U.S. Air Force

Integrity - Service - Excellence

Shifting Further Left!

An Approach to Virtually Testing Interoperability and Cybersecurity during Developmental Planning

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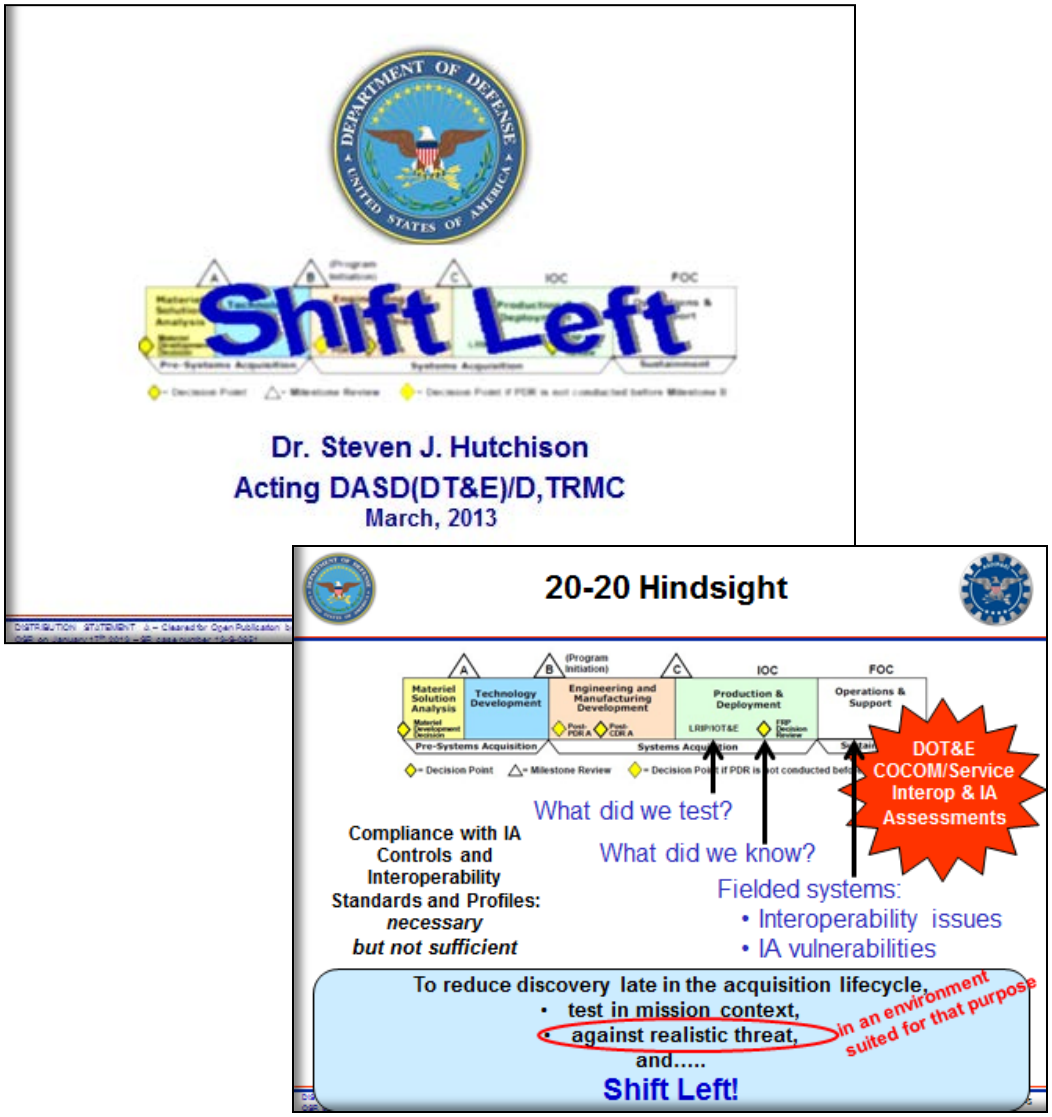
Objective

Create a vision for the integration of open, modular architectures, avionics test beds, flight simulators, ISR analyses, and physics-based modeling to evaluate the performance, interoperability, and cyber security of a concept system in a proper mission context much earlier in the life cycle .

The confluence of advances in the associated capabilities enable assessment of interoperability and potential cyber attack surfaces prior to Milestone A which should lead to a more robust TEMP and better planning for cyber testing

Shift Left!

Introduced by Dr. Steve Hutchison through the realization that information assurance, interoperability, and cyber security where not being addressed until Milestone C



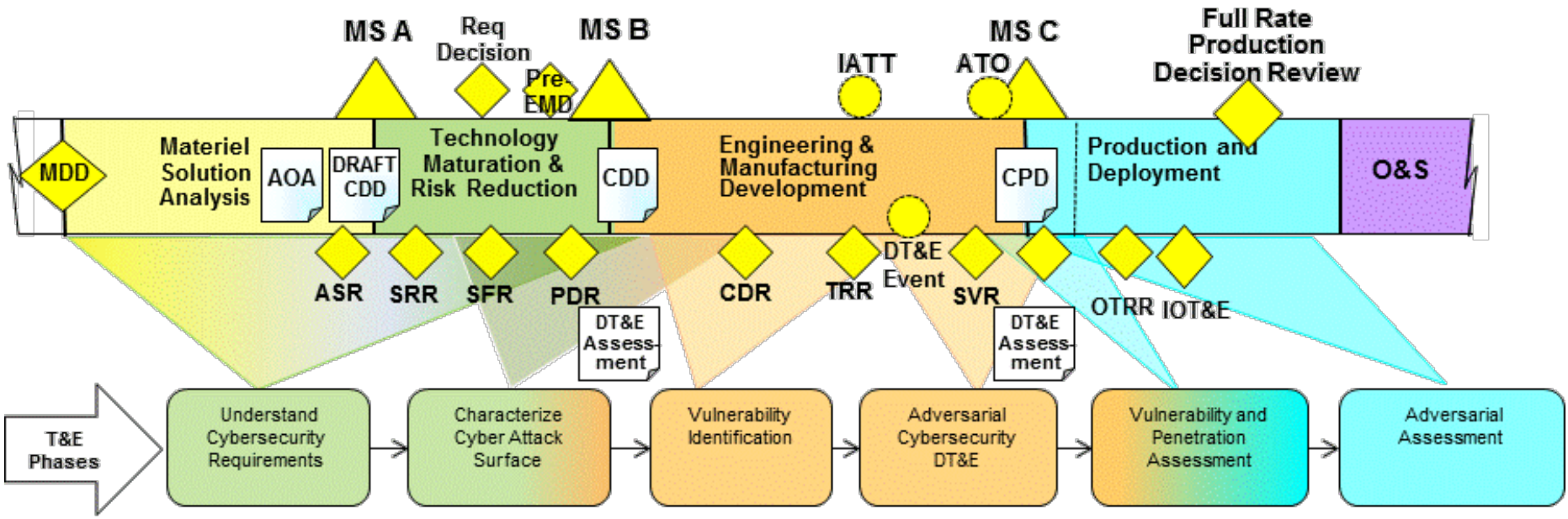
Key Elements of Shift Left!

- **Earlier testing for interoperability**
- **Earlier testing of cybersecurity**
- **Conducting DT&E in a mission context**

To adequately evaluate and expose potential failure modes in the four critical development areas:

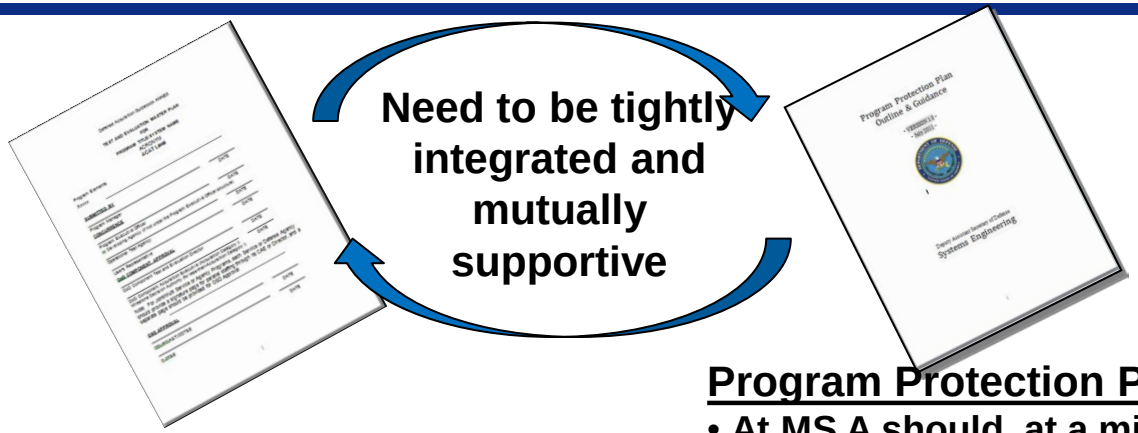
- **Performance**
- **Reliability**
- **Interoperability**
- **Cybersecurity**

Cybersecurity T&E Process Mapped to the Acquisition Lifecycle



Source: C. David Brown, et al "Using the Developmental Evaluation Framework to right Size Cyber T&E Test Data and Infrastructure Requirements." The ITEA Journal, Vol 36, pp 26-34, March 2015

Need for Shifting Even Further Left!



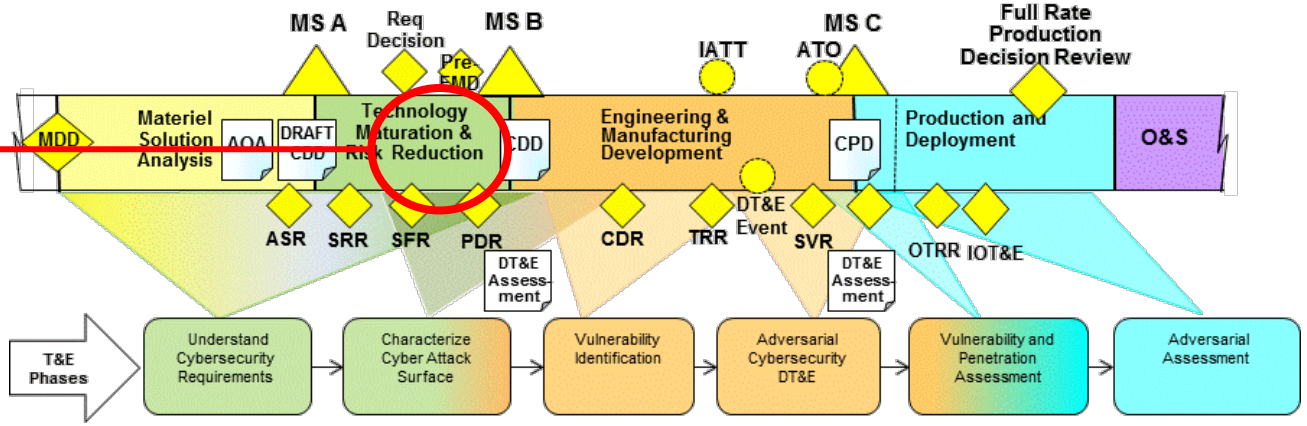
Program Protection Plan (PPP)

- At MS A should, at a minimum include an initial criticality analysis, candidate Critical Program Information, potential countermeasures, and Information Assurance Strategy.
- At Milestone B, PPP should be a comprehensive document.

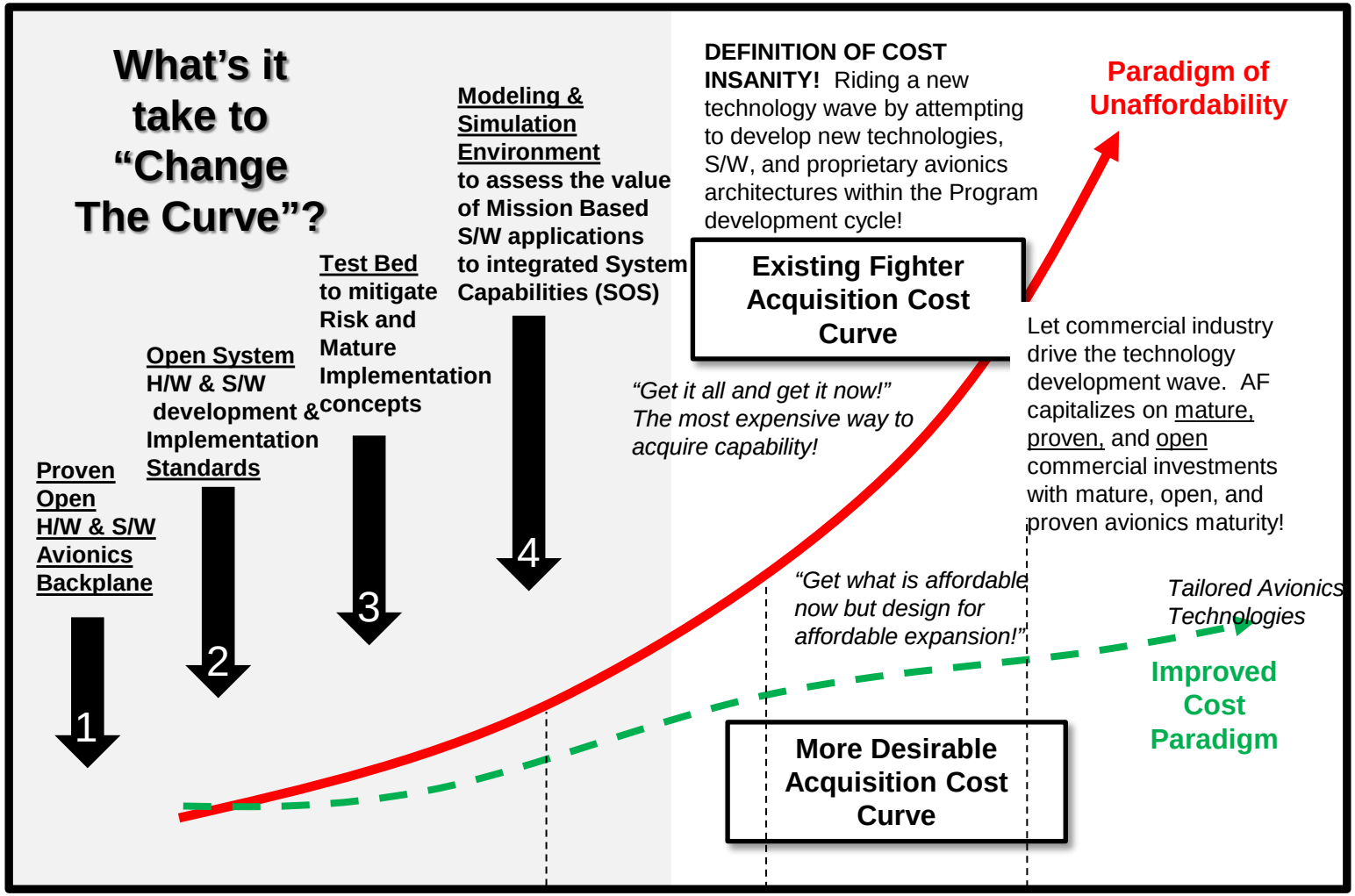
Test & Evaluation Master Plan (TEMP)

- Initial TEMP required at Milestone A
- Opportunity to set stage for integrated DT&E and OT&E

Maximum Impact Will Occur if Integrated Early Enough to Include Well Defined Requirements in the Pre-MS B RFP!!



Getting it Right Earlier Can Bend the Cost Curve



Software Lines of Code (SLOC) as a indicator of Aircraft/Avionics Complexity

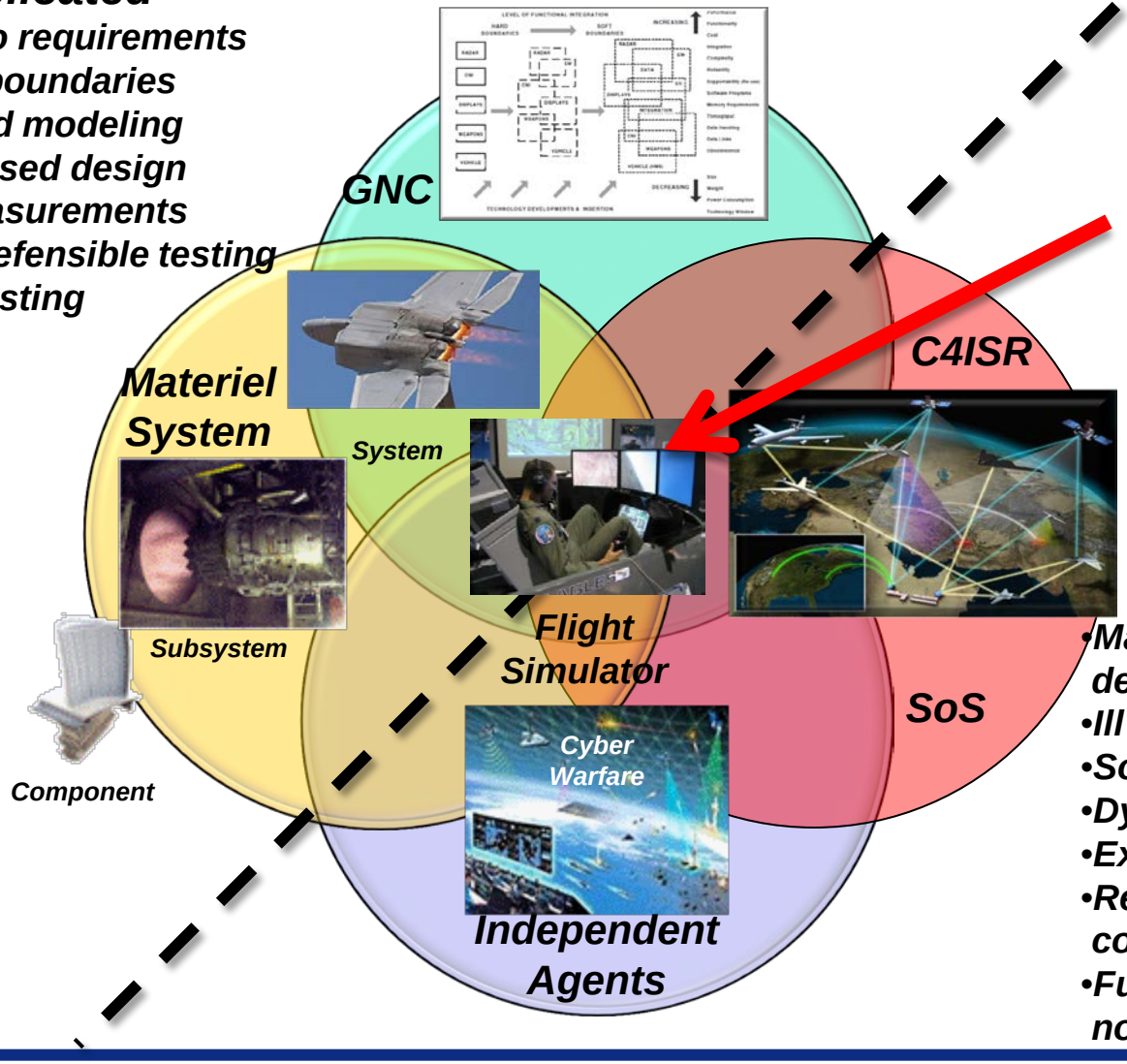
Attributes of the Architecture

1. **Architecture Design must isolate the Flight Control System from the Mission Avionics**
   - **Critical to both software agility and tailorability**
   - **Critical to affordability (minimize regression testing with the ability to accept mission risk (vice flight safety risk)**
2. **Architecture must be OPEN**
   - **Hardware (backplane)**
   - **Software (Mission software, network enabled applications)**

Different Domains Require Different Design, Integration and Testing Approaches

Complicated

- Design, test to requirements
- Well defined boundaries
- Physics-based modeling
- Probability based design
- Precision measurements
- Statistically defensible testing
- Regression testing



Flight Simulator The Natural Interface and Integrator – Also an Opportunity for Integrated DT/OT

Complex

- Manage outcomes vs delivering requirements
- Ill defined boundaries
- Soft, stochastic modeling
- Dynamic environment
- Experiential learning
- Requires holistic, collaborative approach
- Future built on scenarios not predictions

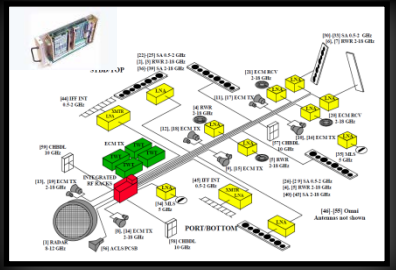
SIMAF Vision

Specifications
- FACE
- OPEN Systems

Implementation of Technical Standards in a Test Bed configuration

Implementation of CONOPS/TTPS via Cockpit interfaces linked to the open avionics architecture, Mission systems software and network enabled applications

Human Interface
- Cockpit
- EPIC

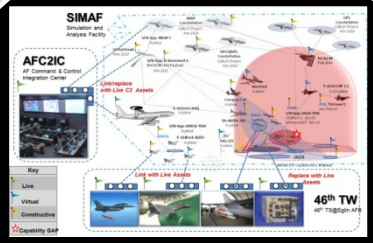


H/W & S/W Avionics TB
- Open H/W
- Open S/W
- S/W Emulators
- Network Enabled Apps

Info Architectures
- A2AD
- ISR MRA
- TMA's

Information Transport across the network to and through the open avionics architecture and to/from the network enabled applications

Avionics/Sensor linkage, simulation, & stimulation to the A2AD and other environments and Blue, Threat, IADS



Environment
- A2AD & ISR MRA
- Threat/Blue
- Sensors/Targets

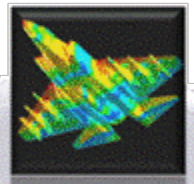
Creating a "Modeling Commons" for Capability Planning & Analysis – 1st Step to the Digital Thread

Disparate skills, models, and communities

ISR
Multi-Resolution Analysis Methodology

ISR MRA
- ISR modeling
- System of Systems
- DOT_PLF
- Networks
- Cyber interface

Physics Modeling
- Discretized Physics
- >> Real Time
- Phenomena Visualization



Physics-Based Models

CREATE-AV Critical to Building Modeling Commons

"Modeling Commons"
Cross-domain model of a physically feasible, affordable, interoperable, and interdependent materiel solution

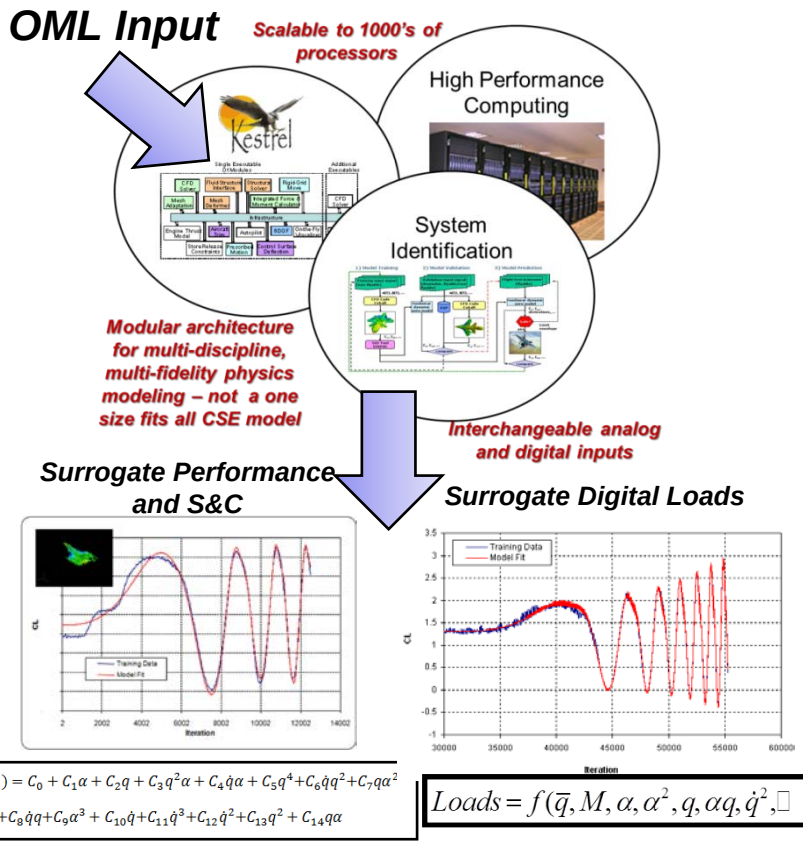
Operational Modeling
- Discrete Event Simulation, Agent Based Modeling
- < Real Time
- Scenario Visualization
- Event Engineering Models
- Table Look Ups

Simulator Models

LVC Simulator
- Discrete Event Simulation
- Real Time
- High Resolution Time–Space Visualization
- Event Engineering Models
- Table Look Ups

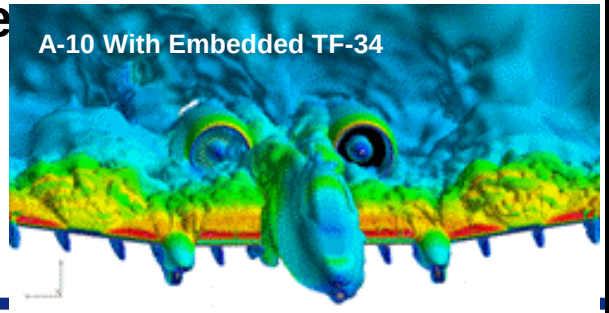
Importance of CREATE-AV in the Digital Thread Approach

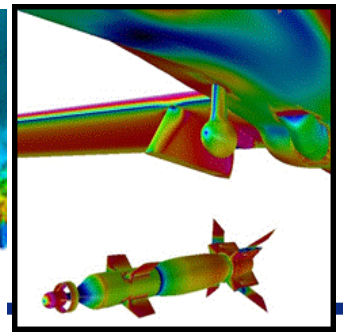
- **Multi-discipline, multi-physics, multi-fidelity capability**
- **Ability to rapidly and efficiently generate reduced order models for surrogate representations**
- **Ability to address system integration issues during detailed design (fluid/structures, airframe/propulsion, airframe/weapons)**
- **Scalable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



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

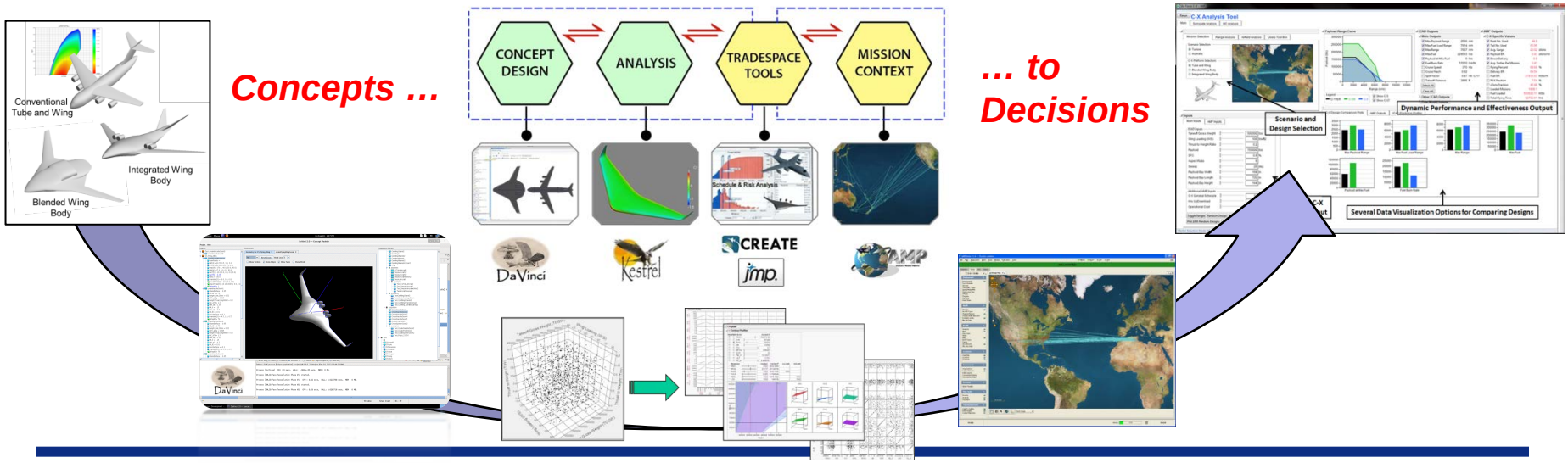
$$Loads = f(\bar{q}, M, \alpha, \alpha^2, q, \alpha q, \dot{q}^2, \square)$$





Engineering Resilient Systems (ERS) Demonstration Project

- **ERS one of top seven technologies signed out by SECDEF Gates**
- **ERS funded demo project through CREATE-AV; DaVinci Team executing**
- **Project successfully demonstrated advantages of CREATE-AV tools in support of early Analysis of Alternatives (AoA)**
  - **HPC enabled application of DaVinci provides efficient, rapid, *comprehensive evaluation of a resilient design space***
  - **Surrogate design response surface enables *interface with operational models to assess mission utility* against costs and risks**
  - **Probability-based analysis provides *quantified assessment of <u>feasibility</u>, <u>mission utility</u>, and <u>affordability</u> displayed in useful format for decision makers***

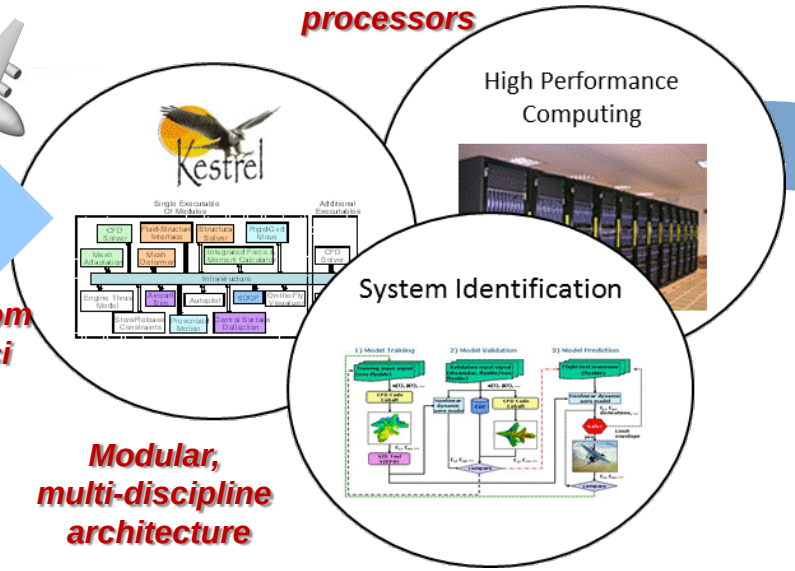


Connecting Physics Based Modeling and the LVC Simulator Environment

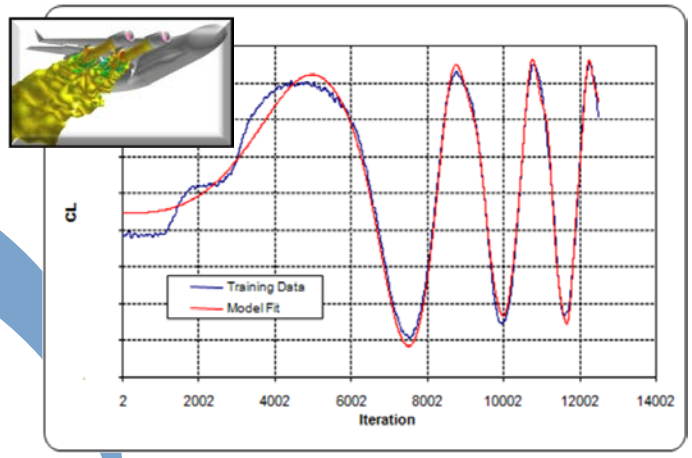
Perform a very high-fidelity, multi-disciplined simulation of the air vehicle combined with system identification techniques to directly and efficiently produce a light weight algebraic description of the vehicle aerodynamics for insertion into SIMAF/EAAGLES

Input from DaVinci

Scalable to 1000's of processors



Modular, multi-discipline architecture



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

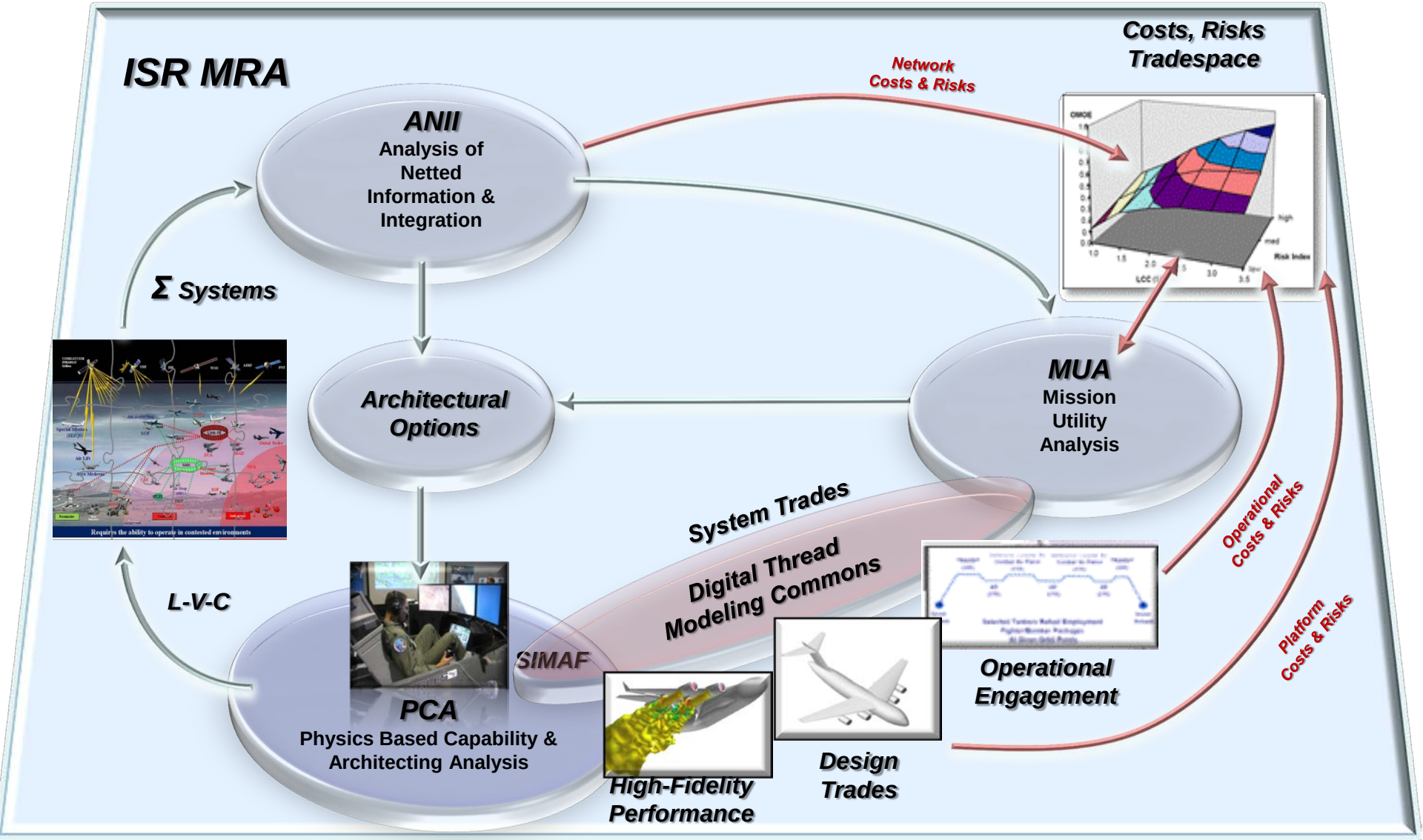
Algebraic formula for vehicle aerodynamics input to simulator aero module

Going from early vehicle concept studies to dynamic distributed mission simulations at earliest analysis phases possible

EAAGLES

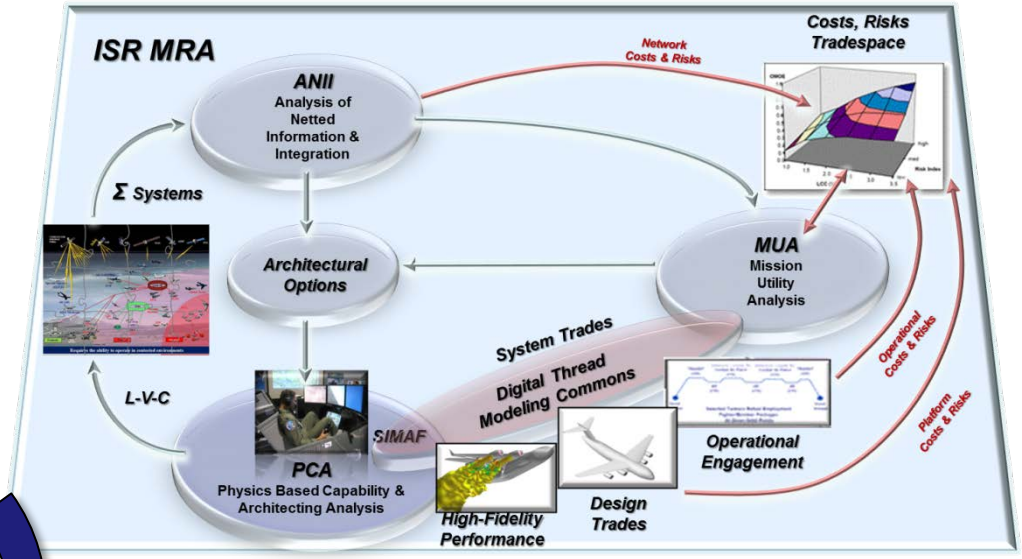
Doable in days, not weeks or months!

Assessing Interoperability and Systems of Systems

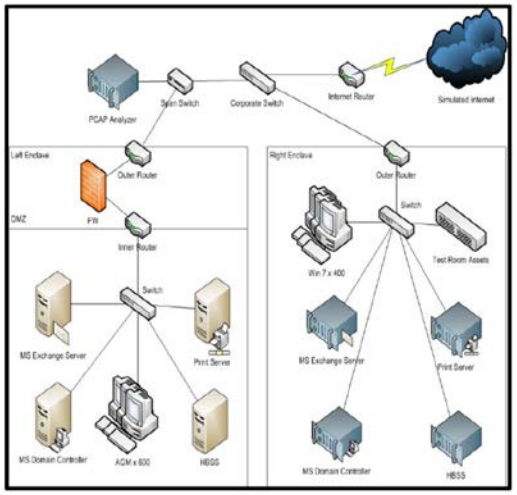


Cybersecurity Architecture Evaluation

Assessment of Architectures and Cyber Attack Surfaces



National Cyber Range



JMETC

- ***Backplane architecture enables experimentation***
- ***Upgradeable through digital apps***
- ***Can be supported over the life cycle by an avionics Digital Twin, i.e., by component, by tail number***

Summary

- An innovative approach to integrating recent advances in emulation of modular open avionics architectures, simulation of the ISR environment, and physics-based modeling is presented
- Enables ability for testing performance, interoperability, and cyber security of new concept system in a relevant operational context early in the pre-MS-A development planning phase.
- Shifting DT&E left of MS-A will enable
  - More robust inputs into the MS-A and subsequent TEMPS/PPP
  - Better understanding of requirements testability for inclusion in the System Engineering Master Plan
  - Earlier interfacing with the National Cyber Range
  - Enhance language in the pre-MS-B RFP.
  - Development of an IT&E approach
- The same innovative integrated environment will also enable rapid assessments of dynamic changes in mission scenarios, configuration changes in software and hardware, and incremental development activities that deliver new features.