Air Force Materiel Command

Developing, Fielding, and Sustaining America's Aerospace Force

U.S. AIR FORCE

CREATE Activities in the Air Force

Dr. Ed Kraft
AEDC Chief Technologist

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Outline

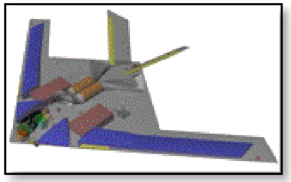
- CREATE-AV Development Activities
- Pilot studies
- Engineering Resilient Systems pilot program application to Analysis of Alternatives
- Long term sustainment and deployment of CREATE-AV
- Future vision of CREATE-AV and Defense Acquisition

CREATE-AV

(Computational Research Engineering Acquisition Tools Environment for Air Vehicles)

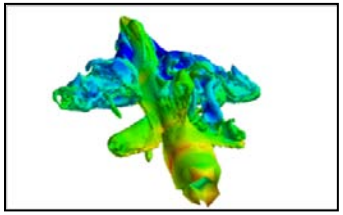
- A rapidly maturing physics-based flight system modeling architecture enabled by large scale computing
  - Development focused on impact to acquisition by embedded subject matter experts
    - DaVinci at AFMC/LCMC/XZ
    - Kestrel at 96th TW, Eglin AFB
    - Helios at Army Rotorcraft, Moffet Field
    - Firebolt at AEDC
    - Sentri at AFRL
    - Shadow Ops at NAVAIR, Pax River
  - Annual release of 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



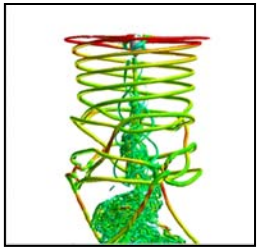
- Early engineering, design, and analysis

Kestrel



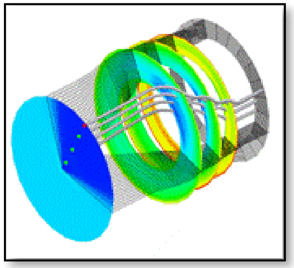
- High-fidelity, fixed wing flight system modeling

Helios



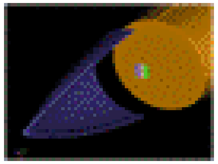
- High-fidelity, rotary wing flight system modeling

Firebolt



- Propulsion module integrated into Kestrel and Helios

Sentri



- CREATE-RF radio frequency modeling capability compatible with DaVinci

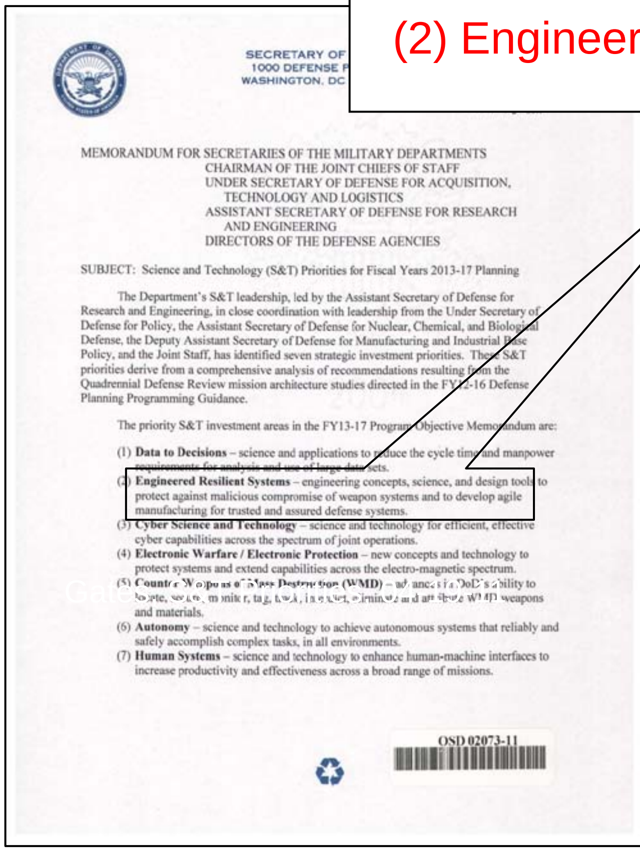
CREATE-AV Already Impacting Real Systems

- Shadow-Ops and Pilot Programs successfully demonstrating capabilities and impacts on ongoing programs
- Practitioners (~250) already imbedded in services
- Industry showing significant interest
  - NDIA support
  - Growing interest from multiple airframe and engine companies

Rethinking the Role of Systems Engineering

SECDEF Priority S&T Investment Areas:

(2) Engineered Resilient Systems (ERS)



SECRETARY OF
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WASHINGTON, DC

MEMORANDUM FOR SECRETARIES OF THE MILITARY DEPARTMENTS
CHAIRMAN OF THE JOINT CHIEFS OF STAFF
UNDER SECRETARY OF DEFENSE FOR ACQUISITION, TECHNOLOGY AND LOGISTICS
ASSISTANT SECRETARY OF DEFENSE FOR RESEARCH AND ENGINEERING
DIRECTORS OF THE DEFENSE AGENCIES

SUBJECT: Science and Technology (S&T) Priorities for Fiscal Years 2013-17 Planning

The Department's S&T leadership, led by the Assistant Secretary of Defense for Research and Engineering, in close coordination with leadership from the Under Secretary of Defense for Policy, the Assistant Secretary of Defense for Nuclear, Chemical, and Biological Defense, the Deputy Assistant Secretary of Defense for Manufacturing and Industrial Base Policy, and the Joint Staff, has identified seven strategic investment priorities. These S&T priorities derive from a comprehensive analysis of recommendations resulting from the Quadrennial Defense Review mission architecture studies directed in the FY12-16 Defense Planning Programming Guidance.

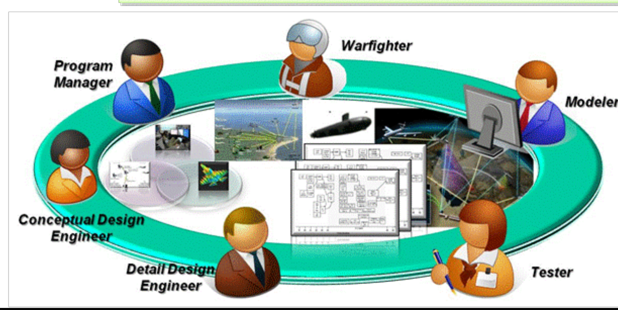
The priority S&T investment areas in the FY13-17 Program Objective Memorandum are:

(1) **Data to Decisions** – science and applications to reduce the cycle time and manpower requirements for analysis and use of large data sets.
(2) **Engineered Resilient Systems** – engineering concepts, science, and design tools to protect against malicious compromise of weapon systems and to develop agile manufacturing for trusted and assured defense systems.
(3) **Cyber Science and Technology** – science and technology for efficient, effective cyber capabilities across the spectrum of joint operations.
(4) **Electronic Warfare / Electronic Protection** – new concepts and technology to protect systems and extend capabilities across the electro-magnetic spectrum.
(5) **Counter Weapons of Mass Destruction (WMD)** – advances in DoD's ability to locate, secure, monitor, tag, track, interdict, eliminate and attribute WMD weapons and materials.
(6) **Autonomy** – science and technology to achieve autonomous systems that reliably and safely accomplish complex tasks, in all environments.
(7) **Human Systems** – science and technology to enhance human-machine interfaces to increase productivity and effectiveness across a broad range of missions.

OSD 02073-11

Key Concepts of ERS

- *Consistent system and contextual info represented in many forms*
- *Mission effectiveness proven wrt operational context*
- *Large scale managed collaborative environment*
- *Exploration and analysis of appropriately sized tradespaces*



Coupling of knowledge across engineering disciplines, acquisition activities and representations

CREATE is recognized as an enabler for ERS objectives

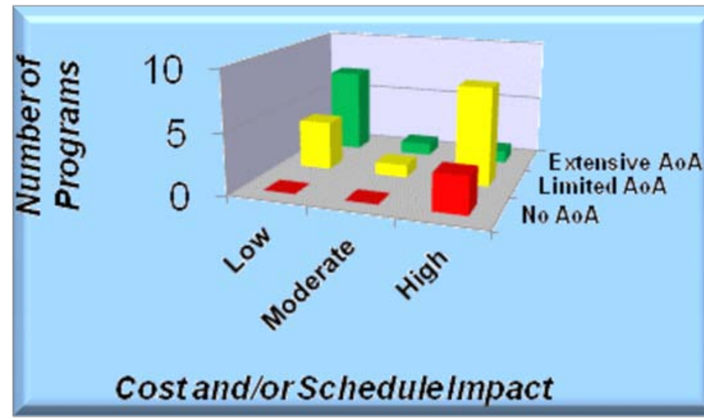
CREATE-AV ERS Pilot Study for Better Analysis of Alternatives

AFMC

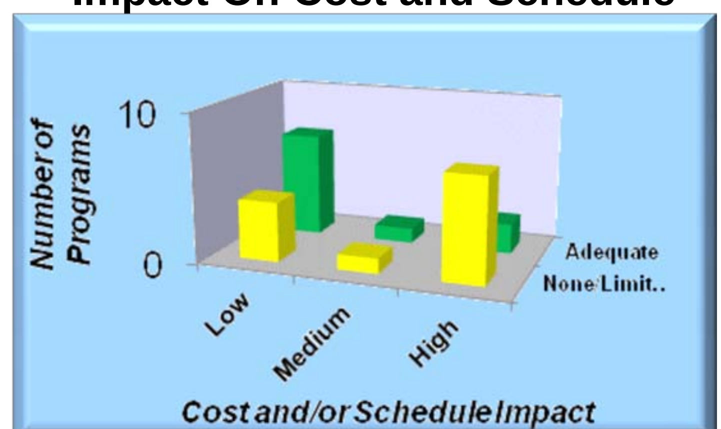
- GAO* concluded that the majority of AoA's evaluated did not sufficiently inform the business case for starting new programs.
- AoA should provide the basis for a solid, executable business case before committing resources to a new system development;
  - Warfighter needs are valid and can be best met with chosen concept
  - The chosen concept can be developed and produced within existing resources (proven technologies, design knowledge, adequate funding, and adequate schedule)
- Narrow scope and limited risk analysis in AoA's attributed in part to:
  1. Choosing a solution too early in the process
  2. Compressed timeframes for conducting an AoA
  3. Lack of guidance for conducting an AoA including to what extent to perform a risk analysis

Can ERS positively impact acquisition by providing resilient and robust trade study capabilities, tools to expedite the AoA processes, and a framework for consistent and comprehensive risk assessment?

Scope of AoA Analyses Impact On Cost and Schedule

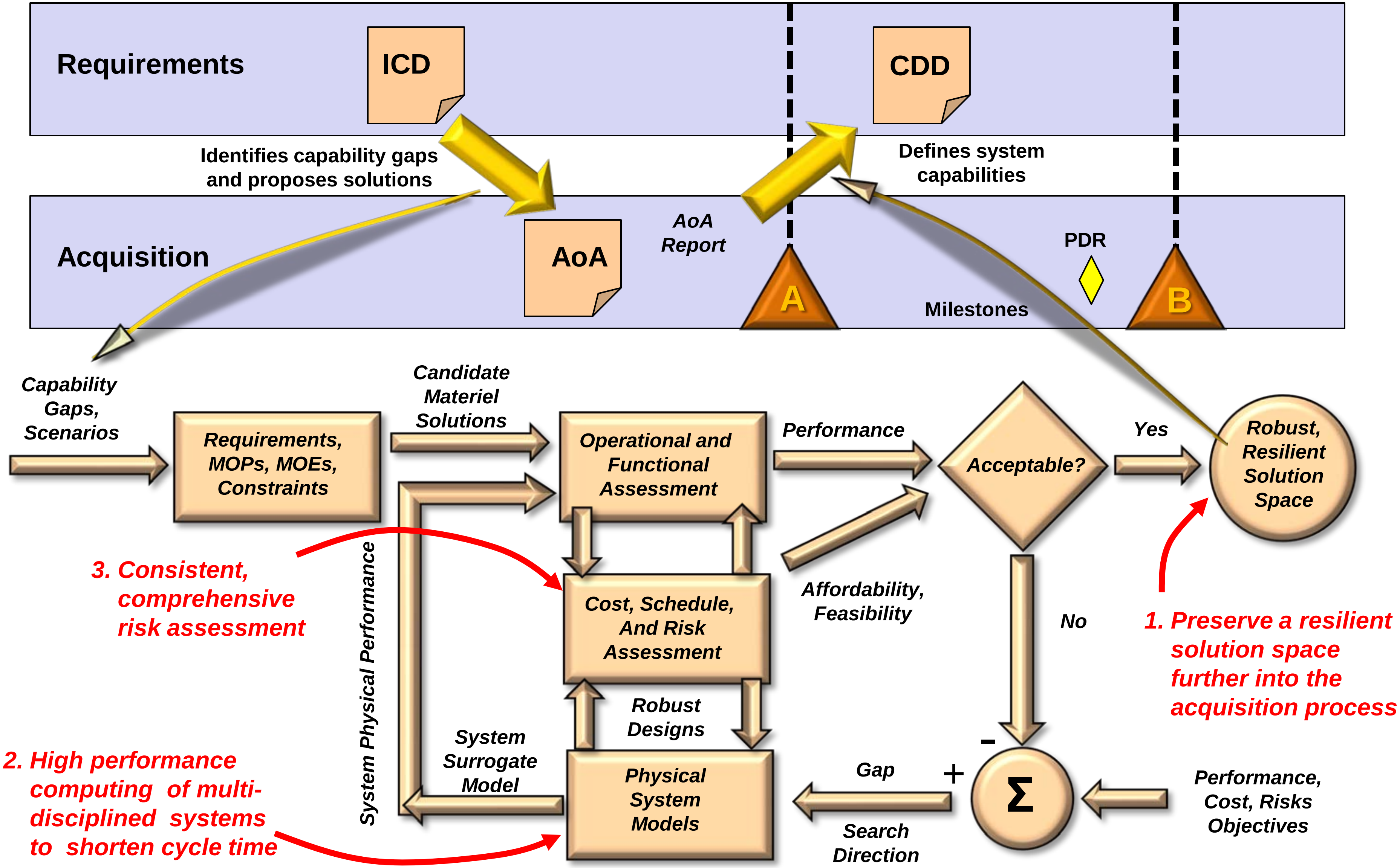


Quality of AoA Risk Assessment Impact On Cost and Schedule



**Source:GAO-09-665 "Many Analysis of Alternatives Have Not Provided a Robust Assessment of Weapon System Options", September, 2009*

ERS Concepts Applied to Improving the AoA Phase of Weapon System Acquisition



Objectives for an ERS Demonstration

Through application to a flight system of interest, demonstrate the use of ERS concepts and enabling tools can improve the Pre-Milestone A Analysis of Alternatives process by:

1. ***Identifying and maintaining a broader range of feasible solutions** using high-performance computing and scalable, multi-discipline, physics-based models to efficiently and rapidly provide a data-driven resilient trade space for exploration and analysis of alternative materiel solutions*
2. ***Accelerating the analysis time** by connecting physics-based models through surrogate response surfaces with operational and functional models to dynamically evaluate alternative materiel concepts against requirements*
3. ***Performing a structured assessment of cost, schedule, and performance risk** using probability based design methods to statistically connect concept feasibility with performance and affordability*

Proposed ERS C-X Pilot Demonstration

1. C-X Strategic Airlift proposed as system of interest
   - Long-range airlifter with fuel efficient propulsion
   - Identified by the Air Mobility Command (AMC) to meet future airlift requirements
   - Support an early preliminary trade space analysis to address multiple missions, manned vs unmanned, range of payloads, intra- and inter-theater operations, efficient propulsions and structural systems, airdrop/airfield operations in remote areas, etc.
   - Opportunity to develop and validate an enhanced Analysis of Alternatives process using ERS concepts prior to actual application
2. Apply operational engagement models such as Air Mobility Operations Simulation (AMOS) against various mission scenarios and threats to identify requirements, MOPs, MOEs, etc.
3. Create a set of operational performance characteristics and system design variables that impact operational requirements, e.g.
   - Range, payload, sustainable sortie rates, landing/takeoff distances, etc.
   - Speed, lift to drag ratio, wing loading, thrust to weight, specific fuel consumption, weights of key technologies, payload SWAP, etc

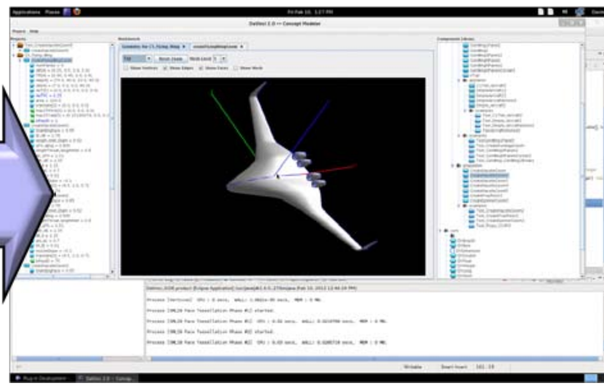
Proposed ERS C-X Pilot Demonstration (continued)

4. **Use the CREATE-AV DaVinci modeling capability as the scalable multi-physics based design tool to efficiently explore a resilient design space using the associated design variables,**

DESIGN VARIABLES

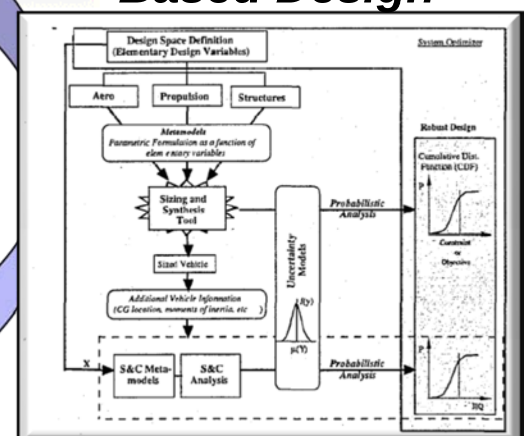
- ***Size***
- ***Planform***
- ***Component layout***
- ***Aspect ratio***
- ***Propulsion system***
- ***Materials***
- ***et***

DaVinci



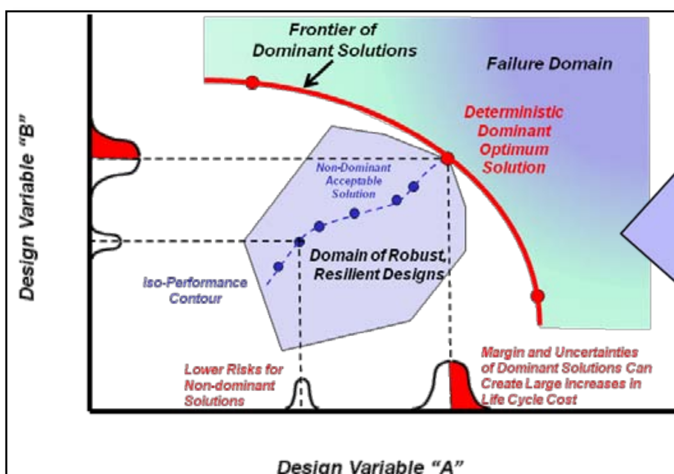
High Performance Computing

Probability Based Design



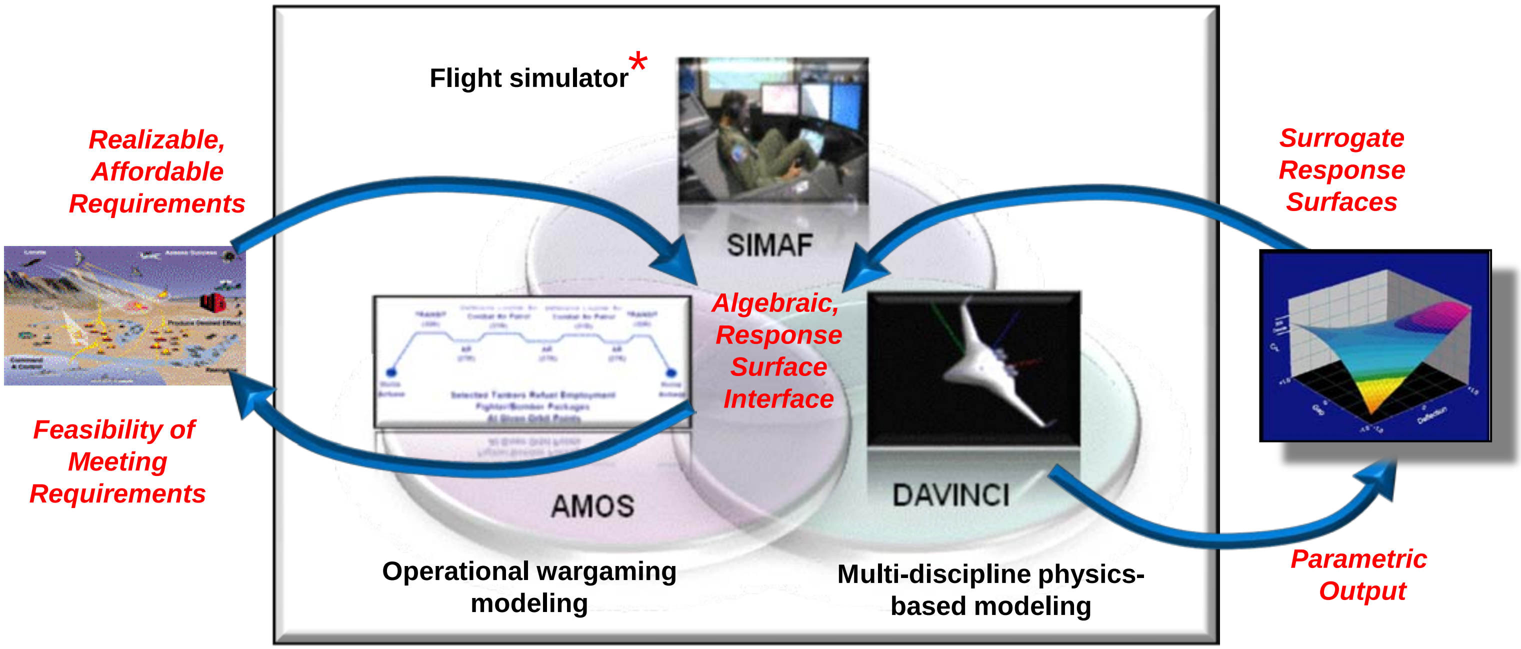
Includes probability of achieving performance goals

Resilient Design Space



Proposed ERS C-X Pilot Demonstration (continued)

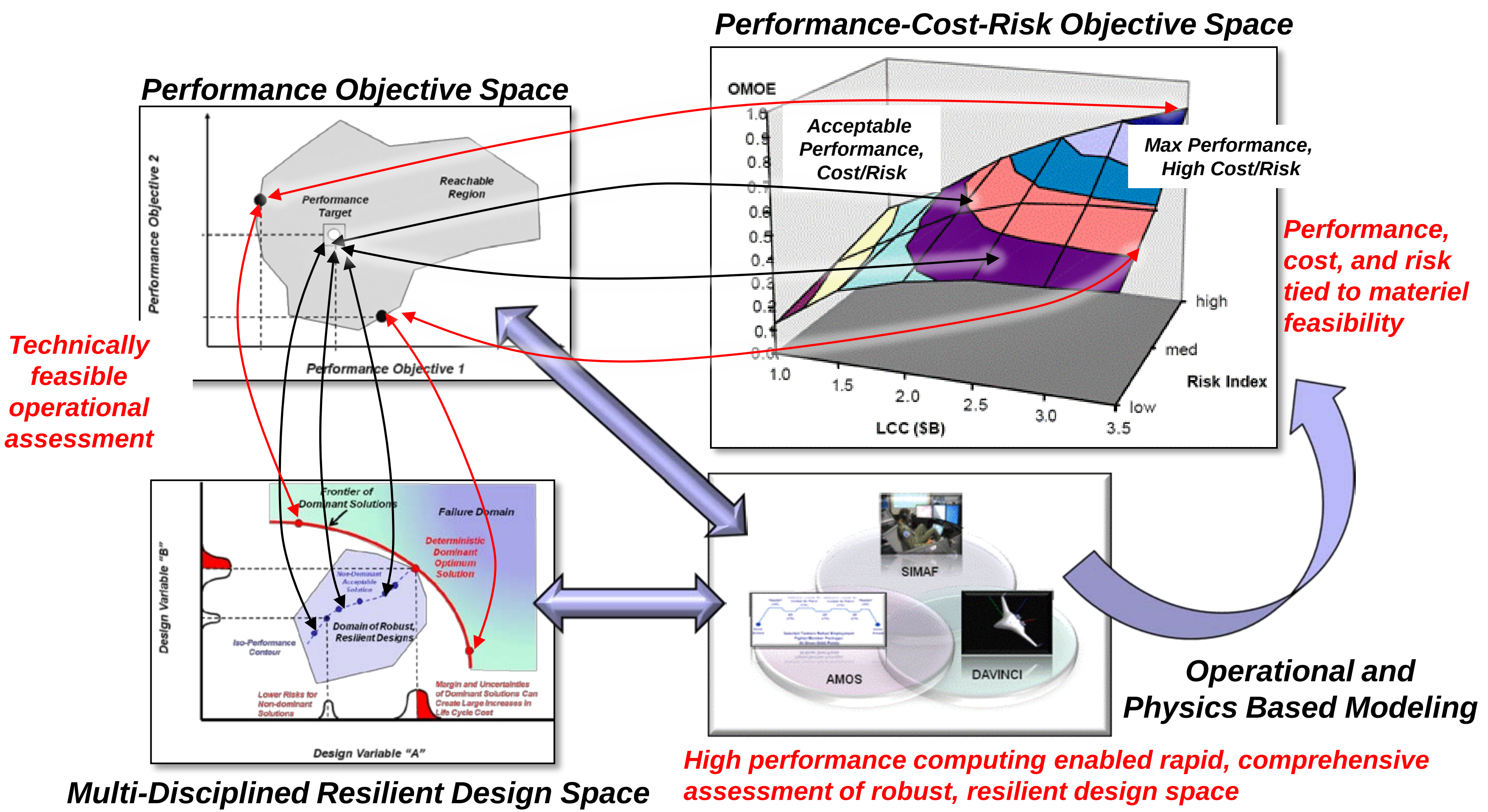
5. Demonstrate that the DaVinci model output can be accurately represented by a surrogate response surface and injected into engagement models to show an iterative ability to adjust scenarios and requirements to physical feasibility



* Future potential demonstration using the same surrogate response surface model to interface with flight simulators in a distributed mission operation to assess interoperability of alternative concepts.

Proposed ERS C-X Pilot Demonstration (continued)

6. *Perform a structured assessment of cost, schedule, and performance risk using probability based design methods to statistically connect operational requirements and concept feasibility with performance and affordability*



Status of ERS Pilot Study

- Proposal accepted, funding in process
- AF Team in place, coordinating support from academia

Moving to the Next Stage

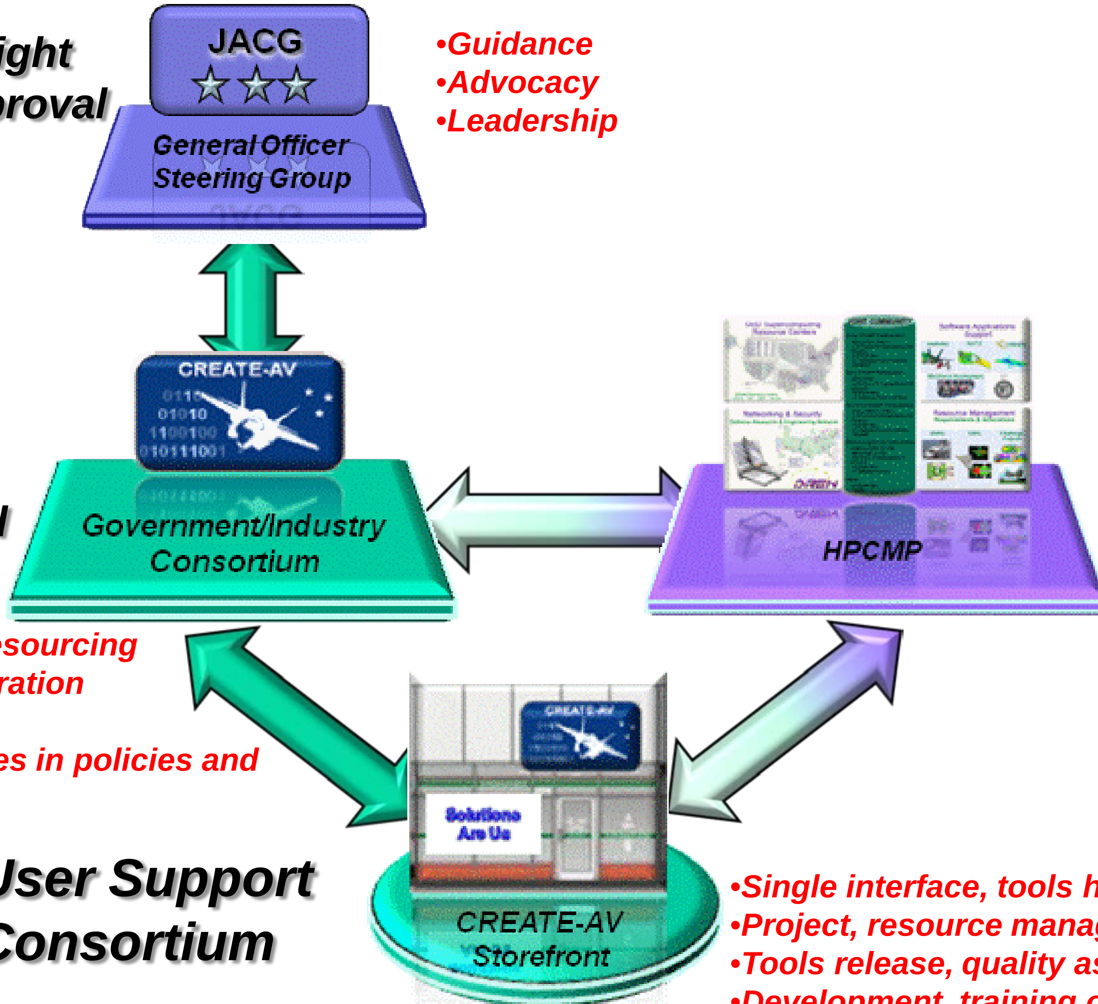
- Need to move long term sustainment and deployment to services and industry
  - Where the needs exist
  - Integration into acquisition processes
  - Adoption by acquisition professionals
- Need to assure resources to sustain tools and expertise
- Need investment in decisive improvements in research, engineering, and acquisition <u>processes</u> across the aerospace community
  - CREATE-AV and HPC as enablers
  - Investment in activities to change processes
  - Collaboration with industry
  - Leadership to influence policies and RFP language to institutionalize changes

Integral Components to Long Term Sustainment and Deployment

AFMC

Oversight and Approval

- Guidance
- Advocacy
- Leadership



Resources and Guidance

- Stakeholder buy-in, resourcing
- Govt/industry collaboration
- Advocacy
- Leadership for changes in policies and practices

Resources and Infrastructure

- HPC Systems
- Networks
- CREATE Development
- Infrastructure help desk

User Support Consortium

Skills and Execution

- Single interface, tools help desk
- Project, resource management
- Tools release, quality assurance
- Development, training of expertise
- Pilot projects coordination and execution
- Facilitate process changes with CREATE-AV

CREATE-AV
Transition

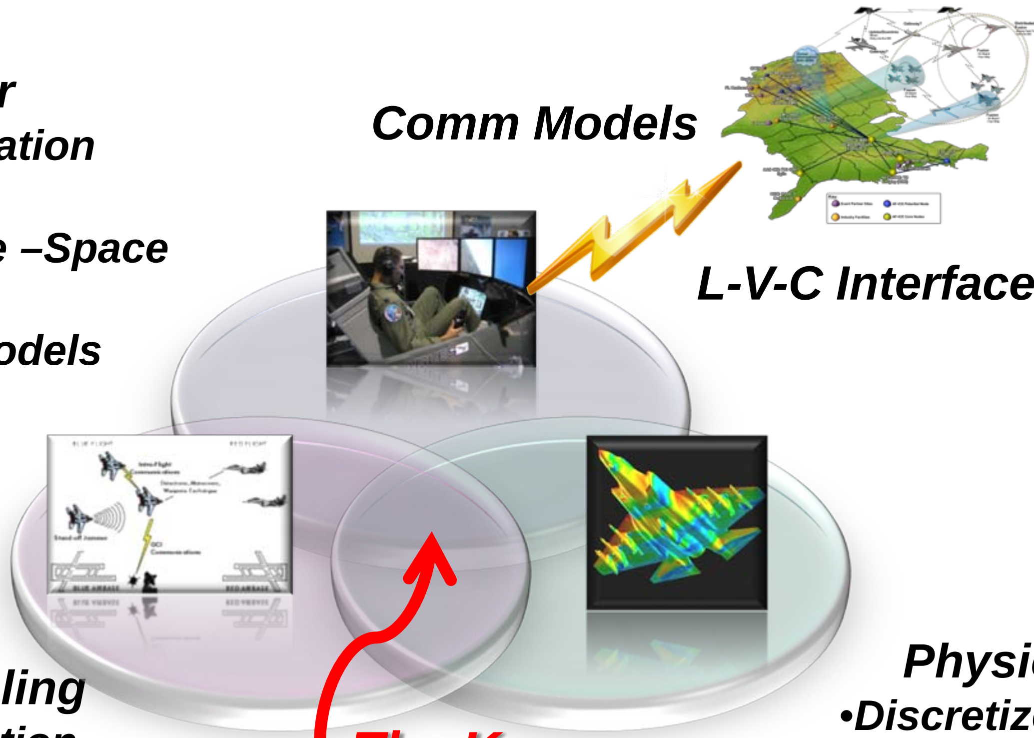
- User Support Consortium IPT and HPCMP funding in place – 8 transition pilot studies being initiated
- Transition CREATE-AV for initial user support and sustainment activity functions by FY14, full devolvement to services no later than FY17
- CONOPS and Governance Options Require Exploration
  - 6-8 Month Activity to Provide Options
  - Endorsement from JACG Requested
- Activity Outcome: Options and Recommendations
  - Resource Requirements and Method
  - Service Agreement on Share of Responsibilities
  - Help Needed Items (if required)

Future Vision for CREATE

Integrating M&S Domains to Address Complexity

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*

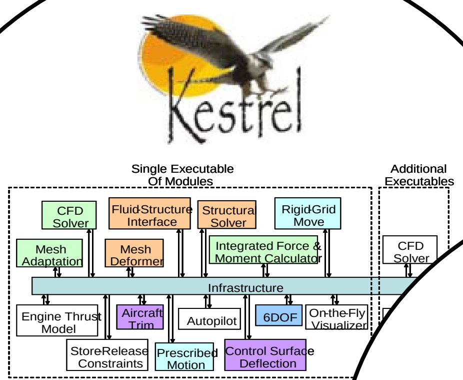
The Key

Common Interface Built on Reducing Physics Models to Light Weight Algebraic Relations Using High Performance Computing

Recent Breakthrough
CREATE-AV

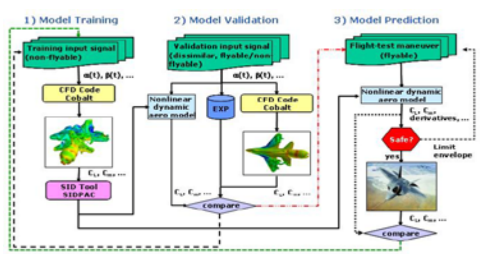
Game Changing Engineering Process Improvement that creates lightweight algebraic models from hi-fi simulations

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

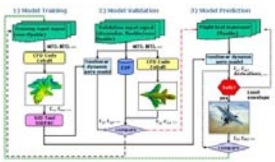
Interchangeable analog and digital inputs

Conceptual Design
- Early discovery of nonlinear aerodynamic issues
- Nonlinear aero surface loads for conceptual structural design
- Nonlinear aero loads for flight control law development

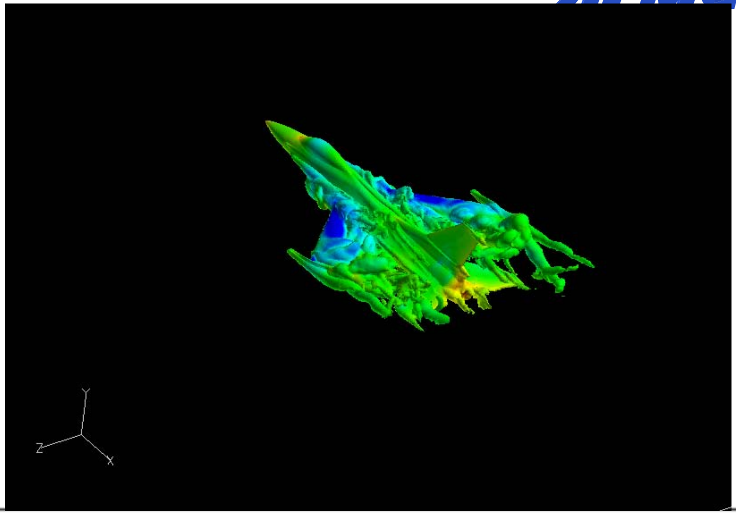
Detailed Design
- Evaluation of aerodynamics from outer mold line (OML) changes
- Updated nonlinear aerodynamic surface loads for changed OML to evaluate structural design
- Nonlinear loads for flight control law refinement with detailed control surfaces

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

System Identification Model Building



Example Game Changing Process

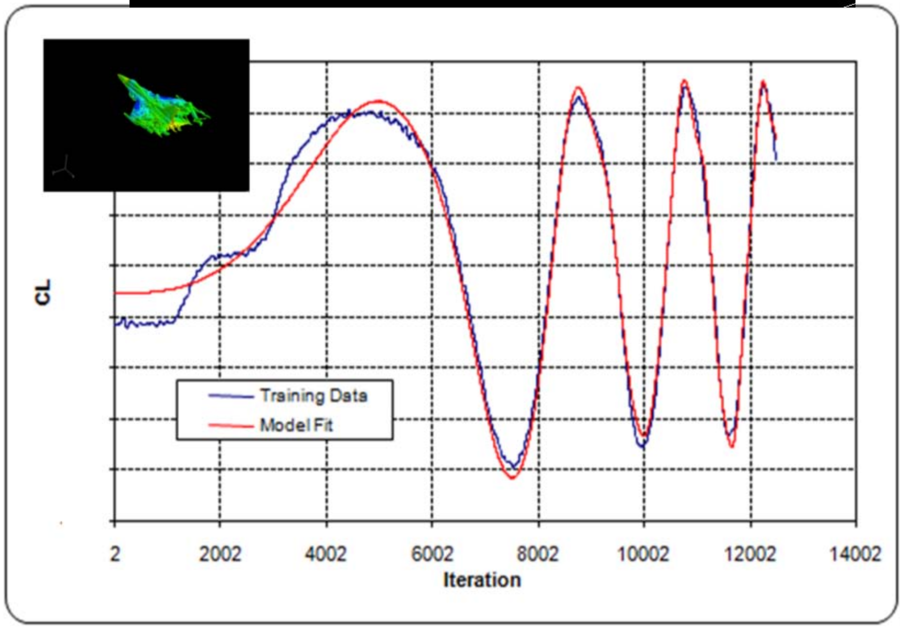


- **Compute a maneuver at a particular flight condition (only need OML)**
- **Knowing input angles, rates and output loads, allows an algebraic model to fit to the data**

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

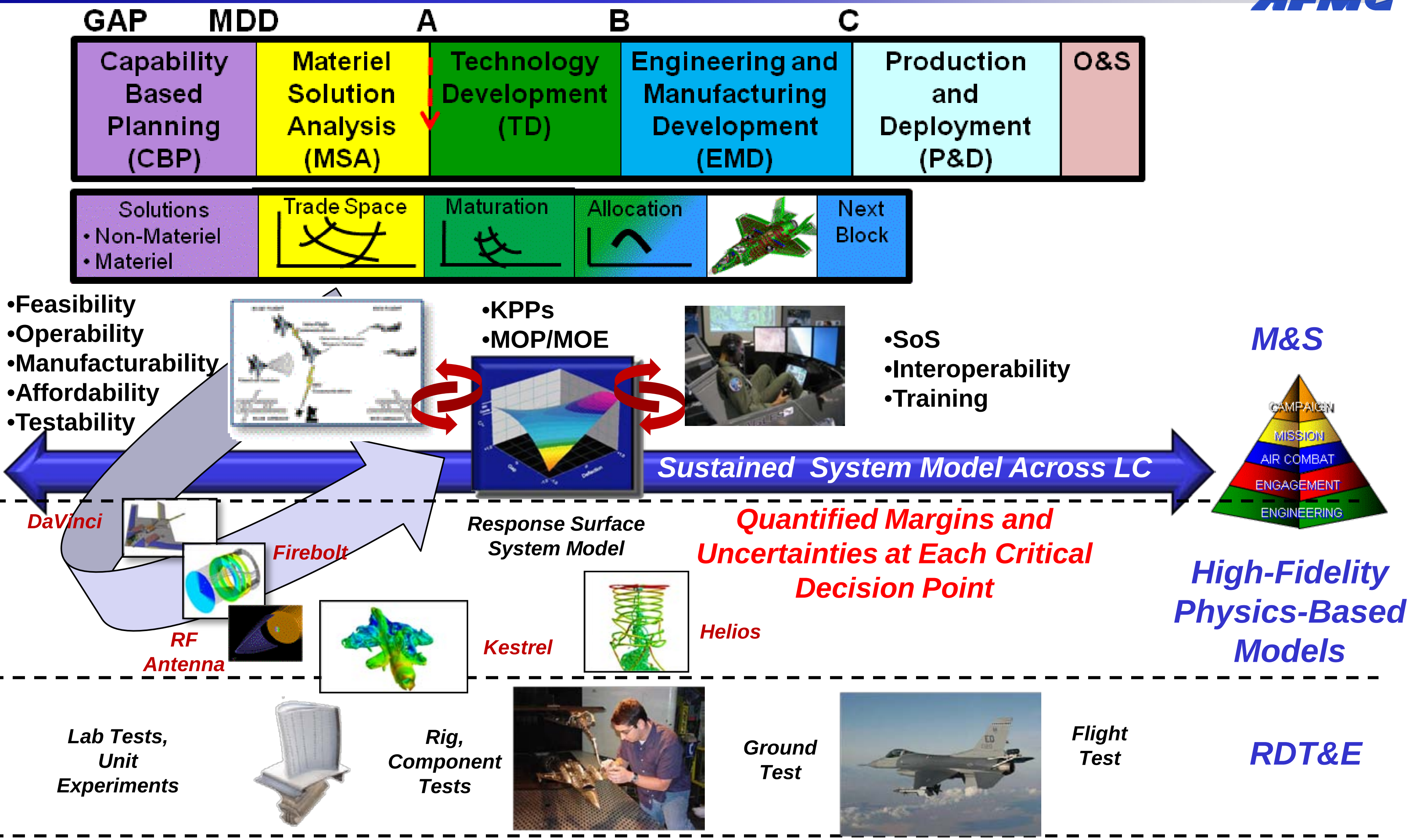
$$+ C_8\dot{q}q + C_9\alpha^3 + C_{10}\dot{q} + C_{11}\dot{q}^3 + C_{12}\dot{q}^2 + C_{13}q^2 + C_{14}q\alpha$$

- **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***



Effects Based Systems Engineering

Integrating M&S, RDT&E, and Statistical Engineering



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

Summary

- CREATE-AV is already embedded in AF, Army, and Navy – numerous shadow-ops and pilot projects validating capabilities and demonstrating value
- CREATE-AV being applied to ERS pilot demonstration for improved AoA process
- Much work yet to be done on impacting other system life cycle processes
- Transition of CREATE-AV to a government/industry consortium for long term sustainment and deployment just getting started

Contact me at edward.kraft@arnold.af.mil