



**2022**  
Annual **INCOSE**  
international workshop  
HYBRID EVENT  
Torrance, CA, USA  
Jan 29 - Feb 1, 2022

*INCOSE MBSE Initiative - DECO Challenge Team Wiki*  
<https://www.omgwiki.org/MBSE/doku.php?id=mbse:ecosystems>

# *Digital Ecosystems (DECO) Challenge Team*

*Team POC: Russell Peak (Georgia Tech)*

## *Update for INCOSE MBSE Initiative*

Sun Jan 30, 2022

[https://www.omgwiki.org/MBSE/doku.php?id=mbse:incose\\_mbse\\_iw\\_2022](https://www.omgwiki.org/MBSE/doku.php?id=mbse:incose_mbse_iw_2022)

MBX = model-based X, where X includes engineering (MBE), systems engineering (MBSE), manufacturing (MBM), test (MBT), operations (MBO), ..., enterprise (MBE), sales/application engineering (MBSAE), ..., living (MBL), ...

# Challenge Team Wiki @ INCOSE/OMG Site

<https://www.omgwiki.org/MBSE/doku.php?id=mbse:ecosystems>



MBSE Wiki



[Recent Changes](#) [Media Manager](#) [Sitemap](#)



*We help organizations better define & manage their **digital ecosystems** ...*

mbse:ecosystems

## Digital Ecosystems Challenge Team -- DECO

### Purpose

The INCOSE Digital Ecosystems Challenge Team collaborates on pre-competitive capabilities that help organizations better define and manage their digital ecosystems using model-based technology. Originally we were called the "MBX Ecosystems" Challenge Team since MBX ecosystems are an important subclass of digital ecosystems.

In simple terms, your digital ecosystem consist of the models, tools, processes, and people/roles that come together to develop the systems/products your organization cares about.

But a digital ecosystem (DECO) can be broader than that, depending on the scope you are concerned about. For example some organizations utilize their digital ecosystems to also support the operation of their systems/products. And some organizations include cross-project libraries and methods in their digital ecosystems, as well as interconnections with external digital ecosystems across their supply chain.

To date digital ecosystems are typically implicit systems that are documented and managed (if at all) using various ad-hoc, disconnected, and silo'ed techniques. Our challenge team targets to improve the situation by helping model-based approaches become standard practice for digital ecosystems.

If these digital ecosystem topics are of interest to you, come and join us to help move things forward!

### Table of Contents

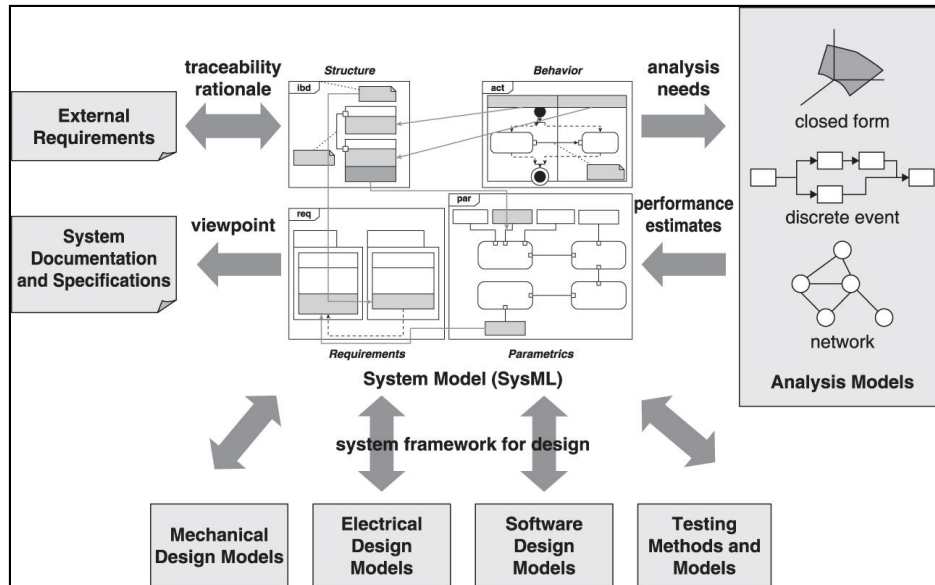
- ♦ [Digital Ecosystems Challenge Team -- DECO](#)
- ♦ [Purpose](#)
- ♦ [Context and Status](#)
- ♦ [INCOSE DECO Challenge Team Leads](#)
- ♦ [INCOSE DECO Challenge Team Meetings](#)
- ♦ [INCOSE DECO Challenge Team Webcons](#)
- ♦ [Other Meetings, Webcons, and Collaborations](#)
- ♦ [History and "MBX Ecosystems" versus "Digital Ecosystems" Team Name](#)

# What is a Digital Ecosystem (DECO)?

## SysML-based Ecosystems: Example Early Work

### Generic Model Architecture in a SysML-based Ecosystem

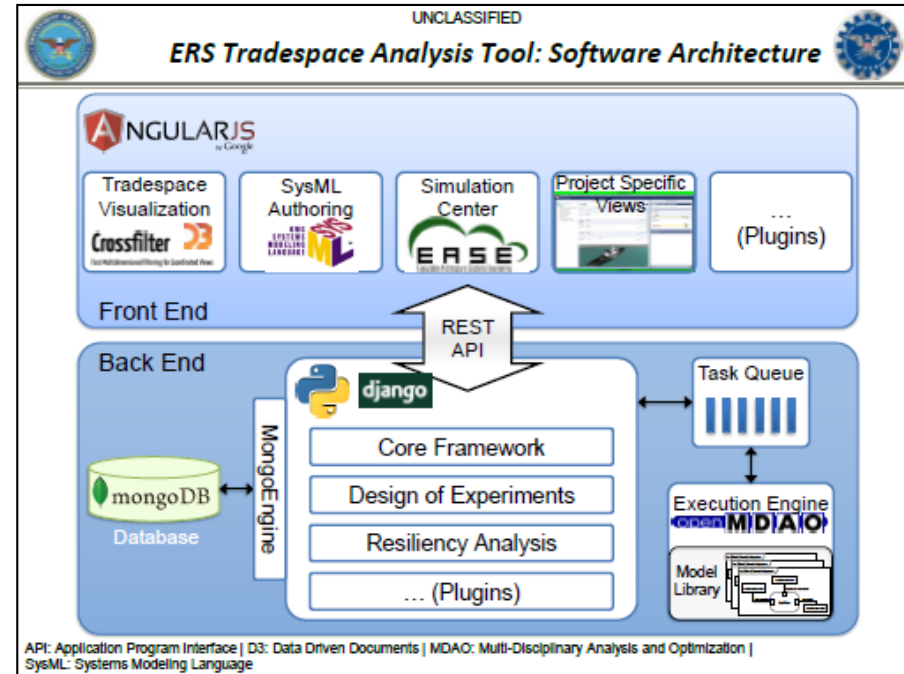
View: Framework for Models, Design/Analysis, and Traceability



Source: [Friedenthal et al. 2012]

### FACT/ERS Environment (example MBX ecosystem for trade studies)

View: Software Implementation Architecture



API: Application Program Interface | D3: Data Driven Documents | MDAO: Multi-Disciplinary Analysis and Optimization | SysML: Systems Modeling Language

Source: [Ender et al. 2014]

# What is a Digital Ecosystem (DECO)?

## Early Example in INCOSE MBSE Initiative

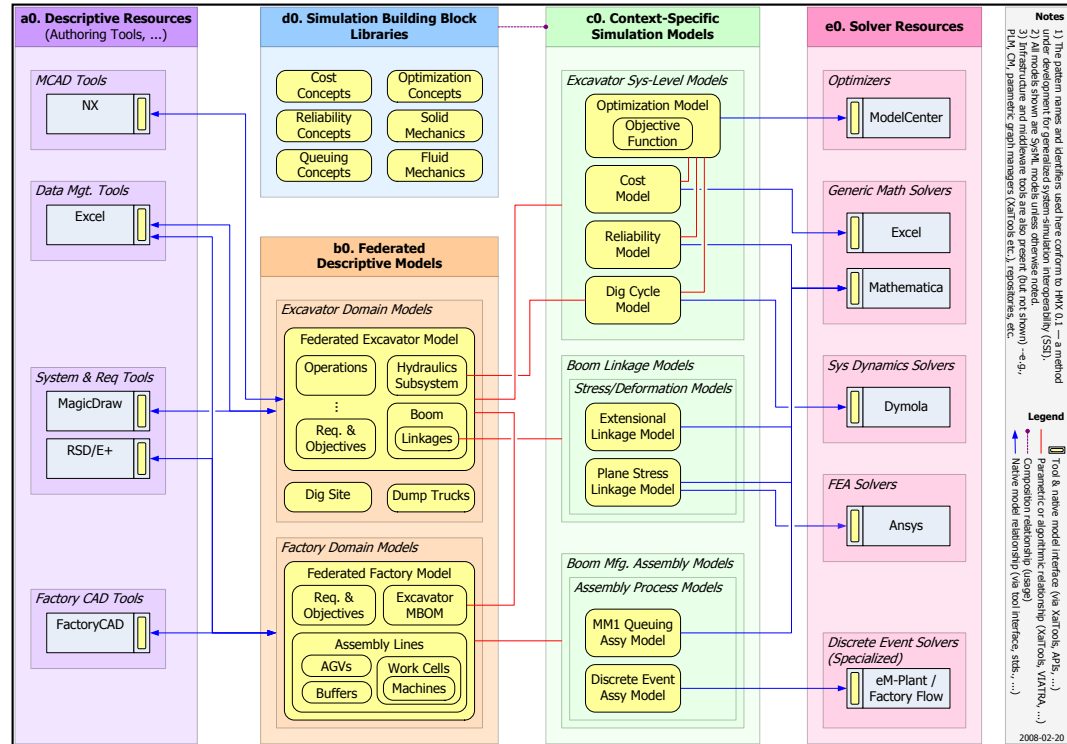
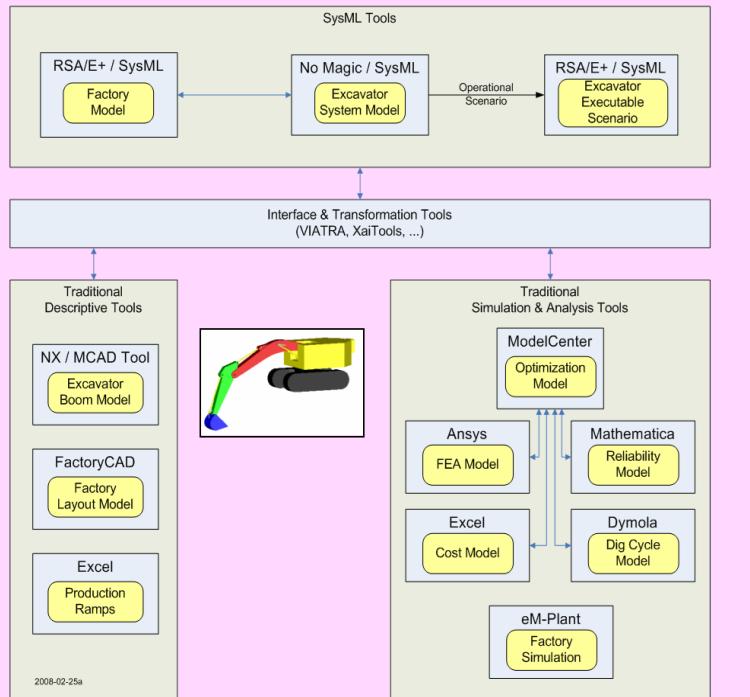
### Prototype SysML-based MBX/Digital Ecosystem for Excavator Systems

Case study c.2008-2010 in Georgia Tech project sponsored by Deere and Lockheed Martin

<http://www.pslm.gatech.edu/projects/incose-mbse-msi/> including presentations at IW09 and IW10

View1: Tool Categories (with coarse-grain connections)

View2: Model Architecture - Patterns & Tools (with medium-grain connections)



**Notes**  
 1) The pattern names and interfaces used here conform to IAXX 0.1 - a method under development for generalized system simulation interoperability (SSII).  
 2) All models shown are SysML models unless otherwise noted.  
 3) Architecture and middleware tools are also present (but not shown) - e.g., PEX, C#, parametric graph managers (all tools), repositories, etc.

**Legend**  
 - Tool & native model interface (via XAI tools, APIs, ...)  
 - Federated or aggregate relationship (via tools, VIATRA, ...)  
 - Native model relationship (via tool interface, stubs, ...)

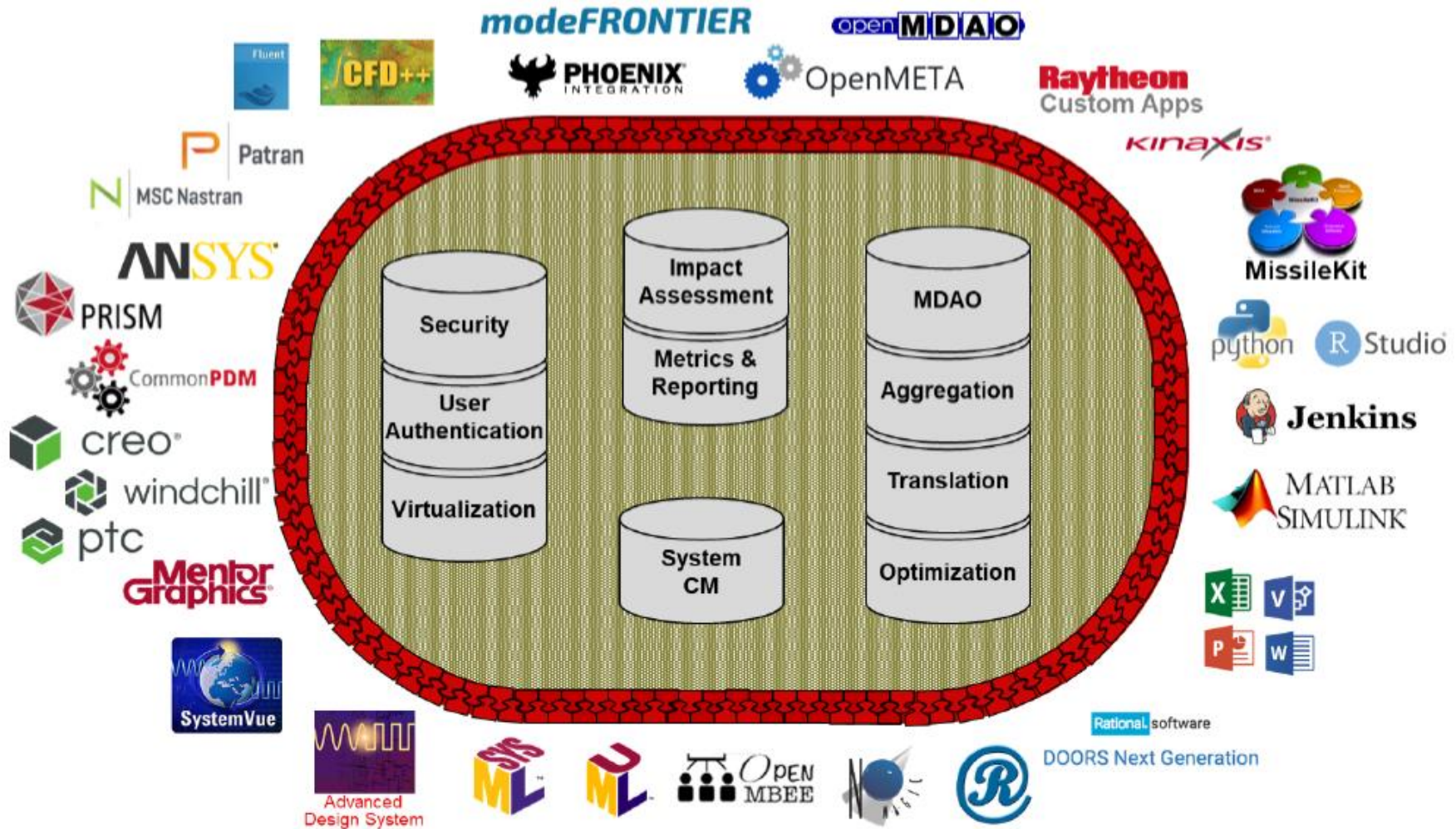
2008-02-20

# What is a Digital Ecosystem (DECO)?

## Example "Seat at the Table" View - Raytheon

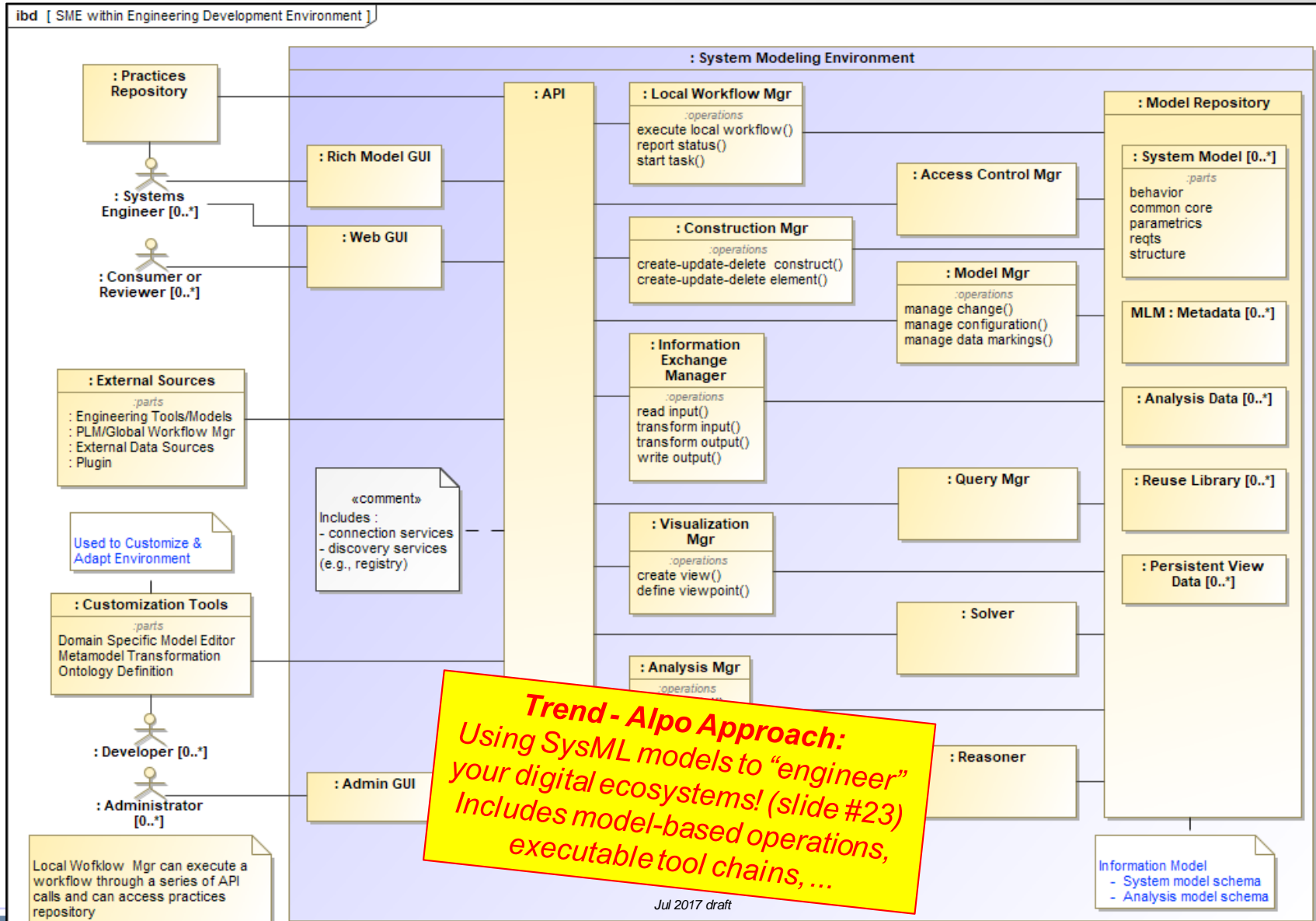
### Raytheon Missile Systems MBE Efforts

McCarthy, Cribb, and Brown (Aug 20, 2019) OpenMBEE Community Webcon Series



# What is a Digital Ecosystem (DECO)?

## Generic Example - OMG SysML v2 RFP (SysML model excerpt)



# What is a Digital Ecosystem (DECO)?

## Context & Terminology (Informal)

### *Digital/MBX Ecosystem Management*

- ◆ **MBX**, where X = MBE, MBSE, MBM, ...
- ◆ **Ecosystem** = combined system of tools, models, products, repositories, interconnections, people, processes, workflows, ... [a “system of systems” - largely computer-based]
  - Level 1 – Overall ecosystem for organization X
  - Level 2 – Division sub-ecosystems
  - Level 0 – Level 1 in a global ecosystem with interfaces to ecosystems of customers, suppliers, regulators, ...
- ◆ **Management** = handling all ecosystem lifecycle phases
  - Vision/concepts, prototype, preliminary design, detailed design, deployment, maintenance, updates, migration, decommissioning
- ◆ Therefore, treat your MBX ecosystem as a system!
  - Apply systems engineering principles (“Alpo” approach) w/ ecosystem know-how
- ◆ Similar terms: system development environment, decision support system, modeling & simulation framework, ...

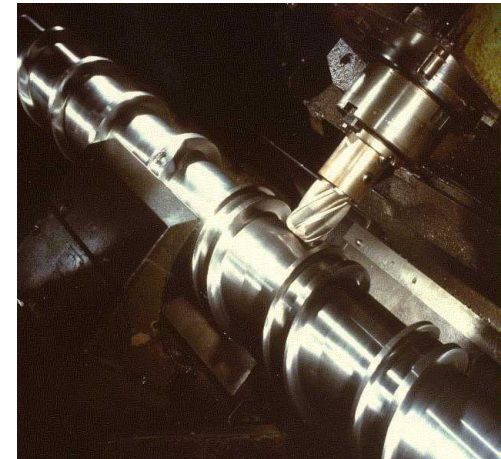
# What is a Digital Ecosystem (DECO)?

## Digital / MBX Ecosystem Metrics & Objectives

### *Benefits of SysML-based MBE/MBSE Approach*

Primary Impacts <i>enterprise MOEs (measures of effectiveness)</i>	Reduced Time	Reduced Cost	Reduced Risk	Increased Understanding	Increased Corporate Memory	Increased Artifact Performance
<i>ecosystem MOPs (measures of performance)</i>						
Enabling Capabilities						
Increased Knowledge Capture & Completeness			■	■	■	■
Increased Modularity & Reusability	■	■	■	■	■	
Increased Traceability			■	■	■	
Reduced Manual Re-Creation	■	■	■			
Increased Automation	■	■	■			
Reduced Modeling Effort	■	■				
Increased Analysis Intensity			■			■

*Precision Knowledge  
for the  
Model-Based Enterprise*





# Other DECO Metrics

*Trend: DECO system models that help track & manage DECO metrics ...*

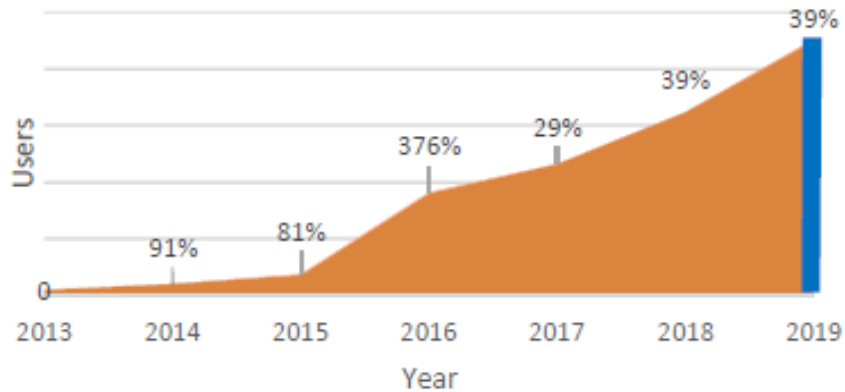
- Number of users
  - By user type, by tool / DECO subsystem, by time, ...
  - By organizational unit, by geographic location, ...
- Number of projects / models
  - By project/model type, by tool / DECO subsystem, by time, ...
- Cost
  - Of tool licenses, of servers/clouds, of supporting personnel ...
  - Of training, of effort-to-use, ...
  - By cost type, by tool / DECO subsystem, by time, ...
- Model size / model complexity
  - By supported content: features/behaviors, project processes, ...
  - By model type, by model aspect, by time, ...
- Other metrics ...
  - Maturity levels, security/classification levels, IP rights, ...

# DECO Metrics: MBSE/SysML Usage at Ford

IW19 - [Walley et al. 2019] highlights

## SysML Modeling User Base

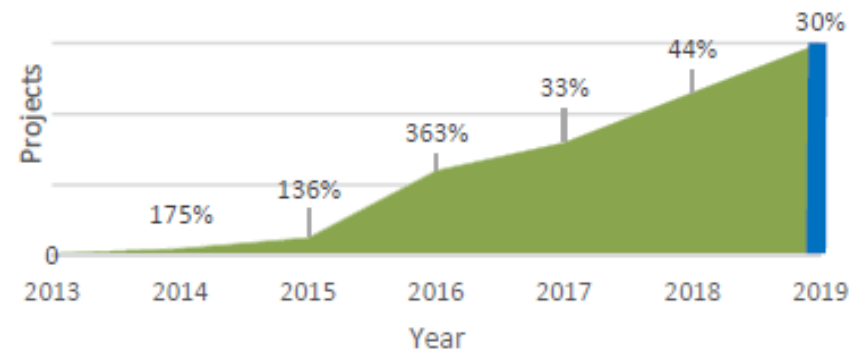
(labels reflect % growth over prior year)



## Managed Teamwork Projects

(labels reflect % growth over prior year)

[# of SysML models]



# DECO Metrics: MBSE/SysML Usage in US Navy

IW20 - [Fields et al. 2020] highlights

(p1/2)

## Vision Statement

*"Low Barrier of Entry"*



### Naval Integrated Modeling Environment (IME)

- Comprehensive, enterprise-wide capability that provides tools, infrastructure, and support for Naval Model-Based Systems Engineering (MBSE) efforts.
- Covers a wide range of areas from shared licenses and server-based repositories to knowledge and data management.
- Available to all Navy and Marine Corps users regardless of network, classification, or location.

The Naval IME is sponsored by the Digital Warfare Office (DWO)/Navy Digital Integration Support Cell (N-DISC) with team members from various warfare centers across multiple SYSCOM's.



NAVAIR Public Release 2020-45. Distribution Statement A - "Approved for public release; distribution is unlimited"

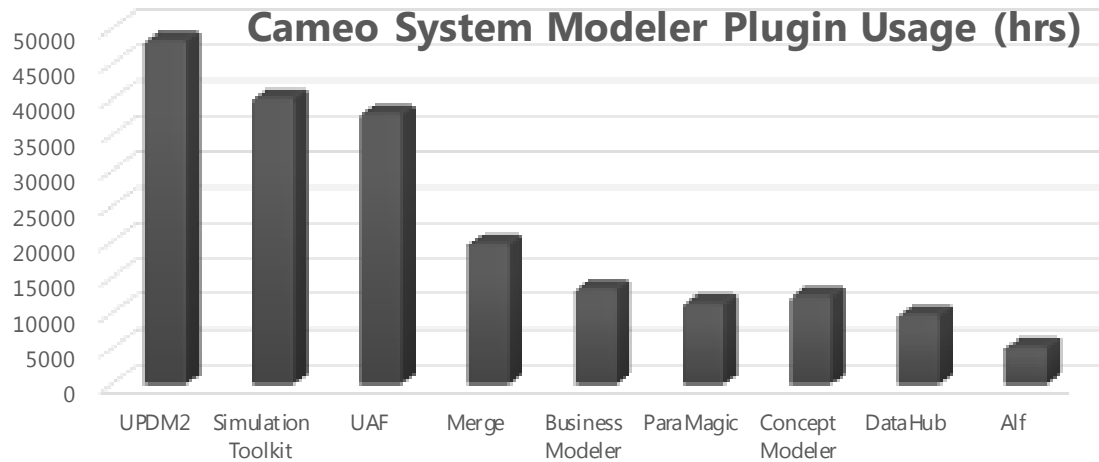
# DECO Metrics: MBSE/SysML Usage in US Navy

IW20 - [Fields et al. 2020] highlights

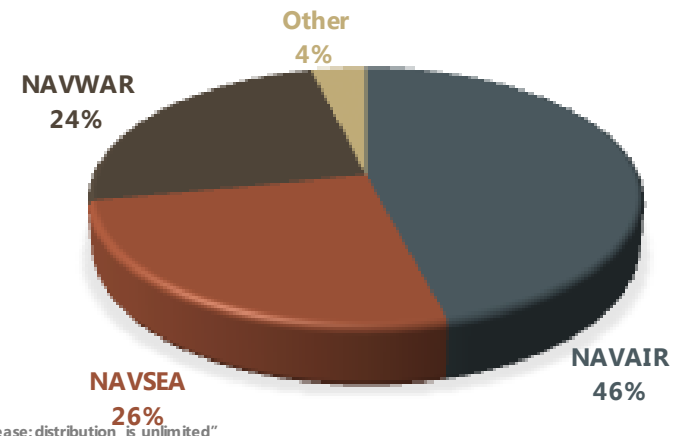
(p2/2)

## Usage Metrics

From July 25<sup>th</sup> 2019 to January 13<sup>th</sup> 2020



## Teamwork Cloud Accounts



NAVAIR Public Release 2020-45. Distribution Statement A - "Approved for public release; distribution is unlimited"

# DECO Metrics: Model Size & Model Complexity

*Example published statistics in production programs*

- ◆ Lockheed - Navy SWFTS submarine SysML model: ★ = Using OpenMBEE  
*More than 400k model elements*
- ◆ Thirty Meter Telescope (TMT) Alignment & Phasing System (APS):  
*More than 250k<sup>[1]</sup> elements; [open source SysML model](#); executable stm/act/par* ★
- ◆ ESO APE/Extremely Large Telescope (ELT) SysML model:  
*Generated production code containing 432 states & 1260 transitions*
- ◆ NASA SMAP satellite SysML model:  
*Executable state machines with ~2000 states and ~3000 transitions*
- ◆ SysML model size<sup>[2]</sup> for selected key NASA missions:
  - Mars 2020 Rover (*Perseverance*): 1M+ elements ★
  - Europa Clipper: 2M+ elements (17M+ including branches) ★
- ◆ Boeing 787 SysML model: 44M+ elements<sup>[3]</sup>
- ◆ *Contact us if you can provide similar sanitized statistics for your projects.*
- ◆ *How will SysML v2 affect these statistics?*
  - *Early estimates: Approximately 1-2x larger (depending on model content types)*

[1] As of ~6/2017

[2] As of ~5/2016

[3] As of ~1/2020

# INCOSE DECO Challenge Team Collaboration with OpenMBEE/NumFOCUS and OMG

<https://www.omgwiki.org/MBSE/doku.php?id=mbse:ecosystems>

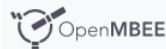
## INCOSE DECO Challenge Team Webcons

We currently do not hold a separate webcon specific to our INCOSE DECO Challenge Team. Instead, we join other in-person meetings and webcons highlighted in the next subsection below. We hold INCOSE DECO Challenge Team-specific discussions during those meetings/webcons on an as-needed basis.

## Other Meetings, Webcons, and Collaborations

We collaborate closely with the following groups and periodically hold joint meetings at their in-person events:

- **OpenMBEE community** – a NumFOCUS-based group ([www.openmbee.org](http://www.openmbee.org))
  - Includes biweekly general group webcons and biweekly leadership team webcons
- **OMG model-based engineering environment (MBEE) interest group** ([omg.org](http://omg.org))
  - Includes quarterly technical meetings (usually in-person)



Home About ▾ Contribute Participate Projects ▾ Community ▾ Events ▾

## Connected engineering information for a connected world

OpenMBEE (Open Model Based Engineering Environment) is an open source collaborative engineering system. It enables engineers to work in the language of their choice and easily share and document their work across other tools.



*Edit once, use everywhere*

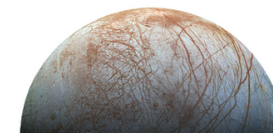
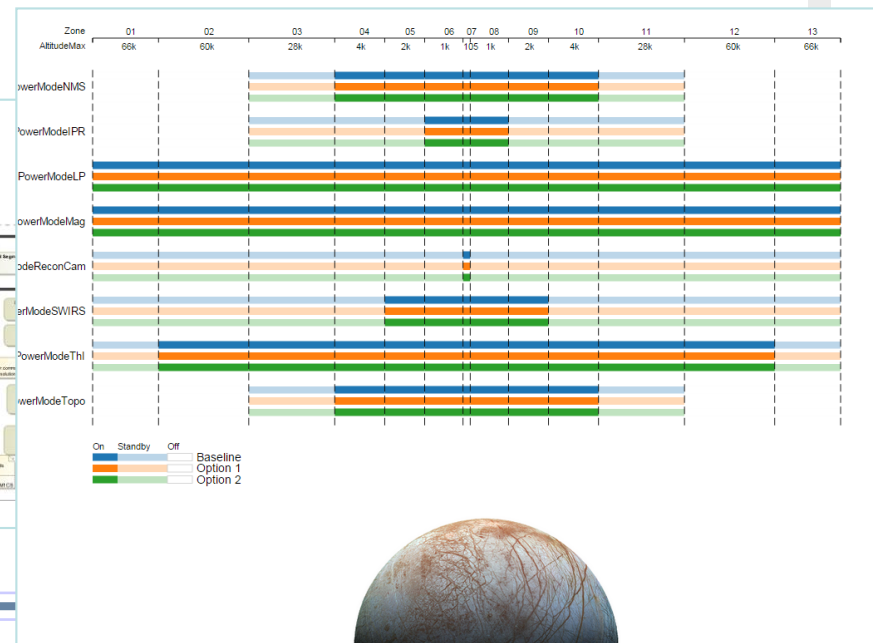
# OpenMBEE: An Open Framework for Digital Ecosystems

[www.openmbee.org](http://www.openmbee.org)

## Simplified Description:

- A practical combination of commercial tools and open-source tools within an extensible framework
- Includes “model-based wiki”-like capabilities
  - Exposes rich underlying SysML models as web pages
  - Engages project members who do not know SysML

The screenshot displays the OpenMBEE project interface. On the left, a navigation tree lists project components such as 'TMT-APS DDD', '1 Introduction', '2 System Concept', '3 Key and Driving Requirements', '4 Operations Concept', and '5 Opto-Mechanical Design'. The main area shows a SysML model with various components and relationships. Below the model is a 3D rendering of the telescope assembly, labeled with 'NFIRAOS', 'IRMS', 'APS', 'WFOS', and 'Broad Band Phasing'.



# Ecosystems/OpenMBEE Community Info

[www.openmbee.org](http://www.openmbee.org)

- ~480 participants in email list / google group (as of Jan 2022)
- ~35 participants in biweekly community webcons (started ~Feb 2017)
- ~15 participants in biweekly developer webcons
- INCOSE MBX / digital ecosystem (DECO) topic formalized as a Challenge Team within the INCOSE MBSE Initiative (2019)
- OpenMBEE formalized as a NumFOCUS project (2020) including explicit collaboration with INCOSE DECO and OMG
- Semi-public OpenMBEE instance:
  - <https://mms.openmbee.org>
  - <https://twc.openmbee.org:8443/webapp>
  - Used for collaboration on work by OMG / INCOSE / etc. (pre-competitive topics & resources)
  - *Thanks to No Magic / Dassault for hosting & support!*



# OpenMBEE Usage: Production Deployments

Jan 2022 status/updates per OpenMBEE community participants – p1/1

Organization	Projects Using OpenMBEE	OpenMBEE Deployment Status
Boeing	Various ( <i>OpenMBEE is Boeing's enterprise model-based solution: ~70+ programs; ~100-1000+ concurrent users</i> )	Production Usage <a href="#">MMS4</a> ★
Lockheed	Various programs (~10+ concurrent users of ~200 total users, ~50 projects)	Production Usage MMS3 (unclassified & classified)
JAXA	~2 main flight projects: RAISE-3 (small satellite), next-gen series, ... (~20 users)	Production Usage MMS3
NASA JPL	~15 main flight projects: Europa Clipper, Mars 2020, Mars Sample Return, ... (~800+ TWC/Jupyter/Syndeia users; ~190 TWC/Jupyter/Syndeia projects)	Production Usage MMS3 (unclassified & classified) (MMS4 ~2022-1Q)
OMG <sup>[1]</sup>	SysML 1.x spec; SysML v2 SST proposed specs (revised submission Nov 2021); TIWG; spec style sheet; <i>Coming: CSRM(?), UML 2.6 spec, ...</i>	Production Usage via <a href="#">openmbee.org</a> MMS3
<a href="#">www.tmt.org</a> <sup>[1]</sup>	Thirty Meter Telescope (TMT) project (~5 users)	Production Usage via <a href="#">openmbee.org</a> MMS3
OpenMBEE & OpenSE <sup>[1]</sup>	SE Cookbook, architecting OpenMBEE itself, operating <a href="#">openmbee.org</a> itself, other community contributions, ...	Production Usage via <a href="#">openmbee.org</a> MMS3

Contact us if you know of other production usage similar to above (and/or updates for below slides)

★ = Key update / addition for IW22 (Jan 2022)

# OpenMBEE Usage: Pilot/Demo Deployments

Jan 2022 status/updates per OpenMBEE community participants – p1/1

Organization	Projects Using OpenMBEE	OpenMBEE Deployment Status
★ Aerospace Corp	Various demos/pilots	<i>Pilot/Demo Usage MMS3</i>
Ford	Various pilots (~4 projects, ~10 users)	<i>Pilot/Demo Usage MMS3 (waiting for MMS4)</i>
GTRI	Various projects ( <i>after production setup is ready</i> ) ( <i>intent: ~6 projects, ~20 users</i> )	<i>Prototype Usage MMS3 (waiting for MMS4)</i>
Raytheon	Piloting setup underway	<i>TBD</i>
★ Sedaro	Various demos/pilots	<i>Prototype Usage MMS3</i>
★ Thales	Case study (IncQuery Labs contractor); includes Capella-MMS connector (open source project)	<i>Prototype Usage MMS3</i>
US Army (Huntsville)	Joint Multi-Role Technology Demonstrator (JMRTD) (Adventium contractor)	<i>TBD</i>
US Navy (NSWC Crane)	Intent for production projects – timeline TBD	<i>TBD</i>

★ = Key update / addition for IW22 (Jan 2022)

Grey = Status as of ~2020/2021 (pending updated info).

# ★ OpenMBEE Usage: Research/Edu Deployments

Jan 2022 status/updates per OpenMBEE community participants – p1/1

Organization	Projects Using OpenMBEE	OpenMBEE Deployment Status
Georgia Tech (GT/ASDL) <i>Since 2014</i>	Academic instruction & class projects (~20 users/yr) Active research projects/demos (~3-6+ projects/yr with ~5-10 users/project) - varies per sponsor interests: <ul style="list-style-type: none"> <li>• Cislunar space habitats (<i>IRAD/others</i>)</li> <li>• Electrified powertrain flight demonstrator (<i>NIA/NASA</i>)</li> <li>• Model complexity &amp; health mgt (<i>Boeing</i>)</li> <li>• Overall aircraft design (<i>Airbus</i>)</li> <li>• ...</li> </ul>	<i>Semi-Production Usage MMS3</i> <i>Pilots/Demos/Research</i>
Stevens/SERC <i>Since 2018</i>  <i>(including SERC university partners)</i>	Academic instruction & class projects Research projects/demos (~5-10 users/project): <ul style="list-style-type: none"> <li>• Model-centric engineering (MCE) project (<i>ARDEC</i>)</li> <li>• Skyzer MCE/supply chain surrogate pilot (<i>NAVAIR</i>)</li> <li>• DE competency framework - WRT-1006 (<i>DoD/OSD</i>)</li> <li>• DAU DE curriculum update - WRT-1043 (<i>DoD/DAU</i>)</li> <li>• ...</li> </ul>	<i>Semi-Production Usage MMS3</i> <i>Pilots/Demos/Research</i>
Rick Steiner <sup>[1]</sup>	Open educational examples (WW1 rifle, etc.)	<i>Semi-Production Usage MMS3</i> <a href="https://openmbee.org">openmbee.org</a>

★ = Key update / addition for IW22 (Jan 2022)

[1] = Using [openmbee.org](https://openmbee.org) semi-public instance (MMS3)

# Others Interested to Pilot/Use OpenMBEE ...

*Jan 2022 status/updates per OpenMBEE community participants – p1/1*

- **Government & Industry Organizations**
  - BAE Systems, Continental, Cox, Draper, ...
  - ESA, L3Harris, Integrity Applications Inc, ...
  - Nova Systems (Australia), SAIC, Sandia, ...
  - AIAA (?), ...
- **INCOSE Teams / Working Groups (WGs)**
  - Critical Infrastructure Protection & Recovery (CIPR) WG (?)
  - Digital Engineering Information Exchange (DEIX) WG
  - Resilient Hospital Reference Model (RHSET) Team (?)
  - Natural Systems WG
  - Smart Cities WG
  - ...
  - Space Systems WG
  - Telecom WG

# Organizations Providing Commercial Services for OpenMBEE

*Jan 2022 status/updates per OpenMBEE community participants – p1/1*

*NOTE: This slide is provided as-is and does not constitute endorsement by INCOSE or any of the Digital Ecosystems (DECO) Challenge Team members. Locations indicated below are for corporate main offices.*

## Deployment Setup/Support Services

★ = Key update / addition for IW22 (Jan 2022)

*(willing to do installation, etc. for-hire by your organization)*

- Tietronix (Houston TX - USA)
- ★• Twingineer (Houston TX - USA)
- Tucson Embedded Systems (Tucson AZ - USA)

## Development/Integration Services

*(willing to do customizations, special projects, for-hire by your organization)*

- IncQuery Labs (Budapest - Hungary)
- Intercax (Atlanta GA - USA)
- LieberLieber (Vienna - Austria)
- Phoenix Integration (Blacksburg VA - USA)
- ★• Sedaro (Arlington VA - USA)
- Tietronix (Houston TX - USA)
- ★• Twingineer (Houston TX - USA)
- Tucson Embedded Systems (Tucson AZ - USA)

# ★ Organizations Providing Commercial Products for OpenMBEE

Jan 2022 status/updates per OpenMBEE community participants – p1/1

*NOTE: This slide is provided as-is and does not constitute endorsement by INCOSE or any of the Digital Ecosystems (DECO) Challenge Team members. Vendor may have more than one OpenMBEE-related product (only a sample is shown below).*

Vendor	Sample OpenMBEE-related Product Excerpt
IncQuery Labs	[IncQuery Suite] “Connects to <b>OpenMBEE</b> , Jupyter, MagicDraw, ...” <a href="https://incquery.io/">https://incquery.io/</a>
Intercax	[Syndeia] “Connection data ... can be published through a variety of viewers, e.g. Jupyter notebooks and <b>OpenMBEE</b> .” <a href="https://intercax.com/syndeia-3-4-faq/">https://intercax.com/syndeia-3-4-faq/</a>
LieberLieber	[LemonTree] “Reading of <b>OpenMBEE</b> models has been improved ...” <a href="https://help.lieberlieber.com/display/LT/Release+3.0">https://help.lieberlieber.com/display/LT/Release+3.0</a>
Maplesoft	[MapleMBSE] “... one of many design tools that can access the <b>OpenMBEE</b> API ...” <a href="https://www.maplesoft.com/ns/MapleBMSE/MBSE-Tool-for-Knowledge-Sharing-and-Collaboration.aspx">https://www.maplesoft.com/ns/MapleBMSE/MBSE-Tool-for-Knowledge-Sharing-and-Collaboration.aspx</a>
Phoenix Integration	[MBSEpak] “[The MBSEpak] extension allows a model stored in OpenMBEE to automatically generate an executable workflow in ModelCenter ..” <a href="https://www.phoenix-int.com/tech-papers/integrated-systems-modeling-analysis-platform-flight-project-work">https://www.phoenix-int.com/tech-papers/integrated-systems-modeling-analysis-platform-flight-project-work</a>
Tom Sawyer	[Model-Based Engineering] “... talk to us about support for IBM Rhapsody, <b>Open MBEE</b> , or other model stores and data providers.” <a href="https://www.tomsawyer.com/model-based-engineering">https://www.tomsawyer.com/model-based-engineering</a>

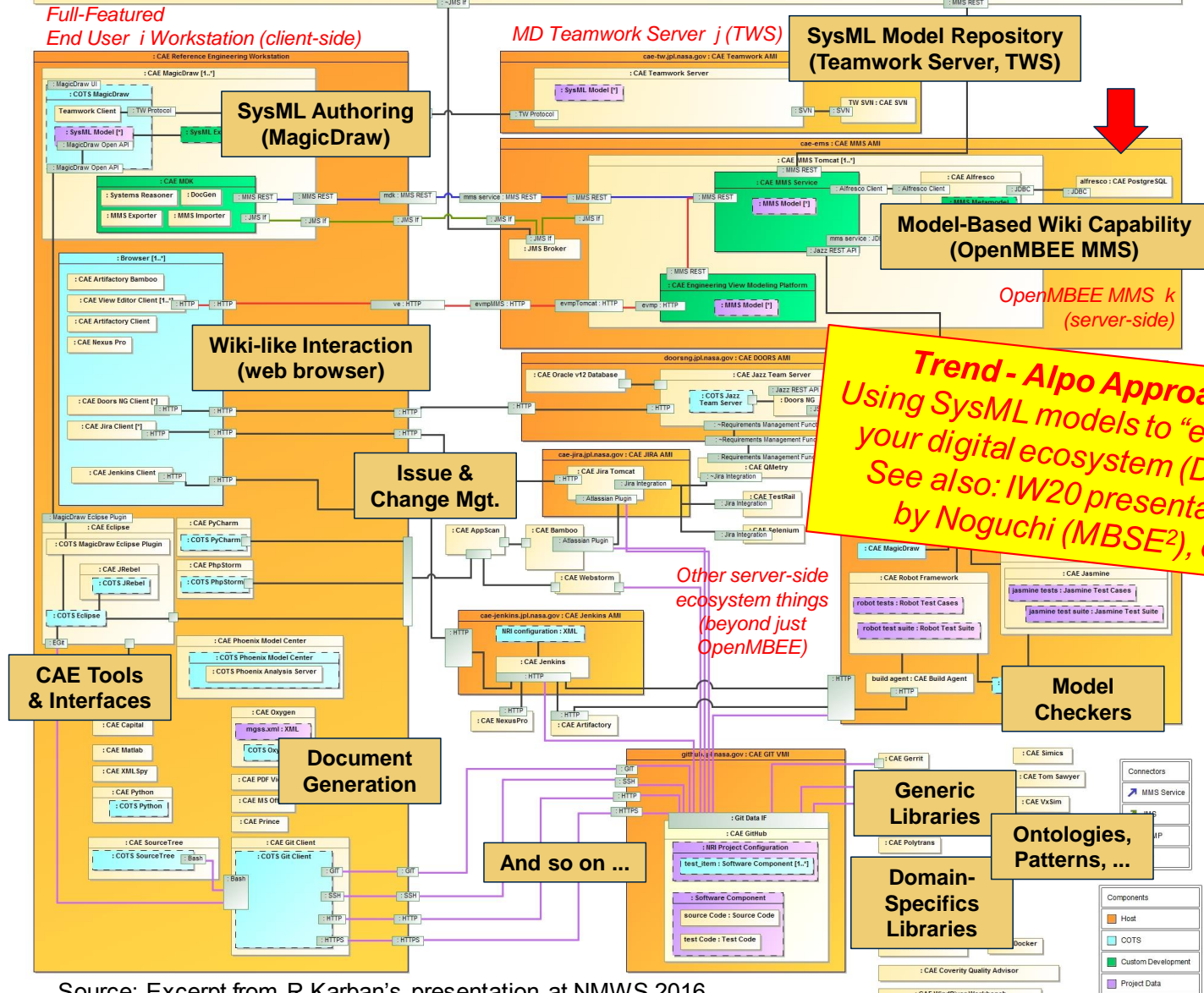
★ = Key update / addition for IW22 (Jan 2022)

\*\*Main requirement to be included in above list: The vendor web site shall have one or more web pages that designate OpenMBEE specifically by name as being supported by one or more of the vendor products.

# What is a Digital Ecosystem (DECO)?

Example OpenMBEE-based Ecosystem @ NASA JPL

DECO SysML model (excerpt representing tool/service interconnectivity)



Source: Excerpt from R Karban's presentation at NMWS 2016

# Join us at joint INCOSE DECO/OpenMBEE workshop!

Mon Jan 31 & Tue Feb 1, 2022 @ INCOSE IW22

- DECO Challenge Team wiki has agenda specifics:
  - <https://www.omgwiki.org/MBSE/doku.php?id=mbse:ecosystems:iw2022>
  - <https://www.openmbee.org/> -- See Events > INCOSE 2022
- Current & past joint workshops include:
  - Overviews of OpenMBEE-based ecosystems:
    - Production usage by Boeing, JPL, Lockheed, OMG, TMT, ...
    - Pilot/demo usage by Ford, Sedaro, ...
    - Research/education usage by Georgia Tech, Stevens/SERC, ...
  - OpenMBEE architecture roadmaps
  - OpenMBEE capabilities & demos (current, emerging, and future)
  - OpenMBEE-SysML v2 outlook
  - Other digital ecosystem (DECO)-related topics