Determining the Contents of the Digital System Model

Dr Thomas Christian
SAF/AQR
30 October 2014

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Digital System Model and AF Digital Thread / Digital Twin - Defined

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.

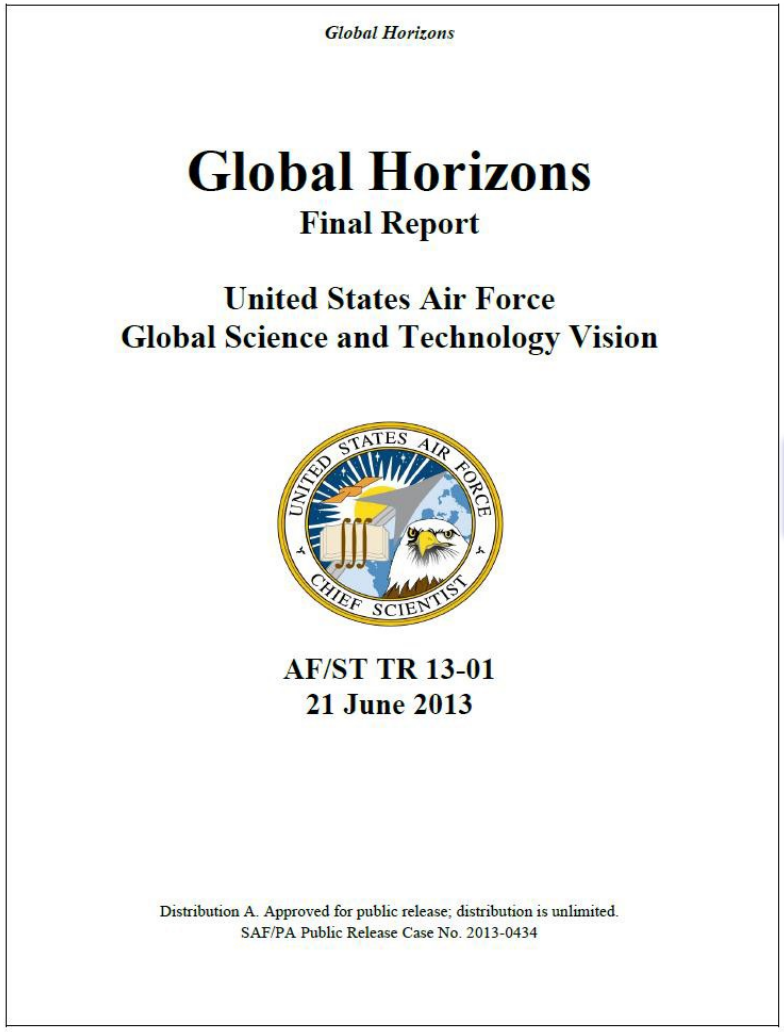
Digital Thread
An extensible, configurable and Agency enterprise-level analytical framework that seamlessly expedites the controlled interplay of authoritative data, information, knowledge, and computer software in the enterprise data-information-knowledge systems, *based on the Digital System Model 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.

The Digital Thread is the physics-based modeling instantiation of the structural view of the OSD System Model via acquisition decision maker information needs

Complementary, Integrable Concepts that put Engineering Back Into Systems Engineering

Why Digital Thread?



Global Horizons

Global Horizons
Final Report

United States Air Force
Global Science and Technology Vision

AF/ST TR 13-01
21 June 2013

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9. Manufacturing and Materials

9.3 Game Changers

Exploiting the three game-changing opportunities below will help the AF meet the need for more rapid development and deployment. The recommendations represent the first steps on the path to future game-changers.

Digital Thread and Digital Twin

The concept of a digital thread/digital twin comprised of advanced modeling and simulation tools that link materials-design-processing-manufacturing (Digital Thread) will be the game-changer that provides the agility and tailorability needed for rapid development and deployment, while also reducing risk. State Awareness and System Prognosis advantages will be achieved through the Digital Twin, a virtual representation of the system as an integrated system of data, models, and analysis tools applied over the entire life cycle on a tail-number unique and operator–by-name basis. M&S tools will optimize manufacturability, inspectability, and sustainability from the outset. Data captured from legacy and future systems will provide the basis for refined models that enable component and system-level prognostics. Archived digital descriptions of new systems would greatly facilitate any subsequent re-engineering required in the future. Human performance monitoring will enable adaptation of systems to the “mission capable” state of the operator.

Digital Thread, Cost Capability Analysis and BBP 3.0

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Better Buying Power 3.0 DRAFT

Achieving Dominant Capabilities through Technical Excellence and Innovation

Achieve Affordable Programs
- Continue to set and enforce affordability caps

Achieve Dominant Capabilities While Controlling Lifecycle Costs
- Strengthen and expand "should cost" based cost management
- Build stronger partnerships between the acquisition, requirements, and intelligence communities
- Anticipate and plan for responsive and emerging threats
- Institutionalize stronger DoD level Long Range R&D Planning

Incentivize Productivity in Industry and Government
- Align profitability more tightly with Department goals
- Employ appropriate contract types, but increase the use of incentive type contracts
- Expand the superior supplier incentive program across DoD
- Increase effective use of Performance-Based Logistics
- Remove barriers to commercial technology utilization
- Improve the return on investment in DoD laboratories
- Increase the productivity of IRAD and CR&D

Incentivize Innovation in Industry and Government
- Increase the use of prototyping and experimentation
- Emphasize technology insertion and refresh in program planning
- Use Modular Open Systems Architecture to stimulate innovation
- Increase the return on Small Business Innovation Research (SBIR)
- Provide draft technical requirements to industry early and involve industry in funded concept definition to support requirements definition
- Provide clear "best value" definitions so industry can propose and DoD can choose wisely

Eliminate Unproductive Processes and Bureaucracy
- Emphasize Acquisition Executive, Program Executive Officer and Program Manager responsibility, authority, and accountability
- Reduce cycle times while ensuring sound investments
- Streamline documentation requirements and staff reviews

Promote Effective Competition
- Create and maintain competitive environments
- Improve technology search and outreach in global markets

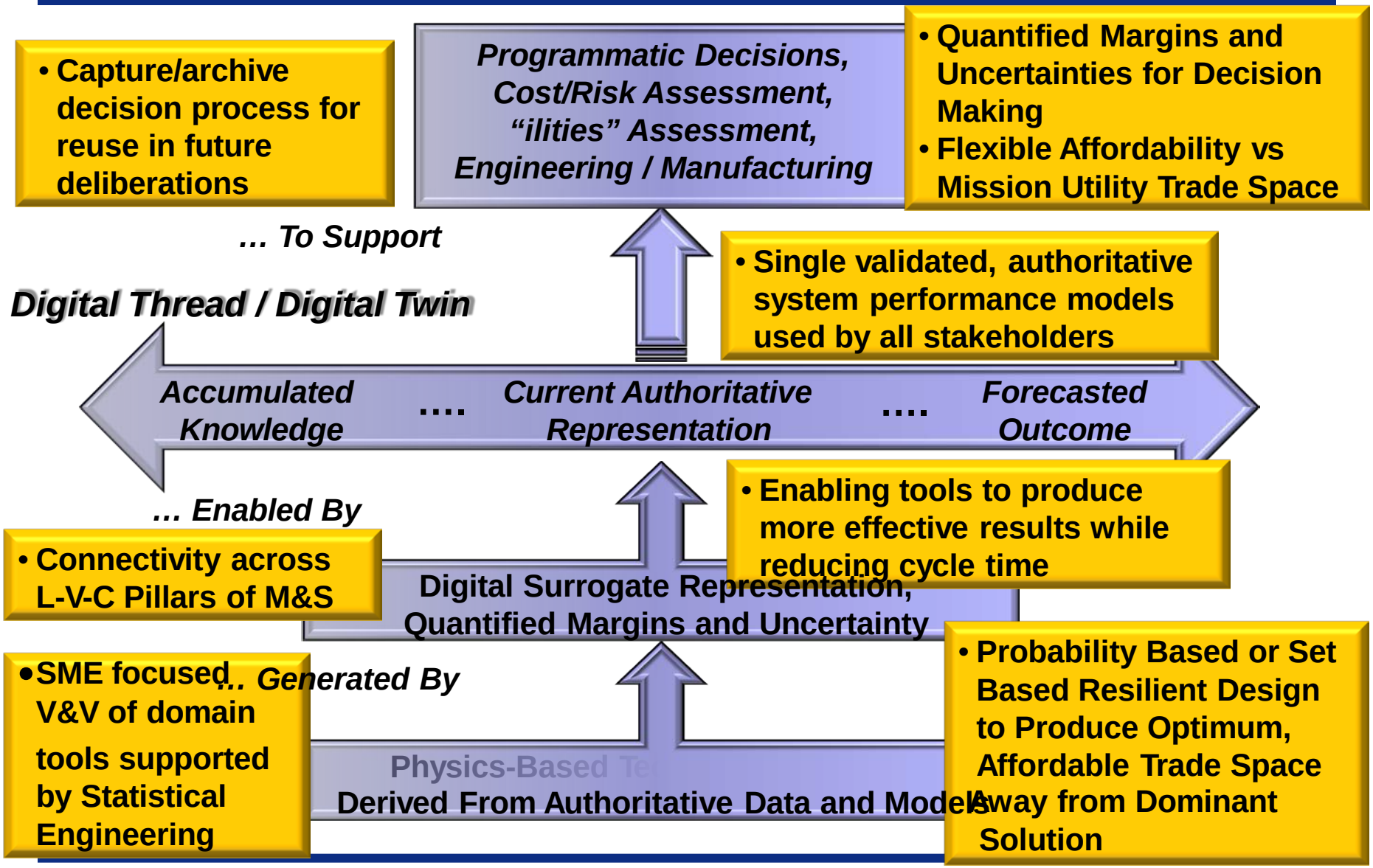
Improve Tradecraft in Acquisition of Services
- Increase small business participation, including more effective use of market research
- Strengthen contract management outside the normal acquisition chain
- Improve requirements definition
- Improve the effectiveness and productivity of contracted engineering and technical services

Improve the Professionalism of the Total Acquisition Workforce
- Establish higher standards for key leadership positions
- Establish stronger professional qualification requirements for all acquisition specialties
- Strengthen organic engineering capabilities
- Ensure the DOD leadership for development programs is technically qualified to manage R&D activities
- Improve our leaders' ability to understand and mitigate technical risk
- Increase DoD support for Science, Technology, Engineering and Mathematics (STEM) education

Continue Strengthening Our Culture of:
Cost Consciousness, Professionalism, and Technical Excellence

Direct Correlation

What the AF DT/DT Brings to SE and Life Cycle Management



Modeling Support to DoD Acquisition

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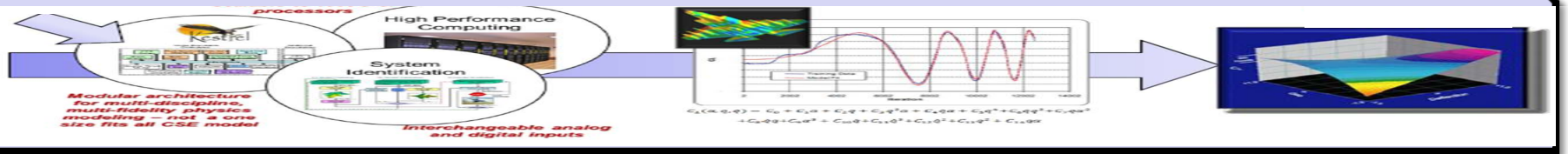
JCIDS

A | B | C | IOC | FOC

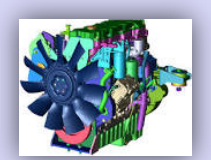
Materiel Solution Analysis	Technology Maturation & Risk Reduction	Engineering & Manufacturing Development	Production and Deployment	Operations and Support

Digital System Model - Data

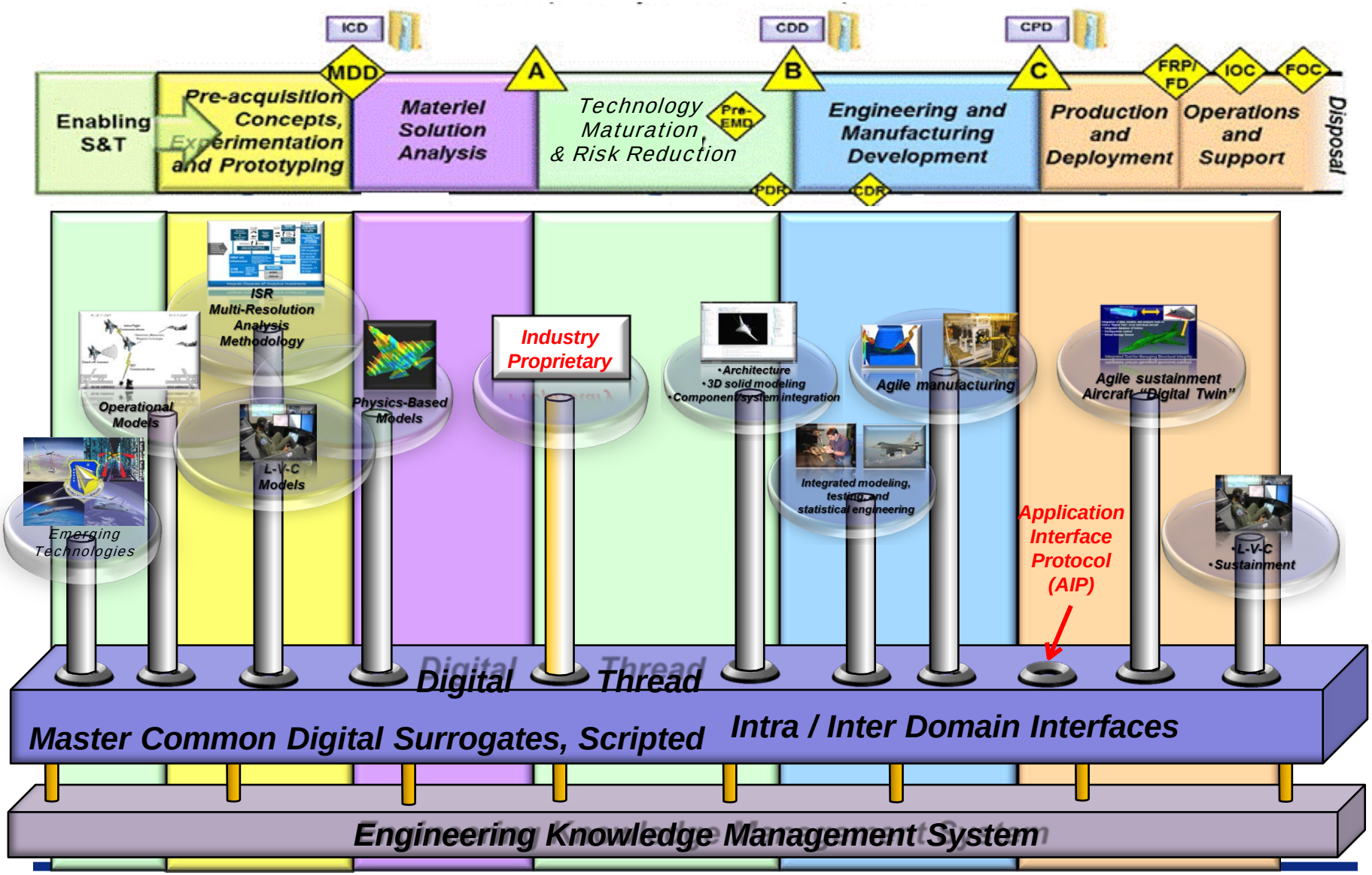


Digital Thread – Framework for DSM use

Information Management System Supporting Digital Artifacts

Distributed Collaboration	Automated Artifact Generation	Visualization	Analytics	Configuration Management	Decision Support
					

Digital Thread Architecture



Targeting a 25% Reduction in Cycle Time

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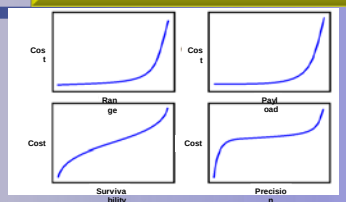
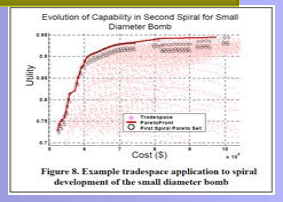
- Capture/archive analysis in support of critical program decision points

LCC vs. KPPs / KSAs and Cost Drivers





- QMU support to Risk/ Consequences Analysis for Not Meeting Critical Decision Gate Criteria
- Risk/Cost trade for not meeting KPPs/KSAs

EMD RFP Release, PDR, CDR, FRR, LRIP, IOT&E

Digital Thread / Digital Twin

Efficient/Effective DT&E Approaches for TEMP and RFP

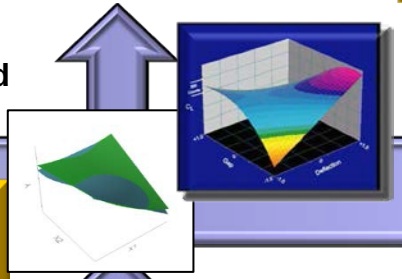
Current Authoritative Representation

Empirically Vetted Authoritative "Fly-Out" Performance Models

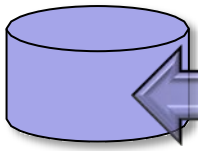
Fly Out Model for HWIL, SITL, SIL

Fly Out Model for Training Simulators

Merged Model/Data Based Digital Surrogate, QMU

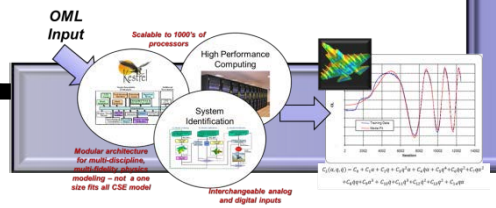


DSM



Reduced Cycle Time For DT&E Campaign – Target 25%

Engineering Knowledge Management System



Physics-Based Technical Description

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USAF Pilots – DSM/DT

- **Current Pilot Activities**
  - **Provide capability for "virtual" lifecycle activity**
    - **Activity is better/faster/cheaper by employing one or more aspects of the Digital Thread concept**
  - **Identifies boundary conditions for the M&S capability**
  - **Provides info needed to develop a strong business case for funding requirements**

Each Pilot is a specific Use Case – Now need a *Thread* Pilot!

- ***Working with ODASD(SE) – identify opportunity for pre-MSA out through O&S pilot***
  - **Example: DP effort, Acq effort, O&S**

USAF DT Projects:
"Testing the Digital Thread Concept"

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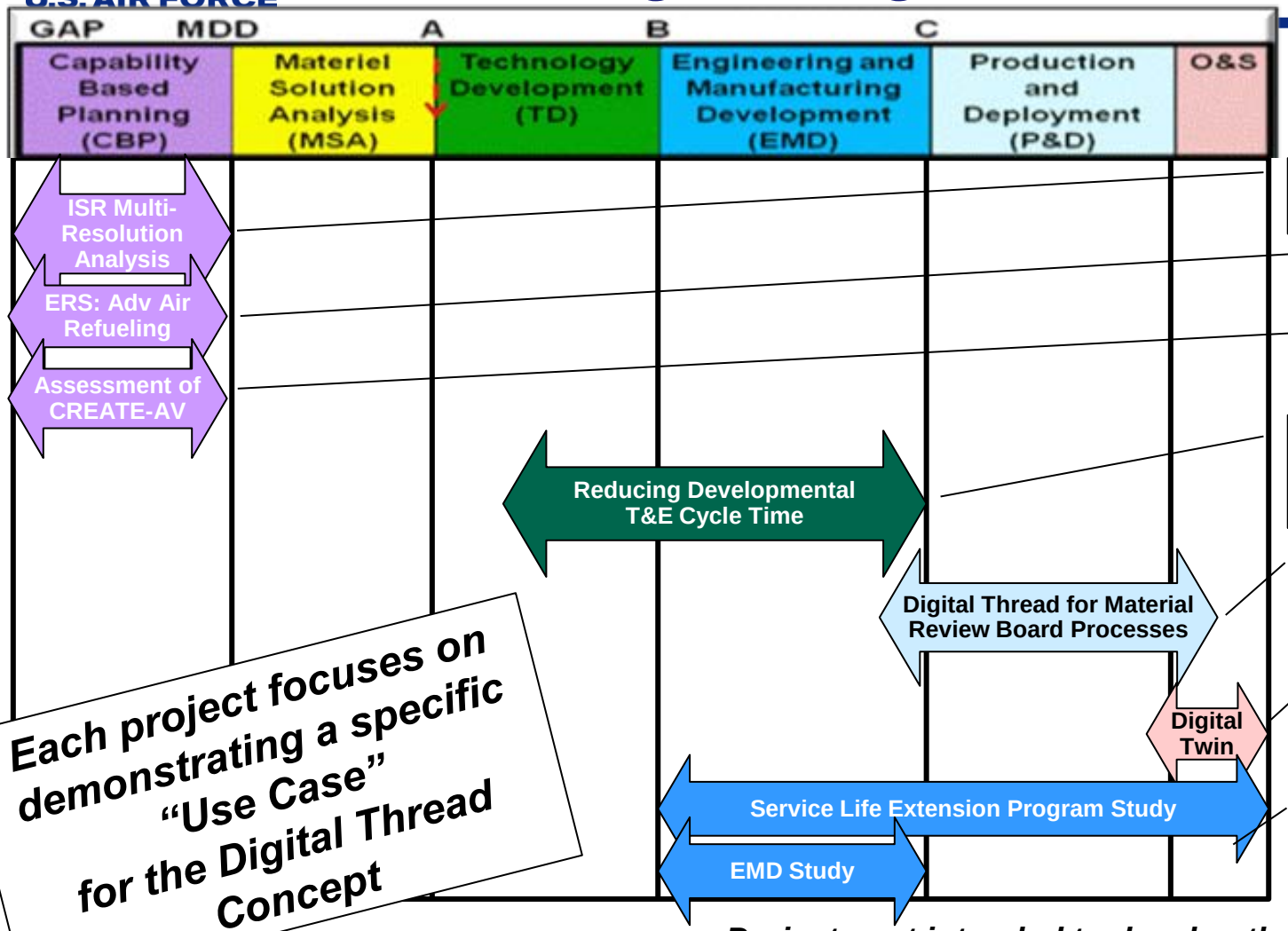

DSM/DT Products:

- ID of Data Elements; Process and Algorithm
- ID of Data Elements; Surrogate representation
- Tool development
- ID of Data Elements; Process and Algorithm
- ID of Data Elements; Initial Architecture
- Analysis Tools; Tech Gaps; Follow-on Programs
- Estimation of Benefits; Rack & Stack of Attributes

Each project focuses on demonstrating a specific "Use Case" for the Digital Thread Concept

Projects not intended to develop the DT or DSM infrastructure, but rather to set the stage for doing so

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Digital Thread Pilot Programs

Air Force has *partnered with ODASD(SE)* in gathering data from various pilots

1. **Capability, Planning and Analysis**
2. **Developmental Testing**
3. **Detailed Design, Manufacturing, and Sustainment**

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Capability Planning and Analysis (CP&A) Pilot

Purpose:

- **In the earliest JCIDS/JROC/MDD/AoA requirements development process, applying an efficient modeling capability will**
  - **reduce the time required for analyses,**
  - **enable comprehensive alternative conceptual designs evaluations to assure robust, resilient, and affordable requirements**
  - **reduce cost, risk, and requirements volatility which can impact up to 60% of cost overruns.**

CREATE

- CREATE products are still under development
- On behalf of DoD HPC - AFLCMC/XZ issued BAA for assessment of CREATE-AV tools
  - Lockheed Martin (Kestrel, Sentri)
  - Boeing (Kestrel, Sentri)
  - Sikorsky (Helios)
  - Contracts signed ~ 1 Oct 2013
    - Lockheed Martin – 9 months
    - Boeing - 6 months
    - Sikorsky – 1 year
- Results to be turned over to CREATE PM (Robert L. Meakin) for future planning

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Digital Thread Pilot Program

1. Capability, Planning and Analysis

2. **Developmental Testing**

3. Detailed Design, Manufacturing, and Sustainment

Streamlining Developmental Testing

(pending funds)

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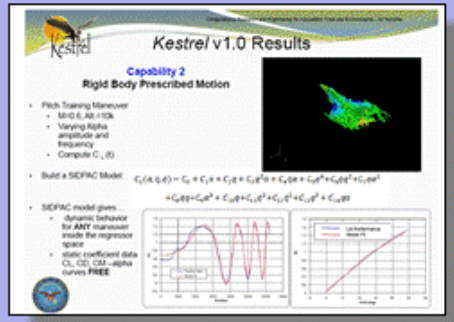
Physics Based Modeling

Common Thread System ID Techniques

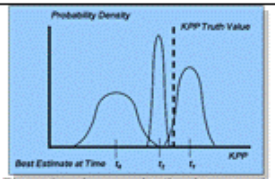
Computational Science and Engineering Dynamic Trajectories



Digital Thread Enables Quantification of Uncertainty with Minimal Experimental Data

"Fly the Mission" Ground Testing

Estimation Theory Quantify Effectiveness of Testing



Using Estimation Theory" variance reduction is proportional to the effectiveness of resources used and resources applied

$p(t_{n+1}) = p(t_i)/(1 + p(t_i)\, u\, \Delta t)$, u = resource effectiveness

Or

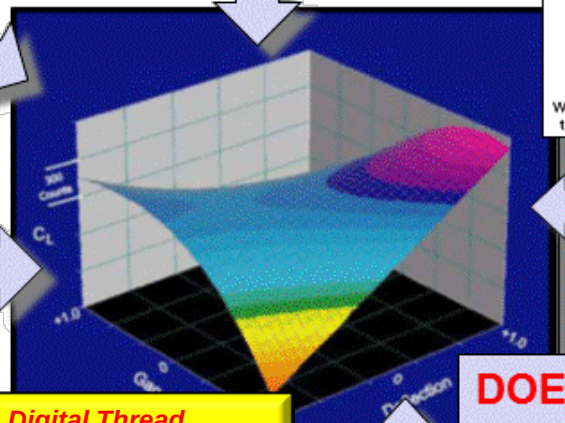
$u(t) = (p(t_i)/p(t_{n+1})-1)/p(t_i)\, \Delta t$

Which can be estimated used the SEMP, TEMP, and KPP values pre- and post-test

Currently 22,000 hrs, 4-yr campaign, 2.5M data points for Stability &Control

Currently 6-8000 Sorties requiring 6-8 years

Flight Testing



Digital Thread Surrogate Response Surface

Value of T&E

DOE
- **Data Merge/Data Mine**
- **Response Surface Analysis**
- **Variance Reduction Strategy**

Kraft, Edward M. " Integrating Computational Science and Engineering with Testing to Re-engineer the Aeronautical Development Process," AIAA Paper 2010-0139 , January, 2010

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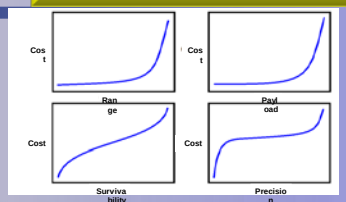

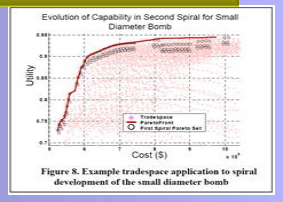

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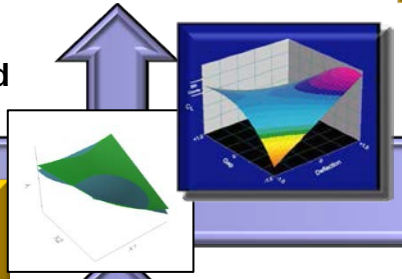

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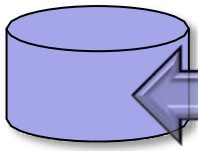

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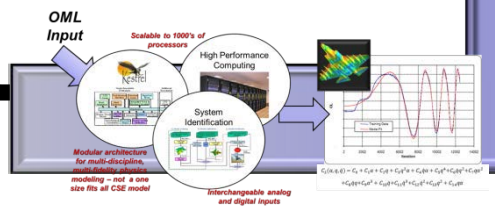

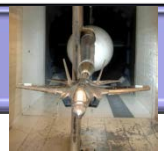

Physics-Based Technical Description

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Digital Thread Pilot Programs

1. Capability, Planning and Analysis

2. Developmental Testing

3. **Manufacturing**

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"The Digital Thread for SLEP" Study

- **Focus on Airframe Structures**
  - Boeing, Lockheed Martin, Northrop Grumman
- **Use Case Brainstorming**
  - Qualitative assessment of how SLEP could be improved if the DT/T existed
    - Descriptions of how the DT/T concept could/would impact previous, ongoing, and anticipated future SLAP/SLEP of existing weapon systems, including specific anecdotal examples
    - Benefits which can be realized during and after the SLAP/SLEP
- **Use Case Definition**
  - Precise and clearly understandable definition of the SLEP Use Case
  - Comparison of "as is" versus "to be" processes/states
  - Data and capability gaps for the "to-be" state
- **Estimation of Benefits**
  - Define metrics for quantifying benefits
  - Quantitatively estimate the benefit of employing a DT/T approach to the proposed SLEP Use Case

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Challenges & Opportunities

- A precise and clearly understandable definition of the proposed Digital Thread capability and its underlying capabilities, and technology
- An assessment of current practices (including industry) and what is new or different in the Digital Thread (if successful, what are the benefits)
- List the Digital Thread products and the interfaces to other acquisition domains
- List the risks and the payoffs
- What exists at the end of the FY 2014 pilot vs. what needs to be done in the future to implement DT
  - Identify the timeline and estimated cost to develop Digital Thread capabilities (10 to 15 year effort)
  - First order estimate of the midterm and final “exams” to check for success

Challenges & Opportunities

- **Chicken & Egg:**
  How can benefits be estimated before the Digital Thread is constructed?
- **Eating the Elephant One Bite at a Time:**
  Where are the best places to start Digital Thread development? Why?
- **Win - Win:**
  How can DoD & Industry work together to develop, mature, and implement the Digital Thread concept in a mutually beneficial way?
- **Base Hits:**
  How can existing/emerging capabilities/activities be leveraged/integrated to show beneficial incremental progress towards the Digital Thread vision in the near term?

Success will require TEAMWORK and LEADERSHIP.

Questions?