The Role of CREATE™-AV in Realization of the Digital Thread

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Introduction

• The Aerospace & Defense Industry is investing heavily in Industry 4.0

• 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

• The HPC CREATE™ Program has evolved into an important source of high-fidelity, physics-based performance modeling tools with inherent capabilities enabling development of authoritative digital surrogate truth sources key to realization of a Digital Thread / Digital Twin

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

Make Informed Decisions Throughout the Lifecycle
Tenets of the Digital Thread/Digital Twin

• 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
Opportunities for CREATE™-AV to Enable the Digital Thread

- Multi-discipline, multi-physics, multi-fidelity capability
- Ability to rapidly and efficiently generate reduced order models for surrogate representations
- Ability to address system integration issues during detailed design (fluid/structures, airframe/propulsion, airframe/weapons)
- Scalable to take advantage of high performance computing assets
- Configuration management and Quality Control critical to confidence in applications across multiple regimes.

To Become an Integral Component of a “Truth Source” Requires a Pedigree, Transformation to a Digital Surrogate, Integration with Other Data Sources, and Uncertainty Quantification
Developing the Pedigree

SOR
Digital Library
Of Unit
Experiments,
Validation Cases,
Quantified Model
Uncertainties

Unit Experiments
Validation Cases

Unit Experiment Data
Vehicle Data

Additional V&V, Application
Case Studies

Digital Thread

1. SmartUQ
   Simulation DOE

2. High Fidelity Physics-Based Model
   Lab Unit Experiments

3. High Fidelity Physics-Based Model Responses
   Lab Unit Experiments Measurements

4. SmartUQ Calibrated Emulator
   (Bayesian, Statistical)

CREATE™-AV

Quantified Model
Uncertainties

Library of Experimental Validation Data and V&V of Models Digitally
Preserved as a System of Record Will Expedite a Digital Truth Source
Developing the Model-Based Digital Surrogate

Reduced Order Model Response Surface Generation Over Entire Operating Envelope

Model-Based Performance Response Surface 1.0 + QMU 1.0

Digital Authoritative Truth Source

Digital Thread

Minimize the Number of High Fidelity Modeling Computations

Space Filling DOE Analysis

Initial DOE

Statistical Calibration

Adaptive DOE

Final Emulator

CREATE™-AV

High Fidelity Physics-Based Models

Quantified Model Uncertainties

Additional V&V, Application Case Studies

Modeling Efficiency, Scalability, and Optimized UQ Methods Will Be Required to Generate Comprehensive Model-Based Surrogates
Merging Model and Test Data

1. Modeled Assessment / Correction of Epistemic Uncertainty

2. Combined Epistemic and Aleatory Analysis of Experimental Data

3. Merge of Experimental and Modeled Data into New Authoritative Truth Source with Quantified Uncertainties

A 3-Step Process

Digital Authoritative Truth Source

Digital Thread

CREATE™-AV
V&V'D Applied High-Fidelity Model

Digital Authoritative Truth Source

Epistemic Delta

Identification of Source and Range of Epistemic Uncertainties

Additional V&V, Application Case Studies
MBSE, MBE, UQ, and T&E – Transforming to a Digital Process

Moving Toward a “Digital TEMP” to Improve Quality of Performance Against Requirements and Reduce Cost and Schedule for T&E
CREATE™-AV Lifecycle Impact as a Truth Source
A Vision Realized

Systems Engineering Leverage Points for Reducing Total Ownership Costs

Affordable, Feasible, Interoperable System Requirements

TRL Maturation
Integrated Design

Requirements Volatility
Technology Maturation

Design Closure @ CDR
Late Defect Discoveries
IOT&E Pause Test

% Design Drawings Completed at CDR
% Growth in Development Schedule

Suitability
Weapon Integration
Optimum Maintenance
Mishap Investigations
System Modifications
SLAP/SLEP

Digital Thread / Digital Twin

Single, Authoritative, Digital Representation of the System

Minimize Defect Discovery
Air Worthiness

Integrated Computational Materials Engineering (ICME)

Integrated Tool for Managing Structural Integrity

Material Scale
Loads Spectra Surrogate
Loads = f(\bar{G}, M, \alpha, q, c, a, \theta, \lambda)

Performance Surrogate
Integrated Design Evaluation @ MS B

Independent Design Closure @ MS B
Minimum Test Campaign

DaVinci
Kestrel

High-Performance Computing
System Identification
Modular, multi-disciplinary architectures

Input from Delphi
Loads Spectra Surrogate

Integration of data, models, and analysis tools to form a "Digital Twin" of an individual aircraft
• Integrated database of history
• Configuration control
• Virtual Damage Sensor

Program "Get Started" Stage

Optimum

Integrated Design Closure @ CDR
Design Closure @ MS B

Late Defect Discoveries
Minimum Test Campaign

Manufacturing
MRB Processing

system
Summary

• The Digital Revolution is reshaping the development and sustainment of aerospace and defense systems

• The DoD is moving forward with Industry to develop the architecture for a Digital Engineering Ecosystem

• The crucial elements for a Digital Ecosystem are
  • Identification and preservation of Sources of Record
  • Transformation of SOR data into digital surrogates
  • Quantification of the quality of the digital surrogates
  • Governance of the Authoritative Digital Surrogate Truth Source

CREATE™-AV has inherent capabilities conducive to providing an authoritative digital surrogate truth source for air vehicle performance, but will require focused attention on establishing its pedigree and persistently quantifying uncertainties at each application phase over a system lifecycle
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