Digital Engineering
Applications to
Developmental Test &
Evaluation

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October 24, 2016
NDIA 19th Annual
Systems Engineering Conference
Springfield, VA
Introduction

• There is a Digital Engineering revolution sweeping the Aerospace and Defense Industry
• The DoD is focusing on Digital Engineering applications to Systems Engineering in support of Acquisition and Sustainment
• Most OEMs have ongoing internal digital thread model-based engineering activities
• Industry related groups like the AIAA, NDIA, ITEA, etc., are focusing symposia on topics related to Digital Engineering

How does the T&E community fit in and how can we leverage the Digital Engineering environment to increase the value of T&E to acquisition and sustainment?
Why T&E Needs to Change

The Burning Platform for Acquisition
Unsustainable Increases in Costs/Cycle Time

MS B to IOC has grown from 5 to 20+ Years

T&E isn’t the only cause, But overlays 85% of the cycle time . . .

Flight Test Hours

Wind Tunnel Hours

INSANITY: doing the same thing over and over again and expecting different results.

Integrity - Service - Excellence

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Leveraging Multiple Activities to Advance Digital Engineering within DoD

**Infusion in Policy and Guidance**
- DoD 5000.02, Enclosure 3, Section 9: Modeling and Simulation
- Defense Acquisition Guidebook Chapter 4
- DoD Digital Engineering Fundamental
- Defense Acquisition Guidebook Chapter 4

**DoD Initiatives**
- Digital Engineering Working Group
- ERS: Adapting to changing requirements
- DSM Taxonomy: Foundation for defining categories of data across acquisition
- HPCMP CREATE: Physics Based Modeling
- NDIA: Essential Elements of the System Model

**Other Partnerships**
- IAWG
- DMDII: Inter-Agency Working Group on the Engineering of Complex Systems
- Additive Manufacturing
- NASA: Sounding Rocket Program
- USAF Own the Technical Baseline
- Digital Thread/Digital Twin

**Advancing the state of practice for Digital Engineering within DoD**

http://www.acq.osd.mil/se/pg/guidance.html
OSD Digital Engineering Definitions
(Defense Acquisition Guide Glossary)

- **Digital Engineering**: An integrated digital approach that uses authoritative sources of systems' data and models as a continuum across disciplines to support lifecycle activities from concept through disposal.

- **Digital Engineering Ecosystem**: 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.

- **Digital Artifact**: The artifacts produced within, or generated from, the digital engineering ecosystem. These artifacts provide data for alternative views to visualize, communicate, and deliver data, information, and knowledge to stakeholders.

- **Technical Coherency**: The logical traceability of the evolution of a system's data and models, decisions, and solutions throughout the lifecycle.

Digital Engineering Tenet - The Models are the Master Moving from Paper to Digits

**Integrity - Service - Excellence**
1. Policy changes – government as virtual monopsony
   - OSD BBP 3.0 Organic Engineering Capability
   - SAF/AQ Own the Tech Baseline/Bend the Cost Curve
   - AF Engineering Enterprise Strategic Plan – policies, tools, structure, skills

2. Analytic Framework
   - Digital Thread/Digital Twin – life cycle digital engineering
   - Knowledge Management

3. High fidelity, multi-level, multi-physics modeling tools
   - CREATE, ICME, Others
The AF Digital Thread / Digital Twin
The Analytical Framework

**Digital System Model** - A digital representation of a weapon system, generated by all stakeholders, that integrates the authoritative data, information, algorithms, and systems engineering processes which define all aspects of the system for the specific activities throughout the system lifecycle.

**Digital Thread** - An extensible, configurable and Agency enterprise-level analytical framework that seamlessly expedites the controlled interplay of authoritative data, information, and knowledge in the enterprise data-information-knowledge systems, based on the Digital System Model template, to inform decision makers throughout a system's life cycle by providing the capability to access, integrate and transform disparate data into actionable information.

**Digital Twin** - An integrated multiphysics, multiscale, probabilistic simulation of an as-built system, enabled by Digital Thread, that uses the best available models, sensor information, and input data to mirror and predict activities/performance over the life of its corresponding physical twin.

**Common interest in a physics-based, multi-discipline, multi-physics, cross-domain, model of a system’s capabilities and performance**
Tenets of the Digital Thread/Digital Twin

- Access to and ability to exercise data to enable the government to understand performance and technical risk, i.e., “Own the Technical Baseline”
- 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
- 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
Viewing the DT/DTw as the Hub of the System Architecture Model, an integration pattern emerges enabling cross-domain connectivity with minimal set of required integrations.
**Decision Analytics**

**INPUT**
- Quantified assessment of the state of the SUD* relative to KPP/KSAs
- Probabilistic assessment of risk and costs
- COA scenarios
- SUD requirements
- Updated authoritative digital surrogate for system in reduced order model format

**OUTPUT**
- Prognosis of future states
- Comparative analysis of COAs
- Recommended COA
- Quantified margins and uncertainties
- Risk assessment
- Probable cost assessment

**Descriptive Analytics:**
Application of Model Based Engineering analysis tools to transform technical data into useful technical information. Used for data interpretation, evaluation of system/subsystem capabilities wrt requirements.

**Predictive Analytics:**
Probabilistic analysis of system state, used to forecast what might happen or could be accomplished.

**Prescriptive Analytics:**
Used to understand what should be done or to recommend the best course of action for any pre-specified outcome.

* SUD – System Under Development
MBSE instantiation of the Digital Thread can improve test processes in several ways.

- **First**, enhanced communication can help test planners to better understand the system they are testing and influence the SEMP/TEMP processes.

- **Second**, improved requirements definition and an emphasis on requirements traceability and testability can help test planners by providing clear test objectives with measurable outcomes.

- MBSE can help to define an optimum test program by determining the information that is needed and the acceptable uncertainty of the information derived from testing.

- MBSE approaches can use the system model, along with operational analysis, to establish uncertainty budgets for technical performance measures leading to uncertainty goals for specific test events.

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**The Digital Thread is the communication architecture for an MBE/MBSE approach to lifecycle management**

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Eileen A. Bjorkman, Shahram Sarkani, Thomas A. Mazzuchi

“Using Model-Based Systems Engineering as a Framework for Improving Test and Evaluation Activities”
Digital Thread Approach to Aerodynamic Testing – Providing the Performance Baseline Truth

Requires a government/industry enterprise approach to reducing total cycle time

CREATE-AV

OML Input

Surrogate Performance and S&C

Surrogate Digital Loads Spectra

MS A

MS B

Authoritative Digital Surrogate

At Each Instance in Time

Modeled Truth

Quantified Margins and Uncertainties at Key Decision Points

Ground Truth

Quantified Margins and Uncertainties at Key Decision Points

Flight Truth

MS C

Optimum GT Campaign

Merged Model, GT Data

CDR

Optimum FT Campaign

Merged Model, GT, FT Data

CREATE-AV

Scalable to 1000’s of processors

High Performance Computing

System Identification

Modular architecture for multi-discipline, multi-fidelity physics modeling – not a one size fits all CSE model

Interchangeable analog and digital inputs

MS A

MS B

Authoritative Digital Surrogate

At Each Instance in Time

Modeled Truth

Quantified Margins and Uncertainties at Key Decision Points

Ground Truth

Quantified Margins and Uncertainties at Key Decision Points

Flight Truth
Anatomy of a Fixed-Wing Air Vehicle SDD Program

Wind Tunnel Campaign

~48 mos

MS B

~24 mos

First Flight

~96 mos

IOC

Standing Army Effect

Peak Burn Rate Occurs Around FF

Wind Tunnel + Flight Test Campaigns Overlays ~85% Cycle Time
Starting at Milestone B is Late to Need

Requirements, Quantified Margins & Uncertainties

Affordable, Feasible, Interoperable System Requirements

Modeling Commons
Tech Demo, Prototypes

Operational Models

Physics-based Models

Multi-resolution Analysis Methodology

Final AoA Report
Draft CDD
PDR
RFP
Proposals

Updated TEMP
Wind Tunnel Campaign
CDR
First Flight
Flight Test Campaign

~48 mos
~24 mos
~96 mos

MS A TEMP
MS B

Temperature

TL Maturation

Independent Evaluation

Optimum GT Campaign
Merged Model, GT, FT Data

Ground Truth

Modeled Truth

Optimum FT Campaign
Merged Model, GT, FT Data

Flight Truth

Affordable,
Interoperable
System
Requirements
Potential Impacts in the SDD Phase

- Reduce Program Cycle Time, Costs
- Close the Design...
- Minimize Late Defects
- On Time Delivery FF Vehicle...
- Reduce Program Cycle Time, Costs
- Reduce WT Campaign Cycle Time, Costs
- Reduce FT Campaign Cycle Time, Costs
Value of a Quantified Digital Performance Evaluation Baseline

Close the Design at CDR…

Deliver FF Vehicle On Time…

Minimize Late Defects

Minimize RDT&E Overruns

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

Figure 3: Flights/Leave Aircraft Delays from Final Flight Takeoff to Start of Flight-Testing at the Flight Test Center

When normalized by number of aircraft programs in each category, approximately 10 events per aircraft

Figure 2: R&D&E Percentage Increase throughout the Product Development Cycle for 29 Programs Completed in or on Production

Figure 1: Quantity and Program Acquisition Unit Cost of F/A-22

Maximize RDT&E Impact on Lifecycle Value

Deliver Contracted Number of Systems on Time/Cost

Integrity - Service - Excellence
The Digital Engineering revolution is underway across the Aerospace and Defense industry.

The T&E community needs to integrate Digital Engineering as a natural companion to testing.

The T&E community is best positioned to provide a quantified assessment of baseline performance in support of key decision points in the acquisition process, most notably the Critical Design Review.

Successful instantiation of Digital Engineering into the T&E environment will require:

- Policies to ensure T&E expertise is leveraged to provide the quantified baseline performance assessment.
- Very close collaboration between government and industry to improve processes leading to increase value from RDT&E.

“IT IS NOT THE STRONGEST OF THE SPECIES THAT SURVIVE, NOR THE MOST INTELLIGENT, BUT THE ONES MOST ADAPTABLE TO CHANGE.”

Charles Darwin 1809-1882
Heads Up

Upcoming dialogues with industry on digital engineering and acquisition with emphasis on DT&E

- Defense Planning And Analysis Society (DPAAS)
  Dayton Ohio, November 17
  - Luncheon overview of the Air Force Test Center
  - A Dialogue with Industry on Integrating Digital Engineering with Developmental T&E to Streamline Acquisition

- SAF/AQ, NDIA, AIAA, AIA Industry Workshop
  NDIA HQ Washington DC, November 28
  - Digital Thread/Digital Twin Workshop with Industry

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