Air Force Materiel Command

Developing, Fielding, and Sustaining America's Aerospace Force

U.S. AIR FORCE

High-Fidelity Physics-Based Modeling in Support of Test & Evaluation

Dr. Ed Kraft

AEDC/CZ

NDIA M&S Conference

November 5-8, 2012

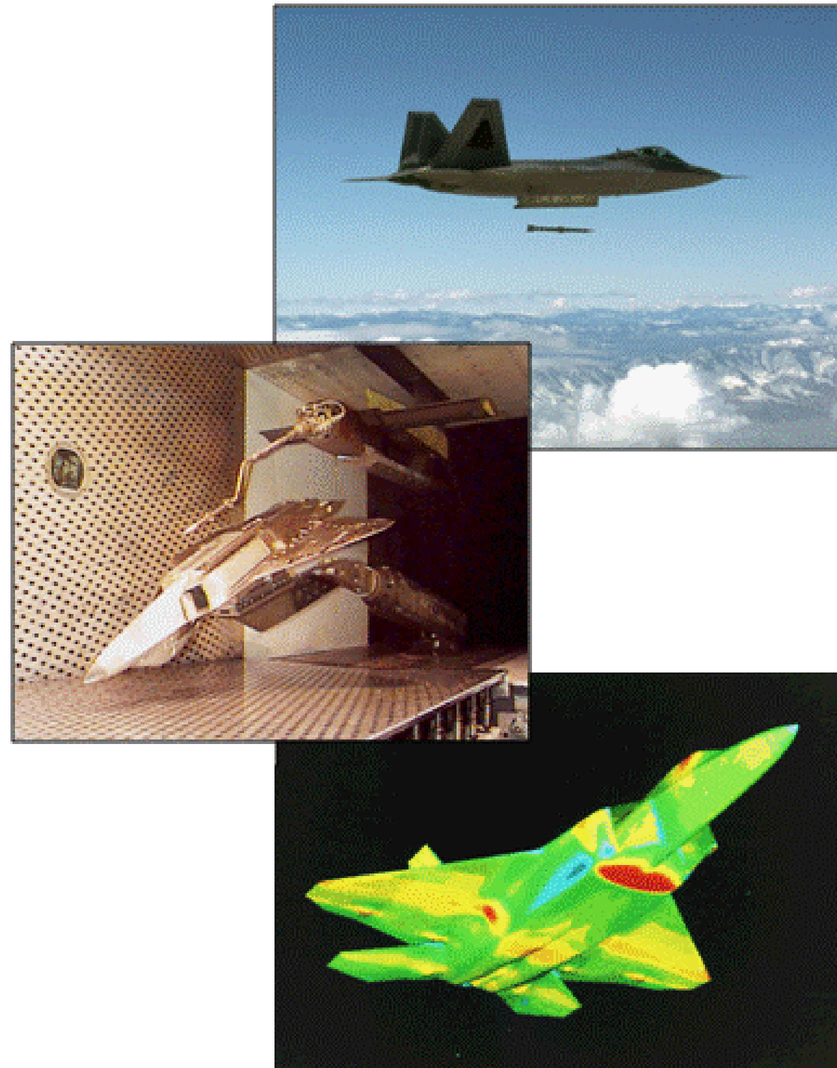
Denver, Colorado

Cleared for Public Release AEDC PA # 2012-0185

Integrity - Service - Excellence

Objectives

- **Illustrate the history, diversity and intensity of physics-based modeling in T&E**
- **Indicate a future vision for increased utility of physics based modeling integrated with T&E in support of weapon system development and sustainment**



Brief History of Physics-Based Modeling in T&E

AFMC

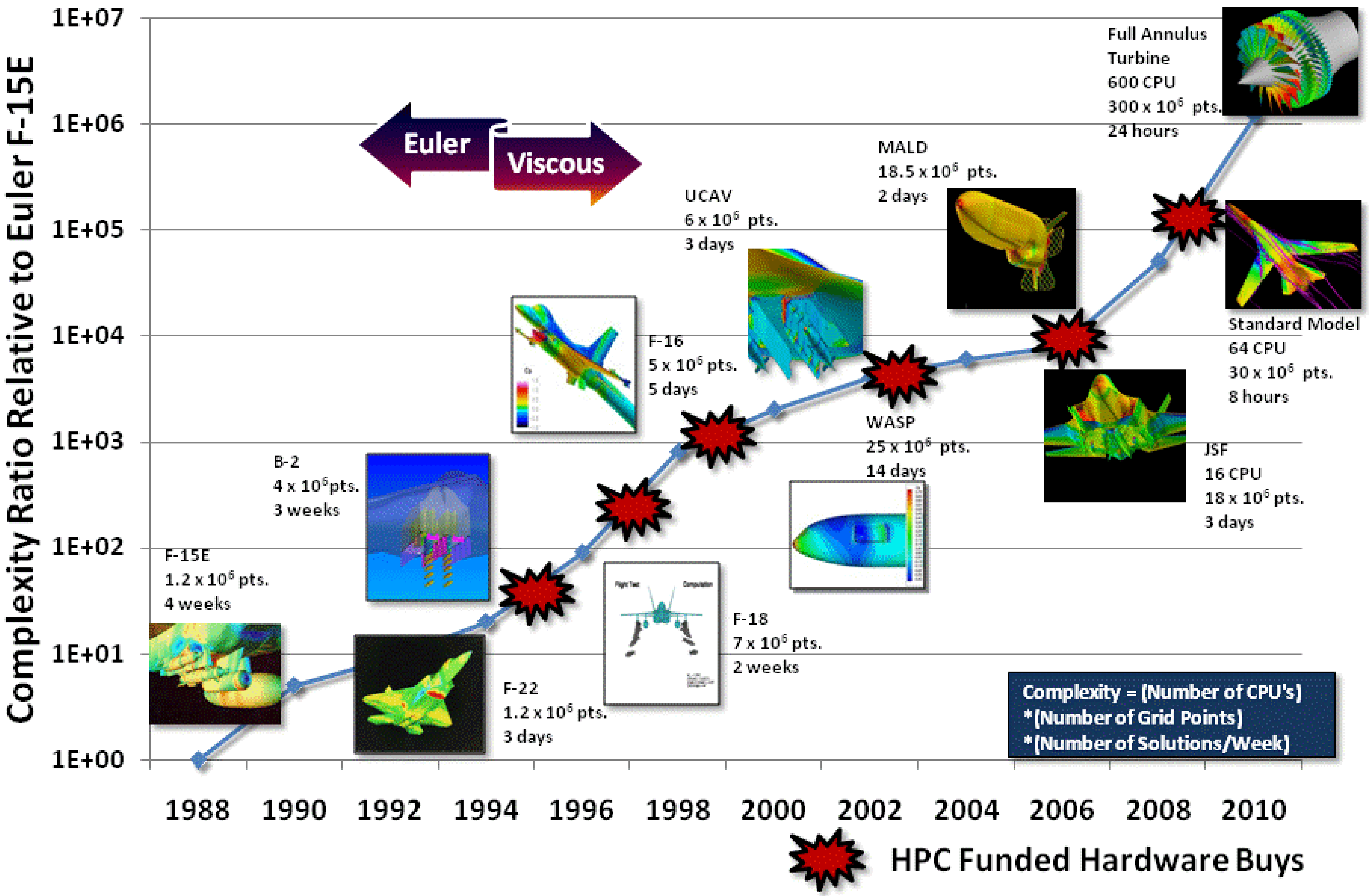
- 50's and 60's
  - MOC, Panel Methods, and Boundary Layer Theory
  - Very limited computer capability
- 70's
  - Non-linear small disturbance equations
  - Early IBM Mainframes
- 80's
  - Euler, Navier-Stokes, Zonal Decomposition
  - IBM 370, Cray XMP
- 90's – today
  - Unsteady RANS Navier-Stokes, LES
  - Clusters, Massive Parallel Processing
  - CREATE-AV Scalable Architecture

Advent of Modern CFD

Watershed for Practical Apps

Enabler for Impact on Acquisition

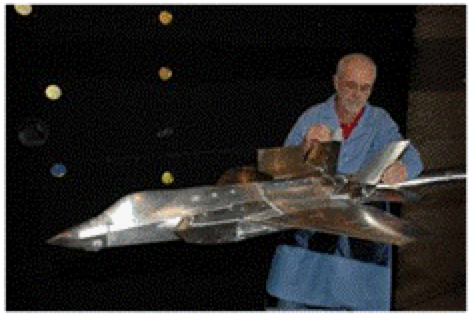
Representative Advances in Physics-Based Modeling in Support of T&E



Early EMD JSF Applications

Objective

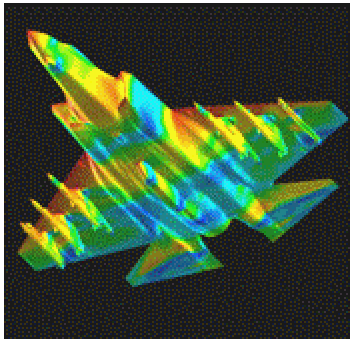
In support of early JSF developmental T&E integrated HPC with wind tunnel testing to reduce epistemic uncertainties, support design changes to improve performance, and reduce costs



Approach

In close coordination with Lockheed-Martin

- Applied high-fidelity steady and unsteady RANS CFD code
- Performed over 1000 individual computations
- Leveraged V&V with wind tunnel data to build confidence to cover regimes without data



18 million mesh points

Outcome

Used computations to increase insight and knowledge into

- Wind Tunnel Wall Effects, Reynolds Number Scaling
- Airframe Loads
- Carriage Loads
- Store Separation (Internal/External Carriage)
- Fuel Tank Design, Loads, and Jettison
- Aircraft lift fan/secondary inlet design

Impact

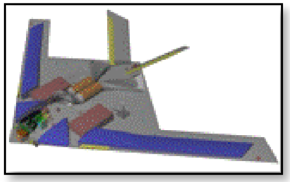
- Eliminated tests for high speed data
- Improved data quality and reduced risk
- Computed trajectories beyond tunnel hardware movement constraints
- Screened test configurations reducing testing costs
- Supported OEM in improving inlet performance
- Total savings = $ Millions

CREATE-AV
(Computational Research Engineering Acquisition Tools Environment for Air Vehicles)

AFMC

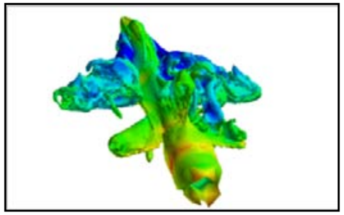
- **A rapidly maturing physics-based flight system modeling architecture enabled by large scale computing**
  - Development focused on impact to acquisition by embedded subject matter experts
  - Successfully delivering a family of products supporting activities from early trade studies to detailed engineering design
  - Using pilot studies to demonstrate ability to efficiently provide better physics-based design and analysis capabilities

DaVinci



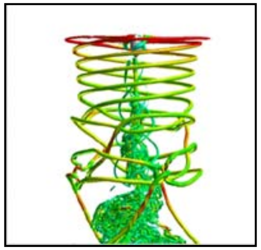
- Early engineering, design, and analysis

Kestrel



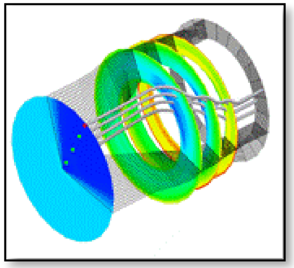
- High-fidelity, fixed wing flight system modeling

Helios



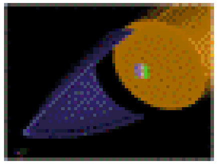
- High-fidelity, rotary wing flight system modeling

Firebolt



- Propulsion module integrated into Kestrel and Helios

Sentri



- CREATE-RF radio frequency modeling capability compatible with DaVinci

Cycle Time
Key Effectiveness Parameter

AFMC

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

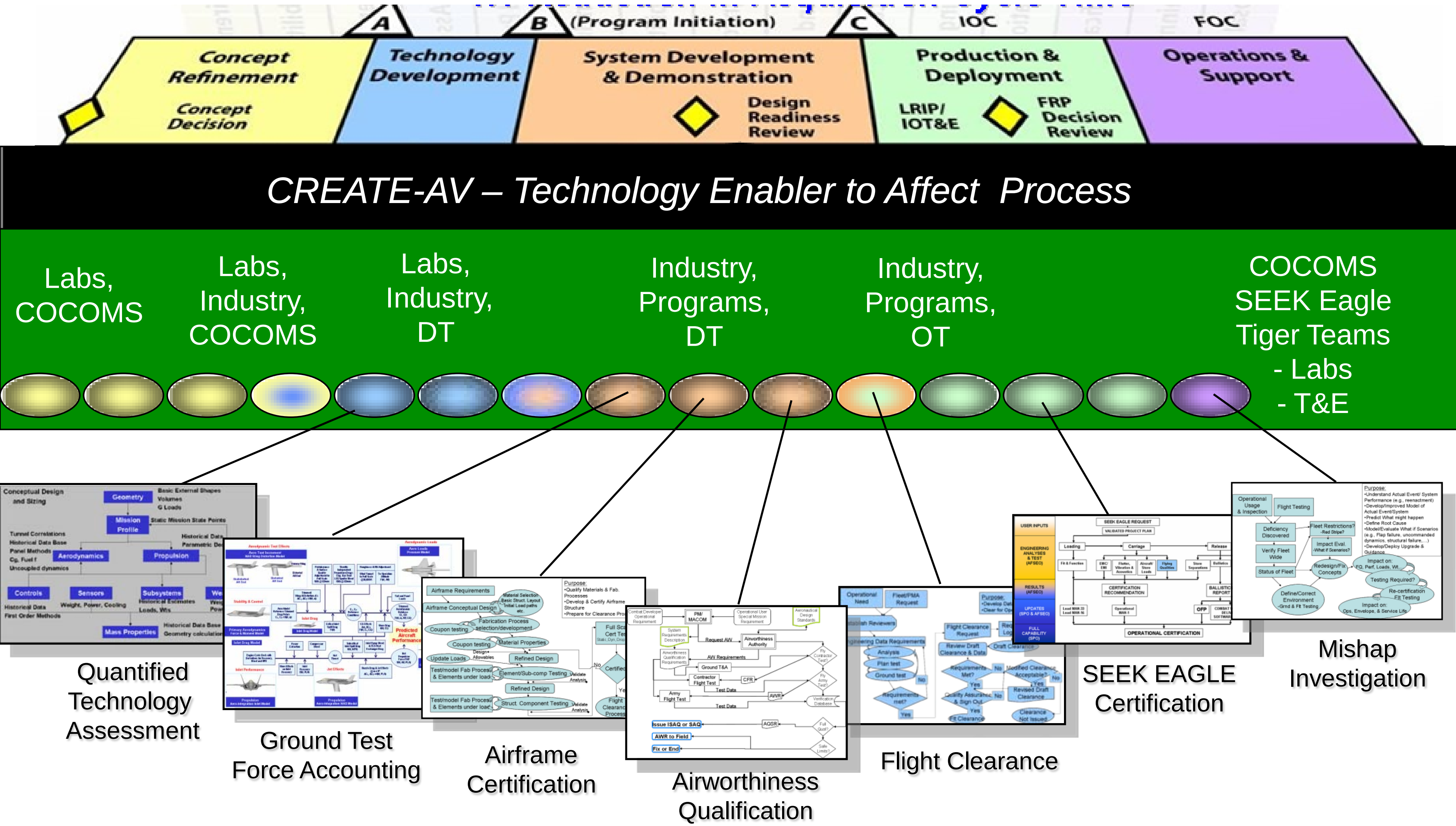
- *Workload* – Process driven, currently ~22,000 of wind tunnel testing and 13,000 of propulsion cell testing
- *q (inverse of rework)* – Process driven, typically have 10 structural failures found in flight
- *Capacity* – Budget driven, availability x staffing x throughput

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

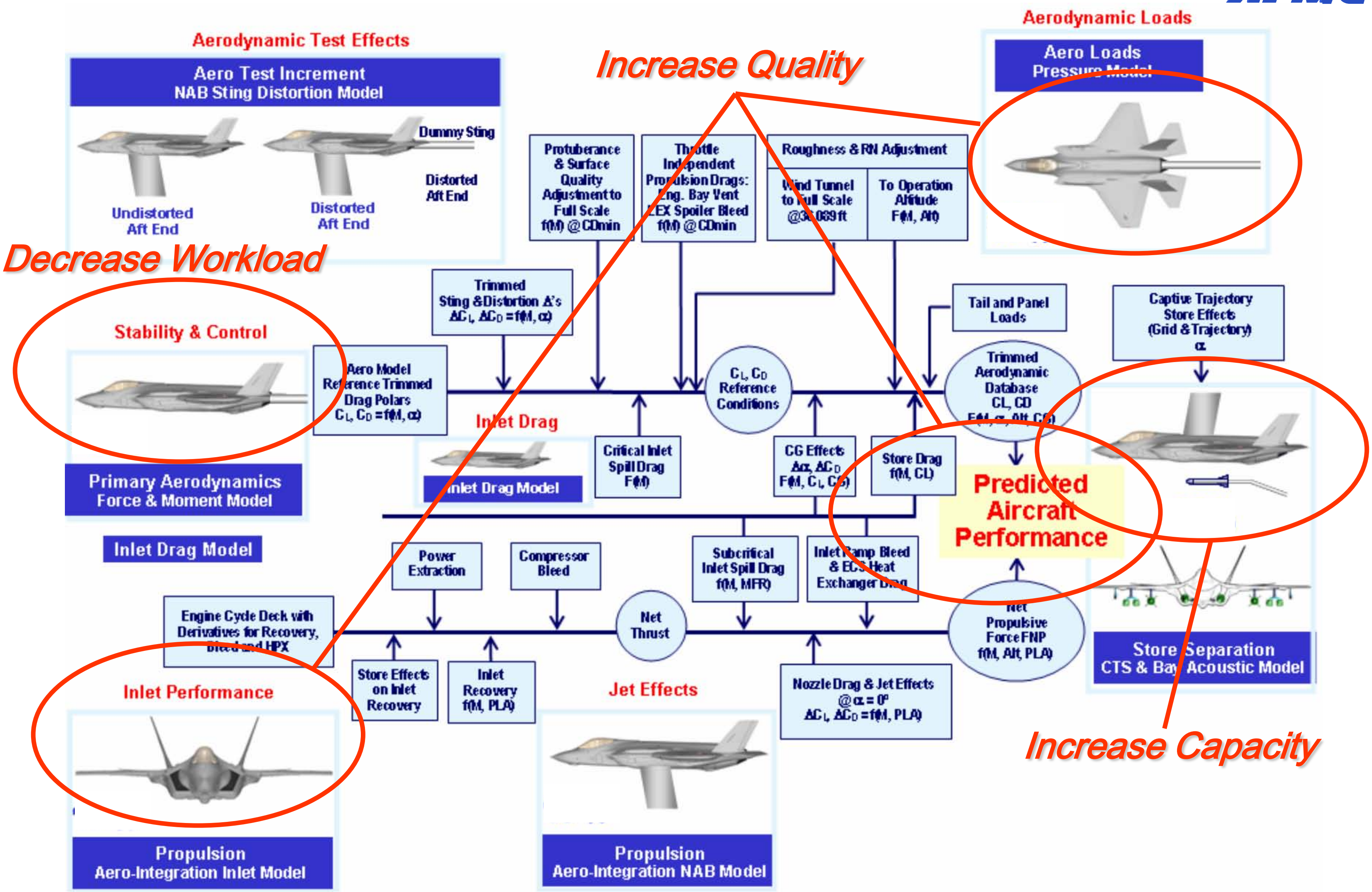
CREATE-AV

Inserting HPC Into Key Acquisition and Sustainment Processes

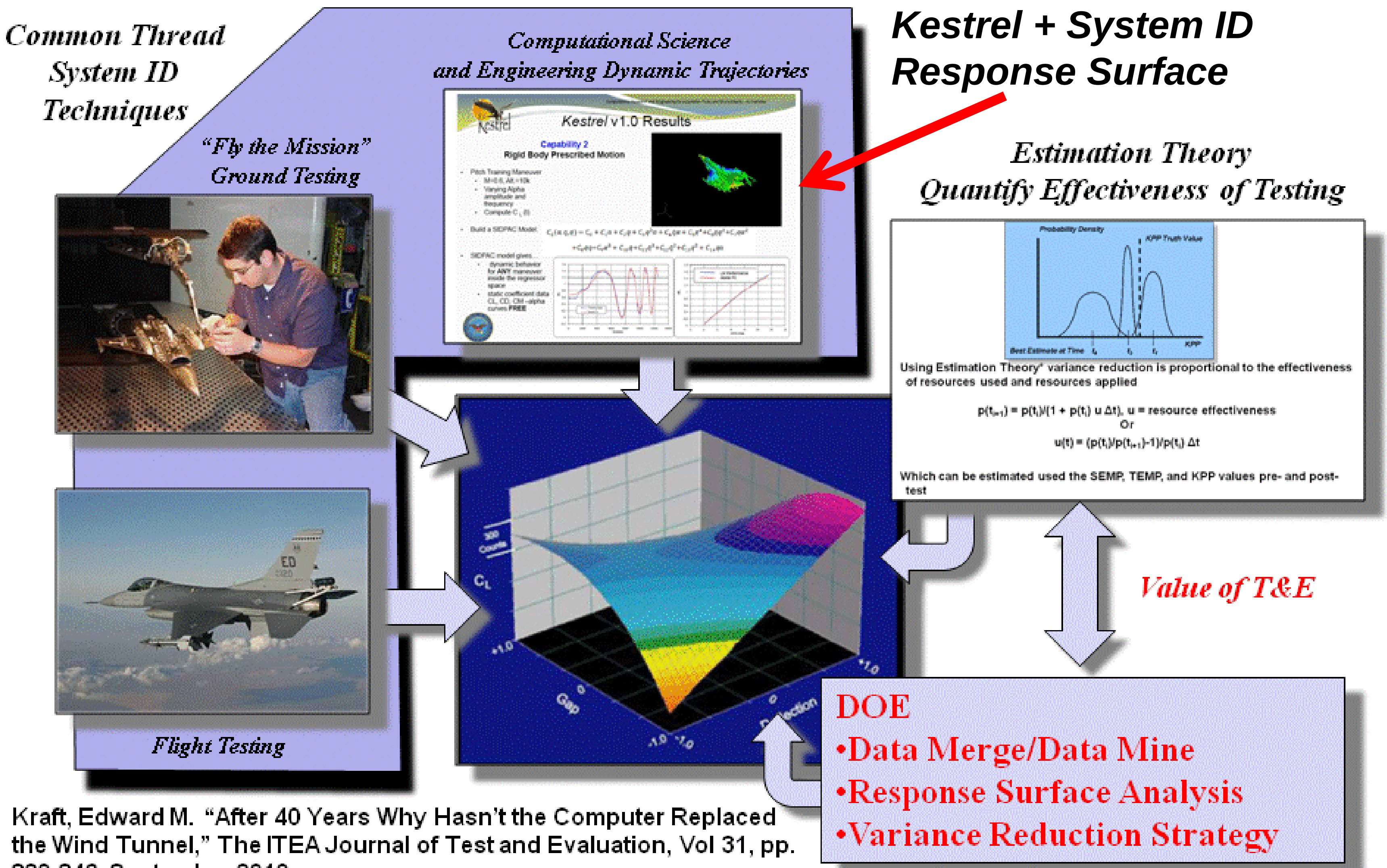
Acquisition Process



Aerodynamic Data Base Development Process



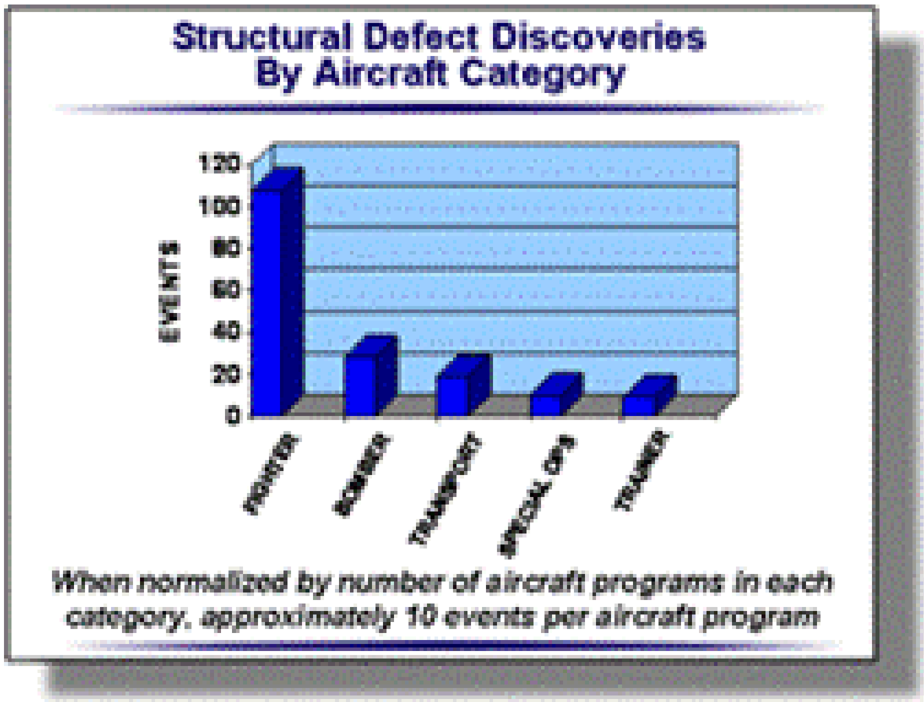
Reducing Workload/Increasing Capacity
Streamlining Testing at the Campaign Level
New T&E Tools + DOE



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.

Increasing Quality
Late Structural Defect Discoveries

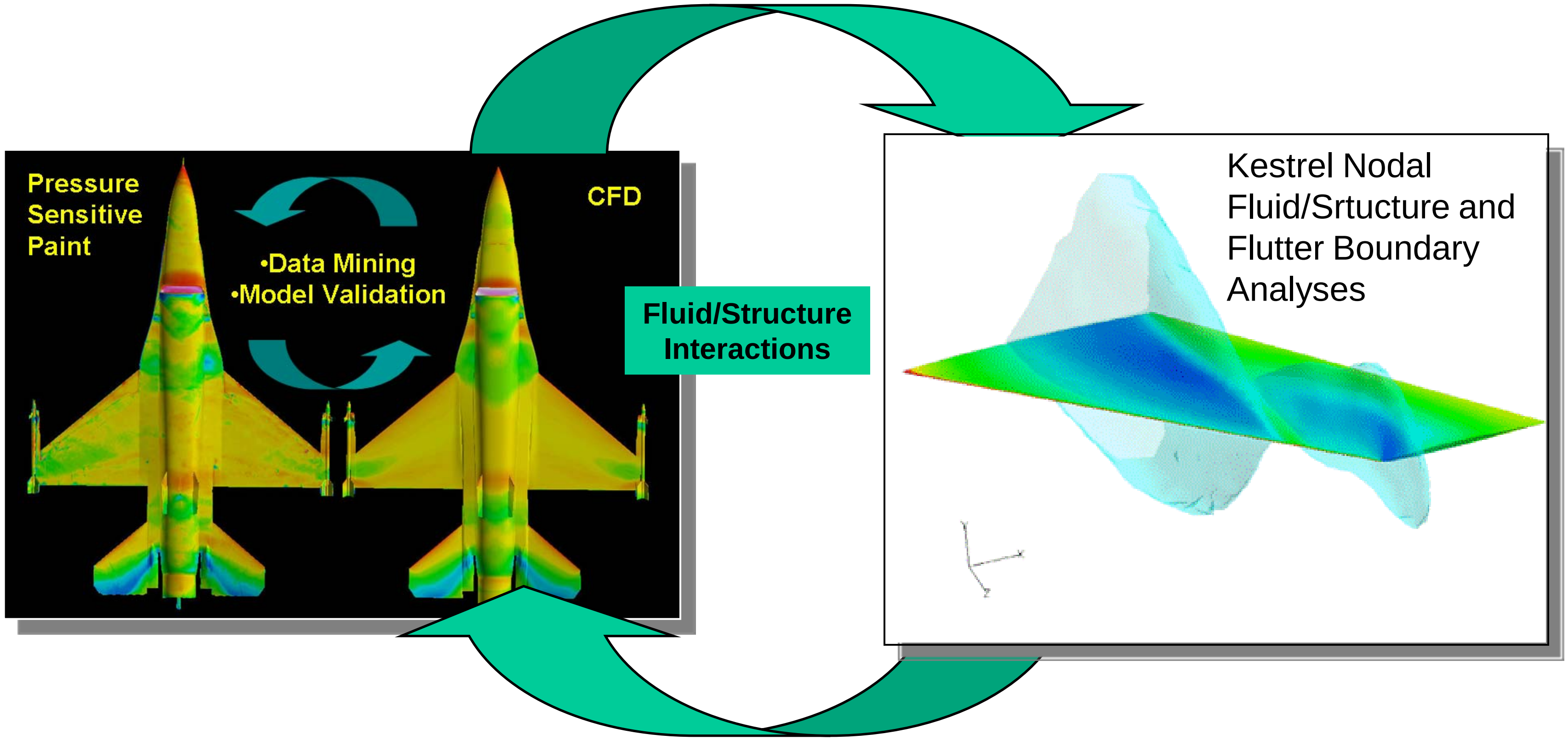
AFMC



- Major Fundamental Causes
  - Inadequate Loads Analysis
    - Aero loads data base
    - Dynamic structural modeling
  - Inadequate Loads Environment
    - Inadequate estimation of non-linear local phenomena (shock, buffet, burst vortex, etc.) – gets worse for high performance aircraft

Aero load data base obtained very early in development program, loft lines not yet frozen – requires faster dynamic structural modeling capability

Reducing Late Defect Discovery
New Technologies Enhance Fluid / Structure Interactions

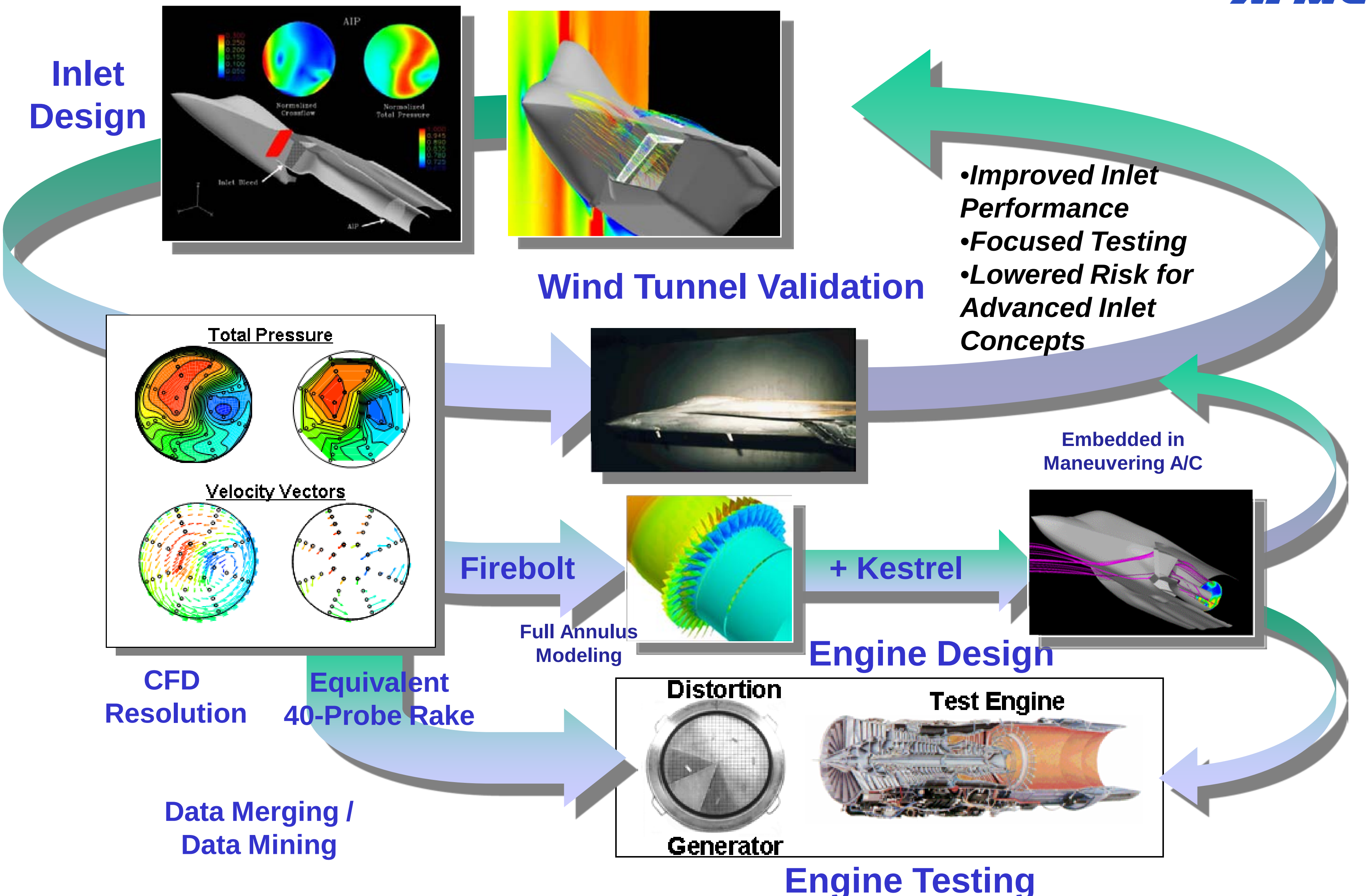


- **Advanced PSP test technologies permit acquiring loads data more frequently during development**
- **Efficient nodal structural models could be updated more frequently**
- **Embedded finite element modeling future update to Kestrel**

Increasing Quality

Early Airframe / Propulsion Integration

AFMC



Summary

- High-fidelity physics based modeling has been an integral part of aeronautical T&E for over 25 years
- CREATE-AV is an enabler to accelerate the acquisition process
- Focus needs to be on processes changes, not just the science of high performance computing