**Investigating JPL's Open-MBEE** Plugin for Application to Large Scale System Modeling

### John Herrold and Brittany Friedland, The Boeing Co.



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### **Biography**

- Brittany Friedland spent the beginning of her career in the Oil and Gas • Industry before making a career change to work in the Aerospace Industry. She currently works for Boeing developing and deploying Model Based Systems Engineering tools and processes with the Boeing Enterprise (Commercial and Defense).
- John Herrold is currently the System Architect for the Integrated Product • Architecture enterprise systems engineering program that provides a service ready model based systems engineering solution (process, tool and training) for systems and design engineers. John has been a Boeing employee for 35 years and has worked mostly in the engineering analysis domain, supporting many of the Boeing Commercial and Military Airplane products. John is a designated Boeing Technical Lead Engineer and a member of the International Council on Systems Engineering (INCOSE). John has a BSEE from the University of Washington.







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#### Investigating JPL's Open-MBEE Plugin for Application to Large Scale System Modeling

System architecture modeling of large scale aerospace products using current off-theshelf Model Based Systems Engineering (MBSE) SysML modeling tools can prove challenging when trying to adequately represent multilevel assemblies, redundant systems and detailed digital interfaces. Tool solutions (plugins) that extend these products to provide partial or full modeling automation show promise of being potentially large timesavers in defining and managing these intricate assemblies. One such solution worthy of investigation is an open source plugin developed by the Jet Propulsion Laboratory in Pasadena, called the Open Model Based Engineering Environment (Open-MBEE). This plugin extends No Magic's Magic Draw modeling solution to provide some interesting architecting, data and configuration management features. Open MBEE adheres to the SysML modeling standard while adding additional capability needed for the development of large scale systems models. This is especially important as Boeing moves into a more standards driven approach. In this presentation, we'll review the genesis of the plugin development, illustrate the infrastructure required to deploy the complete tool solution, explore the plugin's features using actual examples and reveal areas for future improvements.







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- Model Based System Engineering at Boeing
- Scale it up! Modeling Large Scale Integrated System Architectures
- JPL's Open Model Base Engineering Environment (MBEE)
- MBEE Examples of Value-added Features EMS document and Systems Reasoner
- Opportunities for Improvement

Today's Goal: To inform about Boeing's experience with investigating MBEE and to spark interest in the open source solution.







### **Boeing at a Glance**

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- Customers and customer support in 150 countries
  - Total revenue in 2012: \$81.7 billion
  - 70 percent of commercial airplane revenue from customers outside the United States
- Manufacturing, service & technology partnerships with companies around the world
  - Contracts with 22,000 suppliers and partners globally
- Research, design & technology-development centers & programs in multiple countries
- More than 170,000 Boeing employees in 50 states and 70 countries



(Robert Malone, et al, INCOSE IS 2016, Insights from Large Scale Model Based Systems Engineering at Boeing)



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### **A Sample of Diverse Boeing Products**

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(Robert Malone, et al, INCOSE IS 2016, Insights from Large Scale Model Based Systems Engineering at Boeing)

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## Model Based Systems Engineering at Boeing

(Brittany Friedland, et al, INCOSE IS 2016, Systems Engineering a Model Based Systems Engineering Tool Suite: The Boeing Approach)



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### **Model Based Systems Engineering at Boeing**

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(Robert Malone, et al, INCOSE IS 2016, Insights from Large Scale Model Based Systems Engineering at Boeing)







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### **Boeing Successfully Uses Two Primary MBSE Methods**

- Functions Based Systems Engineering Method (R-F-L-P)
  - Various in-house developed technologies have introduced object-oriented concepts to this approach, including classes, objects and inheritance
  - Used for modeling and analyzing large intricate designs with multi-layered assemblies and associated detailed digital networks (black box/white box applications)
- Object Oriented Systems Engineering Method
  - Standard SysML application using domain specific developed custom profiles
  - Proven valuable for tying operational needs to system behavior
- Investigating a blended approach for future applications
  - Tool suite solution must be extendable to support both methods and integration between the methods
  - Understanding how much of SysML can be applied to large scale intricate designs – identifying the gaps







### **RFLP Example: A Simple Integrated System Architecture Model**

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(Robert Malone, et al, INCOSE IS 2016, Insights from Large Scale Model Based Systems Engineering at Boeing)

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### **RFLP Example: A Simple Integrated System Architecture Model**

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(Robert Malone, et al, INCOSE IS 2016, Insights from Large Scale Model Based Systems Engineering at Boeing)



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### **RFLP Example: A Simple Integrated System Architecture** Model

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(Robert Malone, et al, INCOSE IS 2016, Insights from Large Scale Model Based Systems Engineering at Boeing)

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## Scale it up! Modeling Large Scale Integrated System Architectures



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### Features of an Intricate Large Scale Integrated System Architecture within Boeing

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- Multi-leveled system assemblies (ensures adherence to integration and connectivity requirements)
- Redundant system modeling (ensures adherence to failover safety requirements)
- Detailed digital network interfaces (ensure adherence to networking functional, performance and design requirements)

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# Large Scale, Highly Integrated Systems Results in Large, Highly Integrated Models

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

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

(Robert Malone, et al, INCOSE IS 2016, Insights from Large Scale Model Based Systems Engineering at Boeing)

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### Challenges of Large Scale Integrated System Architecture Modeling

- Populating an intricate model is labor intensive
- Model size impacts effective model management
- Complex interrelationships favor a graph-like structure
- Interrogating the model involves complicated queries and obtaining results is time consuming
- Effective modeling requires developing multiple model views (diagramming alone is insufficient)
- Achieving model integrity is difficult and requires a standard data model constrained by rules
- Need to heavily customize COTS platforms in order to achieve desired modeling fidelity
- Scalability, scalability and scalability
- Lack of effective COTS tool configuration and change management capabilities







### Moving from a Custom MBSE Solution to a Standard Approach

- Defining, developing, deploying and maintaining a custom MBSE solution is untenable in the long run.
  - Underlying vendor supplied technologies become obsolete and the solution becomes brittle over time
  - IT organizations struggle to provide adequate resources to maintain large scale one-off solutions
  - **Developing new non-standard MBSE solutions is very** expensive and risky
- Standard/common solutions should be more palatable from a cost perspective and are worth further investigation.
  - Must still be extensible by each customer base
  - Must employ desirable common features (usability)
  - Our analysis shows that JPL's Open MBEE offering is a • strong candidate







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## JPL's Open Model Base Engineering Environment (MBEE)



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### Why JPL's MBEE Solution?

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### JPL problem space aligns with Boeing

- Concurrent user design and collaboration environment
- Tool solutions that deal with many roles including diverse supplier base
- Complex products that require intricate models
- Desire to move to systems that adopt industry standards
- Boeing conducted enterprise MBSE tool trade study using detailed selection criteria
  - MBEE scored the highest and was worthy of further detailed investigation





### JPL Open MBEE Overview

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- Open Model Based Engineering Environment (MBEE) is an open source tool developed by Jet Propulsion Laboratory (JPL)
- Open MBÉE was developed for Multi-mission Ground Systems and Services Ops Revitalization Task
  - **Based on previous MBSE pilots at JPL**
  - 200 users
  - ~20 projects and tasks
  - Removes barrier to using models in real engineering products

https://github.com/Open-MBEE







# Adopting an Open Source Solution – An Intriguing Option

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- Why would Boeing want to develop a design system as Open Source?
- We want to
  - develop a robust, long lived system that can be used to develop multiple generations of airplanes and aerospace products
  - share the costs of developing and maintaining the system
  - move to a standard, neutral knowledge representation
  - enable sharing of design rules, e.g. from NASA, FAA, universities
  - encourage collaboration with universities, government labs and industry to develop state-of-the-art capabilities
    - speed technology transfer into Boeing
    - speed the application of new technologies to Boeing products
    - supports research collaboration with Boeing
    - facilitate hiring of outstanding engineers into Boeing

(Jeff Heisserman, GPDIS 2015, Generative Design and Automated Reasoning in the Design of Aerospace Systems)





### **Example Architecture and User Scenario**

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- We use a modular architecture, with
  - modules that are shared open source
  - proprietary modules that are not shared
- We choose an open source license that allows users to use open source modules with proprietary modules –without having to share the proprietary modules
- Users can decide what design rules to share and what to keep to themselves
- Users can develop proprietary capabilities to augment the open source capabilities

(Jeff Heisserman, GPDIS 2015, Generative Design and Automated Reasoning in the Design of Aerospace Systems)





### Why JPL Developed Open MBEE

- JPL's developed Open MBEE to help address the following common needs across industry
  - A need to communicate with stakeholders
    - According to terms of the stakeholders
    - Views at the stakeholder level
    - Variety of representations that can be collaboratively developed
  - Edit the Model Information through multiple role based User Interfaces
    - Stakeholders Document centric view via EMS web application
    - Architects MagicDraw (Cameo) models applying standard modeling language profiles (e.g., SysML)
  - Enterprise integration of multiple applications and modeling tools
    - Views that facilitate integration between applications (i.e., web document and MagicDraw models)
- According to JPL, Boeing was the first outside company to successfully configure and demonstrate using Open MBEE in a prototype environment





### **JPL Open MBEE Basic User Components**

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#### **Engineering Modeling System (EMS) Web App**

(EMS Web App is used to create documents and for change management) EMS Web App is a JPL developed web interface to enhance usability

> Alfresco (Alfresco is the PDM for the tool)

#### Magic Draw (Cameo)

(Magic Draw is the modeling authoring tool) Magic Draw Plug Ins: SysML, Simulation, Excel, teamwork server, MDK

MDK was developed by JPL JPL used a custom profile in order to add the custom modeling elements needed for their solution. **Open MBEE** provides an enterprise bus ready architecture with the modeling capabilities of magic draw and the additional document generation & CM features of EMS Web App

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### JPL Open MBEE Simplified Architecture

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- EMS Repo Overlay on Alfresco Content Repo.
  - Handles Model Management
- WebApp Gateway to talk to the EMS Repo from Web Client
- EMS Share- Overlay on Alfresco Share
  - Setting up site, doc libraries, wikis etc
- Teamwork Server Interim mechanism to handle model ckin/ckout
- MDK Plugin Connect MagicDraw to Alfresco Content Mgmt Server.
- Db [ Postgres used in this setup], could use SQL Server.

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### Primary System Architecting UI - Magic Draw (Cameo core tool)

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http://www.nomagic.com/support/demos.html

- Selected by JPL as their standard system architecting tool.
- Support several frameworks (DoDAF, MoDAF, NAF)
- Supports UPDM
- Supports several languages (UML, SysML, BPMN, SOAML)
- Supports XMI data exchange standards



### JPL Model Development Kit (MDK) Plugin

- MDK is a MagicDraw Plug-In that was developed by JPL. It connects MagicDraw SysML authoring tool with JPL's Webbased model management system (EMS).
- MDK Plug-In Features include:
  - Creating documents and views in EMS using queries and viewpoint patterns in MagicDraw
  - Model management by using branches of a model (branch, diff and merge features) both within MagicDraw and EMS and synchronizing between them
  - Building system assemblies (in SysML) using the System Reasoner Tool
  - Offline document generation directly from MagicDraw (without EMS connection)
  - Web services needed to support enterprise bus architecture
  - MDK also adds in user access control and workflow capability via Alfresco





### Stakeholder UI - Engineering Modeling System (EMS) Web App

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- The EMS Web App enable users to interact with the system model within a webbased environment.
- The Web App's tools interact with the same system model contained within Magic Draw.



![](_page_27_Picture_5.jpeg)

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![](_page_27_Picture_8.jpeg)

### **Product Data Manager (PDM) - Alfresco Implementation**

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### Alfresco is a Document oriented repository.

- Documents are in hierarchy.
- Documents can have relationships, however that is not the primary focus.
- Documents also have metadata.
- JPL's implementation uses the 'metadata' to store all data, ie all "Documents" are empty.
- Metadata is more graph-oriented than the documents themselves, which is mainly hierarchical.

https://wiki.alfresco.com/wiki/Main\_Page

![](_page_28_Picture_9.jpeg)

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![](_page_28_Picture_12.jpeg)

### **Other Potential Explorations**

- Boeing only explored the MDK (magic draw plugin) and the EMS components of the Open MBEE project
- Additional Open MBEE capabilities not explored
  - Comodo
    - Provides simulation capability
  - Livingston
    - ESO plugin for MagicDraw to create profiles and validation rules from Onotologies modelled with a SysML dialect
  - MBSE Plugin
    - Developed for INCOSE SE2 Challenge team
- Magic Draw may come out with a product next year that utilizes the MDK plug-in within their tool suite.

![](_page_29_Picture_11.jpeg)

![](_page_29_Picture_14.jpeg)

### **Extending the Solution - Customization Mechanisms**

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- EMS Share:
  - Uses the Surf Platform and knowledge of Surf is necessary. <u>https://wiki.alfresco.com/wiki/Surf\_Platform\_-\_Developers\_Guide</u>
- EMP Repo : [ via Alfresco's Content Application Server ] provides Embedded APIs and Remote APIs.
  - Embedded APIs To extend and/or override server capabilities. Depending on the type of extension, different types of API are available.
  - Remote APIs Web Services [ SOAP] and RESTful.

http://docs.alfresco.com/4.1/concepts/content-server-about.html http://docs.alfresco.com/4.1/concepts/api-about.html

- Magicdraw
  - Customizations can be done using MagicDraw Open Java API.
  - Can develop your own magic draw plugin and define dependencies with any existing plugins ( such as the OpenMBEE plugin )

http://www.nomagic.com/files/manuals/MagicDraw\_OpenAPI\_UserGuide\_1701.pdf

![](_page_30_Picture_14.jpeg)

### **Import/Export Options**

- Import
  - CSV
  - Excel
  - XMI
  - Requirements Interchange Format (ReqIF)
  - Using JPL Web Service API, or MagicDraw API
- Export
  - CSV
  - Excel
  - XMI
  - Using JPL Web Service API, or MagicDraw API

![](_page_31_Picture_13.jpeg)

![](_page_31_Picture_15.jpeg)

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![](_page_32_Picture_1.jpeg)

# MBEE Examples of Value-added Features – EMS document and Systems Reasoner

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![](_page_32_Picture_5.jpeg)

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![](_page_32_Picture_7.jpeg)

### **MDK Document Generation Example**

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![](_page_33_Figure_2.jpeg)

SysML Block Definition Diagram (BDD) in Magic Draw representing model of system structure.

> Magic Draw MDK plugin document generation diagram uses SysML views and viewpoints model elements to publish document to EMS for viewing in the web client. In this example, the view collects data from the BDD

![](_page_33_Figure_5.jpeg)

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# MDK Document Generation Example - EMS Web App View

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Results of document generations from MDK plugin in EMS – Note that this is an editable live document in the EMS repository

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# Systems Reasoner Example: The Model Assembly Buildup

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![](_page_35_Figure_2.jpeg)

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### **Systems Reasoner Example - Automated Assembly**

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![](_page_36_Figure_2.jpeg)

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- Automatically creates occurrence (specialization) trees
- Easily redefine ports, assemblies and attributes for unique values or connectivity.
- Ports and attributes are automatically propagated from definition to the usages/occurrences
- Much more efficient way of modeling the occurrence model using SysML – saves time!
- Some manual assembly still required, additional opportunities for further automation

![](_page_36_Picture_9.jpeg)

![](_page_36_Picture_11.jpeg)

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![](_page_37_Picture_1.jpeg)

# **Opportunities for Improvement**

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### **Scalability**

- Currently JPL is approaching 1 million objects, 200 users
  - They expect many times that size
- JPL is concerned about Magic Draw scalability
- We as an open source community, need to engage with No Magic to understand how they will address scalability

![](_page_38_Picture_6.jpeg)

![](_page_38_Picture_9.jpeg)

### **Develop Robust Open-Source Collaboration Model**

- Establish our own contribution plan and process
- Understand planned open-source features and expected target dates from other contributors
- Work with fellow open-source collaborators to address standards needs (e.g., modeling, interoperability and language standards)

![](_page_39_Picture_5.jpeg)

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### **Systems Reasoner Automation Opportunities**

- Propagate relationships (e.g., connections) when new specializations are created
- Automatically redefine (i.e., disconnect) new attributes/ports that are propagated from definition after specialization is created
  - Currently systems reasoner flags a mismatch between the newly propagated attributes/ports and the original definitions and asks the user to verify redefinition of each one.
- Automatically convert constituent part properties created as part of the specialization to "association" type
- Automatically generate part properties based on containment relationship

![](_page_40_Picture_7.jpeg)

![](_page_40_Picture_9.jpeg)

![](_page_40_Picture_10.jpeg)

### Conclusion

- Large scales system architecture modeling using COTS SysML modeling tools can prove challenging when trying to represent multilevel assemblies, redundant systems and detailed digital interfaces.
- Tool solutions (plugins) that extend these products to provide modeling automation show promise of being large timesavers in defining and managing intricate assemblies.
- We evaluated and investigated the open source plugin developed by JPL, called the Open Model Based Engineering Environment (Open-MBEE).
- This plugin extends and integrates No Magic's Magic Draw modeling solution with other essential components to provide a viable MBSE architecting, data and configuration management solution.
- Open MBEE adheres to the SysML modeling standard while adding additional capability needed for the development of large scale systems models which aligns with Boeing move to a more standards driven approach.
- Collaborating via an open source solution is an intriguing approach for addressing industry common modeling and design challenges.

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![](_page_41_Picture_10.jpeg)

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## **Questions?**

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