

Air Force Materiel Command

Developing, Fielding, and Sustaining America's Aerospace Force



U.S. AIR FORCE

Meeting the Challenges of Defense Budget Reductions Through M&S

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Integrity - Service - Excellence



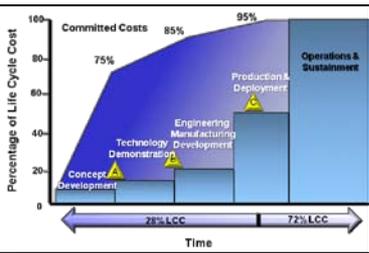
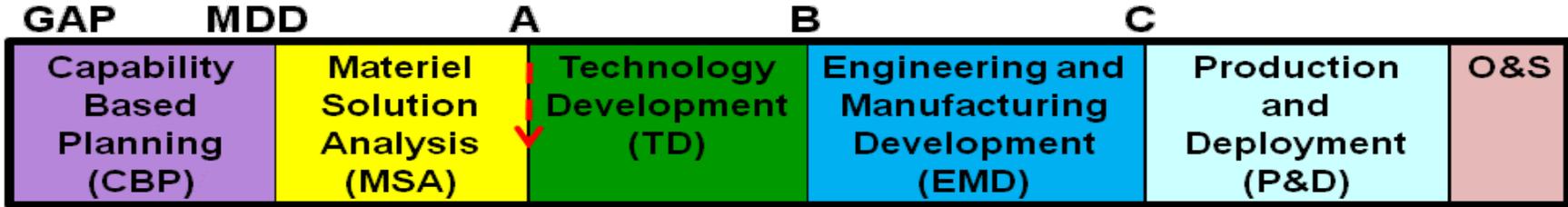
Challenges



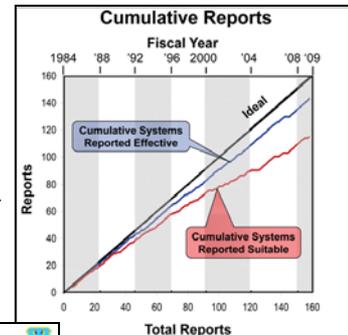
- **Defense acquisition is already broken**
 - **Requirements** – not necessarily connected to physical reality
 - **Systems Engineering** – event driven vs effects based
 - **Capacity** – “procurement holidays” increase cycle time
 - **Complexity** – aerospace/defense community self inflicted wound
- **Reduced budgets are a fact of life**
 - **Fewer acquisition new starts**
 - **Reduced infrastructure, reduced capacity**
- **Over the next decade the US could loose technological superiority, economic competitiveness**
- **Can M&S be an enabler to overcome pending reductions and increase the output of the US aerospace industry?**



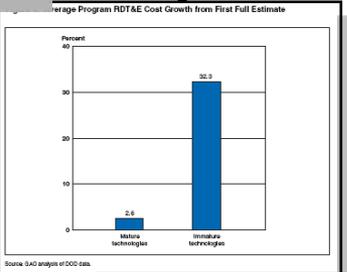
Key Leverage Points Marked by Events – Mired by Lack of Effectiveness



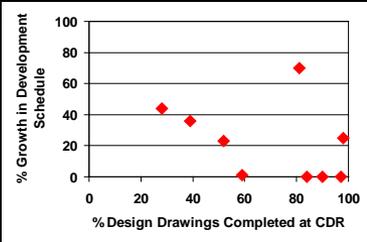
6. Suitability



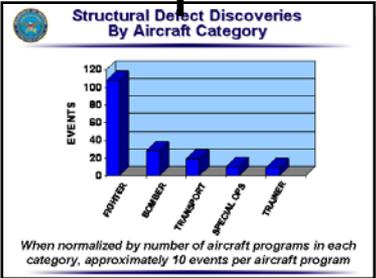
1. 75% LCC fixed @ MS A



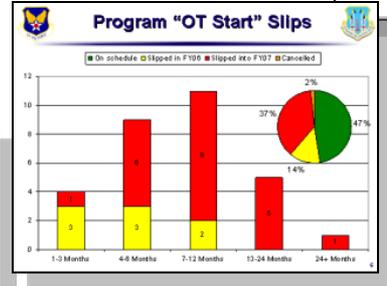
2. Technology Maturity @ MS B



3. Design Closure @ CDR



4. Late Defects



5. IOT&E Pause Test Rate



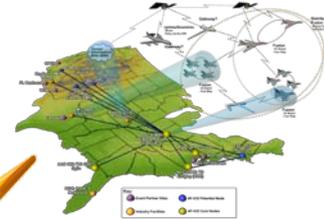
Characteristics of M&S Domains



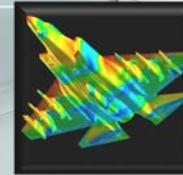
Simulator

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

Comm Models



L-V-C Interface



Operational Modeling

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

Physics Modeling

- Discretized Physics
- > Real Time
- Phenomena Visualization

**Common Interface
Built on Reducing
Physics Models to
Light Weight Algebraic
Relations**

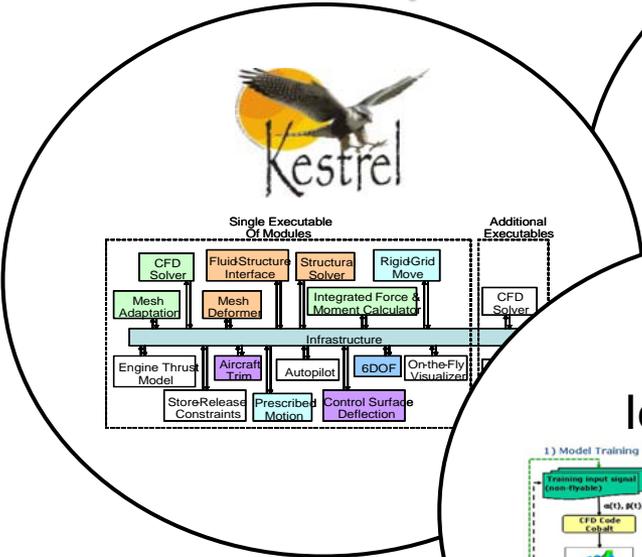


Recent Breakthrough CREATE-AV



**Game Changing Engineering Process Improvement that creates
lightweight algebraic models from hi-fi simulations**

*Scalable to 1000's of
processors*

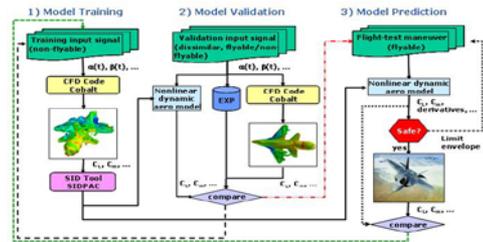


*Modular architecture
for multi-discipline,
multi-fidelity physics
modeling – not a one
size fits all CSE model*

High Performance
Computing



System
Identification

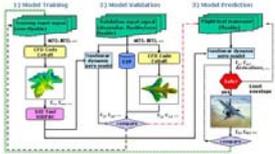


*Interchangeable analog
and digital inputs*

- Conceptual Design**
- Early discovery of nonlinear aerodynamic issues
 - Nonlinear aero surface loads for conceptual structural design
 - Nonlinear aero loads for flight control law development
- Detailed Design**
- Evaluation of aerodynamics from outer mold line (OML) changes
 - Updated nonlinear aerodynamic surface loads for changed OML to evaluate structural design
 - Nonlinear loads for flight control law refinement with detailed control surfaces
- Flight Test**
- Pre-flight maneuvers planned for test with any store loadout
 - Eliminate benign flight tests

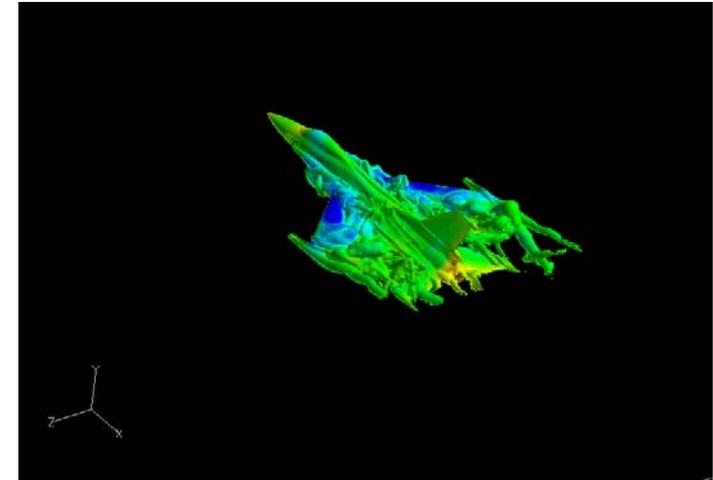


System Identification Model Building



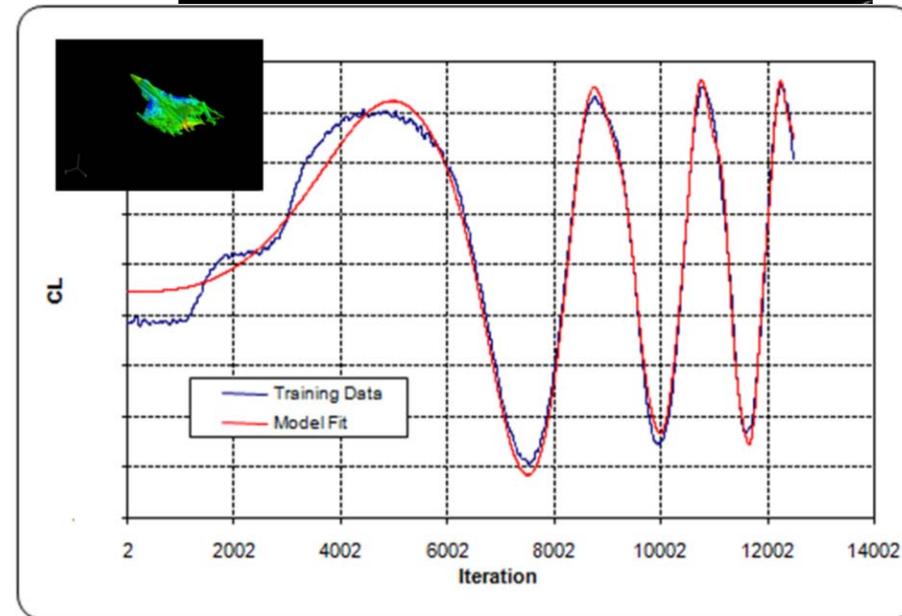
Example Game Changing Process

- Compute a maneuver at a particular flight condition (only need OML)
- Knowing input angles, rates and output loads, allows an algebraic model to fit to the data



$$C_L(\alpha, q, \dot{q}) = C_0 + C_1\alpha + C_2q + C_3q^2\alpha + C_4\dot{q}\alpha + C_5q^4 + C_6\dot{q}q^2 + C_7q\alpha^2 + C_8\dot{q}q + C_9\alpha^3 + C_{10}\dot{q} + C_{11}\dot{q}^3 + C_{12}\dot{q}^2 + C_{13}q^2 + C_{14}q\alpha$$

- Sys ID model gives dynamic behavior for ANY maneuver inside the regressor space AND static lift curve slope
before a wind tunnel or flight test article exists





Streamlining Testing at the Campaign Level

New T&E Tools + DOE



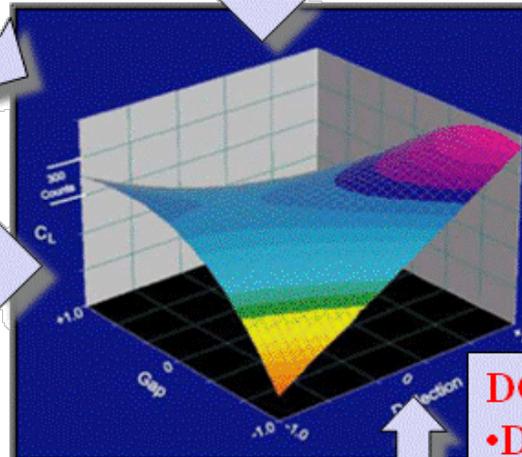
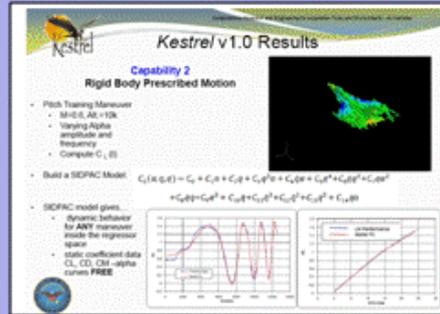
*Common Thread
System ID
Techniques*

*"Fly the Mission"
Ground Testing*

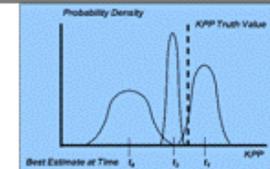


Flight Testing

*Computational Science
and Engineering Dynamic Trajectories*



*Estimation Theory
Quantify Effectiveness of Testing*



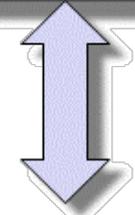
Using Estimation Theory' variance reduction is proportional to the effectiveness of resources used and resources applied

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

Or

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

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



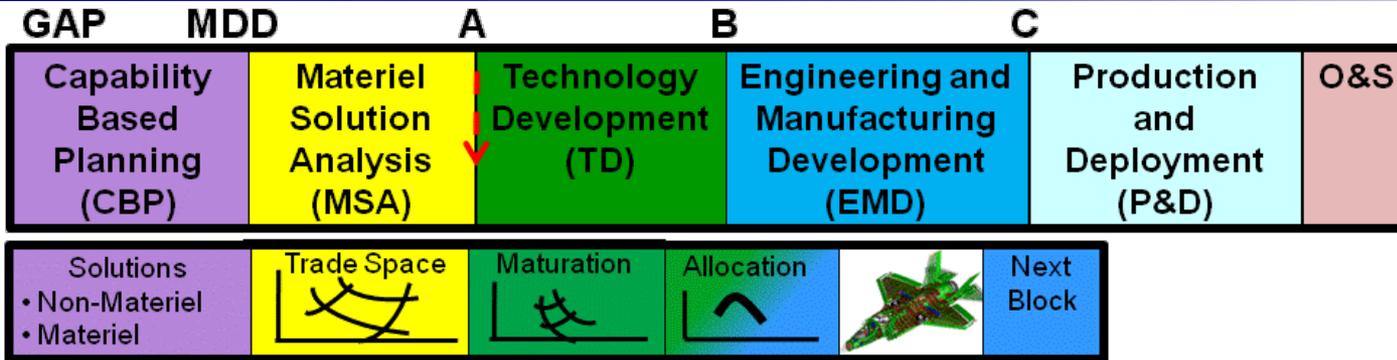
Value of T&E

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

Kraft, Edward M. "After 40 Years Why Hasn't the Computer Replaced the Wind Tunnel," The ITEA Journal of Test and Evaluation, Vol 31, pp. 329-346, September 2010.



Integrating M&S, RDT&E, and Statistical Engineering for Life Cycle Support



- Feasibility
- Operability
- Manufacturability
- Affordability
- Testability

- KPPs
- MOP/MOE

- SoS
- Interoperability
- Training

M&S



Sustained System Model Across LC

Quantified Margins and Uncertainties at Each Critical Decision Point

High-Fidelity Physics-Based Models

DaVinci

Firebolt

RF Antenna

Response Surface System Model

Kestrel

Helios

Rig, Component Tests

Ground Test

Flight Test

RDT&E

Underpinned with Statistical Engineering to Quantify Margins and Risks at Key Decision Points



Summary



- **The DoD is facing a critical challenge to improve acquisition in an era of reduced budgets**
- **M&S can be an enabler for offsetting budget reductions and improving acquisition outcome**
- **Challenges**
 - **Technologies are attainable, but will require focused efforts to validate and implement**
 - **Process changes to use new technologies and increased discipline at key decision points very challenging**
 - **Process and data/model ownership critical to success – will require collaborative government and industry approach**
- **NDIA Members represent key industry process owners – need to collaborate with government to help lead acquisition process changes**