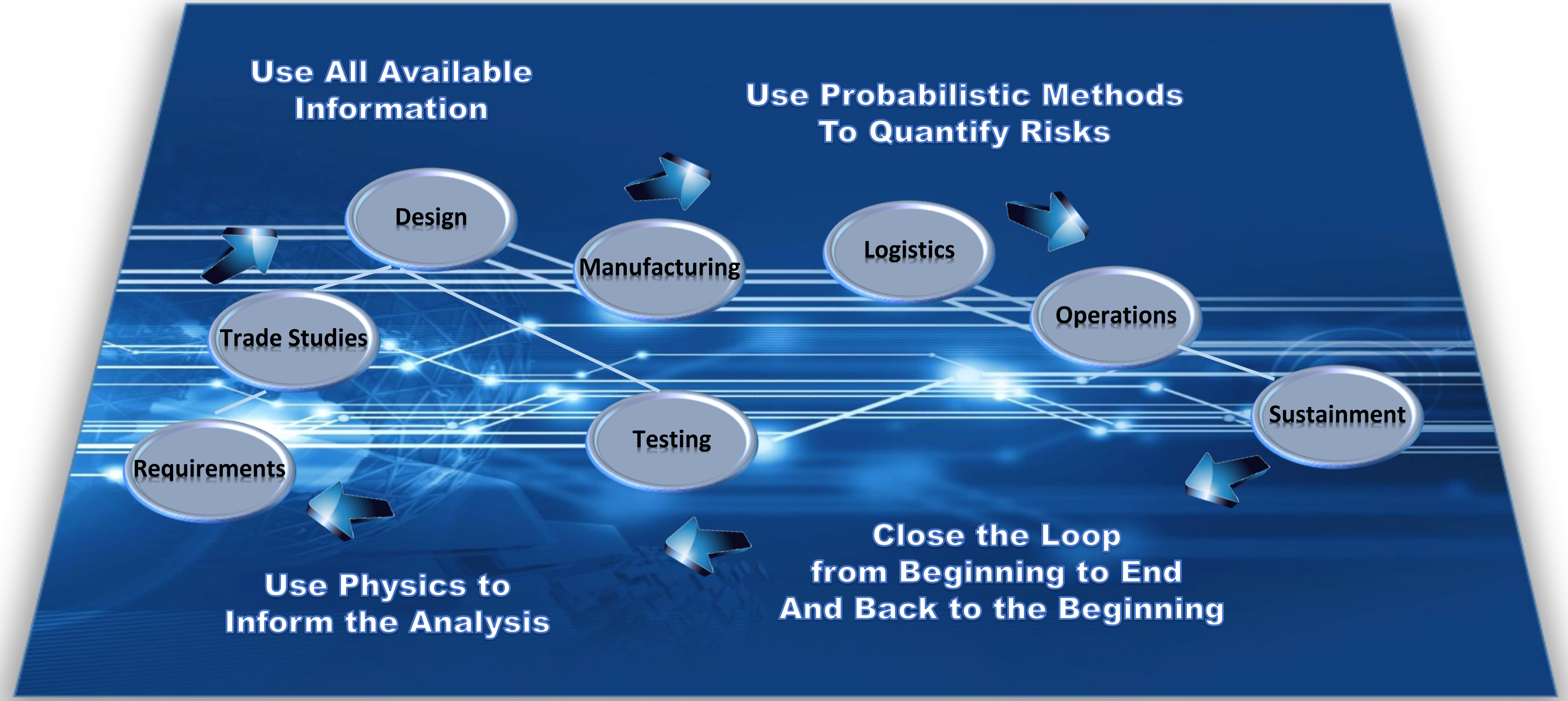

Make Informed Decisions Throughout the Lifecycle

Tenets of the Digital Thread/Digital Twin

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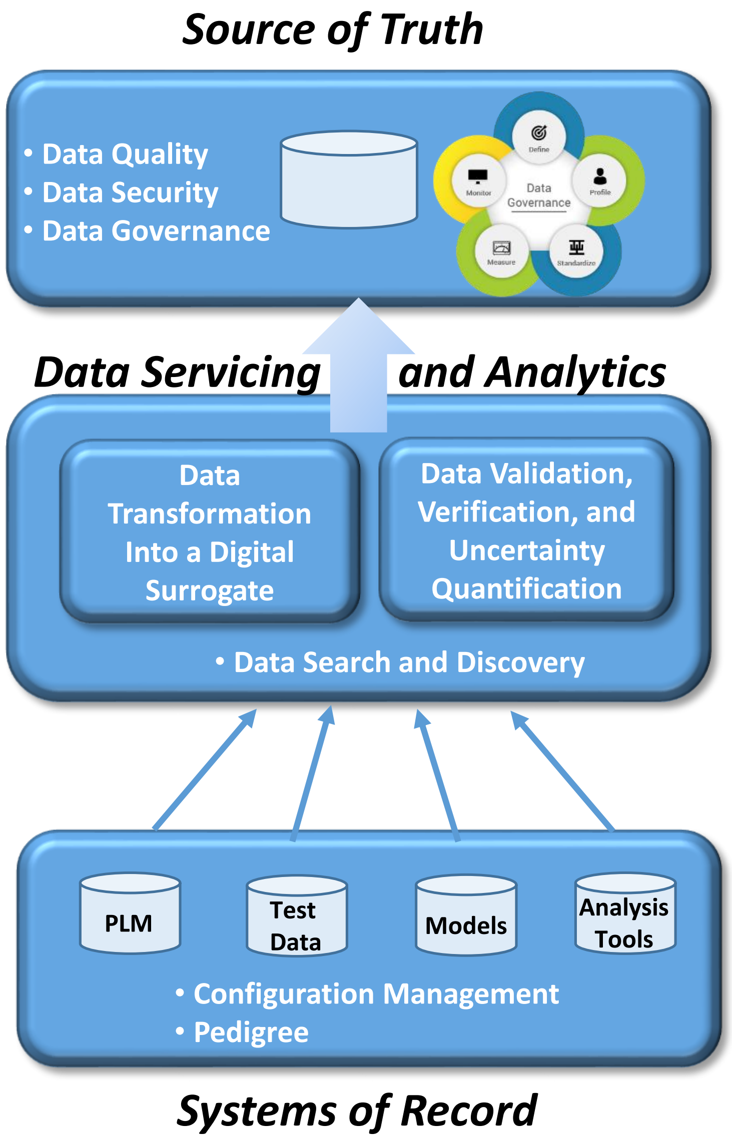
- Access to and ability to exercise data to understand performance and technical risks
- End-to-end system model – ability to transfer knowledge upstream and downstream and from program to program
- Single, authoritative digital representation of the system over the life cycle – the authoritative digital surrogate “truth source”
- Application of reduced order response surfaces and probabilistic analyses to quantify margins and uncertainties in cost and performance
- Preserve meta-data on decision processes and outcomes

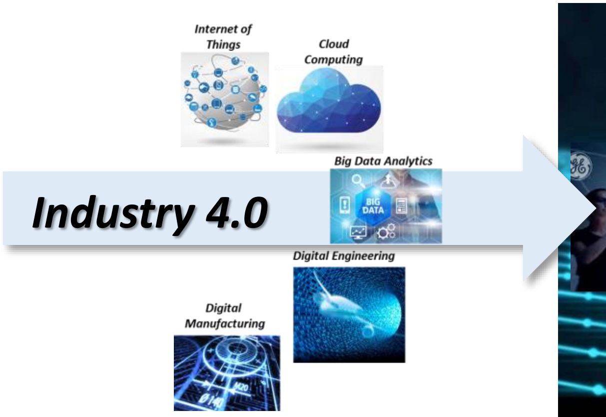
It is Not Sufficient to Just Digitize Current Processes – We Need to Reinvent Processes Leveraging the Digital Connectivity of Trusted Data and Knowledge

A Single, Authoritative Digital Surrogate "Truth Source"

- A technical definition declares quality of a truth source to be "the state of completeness, validity, consistency, timeliness and accuracy that makes the data appropriate for a specific use"
- System of Record (SOR) – the authoritative data source for a given element or piece of information
- Source of Truth (SOT) – trusted data source that gives a complete picture of the data object as a whole
- Trusted data source connotes
  - An entity authorized by a governing authority to develop or manage data for a specific purpose
  - Shared by all stakeholders with all equities preserved

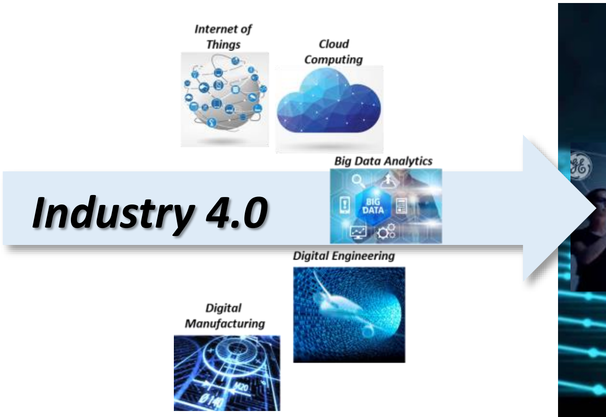


Current Industry Digital Engineering Ecosystems



- Single Owner Enterprises
- Expanding Rapidly, Significant Investments – Next Big Thing in Industry 4.0
- Internally Connected to Enterprise Business Model
- Proprietary, Competition Sensitive ***Digital*** Processes and Tools
- Early Successes in Aerospace Industry

Challenges to Shaping a DoD Digital Engineering Ecosystem



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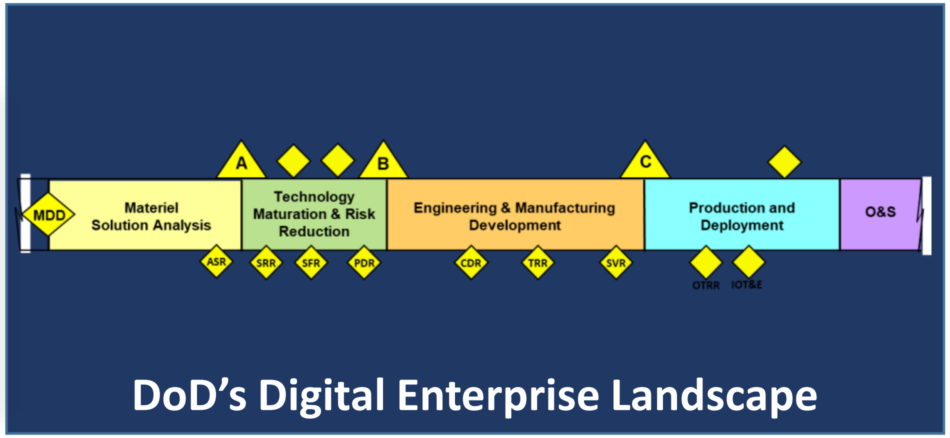
How do we build a Public / Private Partnership to create a DoD Digital Engineering Ecosystem?

How do we shift from a positional document to a digital approach to meet the intent?



- Complex Enterprise
- Arcane, Positional, Paper-Driven, Policies and Processes Not Easily Changed to Digital Processes
- Entrenched Functional Stovepipes Not Necessarily Digitally Savvy
- No Architecture for a Digital Enterprise
- Still in Conceptual Phase – No Dedicated Funding

Challenges to Shaping the Digital Engineering Ecosystem

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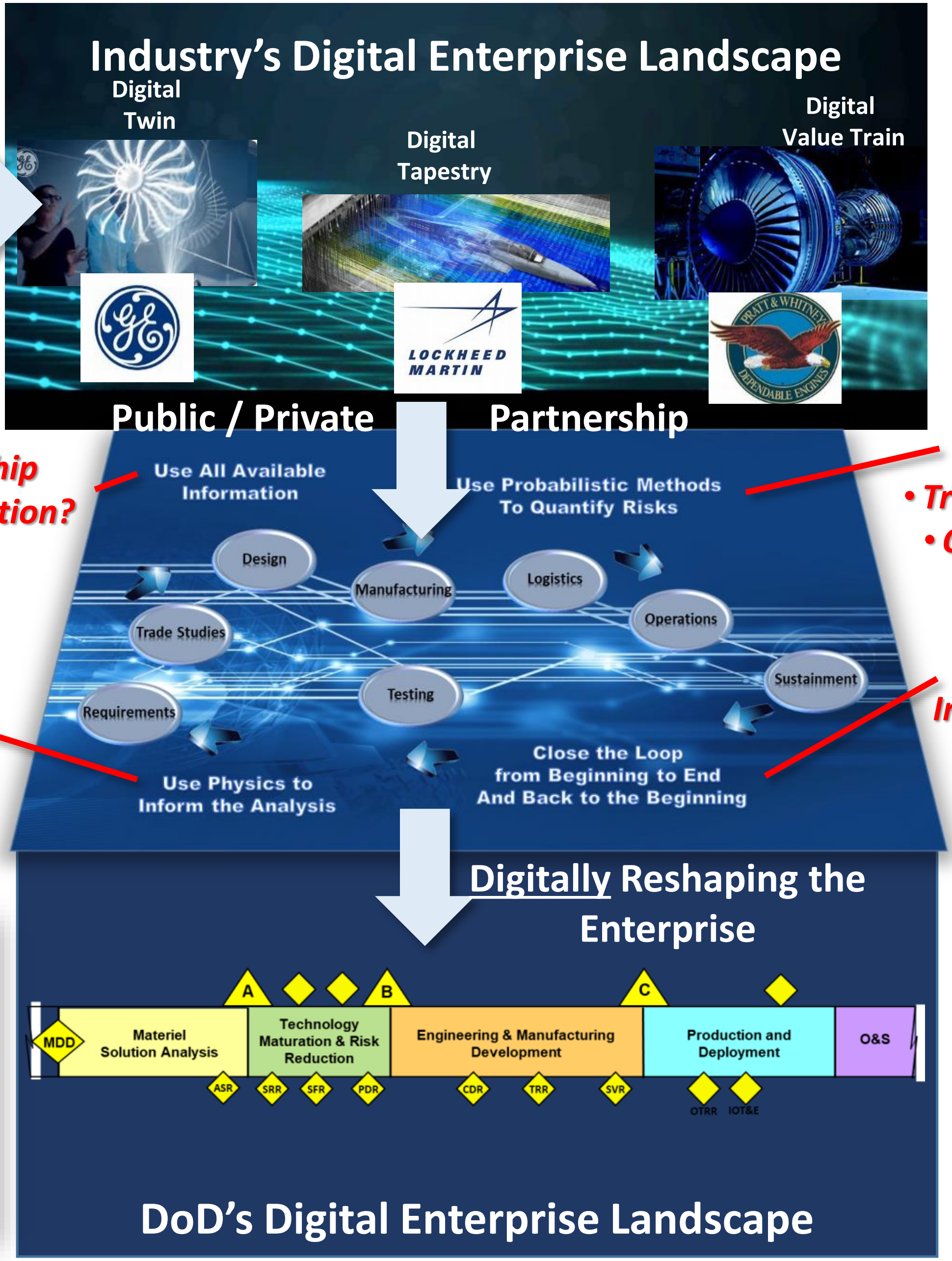

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Source / Ownership of Needed Information?

Digital Authoritative Truth Source
- ***Trust Between Government and Industry?***
- ***Quantified Margins and Uncertainties?***

Digital Thread / Digital Twin
The Bridge

MBSE/MBE Tools
- ***Commonly Accepted Tools?***
- ***Connectivity of Models and Data?***
- ***V&V?***

Digital Connectivity Between Functional Areas?
Interfaces with IoT, Cloud Computing, Big Data Analytics?

How do we shift from a positional document to a digital approach to meet the intent?

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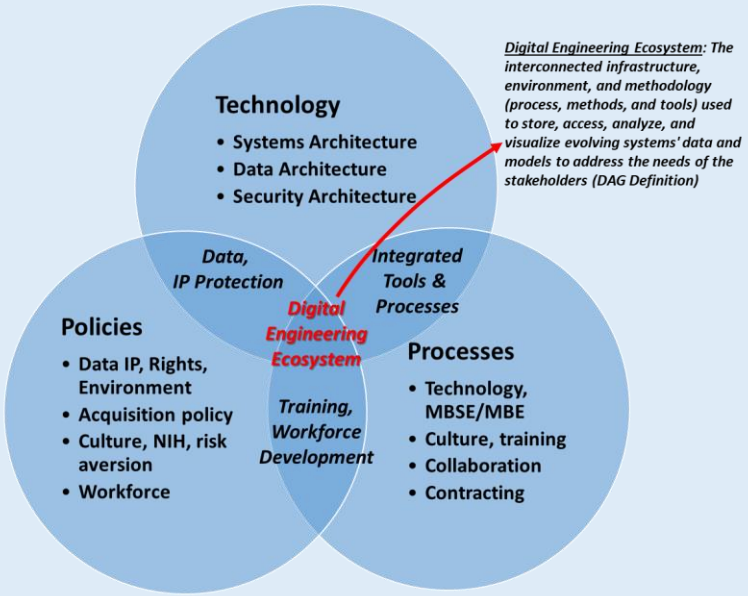
Digital Thread Workshops
Working the Government / Industry Interface

Workshop #1

Objective – Provide an assessment of the tools & technologies, policies & practices affected, and the barriers to establishment of a digital engineering ecosystem across AF systems



Workshop # 2

Objective - develop a concept for a Government / Industry collaborative partnership to develop the principles, practices, and concept of operations for a common Digital Engineering Ecosystem

SCOPE

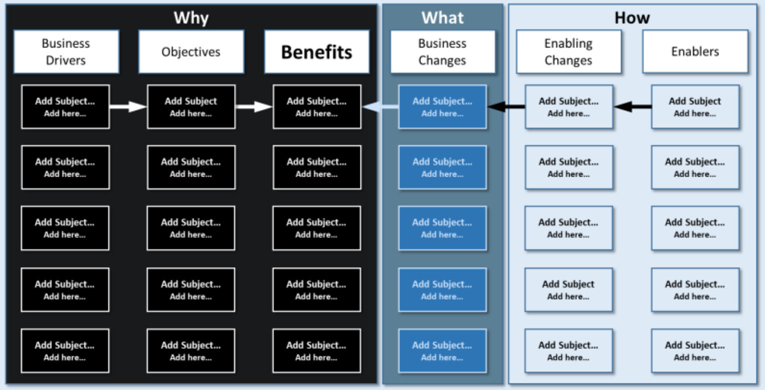
- Effect on Policy and Guidance
- Extension from Service (AF initially) to DoD to Aerospace & Defense
- Initial smaller functional scope, simple demo, expandable to the lifecycle

CONOPS

- Shape the architecture for model/data traceability from concept throughout lifecycle
- Produce modeling guide and V&V as output
- Demonstrate and mature MBSE/MBE from the start – appropriate level of detail
- Identify non-traditional process using the advantages of a digital ecosystem, e.g., a digital TEMP process
- Connections with DMDII CONOPS?

Workshop #3

Objective - develop a value proposition for implementation of a Digital Engineering Ecosystem to support applications of the Digital Thread / Digital Twin concept to improve the acquisition and sustainment of defense systems.



- IT Enablers have ***no inherent value***
- Benefits arise when IT enables people do things ***differently.***
- Benefits come from ***Policy and Operational Changes***

Air Force Materiel Command Digital Ecosystem Pilot Project

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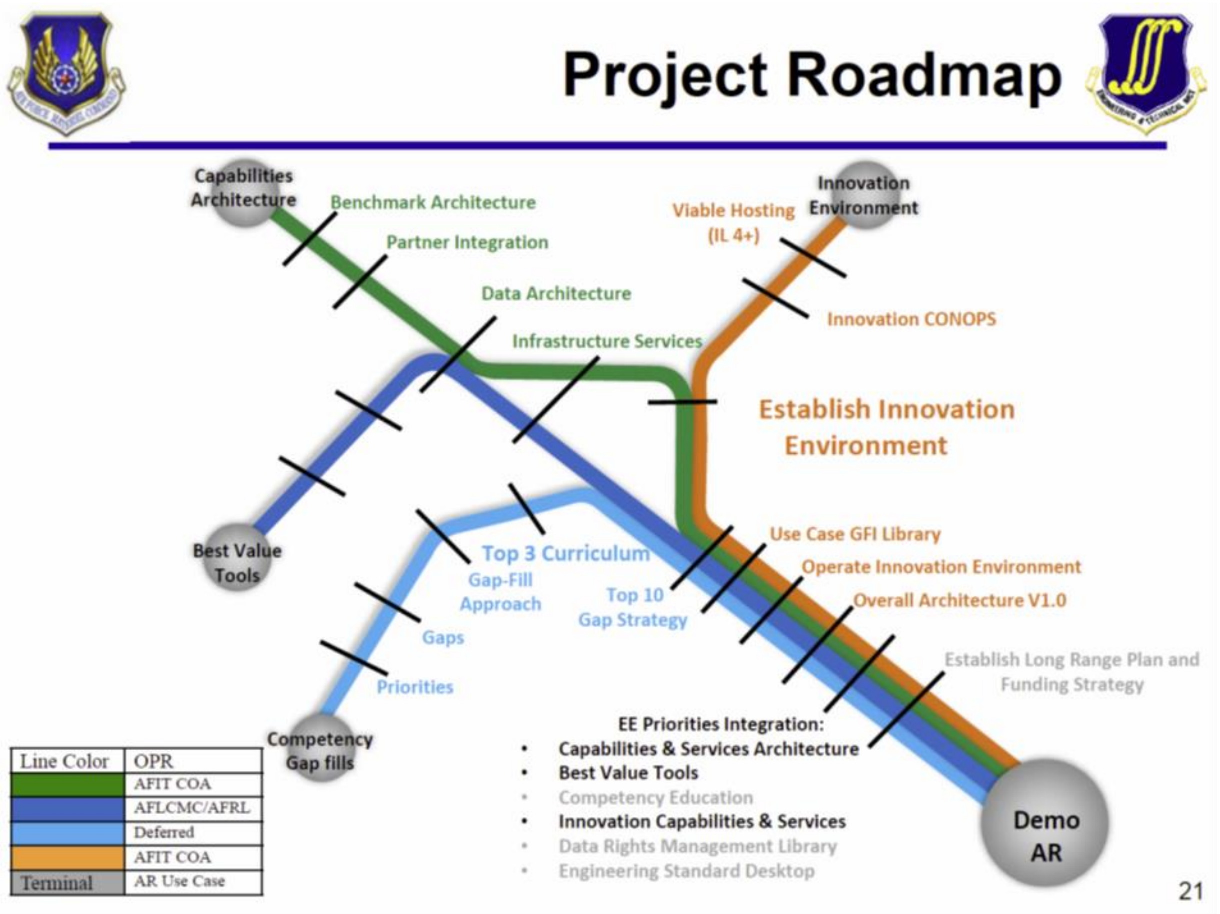

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Pilot Project (year 1-2, $2M)

Sandbox / Proof of Concept Demo

Allow Tool Experimentation, Use Cases Analysis

Demo: Assistance Request (AR) requiring a modified part

- Receive AR
- Engineering to Access all historical data, current data and tools
- Perform analysis Using M&S, demonstrate CREATE value beyond S&T
- Down select to final design
- Produce (Additive Manufacturing if possible) prototype, test
- Deploy Representative Architecture to WPAFB DEATHSTAR
- Document new configuration
- Store for future use

Inform Strategy, Roadmap, Requirements, Data Needs…

Transforming to a Digital World
A Digital Test and Evaluation Master Plan (TEMP)

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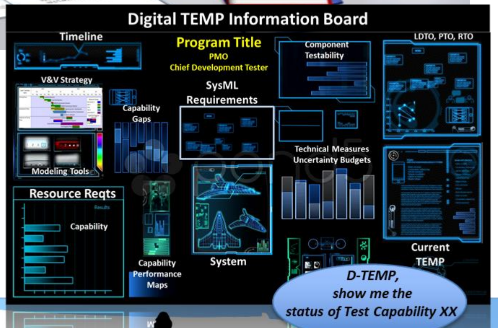
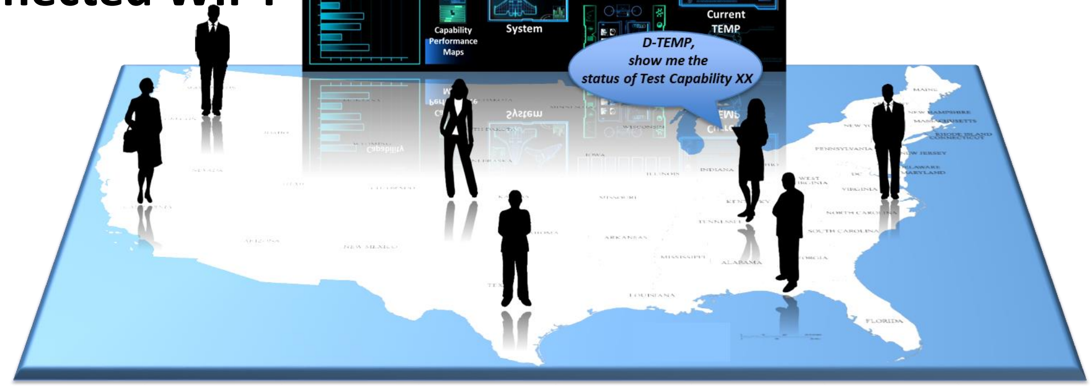
Integrated Test Team -
Stuck in a Document Centric Mode…



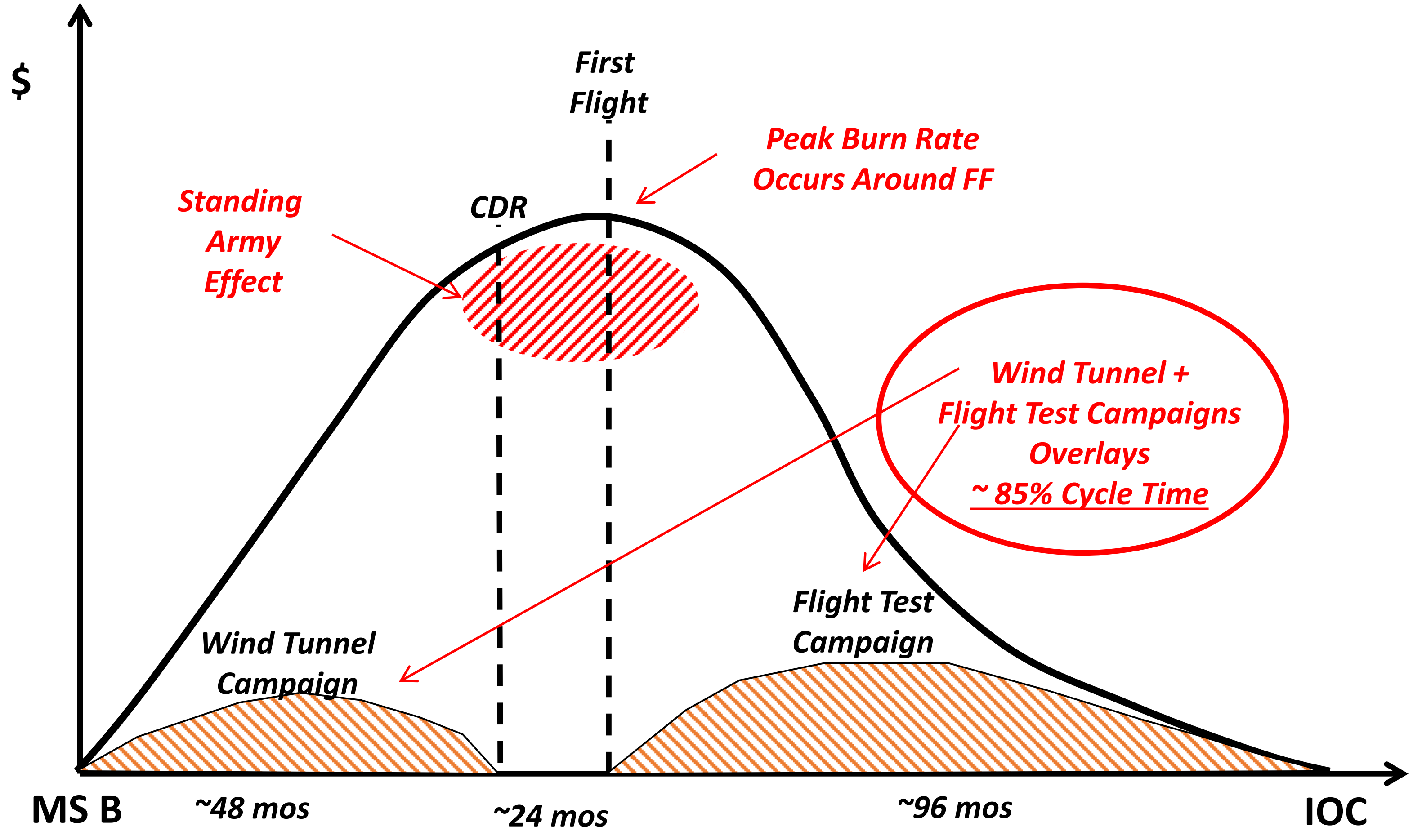
…or Moving to a Digitally Connected WIPT



A Digital TEMP would

- Provide a model-centric approach focused on delivering the intent of the test planning processes in 5000.02 dynamically coupled to digital Requirements
- Apply digitally preserved Systems of Record (SOR) such as
  - Capability/performance maps for MRTFB test capabilities,
  - System performance parametric sensitivities from trade studies,
  - Modeling Tools V&V, uncertainty quantification
  - Quantified epistemic and aleatory uncertainties for MRTFB test capabilities and processes
- Use early model-based authoritative digital surrogates and SORs combined with requirements and uncertainties to develop an optimum test campaign to reduce time/costs and close the design
  - Digitally complete the Developmental Evaluation Framework
    - Decisions supported
    - Knowledge Required
    - Summary and top-level objectives for evaluation, test, and modeling
    - Key resources
    - Program schedule

Target of Opportunity for a Digital TEMP

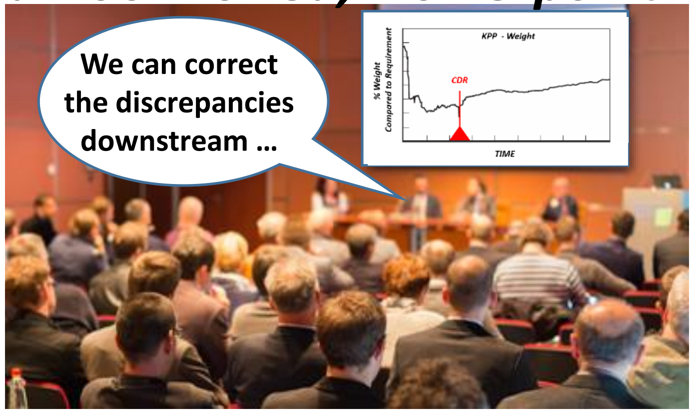


Use the Digital TEMP to Either Reduce the Resources and Cycle Time for DT&E and/or Increase the Probability of Design Closure at CDR

A Digital Critical Design Review (CDR)

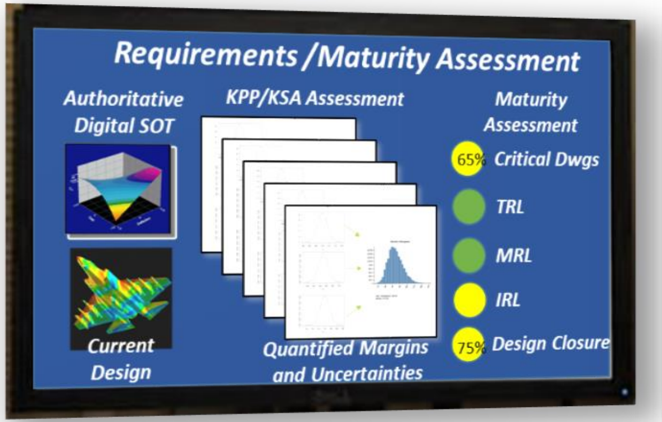
Moving From a Calendar-Driven, Ballroom-Sized, Powerpoint Event . . .

…to a Digitally Current, Quantified Risk Assessment to Support Better Decision Making



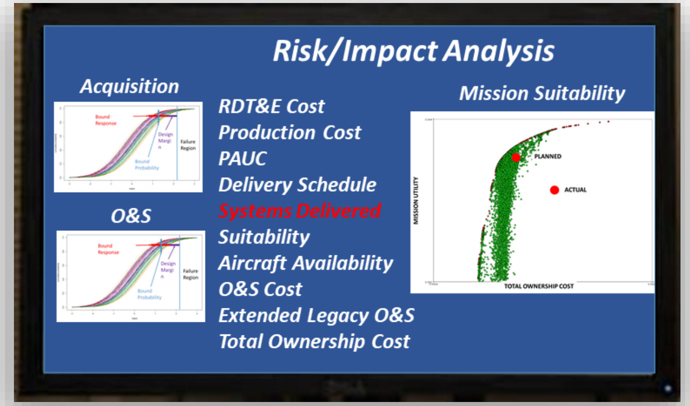
- ***See*** – bring all authoritative digital surrogate truth sources to understand the performance of the system at CDR vs requirements **– target 90% confidence level in design closure**
- ***Think*** – use data analytics/probabilistic analyses to assess risk, impact on military utility, and total ownership cost of any requirements gaps
- ***Do*** – analyze multiple decision scenarios to select the best value course of action including data-driven mitigation strategies

See



Use All Available Information

Think



Use Probabilistic Analysis to Inform

Do

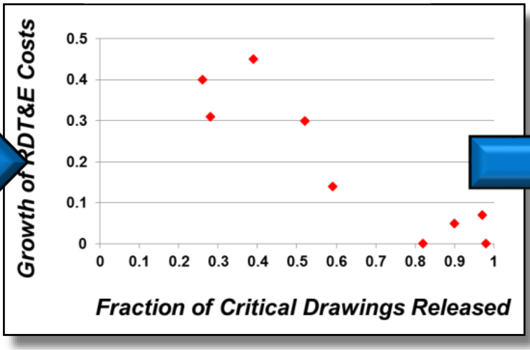
Select Best Value COA

Risk = Uncertainty with Consequences

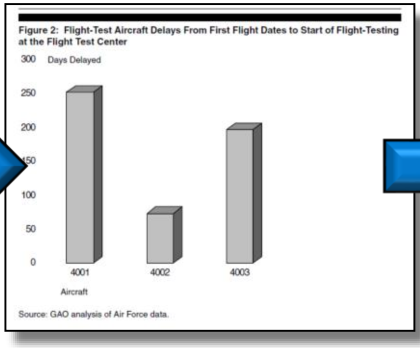
Value of a Digital CDR
Connecting Critical Decisions to Lifecycle Value

Previous Knowledge
- ***Requirements Volatility***
- ***% Design Closure at PDR***
- ***TRL at MS B***

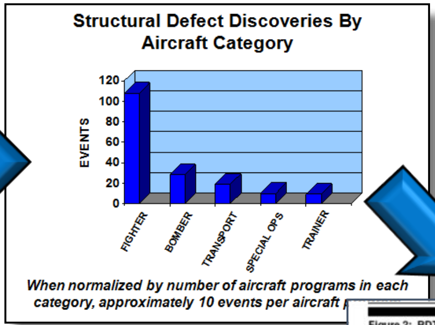
Close the Design at CDR…



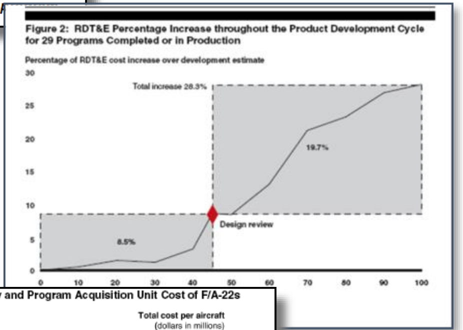
Deliver First Flight Vehicle On Time…



Minimize Late Defects



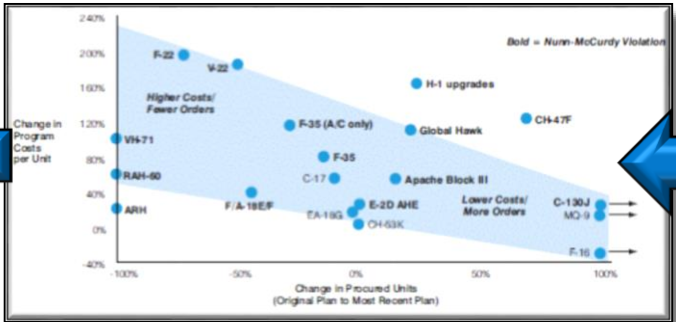
Minimize RDT&E Overruns

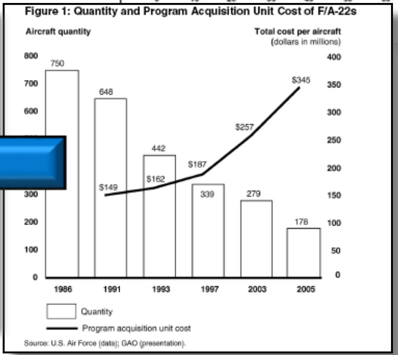


It All Starts with Quantified Performance Margins and Uncertainty Assessments at CDR

Maximize RDT&E Impact on Lifecycle Value

$$VALUE \equiv \frac{AIRCRAFT\ AVAILABLE}{PV(TOTAL\ OWNERSHIP\ COST)}$$





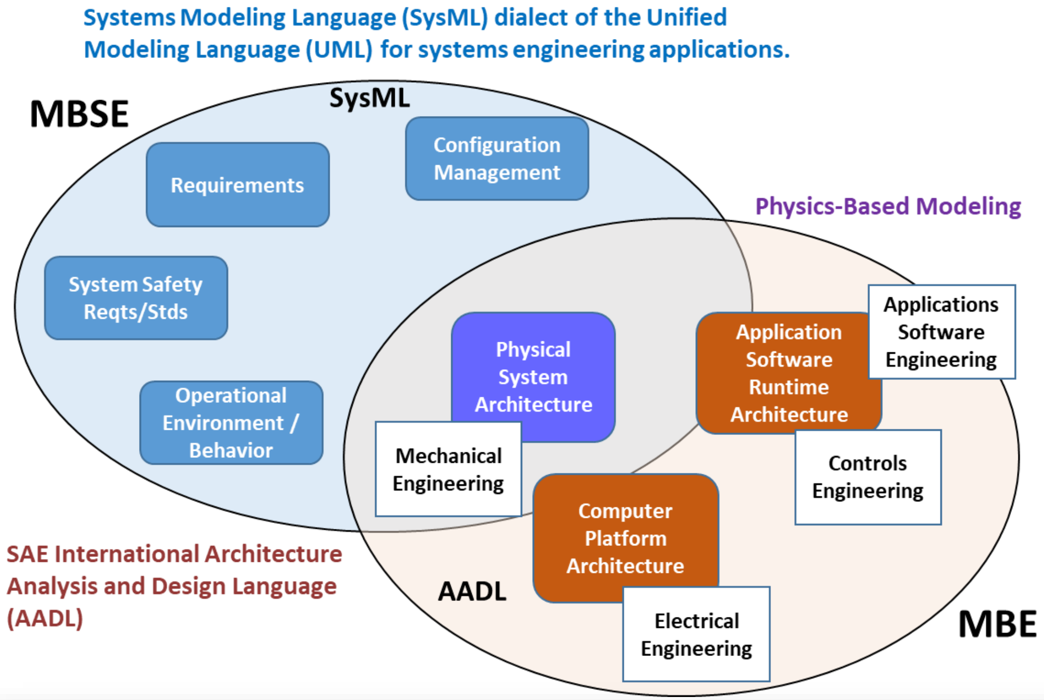
Deliver Contracted Number of Systems on Time/Cost

Consequence of implementing DODI 5000.02 as a positional vice an intentional process has lead to a cascade effect of unconnected decisions not supported by quantified risk assessments

The Next Generation of Digital Systems Engineers Training/Education

- Trained in Digital Modeling
  - Systems Modeling Language (sysML)
  - Architecture Analysis and Design Language (SAE AADL)
  - Physic-Based Modeling
  - Uncertainty Quantification / Risk Analysis
  - Systems Thinking / Systems Dynamics
- Translate traditional Case Study reports to scenario emulators for a digital engineering ecosystem
- Train on Systems Engineering / Program Manager “Flight Simulators” with real world consequences for decisions made
- Use the Digital Engineering Ecosystem to “See-Think-Do”
- Capstone projects focused on streamlining digital processes to increase value

Move from a Build-Test SE paradigm to a new Integrate-Analyze-Build SE Paradigm



Early SE analysis of the total system including the architecture for software intensive systems will be essential for cyber and autonomous systems

Summary

- The Digital Revolution is reshaping the development, fielding, and sustainment of aerospace and defense systems
- The DoD is at the front end of a significant journey toward a Digital Engineering transformation mandated by the need to maintain technical dominance over adversaries
- The Keys to Success encompass
  - Connecting tools and technologies to support a Digital Engineering Ecosystem
  - Establishing policies to enable a public/private partnership while respecting data rights and intellectual property
  - Moving from positional document-centric to fully digital, model-based, intentional processes
  - Educating and training Systems Engineers and Program Managers to lead the Digital Revolution

The Value of the Digital Revolution to the Development, Operation, and Sustainment of DoD Systems Seems Self-Evident But Must Be Proven at Each Stage of Implementation

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