



NASA JPL Systems Environment

Robert Karban, *CAE Project Systems Engineer*
Jet Propulsion Laboratory,
California Institute of Technology

December 2018 – OMG Technical Meeting – Seattle, WA, USA

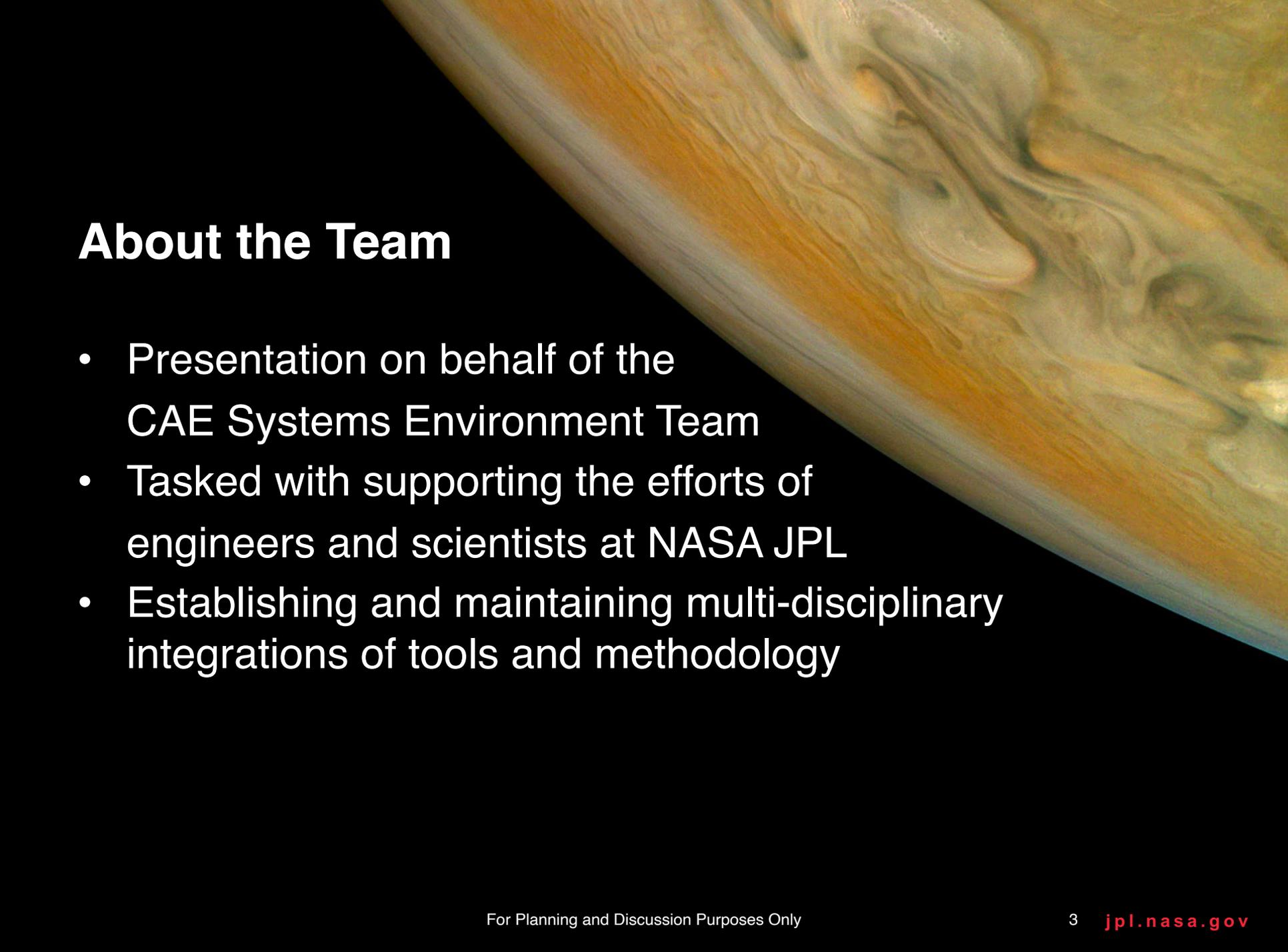
The cost information contained in this document is of a budgetary and planning nature and is intended for informational purposes only. It does not constitute a commitment on the part of JPL and/or Caltech. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not constitute or imply its endorsement by the United States Government or the Jet Propulsion Laboratory, California Institute of Technology.



Agenda

- Introduction
- OpenCAE Approach
- Open Source Contributions
- Questions





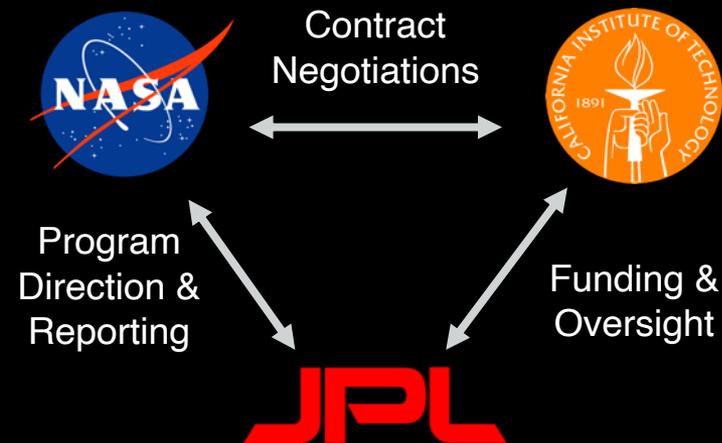
About the Team

- Presentation on behalf of the CAE Systems Environment Team
- Tasked with supporting the efforts of engineers and scientists at NASA JPL
- Establishing and maintaining multi-disciplinary integrations of tools and methodology

NASA Jet Propulsion Laboratory (JPL)



- Located in Pasadena, CA
- NASA-owned “*Federally-Funded Research and Development Center*”
- University-operated
- ~5,000 employees



Computer Aided Engineering (CAE)

- Computer Aided Engineering provides the Laboratory's Engineering Staff and Scientific communities with tools and technical expertise
- Four Environments:
 - Systems Environment
 - Software Environment
 - Mechanical Environment
 - Electrical Environment

OpenCAE Vision

- Provide an open portfolio in a shared environment that seamlessly connects engineers developing missions and systems.
 - Open - Processes, code, apps, services and artifacts are accessible by JPL users as well as vendors and partners
 - Shared - The diverse community of users, developers partners and vendors are able to contribute
 - Connected - Collaboratively construct and analyze the same precision products needed to develop Missions and Systems at JPL using the CAE environment.

OpenCAE Mission

- Develop the CAE environment from a user centered architecture leveraging vendor partnerships using robust life cycle processes.
 - Vendor partnerships – Crucial feedback and insight into how Vendor products are serving the needs of engineers and developers
 - User centered – Architecture for CAE is driven by the needs of the practitioners and projects
 - Life-cycle process – Provide the integrity of the the applications services and support



Agenda

- Introduction
- OpenCAE Approach
- Open Source Contributions
- Questions



Model-Based Engineering applied by Projects for delivering Engineering Products

Projects:

- Europa Clipper
- Europa Lander mission concept
- InSight
- Mars 2020
- Mars Sample Return (MSR) – potential missions concept
- Thirty Meter Telescope
- Ground Data Systems
- Psyche
- MAIA

Products:

- MELs, PELs
- Resource allocation analysis
- System decomposition,
- Libraries / Reusable models

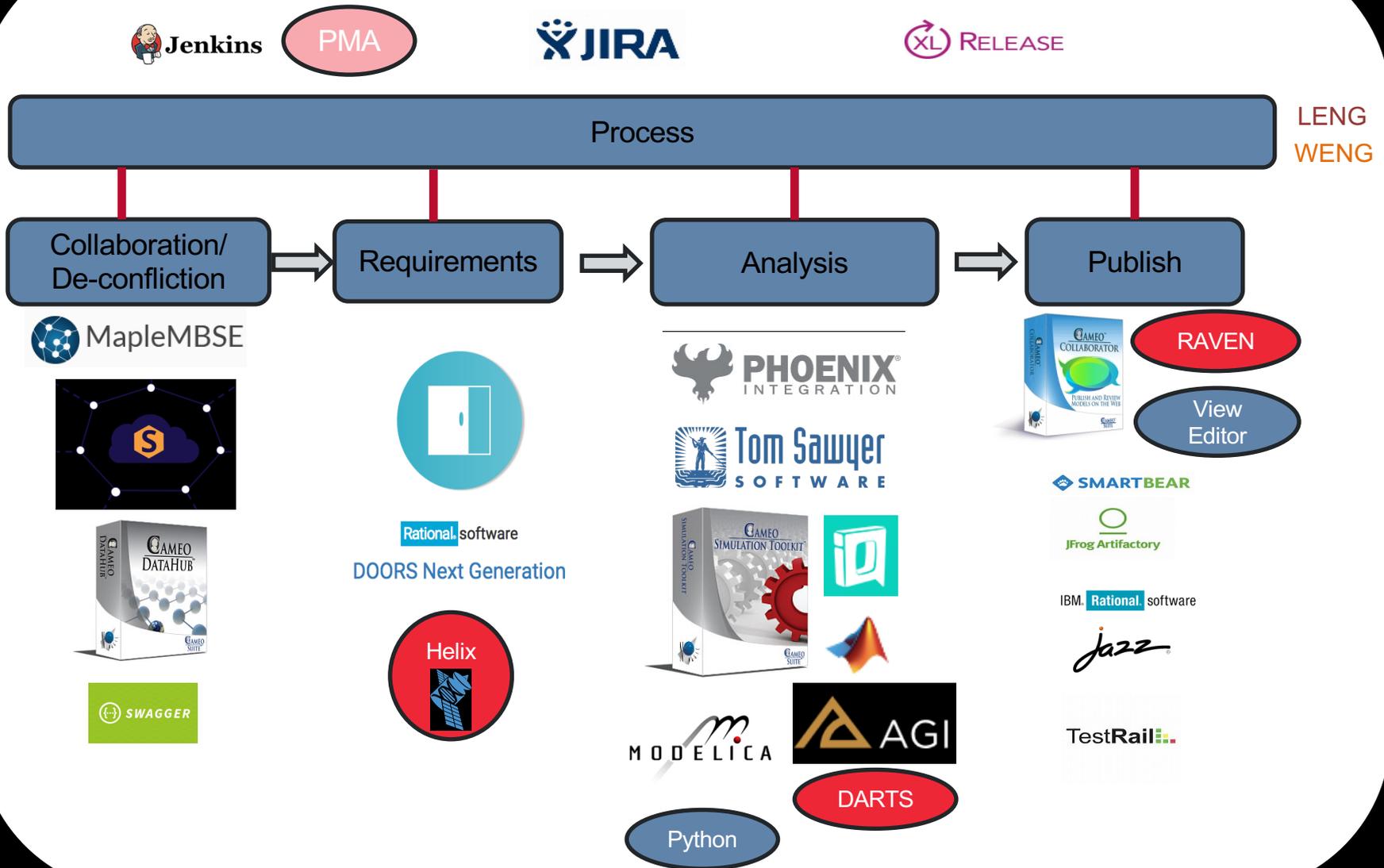
Not just spacecraft missions!

Not just early phases of design!

OpenCAE provides the engineering platform

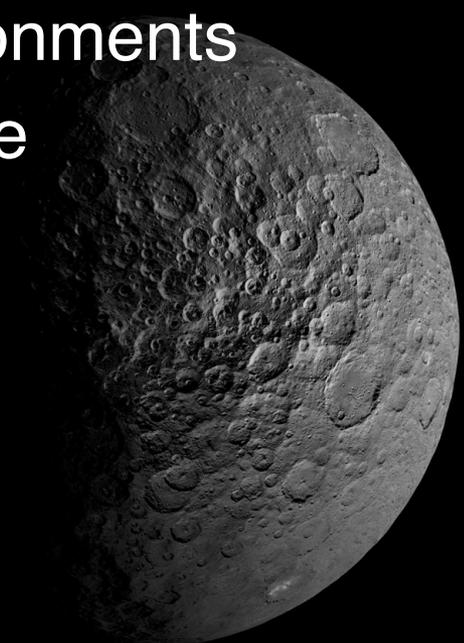
- A platform for engineering tools to work together
- Incorporate tooling from systems, software, mechanical, and electrical domains
- Platform integrates heterogeneous data sources
- Emphasize standards for data interchange
- Case studies inform the architecture of the engineering environments
- Multi-model environment

CAE Systems Environment Provides Integrated Life-Cycle Support



OpenCAE evolves through User Centered Design

- User Centered Design steers the development of the OpenCAE infrastructure
- Continuous communication with users to understand their experience in the OpenCAE environments
- Users evaluate solutions before they are implemented
- Following standard UX practices



OpenCAE engages the User Community

- Mailing lists generated by tool license use
- Slack channels per each tool for general questions (with vendors)
- Technical Working Groups held biweekly with vendors for tool-specific questions
- OpenCAE Systems Environment Team Office Hours held biweekly for general questions and support

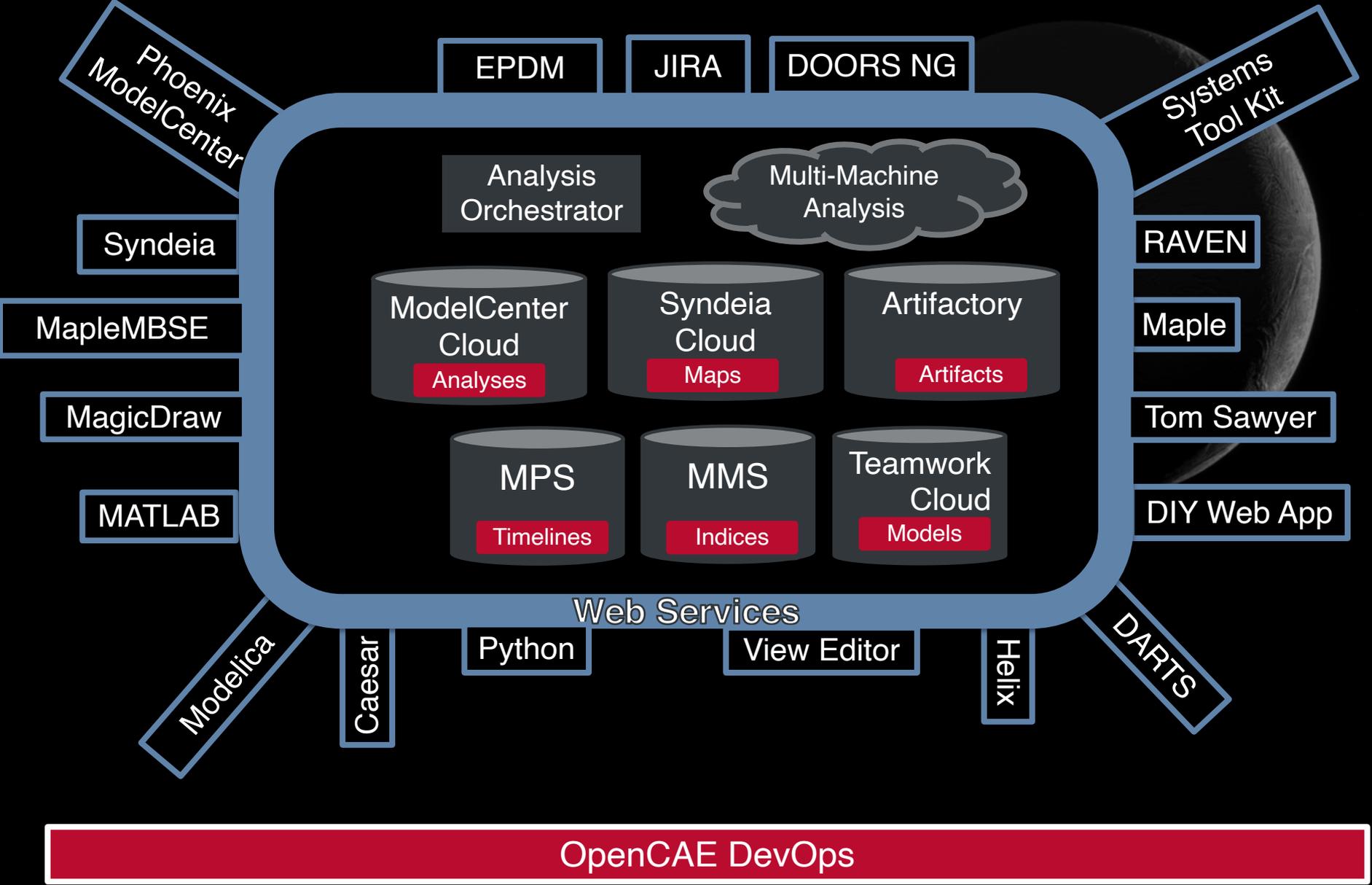


OpenCAE develops requirements through Case Studies

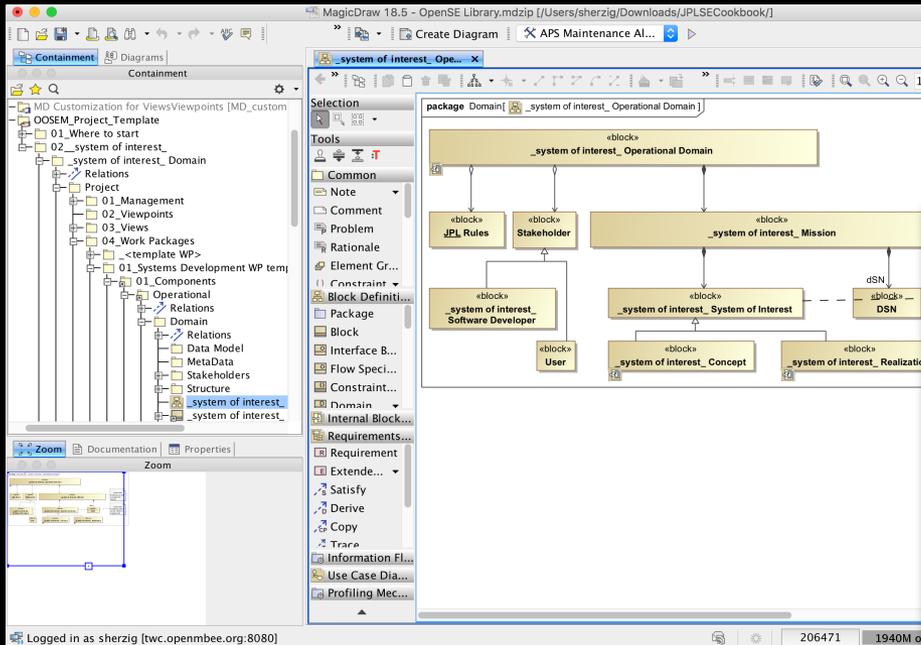
- Requirements Management
- Interface Management
- Design Management
- Trade Studies
- Interdisciplinary Integration
- Analysis Management
- Resource Management



CAE delivers an integrated Systems Environment



CAE Systems Environment: Cookbook and Template Model



“Cookbook” for modeling methodology and patterns



MBSE Initiative – SE2 Challenge

COOKBOOK FOR MBSE WITH SYSML

Issue 1
19/01/2011

SE2 Cookbook for MBSE with SysML Issue 1 19/01/2011 Page 15 of 120

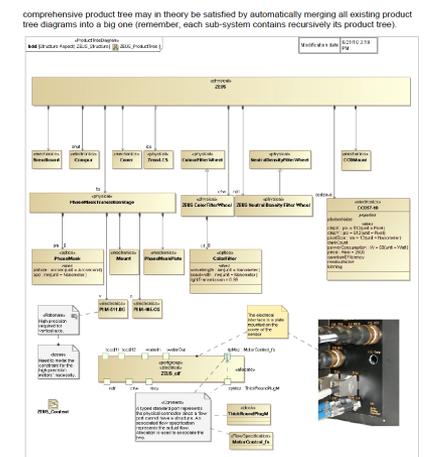


Figure 5 Product Tree of the ZEUS subsystem

ZEUS is one of the evaluated phasing sensors (Figure 5) and is based on the modified Mach-Zehnder interferometer phasing sensor. It is mounted on a breadboard and consists of a shutter, a cover, a color filter wheel, a neutral density filter wheel, and a translation stage which carries a phase mask. Different phase masks can be moved to the focal position by means of a translation stage, able to move in the X and Y directions.

- The two filter wheels located after the phase mask translation stage:
- A Neutral Density Filter wheel, a set of 8 different neutral density filters are available
 - An optical filter wheel, a set of 8 different optical filters centered on different wavelengths and with different bandwidths are available

Template models to be used by projects as a starting point, with recommended organization, model libraries, etc.

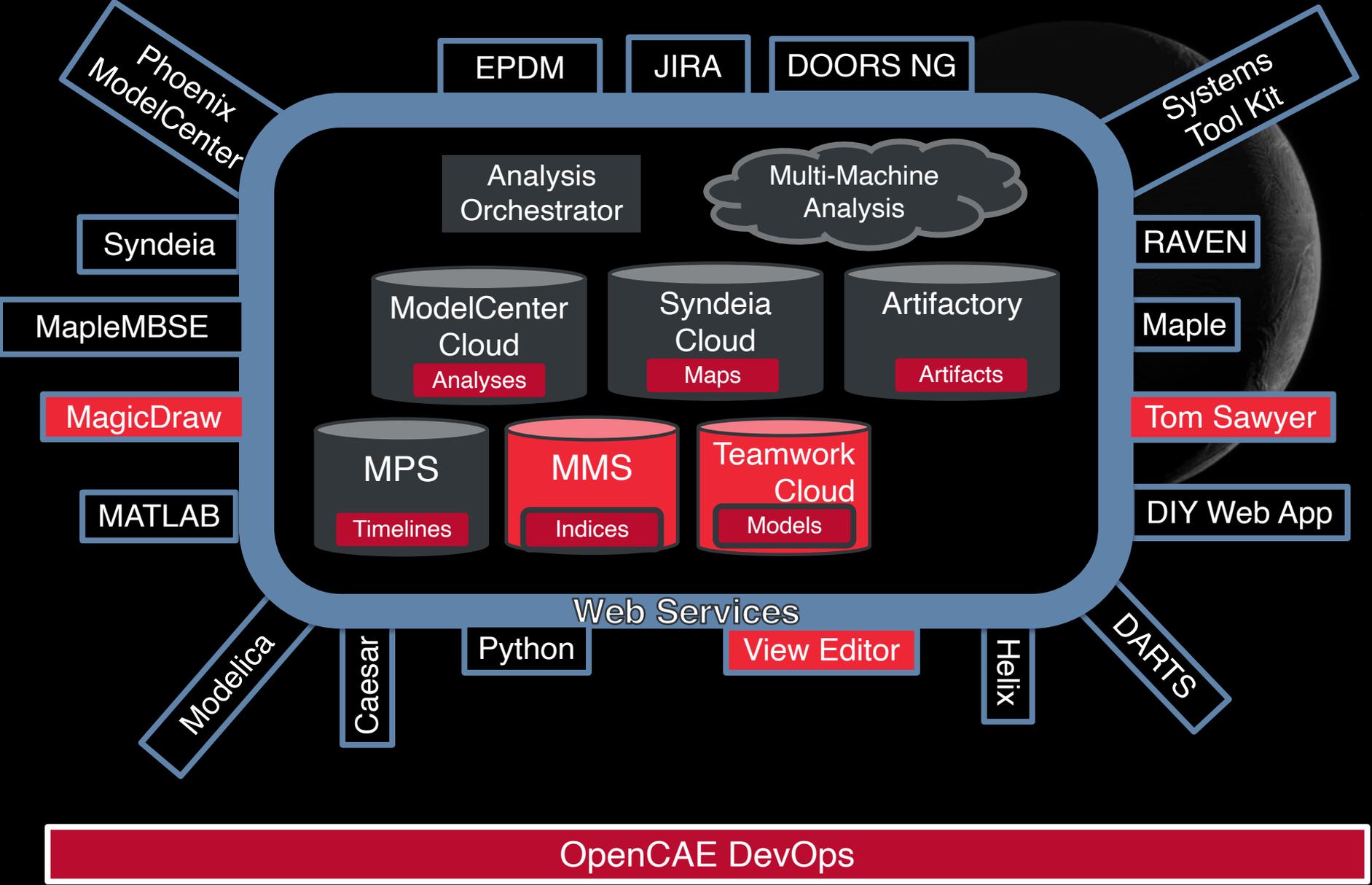
CAE offers project and domain specific adaptations

- CAE provides the same environment to all its customers (engineers and scientists)
- Embedded roles work directly on projects to adapt the standard environment specific to the project goals or methodology
- Embedded roles capture needs in general case studies which inform the CAE architecture

Mars2020 Embedded Role

- Ground Data System (GDS) Consolidation
- Flight System Model integrity
- Integration for generated artifacts
- Customized documents support
- Testing and Deploying various customizations of CAE Systems Environment

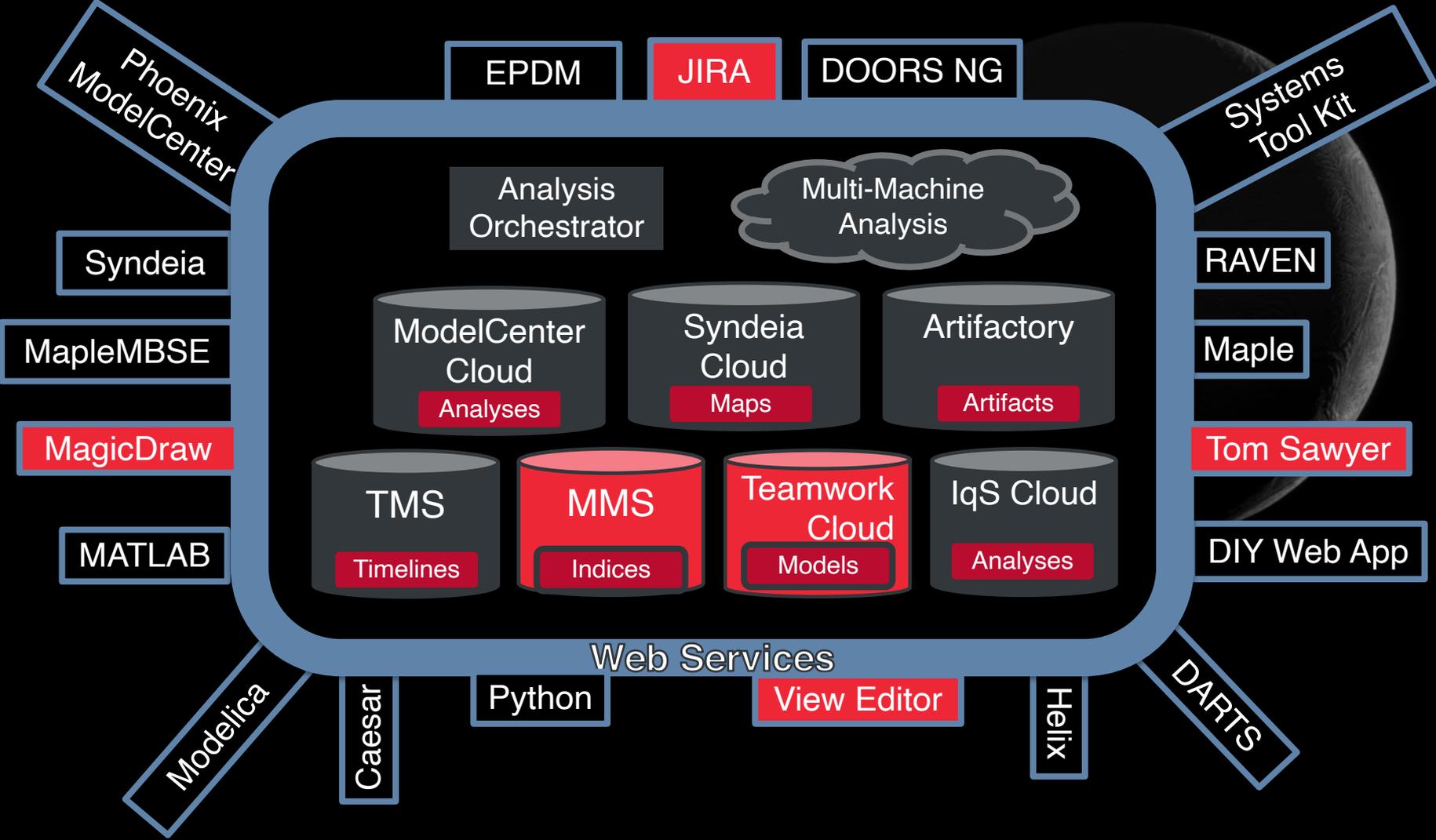
CAE delivers an integrated Systems Environment



NEESC MBSE Pathfinder Embedded Role

- Apply Best Modeling Practices
- Investigate and use various workflows in environment in a restricted environment
- Specified Training and Tutorials
- Team meetings and evaluation support
- On Call Support

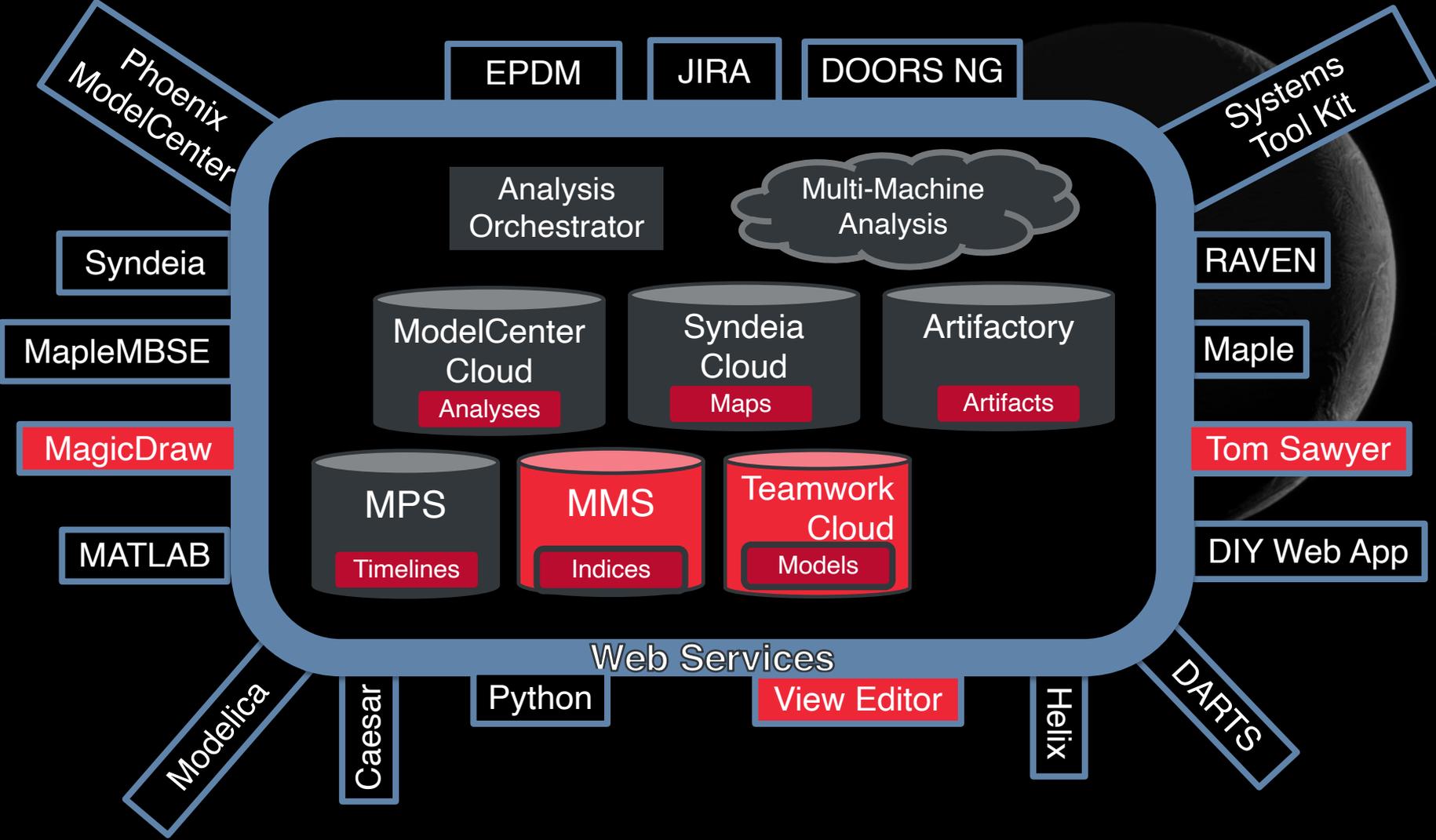
CAE delivers an integrated Systems Environment



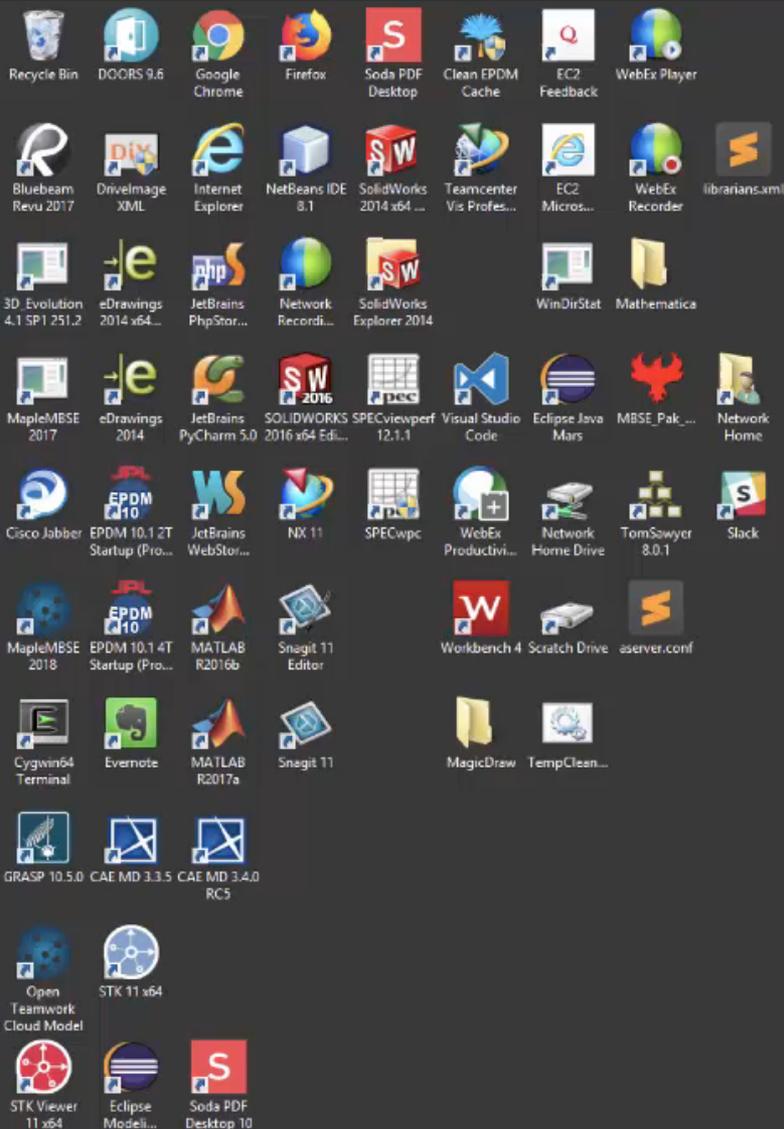
Europa Lander Embedded Role

- Need:
 - Generate orderly and palatable diagrams from a system model describing the Lander
 - SE products should never be out of sync with the system model
- Approach:
 - Leverage Tom Sawyer plugin for MagicDraw development effort
 - Supply requirements directly from the project to the vendor
 - Coordinate with CAE development team on the use case for Tom Sawyer integration with DocGen and View Editor

CAE delivers an integrated Systems Environment



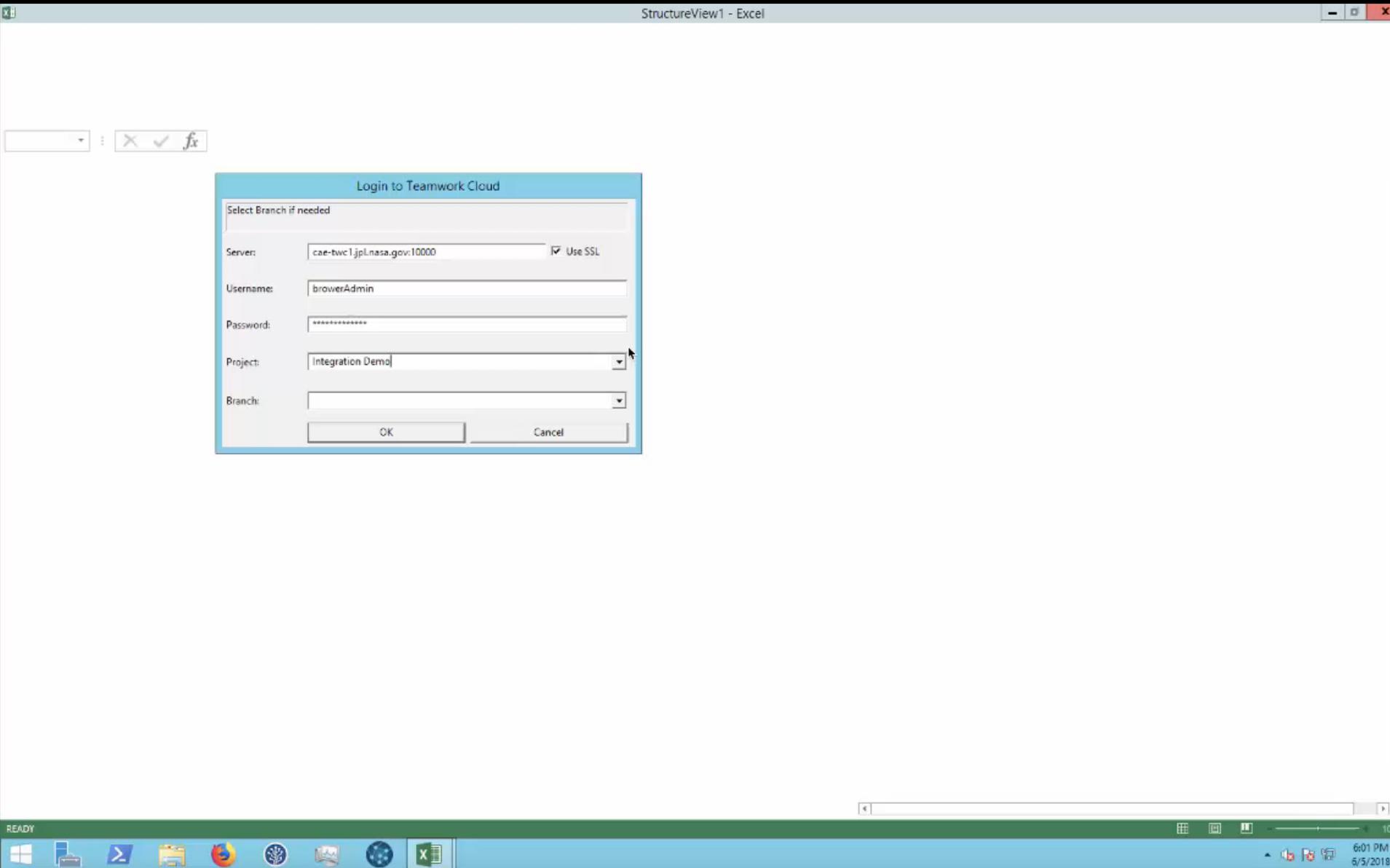
Managed Excel 1/3



Managed Excel in a collaborative environment

Windows Server 2012 R2

Managed Excel 2/3



Managed Excel 3/3

The screenshot displays a Windows desktop environment. A dialog box titled "Login to Teamwork Cloud" is open, prompting for login details. The fields are as follows:

- Server: cae-twc1.jpl.nasa.gov:10000 (with a checked "Use SSL" option)
- Username: browerAdmin
- Password: [Redacted]
- Project: Integration Demo
- Branch: toy-car

Buttons for "OK" and "Cancel" are visible at the bottom of the dialog. In the background, an Excel window titled "StructureView1 - Excel (Not Responding)" is open. Overlaid on the right side of the Excel window is the text "Open empty project from server in Excel" in red. The Windows taskbar at the bottom shows various application icons, including Chrome, Firefox, and several instances of EPDM software.

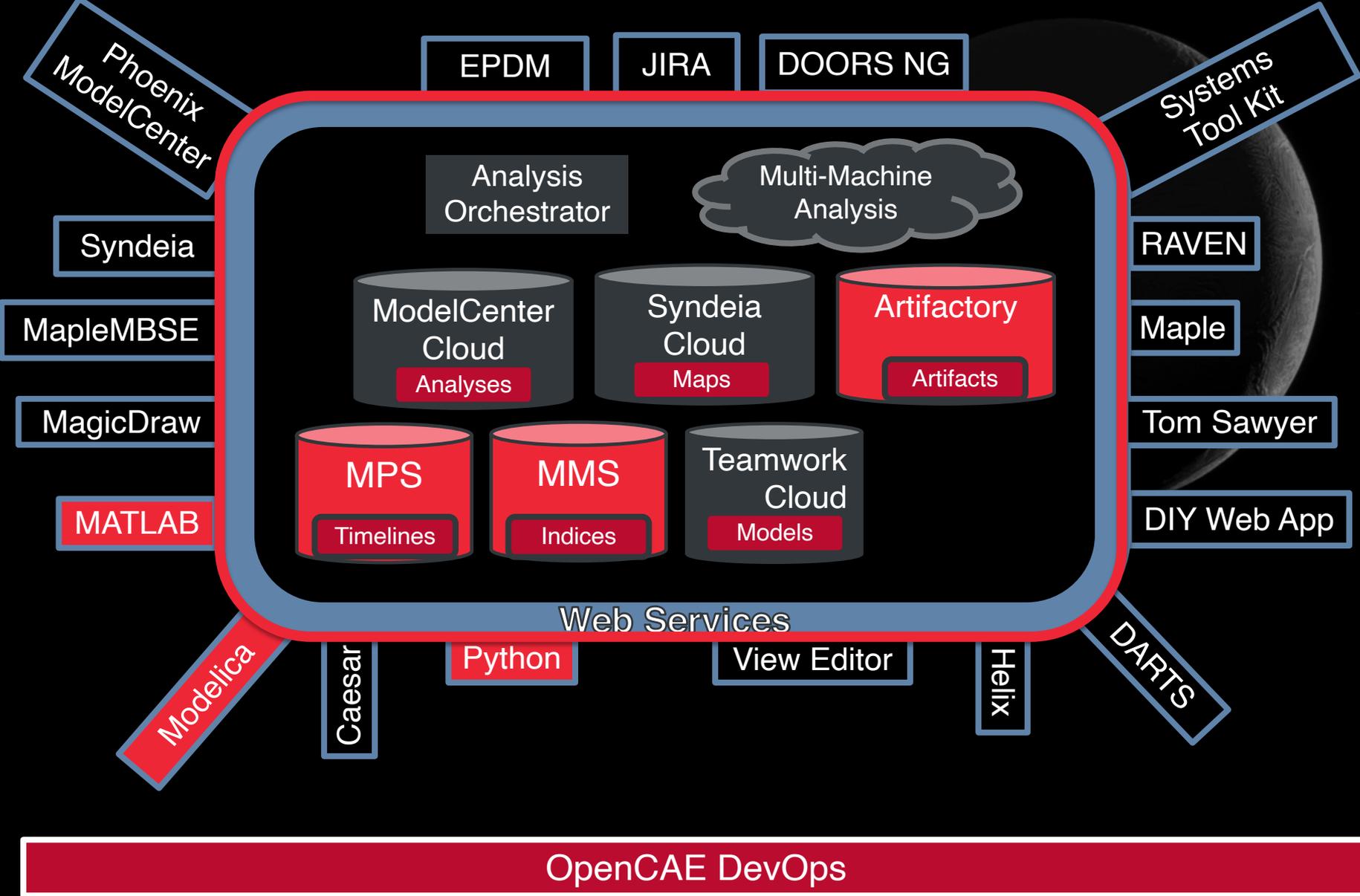
Open empty project from server in Excel

erver 2012 R

Europa Clipper Embedded Role

- Need:
 - Publish artifacts to CAE services (MMS, TES, Artifactory)
- Approach:
 - Express the REST API endpoints of these servers in OpenAPI standard specification
 - Use Swagger codegen to generate clients for specific analysis environments
 - Mathematica, MATLAB, Python, Java
 - More than 20 other languages available

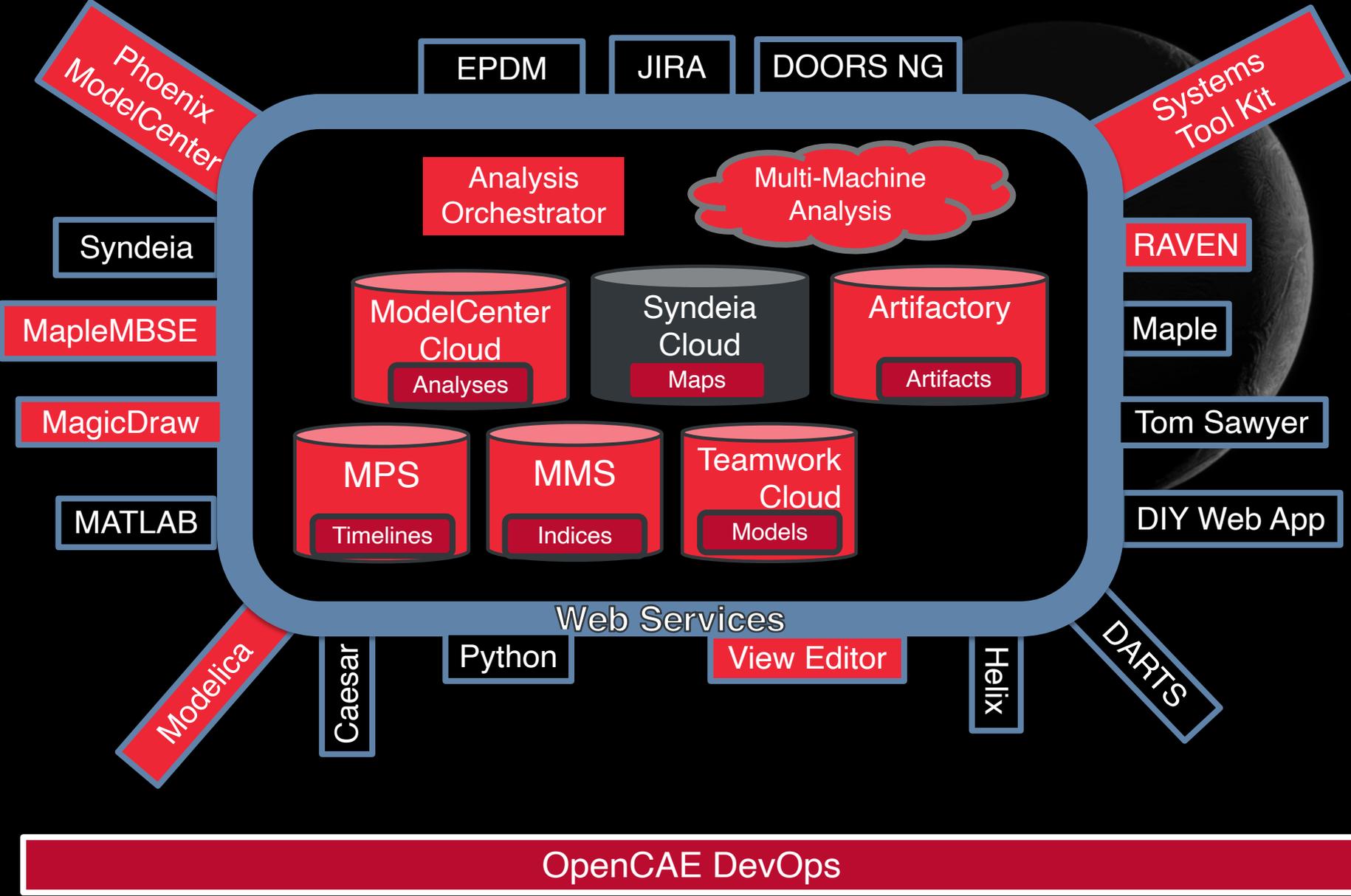
CAE delivers an integrated Systems Environment



Europa Clipper Embedded Role

- Need:
 - Formalize analysis workflows related to the Clipper Flight System
 - Want to capture the workflows in a model, but also want them to be executable
- Approach:
 - Use Phoenix MBSE Pak plugin for MagicDraw to translate the workflow parameters into Phoenix ModelCenter
 - Configure ModelCenter to use shared components in the Analysis Library of ModelCenter Cloud

CAE delivers an integrated Systems Environment



OpenCAE: What Has Worked

- Domain specific adaptations
 - Managed Services with vendors
 - Embedded roles
- Server-side operations preferred
 - Easier to update a server than many clients
 - COTS connections between services
- Speak the same language (SysML, FMI)
- OpenAPI REST specification
 - Generate clients for users' preferred languages
 - Enforces OpenAPI on environment services

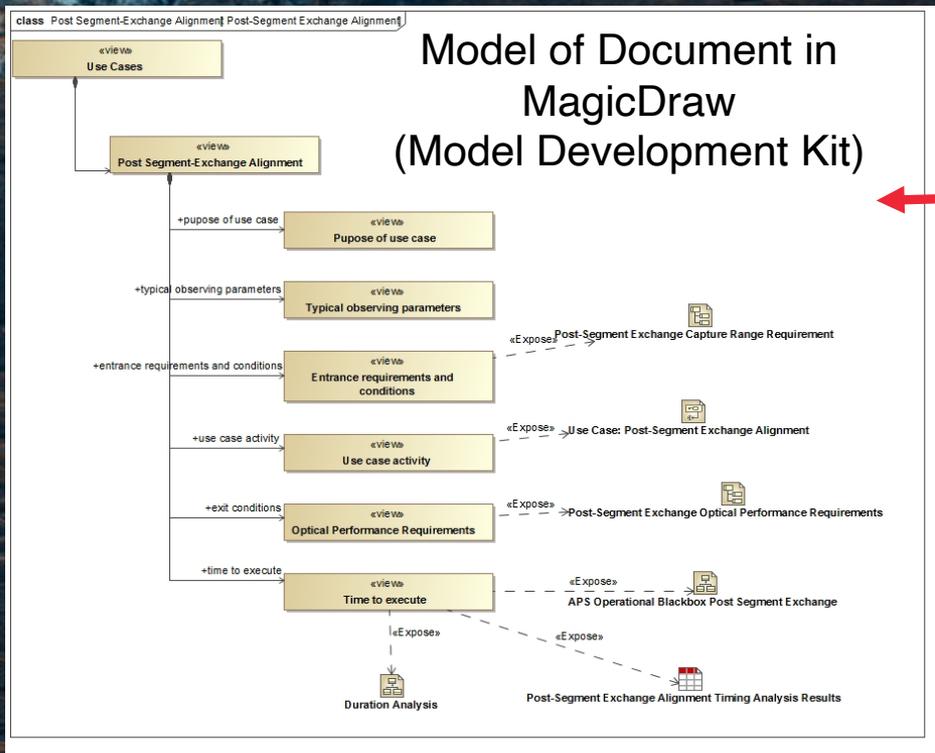


Agenda

- Introduction
- OpenCAE Approach
- Open Source Contributions
- Questions



Core Integration of MMS, MDK, and VE



Rendered and editable document in Web interface (View Editor)

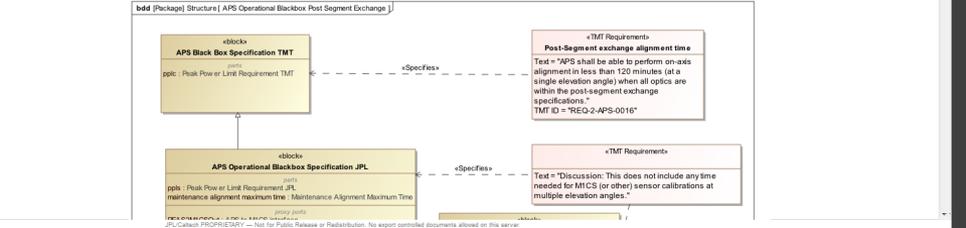
3 Time to execute

below shows our current bottom-up time estimate for each of the activities that make up this use case. The total time estimate is ~96 (TBR) minutes, which is to be compared with our ent of 120 min (as shown in the figure below).

we routinely perform post-segment exchange alignment in 120 minutes or less. However, at Keck the segment shapes are measured in a separate test, with each segment measured separately, iment of the segment warping harnesses is manual and occurs the next day. We will measure the TMT segment shapes in parallel as part of the rigid body and segment figure activity and imidiaty segment shapes during the night via the motorized warping harnesses and iterate the control at least once. Given our bottom up estimate and our Keck experience we have a high degree of e we can met the 120 minute requirement.

Name	Classifier	Post Seg M3g Time Level	1 Final - Real	2 Final - Real	Post Segment Exchange Post Segment Exchange Time Constant	Bandwidth Phase Steps Integer	Narrowband Filter Steps Integer	Rigid Body Steps Integer	RS D1 Integer	Flaring D1 Integer	1574 - Real	1800 - Real	1900 - Real	1950 - Real	1980 - Real	1990 - Real	2000 - Real	
1	post-Segment Exchange Duration For	Precedent Executive and Aux	3634.0			13	2	6	45	20	151.0	767.0	36.0	466.0	465.0	613.0	637.0	338.0
2	post-Segment Exchange Duration For	Post Segment Exchange Durat																
3	post-Segment Exchange Duration For	On-use alignment maximum CS&S																

Post-Segment Exchange Alignment Timing Analysis Results



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, OMG, NavAir, Ford, Stevens, GaTech, ESO
- Vendor participants
- ~200 members

References

- Karban, R., Jankevičius, N., Elaasar, M. “ESEM: Automated Systems Analysis using Executable SysML Modeling Patterns”, (to appear in the proceedings of INCOSE International Symposium (IS), Edinburgh, Scotland, 2016.)
- Karban R., Dekens F., Herzig S., Elaasar M, Jankevičius N., “Creating systems engineering products with executable models in a model-based engineering environment”, SPIE, Edinburgh, Scotland, 2016
- Karban, R., “Using Executable SysML Models to Generate Systems Engineering Products”, NoMagic World Symposium, Allen, TX, 2016
- Open Source TMT model: <https://github.com/Open-MBEE/TMT-SysML-Model>
- Open Source Engineering Environment: <https://open-mbee.github.io/>
- Docgen, View&ViewPoints: <https://github.com/Open-MBEE/mdk/tree/mdk-manual/src/main/dist/manual>
- JPL Model-Based Systems Engineering Case Study: http://omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:incose_mbse_iw_2017:iw_2017_open_mbee.pdf
- A Practical Guide to SysML, 3rd Edition, Chapter 17 by Friedenthal, Moore, and Steiner
- Zwemer, D., “Connecting SysML with PLM/ALM, CAD, Simulation, Requirements, and Project Management Tools”, May 2016
- <https://www.jpl.nasa.gov/spaceimages/>

The image is a composite of two astronomical scenes. The left side shows a galaxy with a bright, glowing core and a surrounding ring of reddish-purple dust and gas. The right side shows a vast field of stars, with a prominent purple nebula or star-forming region. The word "QUESTIONS?" is written in a bold, white, sans-serif font across the center of the image.

QUESTIONS?



Jet Propulsion Laboratory
California Institute of Technology

jpl.nasa.gov