

Jet Propulsion Laboratory
California Institute of Technology

JPL Systems Environment

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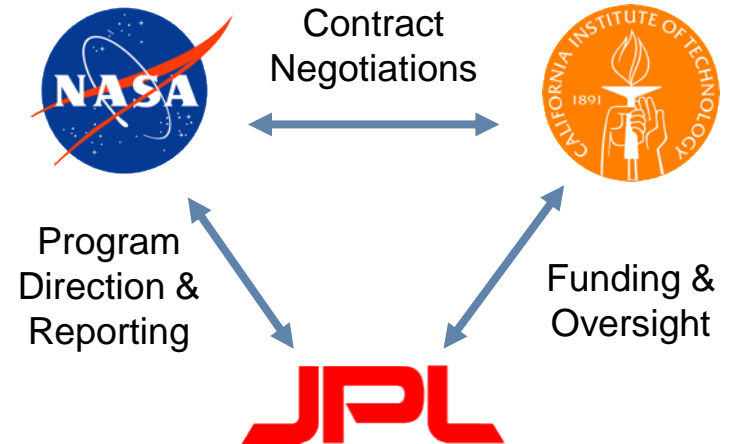
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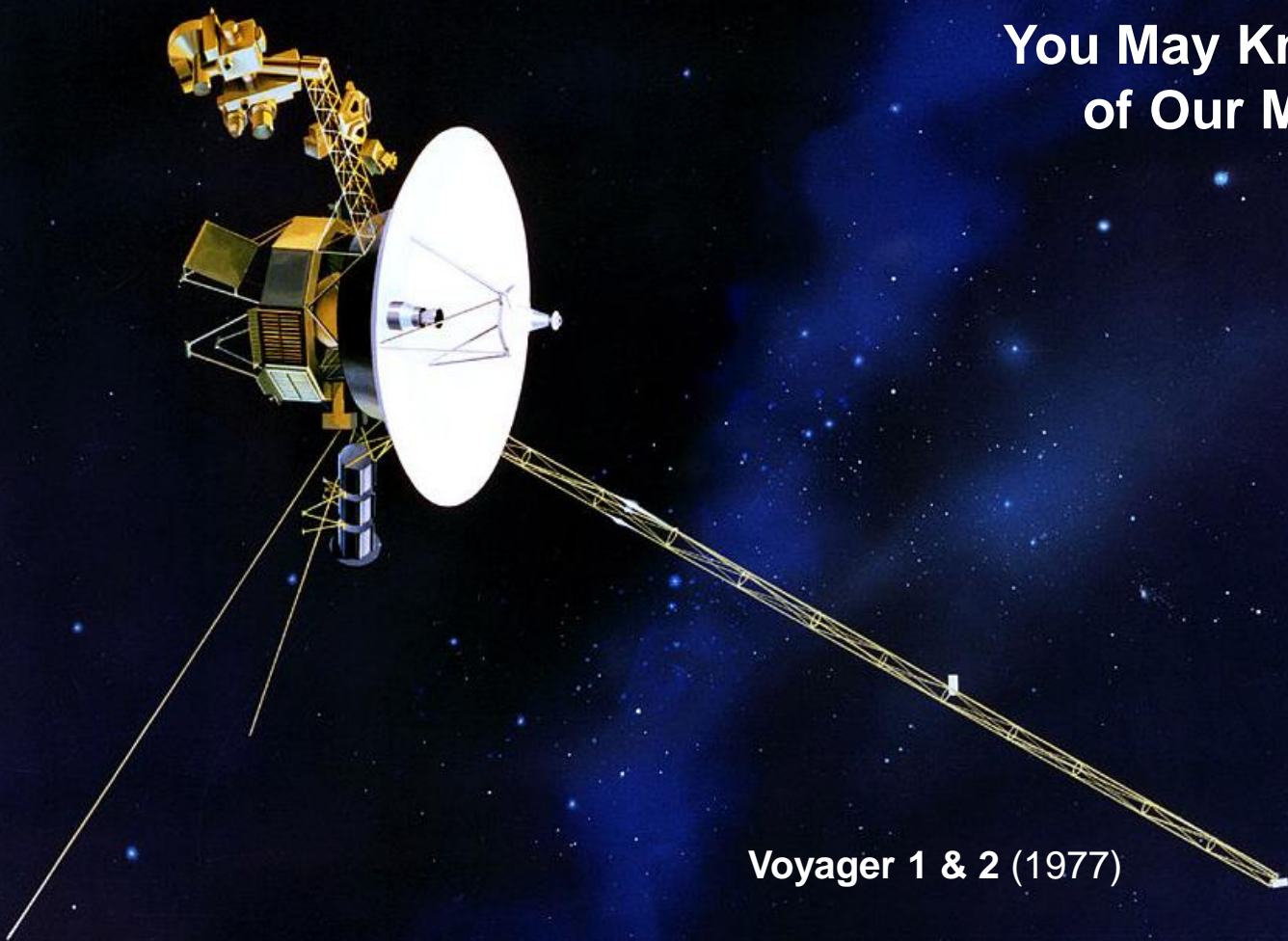
NASA Jet Propulsion Laboratory (JPL)



- Located in Pasadena, CA
- NASA-owned “*Federally-Funded Research and Development Center*”
- University-operated
- ~6,000 employees



**You May Know Some
of Our Missions...**



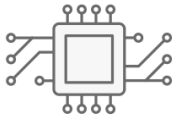
Voyager 1 & 2 (1977)

JPL's Mission is Robotic Exploration

Mars Science Laboratory (2012)

JPL Computer Aided Engineering (CAE)

- CAE provides the Laboratory's Engineering Staff and Scientific communities with integrated tools, environments, and technical expertise
 - Platform integrates heterogeneous data sources, multi-model environment
 - Emphasis on standards for data interchange
 - Case studies inform the architecture of the engineering environments
- CAE supports four engineering environments:
 - Electrical Environment
 - Mechanical Environment
 - Software Environment
 - Systems Environment



Electrical
Engineering



Mechanical
Engineering



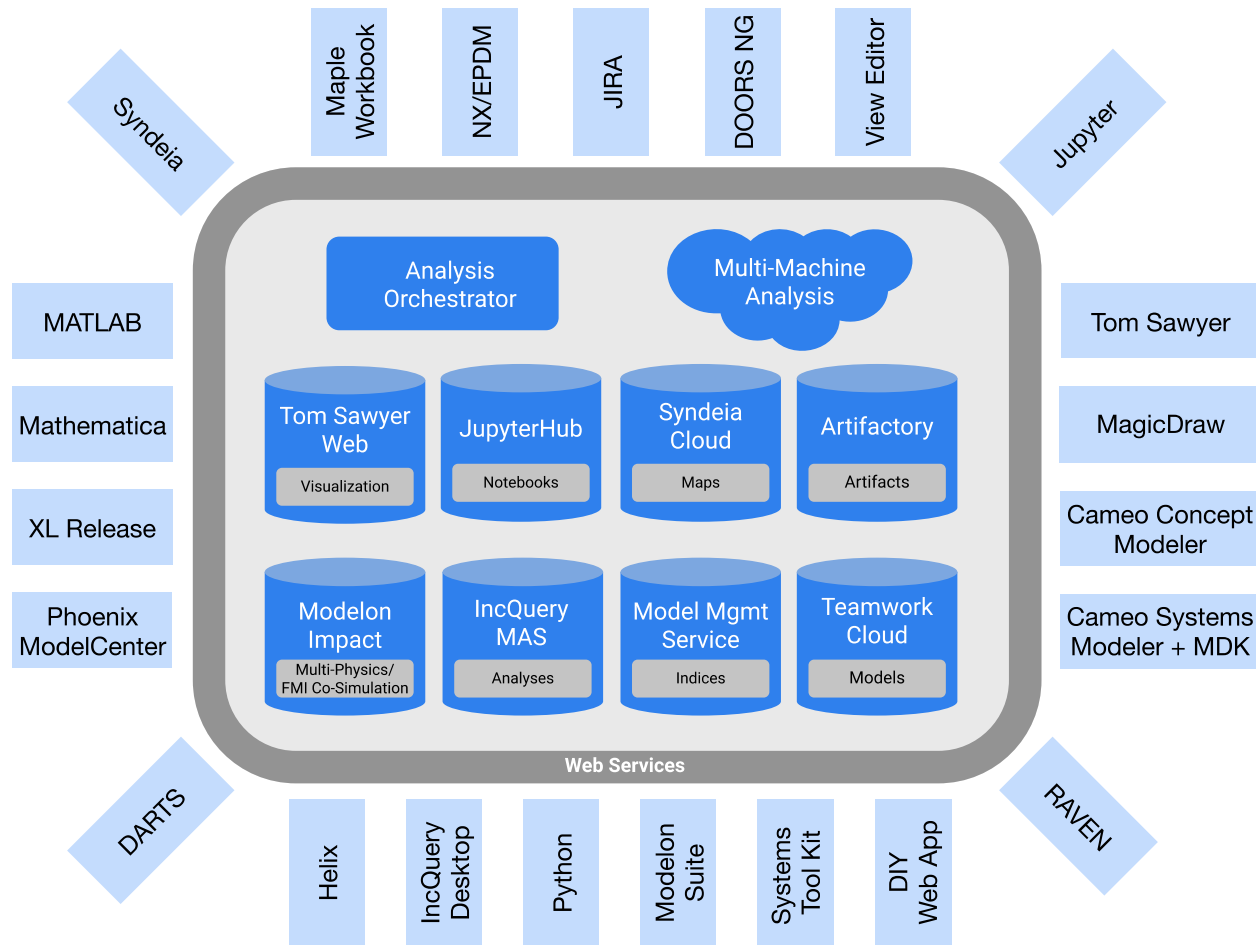
Software
Engineering



Systems
Engineering

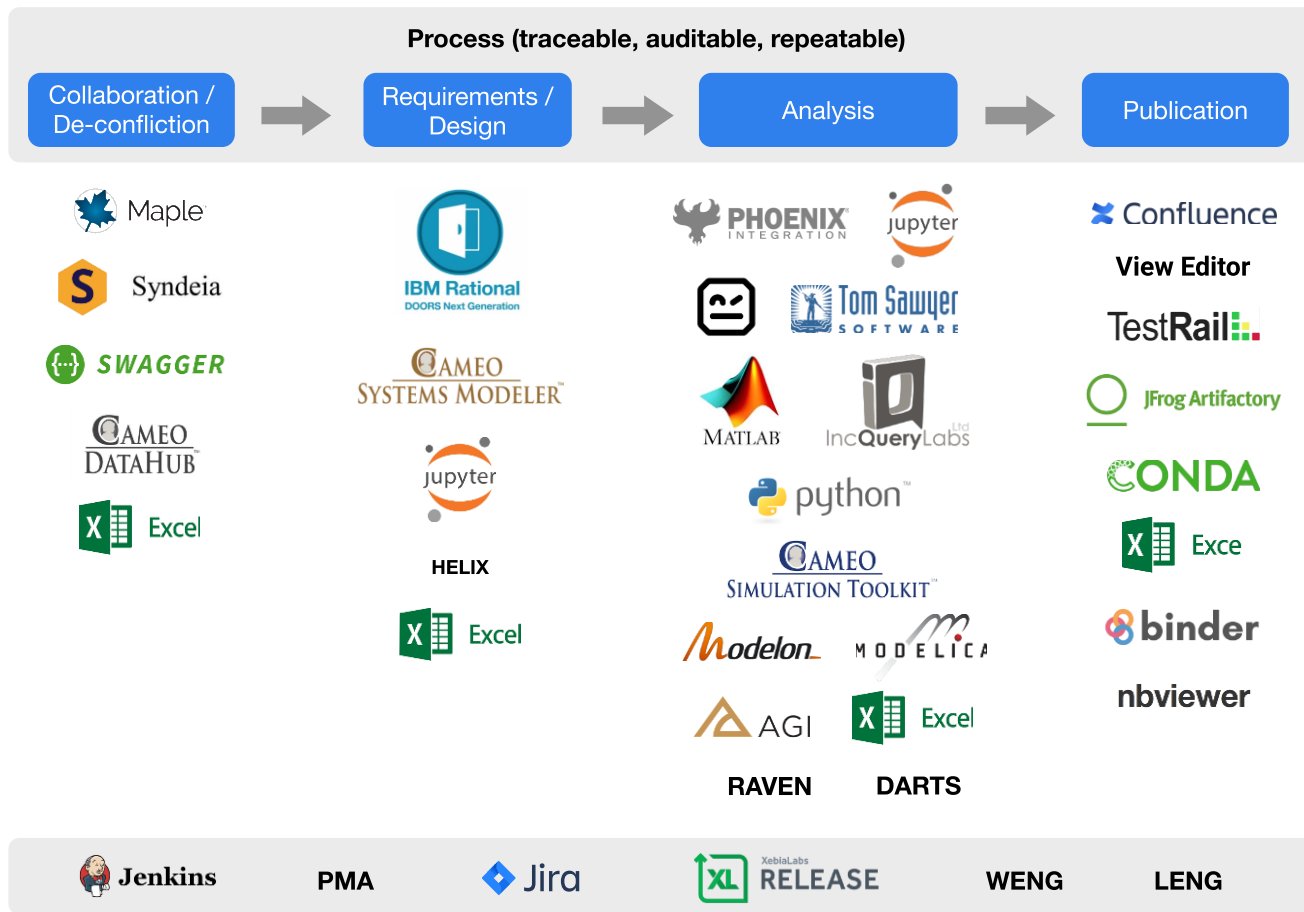
OpenCAE

Systems Environment Overview



OpenCAE

Systems Environment Pipeline



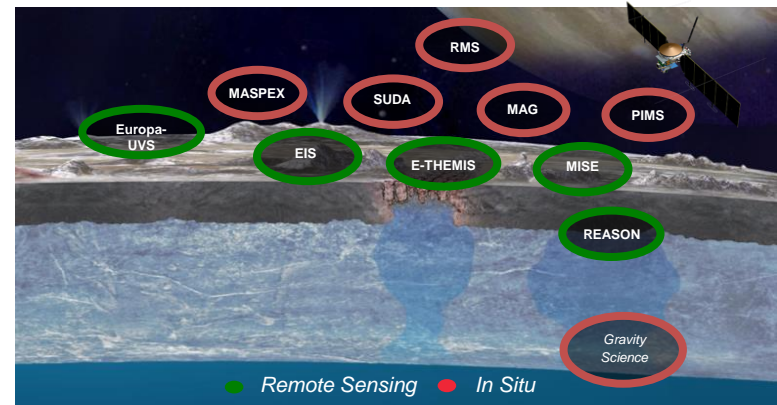
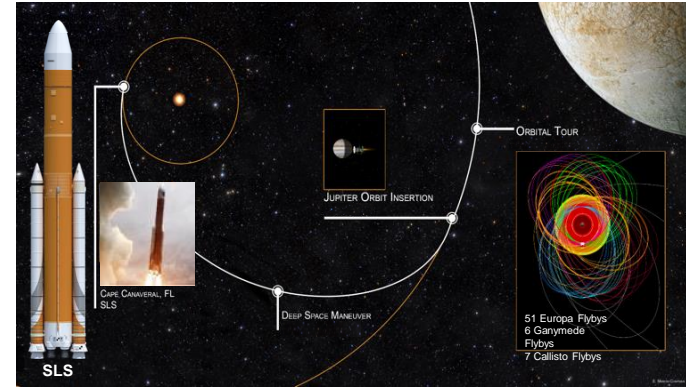
CAE Offers Project and Domain Specific Adaptations

- CAE provides the same environment to all its customers
- Embedded roles work directly on projects to adapt the standard environment specific to the project goals or methodology
- This includes but is not limited to:
 - Project specific integrations
 - Project specific configurations
 - Project specific customizations
- Embedded roles capture needs in general case studies which inform the CAE architecture
- This has been demonstrated on M2020, Europa Lander, Europa Clipper, Psyche, Mars Sample Return, Thirty Meter Telescope

Europa Clipper Overview

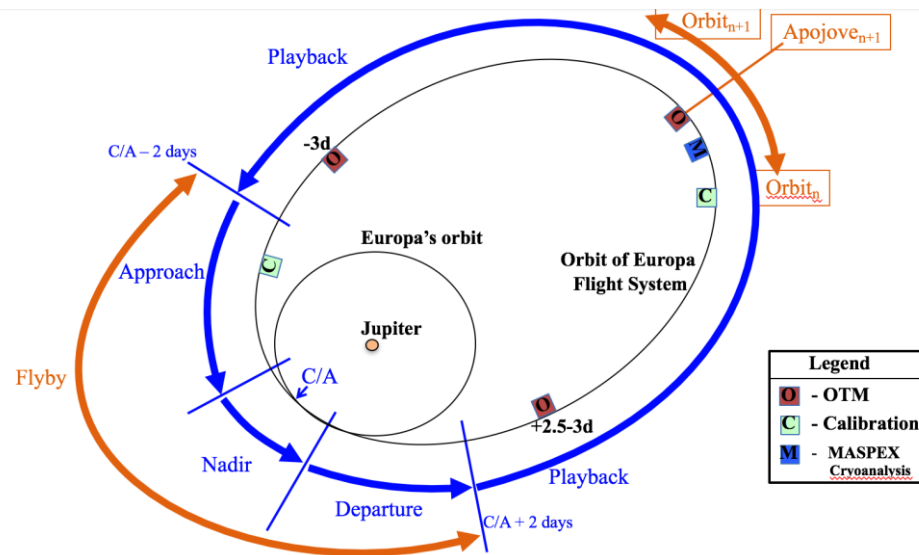


- Launch
 - SLS Block 1
 - No later than 2025
- Trajectory
 - Cruise:
 - Earth-Jupiter Direct
 - 2.8 - 3.1 years
 - Transition to Europa Science
 - 1.3 years
 - 6 Ganymede flybys, 1 Callisto flyby
 - Europa Science Campaign
 - 2.5 years
 - 51 Europa flybys, 6 Callisto flybys
- Flight System
 - 6001kg lift off mass
 - 10 science investigations
 - Compatible with non-SLS EELV



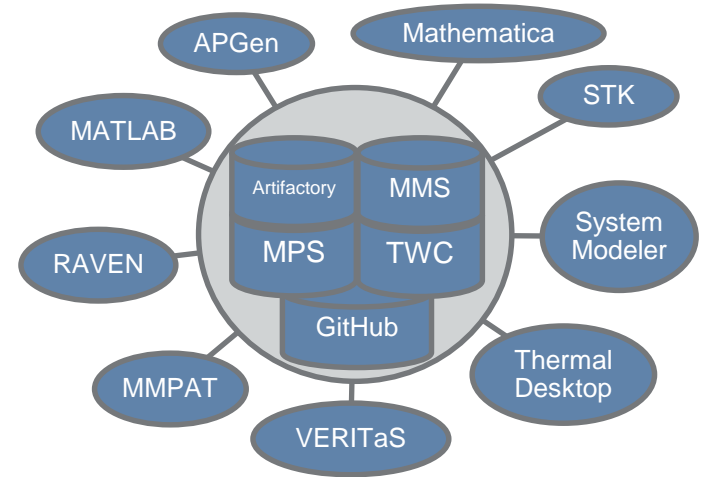
Resource Challenges

- Mission divided into “Encounters”
 - Minimum Europa-Europa encounter ~10 days
 - Minimum encounter ~5.5 days
- High resource demands during “Nadir” portion of Europa flyby
- Limited time to downlink data and recharge during “Playback” prior to next encounter



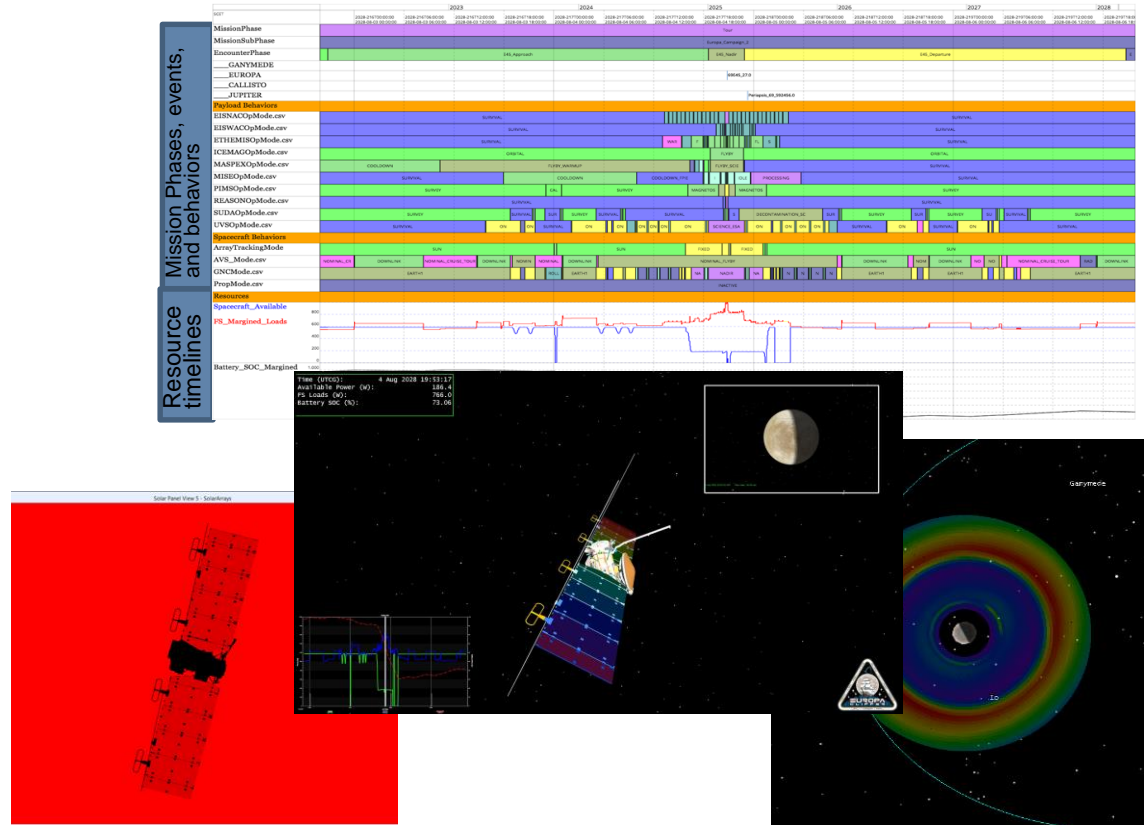
Analysis Architecture Overview

- Comprehensive analysis suite that leverages new development and existing tools
 - Heritage: MMPAT, Thermal Desktop, System Tool Kit (STK), APMGen, Excel
 - New: Teamwork Cloud (TWC), Model Management System (MMS), MPS Server, Timeline Management Service (TMS), RAVEN, GitHub, Tableau, System Modeler, Mathematica
- SysML model serving as single-source-of-truth for mass, power, allocations, etc.
- Strong integration with diverse tool set
- Data provenance maintained across project



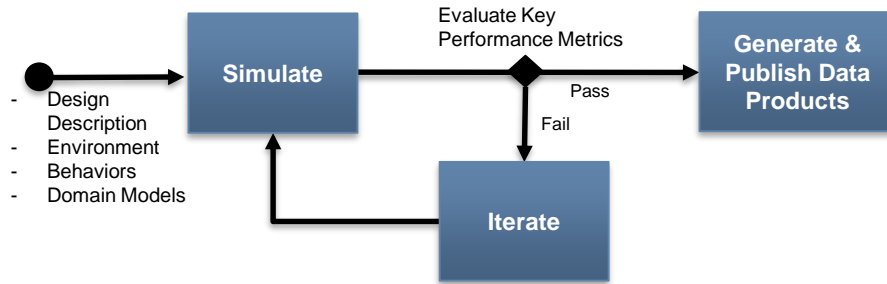
Architecture Capability Summary

- End-To-End analysis linking science requirements to behaviors and technical resource
- Separate and compare project baseline and what-if assessments
- System level impacts can be assessed in hours
- Produce standard reports and visualizations of analysis products




Nominal Simulation Workflow


System Level Assessment



- Project & Flight System assessments support system level impacts of trade studies and Engineering Change Requests
- Focus on relative impacts of changes and quick turn around
- Models developed by subject matter experts



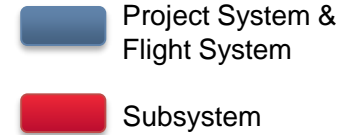
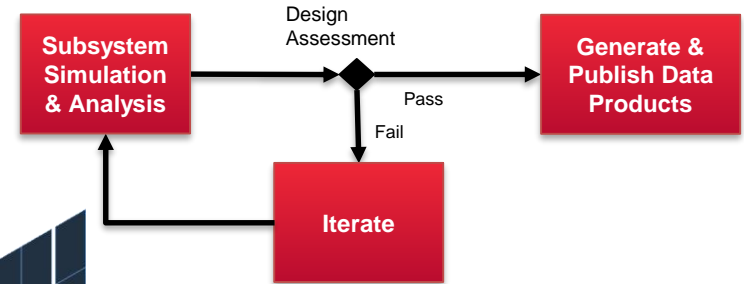
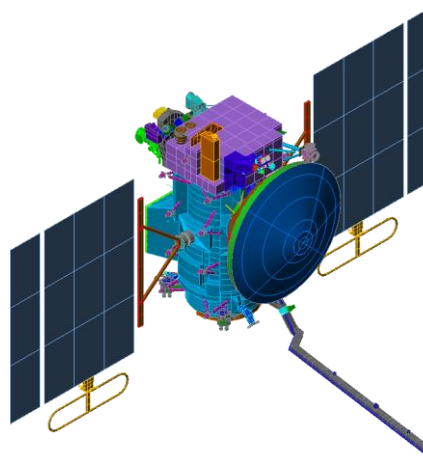
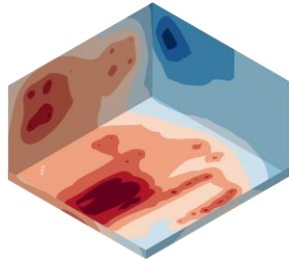
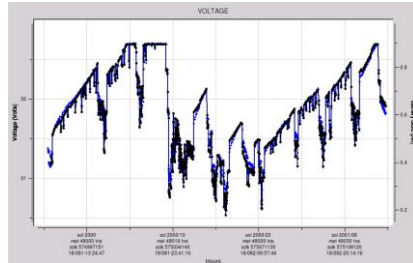
 Project System & Flight System

 Subsystem

Nominal Simulation Workflow

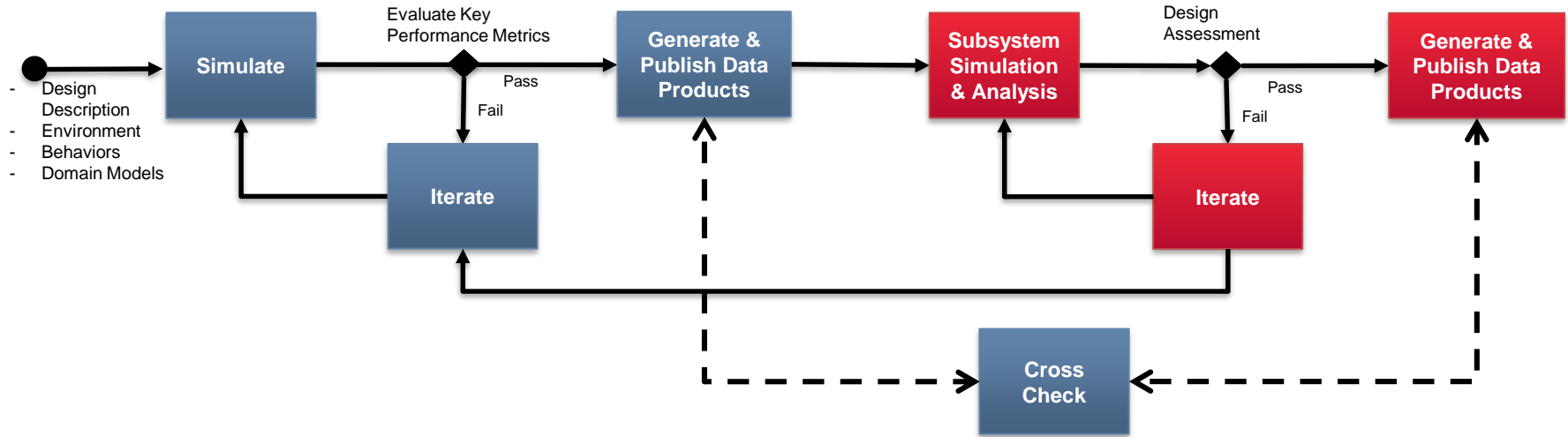
Subsystem Level Assessment

- High fidelity subsystem analysis assess hardware design and requirements compliance

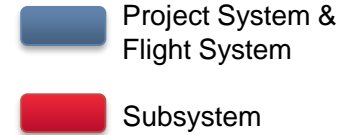


Nominal Simulation Workflow

Feedback

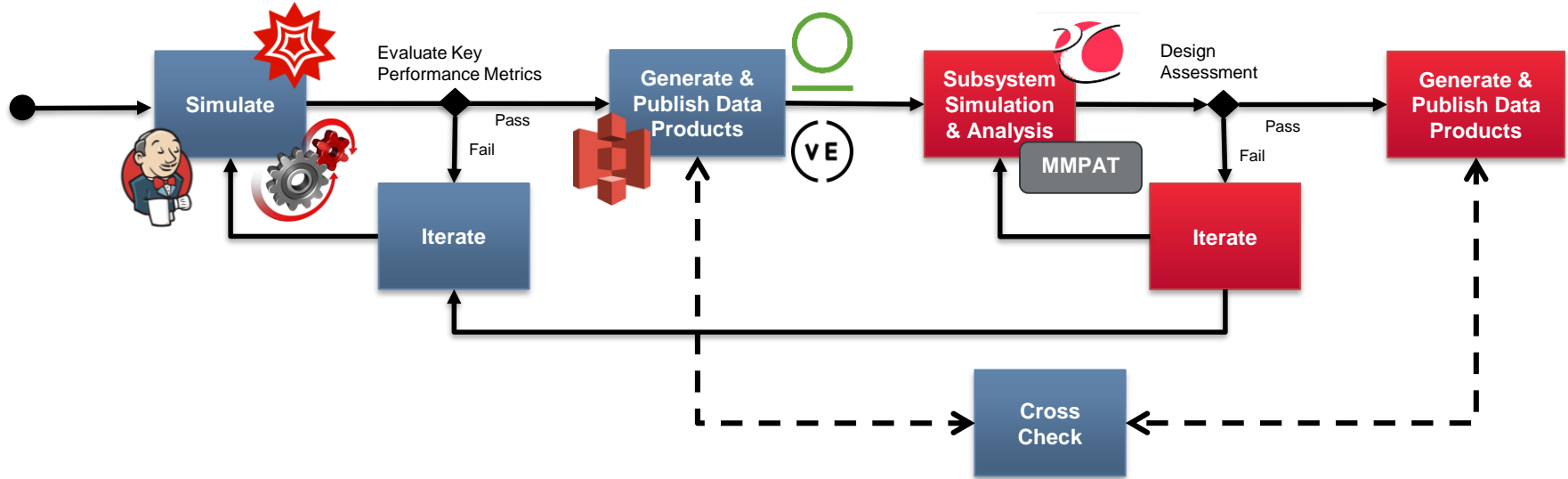


- Regular cross-check between system and subsystems
 - Improve confidence in results and analysis pipeline
 - Issues are caught and resolved early

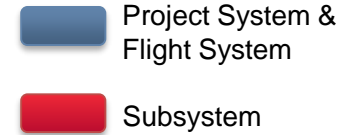


Nominal Simulation Workflow

Tools Used



- Leverage common services and capabilities to streamline workflows
 - E.g., Jenkins, interface libraries, data repositories

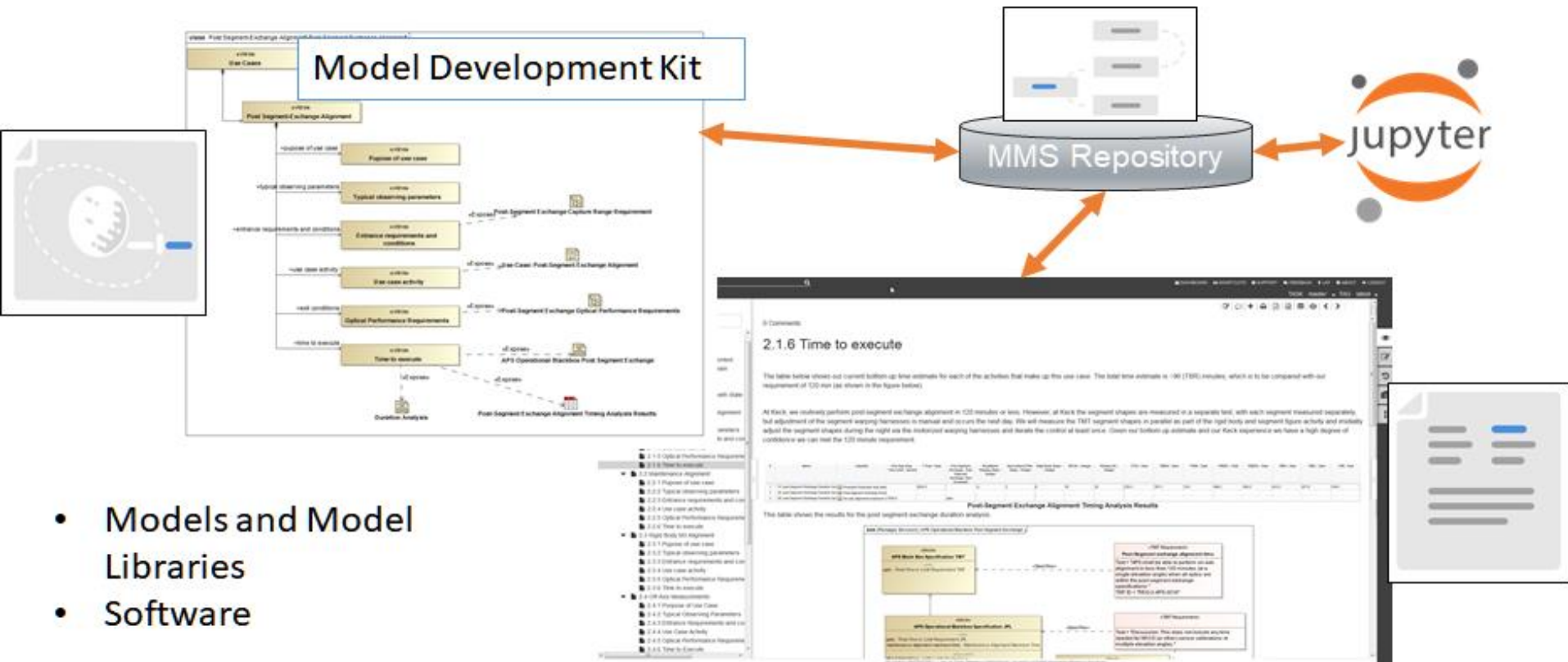


Open Model Based Engineering Environment

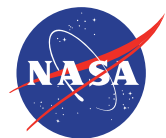
openmbee.org

- OpenMBEE is a community for open-source modeling software and models
 - Number of open source software activities
 - Number of open source models
- JPL is a participant and adopter of OpenMBEE software and models
- Along with Boeing, Lockheed, OMG, NavAir, Ford, Stevens, GaTech, ESO
- Vendor participants
- ~350 members

OpenMBEE Model and Content



- Models and Model Libraries
- Software



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