



Jet Propulsion Laboratory
California Institute of Technology



How OpenMBEE enables the adoption of a model-based digital ecosystem at Boeing and the Jet Propulsion Laboratory

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Scalable Management of Low-Code Artefacts Workshop, April 2021, Virtual

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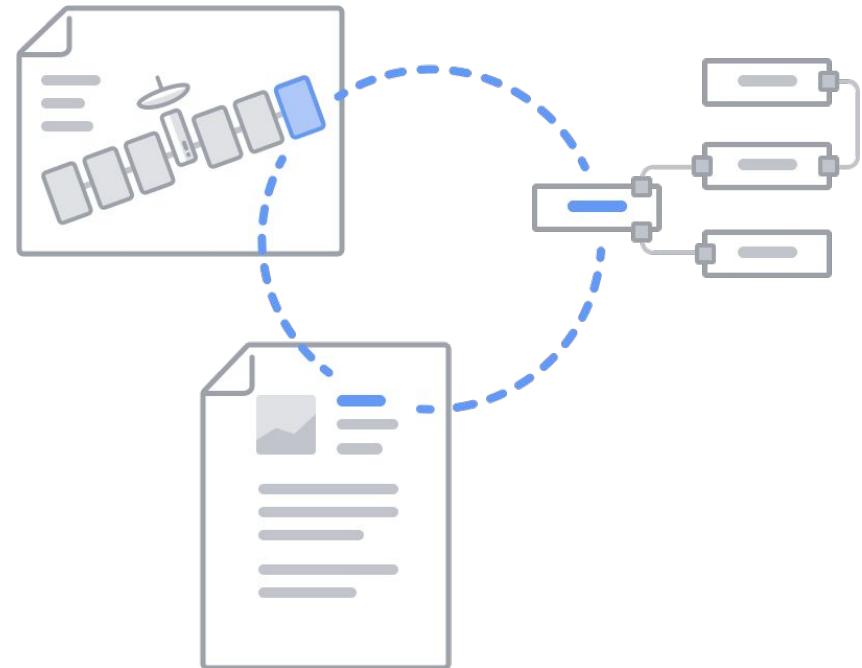
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Open Model-Based Engineering Environment



- OpenMBEE is a **community** for open source modeling software and models
 - Open source software activities
 - Open source models
 - Open source exchange of ideas
- Participants and adopters:
JPL, Boeing, Lockheed Martin, OMG, NavAir, Ford, Stevens, Georgia Tech, ESO, ...
- > 400 members



Linked Data Documents with OpenMBEE



Topic: Engineering Documents

From Engineering Models to Engineering Documents





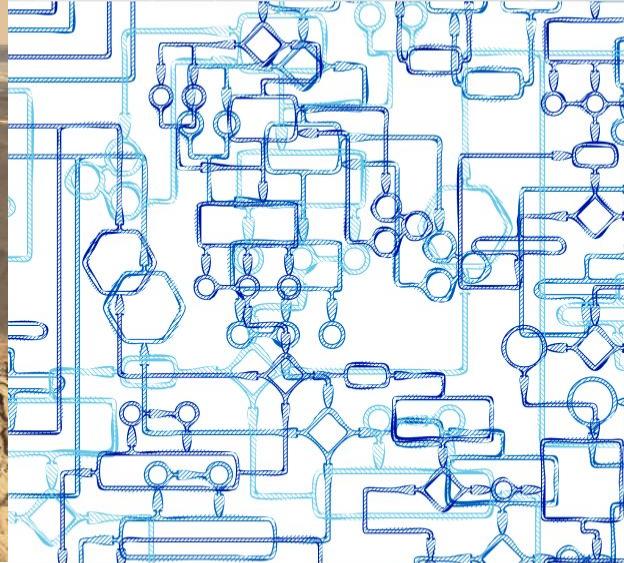
**Systems Engineers guide the
concurrent collaborative design
of complex technical systems**



Leadership



**Architect and Design
Cyber-Physical Systems**



Manage Complexity

Project teams are large - Perseverance



A project starts simple



Engineers iterate on their models



Systems engineers enter this data into their rollup



They add it to a document and get inputs from others



And add it to a spreadsheet to track it over time



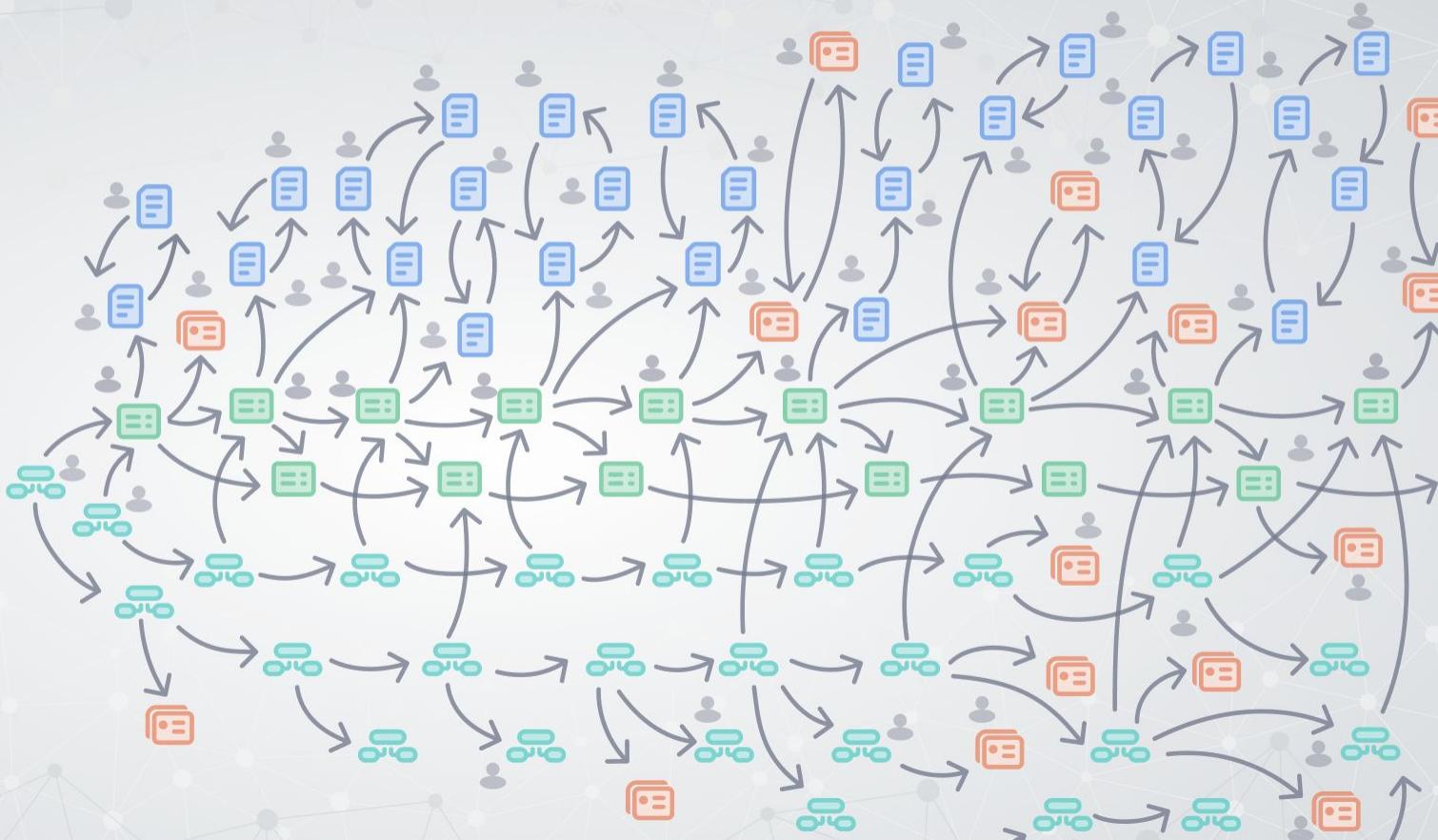
It can get complicated quickly



It can get complicated quickly



It can get complicated quickly



And become overwhelming...





**Most of my job is data entry.
I want to do REAL ENGINEERING.**

JPL Systems Engineer



**Using engineers as information
janitors isn't the best use of
their skill.**

JPL Systems Engineer

Real engineering vs. overhead



Repetitive Data Entry

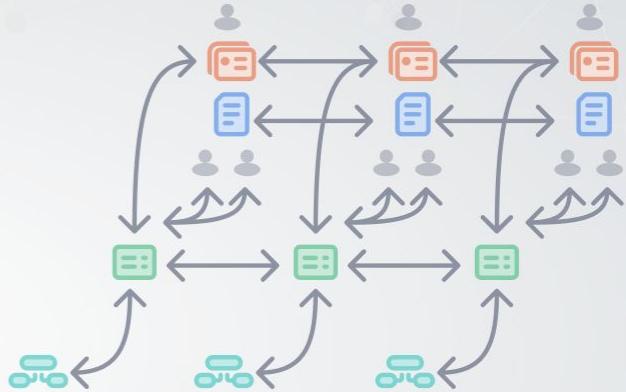
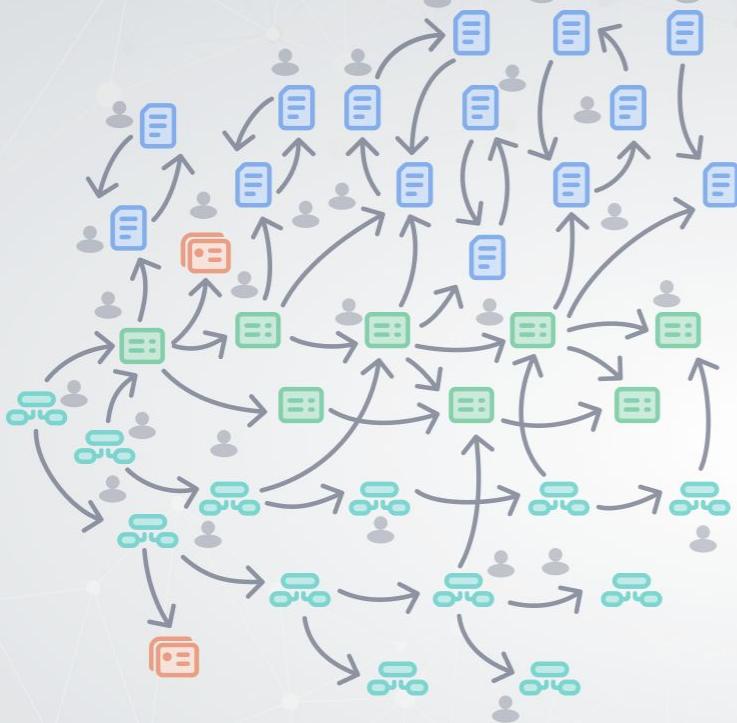


Version Confusion

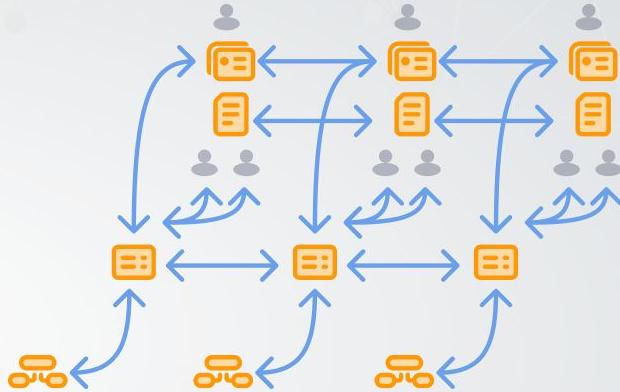


Constant Searching

A better way...



A better way...



Connected information, connected engineers



**“Update once,
use everywhere”**



100% **JPL**
Core Components



Model Management System



**View Editor & Platform
for Model Analysis**



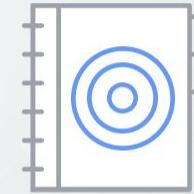
Model Development Kits



**Documentation
and Training**



**Thirty Meter
Telescope Model**



OpenSE Cookbook

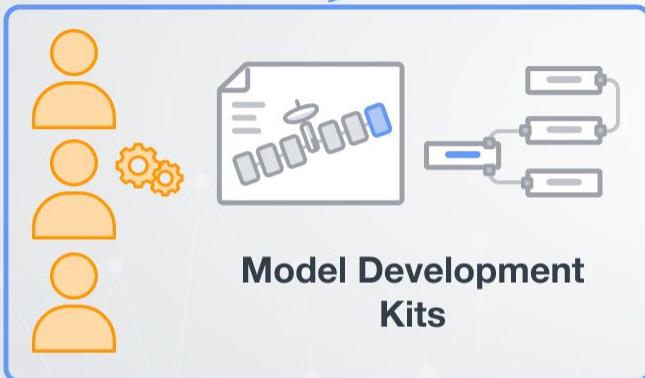


OpenMBEE

Thirty Meter
Telescope
Model



Authoritative
Source



Engineering Modeling

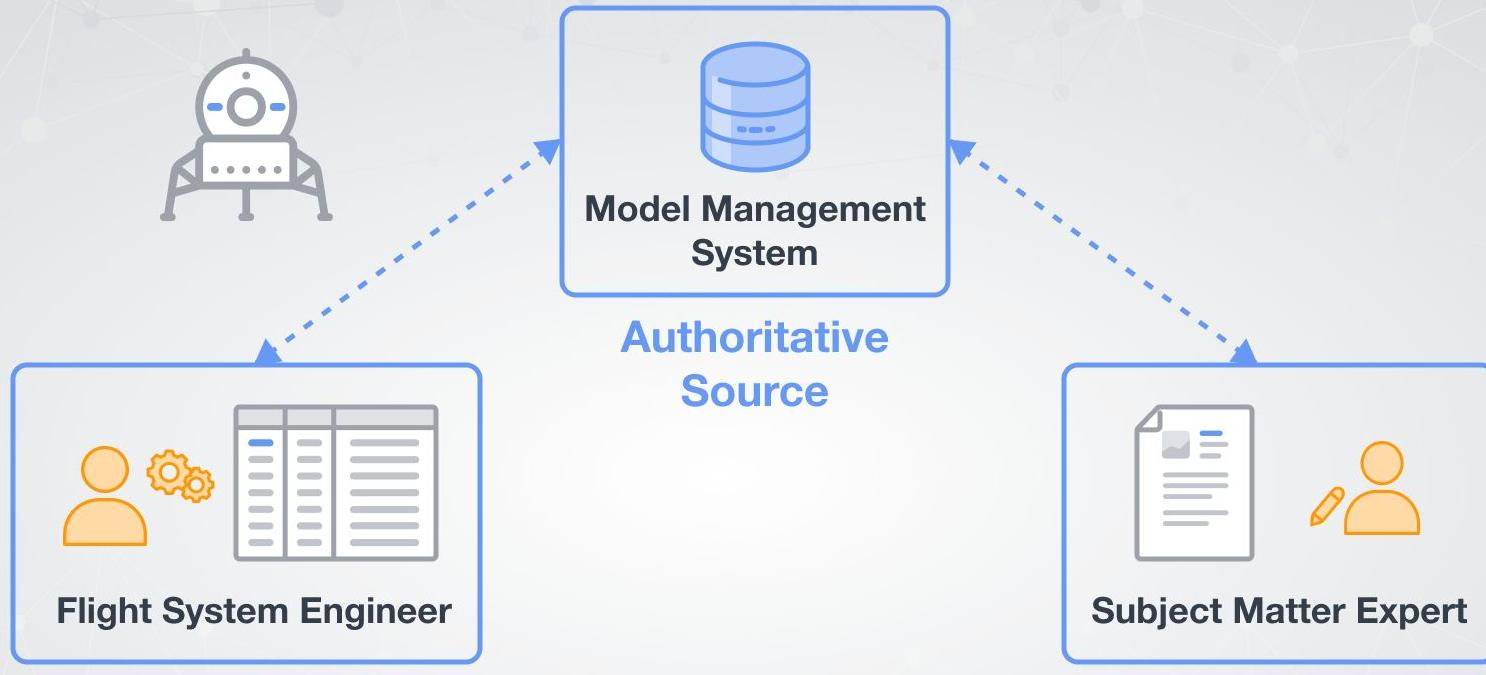


OpenSE
Cookbook



Document Authoring

Master Equipment List



Master Equipment List
analysis

Master Equipment List
document report

Demo



<https://www.youtube.com/watch?v=4KB0p97PvtM>

OpenMBEE adopters and contributors



NASA

Mars 2020
Europa Clipper
ARRM
Mars Sample Return
MAIA
SWOT
NASA Pathfinder
Europa Lander



Science & Engineering

Thirty Meter Telescope
Japan Aerospace Exploration Agency
Stevens Institute of Technology
Systems Engineering Research Center
Georgia Tech Research Institute
Georgia Tech Aerospace Systems Design Laboratory



Industry

Boeing
Ford Motor Company
Lockheed Martin Corporation



Standards

Object Management Group
INCOSE



Vendors

Dassault Systemes
IncQuery Labs
Capella
Intercax
Tom Sawyer
Phoenix Integrations
Maplesoft

Flight Project Impact: Reduction of Overhead



Europa Clipper

100

Concurrent users



230+

Documents and decision
gate deliverables including



445,000

Connections between elements



Flight Project Impact: Technical Rigor



Mars 2020

50

Concurrent users



90+

Documents and decision
gate deliverables including



Reference Designator List



Electrical Function List



Electrical Functional Block Diagram

180,000

Connections between elements



Aerospace Industry Impact: Enterprise Scalability



1,000

Concurrent users



50

Programs

100

Concurrent users



50

Projects

Intra-Organizational Environment Today



Inter-Organizational Concept



Mars Sample Return Concept



Global Engineering Ecosystem Vision



**Connected engineering information
for a connected world**



Topic: Boeing Commercial Airplanes

Deploying OpenMBEE across its global enterprise



Large Scale, Highly Integrated Systems : Large, Highly Integrated Model

Typical Digital Networks System Architecture Model Data Volume (Tens of GBytes)

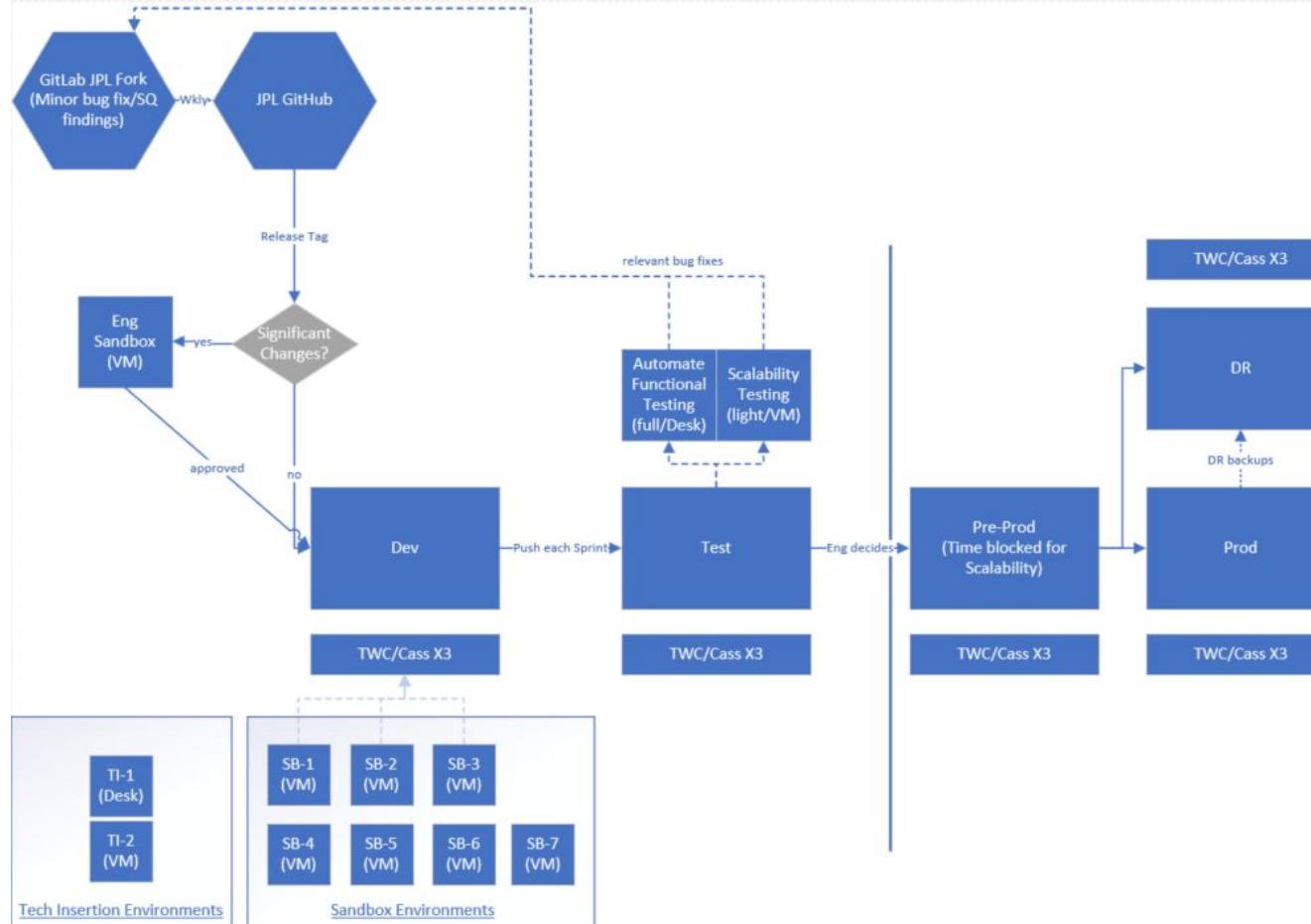
~1,000 modelers	Functions	~2,300
	Functional Data Flows	~10,000
	Equipment Installations	~5,000
	Data Parameters Processed by Installed Equipment	~1,000,000
	Electrical Connections Between Installed Equipment	~9,000
	Objects in Model	~ 50,000,000 (~ 3 relationships (links) per 1 object)

Insights

Deploying OpenMBEE

- Utilizing a Scaled Agile Approach
- Internal Website that details:
 - Installation Instructions
 - User Guides
 - Help Desk
 - Training (primarily video based)
 - Release Notes
 - User Community Blog
 - Bug Reporting Mechanism
- Weekly No Magic TIM
- Weekly User Forum
- ~100-1000 concurrent users across the enterprise

Automation: Development Environment Cadence



Global Readiness: Global Deployment

- Boeing has approved the suite for international use, with software usage agreements for India and Russia in place today
- Citrix (or desktop virtualization) is key for global deployment
- TWC & MMS adequately partitions data –approval can be granted at a tool + project level.



Deployment Benefits

- Common Tool, Modeling Language and Training Across the Boeing Enterprise
- Functionality supports systems architecting and integration with downstream consumers
 - Using the open source tool provides the flexibility needed to integrate with downstream consumer tools (Electrical, PLM, MBD, etc)
- Common IT Infrastructure (server resources, admins, architects, SLA's for backup and recovery) meaning each program doesn't need to build their own hardware and services environment

Lessons Learned

- Migrations are tested early with real data
- Contributing back to open-source avoids code deviation and enables smoother merging
- Vet it, own it – adequate testing of security should be done at a commercial level
- Citrix solution not only mitigates latency and collaboration obstacles but also mitigates configuration management concerns when it comes to the tool suite
- Use restricted repositories for sensitive information (passwords etc.) so that the teams can collaborate freely for a majority of efforts

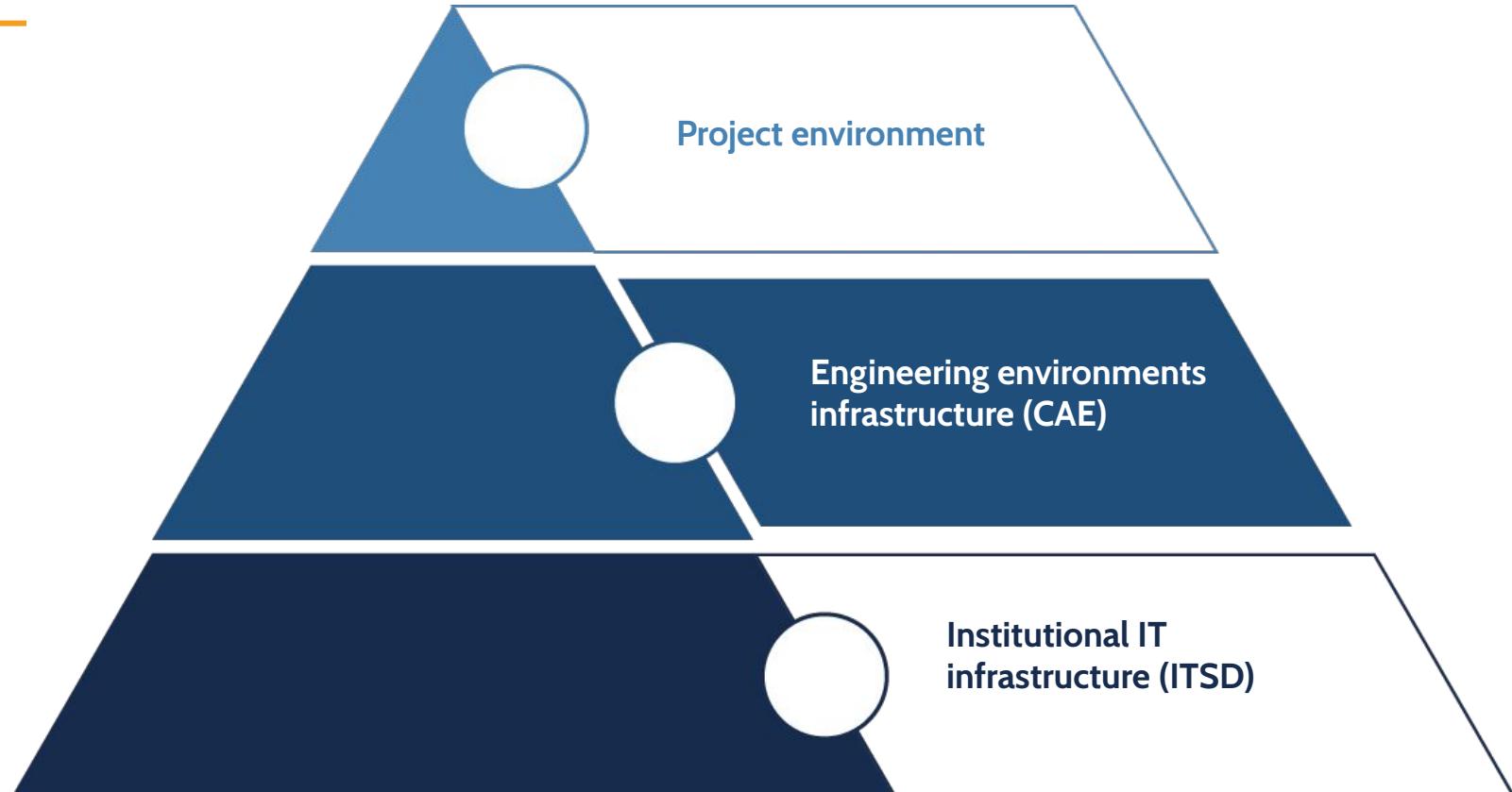


Topic: JPL Engineering Environments

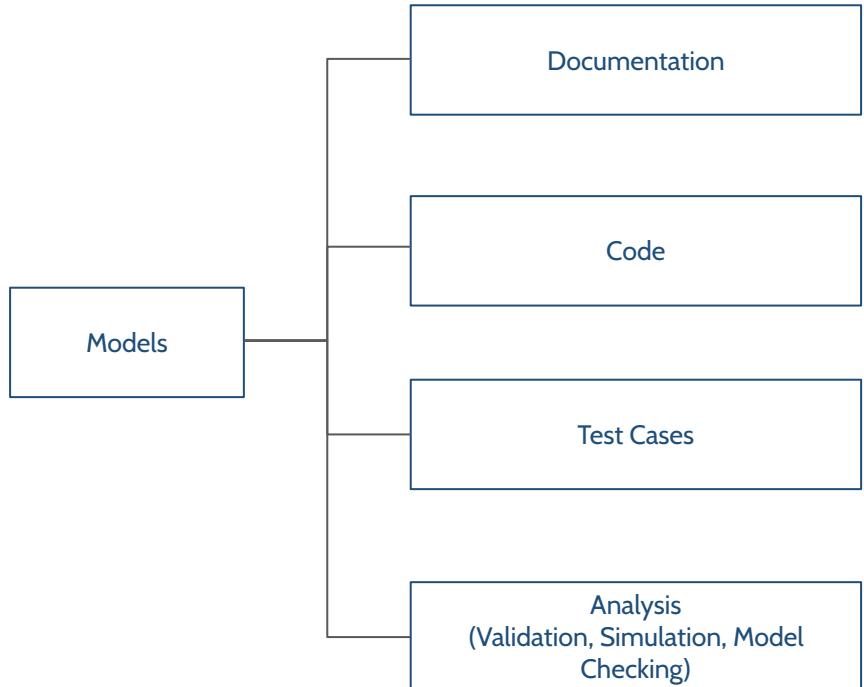
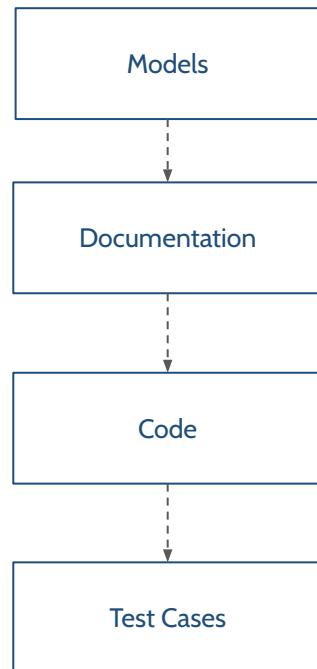
JPL OpenCAE

Providing an integrated environment for Systems and Software

Who We Are



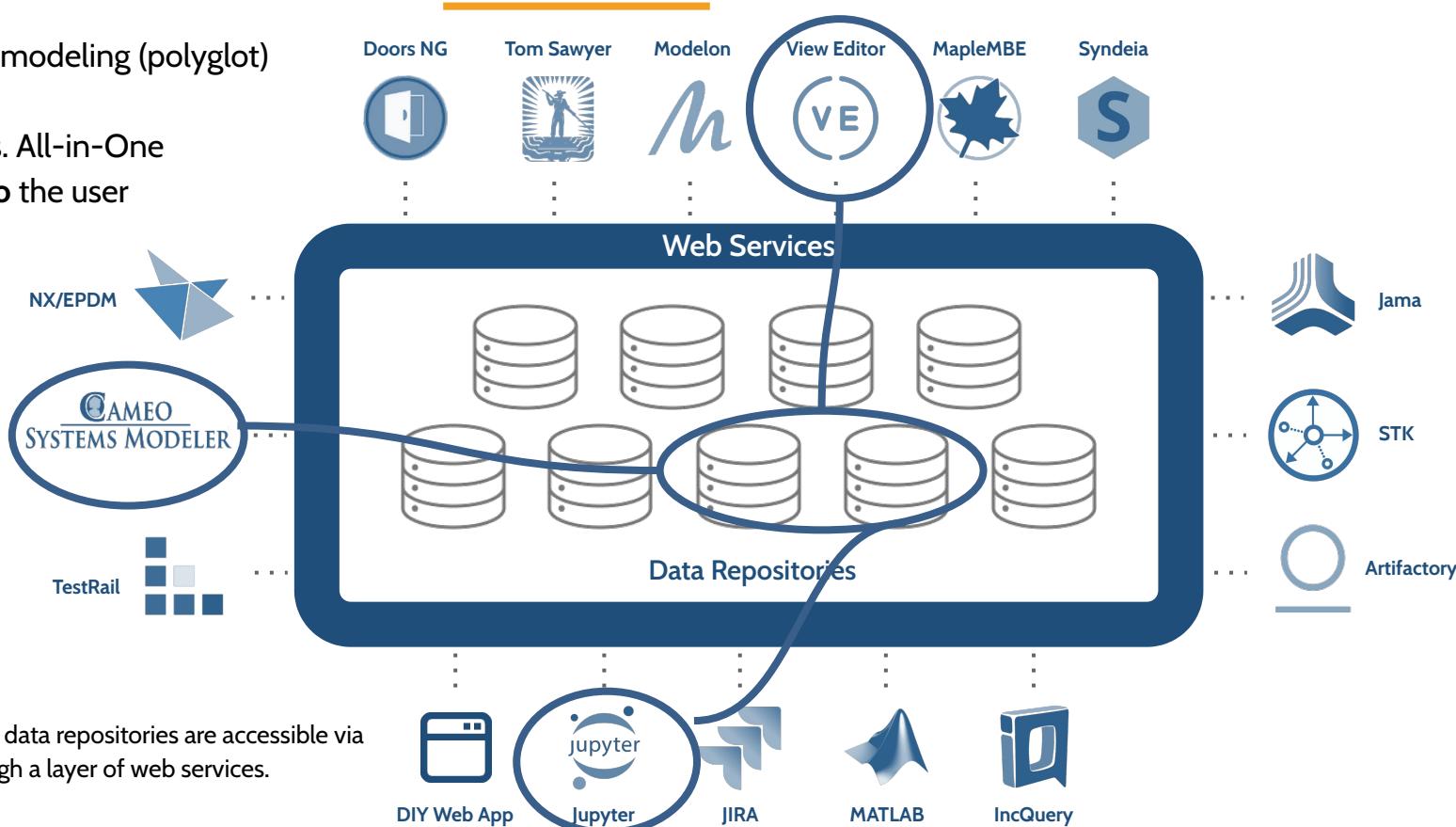
Model Driven instead of Document Driven - from System to Software



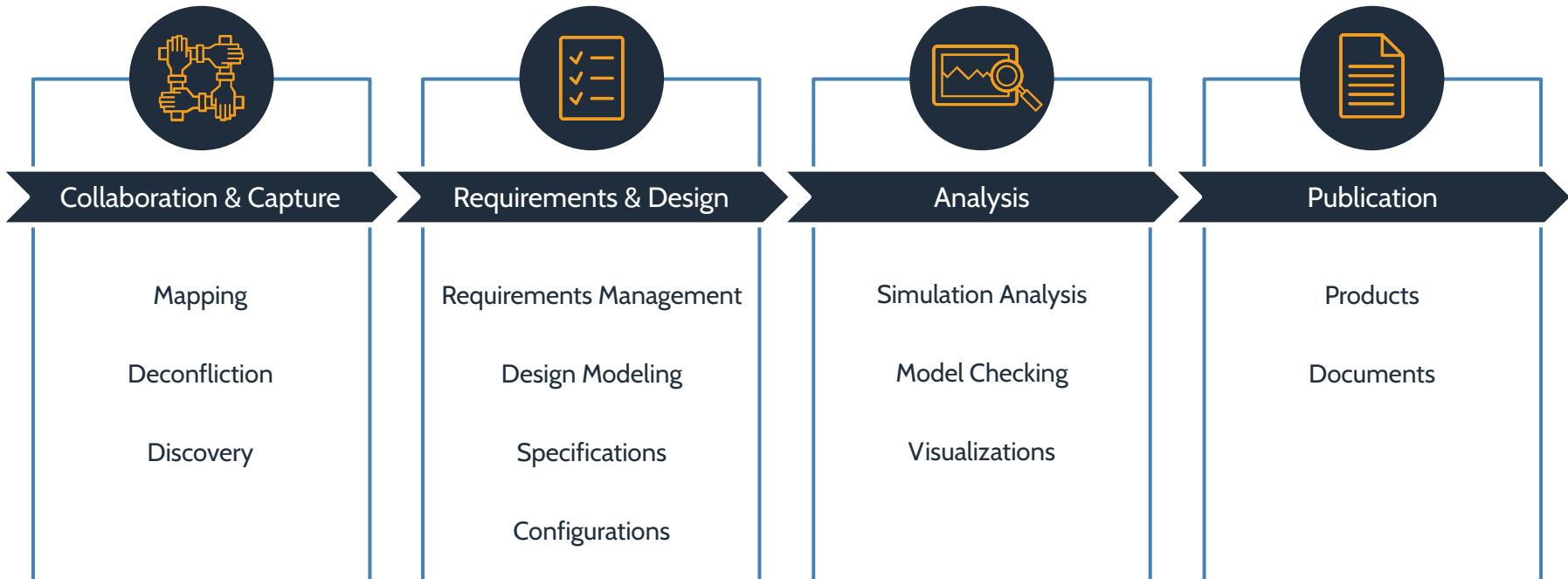
Semantic consistency across all transformed artifacts

CAE Systems Environment - Architectural Principles

- Multi-paradigm modeling (polyglot) environment
- Best of Breed vs. All-in-One
- Bringing value **to** the user



Continuous Analysis/Continuous Publication Integrated Pipeline



Issue Management

Continuous Integration

Process Orchestration

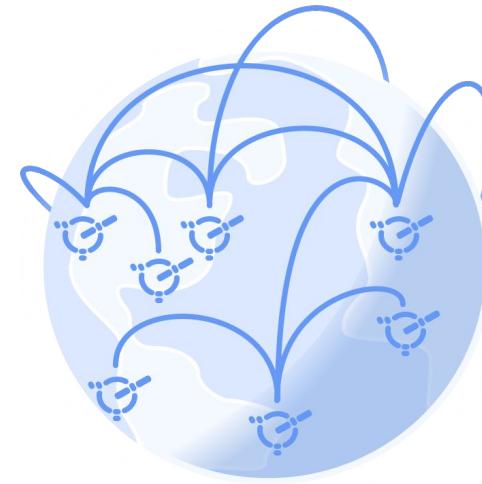


Process (Traceable, Auditable, Repeatable)

OpenMBEE Vision



- Augment Jupyter's **multi-language analysis** capabilities with modeling and connected engineering
- Enable novel data-driven analyses with advanced capabilities, as a **service**
- Unlock value through **commoditization**
- **Standards** powered engineering **platform** using SysML v2 + API & Services, FMI



Global Engineering Ecosystem

Join the community in making this vision
into a reality @ openmbee.org

OpenMBEE Updates

- New home with NumFOCUS
- First *International Workshop on OpenMBEE* at MODELS 2020 on October 19, 2020
- 5th INCOSE International Workshop on OpenMBEE, February 1st, 2021
- Architecture in development simplifies software operations while adding new capabilities



OpenMBEE is now a NumFOCUS Sponsored Project



Questions?



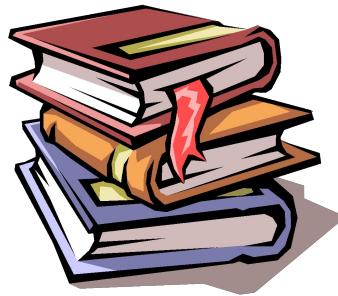
Backup

Model Based Systems Engineering (MBSE)

- MBSE is the **formalized** application of modeling techniques to support system requirements, design, analysis, verification, validation and documentation activities
- MBSE expresses a system using a **Systems Modeling Language** (e.g. SysML, Modelica)
- MBSE is often applied with a **method** like Object Oriented System Engineering Method (OOSEM)

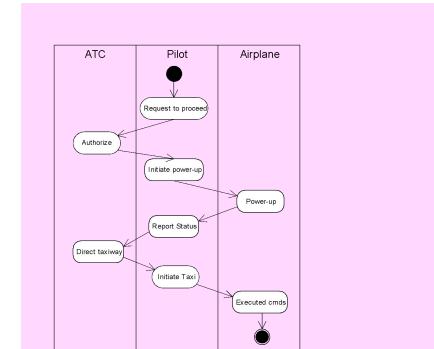
Vision from early 2000's

Present



- Specifications
- Interface requirements
- System design
- Analysis & Trade-off

Future

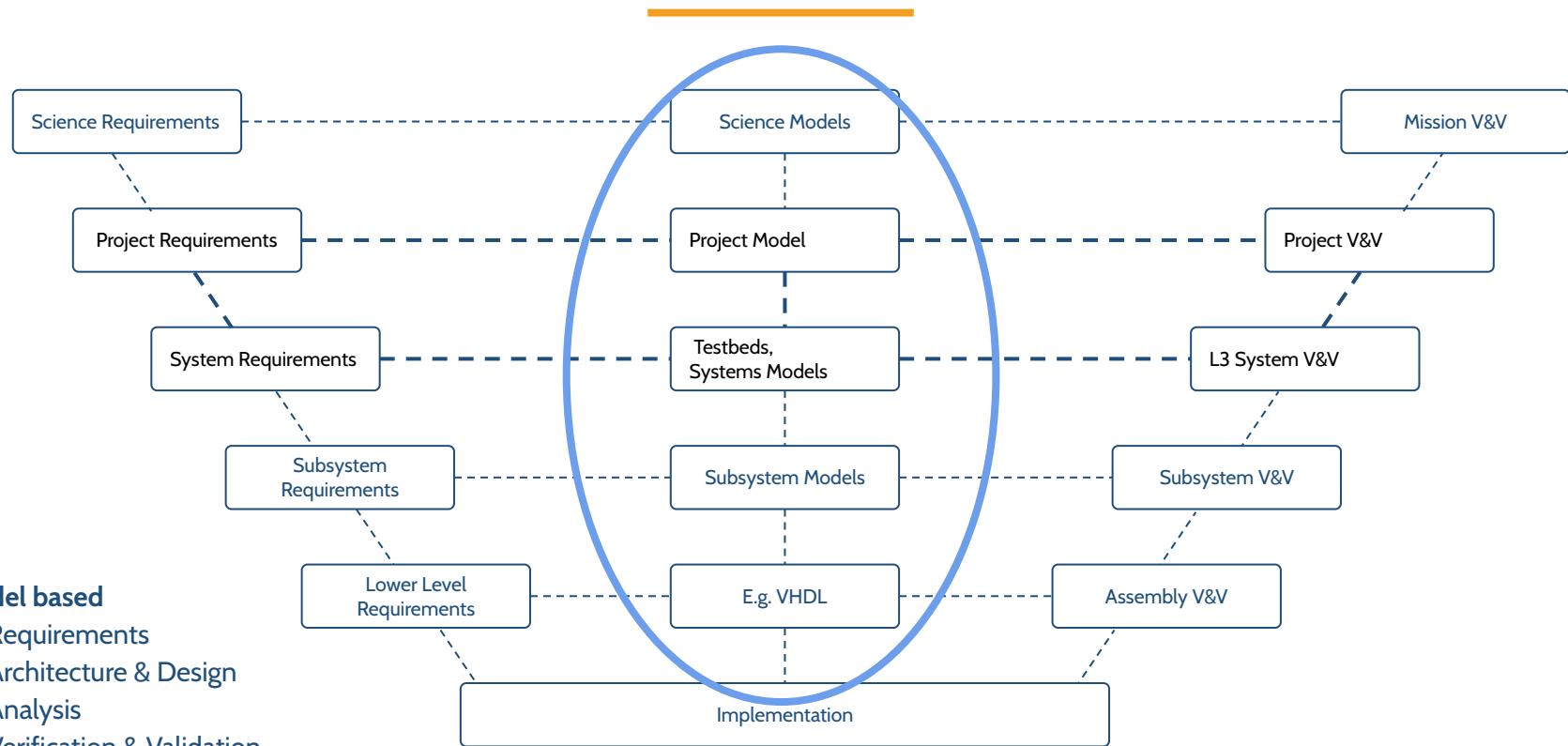


Moving from Document centric to Model centric

20 years later - Connected Information



Model Driven V

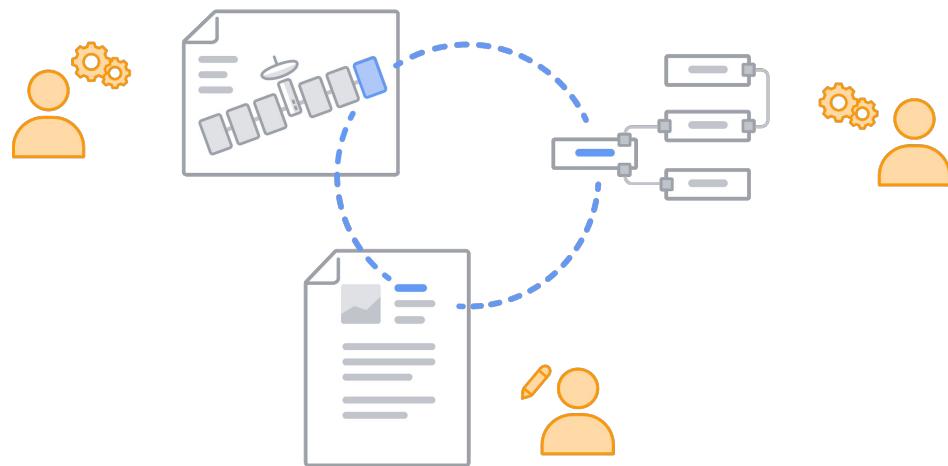
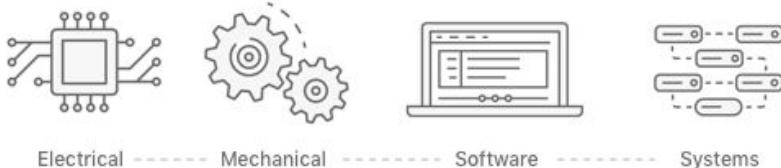


Model based

- Requirements
- Architecture & Design
- Analysis
- Verification & Validation

JPL OpenCAE

Computer Aided Engineering (CAE) supports engineers at JPL by providing and maintaining shared and connected environments of apps and services for engineering.



CAE System and Software Environments Connect Engineering Products

Engineering data can be retrieved and used in many engineering products by connecting to the authoritative source of truth

Continuous Analysis/Continuous Publication Integrated Pipeline

Collaboration & Capture



MapleMBSE



Swagger



DoorsNG



Jama



MATLAB



Jupyter



Tom Sawyer



Confluence



TestRail



Excel



Syndia



Excel



Jupyter



Excel



Helix

CAMEO
SYSTEMS MODELER



Modelon



Excel



PyCharm



IncQuery



STK

Jupyter
nbviewer



Conda



GitHub



Jenkins

PMA



JIRA



XL Release



WENG



LENG

Academia Impact: Inter-Organizational Collaboration



NAVAIR Model-Based Acquisition Strategy

- Surrogate Pilot RFP delivered to NAVAIR
- Data Item Descriptions (DIDs)
- Contract Data Requirements List (CDRL)

A screenshot of the "Surrogate Pilot RFP Response in View Editor" software interface. It shows a navigation tree on the left with items like "Introduction", "Technical Description", and "Requirements". In the center, there is a 3D model of a propeller-driven aircraft labeled "Tiltrotor/CRStructure".

A screenshot of the "Transform CDRLs and DIDS using Digital Signoff in Model Through View Editor" software interface. It shows a document titled "1 Introduction" with sections like "1.1 Overview" and "1.2 Scope". A blue arrow points from the text "1) Enable Editing" to the "Enable Editing" button in the toolbar. Another blue arrow points from the text "2) Add Risk" to the "Add Risk" button. A third blue arrow points from the text "3) Add Approval Status" to the "Add Approval Status" button. Below the document, a note says "Digital Signoff get 'pushed' back into Model (continuing theme of AST)".