U.S. Air Force

Integrity - Service - Excellence

T&E in the Digital Engineering Era

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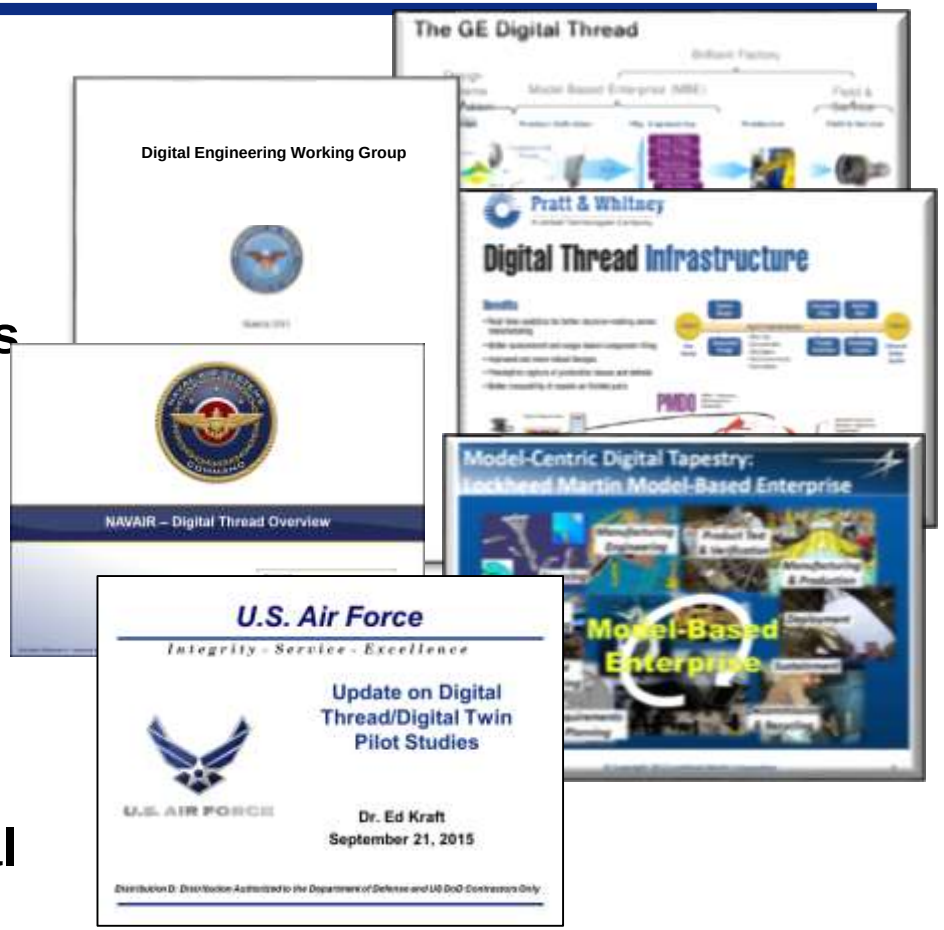
October 5, 2016

33rd Annual International Test and Evaluation Symposium

Reston, VA

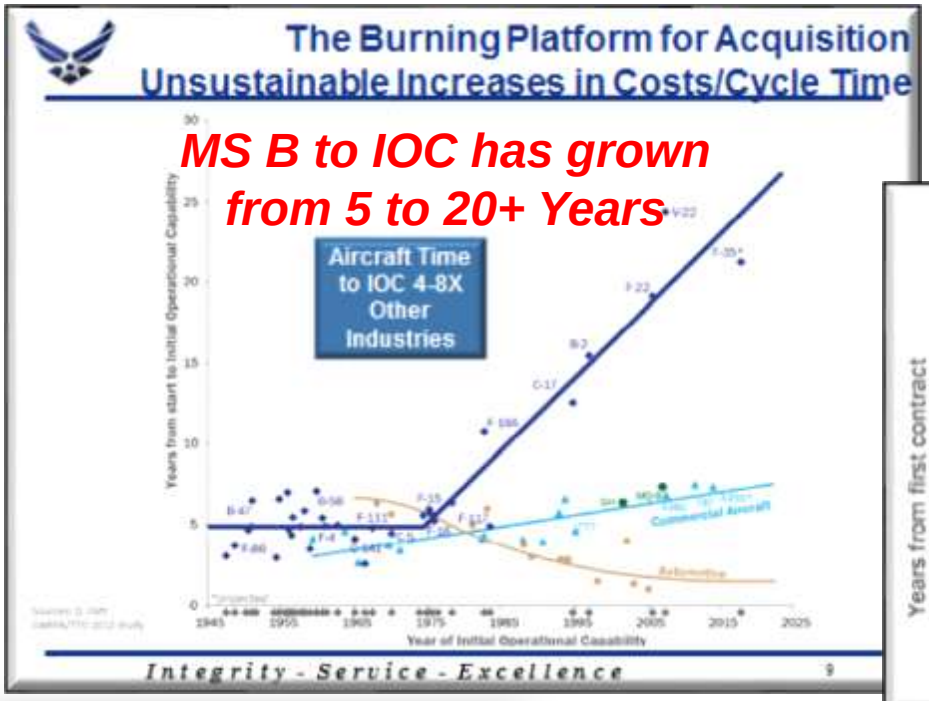
Introduction

- 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

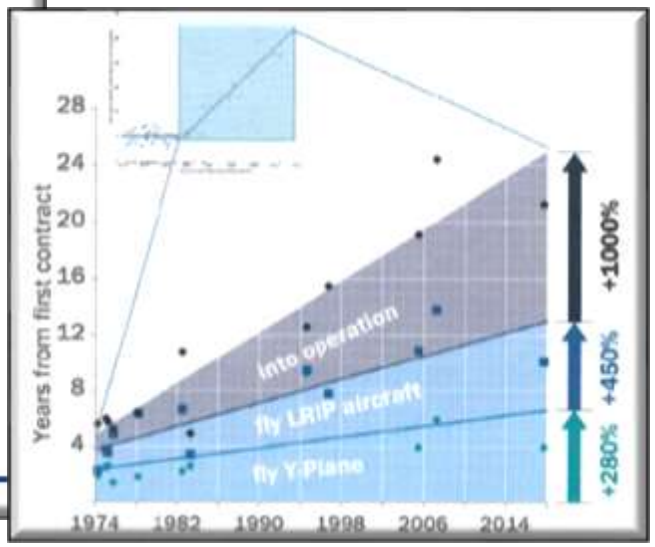


How does the T&E community fit in and how can we leverage the Digital Engineering environment to increase the value of T&E to acquisition and sustainment ?

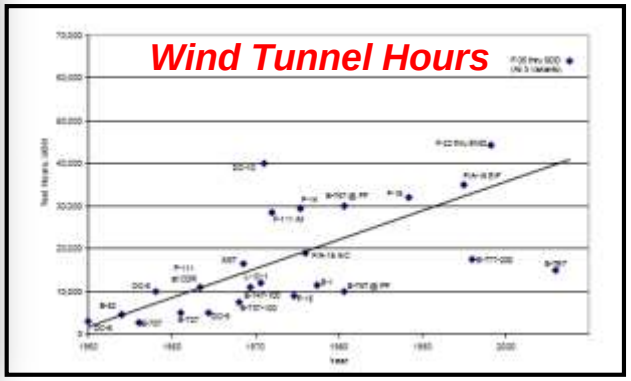
Why T&E Needs to Change

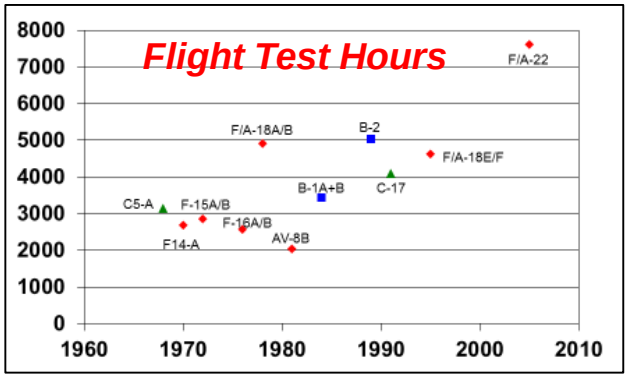


T&E isn't the only cause,
But overlays 85% of the cycle time . . .



Continuing to do the same things qualifies T&E for Einstein's definition of insanity





Leveraging Multiple Activities to Advance Digital Engineering within DoD

Infusion in Policy and Guidance

DoDI 5000.02, Enclosure 3, Section 9: Modeling and Simulation

Defense Acquisition Guidebook Chapter 4

DoD Digital Engineering Fundamental

Defense Acquisition Guidebook Chapter 4

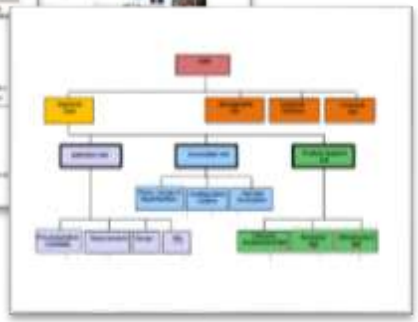
http://www.acq.osd.mil/se/pg/guidance.html

DoD Initiatives

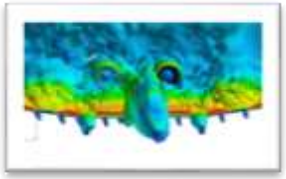
DoD Digital Engineering Working Group

ERS: Adapting to changing requirements

SERC: Model Centric Collaborative Environment



DSM Taxonomy: Foundation for defining categories of data across acquisition



HPCMP CREATE: Physics Based Modeling

Other Partnerships

Additive Manufacturing

IAWG

NASA: Sounding Rocket Program

NDIA: Essential Elements of the System Model

USAF Own the Technical Baseline

Digital Thread/Digital Twin

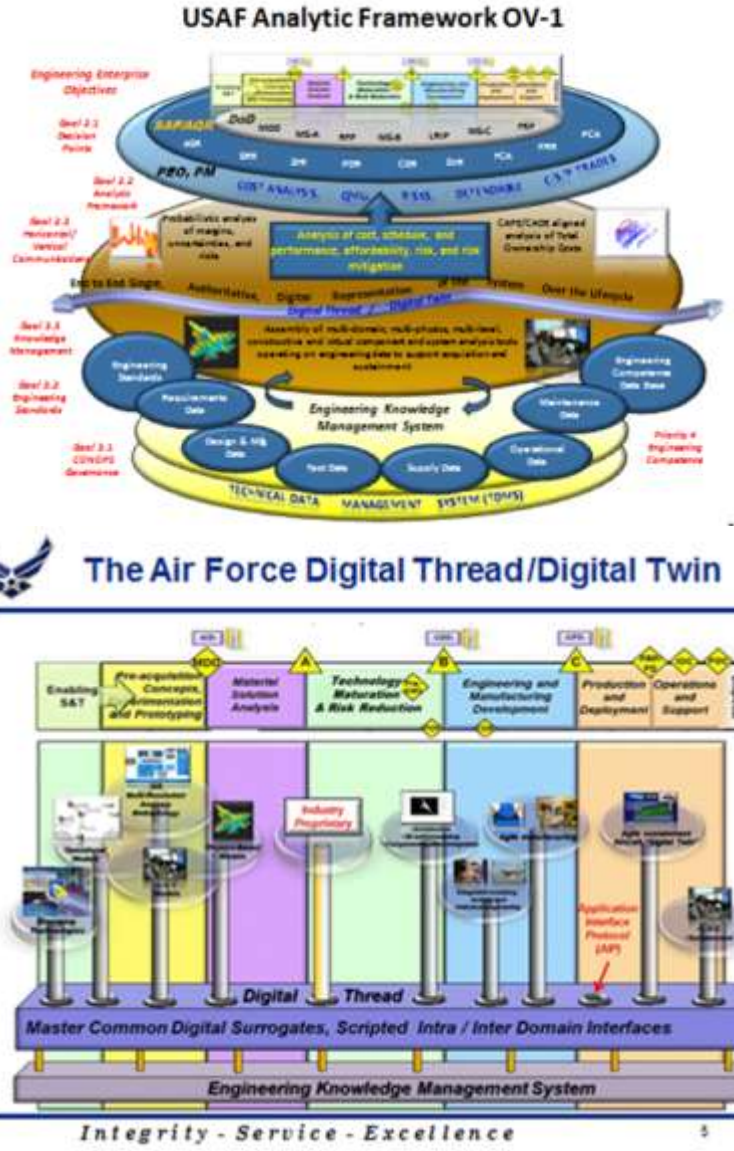
Advancing the state of practice for Digital Engineering within DoD

OSD Digital Engineering Definitions
(Defense Acquisition Guidance 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.**

Paradigm Shift – Keys to Success

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

Integrating Model Based Engineering into Developmental T&E – the Shifting Paradigm

- Current state: everyone uses models in one form or another in isolation and communications happens in the form of separate, disconnected documents.

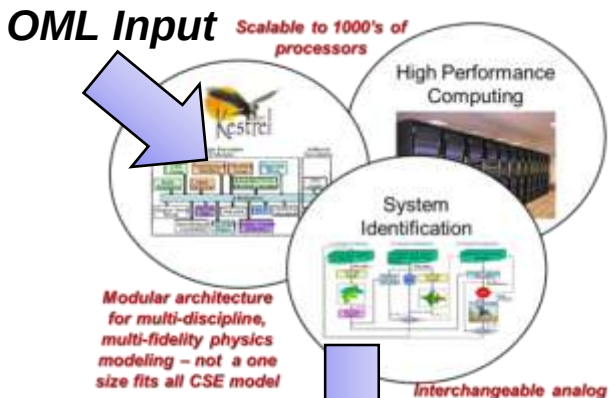
- Future state: models (computer models and data) are linked through a Digital Thread information infrastructure that contains authoritative sources of truth for the disparate functional elements that contribute to the acquisition and sustainment of weapon systems
  - The Digital Thread enables the government to exercise an "Organic Engineering Capability" and "Own the Technical Baseline"
  - The Digital Thread architecture also enables a collaborative government / industry environment to frame authoritative sources of truth while preserving intellectual property
  - Technical data is accessed, integrated, evaluated, and transformed in to actionable digital information in support of critical decisions over the lifecycle
  - Technical Data Package are represented by a federation of digital models that all draw from the linked, authoritative sources of truth

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

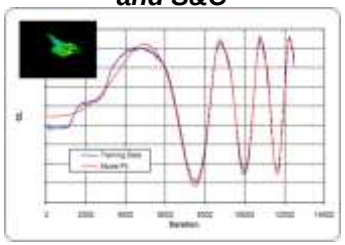
Computational Research Engineering Acquisition Tools Environment (CREATE-AV)

CREATE-AV Kestrel Fixed-Wing Capability

- **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.**
- **Key enabler for AF Digital Thread**

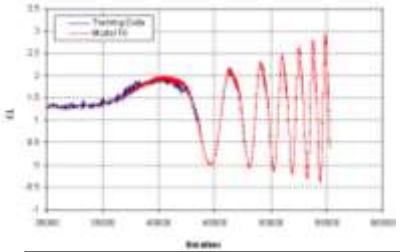


Surrogate Performance and S&C

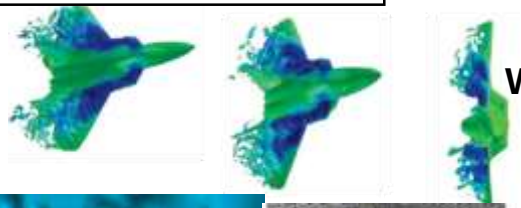


$$C_L(\alpha,q,\dot{q}) = C_0 + C_1\alpha + C_2 q + C_3 q^2\alpha + C_4\dot{q}\alpha + C_5 q^4 + C_6\dot{q}q^2 + C_7\dot{q}\alpha^2 + C_8 qq + C_9\alpha^3 + C_{10}\dot{q} + C_{11}q^3 + C_{12}\dot{q}^2 + C_{13}q^2 + C_{14}q\alpha$$

Surrogate Digital Loads

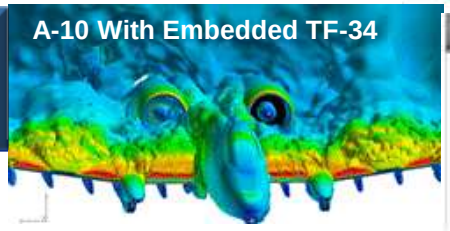


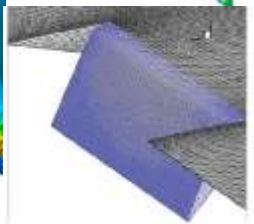
$$Loads = f(\bar{q}, M, \alpha, \alpha^2, q, \alpha q, \dot{q}^2, \square)$$

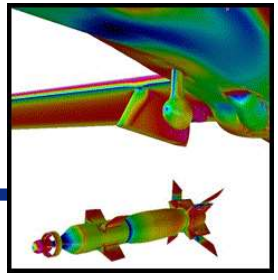


F-22 in Wind Up Turn

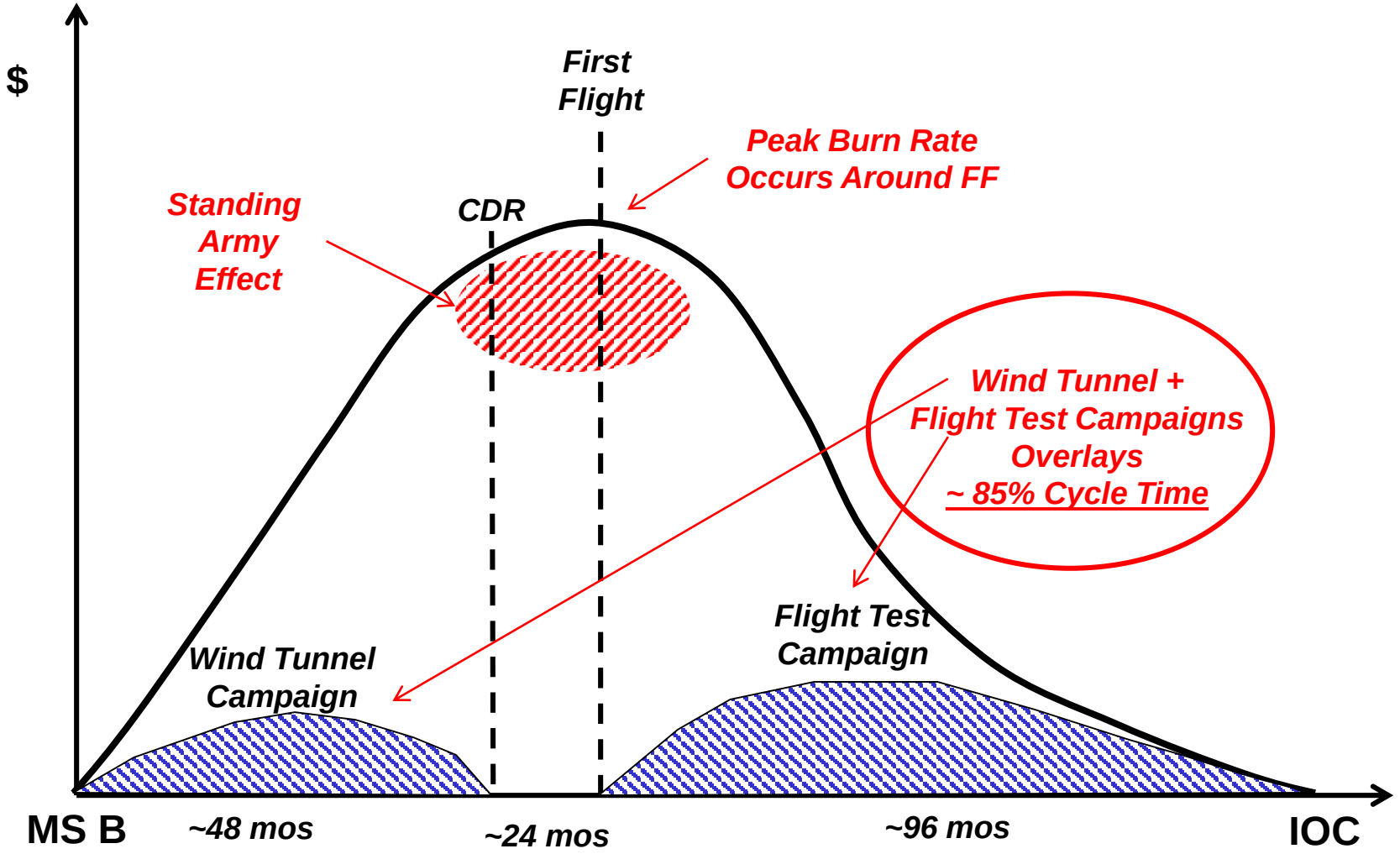
Kestrel developers are embedded in the AF Test Center





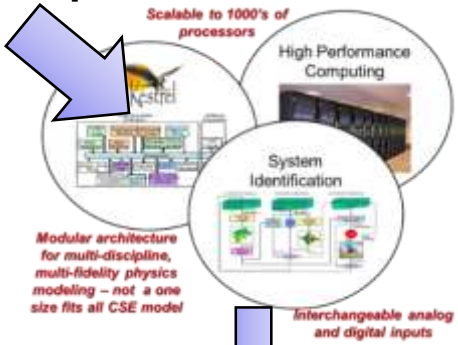


Anatomy of a Fixed-Wing Air Vehicle SDD Program



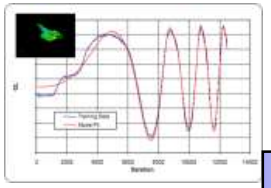
Digital Thread Approach to Aerodynamic Testing – Providing the Performance Baseline Truth

OML Input

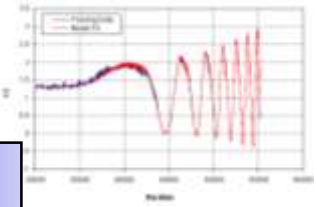


Requires a government/ industry enterprise approach to reducing total cycle time

Surrogate Performance and S&C



Surrogate Digital Loads Spectra



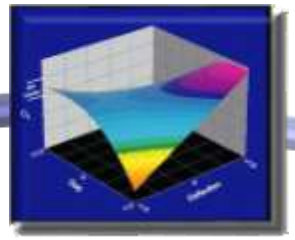
Optimum GT Campaign

Optimum FT Campaign

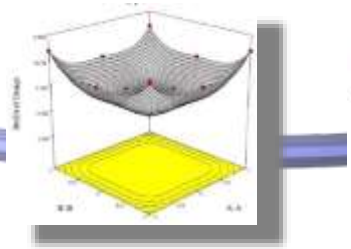
MS A ***MS B*** *Merged Model, GT Data* ***CDR*** *Merged Model, GT, FT Data* ***MS C***

Authoritative Digital Surrogate

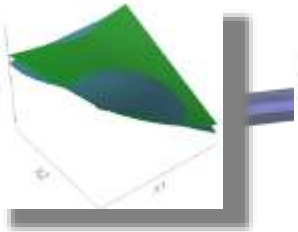
At Each Instance in Time



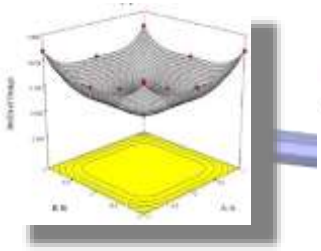
Modeled Truth



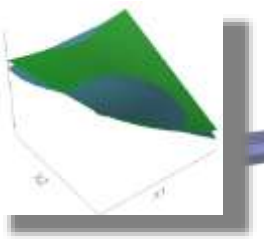
Quantified Margins and Uncertainties at Key Decision Points



Ground Truth

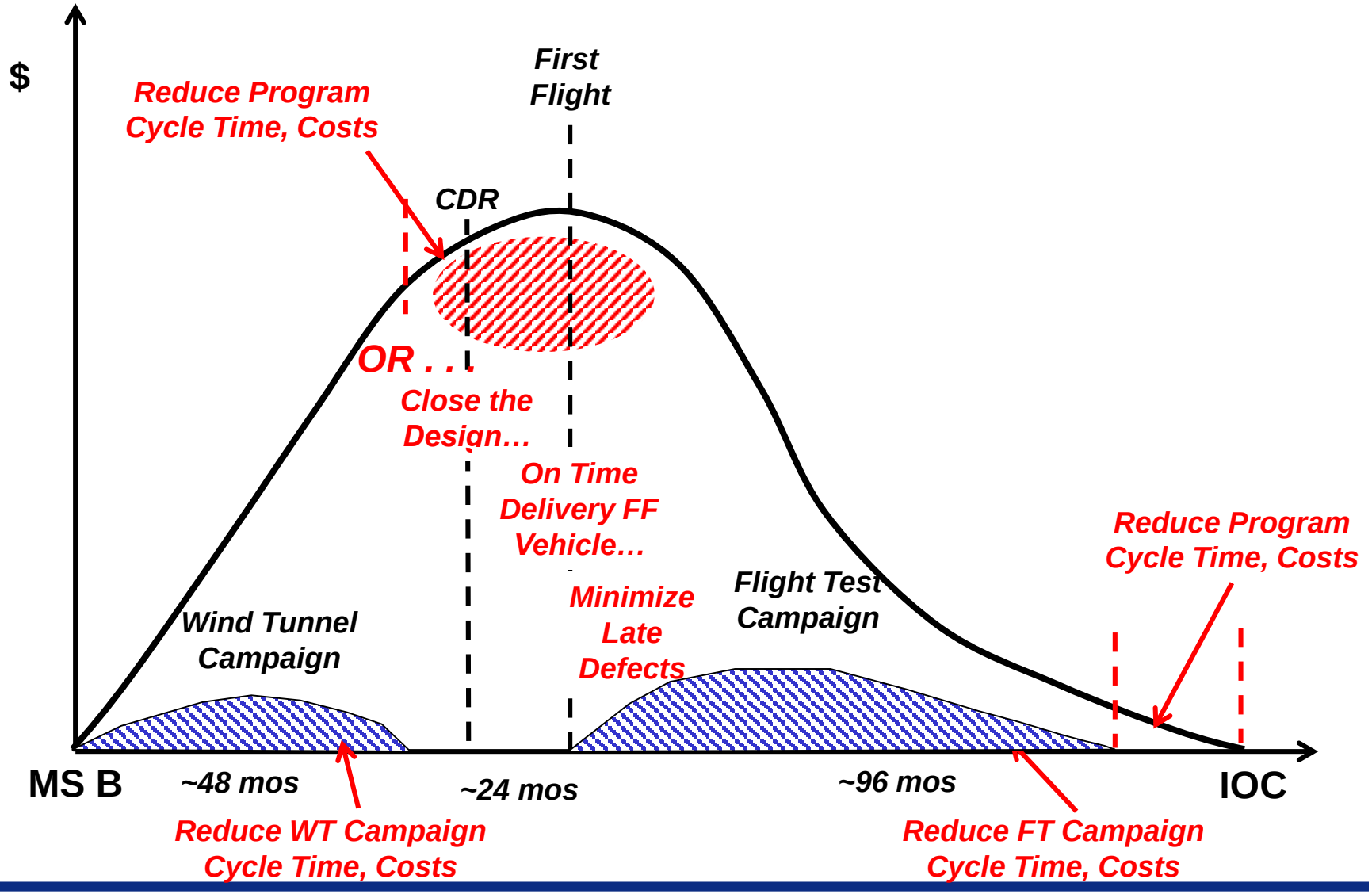


Quantified Margins and Uncertainties at Key Decision Points



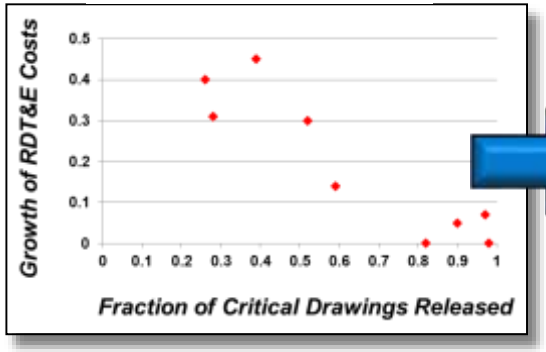
Flight Truth

Potential Impacts

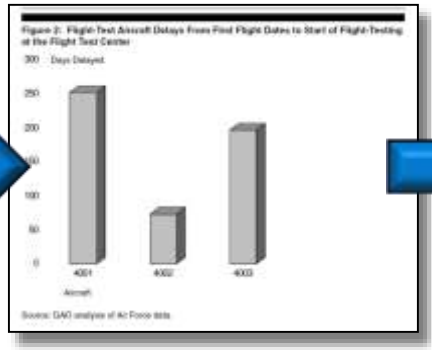


Value of a Quantified Digital Performance Evaluation Baseline

Close the Design at CDR…

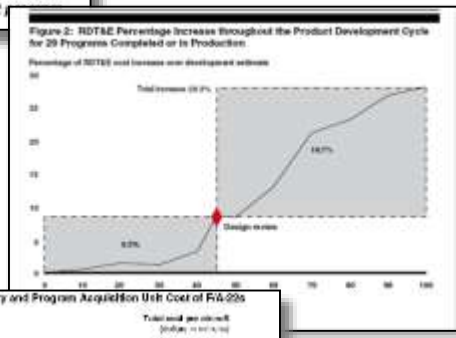


Deliver FF Vehicle On Time…



Minimize Late Defects

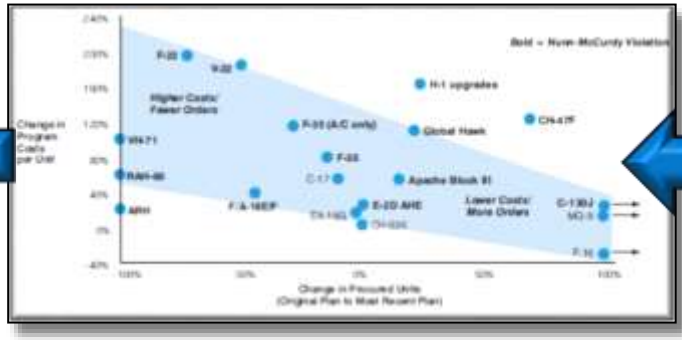
Minimize RDT&E Overruns



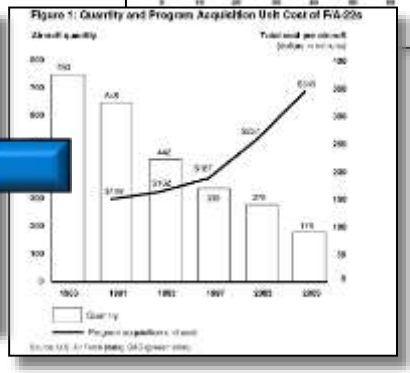
It All Starts with Quantified Performance Margins and Uncertainty Assessments at CDR

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

Maximize RDT&E Impact on Lifecycle Value



Deliver Contracted Number of Systems on Time/Cost



Why T&E as the Authoritative Performance Truth Source?

1. **Original source and knowledge of the test data plus the expertise to provide an independent quantification of performance in support of the Lead Developmental Tester and Chief Engineer**
2. **Resident expertise in the development and integration of advanced MBE tools to DT&E to support and enhance independent evaluations**
3. **Best positioned to leverage Digital Engineering to streamline test processes to reduce cycle time and cost for acquisitions**
4. **Aligns with DoD/AF BBP 3.0 organic engineering, own the tech baseline, and bend the cost curve initiatives**

Summary

- The Digital Engineering revolution is underway across the Aerospace and Defense industry
- The T&E community needs to integrate Digital Engineering to increase the value of 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