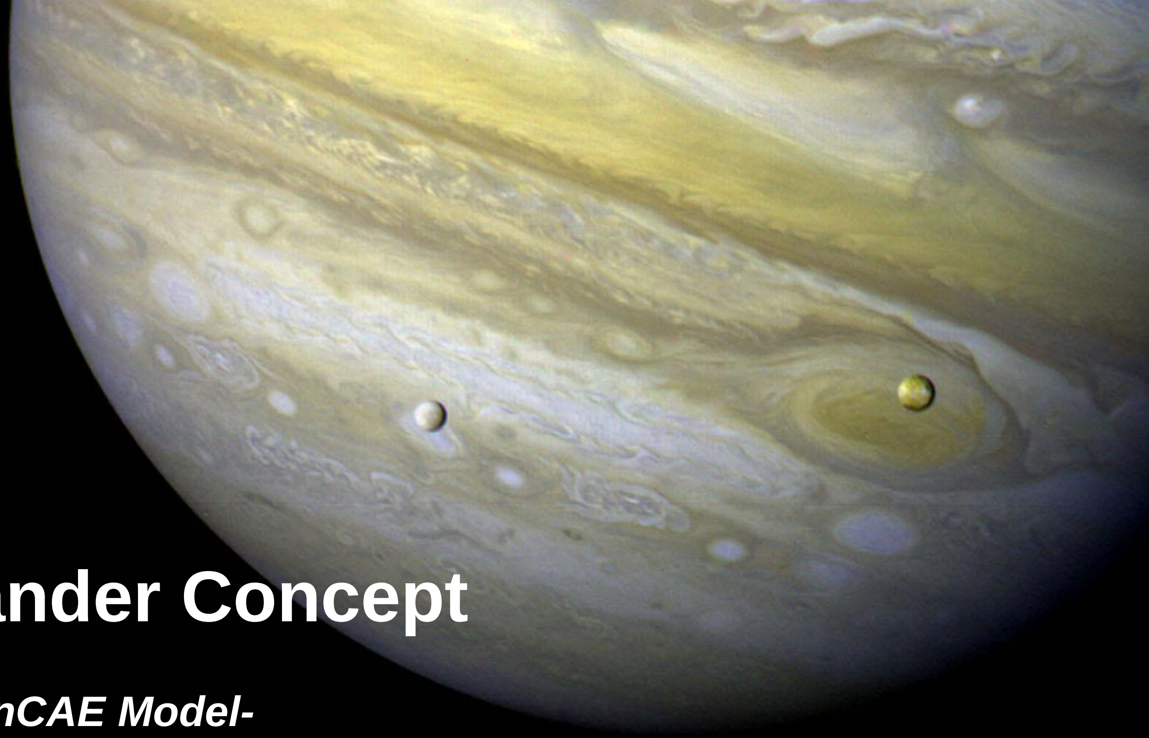
2019 MBSE CYBER EXPERIENCE SYMPOSIUM

OpenCAE Case Study: Europa Lander Concept



Jet Propulsion Laboratory
California Institute of Technology

OpenCAE Case Study: Europa Lander Concept

Model-Based Systems Engineering Products in the OpenCAE Model-Based Engineering Environment with Europa Lander as a Case Study

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The decision to implement the Europa Lander mission will not be finalized until NASA's completion of the National Environmental Policy Act (NEPA) process. This document is being made available for information purposes only.

Agenda

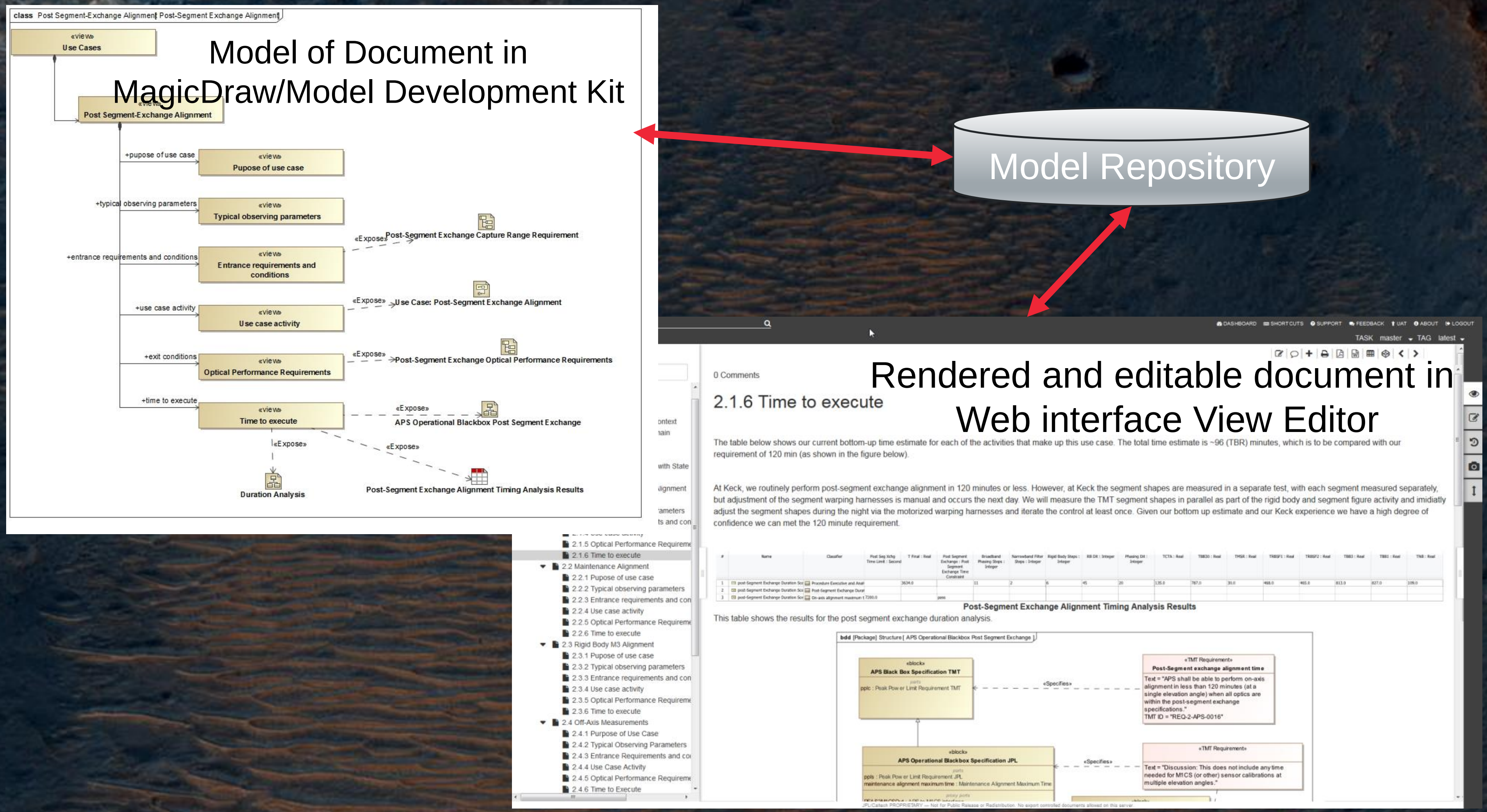
- OpenMBEE and OpenCAE
- Europa Lander Adaptation
- JPL Systems Engineering Products
- Europa Lander Systems Engineering Products

openmbee.org

Open Model-Based Engineering Environment

- 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 Martin, OMG, NavAir, Ford, Stevens, Georgia Tech, ESO
- Vendor participants
- ~300 members

Core Integration of MMS, MDK, and VE

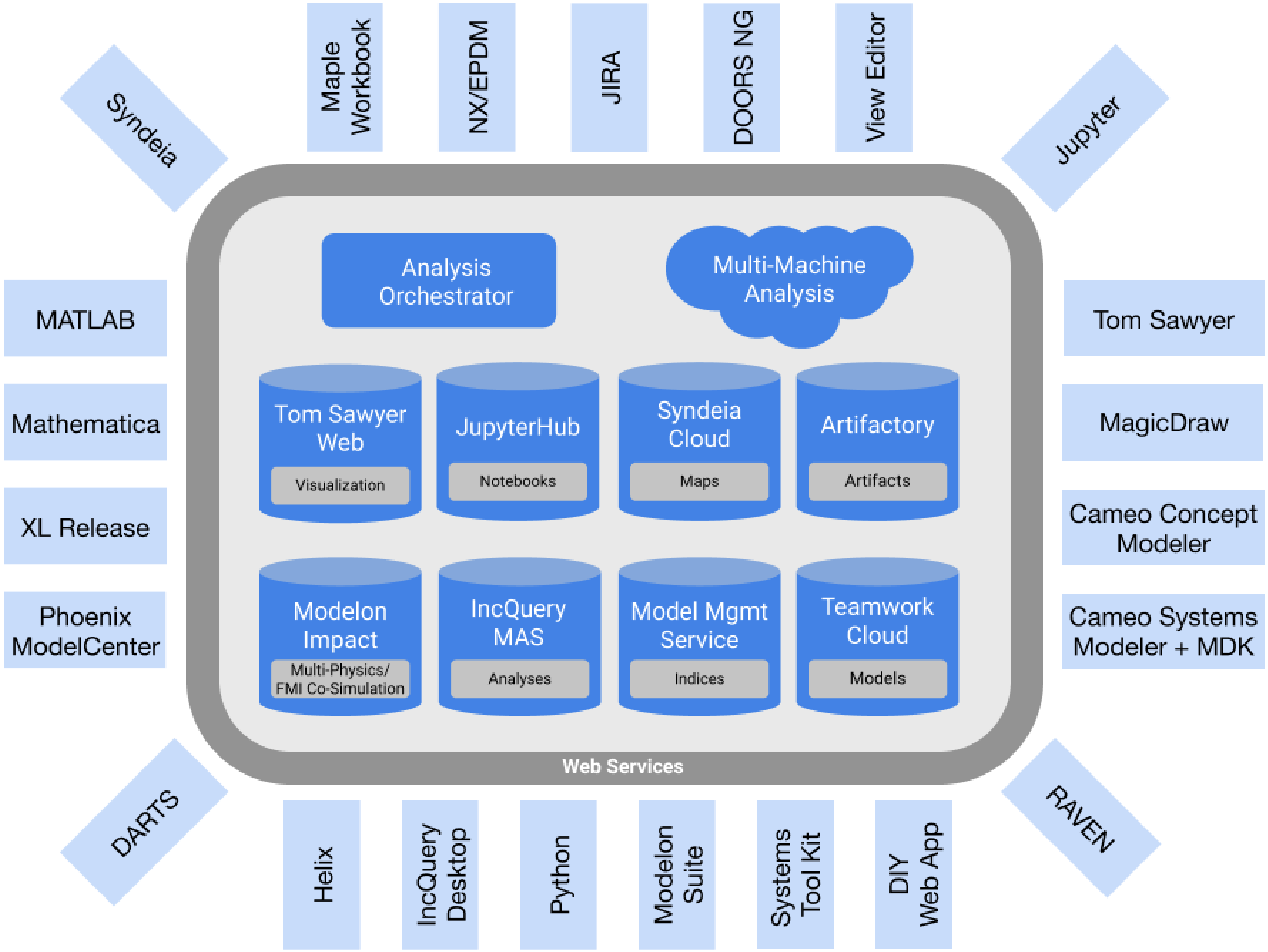


Computer Aided Engineering

- CAE is divided into four engineering disciplines:
  - Electrical Engineering
  - Mechanical Engineering
  - Software Engineering
  - Systems Engineering
- CAE supports the engineers of these disciplines with “engineering environments” – connected software applications and web services
- “OpenCAE” refers to the core CAE team *and* its users

OpenCAE

Systems Environment Overview



OpenCAE

Systems Environment Pipeline

Process (traceable, auditable, repeatable)

Collaboration / De-confliction → Requirements / Design → Analysis → Publication

Collaboration / De-confliction

- Maple
- Syndeia
- SWAGGER
- CAMEO DATAHUB
- Excel

Requirements / Design

- IBM Rational DOORS Next Generation
- CAMEO SYSTEMS MODELER
- jupyter
- HELIX
- Excel

Analysis

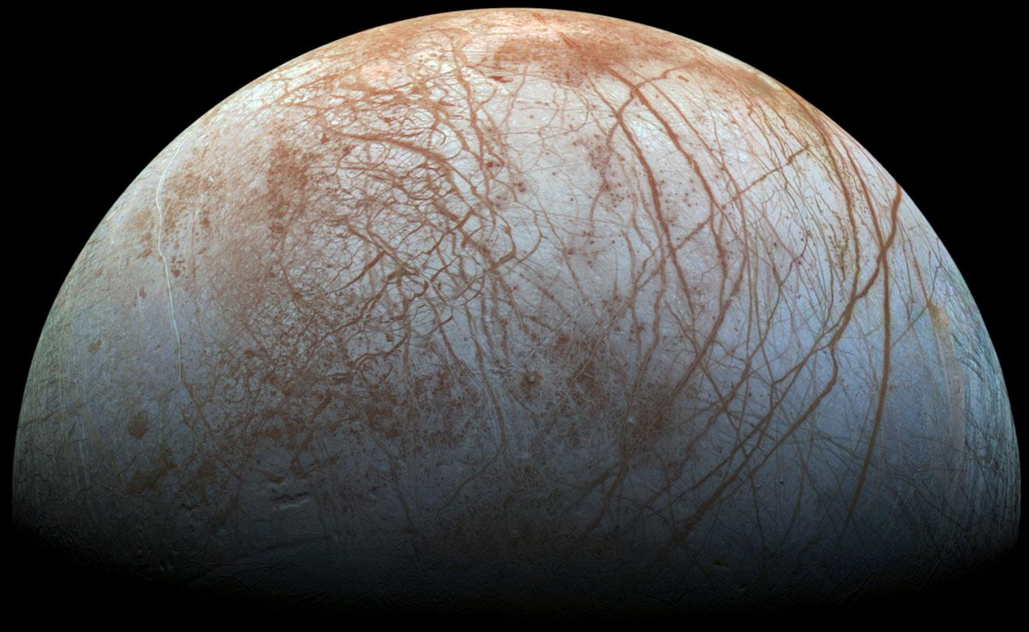
- PHOENIX INTEGRATION
- jupyter
- Tom Sawyer SOFTWARE
- MATLAB
- IncQueryLabs
- python
- CAMEO SIMULATION TOOLKIT
- Modelon
- MODELICA
- AGI
- Excel
- RAVEN
- DARTS

Publication

- Confluence
- View Editor
- TestRail
- JFrog Artifactory
- CONDA
- Excel
- binder
- nbviewer

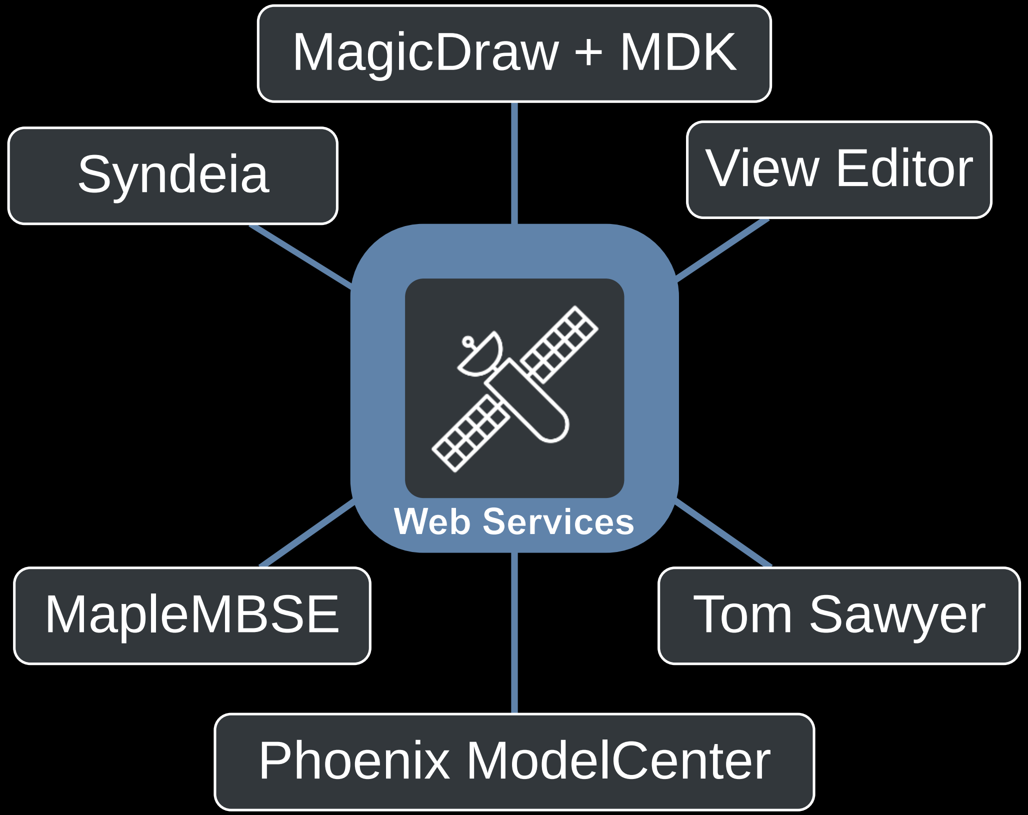
Jenkins | PMA | Jira | XebiaLabs RELEASE | WENG | LENG

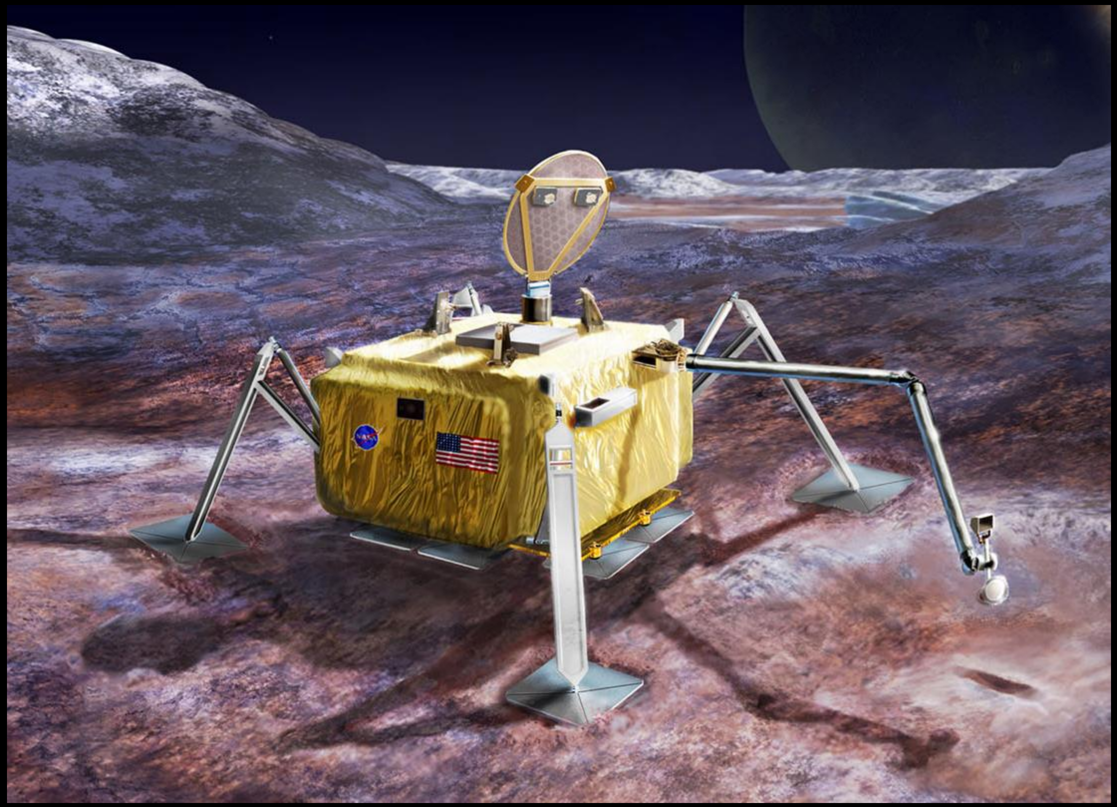
Europa Lander Study



- Proposed astrobiology mission concept by NASA JPL
- Europa is a moon of Jupiter
  - Salty ocean under icy surface
  - Bombarded by constant and intense radiation from Jupiter
  - 390.4 million miles from Earth
- Science Goals
  - Search for evidence of biosignatures on Europa
  - Assess the habitability of Europa
  - Characterize the surface and subsurface of Europa

Europa Lander Environment Adaptation





Artist's Concept

JPL Systems Engineering Products

- Compositional System Design Capture
- Electrical Flight Systems Engineering
  - System Block Diagram
  - Function Lists, Net Lists
  - Circuit Data Sheets
- Scenario Definition, Planning and Analysis
- Fault Protection Monitors and Responses
- Functional Description Document Generation
- Resource Management
  - Mass Management Process, Master Equipment List (MEL)
  - Power Scenario Analysis
  - Data Scenario Analysis
- Equipment List

JPL Systems Engineering Products

- **Compositional System Design Capture**
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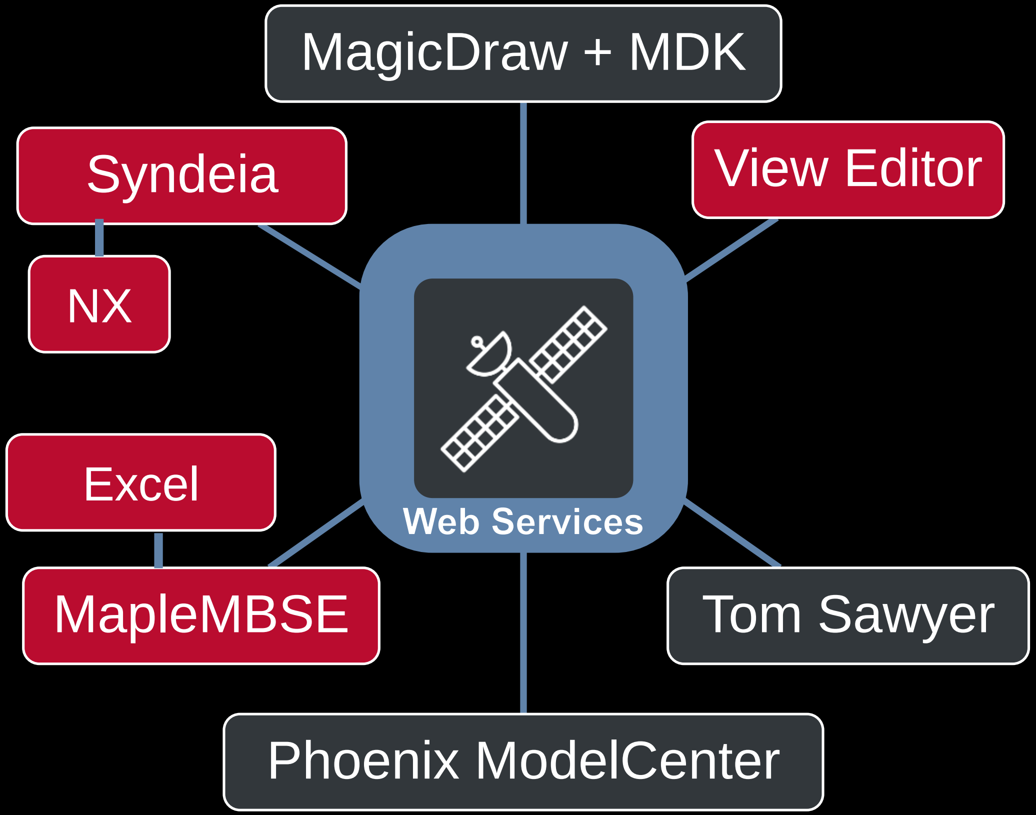
Master Equipment List (MEL)

- Manages the flight system mass
- Each component has the same list of mass attributes
  - Current Best Estimate (CBE)
  - Contingency percentage
  - Other metadata (point of contact, subsystem, stage)
- MEL supplies all component types that can be used in the system design

	A	C	D	E	I	J	K
1							
2		Subsystem	Component	Stage	CBE Unit Mass (kg	Unc %	Commonality
447		PWR-PYRO	CELL	LNDR	22.0800	5.00%	4: New
448		PWR-PYRO	CELLS	DS	9.2200	5.00%	1: Build-to-Print
449		PWR-PYRO	CLOSE-OUT PNL	DS	0.4800	30.00%	3: Modified
450		PWR-PYRO	DBIS CARD	DS	2.6500	30.00%	3: Modified
451		PWR-PYRO	LBIS	LNDR	2.6500	30.00%	3: Modified
452		PWR-PYRO	MPS_0	LNDR	2.4700	30.00%	3: Modified
453		PWR-PYRO	MPS_1	DS	2.4700	30.00%	3: Modified
454		PWR-PYRO	PACKAGING	DS	2.3000	30.00%	4: New
455		PWR-PYRO	PDS	DS	2.4700	30.00%	4: New
456		PWR-PYRO	PFS_0	LNDR	2.4700	30.00%	4: New
457		PWR-PYRO	PFS_1	DS	2.4700	30.00%	4: New

Master Equipment List (MEL) Implementation

- Encode all components as SysML Blocks
- Store SysML Model in Teamwork Cloud
  - Version and Access Control
  - Branching and merging
- Edit components with MapleMBSE
  - Spreadsheet Interface
  - Export and Import
  - Embedded Formulas for implied attributes
- Link SysML components to CAD components with Syndeia
  - Control information between different modeling domains
  - Close information loop between Mechanical and Systems Engineering teams



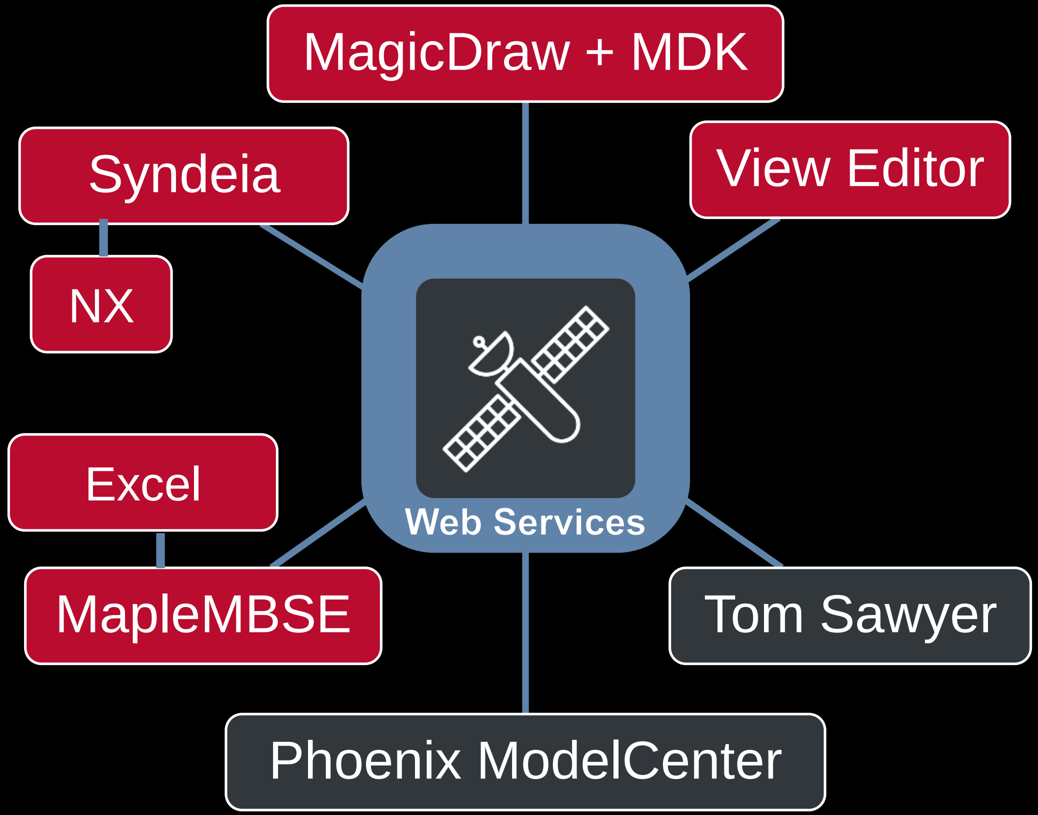
Compositional System Design

- Describes the assembled structure of the spacecraft
- MEL components are composed of other components
- Tracks the rolled up mass of particular sections of the spacecraft
- Reusages of common components that have the same attributes

Level 1	Level 2	Quantit	Type	Level 3
Europa Lander Vehicle				
Europa Lander Vehicle	BIO-BARRIER ASSY	1	BIO-BARRIER ASSY	
Europa Lander Vehicle	BIO-BARRIER ASSY	1	BIO-BARRIER ASSY	ADAPTER, CRS
Europa Lander Vehicle	BIO-BARRIER ASSY	1	BIO-BARRIER ASSY	EJCTD, UPR SHELL
Europa Lander Vehicle	BIO-BARRIER ASSY	1	BIO-BARRIER ASSY	FIXED, LWR SHELL
Europa Lander Vehicle	BIO-BARRIER ASSY	1	BIO-BARRIER ASSY	FIXED, UPR SHELL
Europa Lander Vehicle	BIO-BARRIER ASSY	1	BIO-BARRIER ASSY	FSTNRS
Europa Lander Vehicle	BIO-BARRIER ASSY	1	BIO-BARRIER ASSY	MRMN CLAMP INSTL
Europa Lander Vehicle	DOV ASSY	1	DOV ASSY	
Europa Lander Vehicle	DOV ASSY	1	DOV ASSY	3/8"FSTNRS, SEP NUT
Europa Lander Vehicle	DOV ASSY	1	DOV ASSY	CUP, CATCH (ON DOS
Europa Lander Vehicle	DOV ASSY	1	DOV ASSY	DOS ASSY
Europa Lander Vehicle	DOV ASSY	1	DOV ASSY	DOS ASSY
Europa Lander Vehicle	DOV ASSY	1	DOV ASSY	DOS ASSY

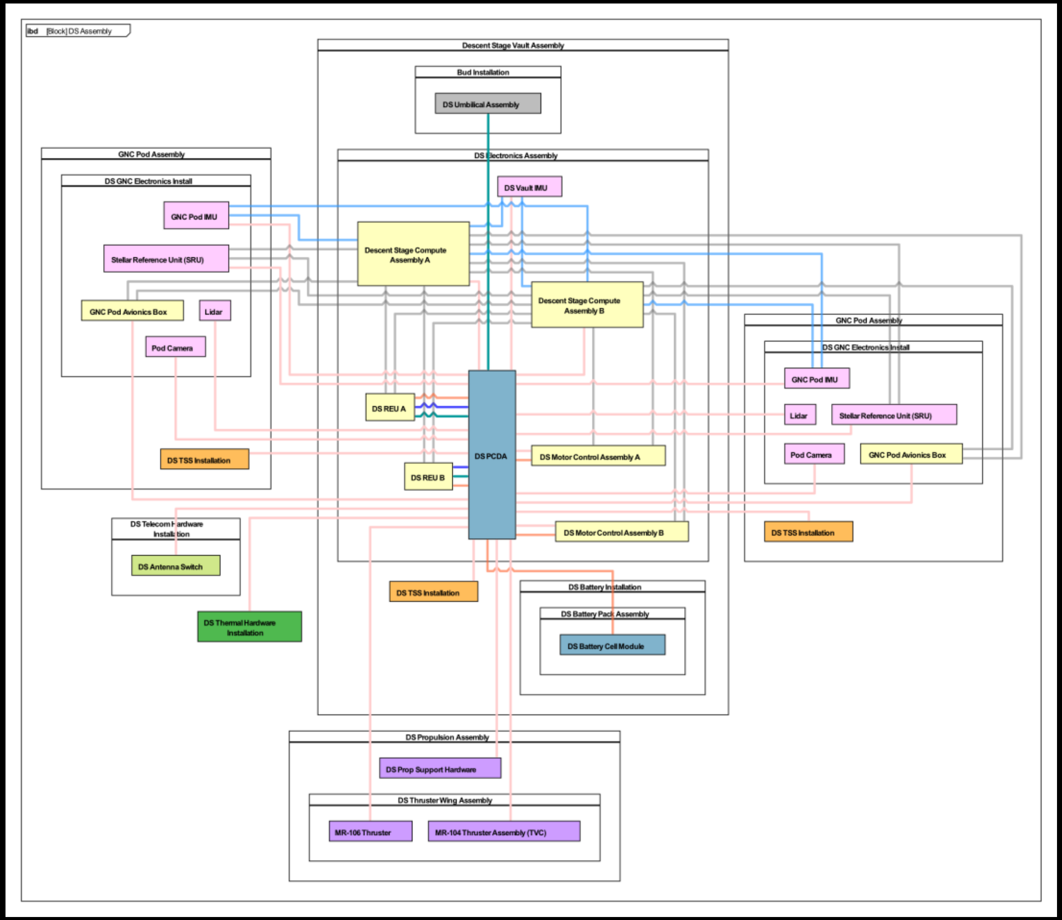
Compositional System Design Implementation

- Use components that are available in the SysML model
  - Describe composition hierarchy with Directed Composition Relationships
- Expose assembled structure in MapleMBSE
  - Spreadsheet view of the composition hierarchy
  - Embedded formulas in Excel control the mass roll up



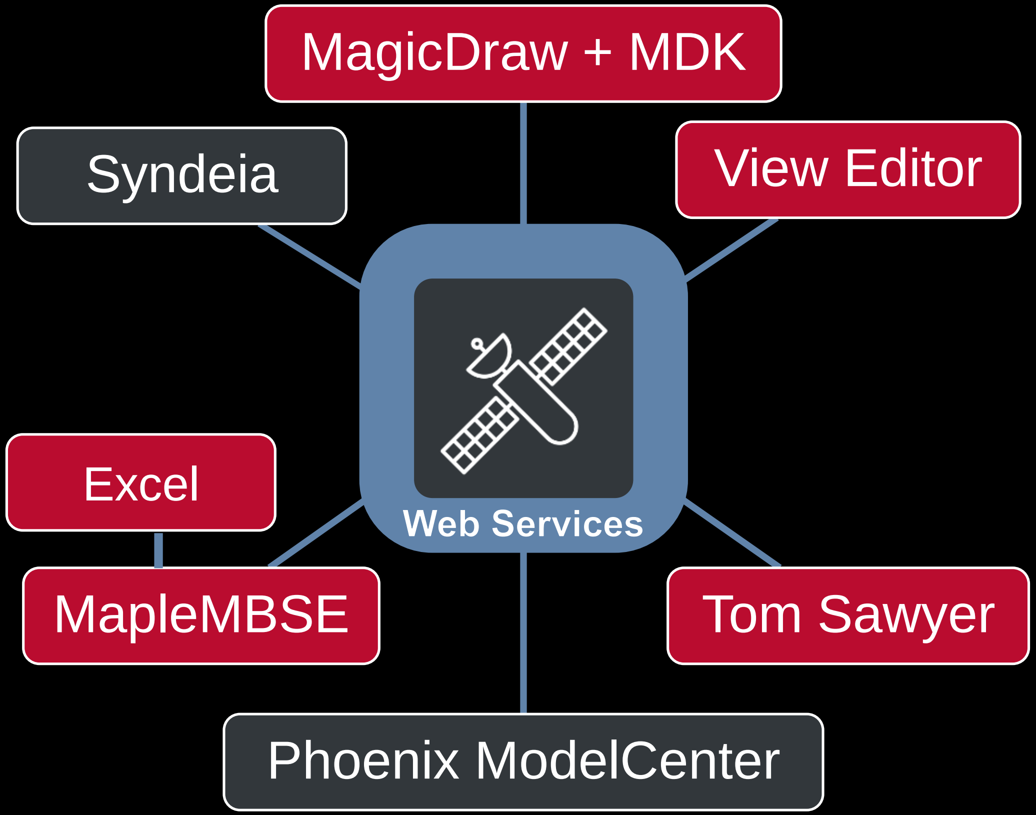
System Block Diagram

- Deliverable for major reviews
- Informs engineers about connected components in the spacecraft
- Informs the available slots on components, based off of component type
- Power connections
- Data connections



System Block Diagram Implementation

- Use MagicDraw to connect components
  - Validate connections with context
  - Create and apply connection types as necessary
- Visualize with Tom Sawyer
  - Explore the connected elements with nested hierarchies
  - Interactive diagrams with filtering
  - Diagrams rendered from the model
- Use MapleMBSE to audit all connections in table view



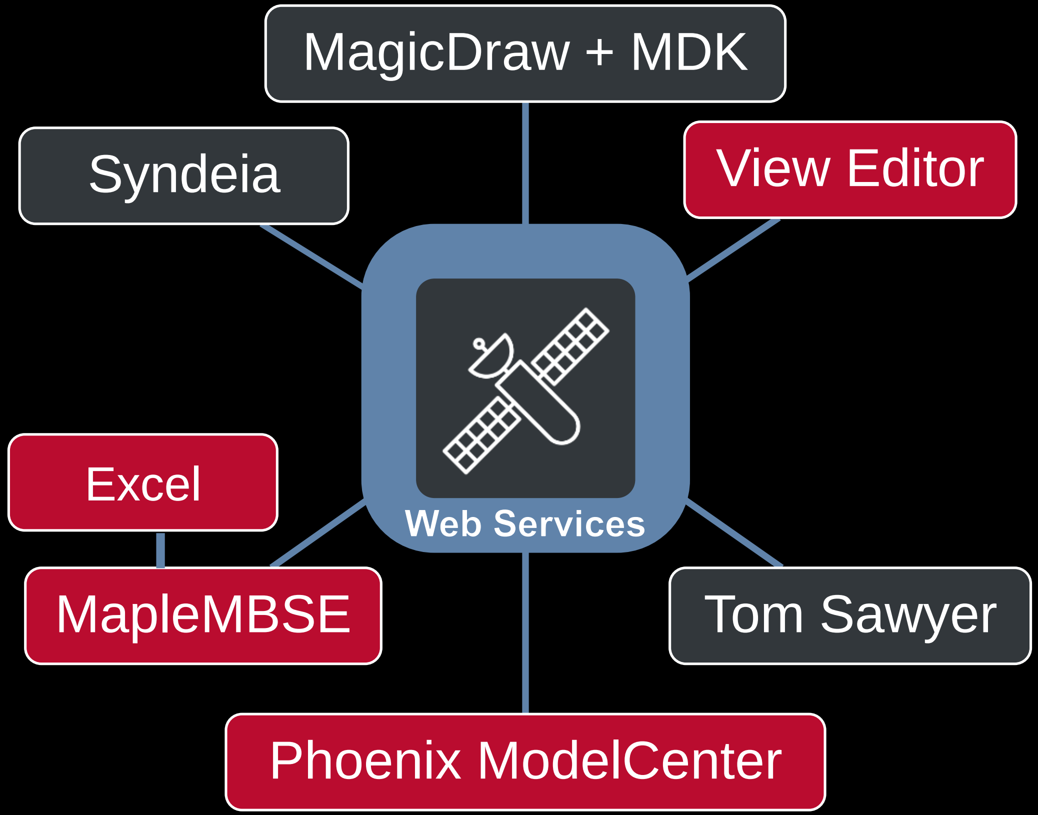
Scenario Definition and Power Equipment List (PEL)

- Describes behavior of the spacecraft, with respect to power usage
- A subset of all MEL components are powered
- Powered components have a set of discrete modes with attributes
  - Power Usage
  - Contingency
- Spacecraft performs certain tasks over a duration, described in scenarios
- Scenarios prescribes each component's mode during the scenario
- Scenarios roll up the power usage of all the components based on attributes of the component modes

PEL Component	Quantity	Cruise	Pwr (W)	Cruise - SSPA on 75% Time	Pwr (W)	Cruise Occultat
		Mode	CBE	Mode	CBE	Mode
REU-A	1	On	9.5	On	9.5	On
REU-B	1	Off	0	Off	0	Off
Reaction Wheel 1	1	Hold	8.15	Hold	8.15	Hold
Reaction Wheel 2	1	Hold	8.15	Hold	8.15	Hold
Reaction Wheel 3	1	Hold	8.15	Hold	8.15	Hold
Reaction Wheel 4	1	Off	0	Off	0	Off
Reaction Wheel Elex 1	1	Hold	8.15	Hold	8.15	Hold
Reaction Wheel Elex 2	1	Hold	8.15	Hold	8.15	Hold
Reaction Wheel Elex 3	1	Hold	8.15	Hold	8.15	Hold

Scenario Definition and PEL Implementation

- Use components that are available in the SysML model
- Create new components that represent generic powered components
  - Power modes are inherited by the MEL components
  - Power modes contain their own attributes, which are inherited as well
- Create new components that represent Scenarios
- Expose powered components in MapleMBSE
  - Spreadsheet view
  - Power roll up on discrete scenarios
- Table are used in Phoenix for Monte Carlo analysis



Accomplishments

- OpenCAE Systems Environment supports the engineering effort on Europa Lander
- We took a model-based engineering approach to developing the standard JPL systems engineering products
- CAE improved the engineering environment for all users based off of findings during this effort

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