SERC TALKS

# How is Johns Hopkins University Applied Physics Laboratory Applying Digital Engineering?

## with Tom Alberi, Johns Hopkins University Applied Physics Laboratory

- Today's session will be recorded.
- An archive of today's talk will be available at: www.sercuarc.org/serc-talks/ as well as on the SERC YouTube channel.
- Use the Q&A box to queue up questions, reserving the chat box for comments, and questions will be answered during the last 5 -10 minutes of the session.
- If you are connected via the dial -in information only, please email questions or comments to SERCtalks@stevens.edu .
- Any issues? Use the chat feature for any technical difficulties or other comments, or email SERCtalks@stevens.edu .

**CELEBRATING SYSTEMS ENGINEERING DIGITALIZATION**

# “Celebrating Systems Engineering Digitalization” Series Moderator

## Tom McDermott

Chief Technology Officer,
Systems Engineering Research Center

# How is Johns Hopkins University Applied Physics Laboratory Applying Digital Engineering?

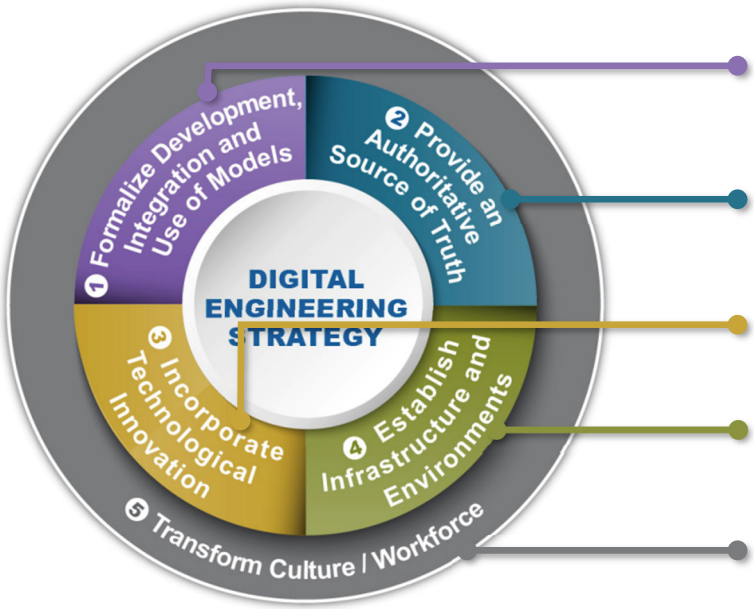

## Tom Alberi

Program Manager– Sentinel Weapon System Engineering,
Johns Hopkins University (JHU)
Applied Physics Laboratory (APL)

# Agenda

Due to presentation time constraints, only a select few of APL's DE efforts are highlighted

- APL Overview
- DE at APL: Examples, Challenges, & Recommendations




- Data Integration
- Strategic Integrated Development Environment
- Architecture Profiles
- Cameo Plugins
- Whole System Decision Model
- Advanced Visualization
- Digital Engineering System Modeling
- Acquisition for Digital Engineering
- Cultural Transformation
- Strategic Deterrence Digital Engineering Conference

Topics organized by DoD DE strategic goals that are most applicable, but may cover multiple goals

# APL Overview

## What are we?

- Research division of Johns Hopkins University
- University Affiliated Research Center

## Who are we?

- Technically skilled and operationally oriented
- Objective and independent

## Who are our sponsors?

- Department of Defense
- NASA
- Department of Homeland Security
- Intelligence Community

## What is our purpose?

- Critical contributions to critical challenges

**Laboratory Statistics**: ~8,500 staff members

# Some Examples of DE in Action Across APL

**Air Base Air Defense Systems**
- **Challenges:** Requirements development, candidate system evaluation
- **Tasking:** Model combinations of systems, identify key system attributes, perform trade and feasibility studies

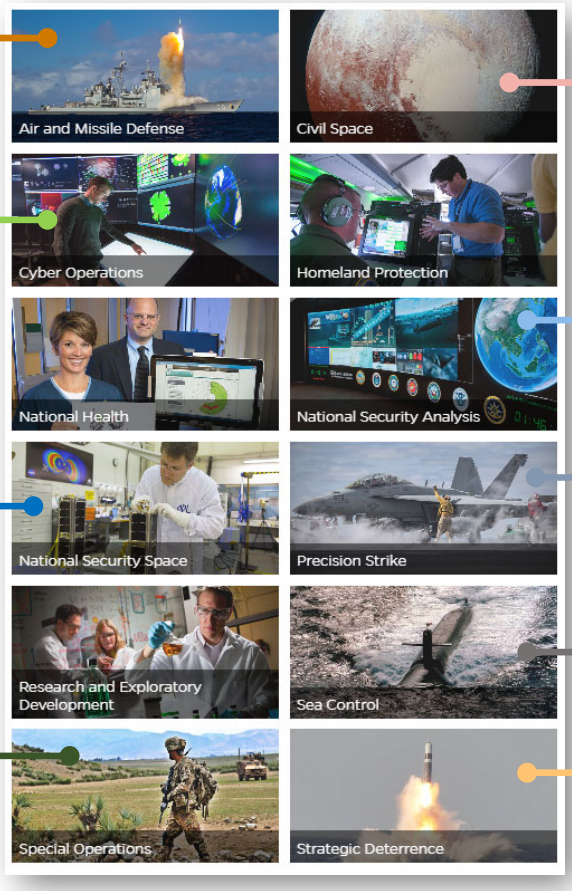
**Nuclear Command and Control Communications (NC3)**
- **Challenges:** Critical components identification, resource prioritization
- **Tasking:** Construct mission dependency models, develop graph-based analytics capability

**Battle Management Kill Chain (BMKC)**
- **Challenges:** End-to-end kill chain modeling
- **Tasking:** Model integration, Monte Carlo simulations

**Next Generation Technologies**
- **Challenges:** Interoperability, system certification, training
- **Tasking:** Digital Twin requirements development

Several efforts highlighted in the following slides

*APL Mission Areas*



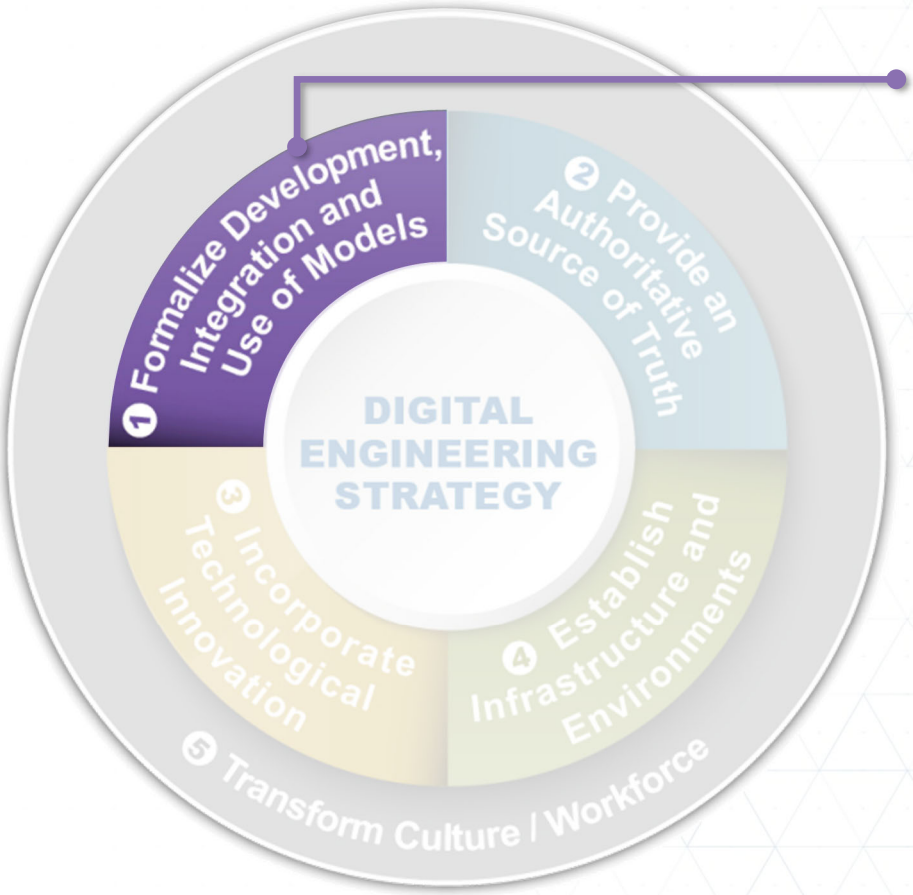

**One-of-a-Kind Spacecraft Production**
- **Challenges:** Product lifecycle management, work and parts planning, fabrication work order support
- **Tasking:** Engineering and manufacturing workflow automation, advanced visualization (e.g. AR)

**Agile Combat Employment (ACE) Missions**
- **Challenges:** Ontology development, staff skillset
- **Tasking:** Model development and integration, performance assessment, decision analysis

**Hypersonic Attack Cruise Missile (HACM) Digital Acquisition**
- **Challenges:** Air force rapid development of air launched hypersonic weapon
- **Tasking:** Pioneering digital engineering for AF weapons

**Next Generation Attack Submarine SSN(X)**
- **Challenges:** DE strategy, cultural transition
- **Tasking:** Training, roadmap development and execution planning, ship concept modeling development

**Intercontinental and Submarine Launched Ballistic Missiles (ICBMs, SLBMs)**
- **Challenges:** DE strategy, decision analysis, complete lifecycle support, system certification
- **Tasking:** Requirements/architecture modeling, data integration, capability prototyping, cultural adoption



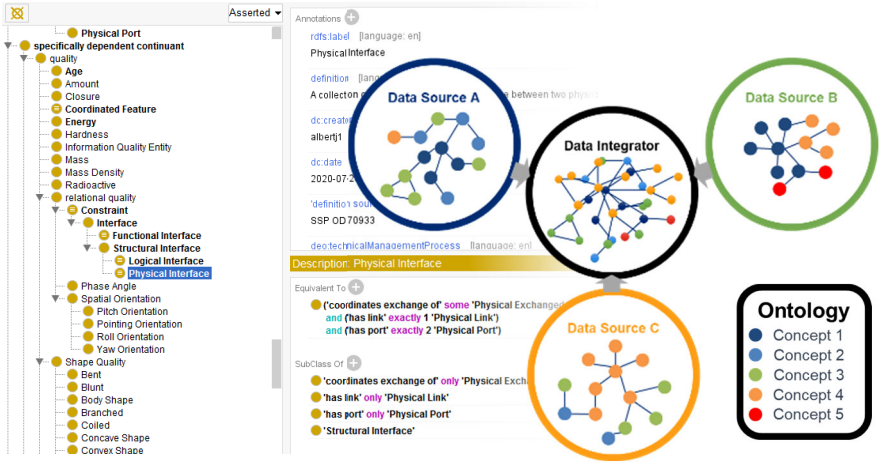

- Data Integration
- Strategic Integrated Development Environment

# Data Integration

Supporting Navy SSP and Air Force Sentinel efforts to integrate data across many tools and databases

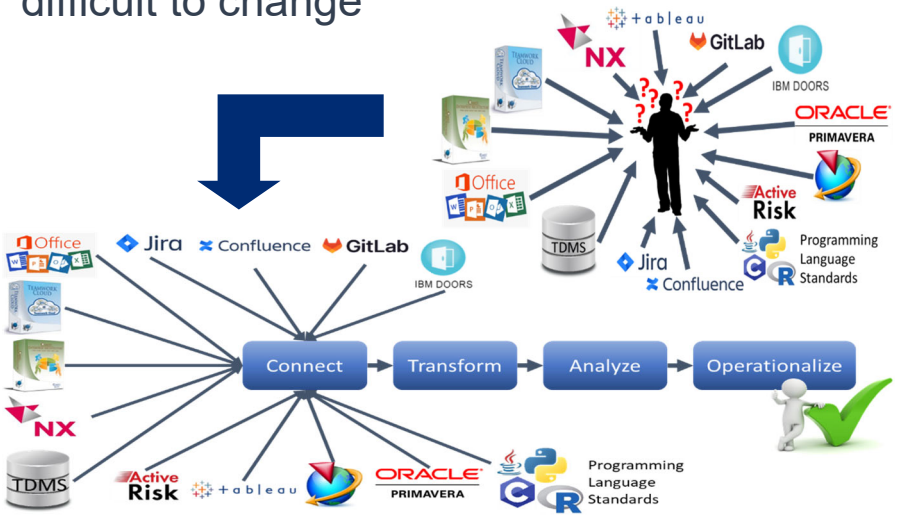
## Strategic Systems Programs (SSP)

- Prescribed formal ontology to drive structure of data
- Best for early or pre-development



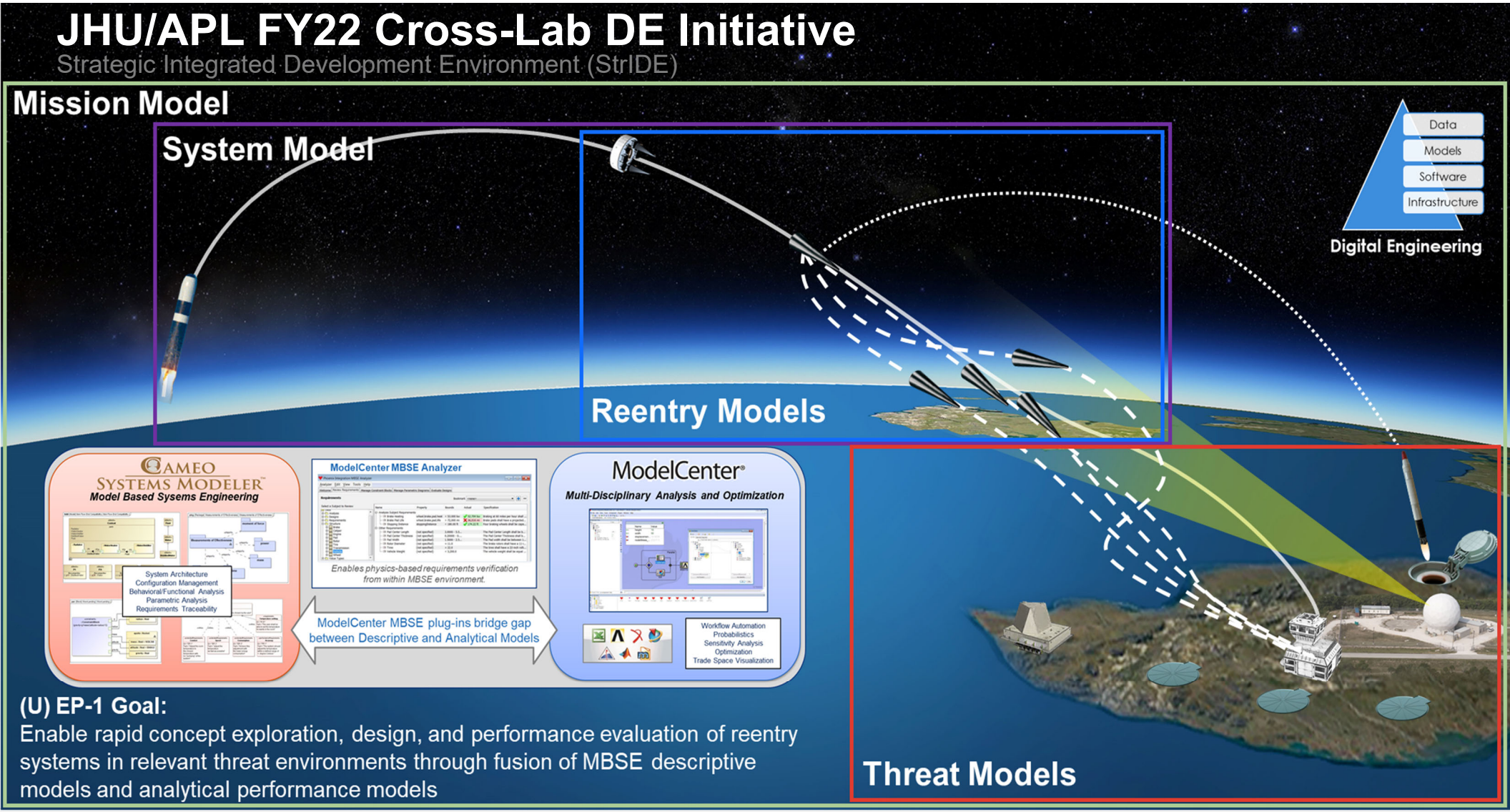

## Sentinel

- Ad-hoc ontology development, based on existing data structure
- Best when data source structure is difficult to change



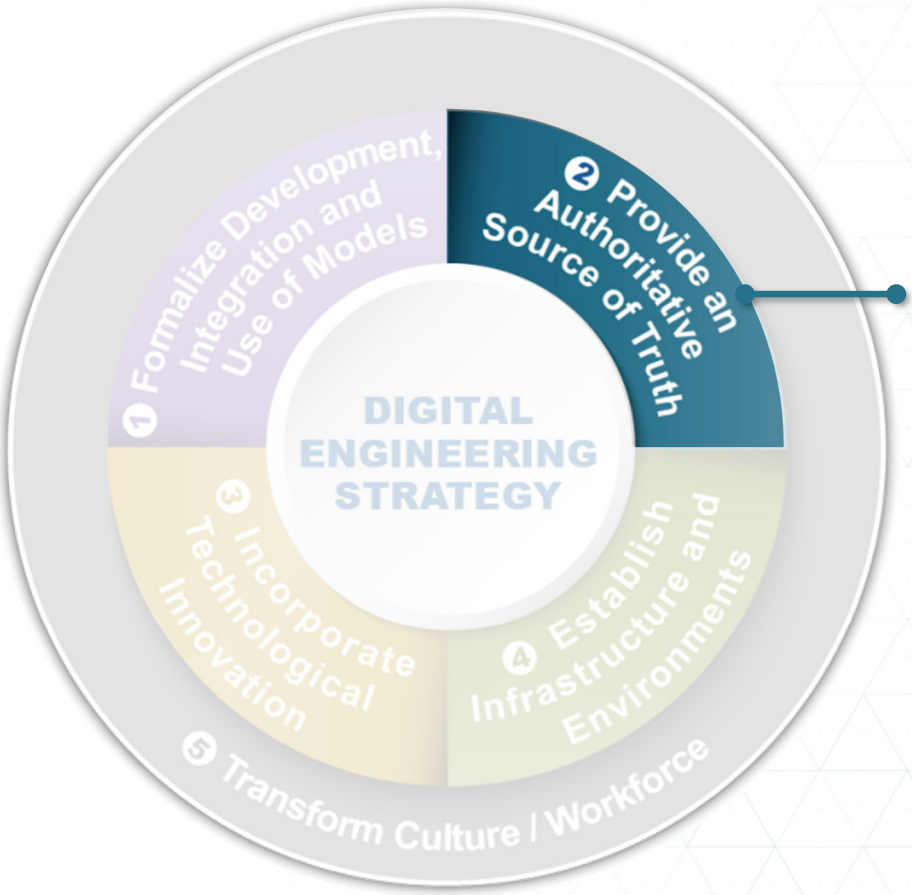
# JHU/APL FY22 Cross-Lab DE Initiative

Strategic Integrated Development Environment (StrIDE)




**(U) EP-1 Goal:**

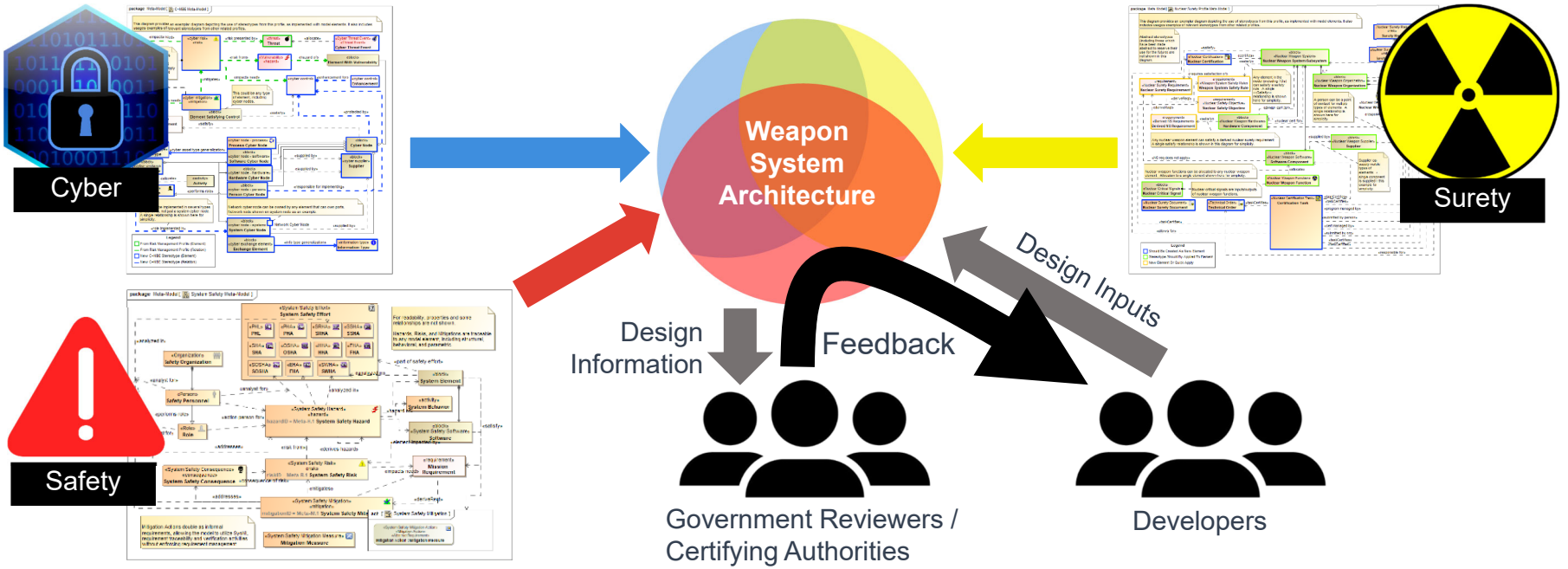
Enable rapid concept exploration, design, and performance evaluation of reentry systems in relevant threat environments through fusion of MBSE descriptive models and analytical performance models




- Architecture Profiles
- Cameo Plugins

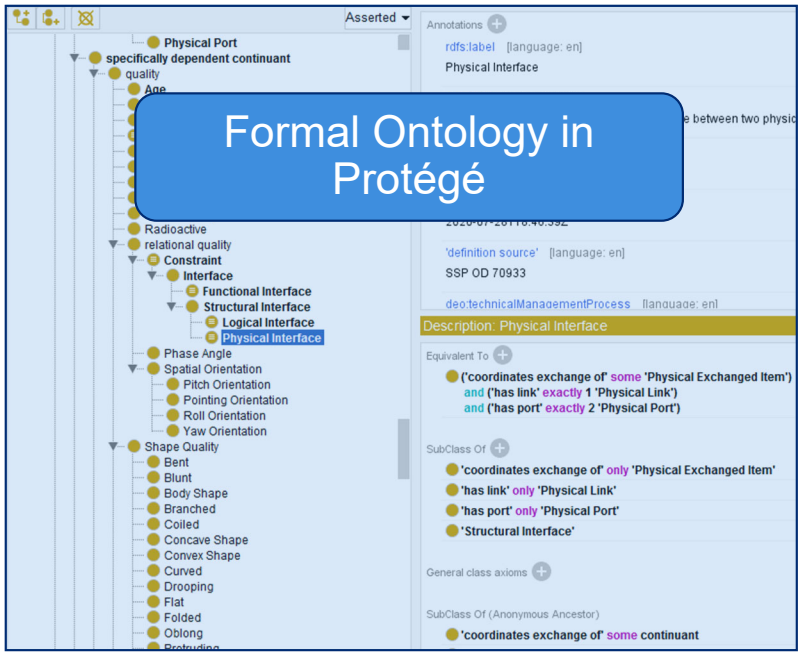
# Sentinel Architecture Profiles

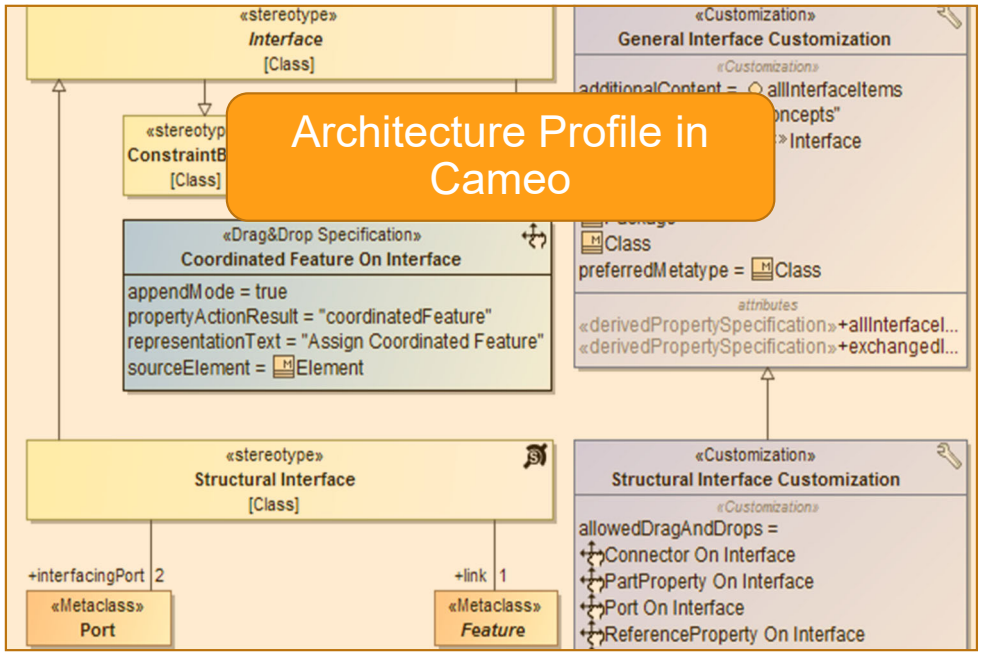
- APL is supporting the development and use of custom architecture profiles for Sentinel
  - Integrate domain-specific information in architecture models to facilitate early evaluation and analysis of contractor design to drive real-time feedback and revision
  - Support unification of nuclear surety, cybersecurity, and safety certifications through risk-based concepts



# Semantically-Driven Profiles for Navy SSP

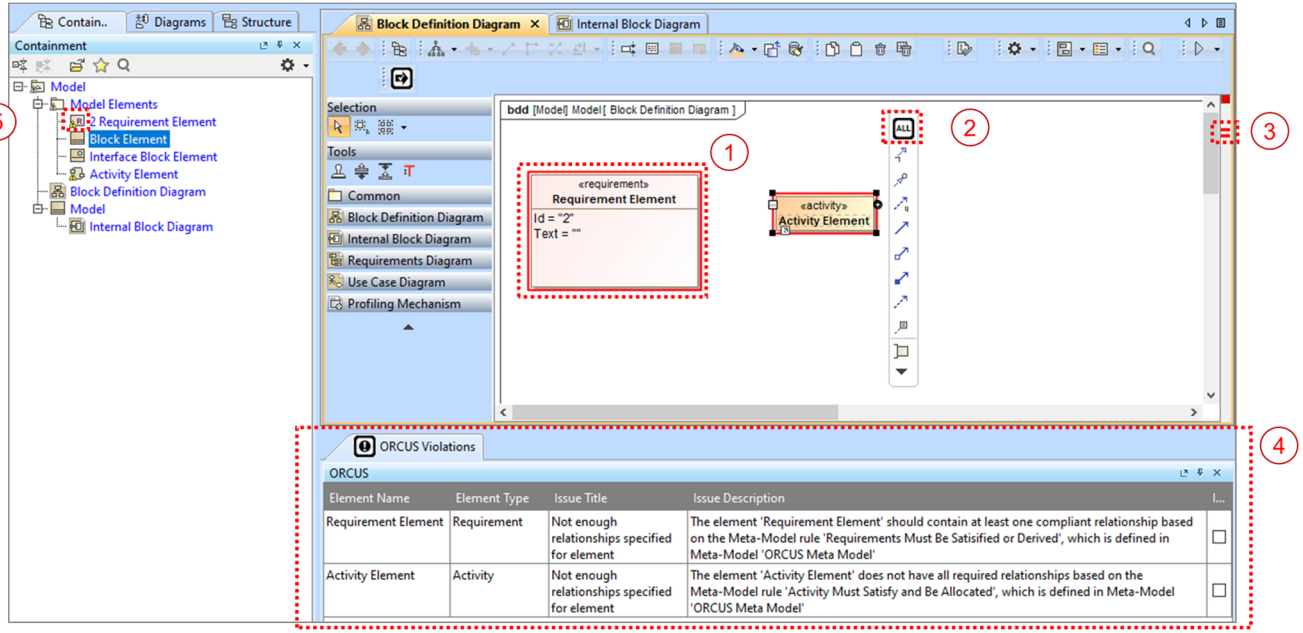
- Using the prescribed ontology to guide the development of Cameo profiles to enforce adherence to the ontology
- Also considering using the ontology to drive data structures in other tools (DOORS, PLM, etc.)



# Object Recognition for Compliance, Usability, and Sustainment

- ORCUS is an APL-developed Cameo plug-in that provides an interactive method to amend model compliance violations
- Ensures model compliance and enables faster development for both new and experienced Cameo users
- Utilizes user-defined meta-models to establish validation patterns for evaluation
  - Meta-model agnostic – no code changes needed to use ORCUS with new models
  - Minimal rework to make existing meta-models readable using pre-defined stereotypes




Available for Download

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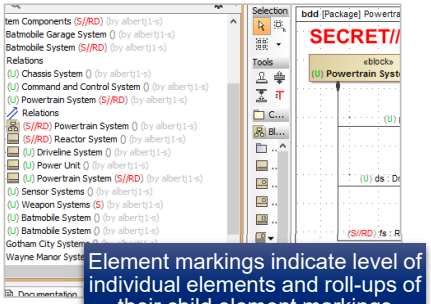
Key:
(1) Element Highlighting
(2) Element Pop-up Menu
(3) Scroll-bar Markings
(4) Violations Table
(5) Containment Tree ⚠ Icon

ORCUS

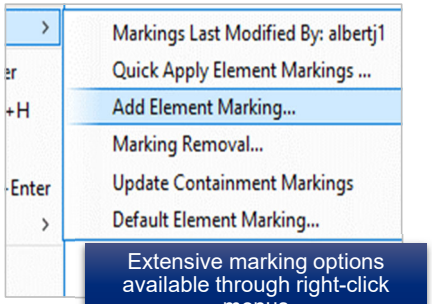
# Information Security Marking Plugin

## For Consistently Applying Information Security Markings in Cameo Models

**MARKINGS SHOWN BELOW ARE FOR DEMONSTRATION PURPOSES ONLY. NO CLASSIFIED DATA IS SHOWN IN THIS SLIDE.**




Element markings indicate level of individual elements and roll-ups of their child element markings




Extensive marking options available through right-click menus

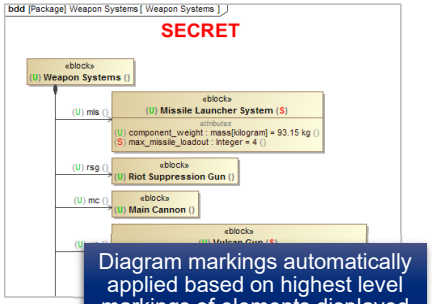
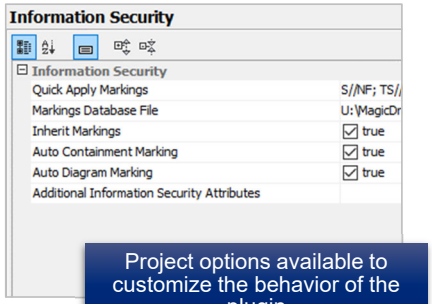
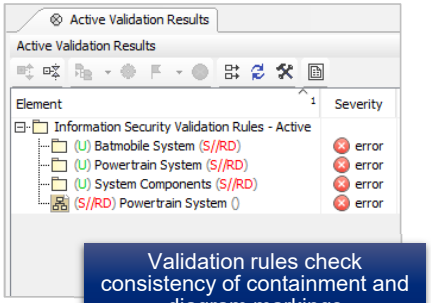


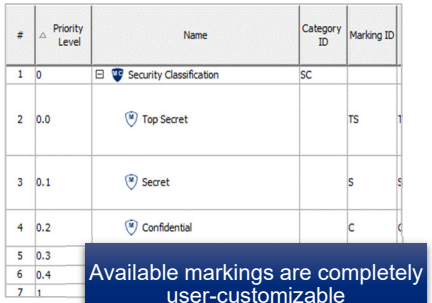

Diagram markings automatically applied based on highest level markings of elements displayed



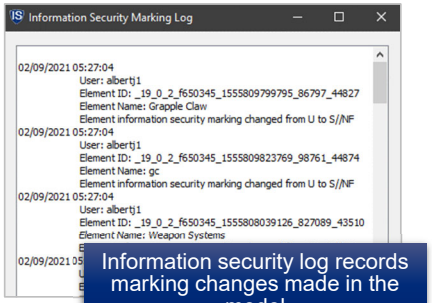

Project options available to customize the behavior of the plugin



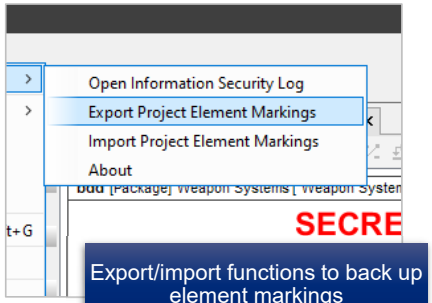

Validation rules check consistency of containment and diagram markings




Available markings are completely user-customizable



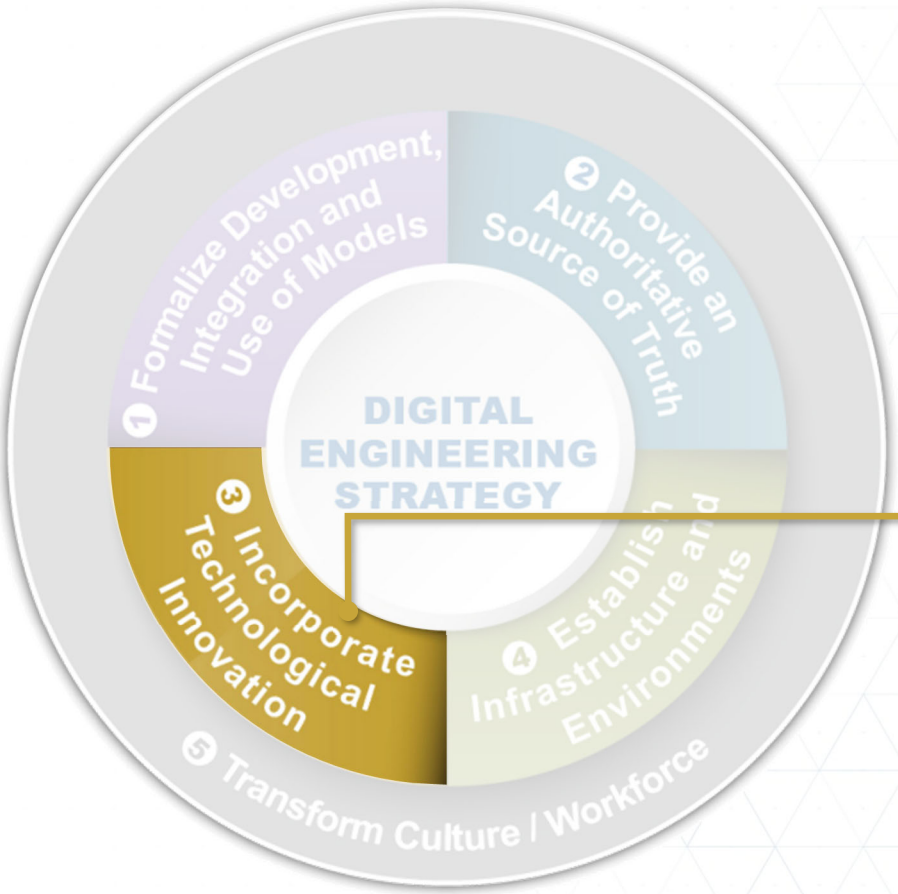

Information security log records marking changes made in the model




Export/import functions to back up element markings

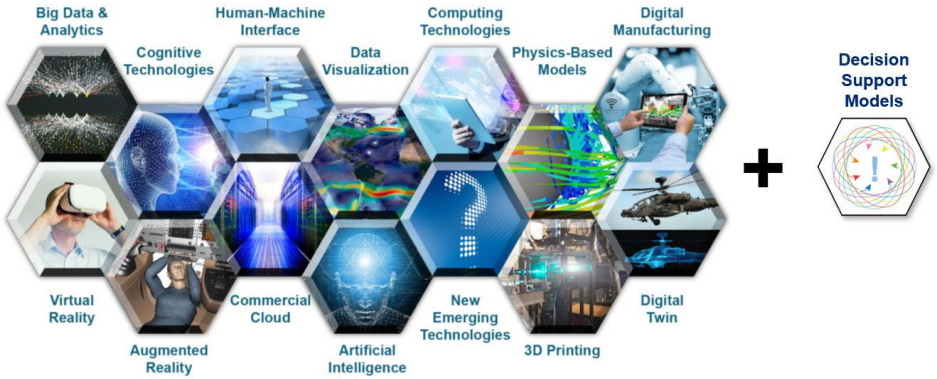
**Selected as the information security marking solution for Cameo by Navy Modeling & Sim Office**

**https://www.jhuapl.edu/TechTransfer/Technologies/Licensing** ← Available for Download

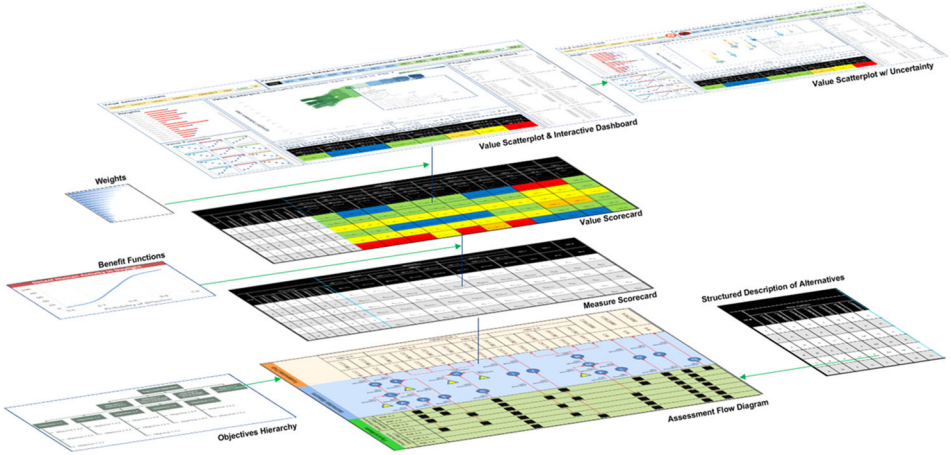



- Whole System Decision Model
- Advanced Visualization

# Whole System Decision Model (WSDM)




High quality data-driven decision making requires decision-driven data-generation, analysis, & synthesis.

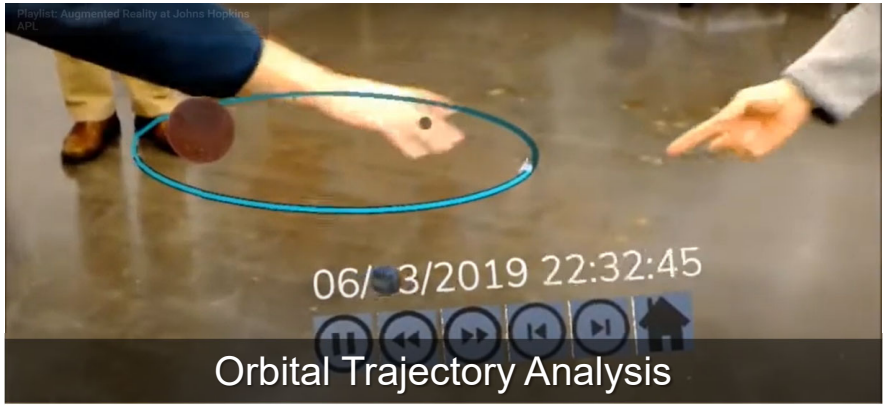



The Whole System Decision Model (WSDM) incorporates best practices to facilitate decision-driven data-generation, analysis, and synthesis.

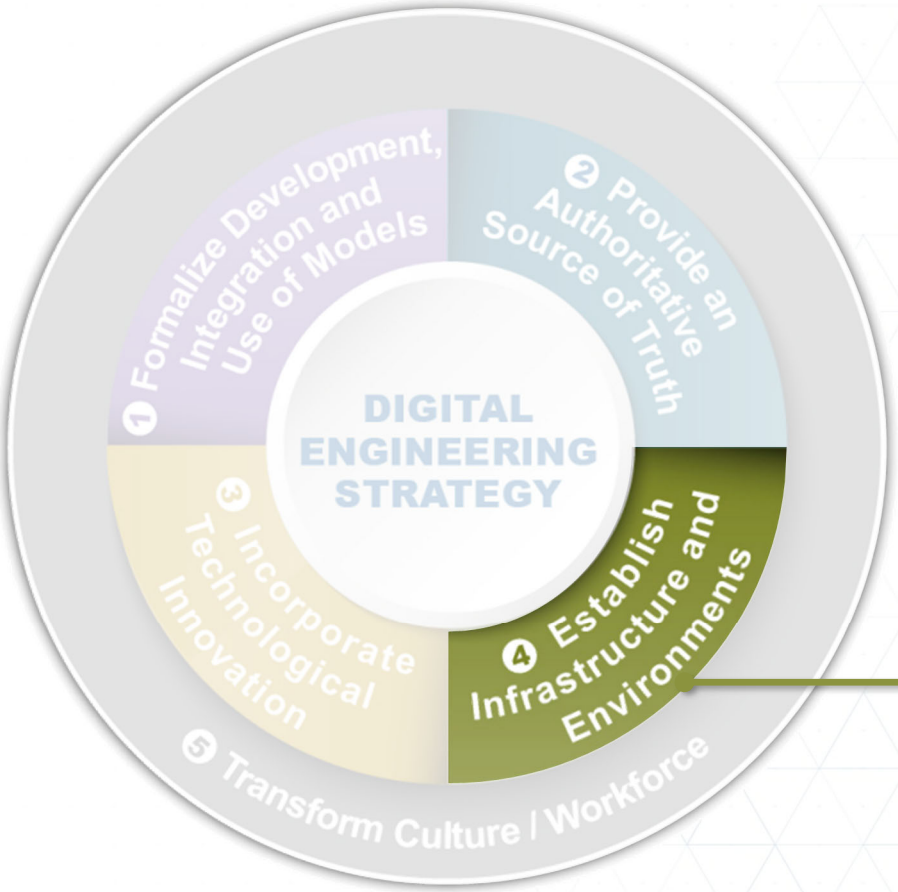
| Best Practice | Description |
|---|---|
| **Establish Frame** | View Engineered System Through Holism / Synthesis Lens. Define SOI Boundary & Planning Horizon. |
| **Express Value** | Express SOI's Stakeholder Value as a Solution Neutral Function in Hierarchical Form. |
| **Define Measures** | Define unambiguous measures of effectiveness for each leaf node of the hierarchy. |
| **Generate Alternatives** | Generate large number of system level alternatives (elements of form). |
| **Map Relationships** | Create a System Value Influence Diagram to clearly map independent variables (alternatives) to dependent variables (MOEs) through appropriate cost, schedule, and performance models. |
| **Deploy Models** | Deploy SMEs and their models to assess each alternative against MOPs and MOEs within their area of expertise. |
| **Synthesize Analysis** | Put all the data in one place. Use exploratory data-analysis techniques to explore tradespace. Show the data – don't rely on summary statistics. Include sensitivity analysis. |
| **Converge Over Time** | Treat decision as a tournament of ideas implemented over time, build intuition about the trade-space, winnow out of dominated alternatives at each round, increase fidelity of filters at each round. |

# Advanced Visualization

## Making Data Actionable

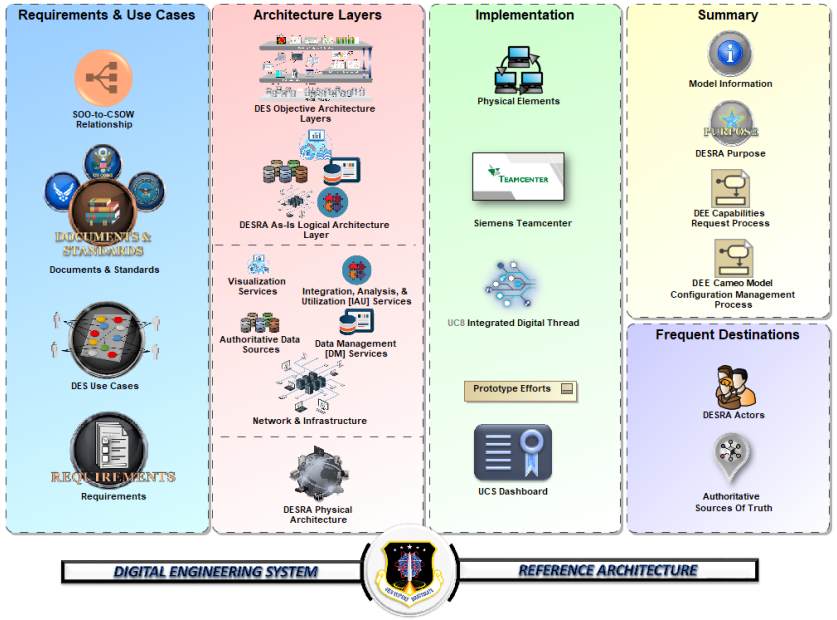


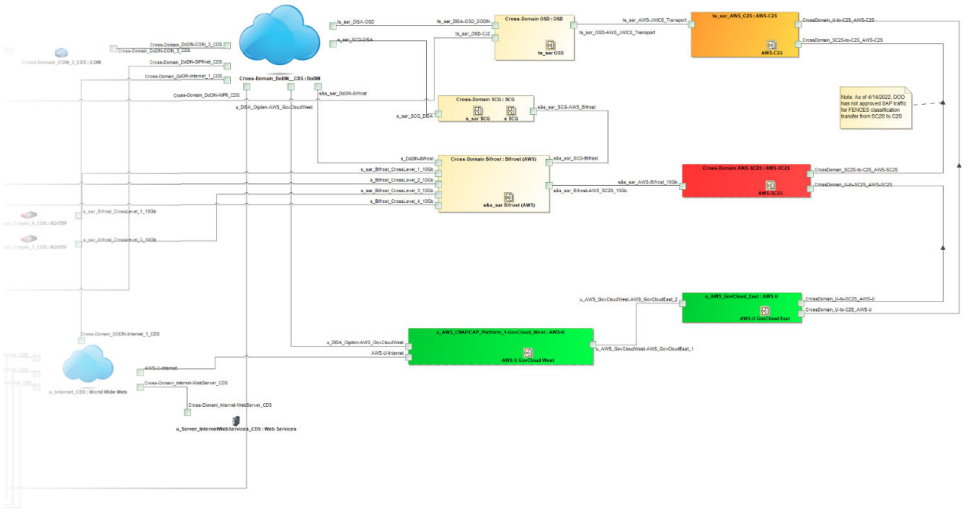


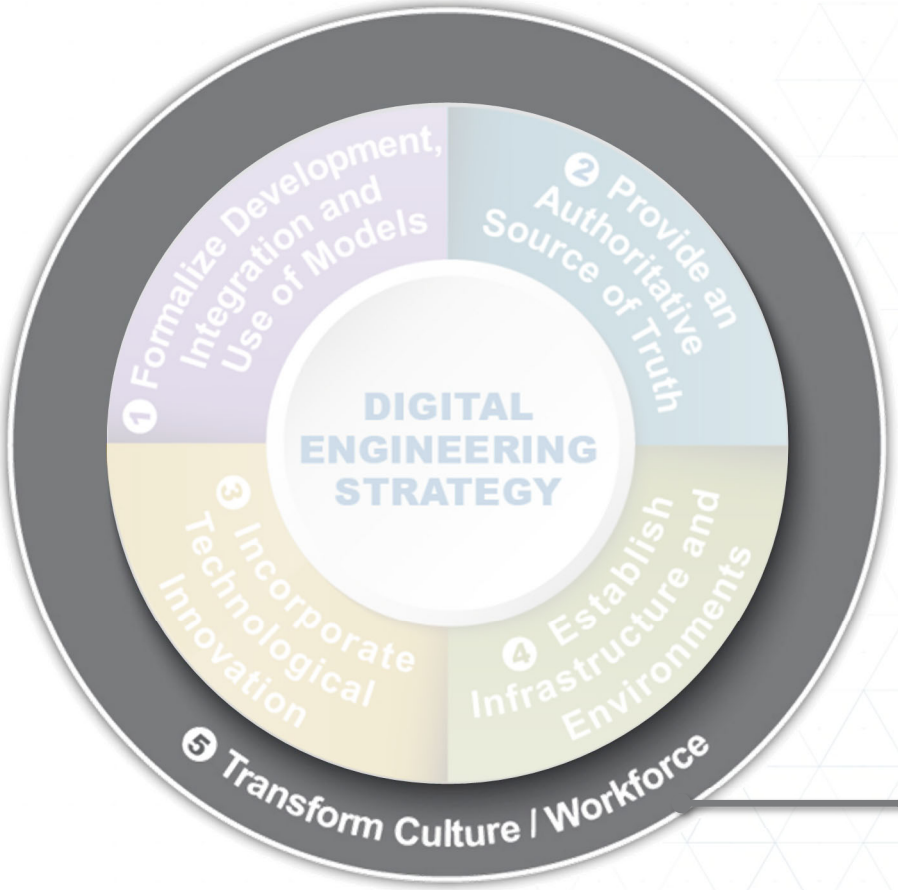

Digital Engineering System Modeling

# Sentinel Digital Engineering System Modeling

- APL is leading the development of Sentinel's Digital Engineering System Reference Architecture (DESRA) and Digital Engineering System Architecture Model (DESAM)
  - Both are used to systematically define requirements for the DES
  - DESRA – Program-agnostic DES functional/logical architecture
  - DESAM – Sentinel-specific DES functional/logical/physical architecture



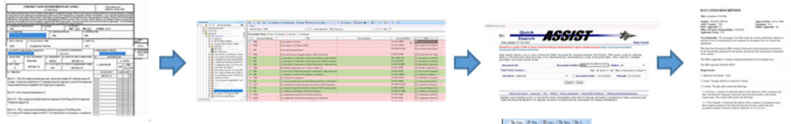



- Acquisition for Digital Engineering
- Cultural Transformation
- Strategic Deterrence Digital Engineering Conference

# Acquisition for Digital Engineering

- Navy SSP
  - SSP stood up their Acquisition IPT specifically to address changes in acquisition strategy and plans
  - RFP/SOW example/template language that accommodate DE concepts
  - CDRL/DID guidance for DE deliverables
  - Data rights and IP guidance
- Air Force Survivable Airborne Operation Center (SAOC)
  - Modeling federated data structure with traceability to contract requirements
  - Mapping between contract requirements and data model

1. Select a CDRL to decompose. (e.g Acceptance Test Plan)
2. Read the corresponding DID and update active hyperlink from Defense Standardization Program (DSP)




3. Make Package within the DID Taxonomy folder
   - Create folder with DI-Document Number as the Name
   - Put the DID element into the folder

4. Create a Block Definition Diagram (BDD)
   - Use new diagram named for the CDRL of interest
   - Put CDRL and DID on the diagram
   - Verify that relationship exists between DID and CDRL

5. Decompose CDRL into sections of content from the DID

6. Align Physical entity with Logical Data Model (LDM)
   - Drag LDM element onto the BDD
   - Connect the physical element to the LDM element
7. If necessary develop a proposed "New Logical Data Entity" for LDM

**Logical Data Model**

Including all CDRL\DID requirements in SYSML ensures traceability throughout the model.

**Extension = Navigable Ontology**


Along with support for the digital thread on this program, this LDM process can be used to develop a navigable ontology for related efforts

# Beyond the Technical – Cultural Transformation

## Awareness

APLWeb

COMMUNITIES of PRACTICE

APL COMM

APL Engineering Services

Surveys and Roadmaps

AMDS Digital Engineering

SDMA DIGITAL ENGINEERING

Coffee, Tea & DE

Navy SSP SET BLAST

## Training

JOHNS HOPKINS WHITING SCHOOL of ENGINEERING

NPS PRAESTANTIA PER SCIENTIAM 1909

APL Strategic Education

DAU

NDIA

coursera

MIT xPRO

Georgia Tech Professional Education

## External Engagement

StratDDEC 2023 Strategic Deterrence Digital Engineering Conference

https://secwww.jhuapl.edu/EventLink/Event/192

OMG

INCOSE

USD R&E

DEWG

DICE | INL Idaho National Laboratory

OHIO STATE

WEBER STATE UNIVERSITY

# StratDDEC 2023 Highlights



- 150 attendees
- 4 keynote presentations
- 13 technical presentations

- 1 roundtable discussion
- 7 “science fair” booths

**Save the Date! STRATDEC 2024 will be February 6-8**
**Expanding scope to strategic *and* tactical systems**
**https://secwww.jhuapl.edu/EventLink/Event/331**

# Challenges

- Technical
  - **Data Management** – Four V's (volume, variety, velocity, veracity), compression, sharing, controls, commonality, integration, utilization
  - **Digitalization and Integration** – Unique identification, metadata, creation, curation, governance, digital threading, ASOTs
  - **Standardization and Interoperability** – Language standards, taxonomies, ontologies, APIs, vendor lock
  - **Security** – Access (all data across all platforms), classification and compartmentalization (UNCLASS to SAP/SCI), need-to-know, protecting the ASOTs
  - **Modeling and Analysis** – Reproducibility, replicability, generalizability, interpretability, transparency, backwards compatibility, CM, VV&A
  - **People and Processes** – Digital acquisition, agile systems engineering, knowledge capture, documentation, training
- Programmatic
  - **Leadership** – Roles and responsibilities
  - **Sharing and Collaboration** – Willingness of enterprise partners (government, industry, labs) to share information and collaborate, need-to-know
  - **Infrastructure** – Governance of information technologies, creation of DE environments, data and model accessibility, protection
  - **Classification** – Ability to cross numerous security boundaries
  - **Workforce** – Expertise, availability, hiring, training
  - **Culture** – Adoption of digital approach and tools at all levels; ability to identify what you are intending to achieve with the digital approach – one size does not fit all
  - **Ownership** – In the end, who owns the capability and how will it be sustained?
  - **Cost** – Development, maintenance, metrics and quantification, ROI

# Recommendations

- Leverage common approaches and lessons learned – Don't reinvent the wheel!
- Get programs to prepare for DE early – While it provides tremendous benefit long term, it's a big lift up front
- Don't abandon engineering fundamentals – While the tools and methods may change, good engineering practices are still necessary
- While "vendor lock" is a risk, don't let it preclude you from using COTS solutions – Many COTS products provide more capability than could ever be custom built or maintained/sustained on typical budgets
- Emphasize training and cultural adoption – You can't do DE without it
- Evolve traditional acquisition practices and processes to support DE – Don't fall for the "if it isn't broken, don't fix it" fallacy
- Many more than can be listed here

If everyone lived by "if it isn't broken, don't fix it", this is how you would have traveled to work today


JOHNS HOPKINS

APPLIED PHYSICS LABORATORY

SYSTEMS ENGINEERING RESEARCH CENTER

- Tuesday, November 14:
  - 11th SERC Doctoral Student Forum (11 - 5:15)
    - Dr. Barry Boehm Award for Doctoral Student Research Excellence
  - Annual Reception: "Cheers to 15 Years!" (5:30-7:30)
- Wednesday, November 15: (8:30 -5:30)
  - 15th SERC Research Review
    - 3 tracks of SERC research highlights
- Registration Open

SYSTEMS ENGINEERING RESEARCH CENTER

SERC TALKS

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