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

Dr. Ed Kraft

Chief Technologist

Arnold Engineering Development Center

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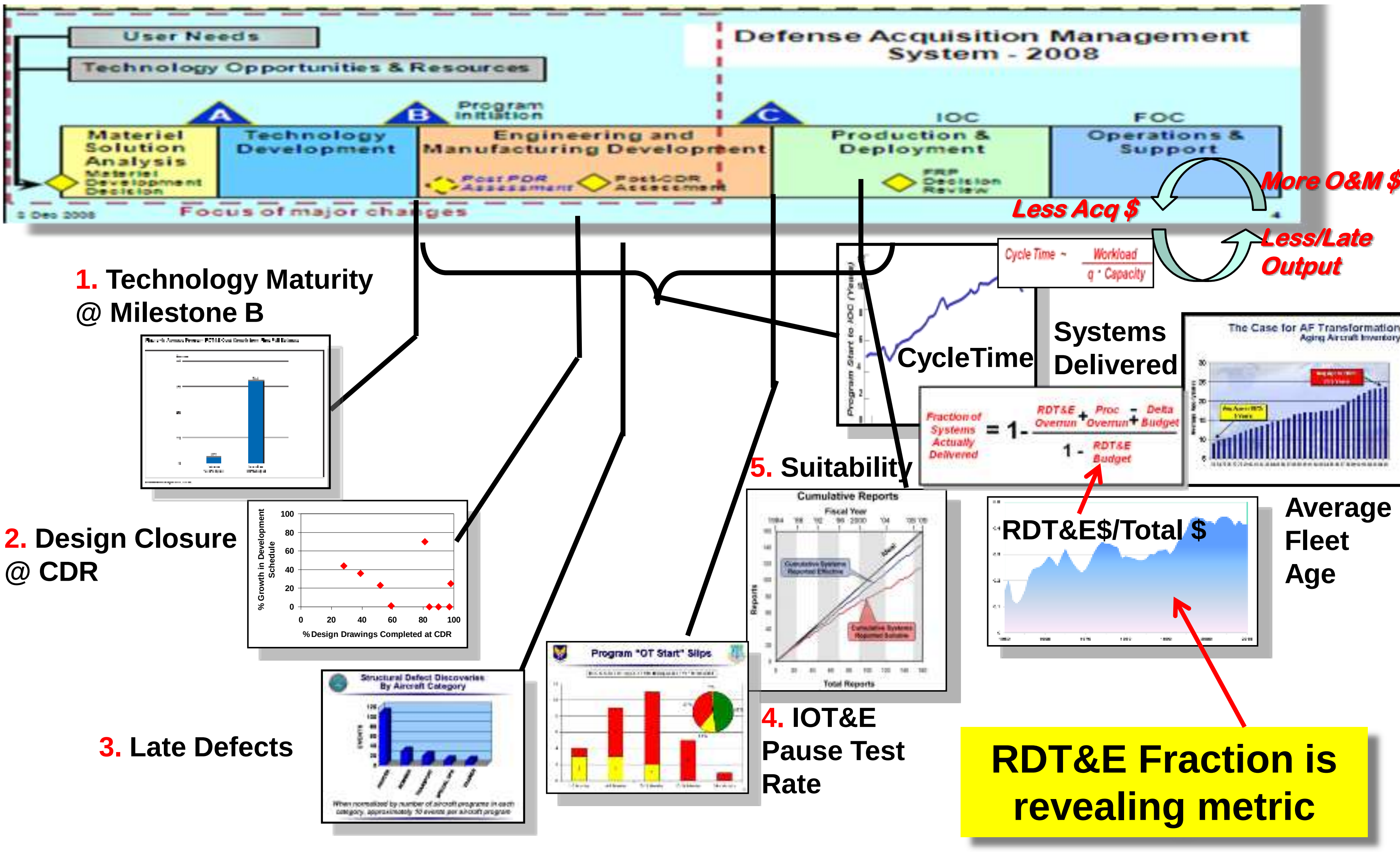
Challenges

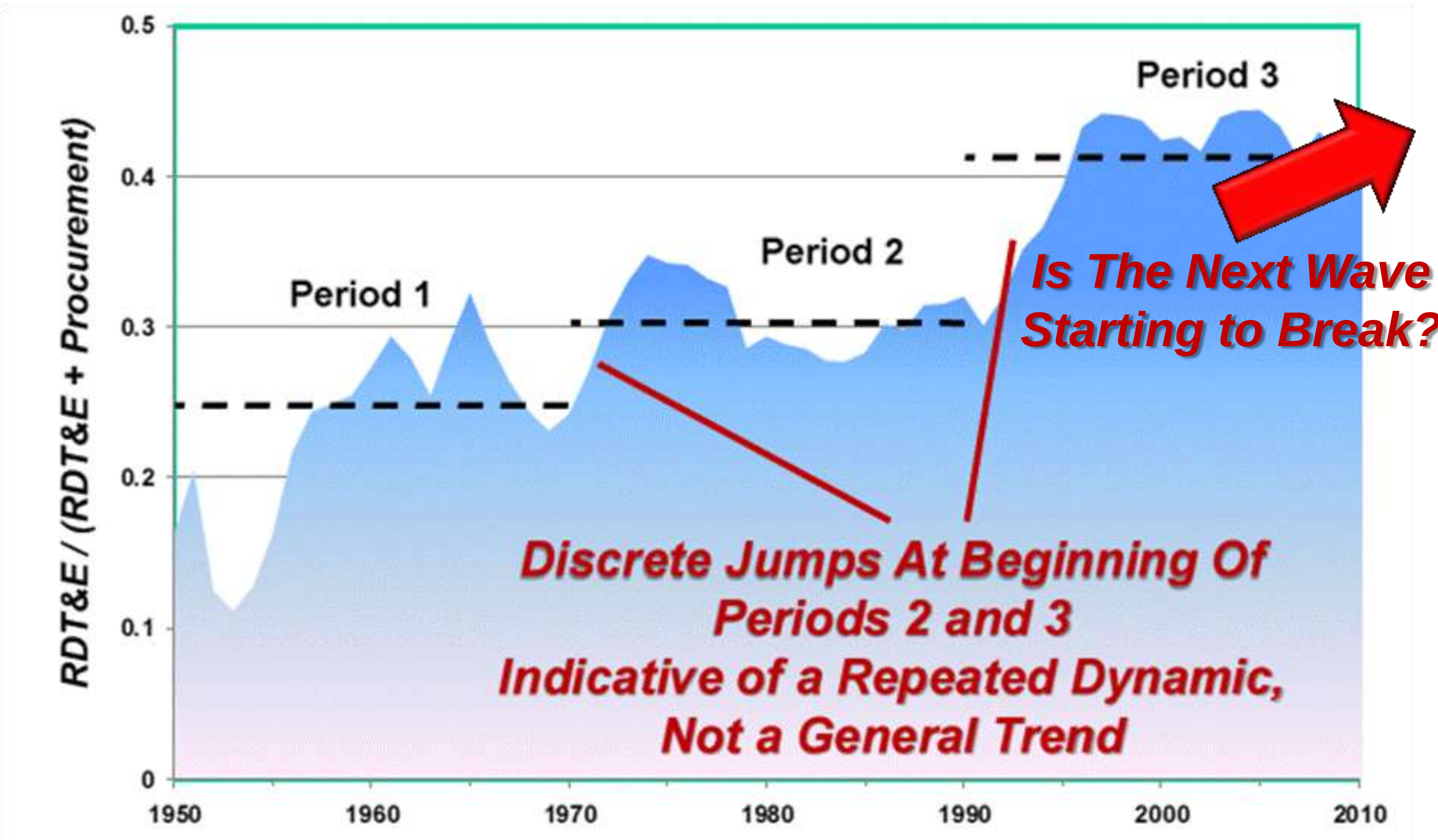
- Defense acquisition is already broken
- Reduced budgets are a fact of life
  - Fewer acquisition new starts
  - Reduced infrastructure, reduced capacity
- Over the next decade the US could loose technological superiority, economic competitiveness
- Can M&S be an enabler to overcome pending reductions and increase the output of the US aerospace industry?

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

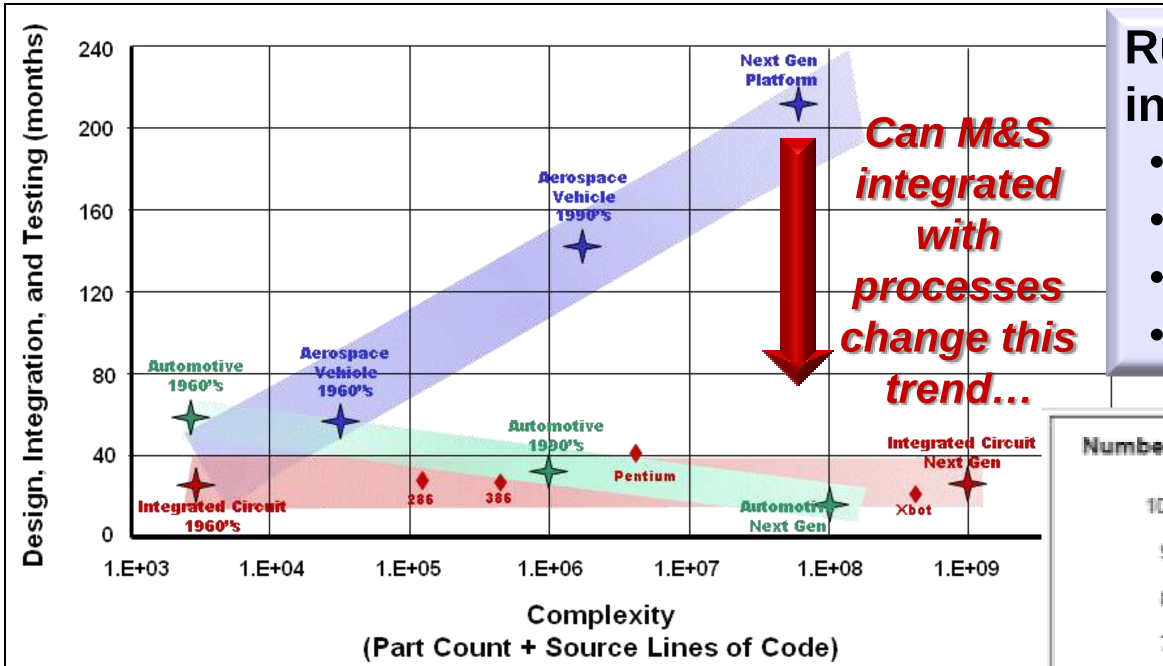
AFMC



RDT&E Fraction of the DoD Budget

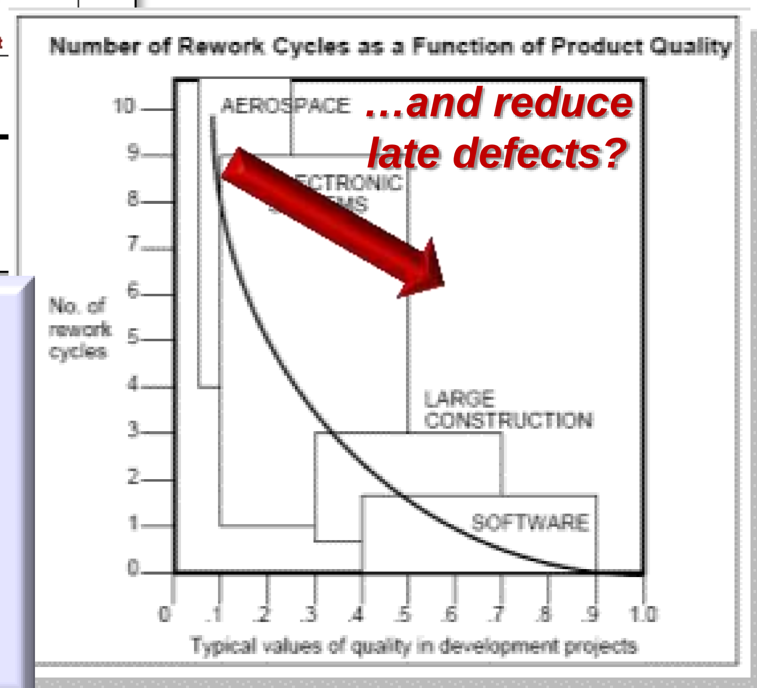


Complexity
A Self Inflicted Wound?



Can M&S integrated with processes change this trend…

Runaway cycle time not inherent to added complexity
- Architecture choices
- Processes
- Process ownership
- Lack of Accountability



…and reduce late defects?

Aerospace industry rampant with late defects and rework
- Design tools and processes
- Lack of feedback to key design and SE processes
- Lack of quantified risk and uncertainty at key decision points

Macro-Dynamics of Acquisition

Moving From Symptoms to Systemic Causes

- **Acquisition output impacted by RDT&E Fraction of acquisition costs**

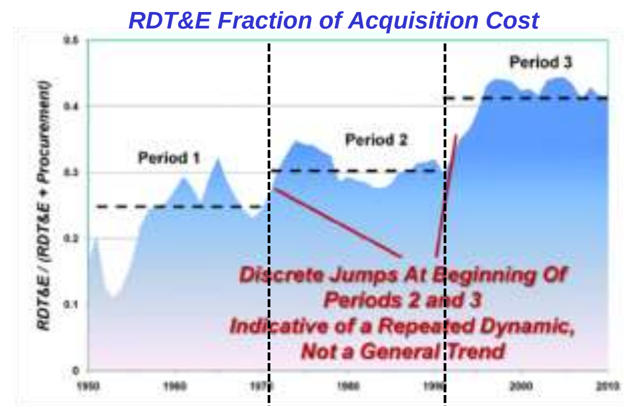
$$\text{Fraction of Systems Actually Delivered} = 1 - \frac{\text{RDT\&E Overrun} + \text{Proc Overrun} \pm \text{Delta Budget}}{1 - \text{RDT\&E Budget}}$$

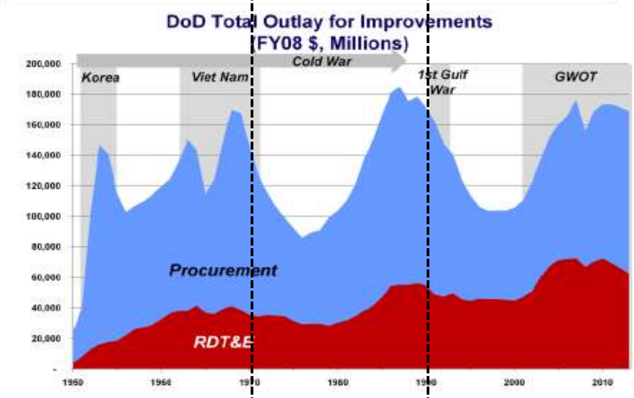
- **<u>Discrete jumps</u> in RDT&E Fraction align with "Procurement Holidays" – not a general increase attributable to complexity**

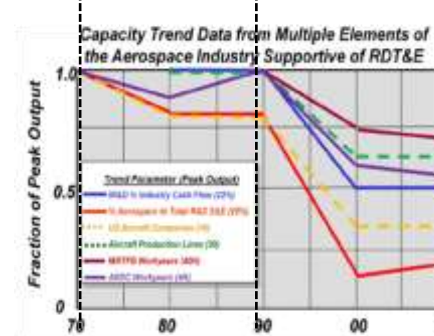
- **Fundamental dynamic cycle –**
  - **at onset of each period, procurement decreases but RDT&E stays constant because of backlog**
  - **At end of each period, procurement increases and so does RDT&E because of new starts added to backlog**

- **Correlating causative factor –**
  - **Capability and capacity of system reduced at beginning of each cycle but not rebuilt during the ascending end of the cycle – bathtub effect, more RDT&E coming in but less going out**

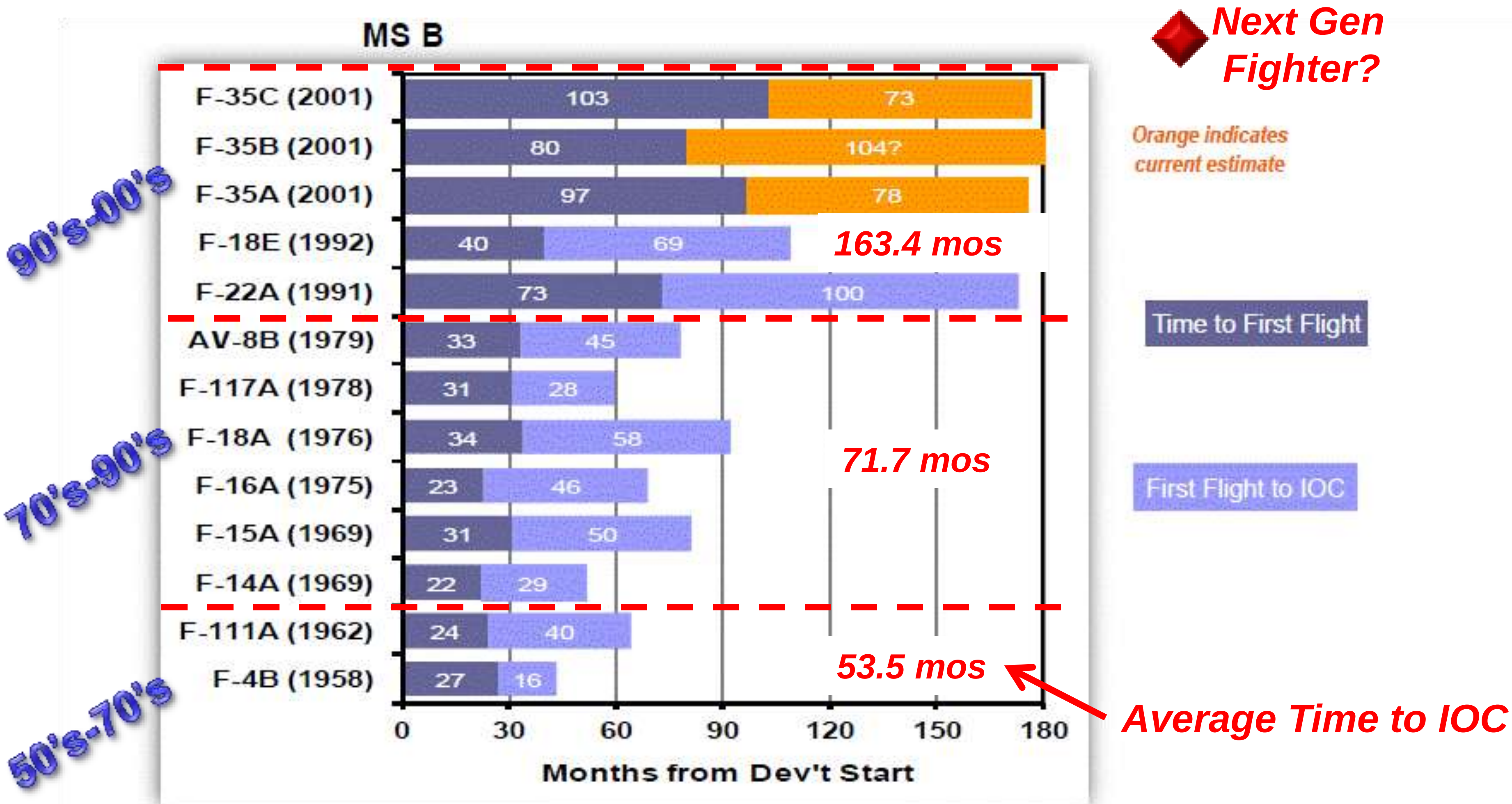
Acquisition system has passed a tipping point leading to pathological firefighting





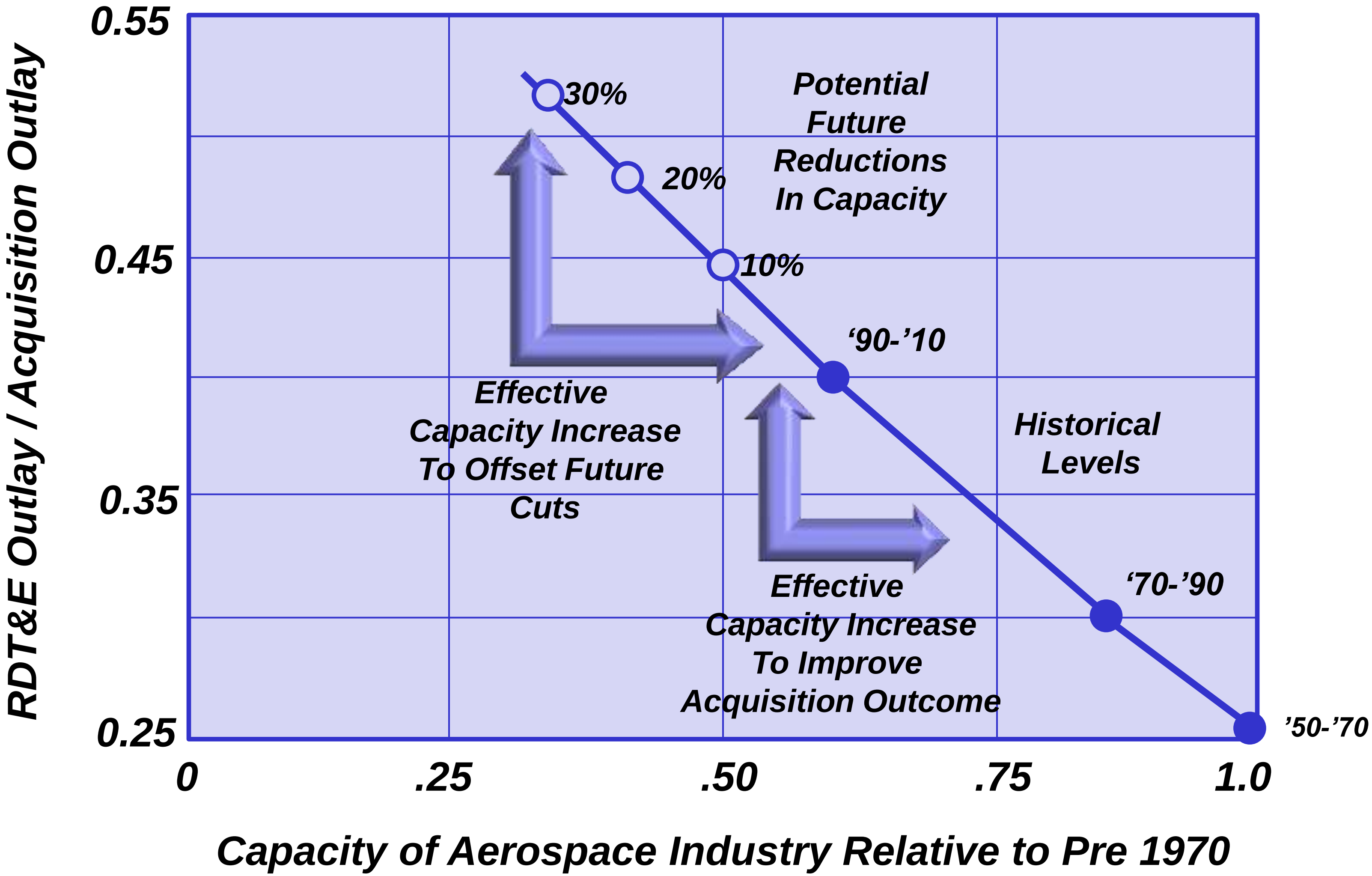


Impact



COMPLEX SYSTEMS + DIMINISHED SKILLS => LONG & COSTLY DEVELOPMENT

Challenge
Offsetting Further Reductions in Capacity



Cycle Time
Key Effectiveness Parameter

$$\textit{Cycle Time} \sim \frac{\textit{Workload}}{q \cdot \textit{Capacity}}$$

- *Workload* – Process driven, currently ~22,000 of wind tunnel testing,13,000 of propulsion cell testing, 6-8,000 flight test hours
- *q (inverse of rework)* – Process driven, typically have 10 structural failures found in flight
- *Capacity* – Budget driven, availability x staffing x throughput

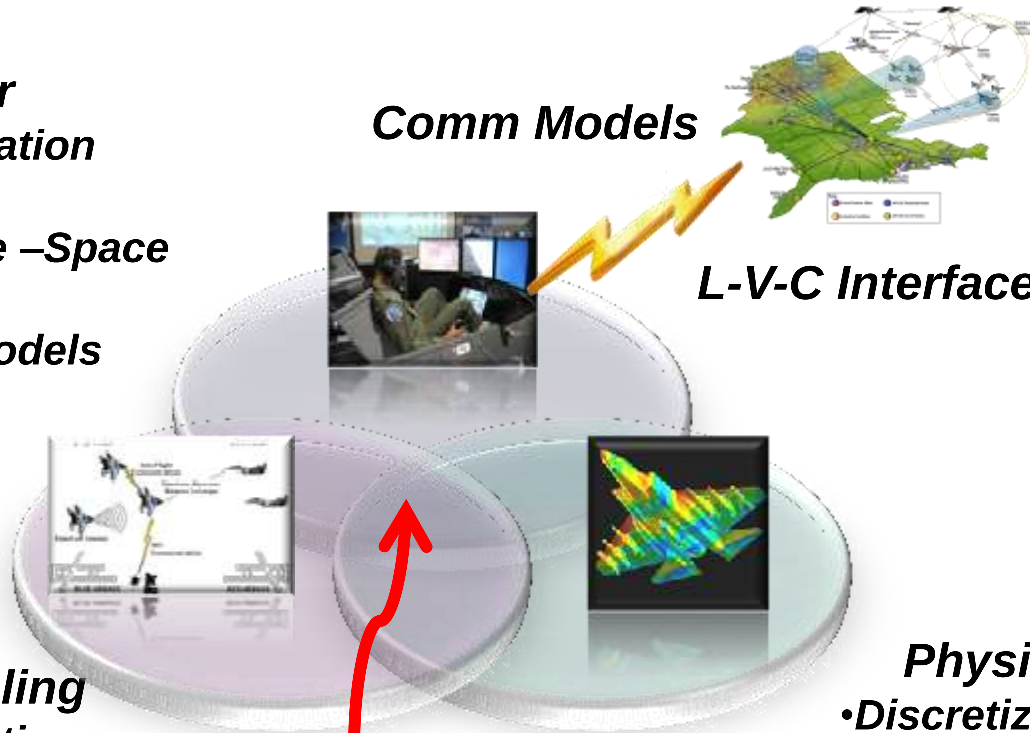
50% reduction in wind tunnel costs equates to just a few tenths of a percent reduction in program costs – Reducing acquisition cycle time by a month could save more than the cost of the entire wind tunnel campaign

Why Hasn't M&S Already Fixed the Problems?

- Which M&S – LVC Simulators, Wargames, or Physics Based Models?
- Point of view
  - M&S vs testing
  - M&S leveraged with testing and statistical engineering to reduce cycle time
- M&S not an integral part of systems engineering processes – need to change processes to leverage M&S to reduce cycle time
- Requires government to act as a monopsony to assure continuity of integrated processes over entire life cycle and from program to program

Characteristics of M&S Domains

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



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

CREATE
Emerging Capability for Improving Acquisition

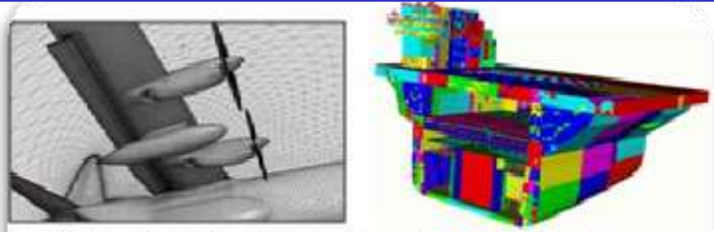
- **CREATE is a DoD program to develop and deploy multiphysics-based software for engineering design and analysis of:**
- **Air Vehicles (AV)**
  - **Aerodynamics, structural mechanics, propulsion, control,**
- **Ships**
  - **Shock vulnerability, hydrodynamics, concept design**
- **Radio Frequency (RF) Antennas**
  - **RF Antenna electromagnetics and integration with platforms**
- **Mesh and Geometry (MG) Generation**
  - **Rapid generation of mesh and geometry representations**

CREATE tools support all stages of acquisition from rapid early stage design to full life-cycle sustainment


Design concept


Seakeeping and resistance


Shock vulnerability

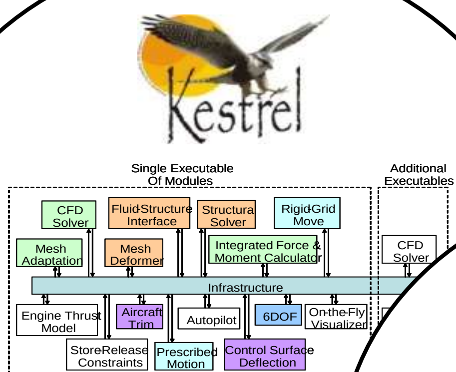

Aircraft and aircraft carrier meshes


Military platforms with antennas

Recent Breakthrough
CREATE-AV

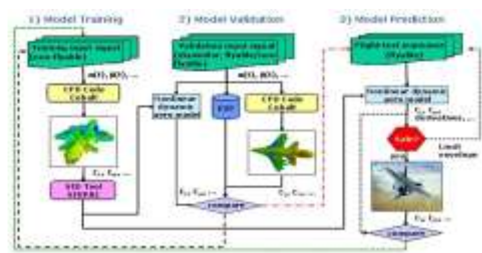
Game Changing Engineering Process Improvement that creates lightweight algebraic models from hi-fi simulations

Scalable to 1000's of processors



High Performance Computing

System Identification



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

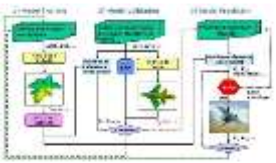
Interchangeable analog and digital inputs

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

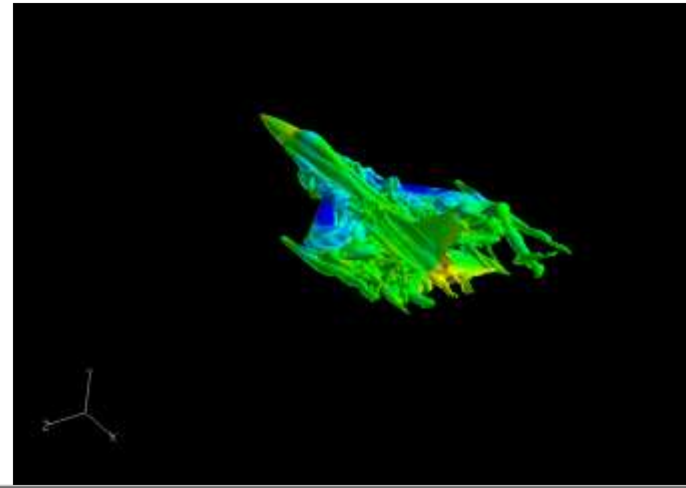
Flight Test
- Pre-flight maneuvers planned for test with any store loadout
- Eliminate benign flight tests

System Identification Model Building



Example Game Changing Process

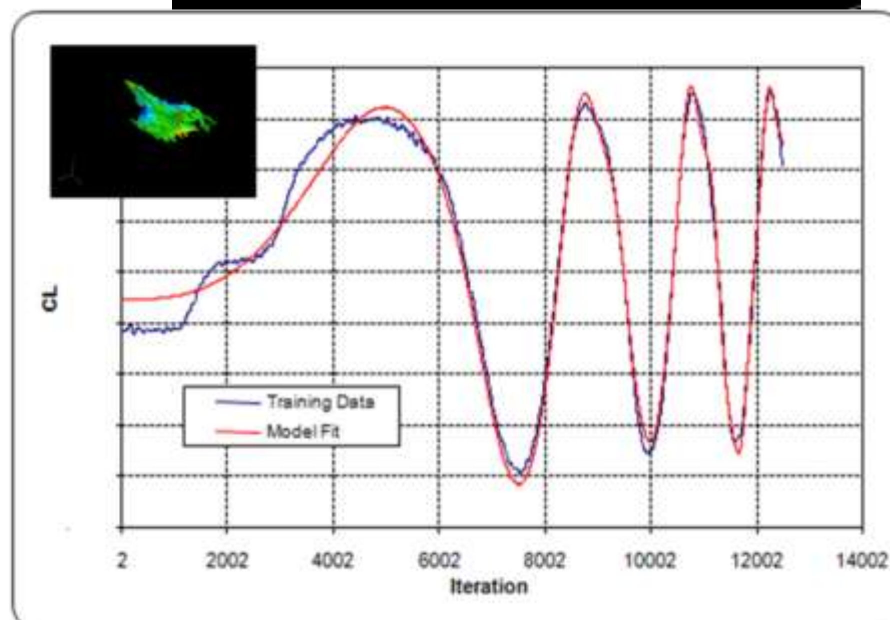
- **Compute a maneuver at a particular flight condition (only need OML)**
- **Knowing input angles, rates and output loads, allows an algebraic model to fit to the data**



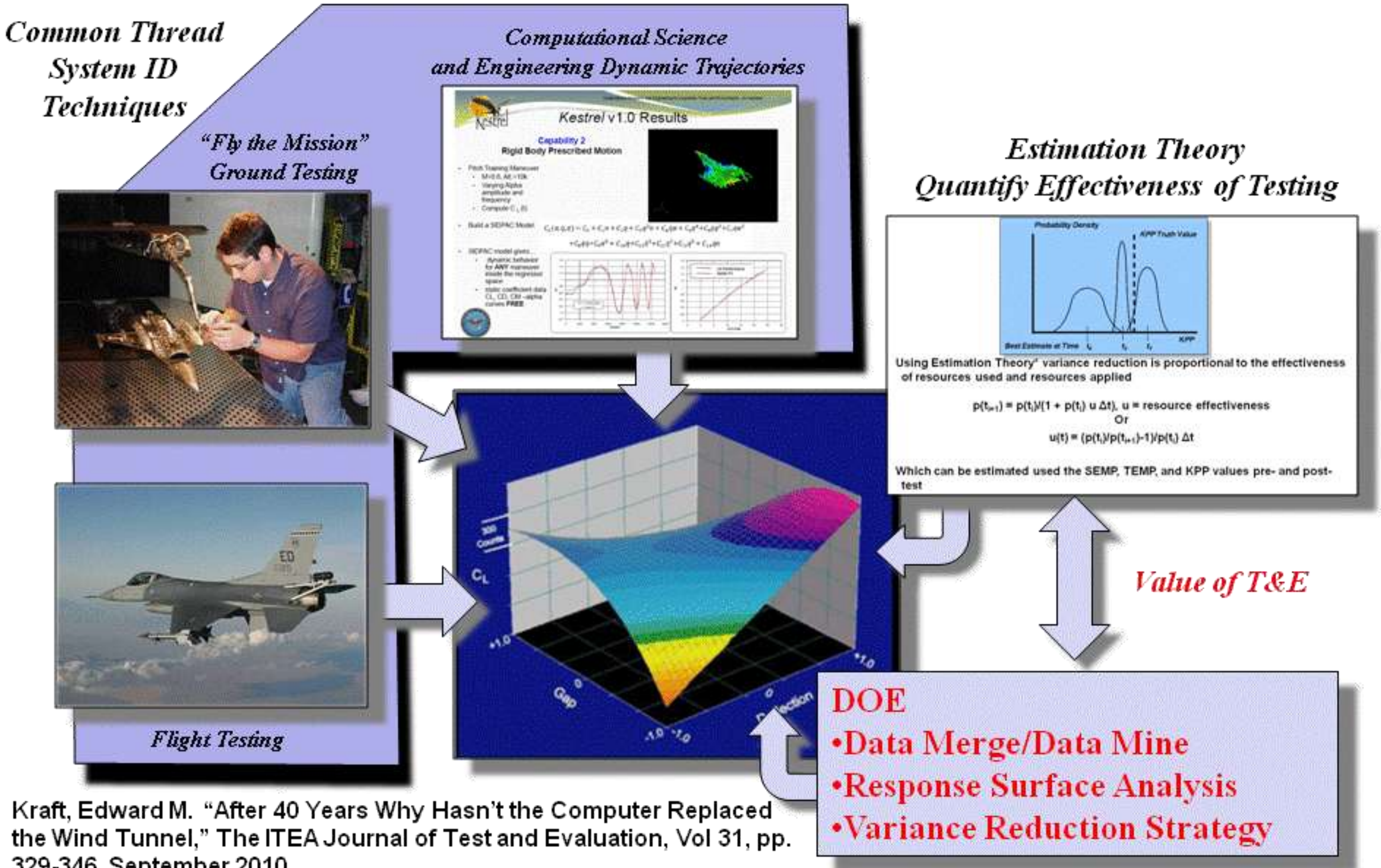
$$C_L(\alpha, q, \dot{q}) = C_0 + C_1\alpha + C_2 q + C_3 q^2\alpha + C_4\dot{q}\alpha + C_5 q^4 + C_6\dot{q}q^2 + C_7 q\alpha^2$$

$$+C_8\dot{q}q + C_9\alpha^3 + C_{10}\dot{q} + C_{11}\dot{q}^3 + C_{12}\dot{q}^2 + C_{13}q^2 + C_{14}q\alpha$$

- **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

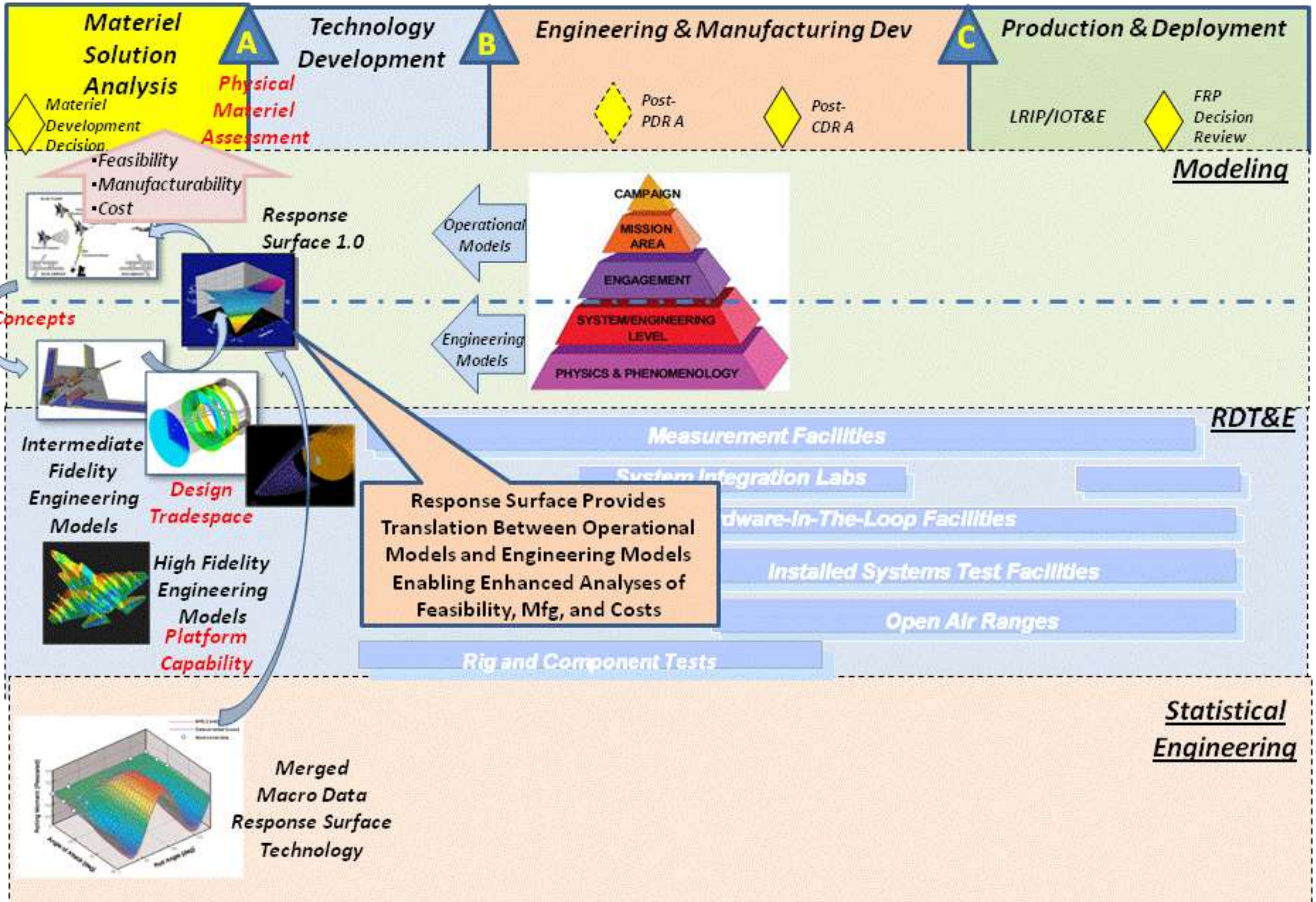


Streamlining Testing at the Campaign Level
New T&E Tools + DOE

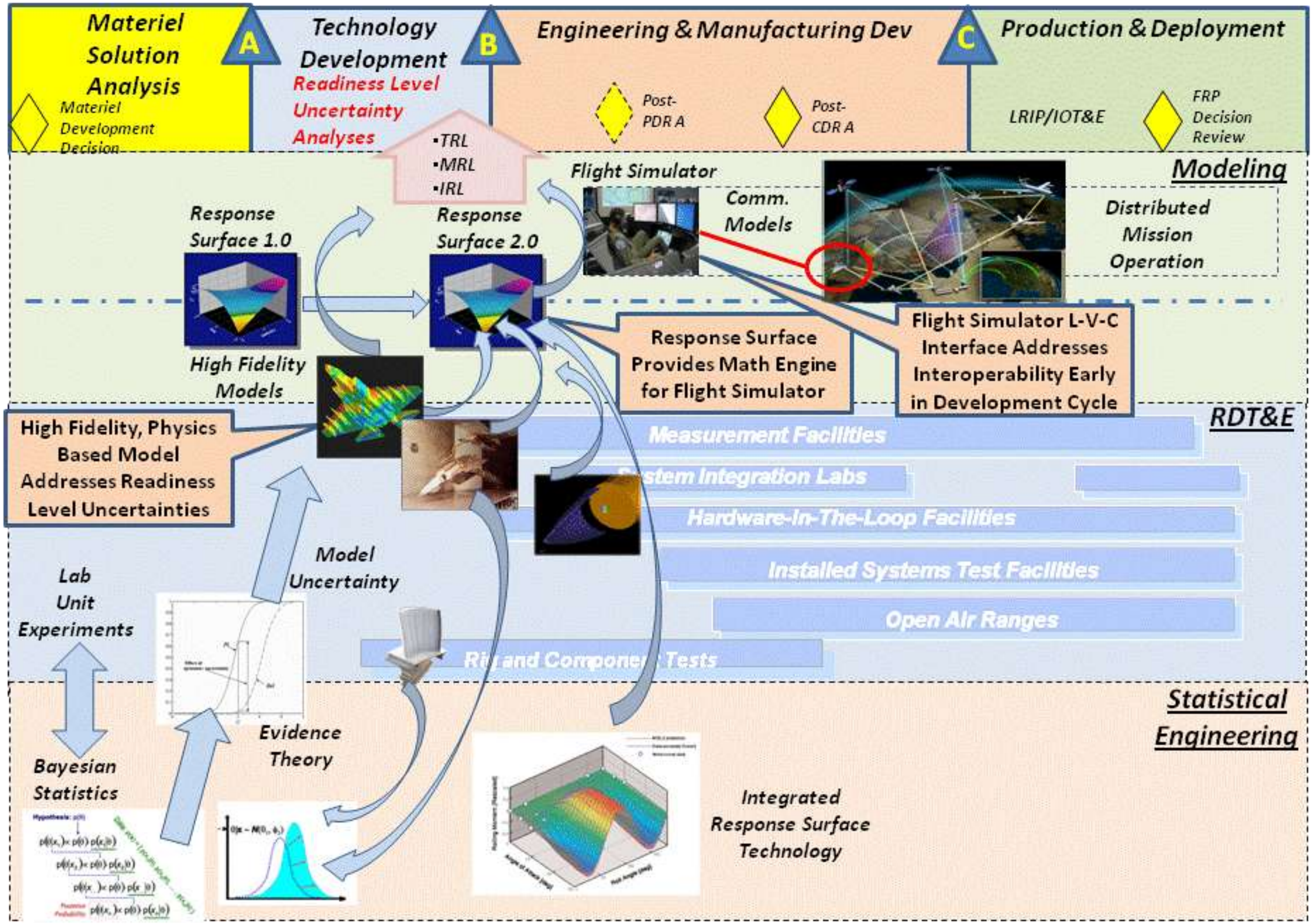


Kraft, Edward M. "After 40 Years Why Hasn't the Computer Replaced the Wind Tunnel," The ITEA Journal of Test and Evaluation, Vol 31, pp. 329-346, September 2010.

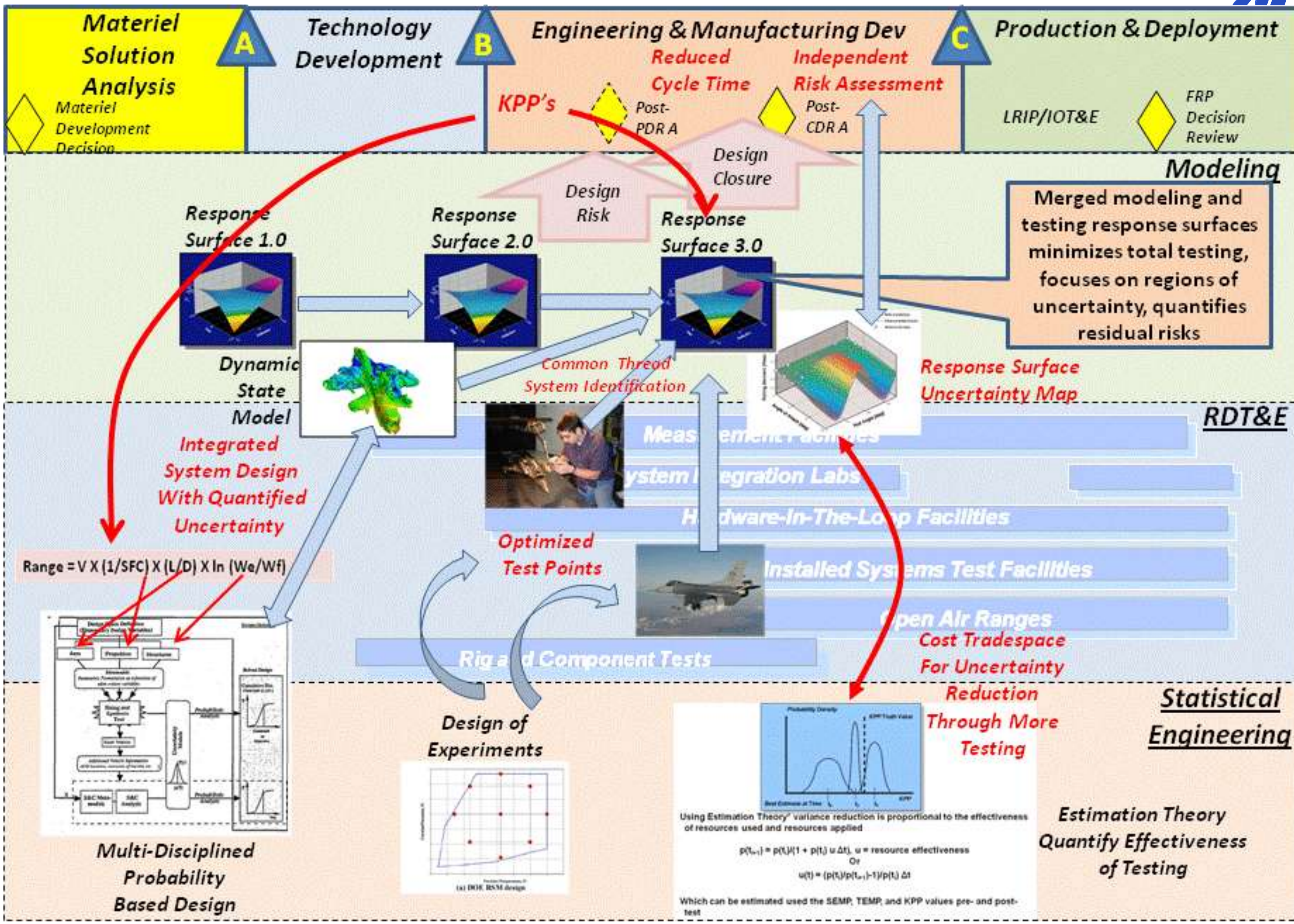
Interfaced Operations and Physics Based Models for Enhanced Analysis



Use of Validated Models to Assess Readiness at Milestone B



Cycle Time and Design Uncertainty Reduction



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