CREATE-AV DaVinci

Informed Systems Engineering Decision Making for DoD Acquisition

07 November 2012
NDIA – Physics Based Modeling

Gregory L. Roth – DaVinci Principal Developer
Wright-Patterson AFB, AFLCMC/XZE
Gregory.Roth@WPAFB.af.mil
(937) 904-5872
http://create.hpcmo.hpc.mil

Outline

- DaVinci Vision/Business Model
- DoD Acquisition Problems Impacted
- DaVinci 2.0/3.0 Capabilities
- DaVinci Roadmap
- Recent Examples and Prototypes
- Conclusion

0110
01010
1100100
010111001

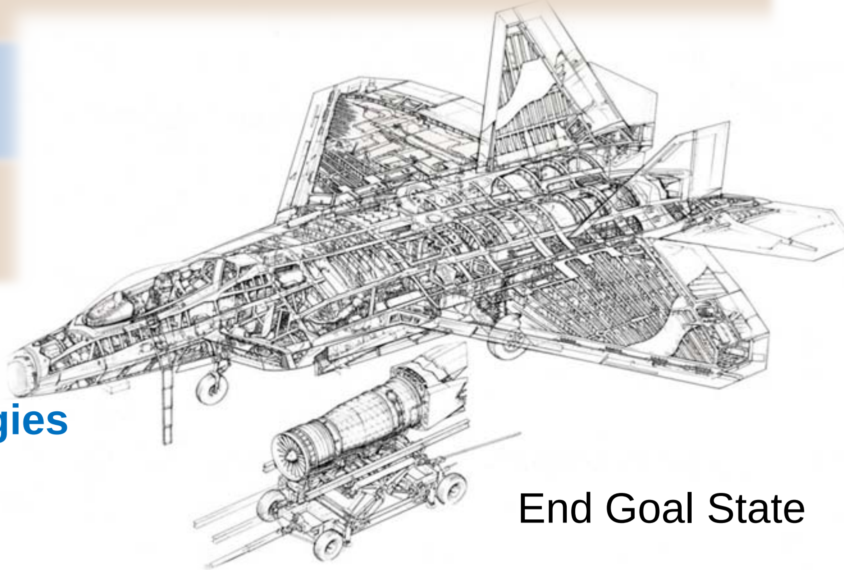
DaVinci Vision

Release
1.0
2.0
3.0

DaVinci

Computational Research and Engineering for Acquisition Tools and Environments

- Bring state-of-the-art **multi-disciplinary**, **multi-fidelity**, coupled physics, **model-based engineering** (MBE) tools to common engineers
- Provide a seamless, **extensible**, **flexible**, **systems engineering infrastructure** spanning the **full aerospace system lifecycle** from requirements generation through sustainment
- Generate **high quality, mesh-able geometry** for CFD/CSM tools
- Explore, optimize, and understand the **system trade-space** and tradeoffs in support of **decision making** at all levels
- Enable effective conceptual studies, **uncertainty quantification**, and **sensitivity analysis**
- Enhance **cooperation** across geographically distributed teams
- Enhance aerospace systems requirements definition and KPPs
- Evaluate benefit of new or **innovative technologies**
- Assess **impacts** of requirements on vehicle **capability**



End Goal State

DaVinci enables model-based engineering and informed decision making with high performance computing

0110
01010
1100100
010111001

DaVinci Business Model

- Seamless integration of HPC resources and network cloud computing into engineers' models
- Unified system modeling - a system model centric approach
- Standards based Systems Engineering Architecture:
  - FOUO, proprietary, & ITAR knowledge reside in the components and services which are restricted and controlled
  - Portable parametric components & services
- Built in core systems engineering functionality
- Development, refactoring, & wrapping of aerospace design and analysis components & services

0110
01010
1100100
010111001

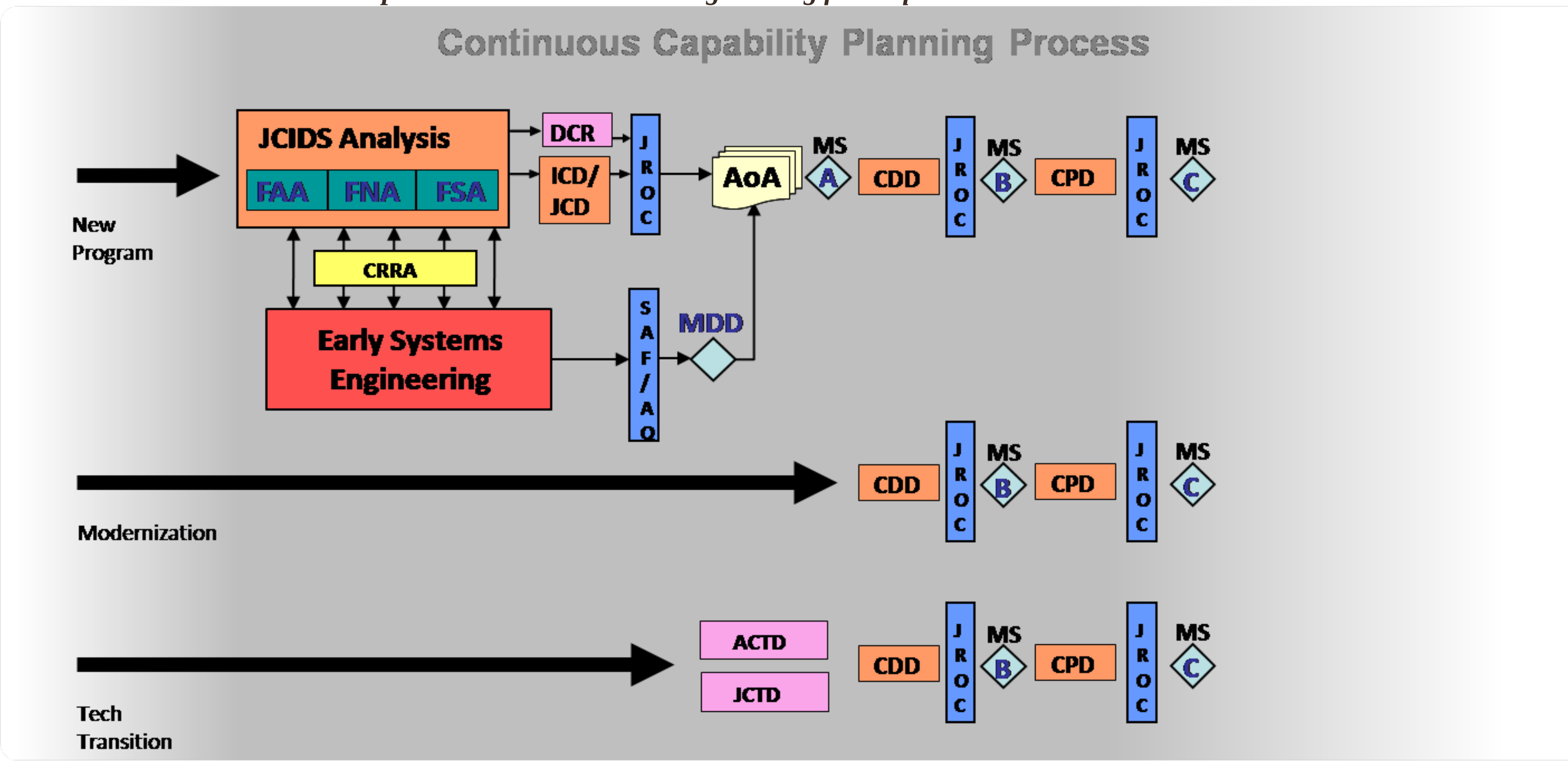
DaVinci eases engineering burden of using HPC

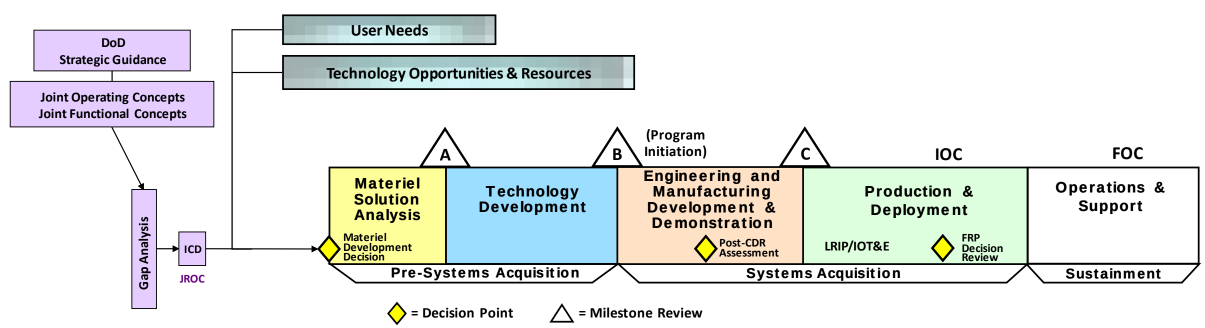
CREATE-AV

Differing Acquisition Entry Points

DaVinci

Computational Research and Engineering for Acquisition Tools and Environments





0110
01010
1100100
010111001

CREATE-AV

DaVinci Focus

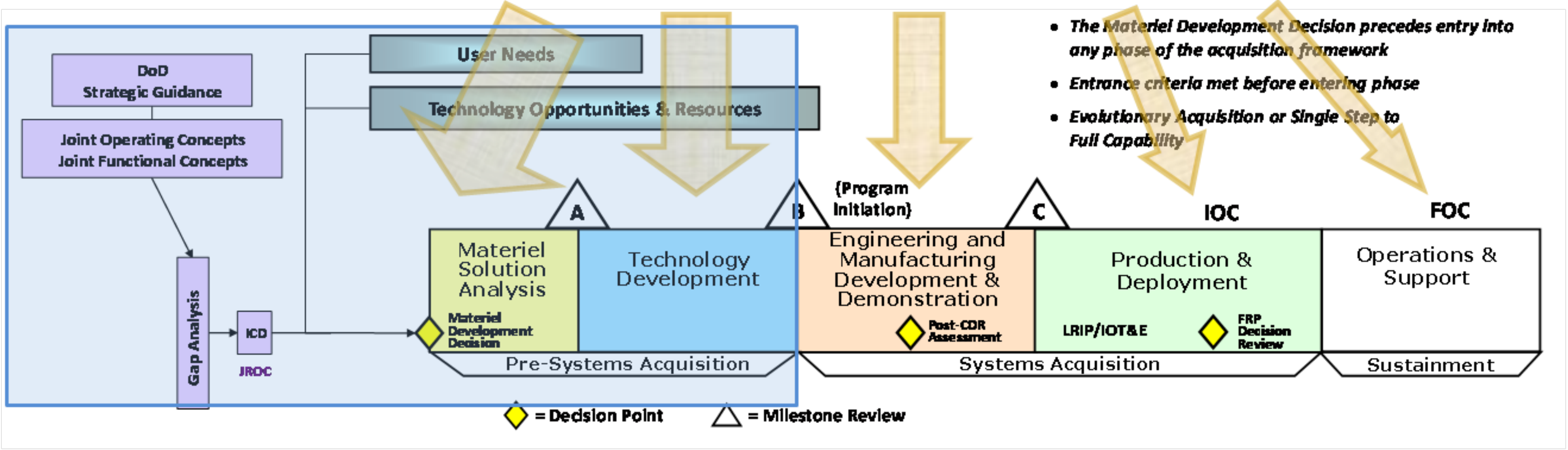
DaVinci

Computational Research and Engineering for Acquisition Tools and Environments

DaVinci Principal Focus

STRENGTHEN ENGINEERING & TEST EFFORTS BY INJECTING COMPUTATIONAL RESEARCH & ENGINEERING FOR ACQUISITION TOOLS & ENVIRONMENTS (CREATE)

DaVinci Architecture needs to span the full life cycle



DaVinci focuses on early acquisition where payoff is the highest while supporting the full acquisition lifecycle

0110
01010
1100100
010111001

DaVinci Impacts

Requirements Determination

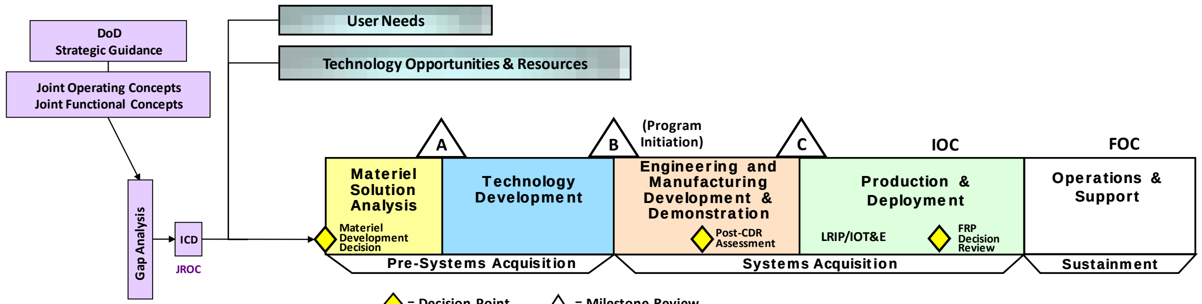
Pre-JCIDS through MS-B, *DaVinci* helps the user:

- Understand the DOTMLPF trade-offs
- Set necessary concepts of operations
- Ensure a quick and preferred materiel solution

Analysis of Alternatives

Given a materiel solution, *DaVinci* allows stakeholders to:

- Quickly understand trade-offs
- Compare types and classes of system solutions



DaVinci Impacts, cont.

Computational Research and Engineering for Acquisition Tools and Environments

Systems Design & Trade Studies

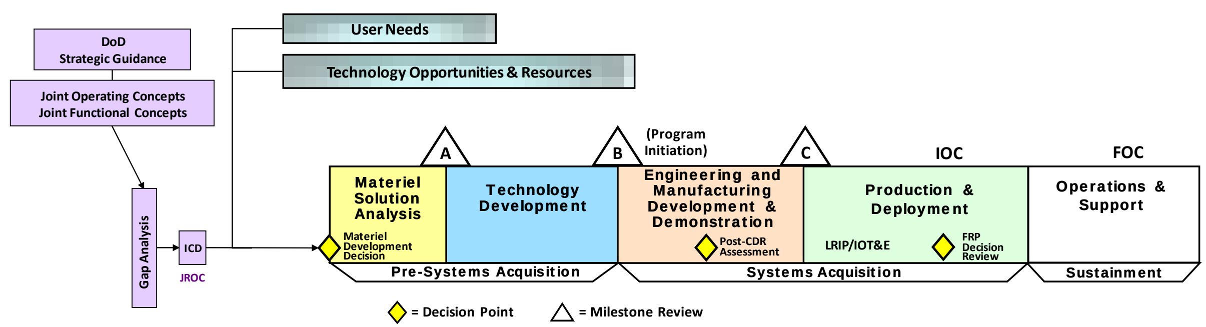
For pre MS-A design efforts, *DaVinci* enables:

- Model persistence through a unified systems model
- Seamless transition through various fidelity levels
- Better understanding of the trade space
- Reduced user subject matter expertise requirements

Decision Making

DaVinci supports and improves intelligent decision making by:

- Giving users the right information at the right time
- Building confidence levels to enable fully informed decisions



0110
01010
1100100
010111001

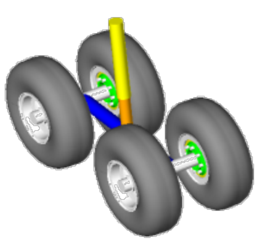
DaVinci 2.0

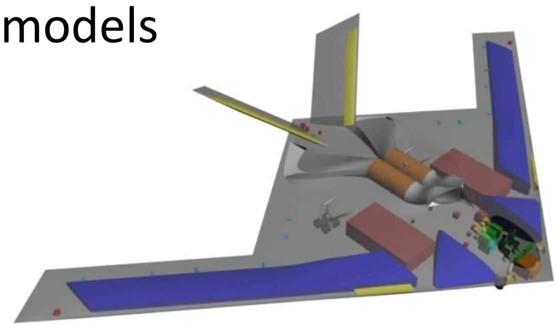
Computational Research and Engineering for Acquisition Tools and Environments

DaVinci 2.0 enables:

available Q1 CY2013

- Parametric execution of a unified system model to support design space exploration
- Uncertainty quantification and sensitivity analysis to better understand the design space
- Internal component layout to locate and size major internal components for volume and point mass distributions
- Initial conceptual design capability with system performance (Breguet based) calculations based on low-fidelity aerodynamic (AVL), structural (mass properties), stability & control, and propulsion (engine decks) models





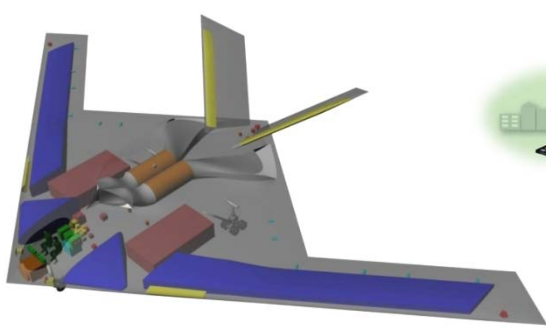
0110
01010
1100100
010111001

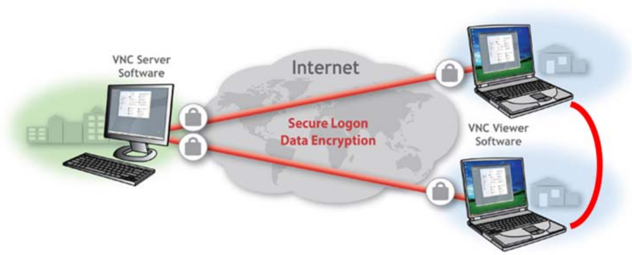
DaVinci 3.0

DaVinci 3.0 enables:

available Q4 CY2013

- Unified system model sharing between agents using multi-level security model for access control and information assurance
- Decision support with uncertainty quantification and sensitivity analysis to fully understand design space characteristics
- Internal component layout to locate and size internal components for volume and mass distributions
- Multi-fidelity system performance calculations and correlations with aerodynamic, structural, stability & control, and propulsion models





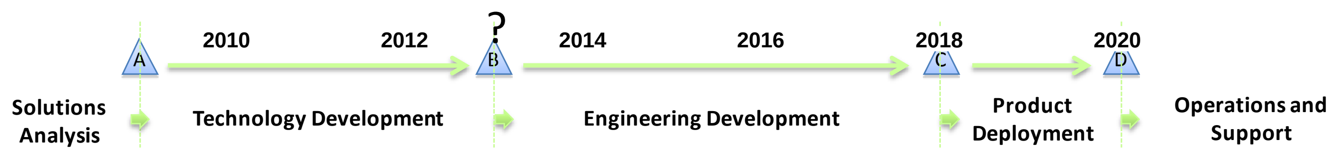
0110
01010
1100100
010111001

Approved for public release; case number 88ABW-2012-5572, on 18 Oct 12.

DaVinci Product Roadmap

Computational Research and Engineering for Acquisition Tools and Environments

Red text indicates current focus areas for *DaVinci*

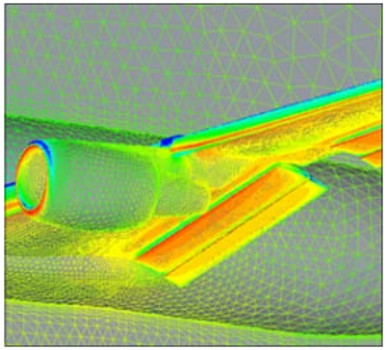


1) Build associative engineering models of fixed and rotary wing aircraft from pre-engineered components resulting in meshable, NURBS-based surface geometry.
2) Systems engineering Integrated Development Environment (SIDE) for engineering model building, sensitivity analysis and uncertainty quantification, complete air vehicle design, seamless transition from conceptual design to preliminary/detailed level analysis (e.g., *Kestrel* and *Helios*).
3) Enhanced user functionality to rapidly develop new components, modify existing models, define internal structure and subsystem layout, and perform trade space exploration; capability additions include component visualizers and editors, simple GUI builders, built-in user feedback, multi-level security, and training material.
4) Next generation pre-engineered components including more detailed control surfaces, more user control of cross-sectional shapes, and improved surface intersections & fillets. Other enhanced capabilities include multi-fidelity model correlation, model persistence and information extraction, and wrappers for legacy C/C++ and Fortran codes for use in *DaVinci*.

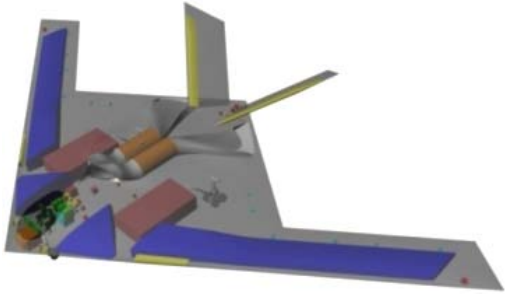
DaVinci End State

Computational Research and Engineering for Acquisition Tools and Environments

Sustained *DaVinci* product capability



- Unified life-cycle systems engineering modeling environment
- Advanced, multi-fidelity conceptual design and analysis
- Fully parameterized, high quality, mesh-able geometry for CFD & CSM
- Rapid development iterations for:
  - Requirements traceability
  - Detailed physics-based systems representations
  - High-fidelity models suitable for early preliminary design
- Fully integrated with other CREATE products for preliminary/detailed level analysis
  - CREATE-MG Capstone for geometry generation and meshing
  - CREATE-AV Kestrel/Firebolt for fixed wing analysis
  - CREATE-AV Helios/Firebolt for rotary wing analysis
  - CREATE-RF SENTRI for avionics design and analysis
- Adopted by, used, and extended by large Government, Industrial, and Academic communities



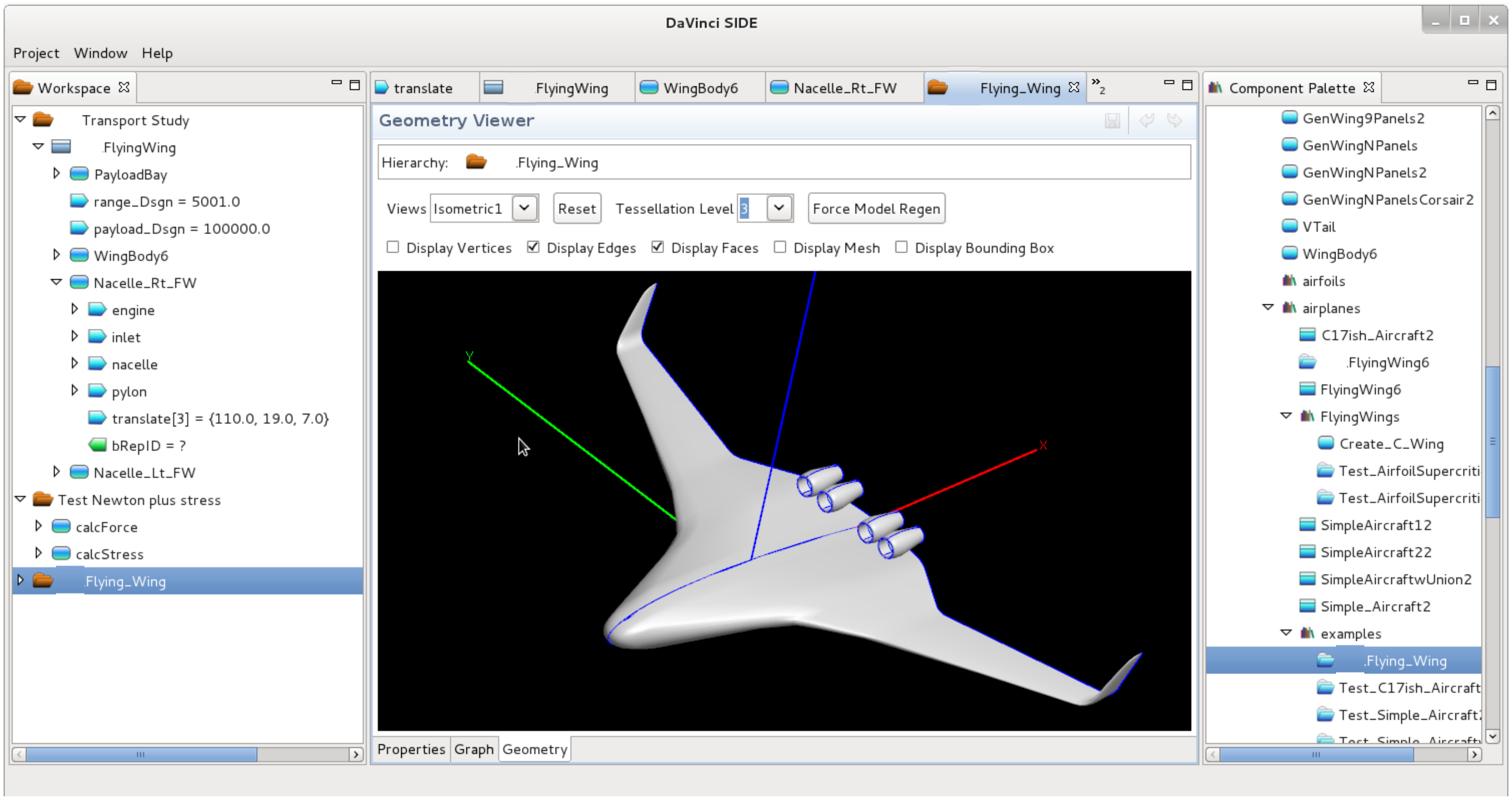
Approved for public release; case number 88ABW-2012-5572, on 18 Oct 12.

CREATE-AV

DaVinci Geometry

Computational Research and Engineering for Acquisition Tools and Environments

Use of the geometry viewer within *DaVinci* provides a visual model of the system to the user

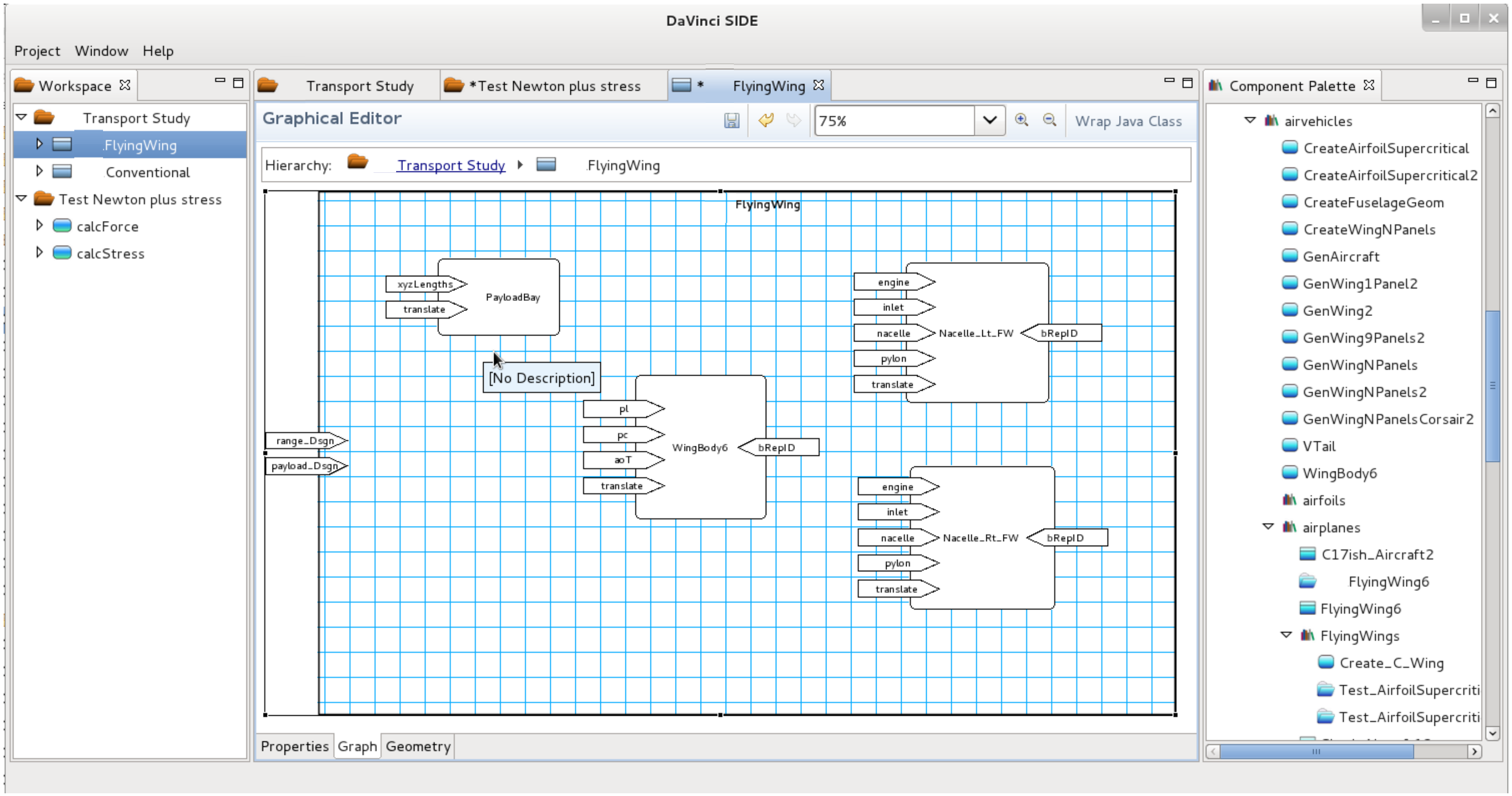


0110
01010
1100100
010111001

DaVinci Sub-Systems

Computational Research and Engineering for Acquisition Tools and Environments

Use of the graphical model within *DaVinci* allows the user to easily see sub-system parts and interactions between those parts

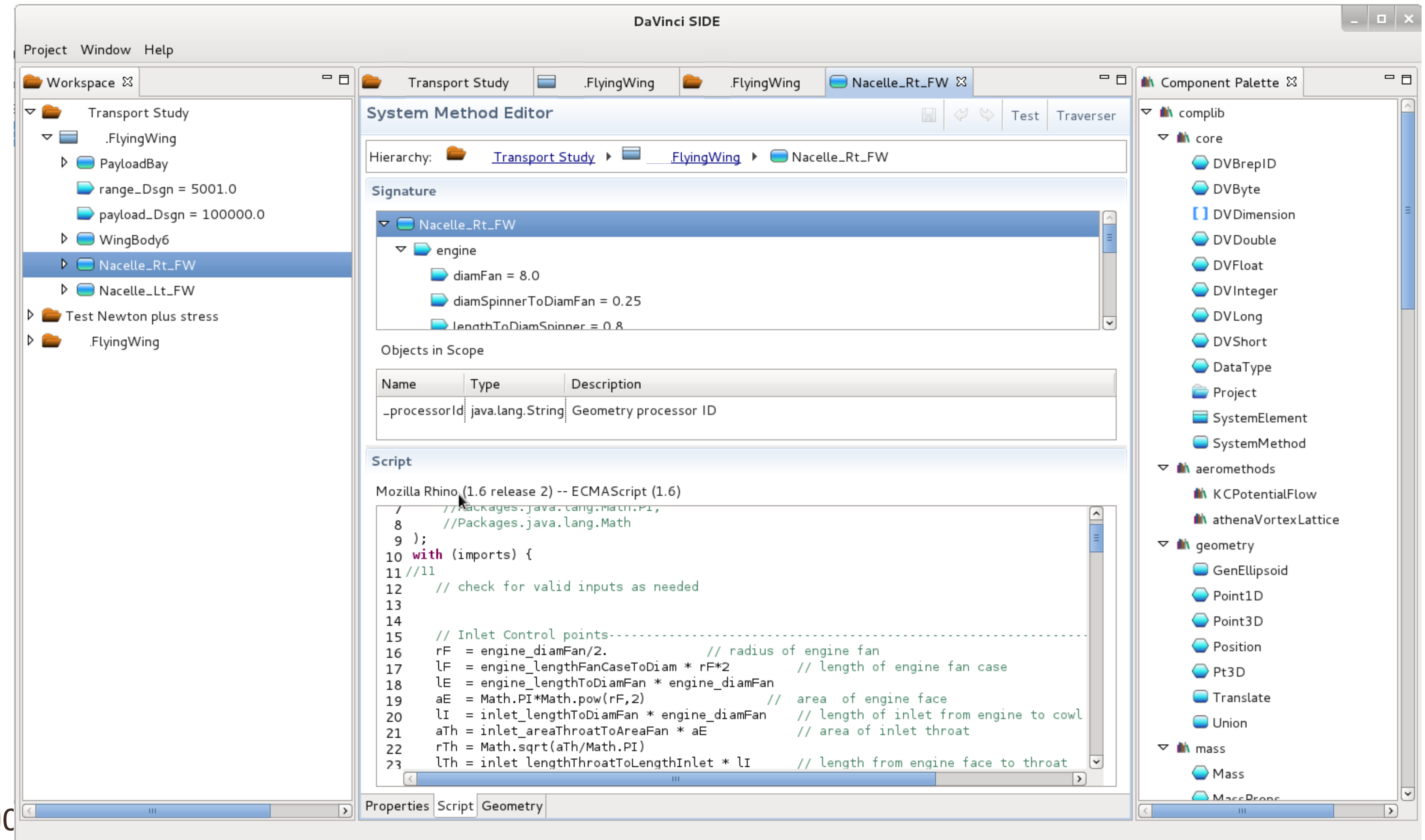


0110
01010
1100100
010111001

DaVinci Extensibility

Computational Research and Engineering for Acquisition Tools and Environments

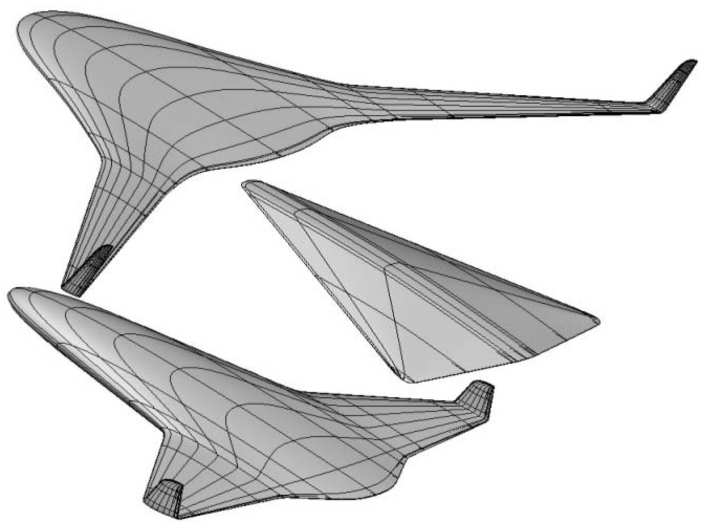
Use of the scripting engine within *DaVinci* allows the user to infinitely extend *DaVinci* capability for any systems problem



Kestrel Integration

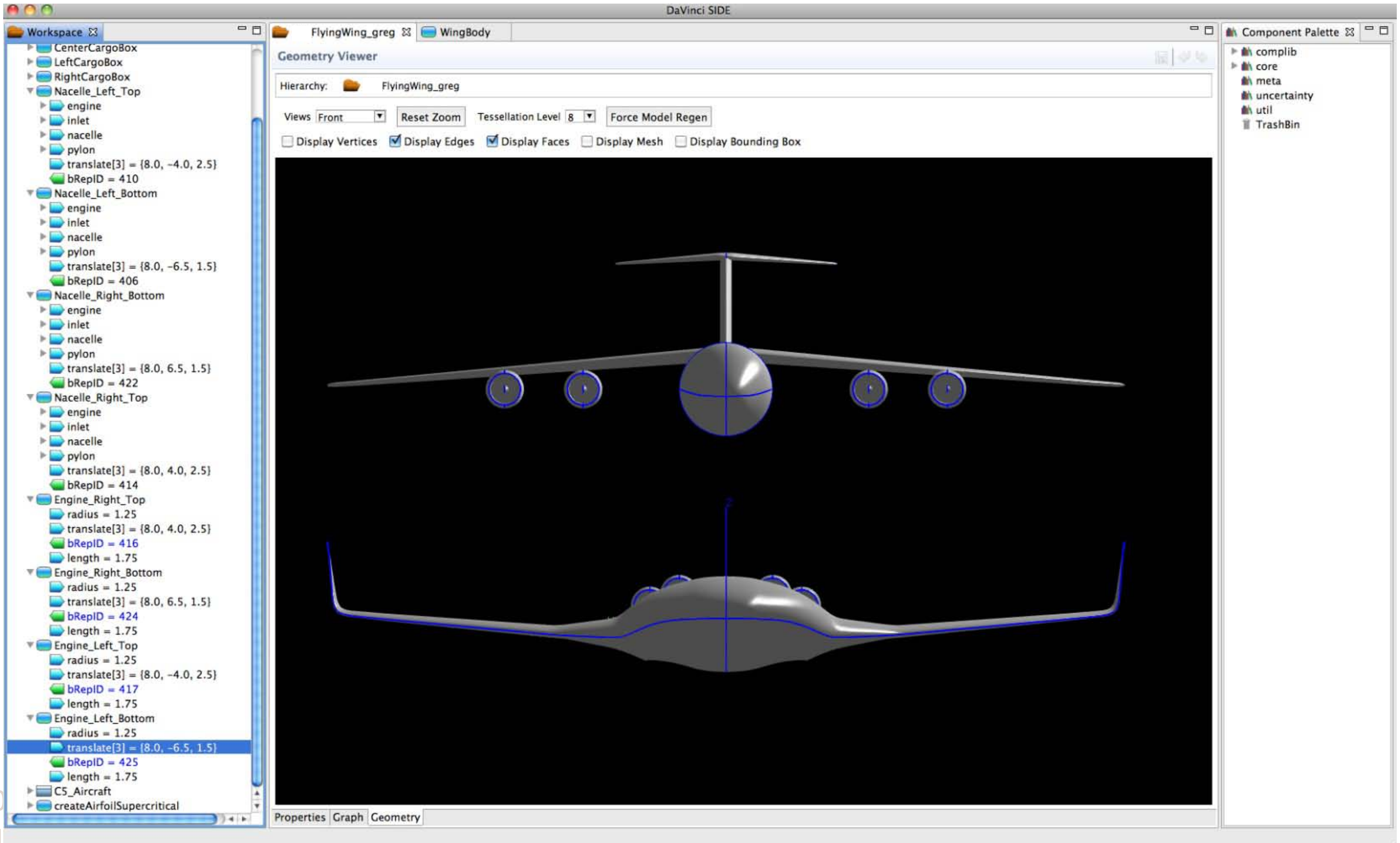
Kestrel use by DaVinci

1. Create water tight OML geometry in *DaVinci*
2. Pass OML geometry to *Capstone* for grid generation
3. Pass grid to *Kestrel* for static & dynamic analyses
    - Static rigid aircraft
    - Rigid single body prescribed motion
4. Pass *Kestrel* analyses in coefficient, force, moment form to *DaVinci*
5. Integrate *Kestrel* results for use in *DaVinci*



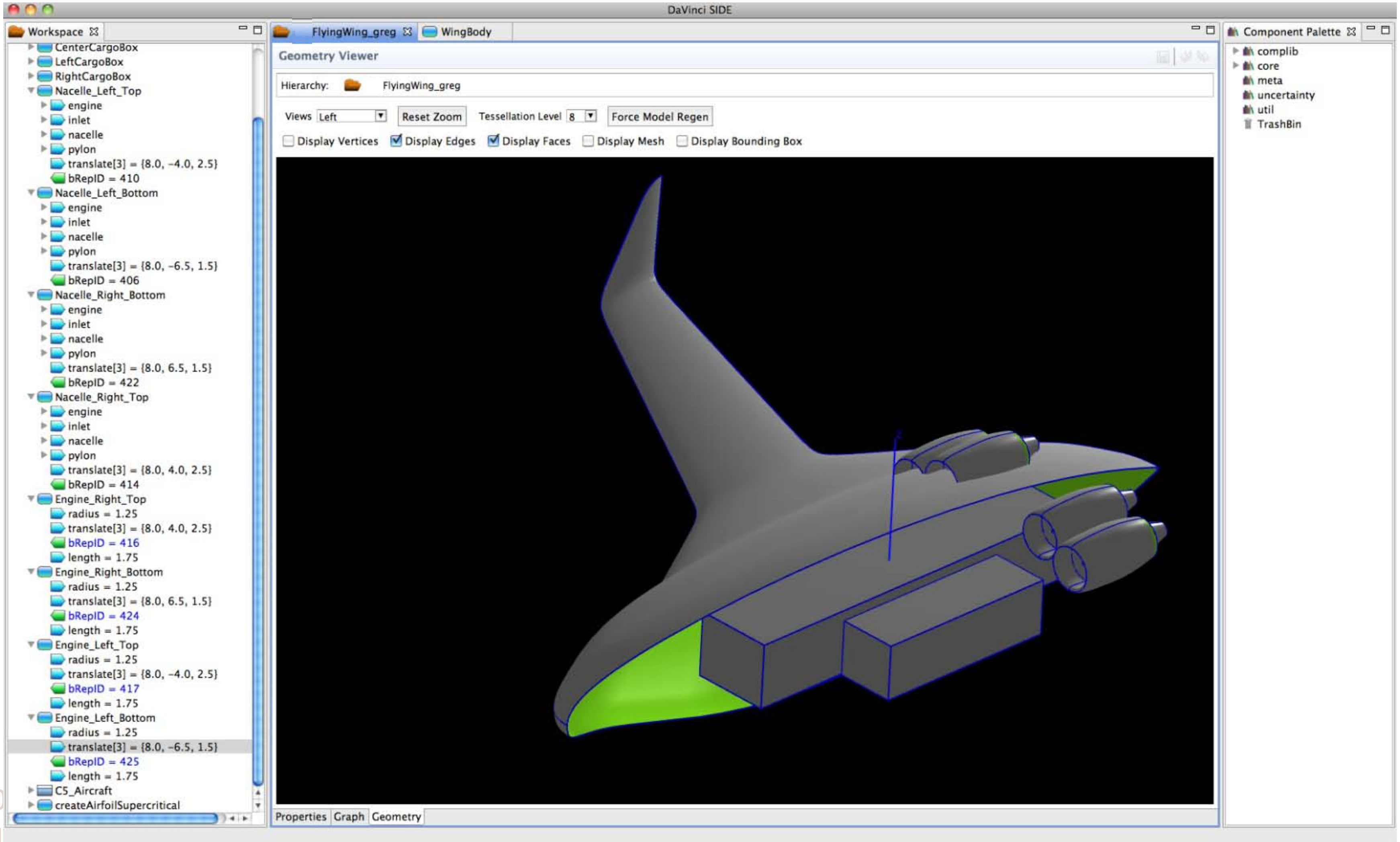
Engine & Inlet Placement

Computational Research and Engineering for Acquisition Tools and Environments



Flying Wing (Cargo View)

Computational Research and Engineering for Acquisition Tools and Environments

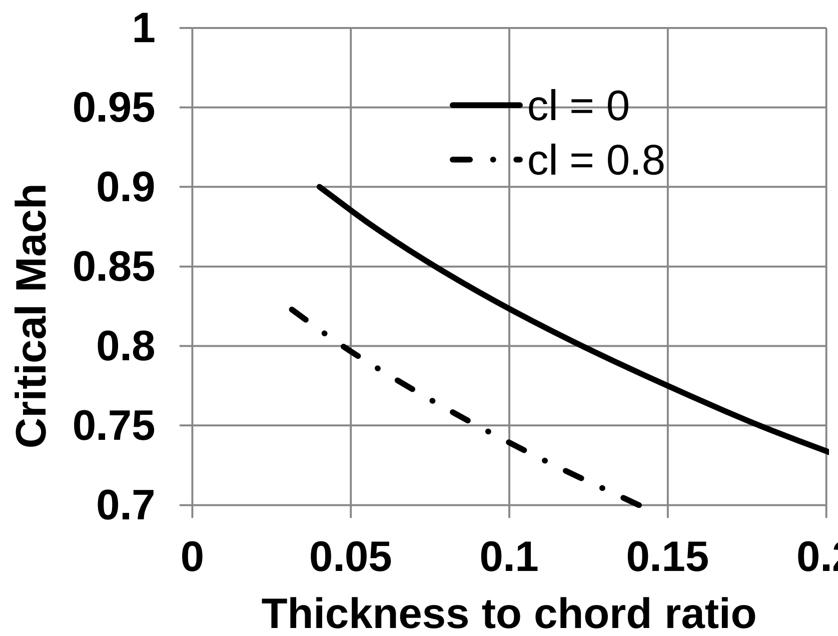


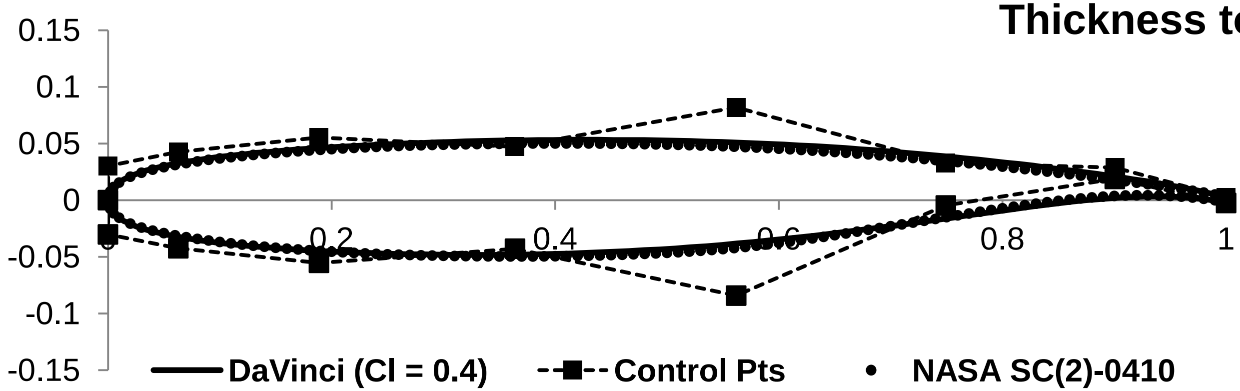
0110
0101
1100100
010111001

Approved for public release; case number 88ABW-2012-5572, on 18 Oct 12.

DaVinci Parametric Supercritical Airfoil Family & Performance Estimates

- **Supercritical airfoil family**
  - **Thin airfoil theory gives max cl limit (t/c = 0), 'point design'**
  - **NASA SC(2) symmetric airfoils give max thickness limit (cl = 0)**
  - **DaVinci family of supercritical airfoils span the design space**



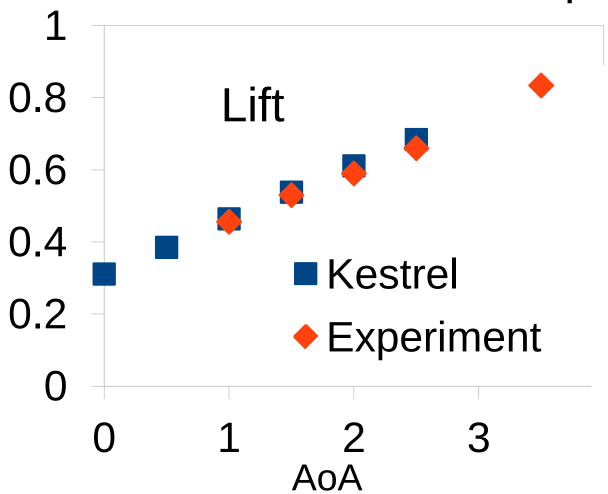


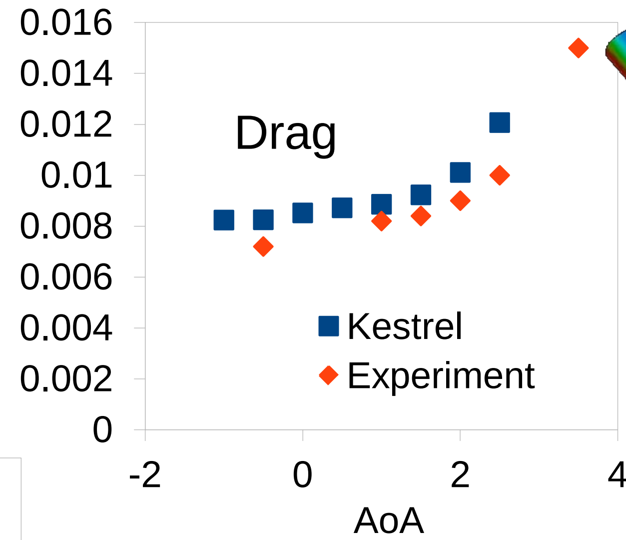
***DaVinci* supercritical airfoil family developed under pilot project**

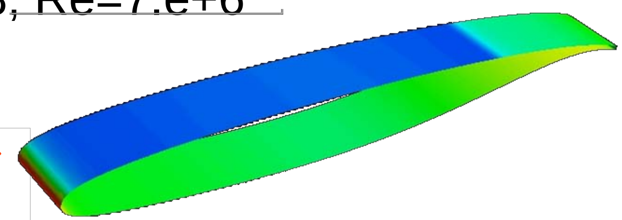
Kestrel Airfoil High-Speed Validation

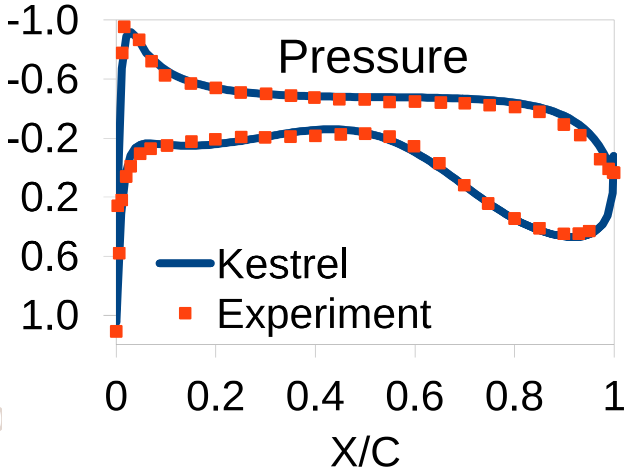
Computational Research and Engineering for Acquisition Tools and Environments

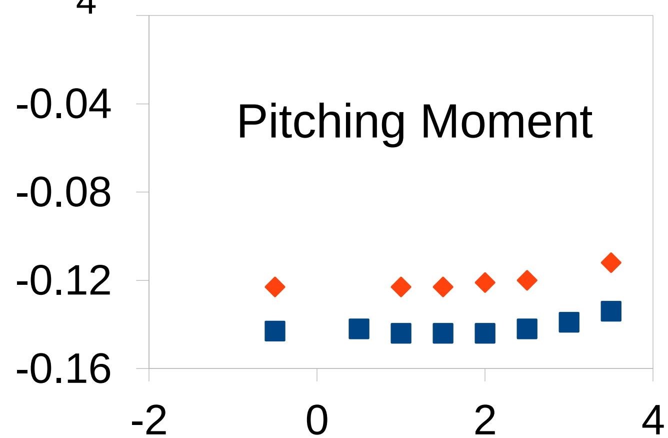
NASA Supercritical Airfoil 26a, Mach 0.68, Re=7.e+6





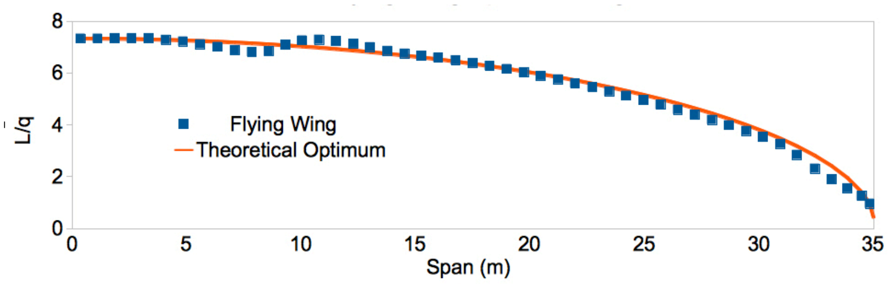






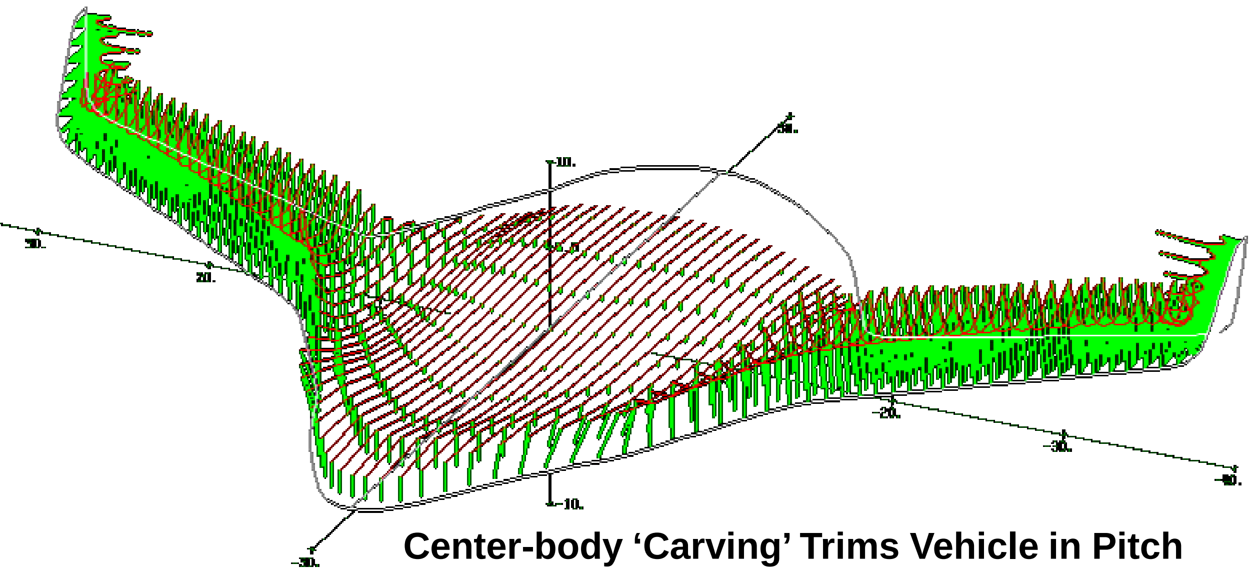
Excellent agreement between Kestrel & Experiment

Airfoil, Wing, Center-Body Design

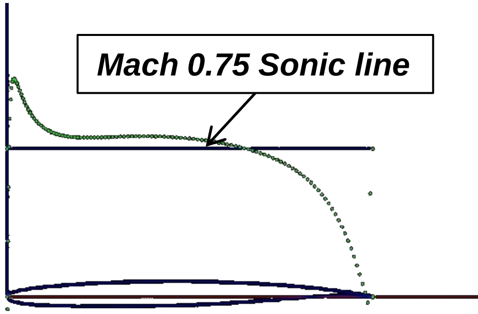


Optimal 'Elliptic' Span Loading at Cruise

- **Aerodynamic performance**
  - **Explored trimmed aero performance**
    - **Planform, and airfoil effects**
    - **Center-body shaping for trim & efficient cruise**



Center-body 'Carving' Trims Vehicle in Pitch

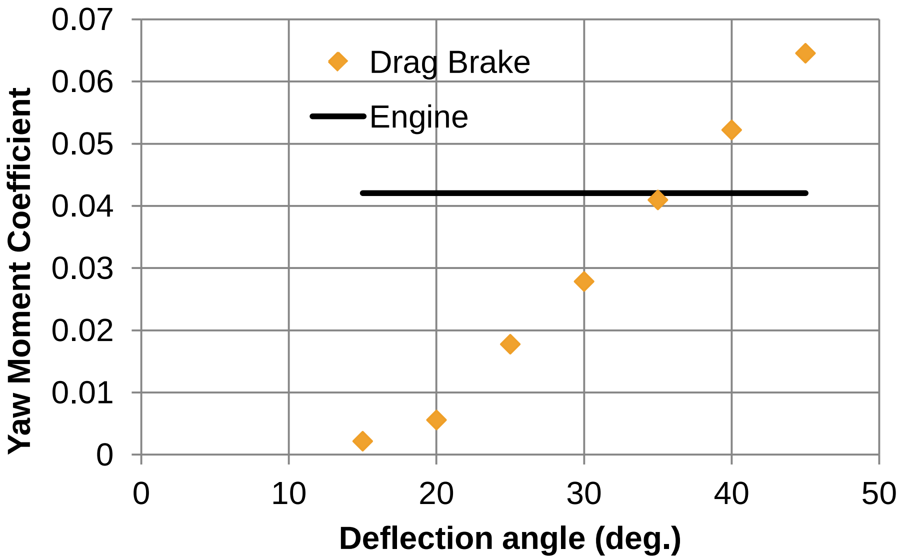


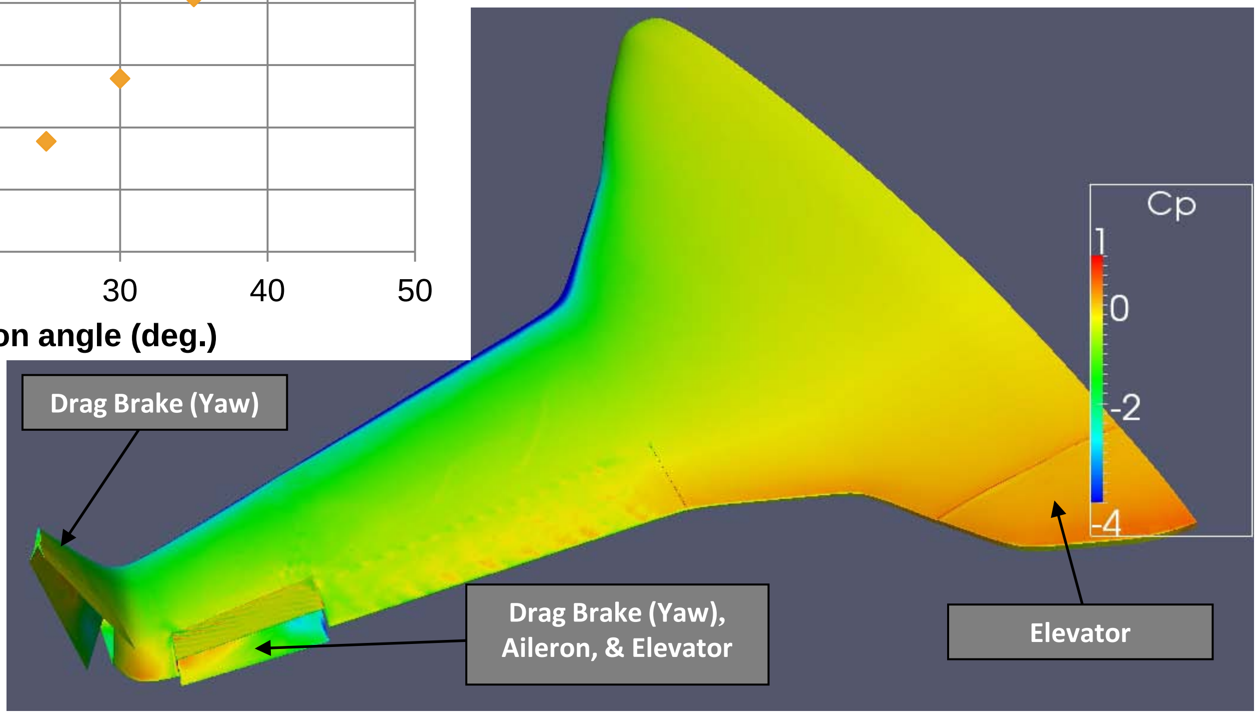
Estimation of Cruise Mach

In-house, CREATE, & Academic Codes were Employed

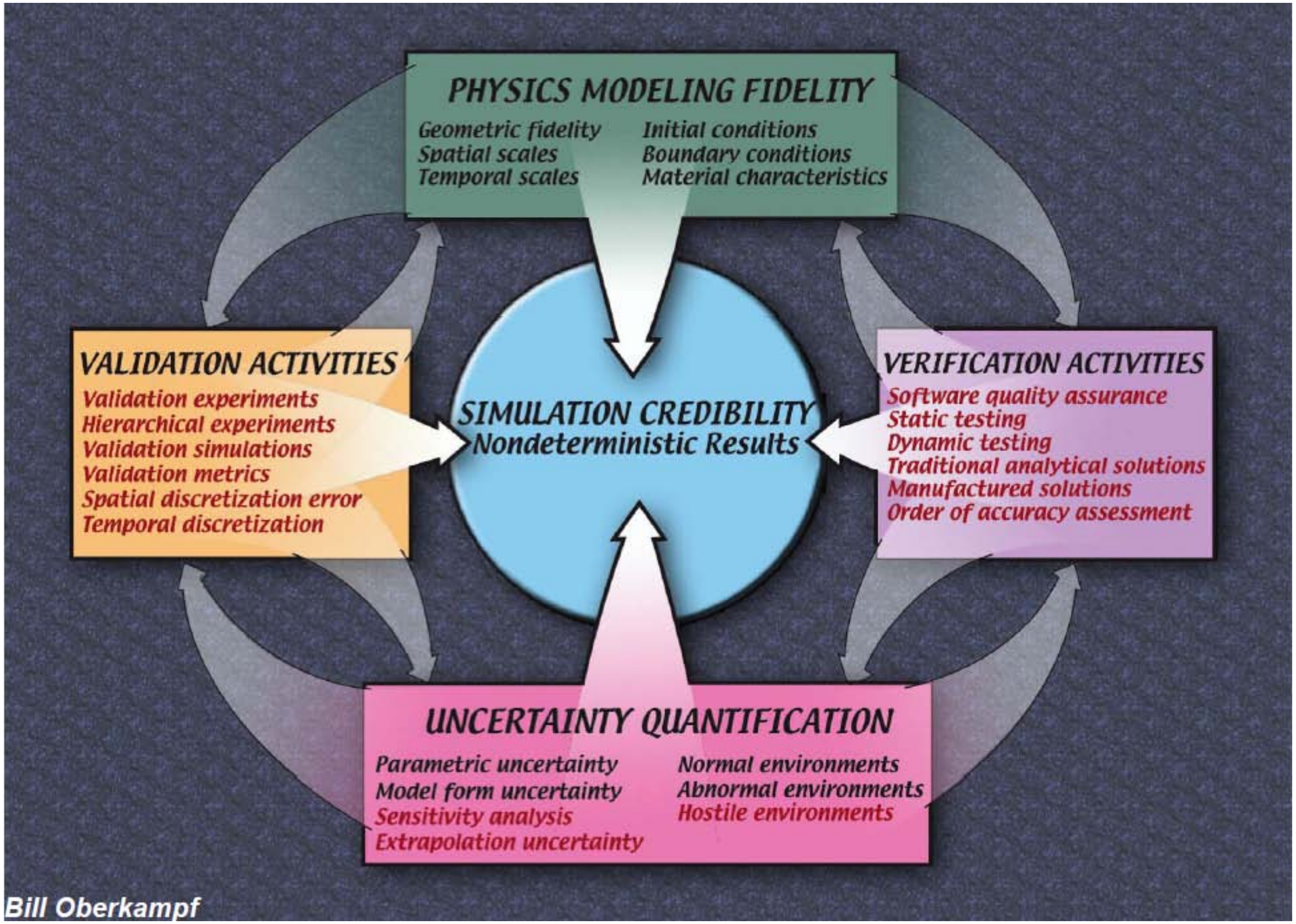
Single Engine Out

- Adequate yaw control with drag brakes
- Drag penalty needs further study





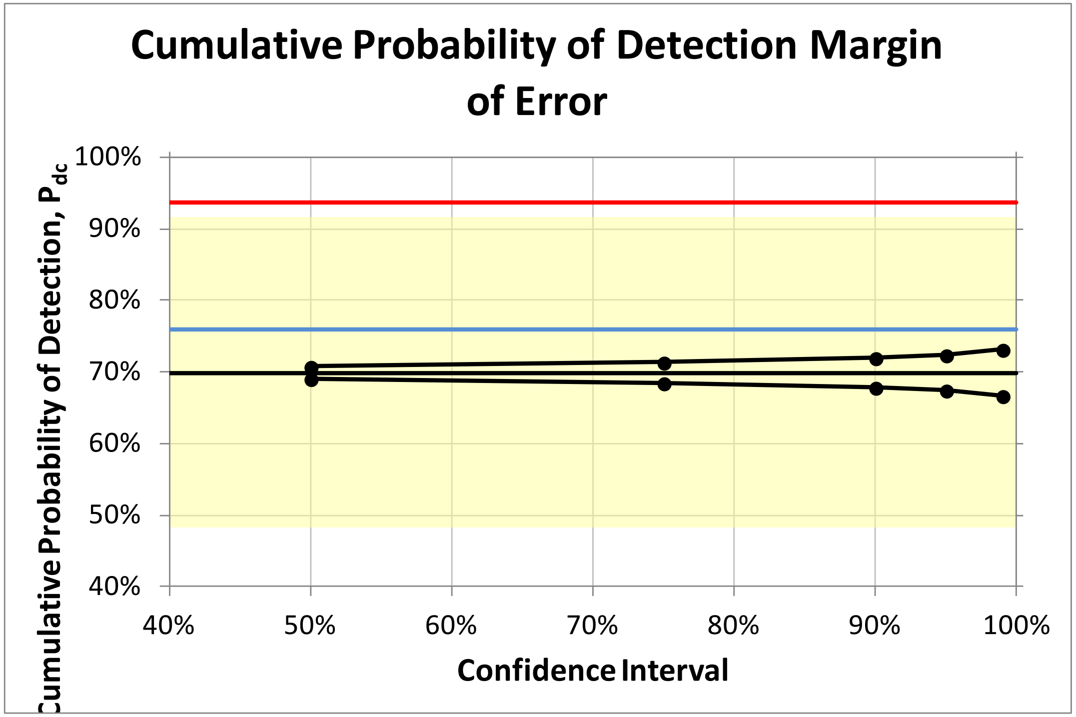
SA/UQ Motivation



Responsible engineering modeling and credible systems simulation

Radar Model Example

- Original set of inputs gives a cumulative probability of detection, P_{dc}, estimate 34.0% high compared to the population mean (red line)
- Using the mean values of all the inputs results in a P_{dc} estimate 8.5% high compared to the population mean (blue line)



- For a 95% confidence interval, using the mean values of all the inputs still gives an estimate of P_{dc} 12.5% high

Approved for public release; case number 88ABW-2012-5572, on 18 Oct 12.

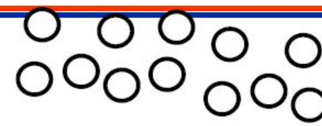
Radar Observations

- Calculations based on a **single application** of the engineering models may give favorable, but **unlikely results**, P_{dc} = 93.7%
- **Sensitivity analysis** can highlight the input parameters that **drive system performance**
- **Uncertainty quantification** can help establish **greater understanding** of both the system being modeled as well as the quality and appropriateness of the model
- **Model choice** and approximating functions (use of the complementary error function in the radar example) can greatly impact results and give **misleading information**
- 95% confidence interval cumulative probability of detection, P_{dc} = 67.5% based on distributions with a mean P_{dc} = 75.9%

Engineered Resilient Systems

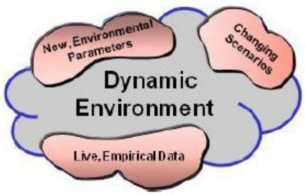
Engineered Resilient Systems
Key Technical Thrust Areas

Systems Representation and Modeling



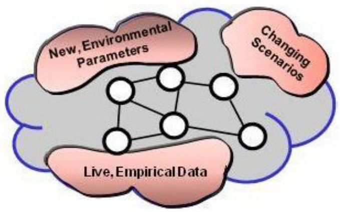
– Capturing physical and logical structures, behavior, interaction with the environment, interoperability with other systems

Characterizing Changing Operational Contexts



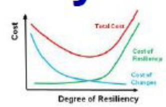
– Deeper understanding of warfighter needs, directly gathering operational data, better understanding operational impacts of alternative designs

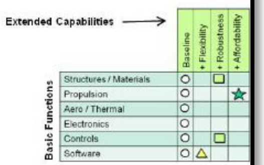
Cross-Domain Coupling



– Better interchange between "incommensurate" models
– Resolving temporal, multi-scale, multi-physics issues across engineering disciplines

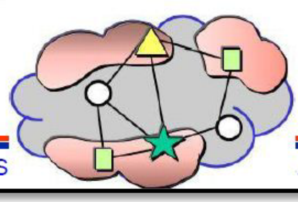
Data-driven Tradespace Exploration and Analysis





– Efficiently generating and evaluating alternative designs, evaluating options in multi-dimensional tradespaces

Collaborative Design and Decision Support



– Enabling well-informed, low-overhead discussion, analysis, and assessment among engineers and decisionmakers

ERS PSC,Overview
31 Octoberr 2011 Page-16

Distribution Statement A – Cleared for public release by OSR on 10/31/2011, S

Approved for public release; case number 88ABW-2012-5572, on 18 Oct 12.

Opportunities for Engagement

Specifying requirements and building models:

- *DaVinci* concept built from inputs from Government, Industry, and Academia
- Initial focus of *DaVinci* software suite on DoD acquisition
- Opportunities for companies with Government contract(s) to request CREATE tools with Government need justification
- Component library model (pre-engineered parts) development open to *DaVinci* users
- Models with re-use and/or sharing potential can be submitted to *DaVinci* Team for consideration to be distributed with future *DaVinci* releases

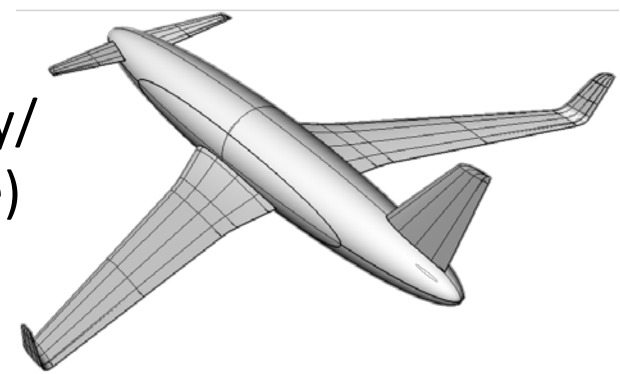
Using *DaVinci* for system studies:

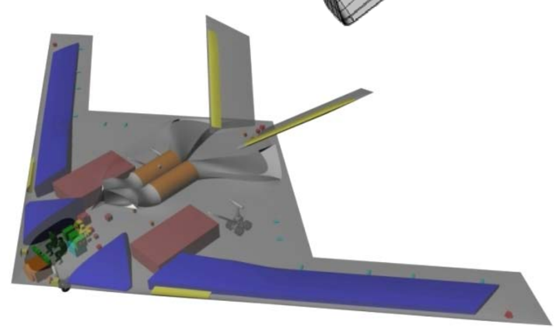
- Initial capability for generating CFD mesh-able outer mold lines ready
- Simple air vehicle performance models can be used now
- Uncertainty quantification/sensitivity analysis to support decision making available
- Some discussion for future CREATE use in RFP responses and source selection
- *DaVinci* is infinitely extensible for any engineering problem

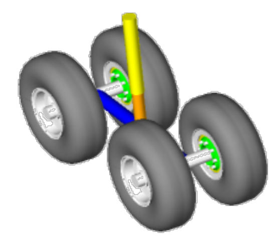
http://create.hpcmo.hpc.mil

DaVinci Summary

- Must enable the use of HPC in early phase DoD acquisition by providing **multi-disciplinary**, **multi-fidelity**, **computationally based systems engineering design** tool sets
- Must rapidly produce high quality **parametric associative mesh-able geometry** & **system models** for design space exploration to support **decision making**
- Must enable **model propagation** to preliminary/ detailed design (Kestrel and Helios for example)
- Must enable user **uncertainty quantification** and **sensitivity analysis** to support confidence in decision making process







0110
01010
1100100
010111001

CREATE DaVinci 2.0

release Q1

CY2013

Physics-based engineering
for rapid design

http://create.hpcmo.hpc.mil