DaVinci

Computationally Based Engineering for Conceptual Design

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NDIA - Physics Based Modeling

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Outline

Computational Research and Engineering for Acquisition Tools and Environments

- What is CREATE?
- Why DaVinci?
- Expected Users/Business Model
- DaVinci 1.0 Capabilities
- DaVinci 2.0 Capabilities
- DoD Acquisition Problems Impacted
- DaVinci Roadmap
- Summary

Why?

Computational Research and Engineering for Acquisition Tools and Environments

Typical Characteristics Today

- The evaluation of numerous alternative concepts to select the “best”
- Begins by gathering needs and setting requirements
- Experience and data extrapolation is often required
- Difficulty arises for unconventional vehicles or extreme missions

Future Challenges

- Will be computationally intensive, multidisciplinary, highly coupled, iterative decision making process
- Will be driven by advancements in supported disciplines resulting in increased modeling complexity
- Will leverage rapid developments of computing technologies and changing landscape
- Will comprise activities conducted in extended enterprise environment
- Will include desire to streamline use of multiple computing assets for efficiency

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What is CREATE?

Computational Research and Engineering for Acquisition Tools and Environments

OSD Program to develop and promote the use of physics-based computational engineering (CE) software tools to:

- Provide the acquisition community the same computational techniques used by the scientific and research communities
  - Investigate larger portion of the design search space
  - Optimize specific performance characteristics
  - Reduce reliance on semi-empirical extrapolations from existing systems
- Provide the capability and capacity to identify design defects earlier in the acquisition process
  - Goal of reducing acquisition time and cost
  - Reduce the number of physical prototypes required for testing

Computational Research and Engineering for Acquisition Tools and Environments

CREATE tools will save money, save time

CREATE Projects

Computational Research and Engineering for Acquisition Tools and Environments

- **Air Vehicles (AV) - Air Force, Army & Navy**
  Aerodynamics, structural mechanics, propulsion, control, …
- **Radio Frequency (RF) Antennas - Air Force, Army & Navy**
  RF Antenna electromagnetics and integration with platforms
- **Ships - Navy**
  Shock vulnerability, hydrodynamics, concept design
- **Mesh and Geometry (MG) Generation**
  Rapid generation of mesh and geometry representations needed by analysis

CREATE tools will support all stages of acquisition

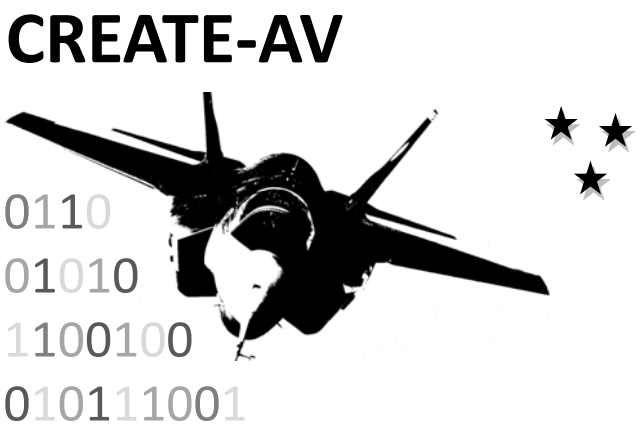
CREATE-AV Mission

Computational Research and Engineering for Acquisition Tools and Environments

Develop & deploy Computationally Based Engineering (CBE) software products that enable…

- **Increased capacity** of the acquisition engineering workforce of the services and industry,
- Reduced workload through **streamlined** and more efficient acquisition **workflows**, and
- **Minimized need for rework** due to early detection of design faults or performance anomalies,

through exploitation of the capacity of next generation computer resources.



CREATE-AV Gap Assessments

Computational Research and Engineering for Acquisition Tools and Environments

Gap Statement 1 – Quantitative Technology Assessments

- Ability to clearly and fully define aircraft requirements and performance metrics is lacking
- Effective conceptual studies (including sensitivity analysis and technology trades) not well enabled
- Impact assessments of key performance parameters on vehicle capability poorly performed
- Physics coupling at proper fidelity level to predict vehicle dynamic responses mostly missing

Gap Statement 2 – Integrated full vehicle physics analysis capability

- Means to test & analyze AIRCRAFT are needed to…
  - Verify vehicle performance
  - Perform flight certification/qualifications
  - Rehearse ground-based and full-scale flight tests
  - Evaluate planned or potential operational use scenarios
- Ground-based or flight test plan evaluation for mission planning/rehearsals not available
- Many legacy tools lack ability to appropriately account for physics coupling
- Most legacy software is not prepared to exploit potential of next-gen computers

Gap Statement 3 – Facilitating environment for CBE application

- Integrated acquisition environment for applying CBE compute resources throughout engineering spectrum does not exist
- Access to compute resources by acquisition community has historically been challenging
- Transitioning design data between phases of acquisition require inordinate amounts of user expertise & human resources or does not happen

CREATE-AV Gap Assessments

Computational Research and Engineering for Acquisition Tools and Environments

Gap Statement 4 – Systems Engineering decision making information

- Decision support information currently is not generated in a timely manner
- Cost of providing decision support is too expensive, leading to reduced quantity and quality
- Quality of support material is often low or even nonexistent
- Resource requirements to convert data to decision support material can be heavy
- Gaps in decision support frequently lead to delays in acquisition programs

Gap Statement 5 – Full life-cycle Systems Engineering infrastructure

- No systems engineering infrastructure spanning the full aerospace system lifecycle from requirements generation through sustainment currently exists
- Disjoint and isolated SE processes are commonplace
- Inflexible processes (not modular or extensible) appear to be the norm
- Majority of generated SE data is not persisted, leading to regeneration over and over
- Uncertainties, sensitivities, & risks are not consistently defined or tracked
- Little or no collaboration support for SE activities outside local team

CREATE-AV Products

Computational Research and Engineering for Acquisition Tools and Environments

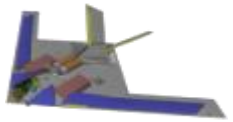
Kestrel is a high-fidelity, full-vehicle, multi-physics analysis tool for arbitrary fixed-wing aircraft

Helios is a high-fidelity, full-vehicle, multi-physics analysis tool for arbitrary rotary-wing aircraft

Firebolt is a module for propulsion systems in fixed and rotary-wing air vehicles

A CREATE-AV Software Product

DaVinci targets early-phase acquisition engineering (conceptual design)



DaVinci Mission

Computational Research and Engineering for Acquisition Tools and Environments

- ***VISION*** - Enhance DoD **acquisition** processes from pre-JCIDS through MS-B by providing **physics-based**, **multi-disciplinary**, **multi-fidelity**, computationally based systems engineering tool sets to exploit the exponential growth in **supercomputer** power enabling the user to:
  - ***DESIGN*** - thousands of systems by running system design generation tools to **create**, **explore**, and **understand** a rich design space
  - ***ANALYZE*** - hundreds of system designs using **physics-based** analysis tools, adding to and refining the **knowledge** captured in the design space exploration
  - ***OPTIMIZE*** - using the design and analysis knowledge, cost, schedule, risk, performance, and effectiveness **trades** are performed to find a set of **preferred systems solutions**

DaVinci will leverage high performance computing resources to reduce the time required to perform these activities so that they can be completed within the **decision cycle** of early stage design and upgrade studies

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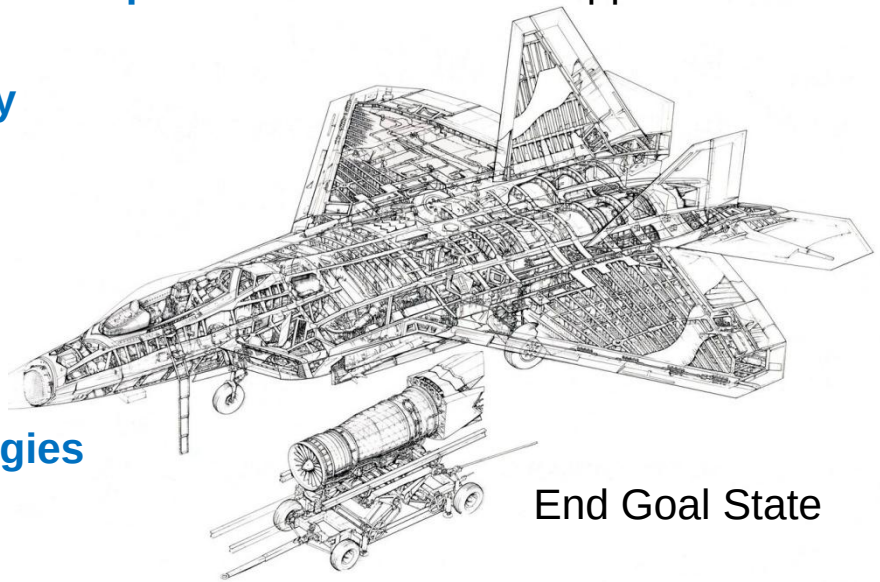
DaVinci Vision

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 **collaboration** 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**

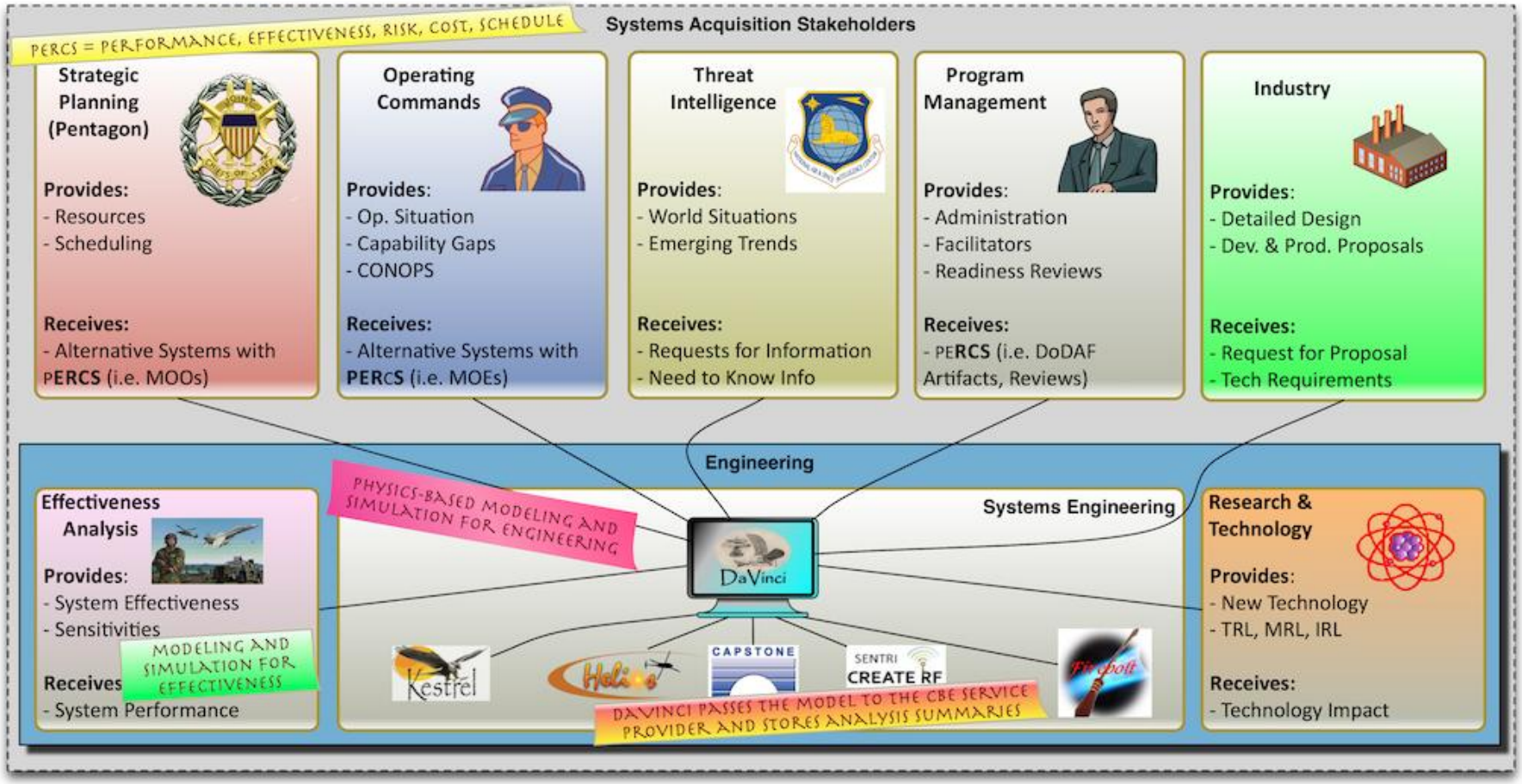


End Goal State

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

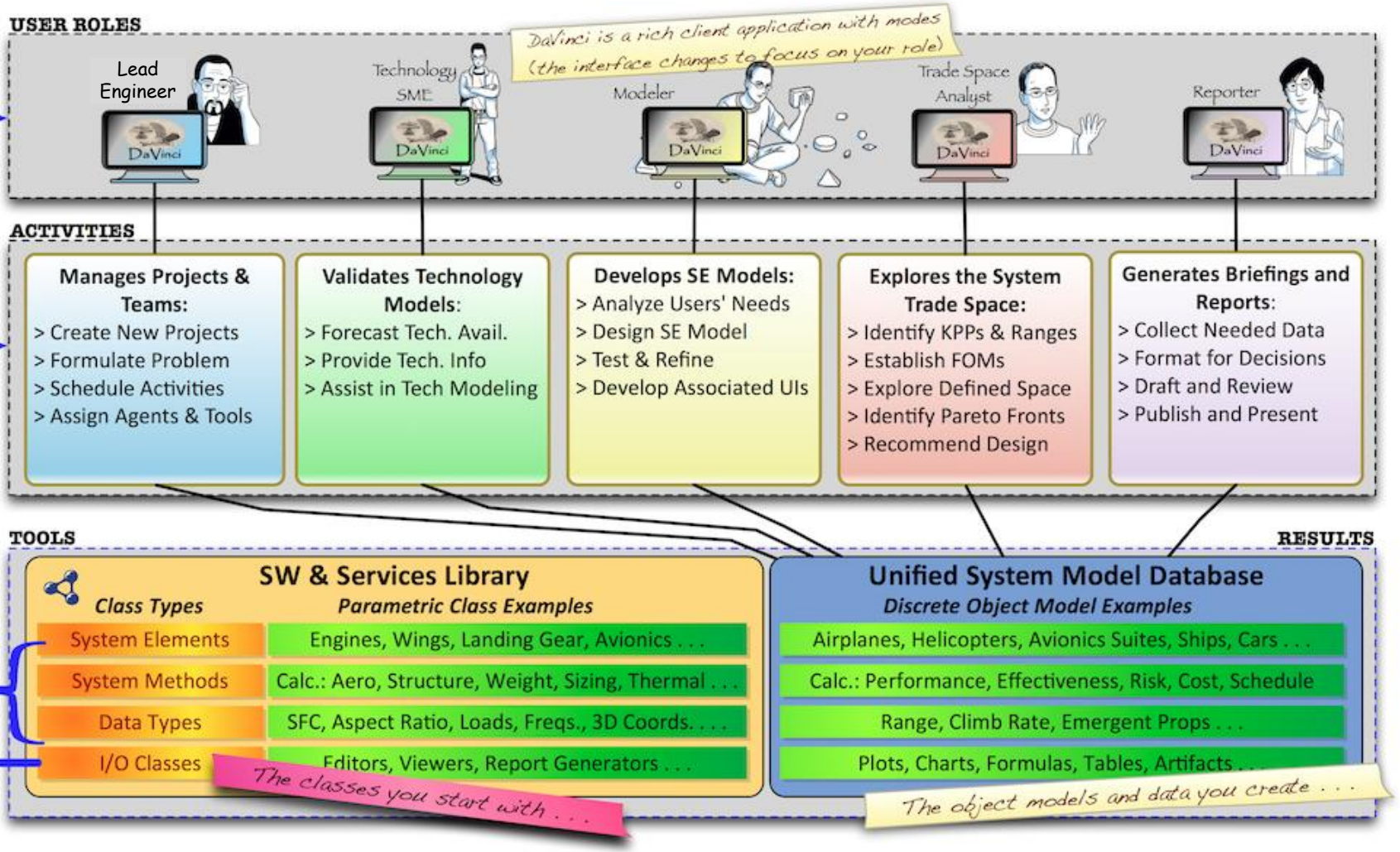
DaVinci Acquisition Interactions

Computational Research and Engineering for Acquisition Tools and Environments



DaVinci Engineering Roles

Computational Research and Engineering for Acquisition Tools and Environments



DaVinci Business Model

Computational Research and Engineering for Acquisition Tools and Environments

- 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

DaVinci eases engineering burden of using HPC

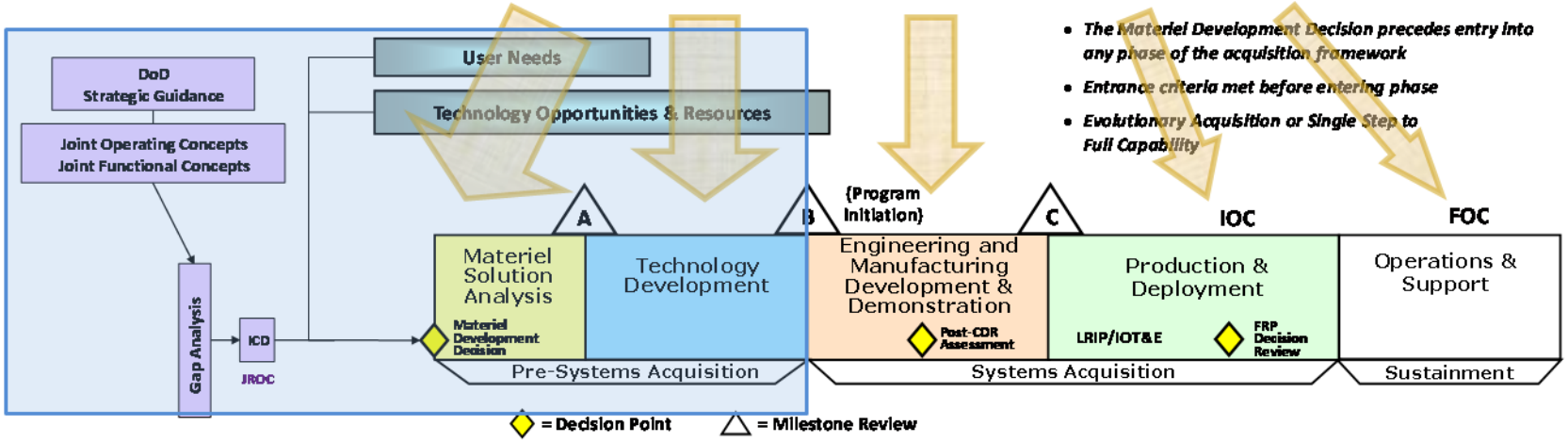
DaVinci Focus

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



- *The Materiel Development Decision precedes entry into any phase of the acquisition framework*
- *Entrance criteria met before entering phase*
- *Evolutionary Acquisition or Single Step to Full Capability*

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

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DaVinci Release 1.0 Capabilities

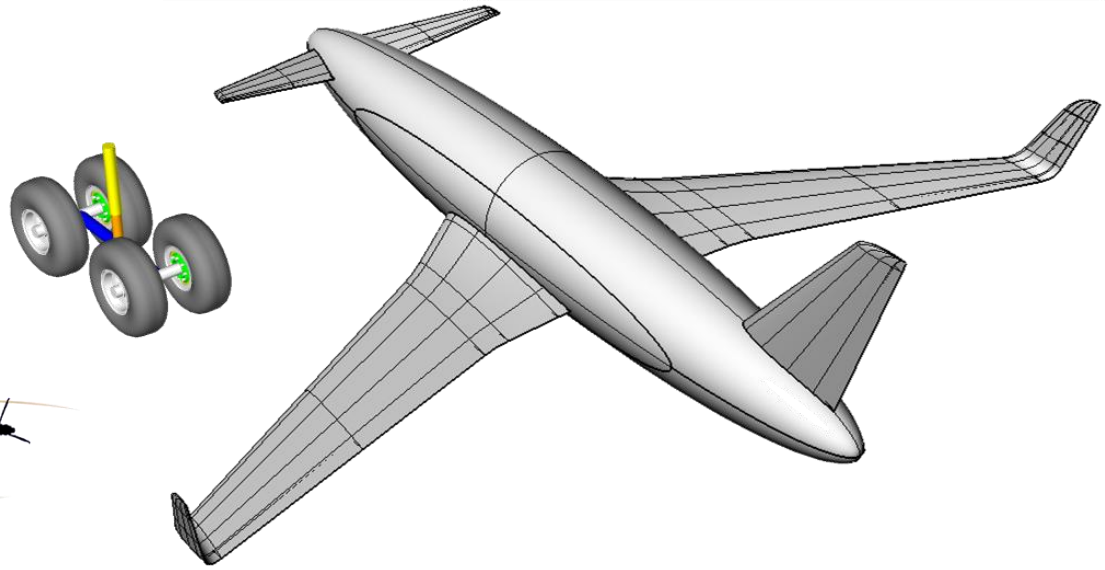
Computational Research and Engineering for Acquisition Tools and Environments

Deliver foundational conceptual design capability to:

- enable creation of parametric, associative engineering models
- of fixed and rotary wing aircraft
- from pre-engineered components (e.g., airfoils, 3-D wing surface, rotor, fuselage, engines)
- resulting in mesh-able, NURBS-based surface geometry

Build capability on an agile infrastructure allowing:

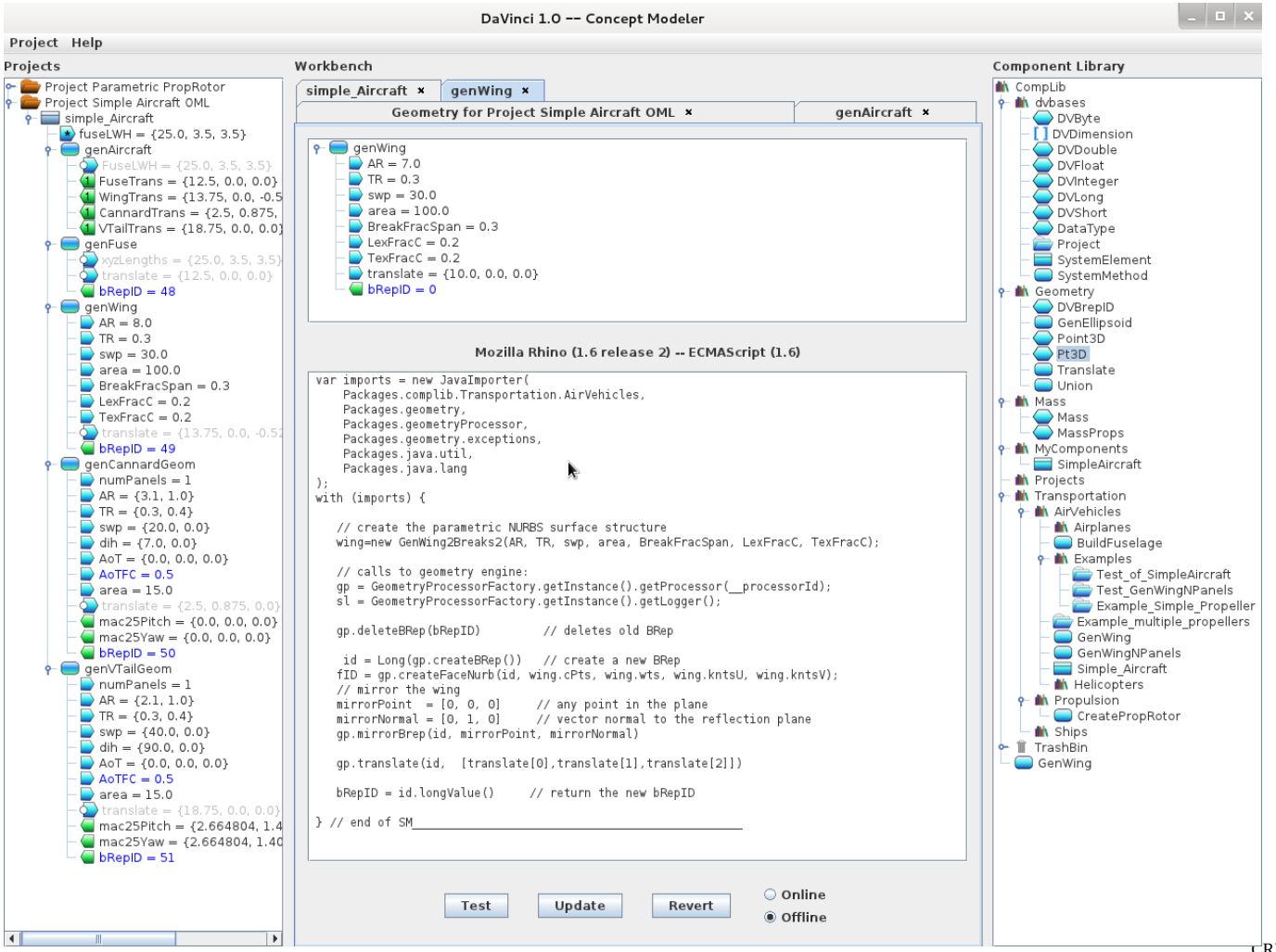
- rapid model development and
- seamless transition from conceptual design to preliminary/detailed level analysis (e.g., Kestrel/ Firebolt and Helios/ Firebolt products)



DaVinci 1.0 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



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DaVinci 1.0

Computational Research and Engineering for Acquisition Tools and Environments

DaVinci 1.0 enables:

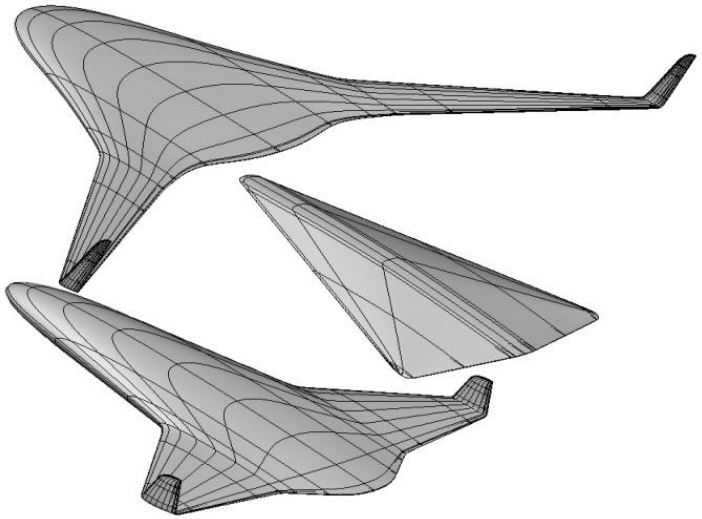
available Q1 CY2012

- Creation of parametric systems engineering models from pre-engineered parametric components
- Generation of water tight outer mold line geometry ready for meshing and input into CFD and signature analysis tools
- Ability to extend or create new components, models, and projects with the scripting editor
- Capability to explore and understand trade space for systems design efforts

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*

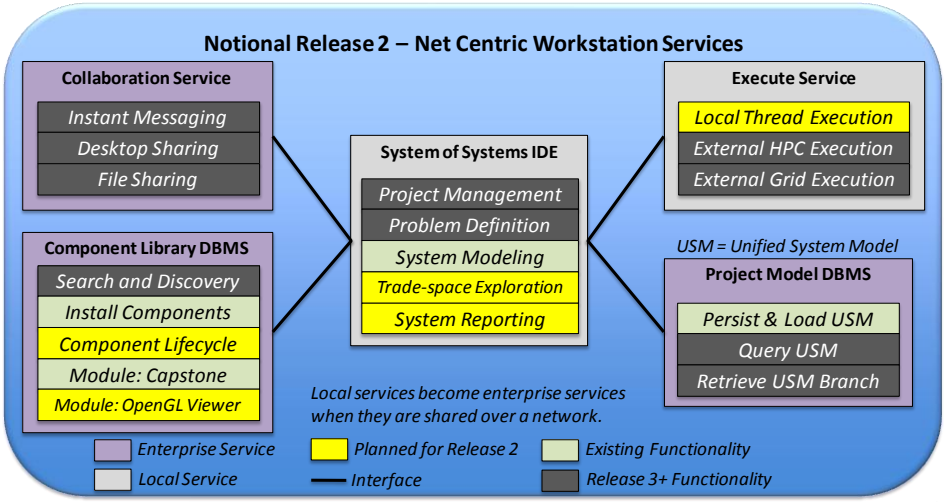


New DaVinci 2.0 Capabilities

Computational Research and Engineering for Acquisition Tools and Environments

Infrastructure Enhancements:

- ad-hoc network support (local team collaboration)
- unified system model server (team access to single, unified system model)
- parametric execution of models to support trade-space exploration
- computing service to ensure responsiveness to user interactions
- **round trip execution through *Kestrel*** leveraging hi-fi analysis results
- automatic unit conversion and compatibility checking
- **uncertainty quantification** built into data types
- refinement of component library functionality (improved library management)
- additional scripting support and improved programming interface
- enhanced testing of user generated functions
- user definable human interface definitions
- dynamic reporting for user feedback



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New DaVinci 2.0 Capabilities

Computational Research and Engineering for Acquisition Tools and Environments

Engineering Enhancements:

- 3D Geometry - additional geometry manipulation by including more functionality through Capstone APIs (surface unions, non-manifold topologies for structures, etc.)
- Surface Meshing - access to Capstone APIs for meshing surfaces (unstructured)
- Internal Component Layout - new capability to locate and size major internal components for volume and point mass distributions
- Airfoil Geometry - geometric specification through smooth NURBS representations of tabulated data and standard NACA series representations
- Structural Layout - support for internal component layout (volume, point masses, packaging), elementary structural analysis and weight estimates
- Engine Decks - propulsion performance specified through interpolated decks
- Aerodynamic Performance - lifting line and vortex lattice pre-packaged components
- System Performance - Breguet range/endurance pre-packaged components
- Multi-fidelity Analysis - geometry generated within *DaVinci* manually propagated through Capstone for meshing, Kestrel for hi-fi analysis, and back to *DaVinci* for model correlation

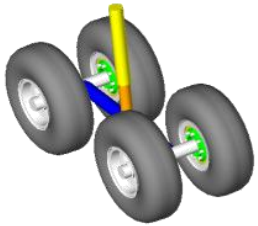
DaVinci 2.0

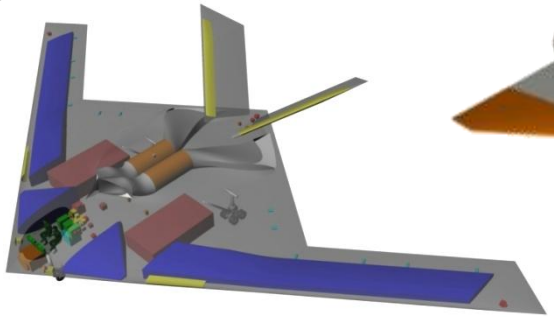
Computational Research and Engineering for Acquisition Tools and Environments

DaVinci 2.0 enables:

available Q2 CY2013

- Unified system model collaboration between agents in an ad-hoc network or within a controlled enclave environment
- Uncertainty quantification and sensitivity analysis to better capture and understand the design space
- Internal component layout to locate and size major internal components for volume and point mass distributions
- System performance calculations based on simple, low-fidelity aerodynamic, structural, stability & control, and propulsion models





CREATE-AV Product: DaVinci

Computational Research and Engineering for Acquisition Tools and Environments

View from User's Workstation

Conditions/meshes sent for Hi-Fi case(s) to be executed at DSRC

"Heavy Weight" data archived…

"Light Weight" results returned…

View from DSRC

DaVinci is a conceptual and preliminary design tool for assessing impacts of key performance parameters on vehicle capability, cost, and technical risk

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DaVinci Stakeholders

Computational Research and Engineering for Acquisition Tools and Environments

Deliver foundational conceptual design capability to:

- Air Force Aerospace Systems Design, ASC/XRE
- Air Force Multi-Disciplinary Technology Center, AFRL/RB
- US Army Advanced Design Office, AFDD (AMRDEC)
- Navy, NAVAIR/4.10.3.1

Driving Objectives:

- Parametric execution for trade space exploration / optimization
- Forward propagation into Kestrel/Firebolt and Helios/Firebolt products
- Uncertainty quantification / sensitivity analysis to support decision making
- Additional pre-engineered components for complete aerospace vehicles
- Internal structural layout (beams, plates, shells) and internal components

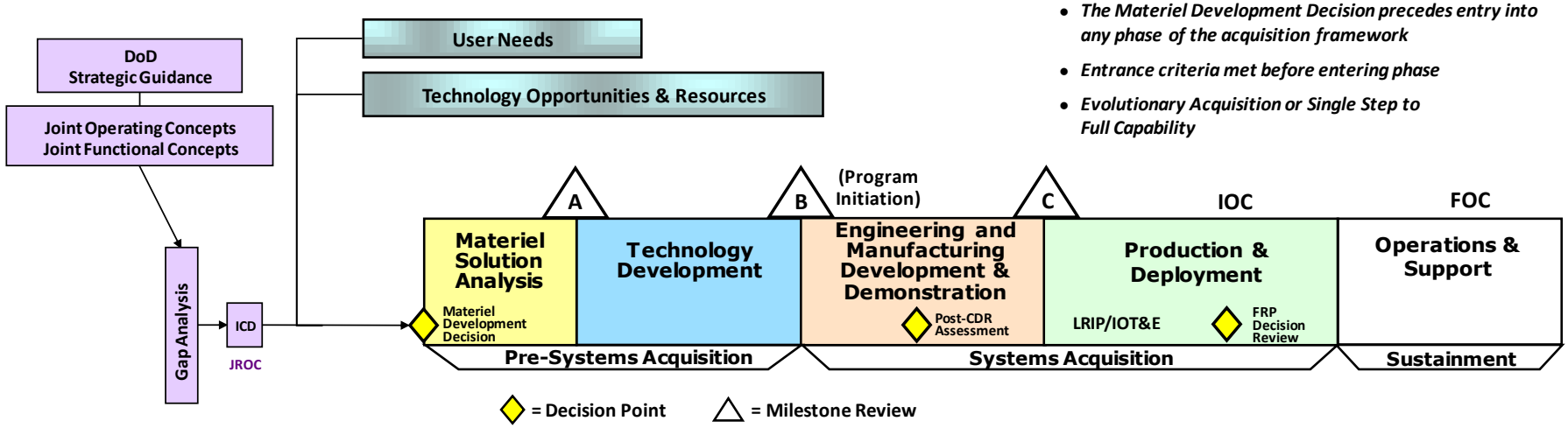
DaVinci Impacts

Computational Research and Engineering for Acquisition Tools and Environments

Requirements Determination - from pre-JCIDS through MS-B, *DaVinci* helps the user understand the DOTMLPF trade-offs, set necessary concepts of operations, and ensure a quick and preferred material solution

Analysis of Alternatives - given a material solution, *DaVinci* allows stakeholders to quickly understand trade-offs between types of solutions as major classes of systems are studied

Systems Design & Trade Studies - pre MS-A design efforts are enhanced through *DaVinci*'s unified systems model to allow seamless transition through various fidelity levels and by giving the user a better understanding of the trade space, while reducing required user subject matter expertise



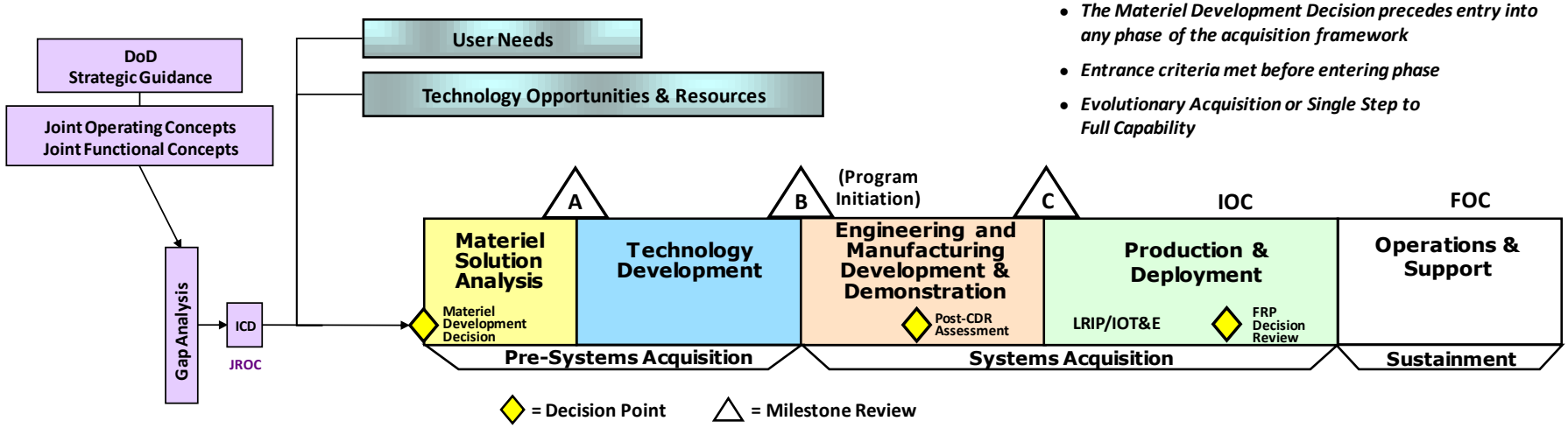
DaVinci Impacts, cont.

Computational Research and Engineering for Acquisition Tools and Environments

Effectiveness Analysis - *DaVinci* supports advanced modeling and simulation efforts by giving the user an easy, intuitive user interface/portal into necessary tools and computational resources for greatest success

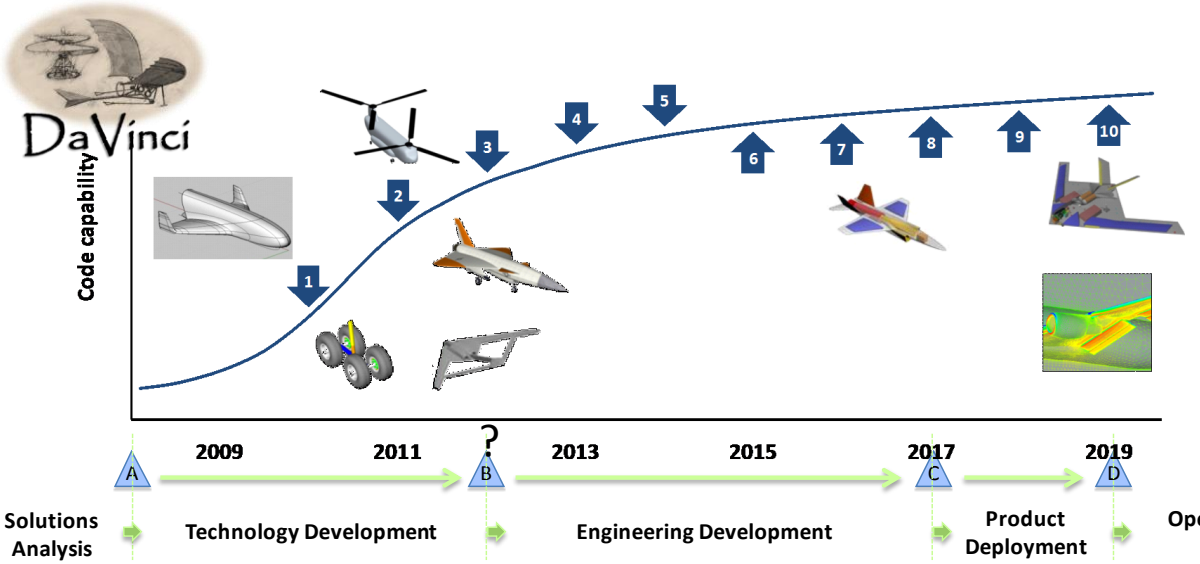
Source Selection - evaluation of proposed contractor designs are simplified and enhanced by the *DaVinci* tool suite tailored specifically for DoD acquisition, including lifecycle cost determination, risk assessments, and performance/ effectiveness calculations

Decision Making - ultimately, *DaVinci* supports and improves intelligent decision making by giving users the right information at the right time with confidence levels that enable fully informed decisions



DaVinci Product Roadmap

Computational Research and Engineering for Acquisition Tools and Environments



1) Foundational conceptual design capability enabling creation of parametric, associative engineering models of fixed and rotary wing aircraft from pre-engineered components resulting in meshable, NURBS-based surface geometry. Capability built upon an agile infrastructure allowing rapid model development and seamless transition from conceptual design to preliminary/detailed level analysis (e.g., Kestrel and Helios products).

2) Enhanced user functionality to rapidly develop new components, modify existing models, define internal structure and subsystem layout, and perform trade space exploration through a Systems engineering Integrated Development Environment (SIDE). Capability additions include component visualizers and editors, simple GUI builders, built-in user feedback, multi-level security, and training material.

3) 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.

4) Expanded trade space exploration tools and sampling techniques including Design of Experiments and evolutionary based search methods to enable more thorough coverage of the design space. Additional enhancements include uncertainty quantification, more powerful user modification of components, decision support techniques, and security improvements. DaVinci's large scale computing and collaboration launch.

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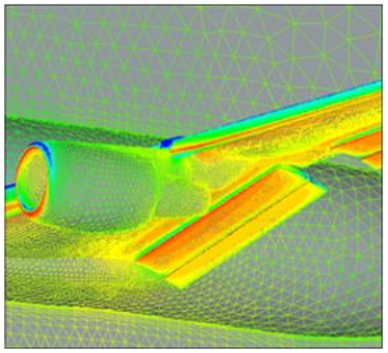
10) Sustained DaVinci product capability to include continued maturation of unified life-cycle systems engineering modeling environment for advanced conceptual design and analysis enabling rapid development iterations for requirements traceability, detailed physics-based systems representations, and high-fidelity models suitable for early preliminary design. DaVinci will be fully integrated with other CREATE products for preliminary/detailed level analysis (e.g., Kestrel, Helios, and SENTRI products).

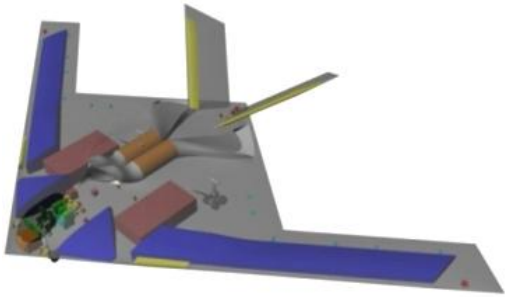
DaVinci End State

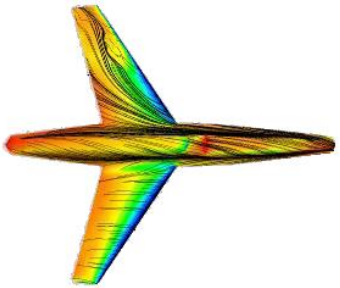
Computational Research and Engineering for Acquisition Tools and Environments

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





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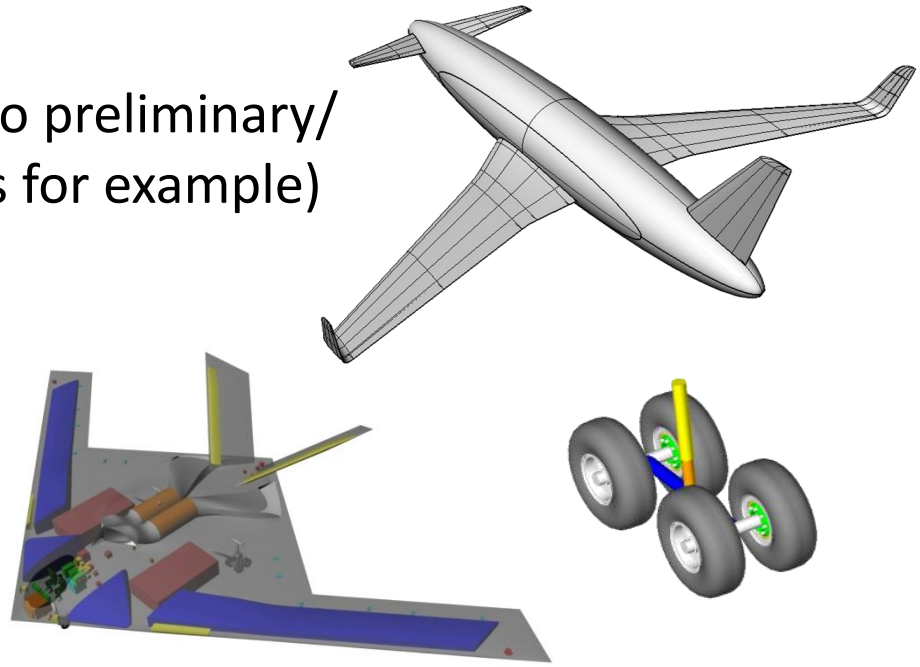
DaVinci Summary

Computational Research and Engineering for Acquisition Tools and Environments

- 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



CREATE-AV Summary

Computational Research and Engineering for Acquisition Tools and Environments

- CREATE-AV is in full swing with several products targeted for aircraft **design and simulation**
- ***Kestrel*** and ***Helios*** high fidelity **multi-physics software** is being **applied** to some of the most vexing acquisition program issues and is **modular** enough to grow with next generation issues
- ***DaVinci*** – combined with *Kestrel/Helios* and ***Firebolt*** – is being developed specifically to target the **early acquisition** phases when improvements have the **biggest payoff**
- ***DaVinci*** will enable **model propagation** through preliminary/detailed design and into system sustainment
- High performance computing is being leveraged by DoD acquisition for **multi-disciplinary**, **multi-fidelity**, systems engineering

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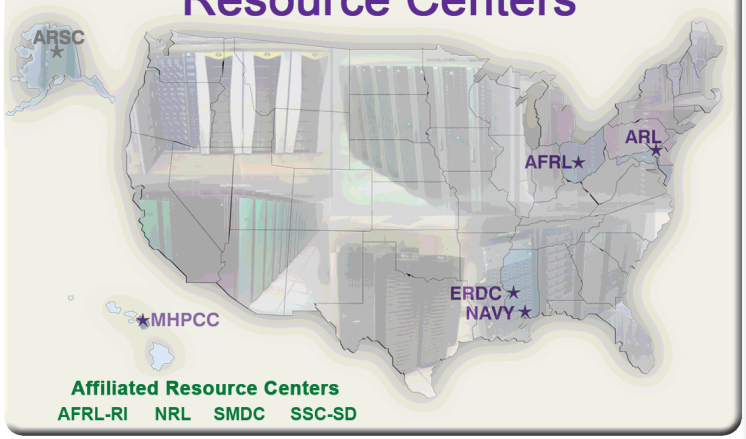
DoD HPC Modernization Program

Computational Research and Engineering for Acquisition Tools and Environments

DoD Supercomputing Resource Centers



Networking & Security

Defense Research & Engineering Network

Joint Community

Army HPCMP Participation

- ARL & ERDC DSRCs
- 1,214 Users
- 22 Organizations
- 96 Projects

Navy HPCMP Participation

- NAVY DSRC
- 1,142 Users
- 16 Organizations
- 197 Projects

Air Force HPCMP Participation

- AFRL & MHPCC DSRCs
- 1,316 Users
- 23 Organizations
- 184 Projects

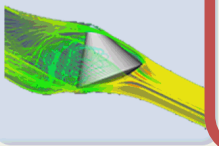
Defense Agencies Participation

- DARPA, DTRA, JFCOM, MDA, PA&E & OTE
- 656 Users
- 4 Organizations
- 24 Projects

Software Applications Support

Institutes

PETTT



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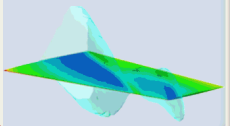


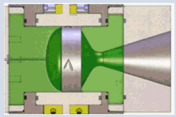
Workforce Development

SPI

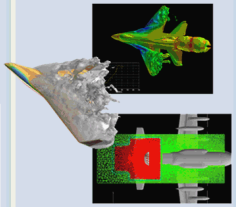
Resource Management

Requirements & Allocations

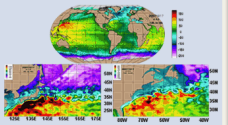
DHPIs



CAPs



Challenge Projects



Enhancing DoD Acquisition

Computational Research and Engineering for Acquisition Tools and Environments

- ***CREATE*** - ***C***omputational ***R***esearch & ***E***ngineering for ***A***cquisition ***T***ools & ***E***nvironments

- Mission - CREATE will develop and deploy three **computational engineering tool sets** for **acquisition program engineers** to exploit the exponential growth in **supercomputer power**
  - Aircraft tools (Aerodynamics & Structures)
  - Ship tools (Hydrodynamics and Structures)
  - RF Antenna Integration tools (Electromagnetics)

Air Vehicles

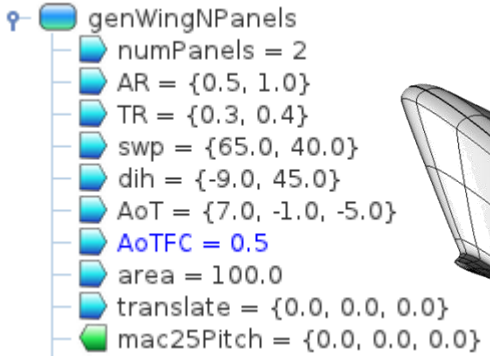
Naval Ships

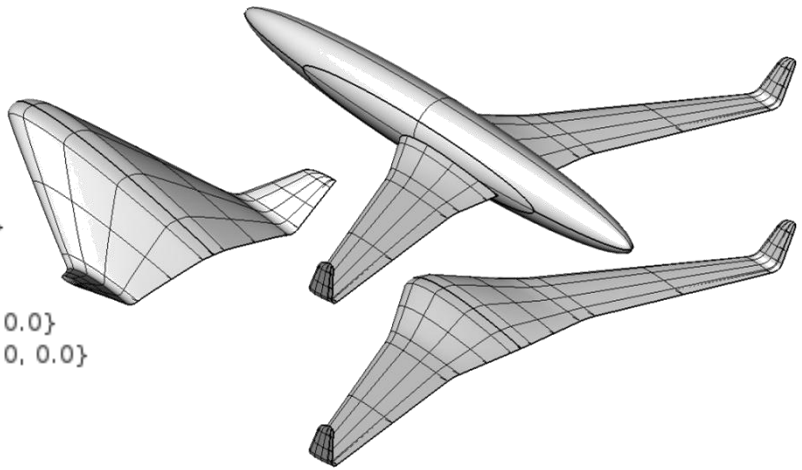
Antenna Integration

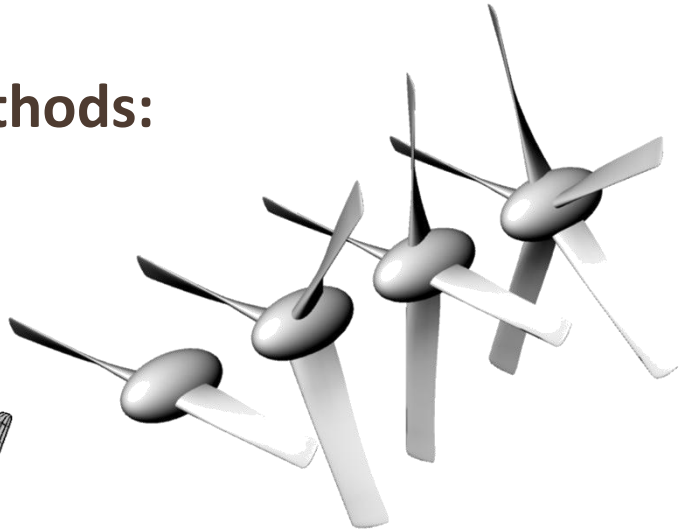
DaVinci 1.0 Geometry

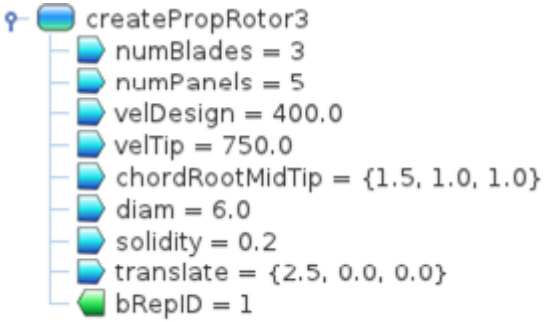
Computational Research and Engineering for Acquisition Tools and Environments

- **Capstone geometric methods:**
  - genPoint - genCurve - genSurf
  - mirror - union - intersect
  - difference ……
- **Geometry generation via System Methods:**
  - Feature driven automatic generation
  - Provides continuous parametric variation
  - May use methods from any library domain









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New DaVinci 2.0 Capabilities

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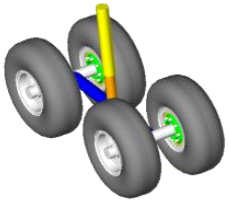
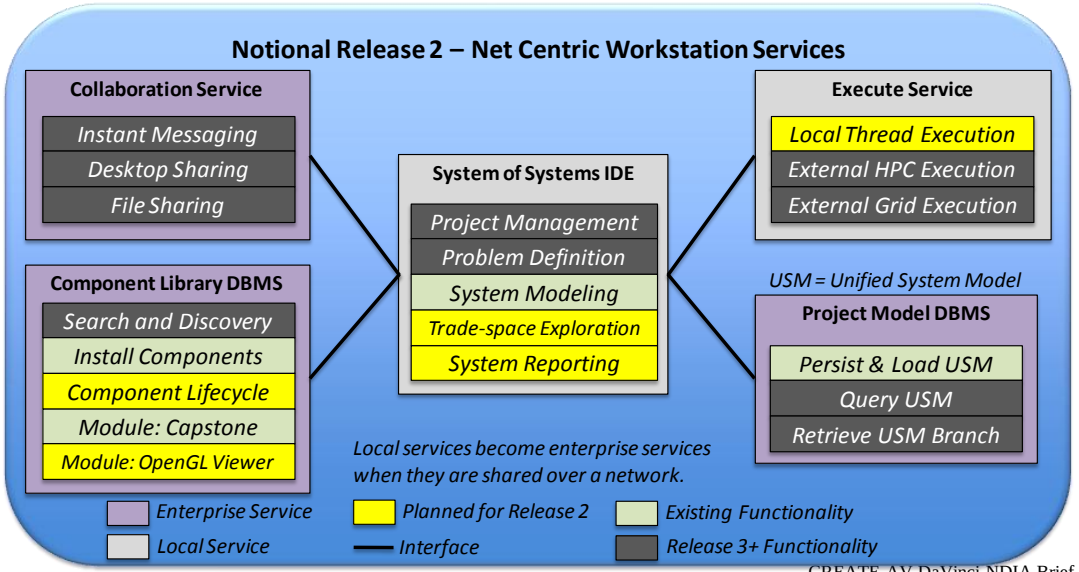
Deliver enhanced conceptual design capability:

- greater manipulation of engineering models
- includes rotary wing aircraft as well as fixed wing aircraft
- results in mesh-able, NURBS-based surface geometry and basic internal layout



Build capability on an agile infrastructure:

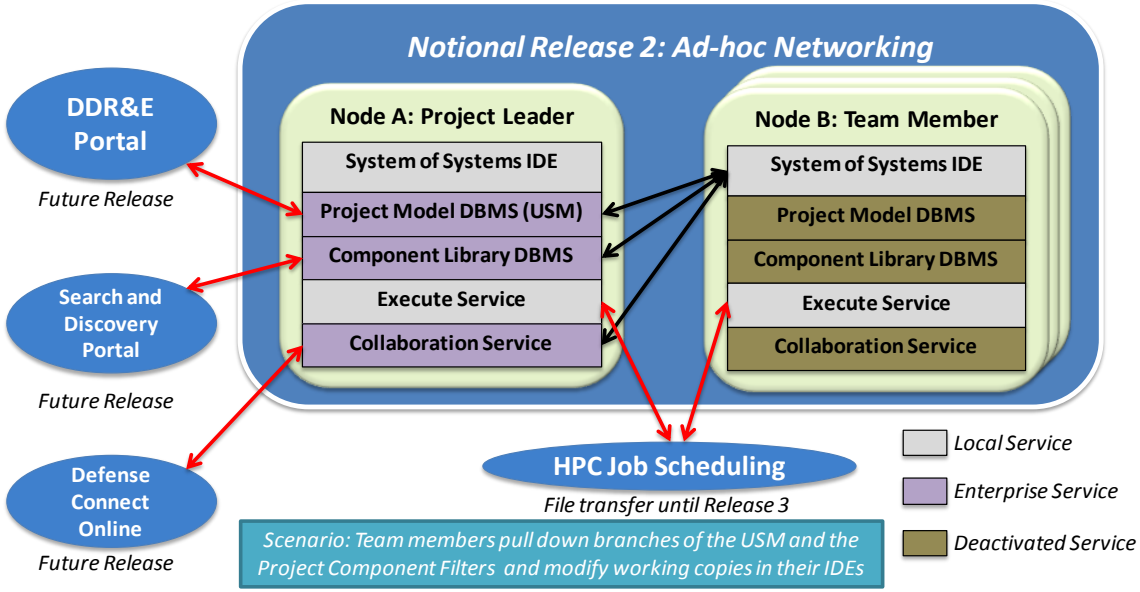
- rapid parametric model development
- user defined human interface definitions
- seamless transition from *DaVinci* to Kestrel and Helios products
- net centric services
- ad-hoc collaboration



New DaVinci 2.0 Capabilities

Computational Research and Engineering for Acquisition Tools and Environments

- Refinement of component library functionality (better searching and management)
- Enhancement of data types for UQ, unit manipulation, and sensitivity studies
- Updates to lazy evaluation for efficiency
- Addition of feedback logic and alternative branching
- Enable dynamic reporting for user feedback
- Expansion of parametric execution capabilities
- Enable user debugging for user generated functionality
- Additional scripting support and improved user interface
- Enhanced Capstone capabilities for geometry manipulation and meshing support
- Additional building block components delivered with standard distribution



Modeling Capabilities

T = Threshold O = Objective

Computational Research and Engineering for Acquisition Tools and Environments

- T **3D Geometry** - additional geometry manipulation by including more functionality through *Capstone* APIs (surface unions, volume unions, "negative" unions, etc.)
- T **Surface Meshing** - access to *Capstone* APIs for meshing surfaces (unstructured)
- T **Internal Component Layout** - new capability to locate and size major internal components for volume and point mass distributions
- T **Airfoil Geometry** - geometric specification through interpolated tables and standard NACA series representations
- T **Structural Layout** - "rule of thumb" capability for packaging and weight estimates
- T **Engine Decks** - propulsion performance specified through interpolated decks
- T **Aerodynamic Performance** - lifting line and vortex lattice pre-packaged components
- T **System Performance** - Breguet range/endurance pre-packaged components
- T **Collaboration** - multi-user cooperation within a single project
- T **Multi-fidelity Analysis** - geometry generated within *DaVinci* manually propagated through *Capstone* for meshing, *Kestrel* for hi-fi analysis, and back to *DaVinci* for model correlation

Modeling Capabilities, cont.

T = Threshold O = Objective

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- **Airfoil Geometry** - geometric representation through Bezier curves to give user finer control of precise external shape while maintaining mathematical representation
- **Structural Layout** - representation of internal structure with beams, plates, and shells with proper "thin" structural models
- **Propulsion Modeling** - integration of *Firebolt* 0D engine model (v 1.0)
- **System Performance** - new capability for aircraft take-off, climb, descent, and landing performance determination
- **Uncertainty Quantification** - new core capabilities to address, model, and manipulate the quantification of uncertainty (e.g., polynomial chaos)
- **Sensitivity Analysis** - addition of capability to automatically calculate first derivatives of user selected variables of interest
- **Scripting** - addition of more scripting languages beyond ECMA Script/JavaScript (Python then MatLab like languages)
- **Multi-fidelity Analysis** - geometry generated within *DaVinci* manually propagated through *Capstone* for meshing, *Helios* (and other system design/analysis tools) for med/hi-fi analysis, and back to *DaVinci* for model correlation

Architectural Development

T = Threshold O = Objective

Computational Research and Engineering for Acquisition Tools and Environments

- T **Install Tool** - new install / uninstall process for additional user control and configuration (preferences) set-up
- T **Component Bundling** - OSGi (Open Services Gateway initiative) framework for dynamically manipulating and managing components and Eclipse RCP (Rich Client Platform) for minimum plug-in implementation
- T **Unit Analysis** - automation of unit analysis and conversions so user can input multiple compatible units and specify preferred output units
- T **Collaboration** - local area network access for enclave collaboration to allow multiple users access and project sharing in real time

- O **Logic** - improved feedback and branching logic for finer user control within System Element and System Method editors
- O **Parametric Execution** - addition of greater flexibility for unstructured inputs
- O **Component Library** - refined organization and management of available components (searching and querying capabilities)
- O **Computing Efficiency** - improvements to “lazy evaluation” to better manage available computational resources

Prototyping Events

T = Threshold O = Objective

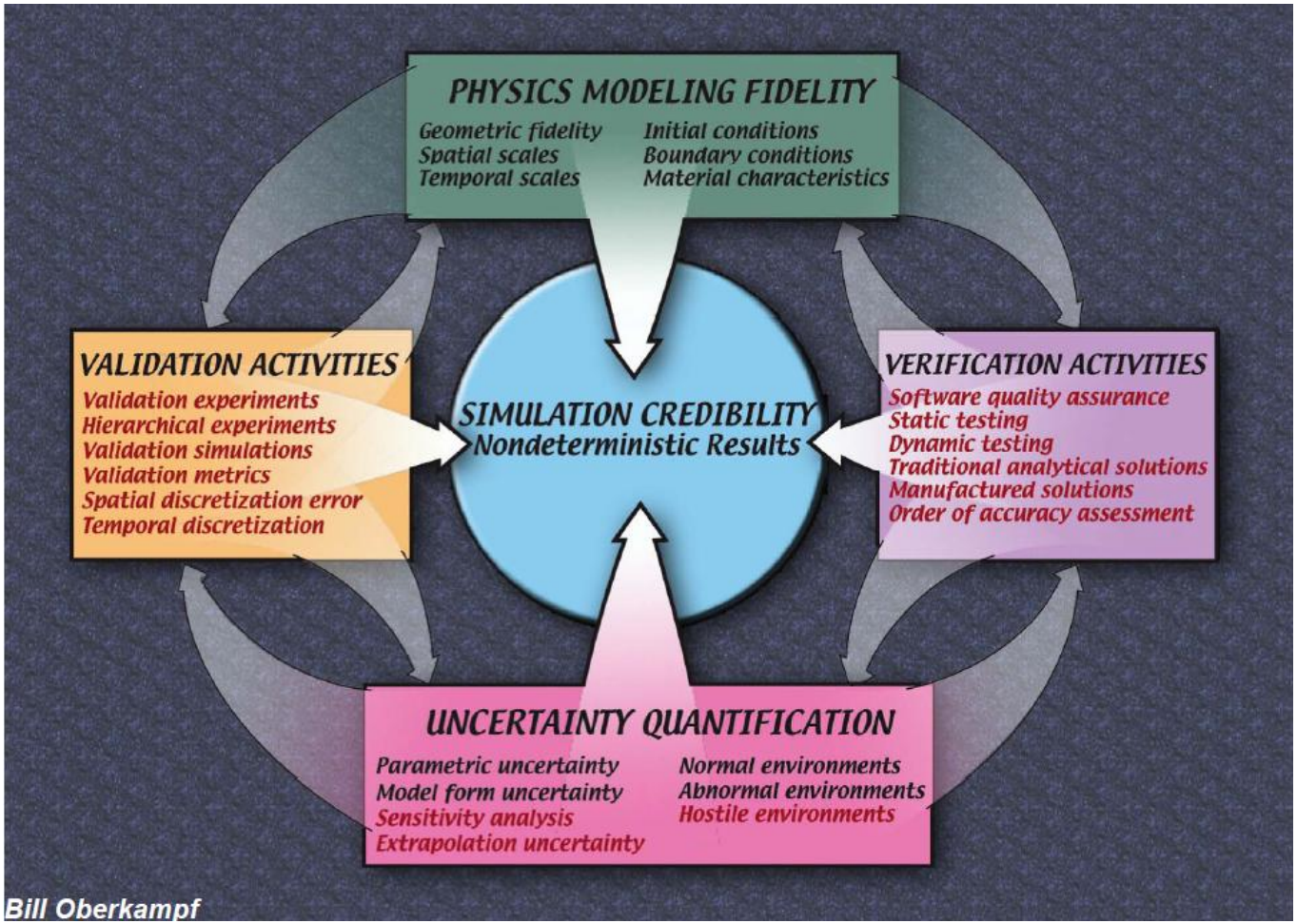
Computational Research and Engineering for Acquisition Tools and Environments

- T **Information Fusion** - initial investigation of Bayesian updating, probability and plausibility determination, Dempster-Shafer theory, and Dezert-Smarandache theory to support reasoning and future decision making
- T **User Functionality Debugging** - studies of syntax highlighting and code debuggers to assist user in developing error free software enhancements
- T **Geometry Engine** - consideration of other geometry kernels for "plug-and-play" use within *DaVinci*

- O **Cybersecurity** - investigation into the DIACAP process and requirements in preparation of full DoD and Internet network access
- O **Dynamic Reporting** - addition of real time feedback of executing jobs to inform user for possible use of job steering
- O **Symbolic Manipulation** - CAS (Computer Algebra System) component to assist user in developing new functionality not delivered with *DaVinci* or available through another component library
- O **User Interface Personalization** - skin-able user interface so others can develop look and feel to best suit individual needs

Credible Systems Modeling

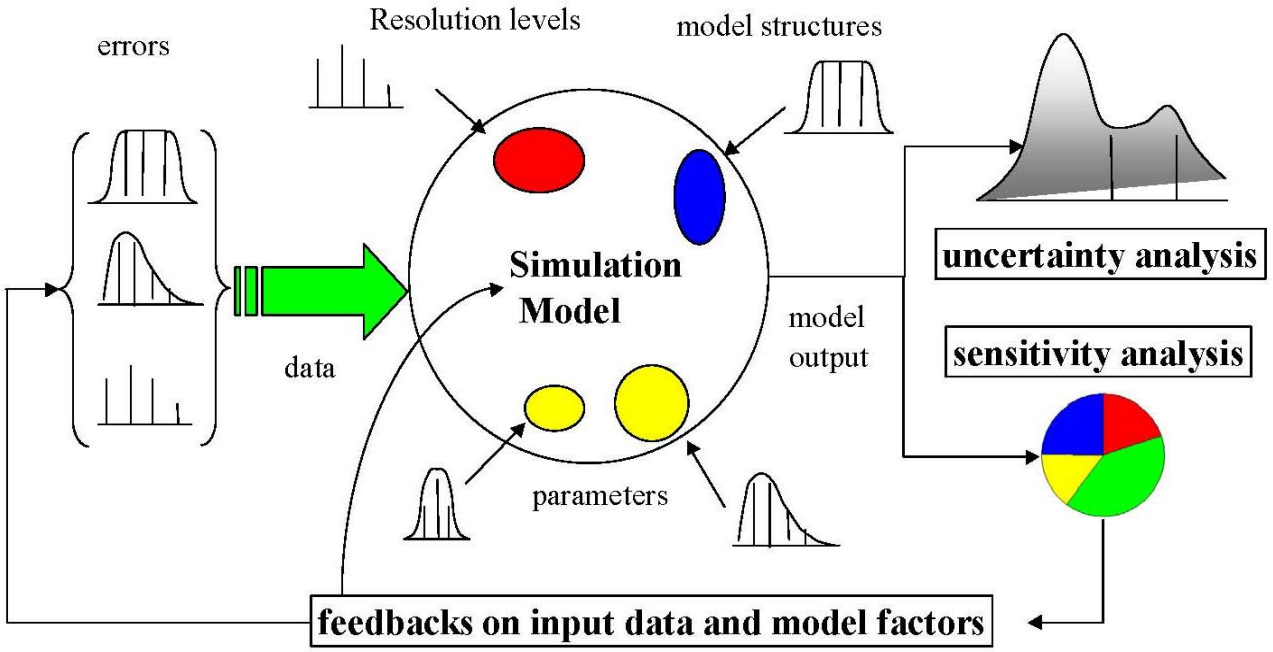
Computational Research and Engineering for Acquisition Tools and Environments



Responsible engineering modeling and credible systems simulation

Sensitivities and Uncertainties

Computational Research and Engineering for Acquisition Tools and Environments



Sensitivity analysis process by which "known" input variability is propagated through the model with measured output variability

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DaVinci CBE Vision

Computational Research and Engineering for Acquisition Tools and Environments

View from User's Workstation

Conditions/meshes sent for Hi-Fi case(s) to be executed at DSRC

"Heavy Weight" data archived…

"Light Weight" results returned…

View from DSRC

- Use *DaVinci* to establish a "model-centric project"
- Use *DaVinci* to build a parametric associative model of aircraft concept OML, internal structure, and subsystem layout
- Use *DaVinci* to launch lo-fi multi-physics analyses to assess impacts of key performance parameters on vehicle capability, cost, and technical risk
- Use *DaVinci* to generate meshes needed for hi-fi multi-physics sims (Capstone enables mesh gen via library calls from *DaVinci*)
- Use *DaVinci* to launch hi-fi multi-physics sims to calibrate lo-fi models, establish data uncertainties, and perform limited vehicle design verification studies

- DSRC executes Kestrel/Helios/Sentri jobs
- Firebolt MODULE enables propulsion effects as needed
- Capstone LIBRARY enables run-time definition of geometry as required for effective near-body adaptive mesh refinement

DaVinci Architecture

Computational Research and Engineering for Acquisition Tools and Environments

The **DaVinci** product suite consists of five core elements:

SIDE - Systems of systems Integrated Development Environment
- Enables unified systems modeling, design space exploration, project management, and report generation
- Supports extension/development of models, component library compliance, and testing/debugging of new models

CASS - Communication, collaboration, And Security Services
- Enables secure collaboration between geographically distributed teams
- Supports ad-hoc networking and a services based approach for the other elements

HPCS - High Performance Computing Services
- Enables unified systems model evaluation for design, analysis, and optimization efforts as well as trade studies
- Supports computing resource management and calibration of lo-fi response surfaces with hi-fi computations

DaVinci Architecture

Computational Research and Engineering for Acquisition Tools and Environments

The **DaVinci** product elements continued:

PMDBS - Project Model DataBase management Services

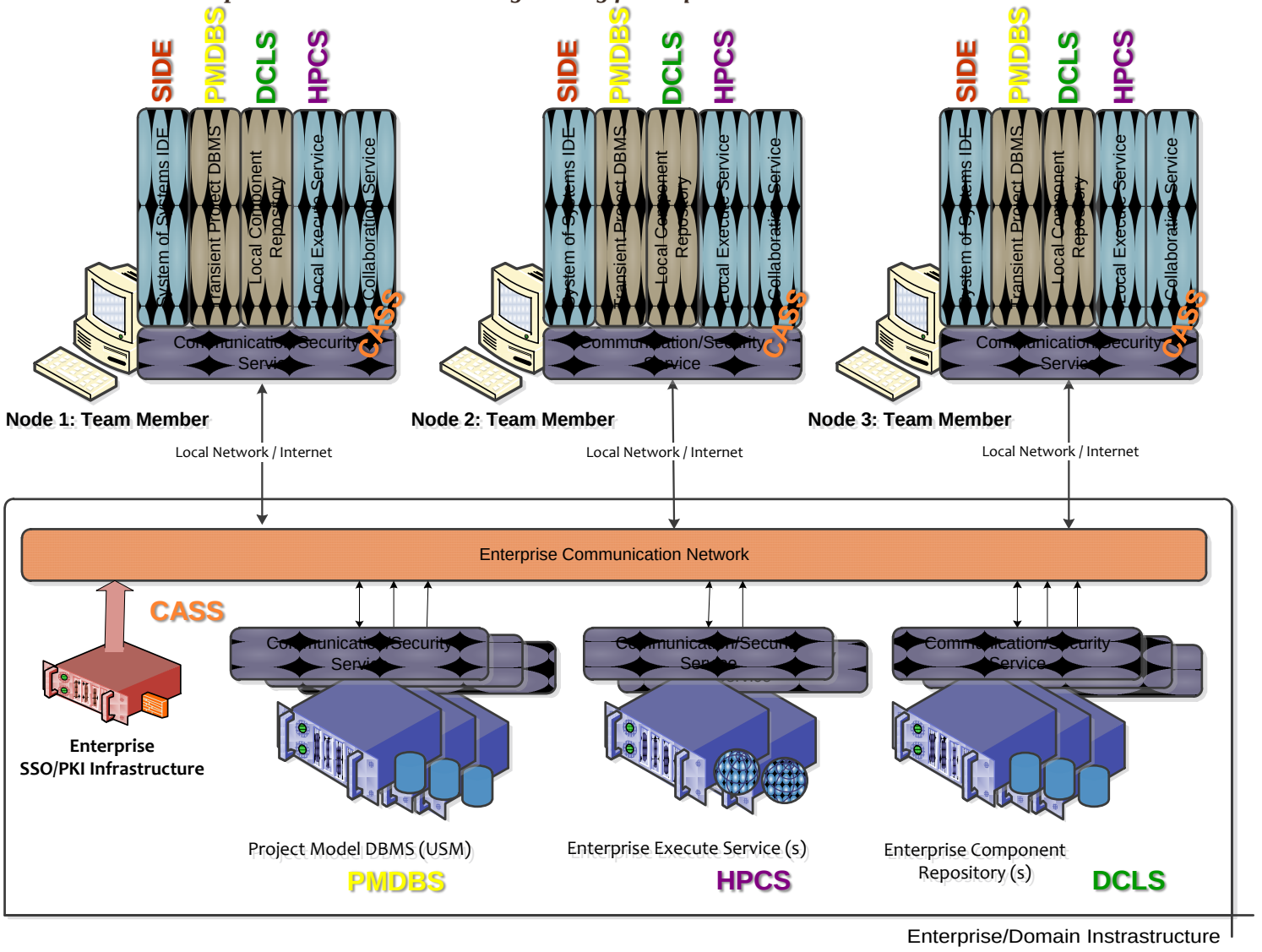
- Enables CRUD (create, read, update, and delete) operations on systems models and other project data
- Supports offline storage of all project data (models, relationships, reports, etc.) in a system independent format

DCLS - Distributed Component Library Services

- Enables component management (registration, retrieval, search, query, creation, deprecation, removal, and updates)
- Supports distributed collaboration and model/component reuse

DaVinci Network Architecture

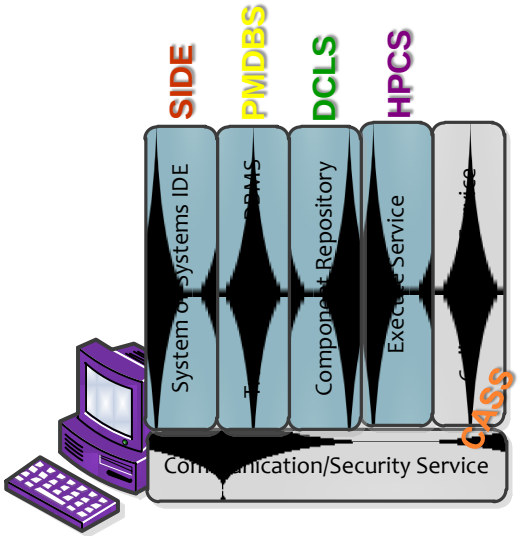
Computational Research and Engineering for Acquisition Tools and Environments



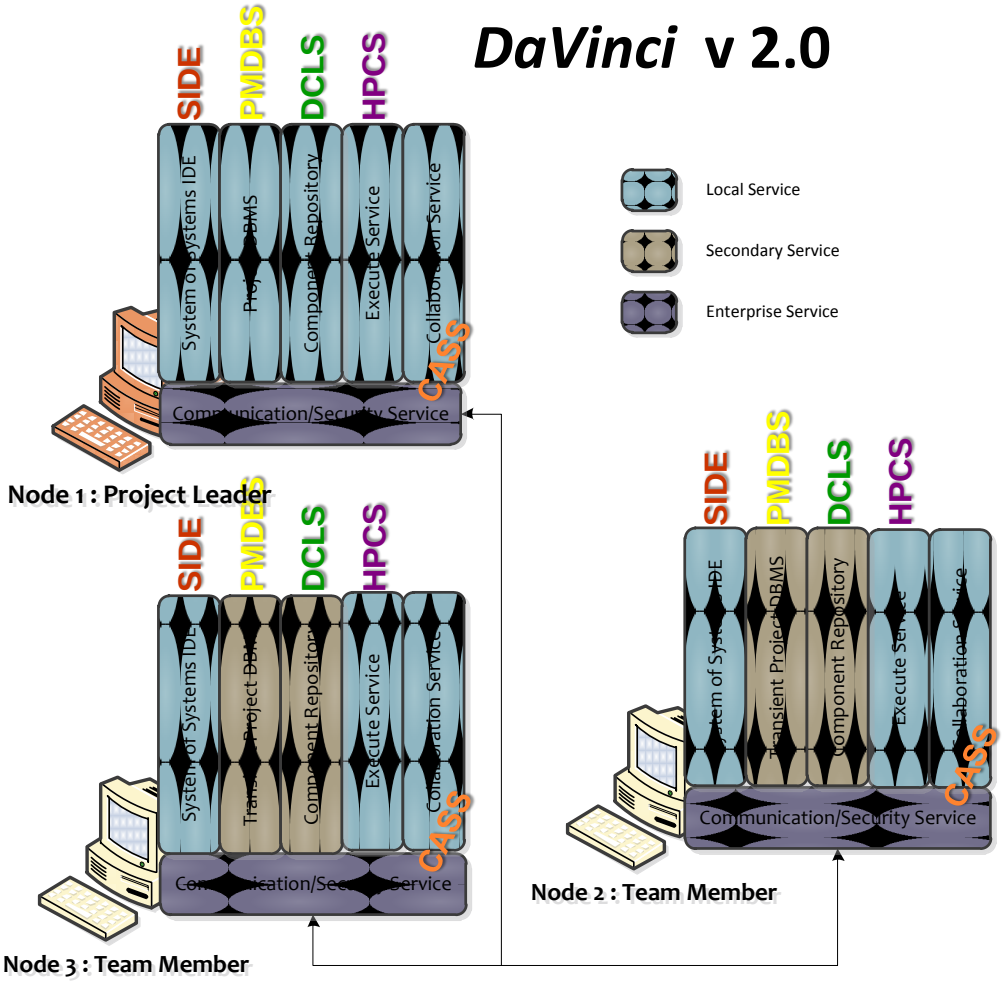
DaVinci Network Architecture

Computational Research and Engineering for Acquisition Tools and Environments

DaVinci v 1.0



DaVinci v 2.0



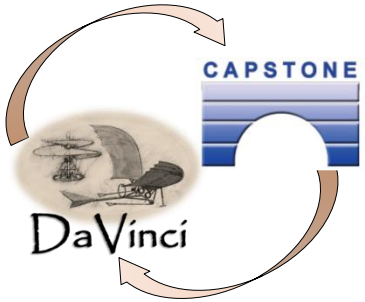
Infrastructure Summary

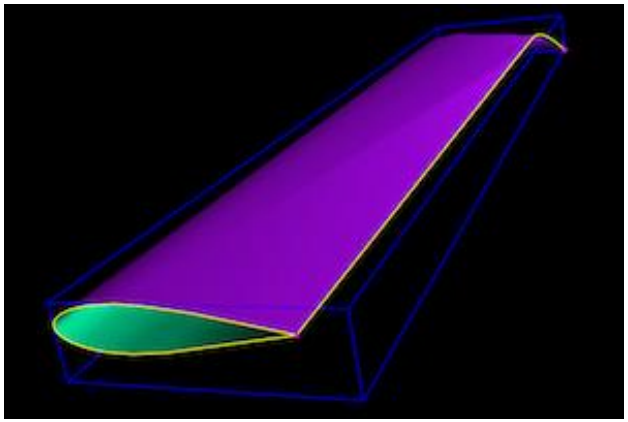
Computational Research and Engineering for Acquisition Tools and Environments

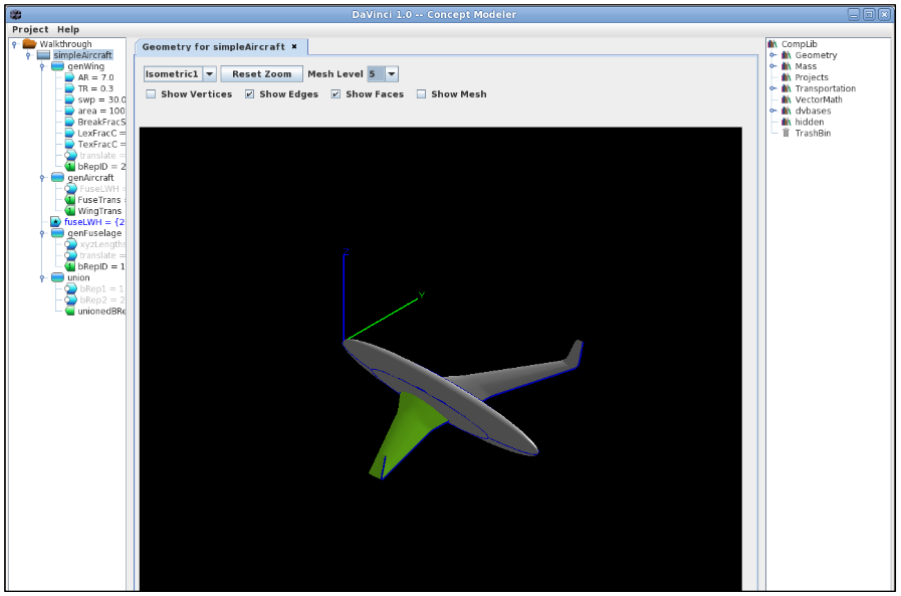
- Unified system of systems modeling architecture
  - DoDAF, SysML & UML are going in the right direction, but they are too complicated, no simple unifying meta-model
- Foundational engineering open architecture to build upon
  - Flexible, pre-engineered component & service based approach
  - Automatic maintenance of functional dependencies
  - Lazy evaluation (only evaluated when needed, or when CPUs idle)
  - Built in uncertainty, sensitivity & risk propagation
  - Automatic unit analysis & conversion
- Easy access to High Performance Computing (HPC) resources
- Full lifecycle data persistence
- Secure collaborative distributed open architecture

Capstone use by DaVinci

1. Create parametric system model in *DaVinci*
2. Generate water tight OML geometry with *Capstone*
3. Use *DaVinci* viewer to display and manipulate OML
4. Integrate needed *Capstone* controls into *DaVinci*







Summary of Basic SE Needs

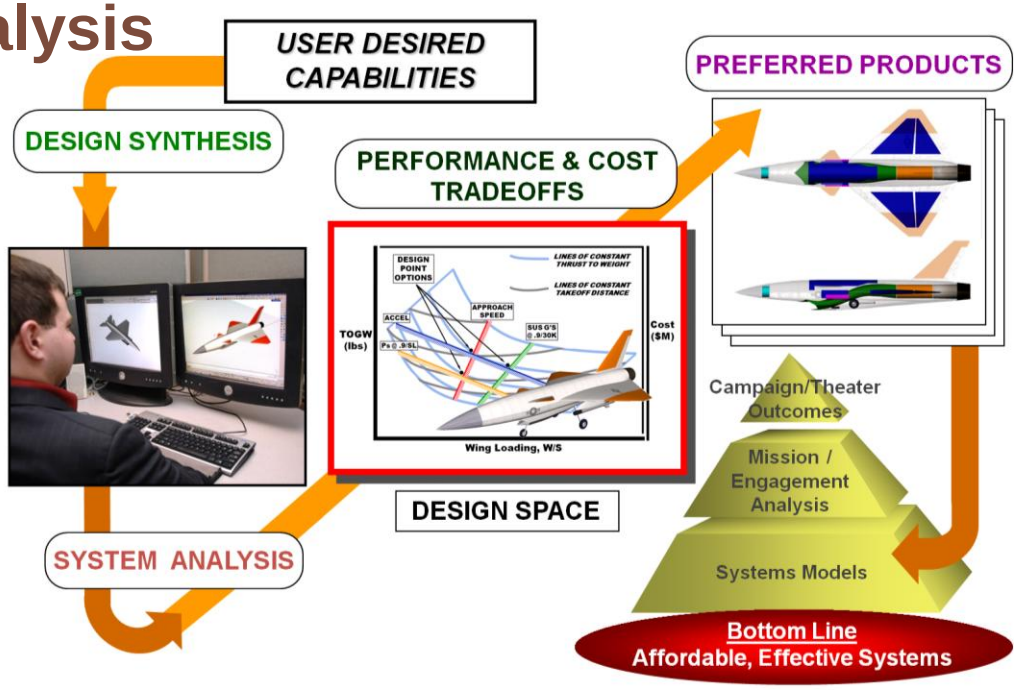
0. Formulate the situational and system of systems context
1. Formulate the system problem
2. Build modular, executable models
3. Tailor model fidelity
4. Extend component set (building blocks)
5. Control model/software variation/version
6. Perform multi-level optimization/exploration
7. Correlate lo-fi models with hi-fi models
8. Generate wide range of I/O for stakeholder decision making
9. Support dispersed, diverse team members

DaVinci – Conceptual Design

Computational Research and Engineering for Acquisition Tools and Environments

Engineering Design & Analysis

- provides **technical leadership**, products, and **sound SE**
- for the generation & evaluation of **effects-based capabilities**
- to support requirements development, technology development, and **early acquisition planning**



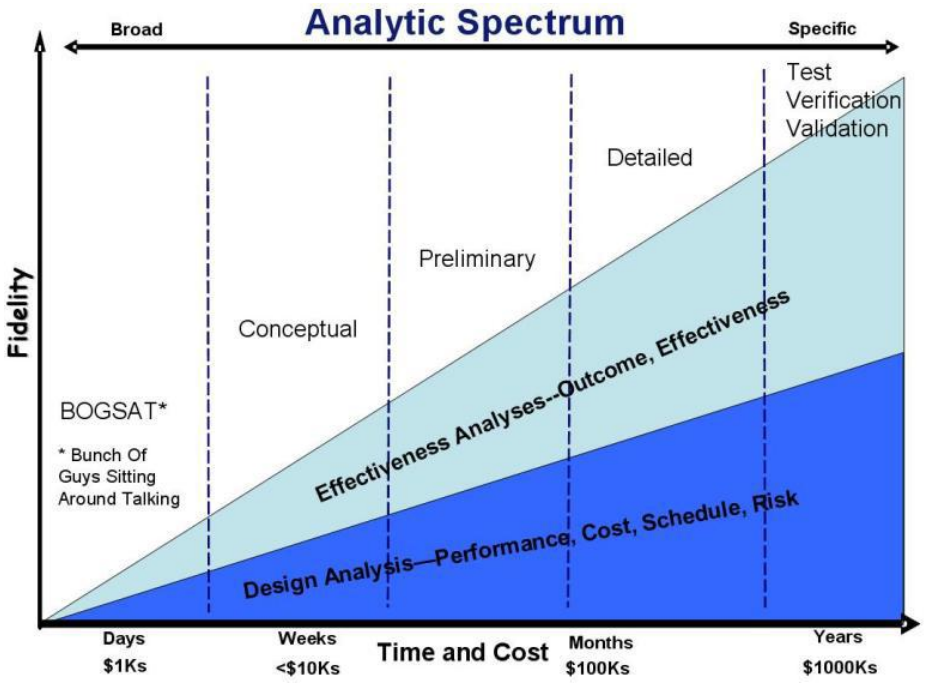
This is achieved by:

- evaluating capability needs through **functional analysis and allocation**,
- scoping the trade-space and generating aerospace **capability options**,
- assessing the **impact of technology**,
- analyzing the performance, effectiveness, risk, cost, and schedule, and
- assessing system capabilities with **multi-level/fidelity modeling** & simulation

Conceptual Design Today

Computational Research and Engineering for Acquisition Tools and Environments

- Is the system lifecycle phase that begins with operational requirements and ends when preliminary design begins
- Iterative process starting with agreed upon operational requirements
- Collective wisdom of engineering design team leveraged to begin
- Desire to focus set of possible concepts to potential solutions
- Risks introducing individual biases
- Much effort in comparative evaluation of numerous alternative concepts
- Perturbations around good designs may locate better designs
- Requirements may be revised based on new knowledge gained

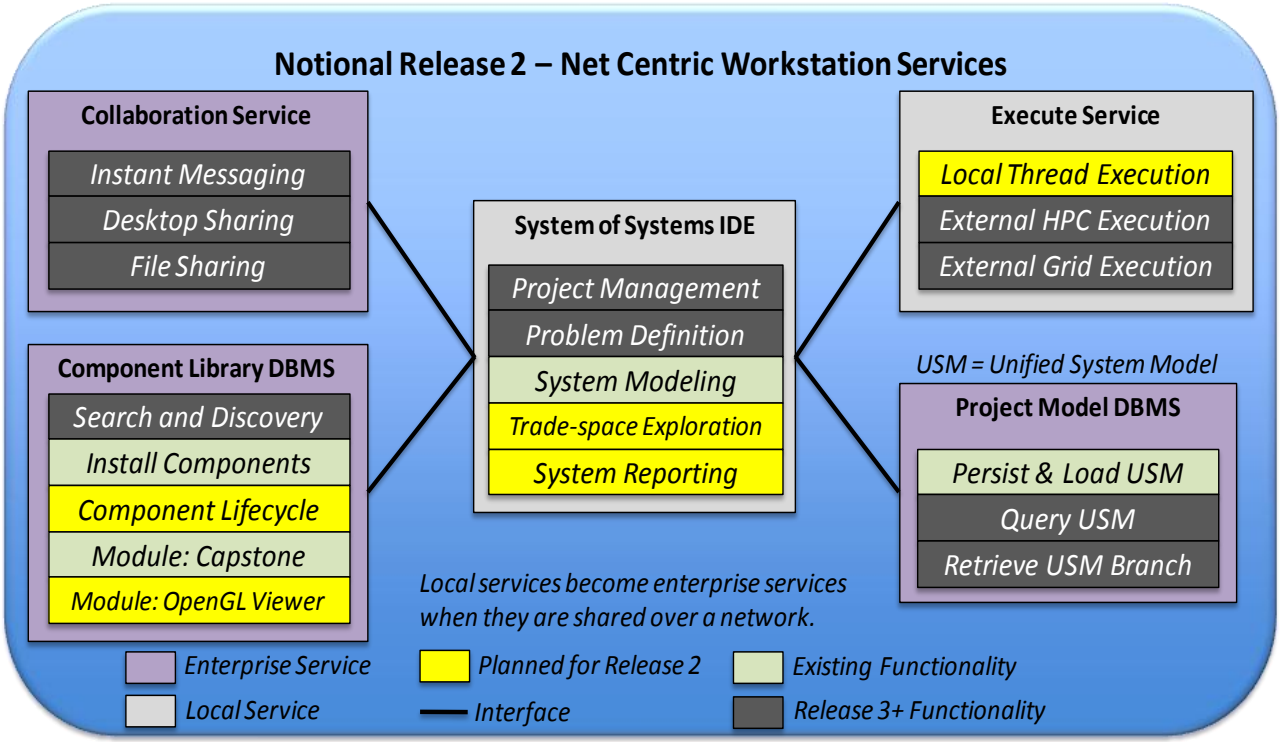


Team support thru
Net Centric Services

Computational Research and Engineering for Acquisition Tools and Environments

Build on an agile infrastructure:

- A single Unified System Model, USM, per project
- Access to extensible libraries of engineering components
- seamless access to external computation services:
- ad-hoc team collaboration services



Kestrel

Helios

Firepolt

and many others…

DaVinci at Maturity

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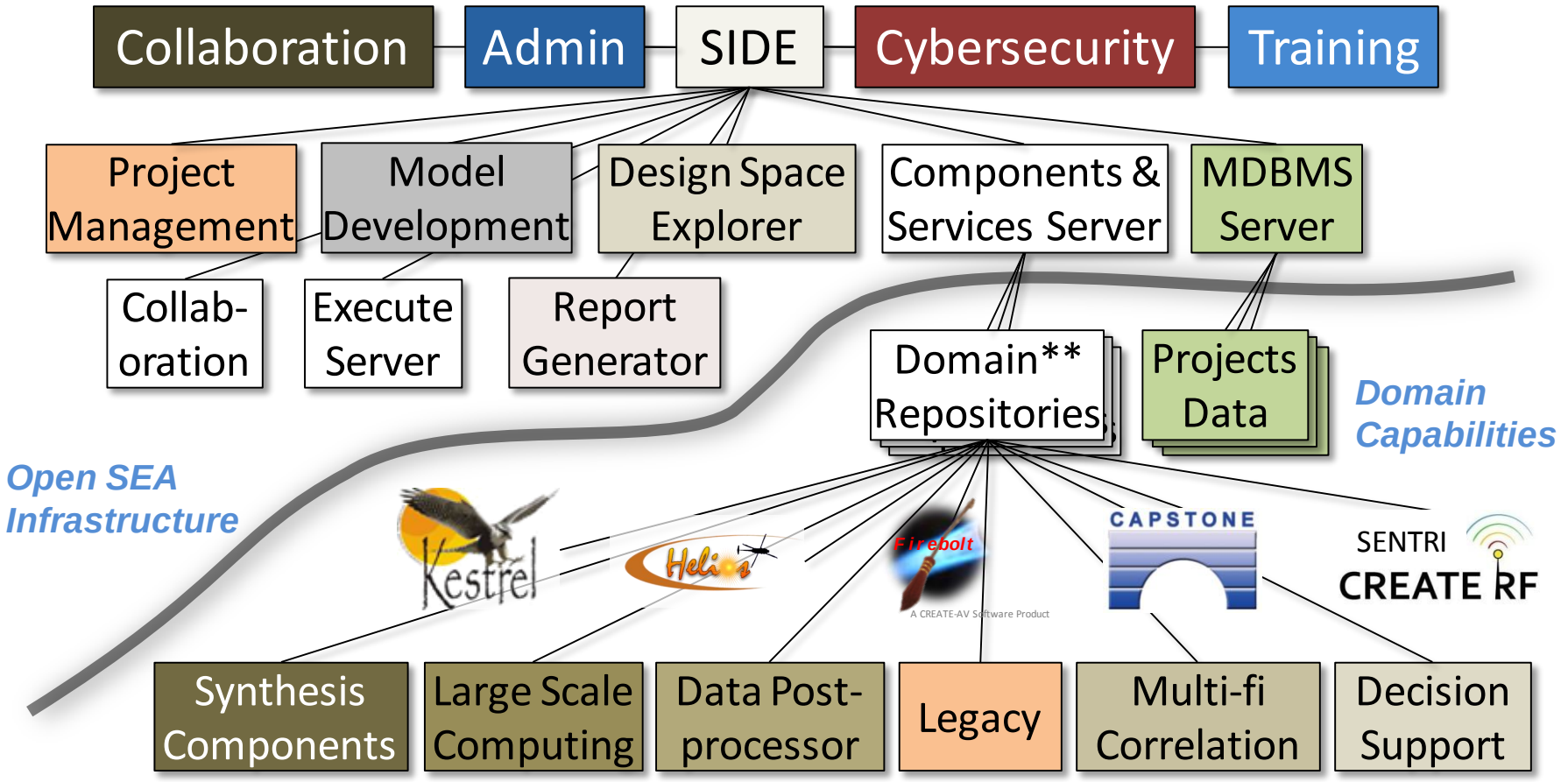


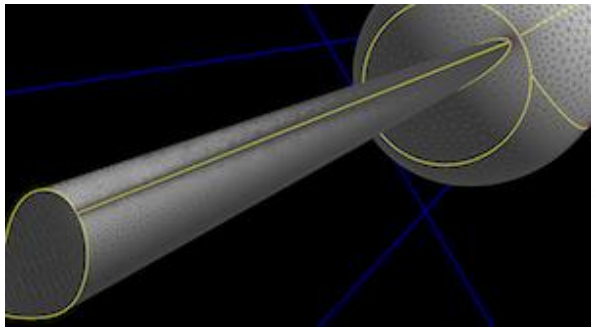
* Model Data Base Management System (MDBMS) handles all project storage, queries, & retrieval

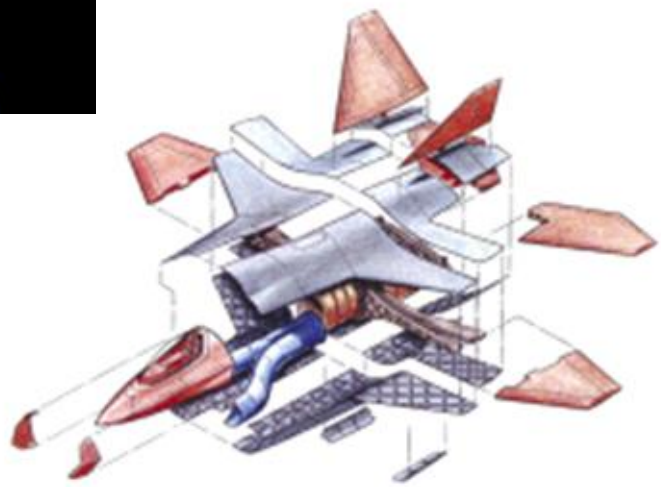
** Domain Repositories manage classes and services

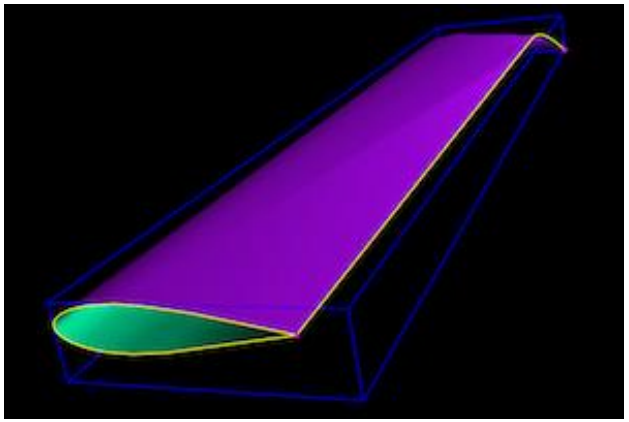
Water Tight Parametric Geometry

Computational Research and Engineering for Acquisition Tools and Environments

- Water-tight parametric geometry generation
  - MG Capstone live install accessed via API in the scripting environment
  - Each encapsulated system may have component B-rep generation
    - Wings, fuselages, nacelles, propellers, landing gear, etc.







How DaVinci is Different
in detail

Computational Research and Engineering for Acquisition Tools and Environments

What Create/DaVinci brings to the table which is beyond currently available commercial software such as Model Center and Team Center w NX. Some of the differentiator are:

- **Provides seamless integration of HPC resources and network cloud computing into engineers' models**
- **Goal of open (source code available), standards based, evolving, affordable software:**
  - **Portable Parametric Component & Service architecture (open architecture)**
  - **FOUO, proprietary & ITAR knowledge reside in the components and services which can be restricted and controlled.**
- **Built in core engineering functionality, open architecture:**
  - **Differentiation & sensitivity analysis,**
  - **Uncertainty & risk analysis,**
  - **Unit analysis & conversion**
  - **Lazy evaluation (calculations are not done until idle CPU time is available or user requests the data)**
  - **Parametric execution**
- **Development, refactoring & wrapping of aerospace design and analysis components & services**
  - **Using open, standards based components & services architecture**
  - **High quality, portable, parametric associative, systems models for wide ranging tradespace exploration and optimization**
  - **No vendor lock in. Your models are yours. They remain portable & can be used in any application**
- **Unified system modeling, a system model centric approach (as opposed to document centric).**
  - **This approach starts by capturing the users' high level emerging situation and capability gaps and drills down using "Functional Decomposition and Allocation Technique (FDAT, a domain specific language/data structure) to create and maintain unified system architecture. This includes capturing alternative branches which lead to alternative system concepts.**
    - **Drag and Drop FDAT graphical Modeling & editing for design and analysis of complex systems' architecture**
    - **Drag and Drop Parametric Component based model building**

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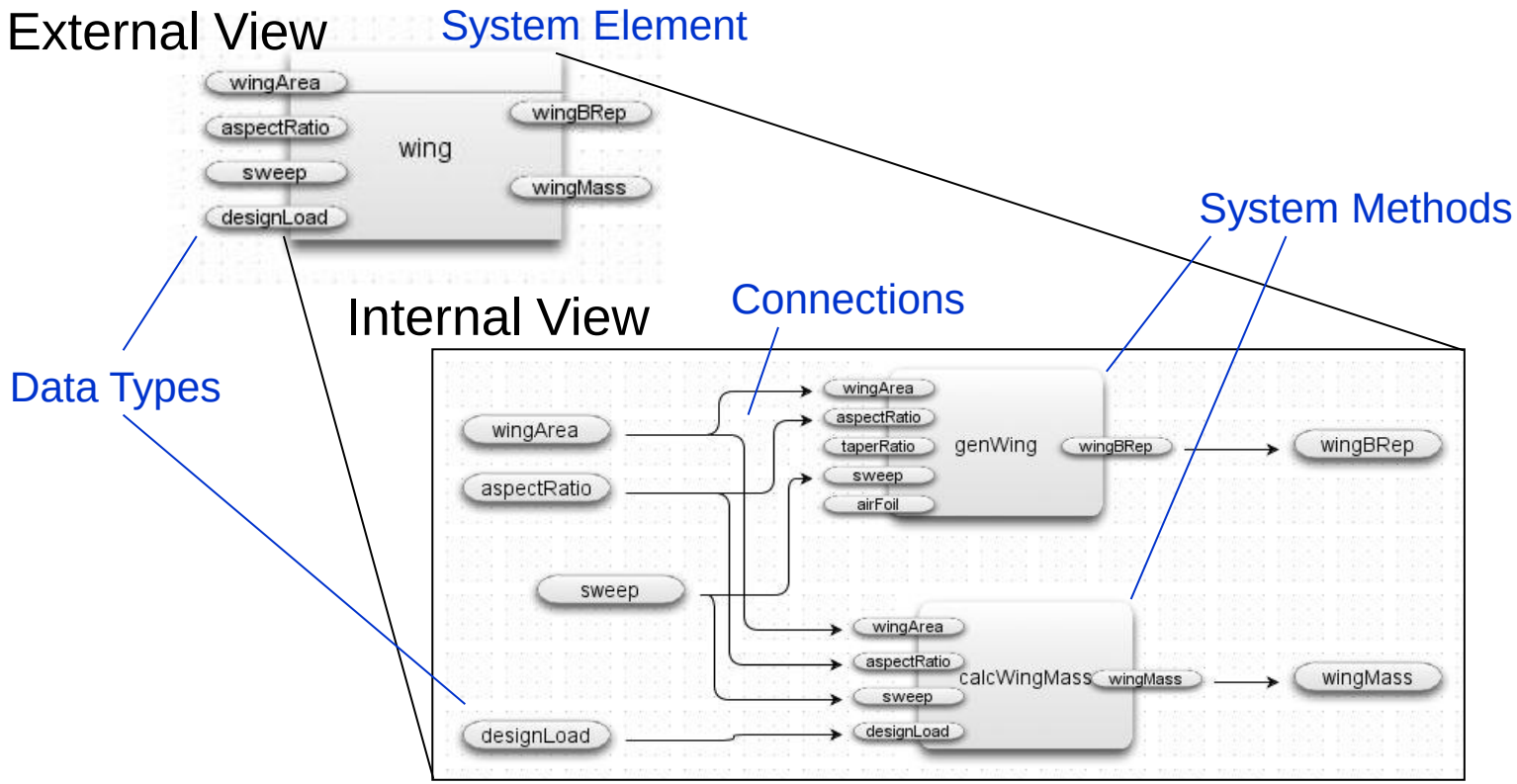
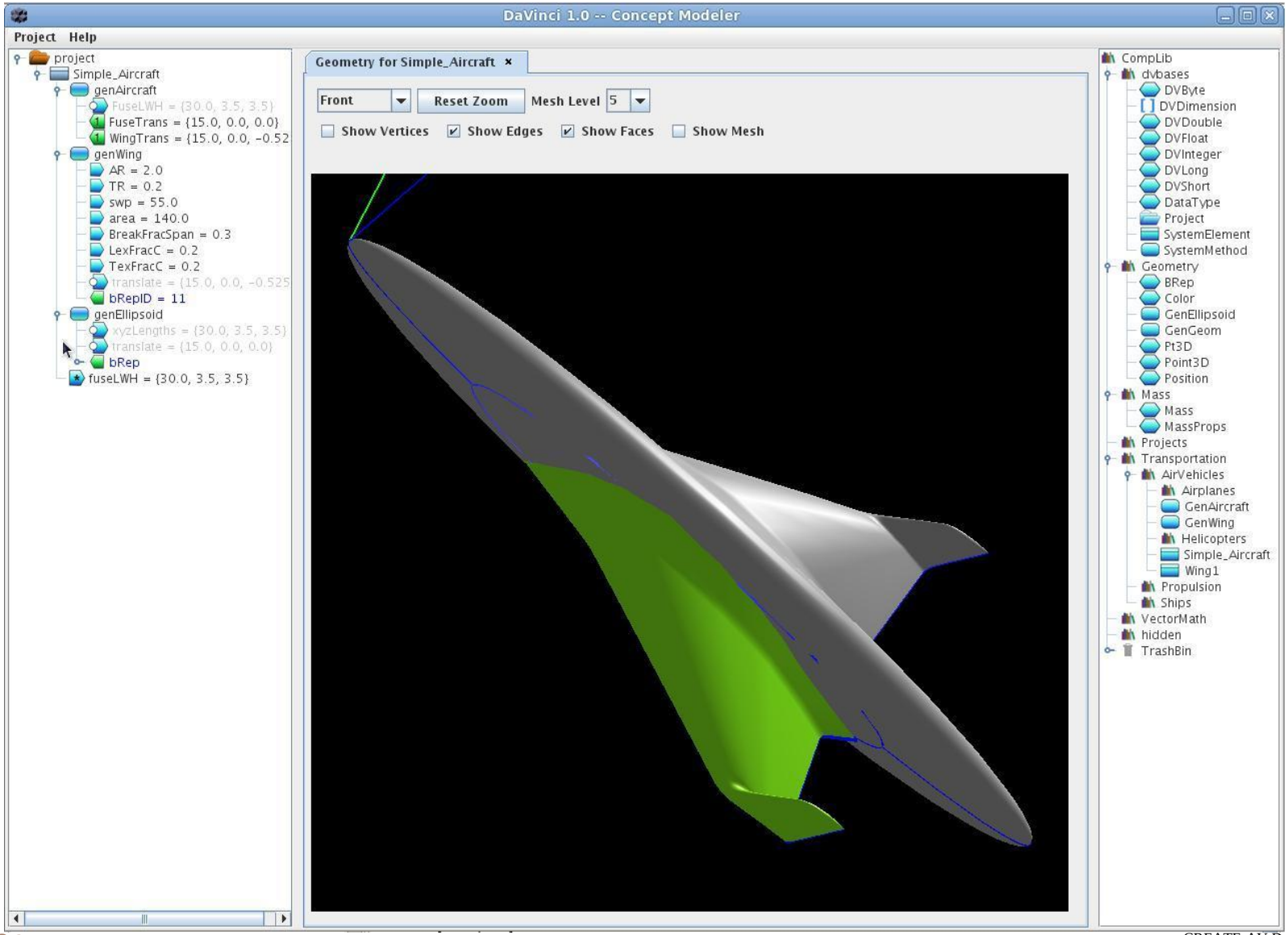
Composite Components

System Element: a modular unit of functionality, state and control
System Method : an basic executable function, compiled or scripted
Data Type : contains data values, uncertainties, sensitivities, units



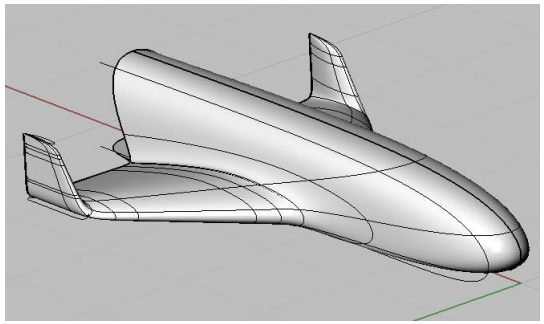
GUI Screenshot

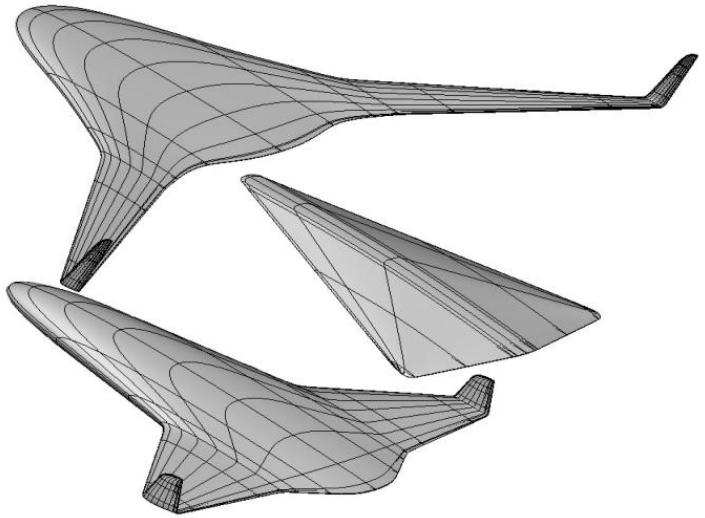
Computational Research and Engineering for Acquisition Tools and Environments



Simple initial model to focus on processes

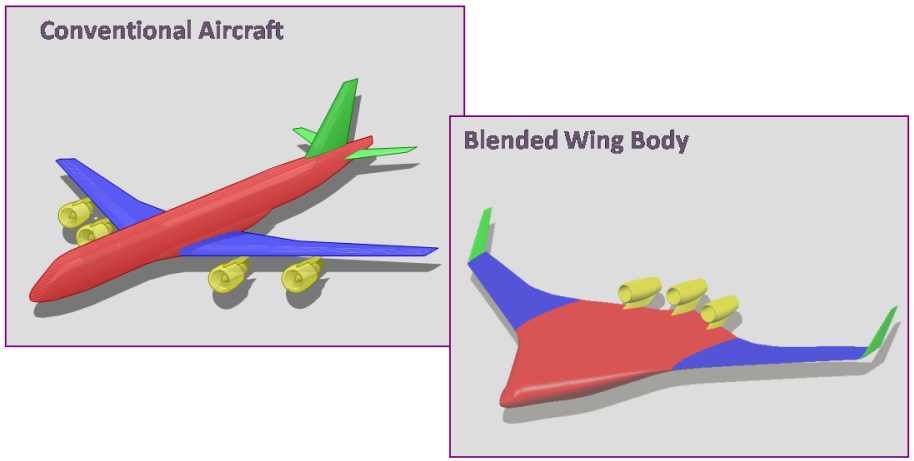
1. Create water tight OML geometry in *DaVinci*
2. Pass OML geometry to *Capstone* for grid generation
3. Pass grid to *Kestrel* for static & dynamic analyses
   - Static rigid aircraft
   - Rigid single body prescribed motion
4. Pass *Kestrel* analyses in coefficient, force, moment form to *DaVinci*
5. Integrate *Kestrel* results for use in *DaVinci*
6. Expected completion date: Summer 2011





Intermediate second model to focus on grid generation

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*
6. Expected completion date: Fall 2011



Intermediate third model to focus on more detailed geometry

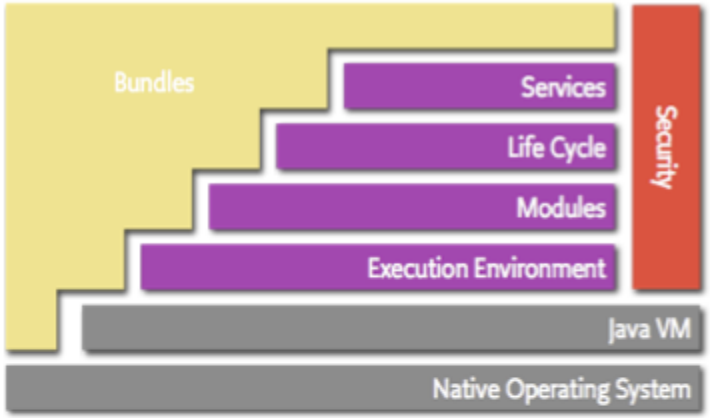
1. Create water tight OML geometry in *DaVinci*
2. Pass OML geometry to *Capstone* for grid generation
3. Pass grid to *Kestrel* for static & dynamic analyses
   - Static rigid aircraft
   - Rigid single body prescribed motion
4. Pass *Kestrel* analyses in coefficient, force, moment form to *DaVinci*
5. Integrate *Kestrel* results for use in *DaVinci*
6. Expected completion date: Summer 2012

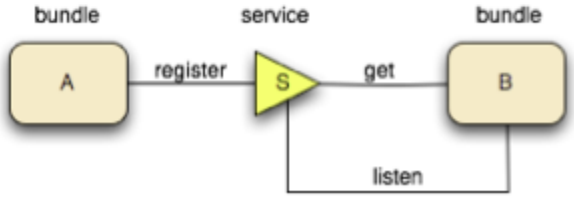
Open Services Gateway

OSGi is a set of specifications geared to define components that share a JVM.

Bullet Primer from http://osgi.org:

- **Bundles** - Bundles are the OSGi components made by the developers.
- **Services** - The services layer connects bundles in a dynamic way by offering a publish-find-bind model for plain old Java objects.
- **Life-Cycle** - The API to install, start, stop, update, and uninstall bundles.
- **Modules** - The layer that defines how a bundle can import and export code.
- **Security** - The layer that handles the security aspects.
- **Execution Environment** - Defines what methods and classes are available in a specific platform.





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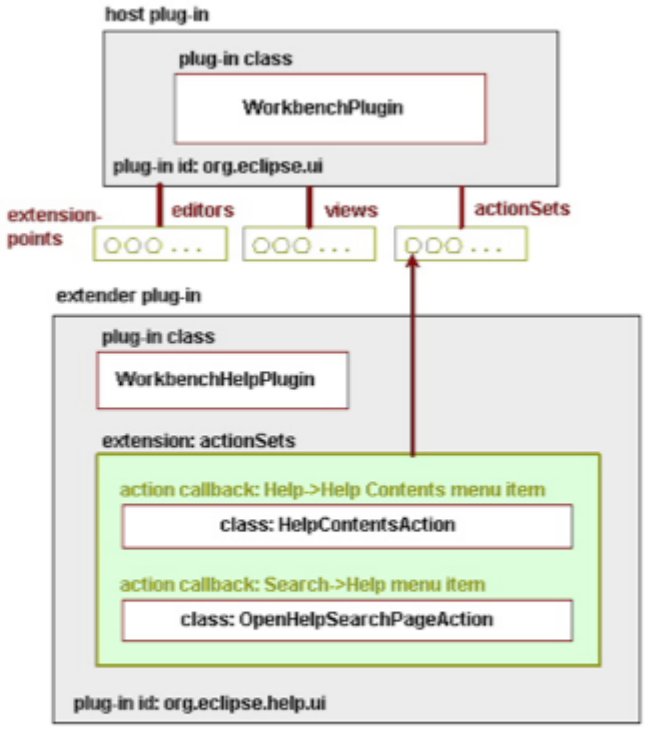
Eclipse RCP

The Eclipse RCP is specifically defined as the minimum set of plug-ins to build a rich client application.

Bullet Primer from http://eclipse.org:

- **Eclipse Runtime** – Built on top of the OSGi framework, foundational support for plug-ins and extension points.
- **SWT** – Standard Widget Toolkit, efficient portable access to the user interface facilities of the operating systems on which it is implemented.
- **JFace** – A UI framework, layered on top of SWT, for handling many common UI programming tasks.
- **Workbench** – Builds on top of the runtime, JFace, and SWT to provide a multi-window environment for managing views, editors, perspectives, actions, wizards, and more. Often referred to as the generic workbench to distinguish it from the IDE plug-in.
- **Prerequisites** – Support for XML expressions language, commands, and help core content model.
- **EMF** – Among others, a plug-in for modeling environments.



Workbench UI plug-in is extended by the Workbench help plug-in via Action Sets

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Risks and Resolution Measures

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Risk	Resolution	Asks
Overly optimistic CREATE-AV schedule pressure	Mitigate by PDR and FDR CCB approvals, based on *DaVinci* Team proposed capabilities	✓
DaVinci schedule leaves out necessary tasks	Mitigate by converging to team agreement on product work plan (PWP)	
Requirements for interfacing with other systems not under *DaVinci* control result in unforeseen design, implementation, or testing efforts	Mitigate by synchronizing development schedules with these products High defect rates or missed deadlines trigger contingency plan to find a replacement or work-around resulting in additional taskings	✓
Optimistic DaVinci schedule	Mitigate by factoring team consensus risks into product work plan (PWP)	
End users insist on new requirements (requirements creep)	Mitigate with change management plan	
Shortage of resources (i.e. hiring of developers takes longer than expected or is fewer in number than needed)	Invoke contingency plan to leverage potential resources form other sources or delay schedule	✓

Risks and Resolution Measures

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Risk	Resolution
Delay in one task causes cascading delays in dependent tasks	Mitigate with team agreement on PWP schedule, track production rates, and adjust resources as needed
Non-technical 3rd party tasks take longer than expected (i.e., clearances)	Mitigate by elevating task priority
Requirements have been baselined but continue to change	Mitigate with change management plan and impact analyses
Building on developmental technology lengthens schedule	Mitigate with stakeholder use case priorities (based on preference, risk, and dependencies) Invoke contingency plan of reducing scope as needed to maintain schedule
Additional requirements are added after Software Requirements Specification is finalized	Mitigate with change management plan and impact analysis
Customer communication time (feedback) is slower than expected	Mitigate with timeliness agreements Invoke contingency plan by escalation and moving on to other tasks
Low quality code libraries causing extra testing, defect correction, or rework	Mitigate with quality plan, and product evaluation & consideration criteria Invoke contingency plan by finding another solution
Customer does not participate in review cycles for plans, prototypes, specifications, etc. resulting in unstable requirements	Mitigate with user acceptance testing on an agreed upon schedule Invoke contingency plan by reprioritizing use cases

Organizational Relationship

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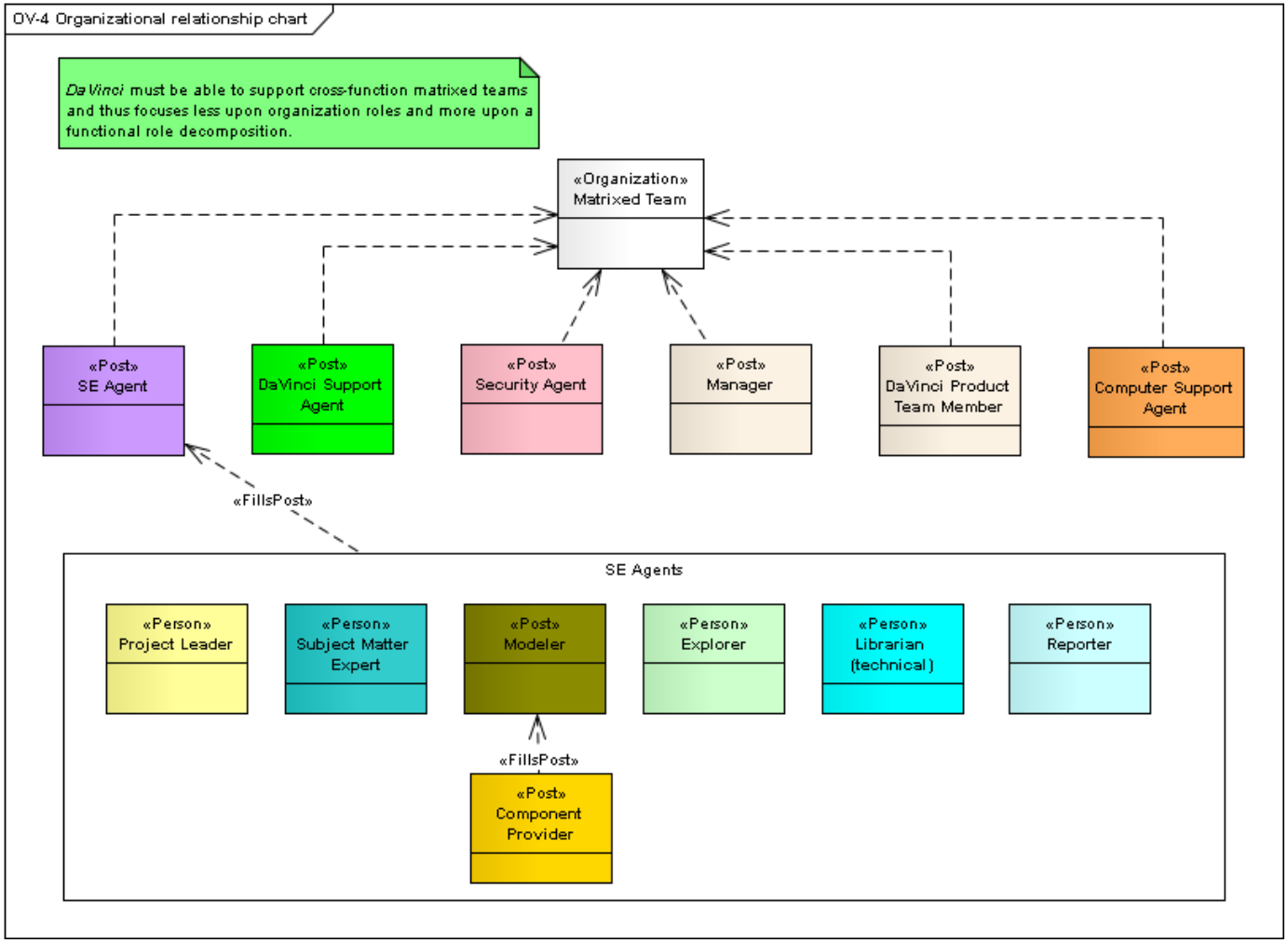

Iteration Process

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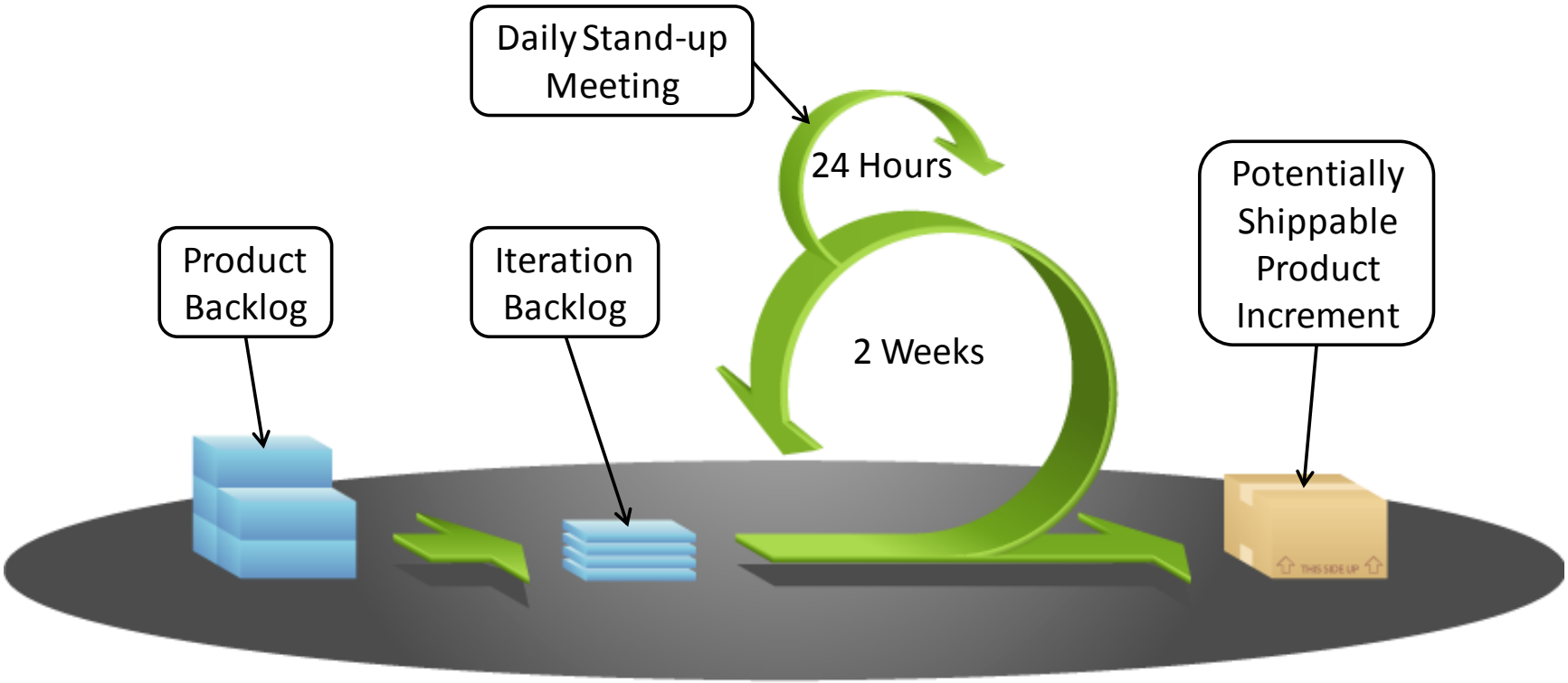

DaVinci Architecture Stack

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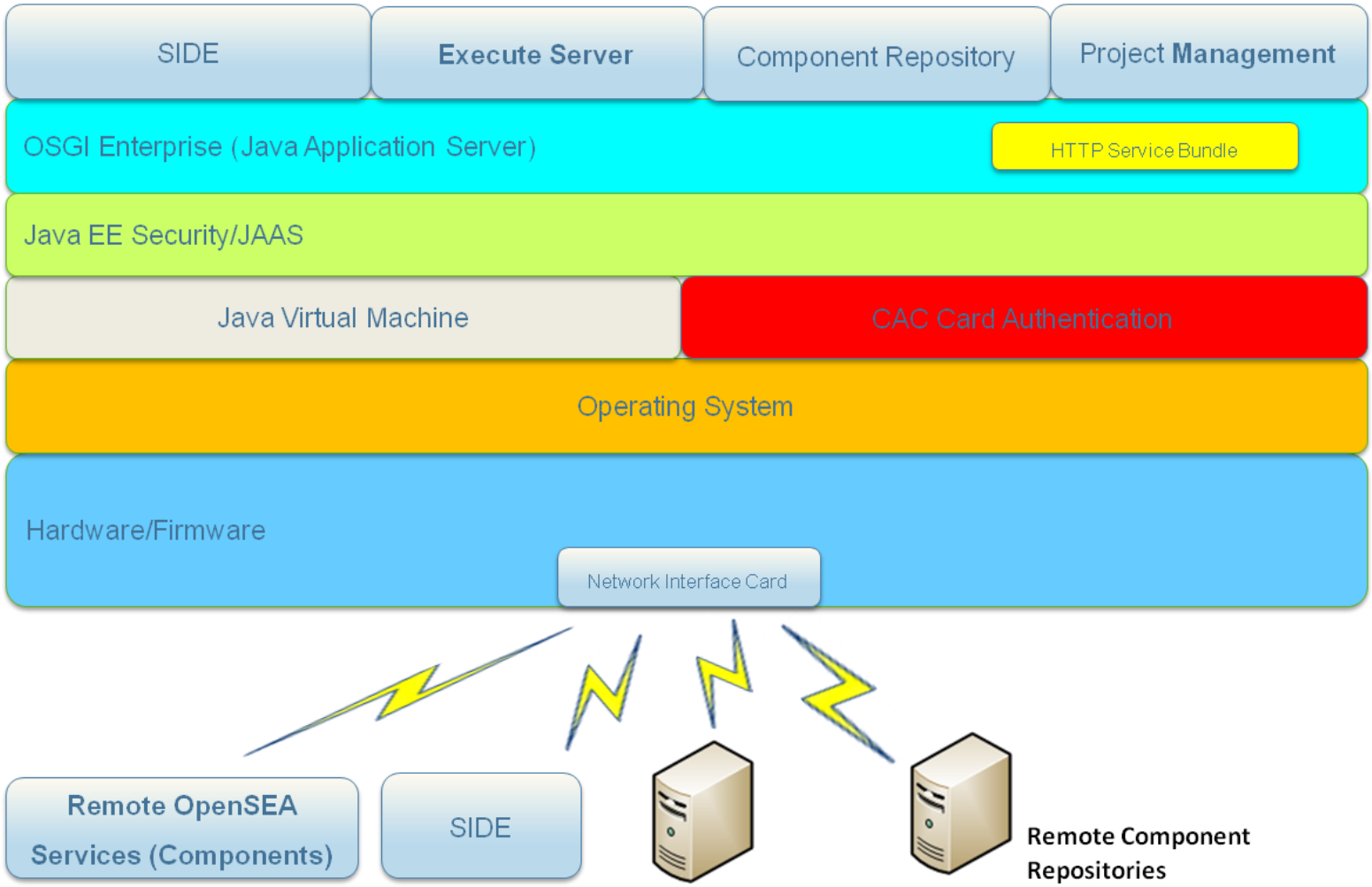

Trade Studies

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Trade-off Category	Examples of technologies to be traded	Expected Timeframe
Languages	Java / C++ / HTML5, Python, UML / BPMN	Release 1+
Data Formats	XML Formats and Alternates	Release 1+
Agile Methods	SCRUM, XP, Iterative, RAD, Spiral	Release 1+
Persistence	OODBMS, RDBMS, NXDBMS, CloudDBMS	Release 2+
Enterprise Mgmt.	Monitoring, Automation, eCRM, Dashboards	Release 2+
Decision Support	Reporting Frameworks, Graphing Toolkits	Release 2+
Search & Discovery	Facets, Harvest vs. Federate, Deep vs. Shallow	Release 3+
Adaptive Computing	SOA, Cloud Middleware, Dynamic Provisioning	Release 3+
Security	SSO, PL/2 through 5, C&A, VPN, Intrusion	Release 3+
High Performance	Grid Computing, Virtualization	Release 4+

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Iteration Planning

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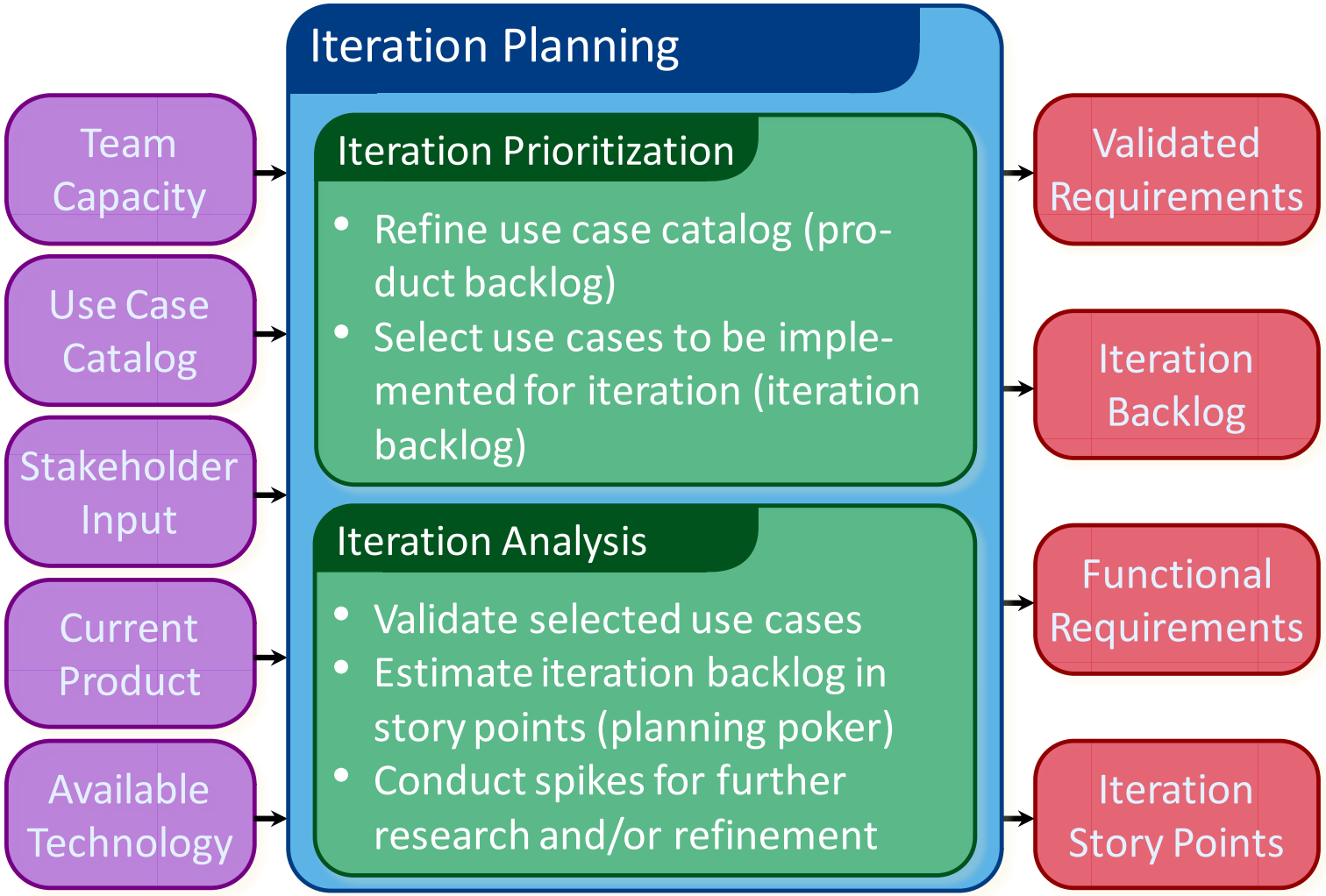

Design and Construction

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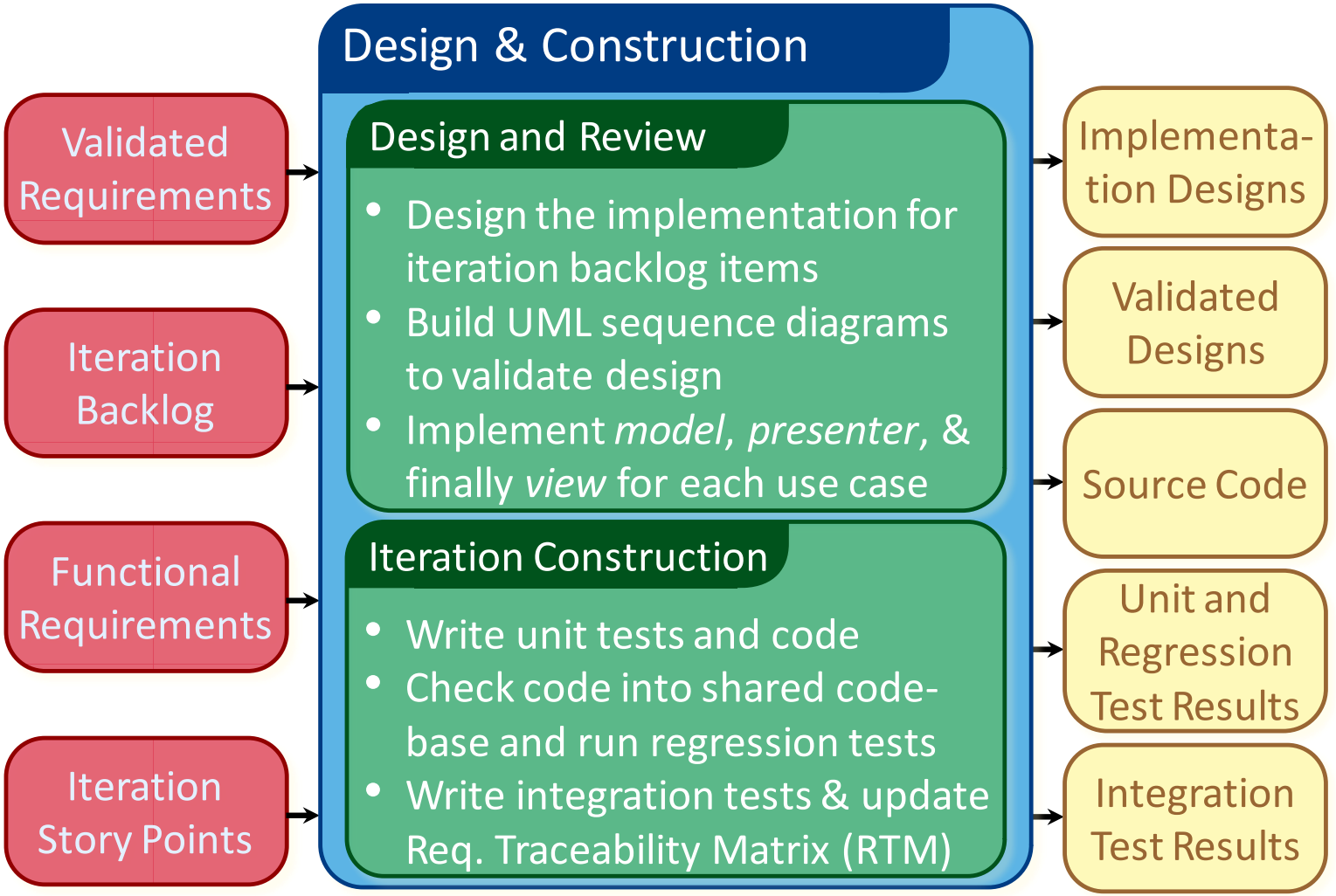

Iteration Testing & Tracking

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