



26<sup>th</sup> annual **INCOSE**  
international symposium

Edinburgh, UK  
July 18 - 21, 2016

# MBSE++ — Foundations for Extended Model-Based Systems Engineering Across System Lifecycle

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**Presenter:** Lonnie VanZandt (*Thank you Lonnie!*)



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**intercax**

[www.intercax.com](http://www.intercax.com)

# Contents

- Introduction
- 6 principles of MBSE++
- Short video illustration
- Summary
- Q & A



# INCOSE SE Vision 2025



Edinburgh, UK  
July 18 - 21, 2016

Interconnected

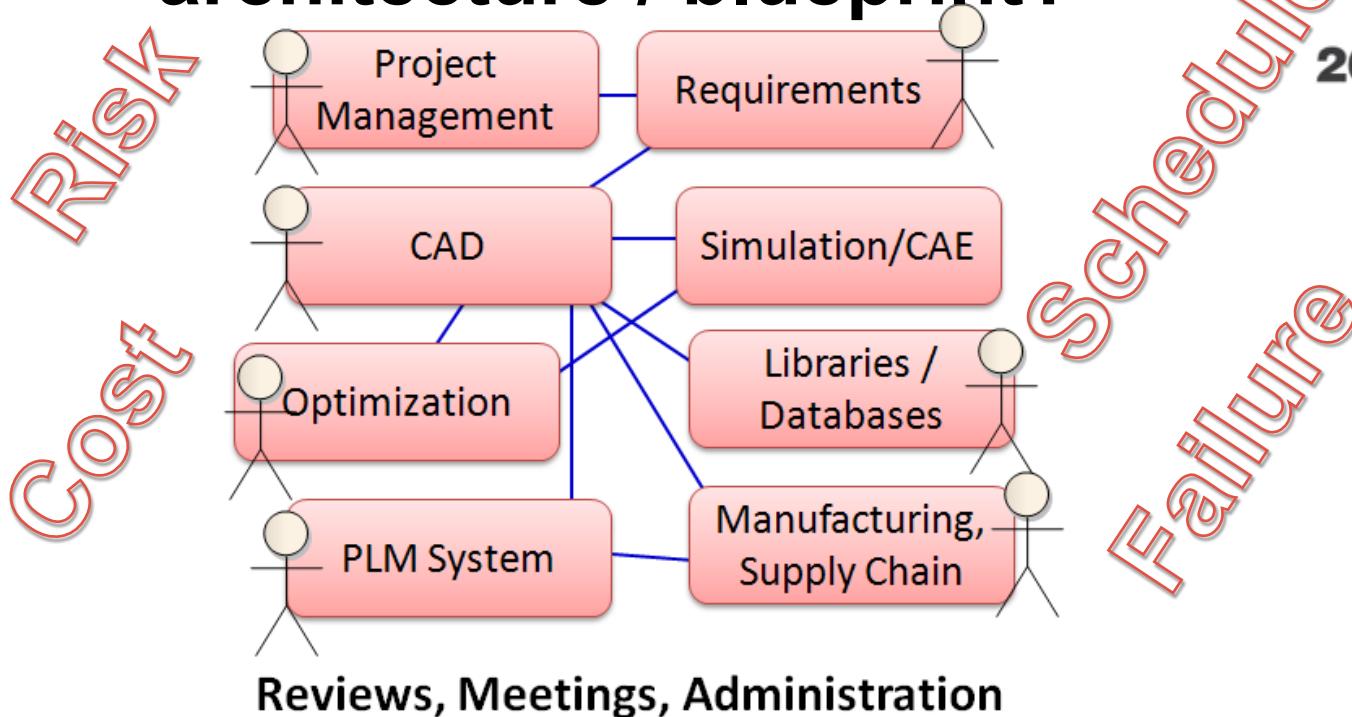
Interdependent

Complex

INCOSE SE Vision 2025  
<http://goo.gl/uE5OS9>

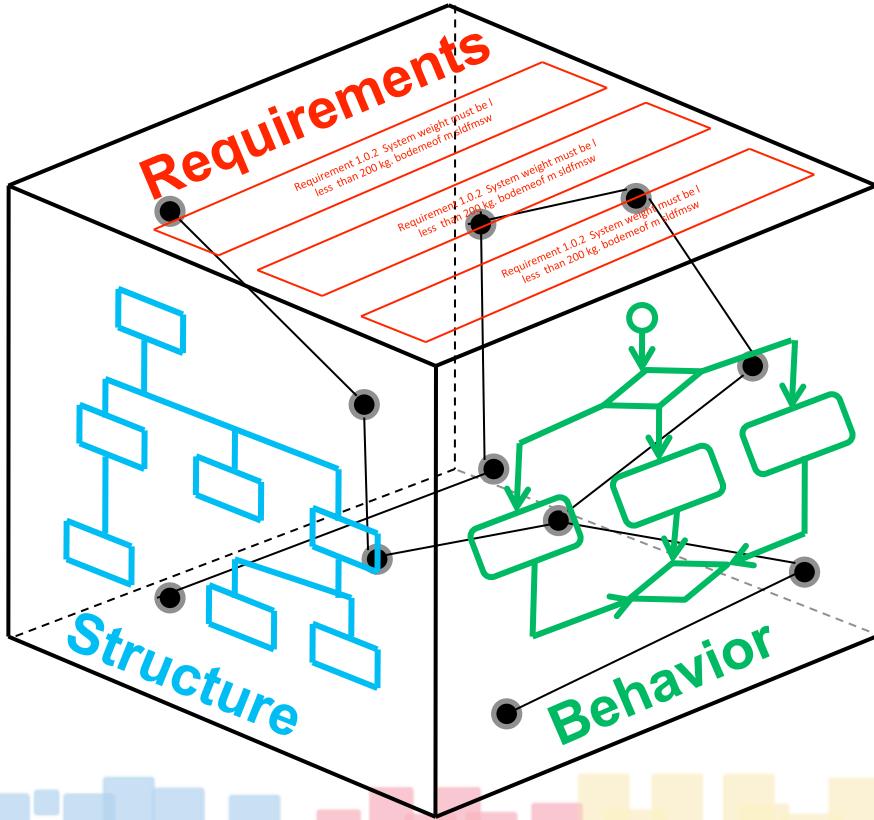
# Challenge – Where is the system architecture / blueprint?

Point-to-point ad-hoc information flows



Use of models in systems engineering IS NOT  
model-based systems engineering (MBSE)

# Transition from Document-Based to Model-Based Systems Engineering



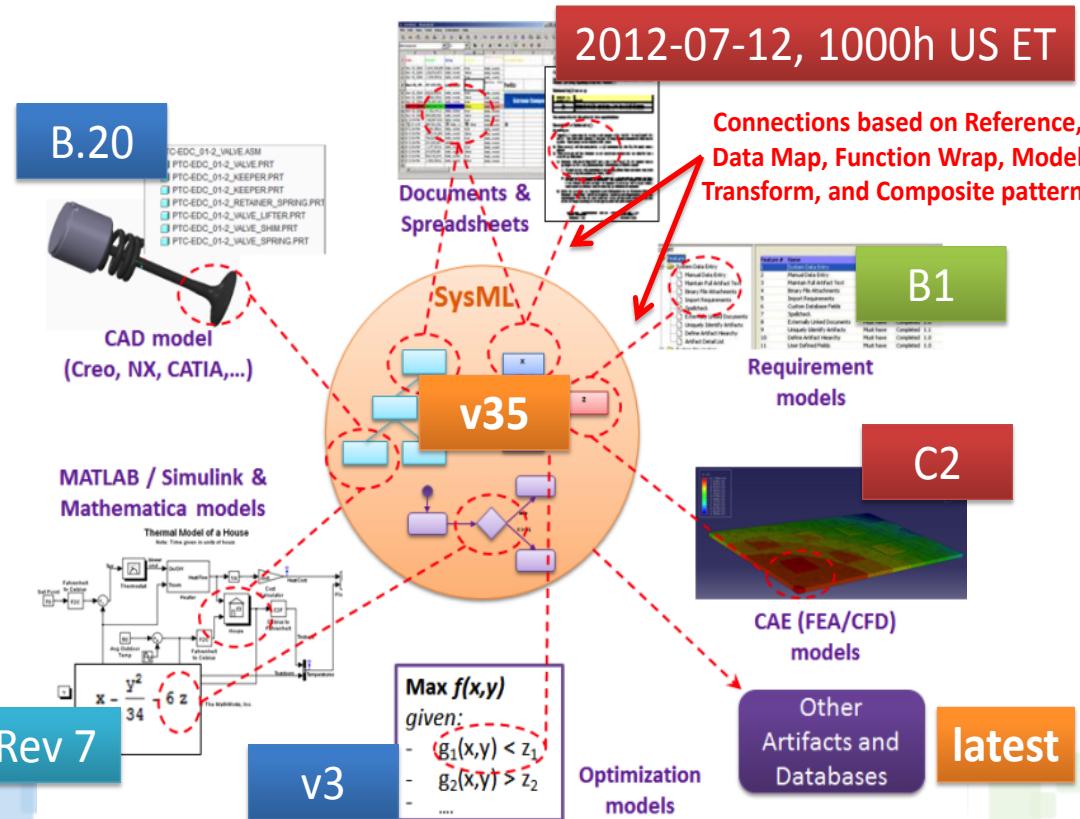
- MBSE = Unified model of the system versus series of disconnected documents (DBSE)
- System docs and views can be generated from this unified model
- DBSE > MBSE  $\Leftrightarrow$  2D > 3D CAD
- Models in SE  $\neq$  MBSE

# DBSE > MBSE > MBSE++



- OMG SysML – [www.omgsysml.org](http://www.omgsysml.org)
  - Widely adopted as a standard for modeling, analyzing, and developing system architecture
- However
  - Most of the detailed engineering carried out in domain-specific tools and repositories, such as in PLM, ALM, Req. Mgt., Databases, Simulation env., Project Mgt., CAD, CAE, and more

# What is MBSE++



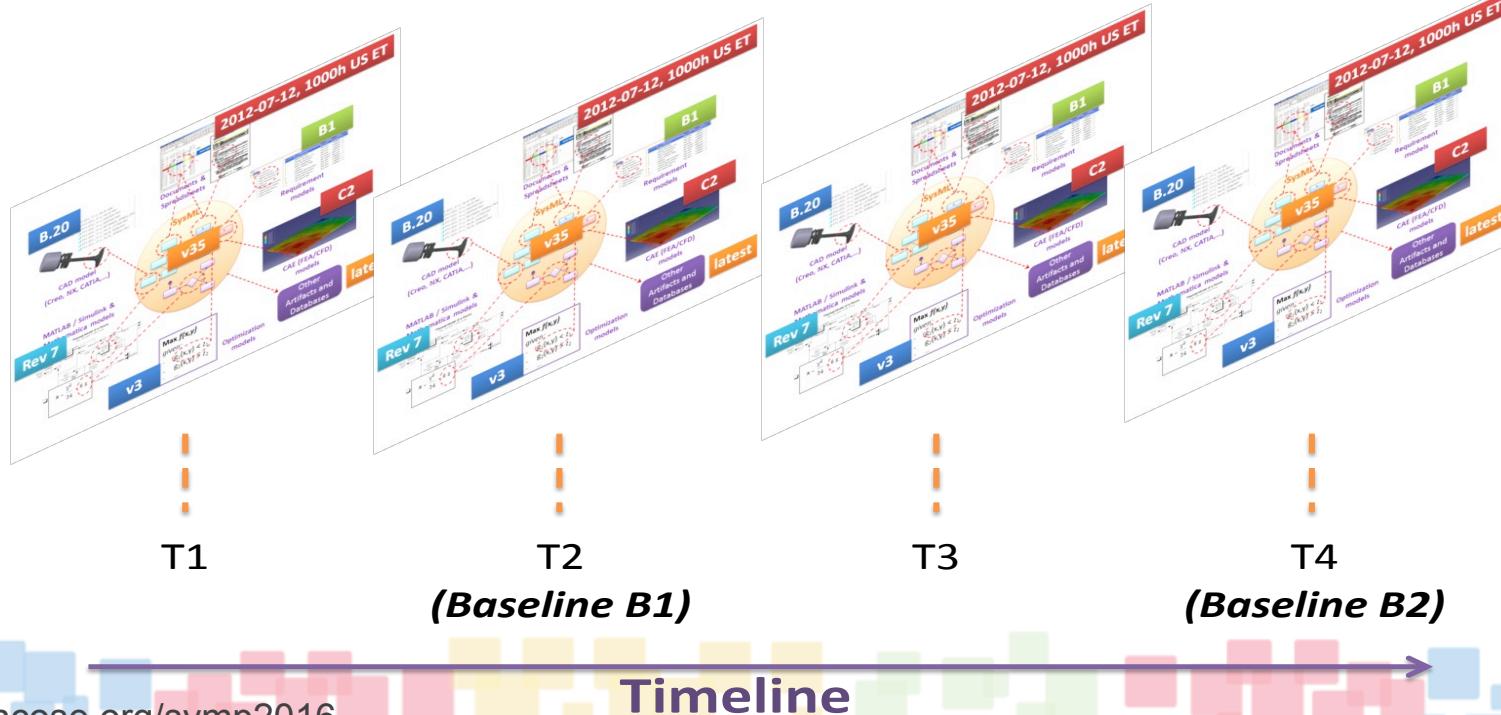
Connect architecture model (SysML) with domain-specific models

**Total System Model (TSM)** as a digital blueprint of the system

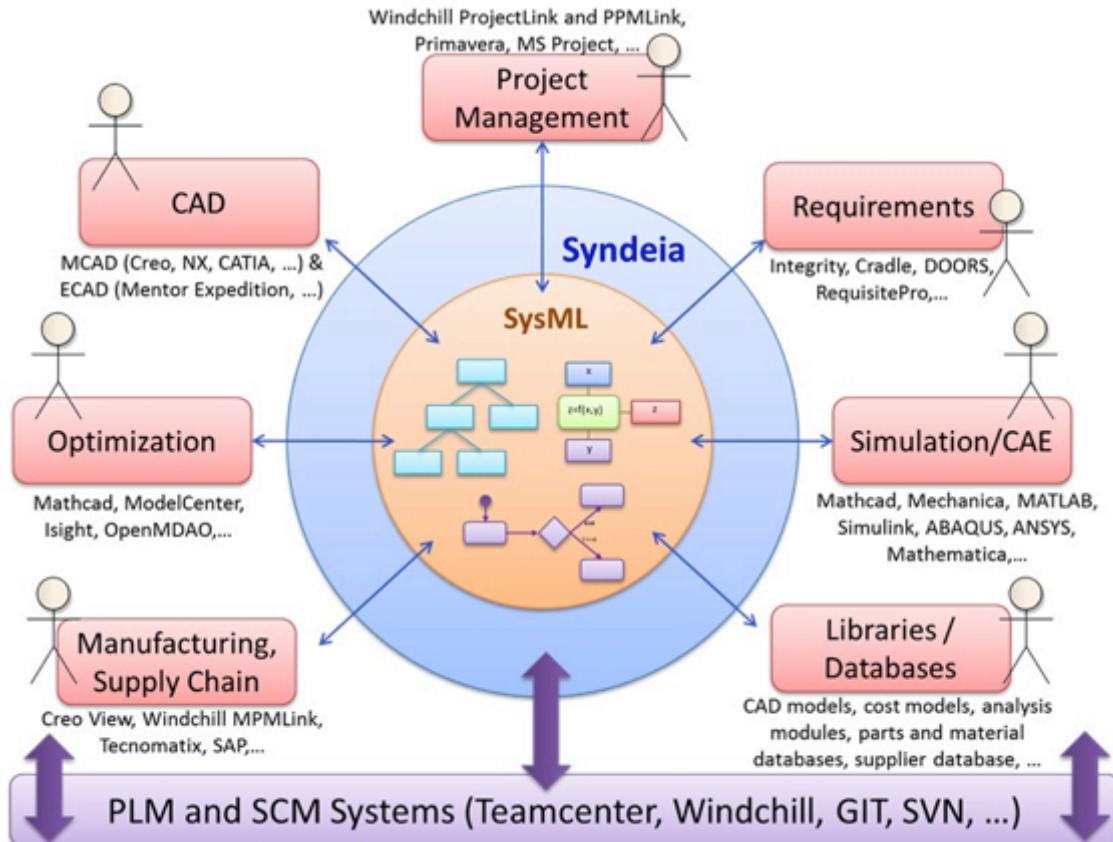
Goal: Seamless traceability between disciplines across the system lifecycle

# Total System Model (TSM)

*TSM evolves as each of the version-managed models evolve*



# Syndeia = Software Platform for MBSE++



Search, Connect, Access,  
Transform, Compare, Sync,  
Visualize models in the TSM

We will Illustrate 6 principles  
of MBSE++ using Syndeia

Syndeia 3.0 released July  
2016 – [www.syndeia.com](http://www.syndeia.com)

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# 1. Heterogeneous and Decentralized Data



- Wide range of tools used for developing a system
- Total System Model (TSM) contains models spread across multiple version-controlled enterprise repositories and tools, such as:
  - System architecture (SysML - MagicDraw, Rhapsody, Enterprise Architect, Integrity Modeler)
  - Project management (MS Project, JIRA)
  - PLM (Teamcenter, Windchill, Aras)
  - Requirements Management (DOORS, JAMA, Teamcenter, Integrity)
  - ALM (GitHub, Bitbucket, JIRA)
  - Simulation (Mathematica, MATLAB, Simulink, Modelica, FEA/CFD – ANSYS, ABAQUS)
  - Databases (MySQL, Oracle, SQL Server, MongoDB, Neo4j)

# 1. Heterogeneous and Decentralized Data



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- Wide range of:
  - Modeling languages (SysML, Modelica, Simscape, XML, EXPRESS,...)
  - Data formats (XML, JSON,...)
  - APIs
  - Standards (ISO STEP, JDBC, FMI, OSLC,...)
  - Communication modes (Web services – REST, SOAP, File exchange,...)

# 1. Heterogeneous and Decentralized Data (Screenshots from Syndeia - 1/2 )



Access →  
multiple  
enterprise  
repositories  
  
(PLM, ALM,  
Databases,  
Req. Mgt,  
Project Mgt,  
Drives)

The screenshot shows the Syndeia Dashboard (3.0.0) interface. The top navigation bar includes tabs for Repository Manager, Connection Manager, Connection Browser, Connection Summary, Comparison Result, and Settings. The Repository Manager tab is active, showing a list of repositories on the left and their contents on the right. The Connection Manager tab is also visible.

**Repository List Panel (Left):**

- Repositories
  - DOORS
    - DOORS @ Intercax
    - DOORS @ Supplier A
  - GitHub
    - GitHub @ Intercax
  - JIRA
    - JIRA @ Intercax
  - Local File System
    - Creo Models
    - Excel Models
    - NX Models
    - Simulink Models
  - MySQL
    - MySQL @ Intercax
    - Parts Lib @ Supplier A
  - RESTful
  - Teamcenter
    - TC9 @ Intercax
    - TC9 @ manas
  - Windchill
    - WC @ Supplier B
    - WC10.2 @ Intercax

**Repository Content Panel (Right):**

- DOORS @ Intercax
  - Automated Meter Reader (Water)
  - Unmanned Aerial Vehicle
  - Fire Station
  - Sandbox
  - Automobile
    - 1171 – Automobile Project-level Requirement Collection
    - 1172 – Automobile Project Kick-off Requirement
    - 1173 – Automobile Project Schedule Requirement
    - 1871 – Automobile Project-level Module
    - 2090 – D1
    - Automobile Project-level Module artifacts
    - Customer Specification
      - 1144 – Automobile Customer Specification Module
      - 1147 – Vehicle Performance
      - 1146 – Passenger and Baggage Load
      - 1159 – Fuel Economy
      - 1152 – Riding Comfort
        - 1153 – Space
        - 1154 – Vibration
        - 1155 – Noise
      - 1156 – Occupant Safety
      - 1157 – Reliability
      - 1158 – Emissions
      - 1160 – Production Cost
      - 1162 – Passenger Comfort-related Requirements

Browse and  
search  
repository  
contents

# 1. Heterogeneous and Decentralized Data (Screenshots from Syndeia -2/2 )

S Syndeia Dashboard (2.0.0) - Unmanned Aerial Vehicle

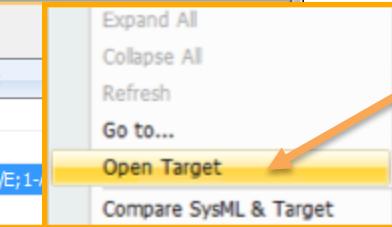
Repository Manager Connection Manager Connection Browser Connection Summary Comparison

Type here to filter connections

Source (SysML Element)	Name	Type	Target
Unmanned Aerial Vehicle			
Aircraft Platform			
Analysis Manager			
APU			
Autopilot			
Battery			
BlackBox			
Body			
Communications Controller			

(loaded) between artifacts {[Unmanned Aerial Vehicle:Communications Interface]} and {[000493/A;1-Comm successfully added to connection manager}

Ready



View models in native repositories from the TSM

SIEMENS

My Teamcenter

000465/E;1-Aircraft Platform

- 000465/E-View
- 000465/E
- View
  - 000478-Body
  - 000479-Engin
  - 000480-Fuel :
  - 000481-Powe
  - 000482-Rotor
  - 000483-Tail A
  - 000484-Electr
  - 002676-Black

Overview Related Datasets Impact Analysis

Available Revisions Viewer Details

000465/E;1-Aircraft Platform Owner : Manas Bajaj (manas)

Last Modified Date : 23-Apr-2014 15:21 Release Status :

Type : ItemRevision

A 3D CAD model of a cylindrical aircraft component with various internal and external features highlighted in orange.

## 2. Capturing & Maintaining the High-level System Architecture



- Challenges
  - High-level system definition to coordinate and orchestrate disciplines – project management, mechanical/electrical design, simulation, software, part suppliers, and other vendors
  - Domain-specific models / specifications should be derived from system architecture, or vice versa, and connected
  - System architecture needed for verifying system-level requirements, assessing emerging system behavior, and as the entry point for system engineers

## 2. Capturing & Maintaining the High-level System Architecture



- Use Cases (some examples)
  - Compose system architecture (SysML) from libraries of parts (PLM), software (ALM), data (DB), and keep all connected
  - Seed PLM BoM & simulation models from system architecture (structure and function), and keep all connected
  - System mass requirement verification needs part/sub-system mass information originating from 3D CAD

## 2. Capturing & Maintaining the High-level System Architecture

(Screenshots from Syndeia 1/2)



System Architecture (SysML)

W

Drag-n-Drop

Drag-n-drop to connect and/or generate models

Local File System Repository

- Creo
- NX
- Simulink
- MySQL Repositories
- MySQL1
- Teamcenter Repositories
- TC101
- TC91
- Windchill Repositories
- WC101
- WC102

Switch repos

Domain-specific models

## 2. Capturing & Maintaining the High-level System Architecture



## *(Screenshots from Syndeia – 2/2)*

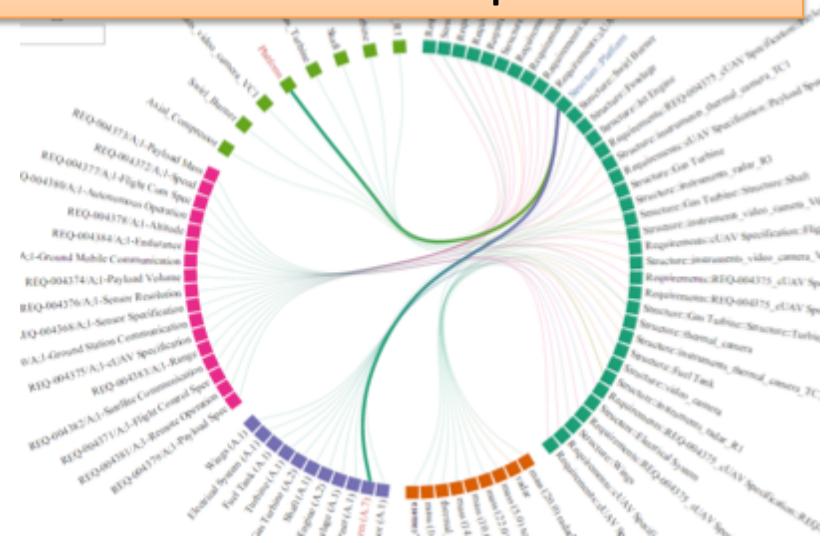
## Connections - Tabular view

Connections Tabular View

Q: Type here to filter connections 50 out of 50 connections Refresh

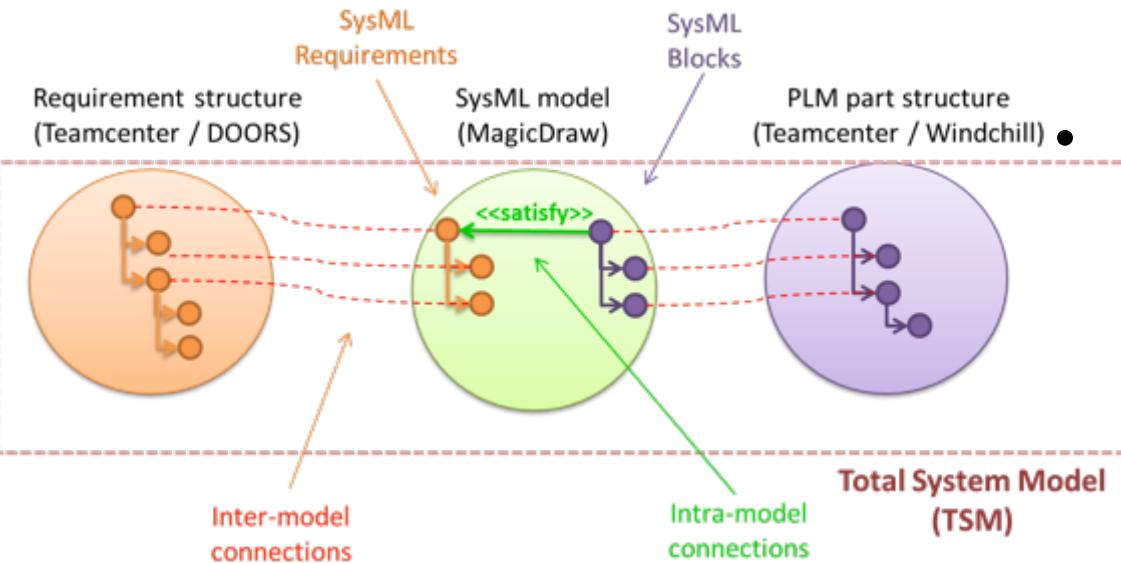
ID	Type	Source	Target	Repository
C51	BLOCK_IWC_PART_MODEL_TRANSFORM_CONNECTION	Unmanned Aerial System:Unmanned Aerial Vehicle	Unmanned Aerial Vehicle (B.4)	WC1
C52	BLOCK_IWC_PART_MODEL_TRANSFORM_CONNECTION	Unmanned Aerial System:Aircraft Platform	Aircraft Platform (A.12)	WC1
C53	BLOCK_IWC_PART_MODEL_TRANSFORM_CONNECTION	Unmanned Aerial System:Body	Body (A.9)	WC1
C54	BLOCK_IWC_PART_MODEL_TRANSFORM_CONNECTION	Unmanned Aerial System:Body	Cooling (A.1)	WC1
C55	BLOCK_IWC_PART_MODEL_TRANSFORM_CONNECTION	Unmanned Aerial System:Body	Fuselage (A.1)	WC1
C56	BLOCK_IWC_PART_MODEL_TRANSFORM_CONNECTION	Unmanned Aerial System:Body	Landing Skids (A.1)	WC1
C57	BLOCK_IWC_PART_MODEL_TRANSFORM_CONNECTION	Unmanned Aerial System:Body	Electrical System (A.7)	WC1
C58	BLOCK_IWC_PART_MODEL_TRANSFORM_CONNECTION	Unmanned Aerial System:Body	APU (A.1)	WC1
C59	BLOCK_IWC_PART_MODEL_TRANSFORM_CONNECTION	Unmanned Aerial System:Body	Battery (A.1)	WC1
C60	BLOCK_IWC_PART_MODEL_TRANSFORM_CONNECTION	Unmanned Aerial System:Electrical System Controller	Electrical System Controller (A.1)	WC1
C61	BLOCK_IWC_PART_MODEL_TRANSFORM_CONNECTION	Unmanned Aerial System:Electrical Bus	Electrical Bus (A.1)	WC1
C62	BLOCK_IWC_PART_MODEL_TRANSFORM_CONNECTION	Unmanned Aerial System:Engine	Engine (A.1)	WC1
C63	BLOCK_IWC_PART_MODEL_TRANSFORM_CONNECTION	Unmanned Aerial System:Fuel System	Fuel System (A.5)	WC1
C64	BLOCK_IWC_PART_MODEL_TRANSFORM_CONNECTION	Unmanned Aerial System:Fuel Distribution	Fuel Distribution (A.1)	WC1
C65	BLOCK_IWC_PART_MODEL_TRANSFORM_CONNECTION	Unmanned Aerial System:Fuel Tank	Fuel Tank (A.1)	WC1
C66	BLOCK_IWC_PART_MODEL_TRANSFORM_CONNECTION	Unmanned Aerial System:Power Train	Power Train (A.6)	WC1
C67	BLOCK_IWC_PART_MODEL_TRANSFORM_CONNECTION	Unmanned Aerial System:Gearbox	Gearbox (A.1)	WC1
C68	BLOCK_IWC_PART_MODEL_TRANSFORM_CONNECTION	Unmanned Aerial System:Tall Rotor Drive Shaft	Tall Rotor Drive Shaft (A.1)	WC1
C69	BLOCK_IWC_PART_MODEL_TRANSFORM_CONNECTION	Unmanned Aerial System:Transmission	Transmission (A.1)	WC1
C70	BLOCK_IWC_PART_MODEL_TRANSFORM_CONNECTION	Unmanned Aerial System:Rotor	Rotor (A.9)	WC1
C71	BLOCK_IWC_PART_MODEL_TRANSFORM_CONNECTION	Unmanned Aerial System:Rotor Blade	Rotor Blade (A.1)	WC1
C72	BLOCK_IWC_PART_MODEL_TRANSFORM_CONNECTION	Unmanned Aerial System:Hub	Hub (A.1)	WC1
C73	BLOCK_IWC_PART_MODEL_TRANSFORM_CONNECTION	Unmanned Aerial System:Shaft	Shaft (A.1)	WC1

## Connections – Graphical view



Track all model-based connections between system architecture (SysML) and domain-specific models in PLM, ALM, Databases, Requirements Mgt. and other repositories

### 3. Spectrum of Model-Based Connections



- Model-based connections are building blocks of interoperability
- #### Types of connections

- **Inter-model** connections are between elements in different models / tools e.g. SysML block – PLM part
- **Intra-model** connections are between elements in same model / tool, e.g. SysML block – SysML requirement

### 3. Spectrum of Model-Based Connections

- What is the purpose of model-based connections?

#### Reference Connections

Track/compare/sync versions of connected elements

#### Data Map Connections

+ Track/compare/sync element attributes

#### Function Wrap Connections

+ Track/execute connection elements

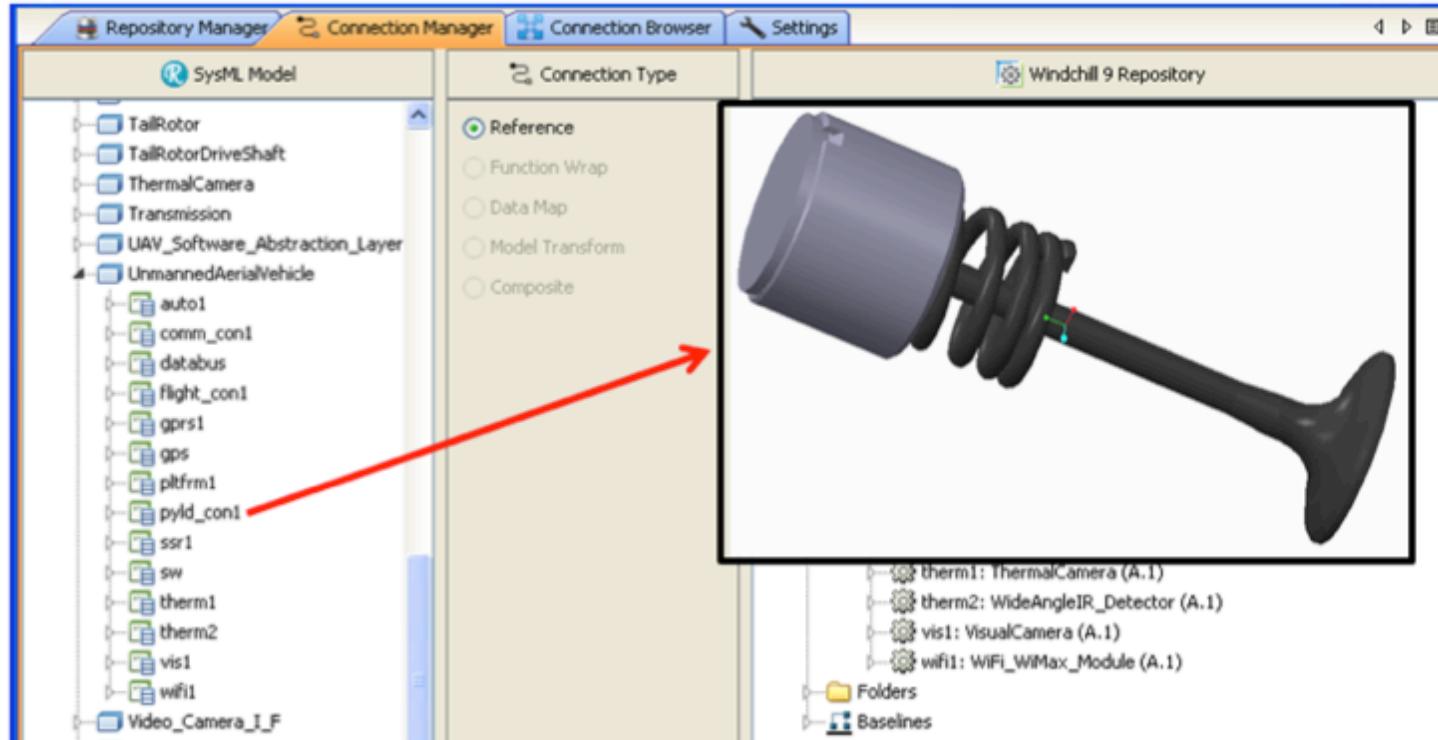
#### Model Transform Connections

+ Track/compare/sync element structure (multi-level)

### 3. Spectrum of Model-Based Connections

(Screenshots from Syndeia – 1/4)

Reference connection between SysML and CAD to track/view 3D geometry

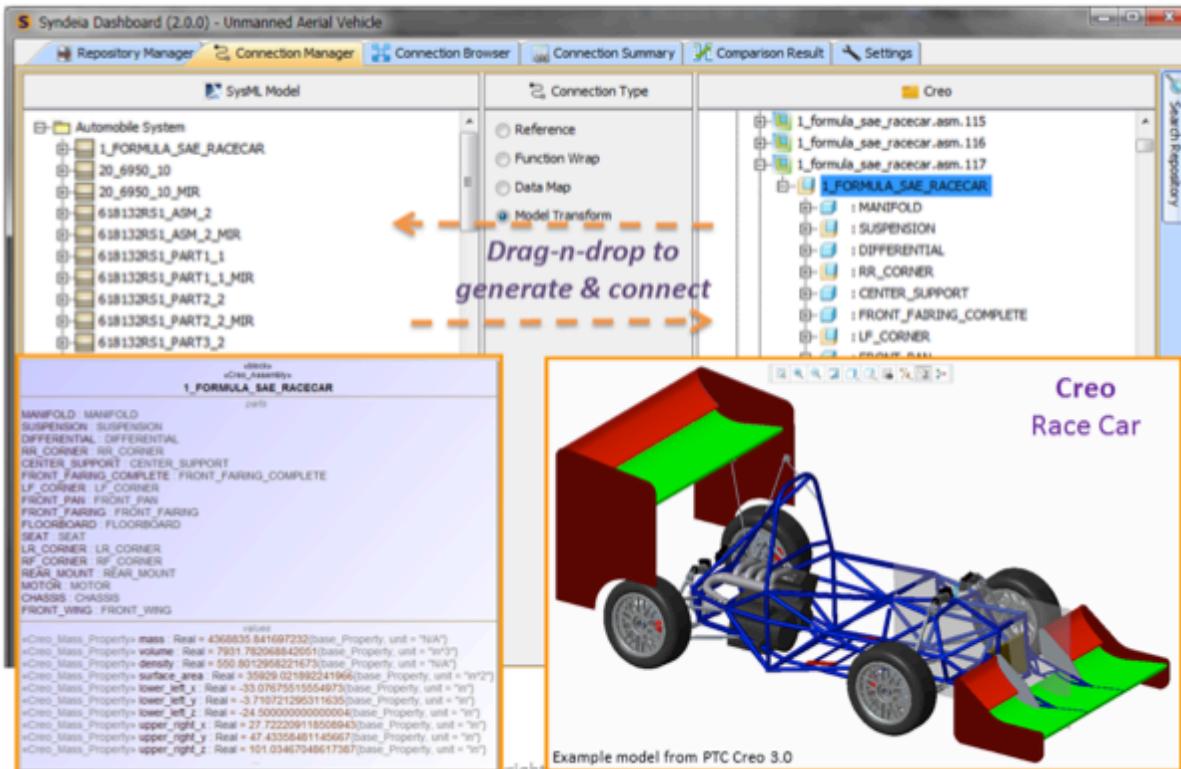


### 3. Spectrum of Model-Based Connections

(Screenshots from Syndeia – 2/4)



Data Map connection to get/compare mass props

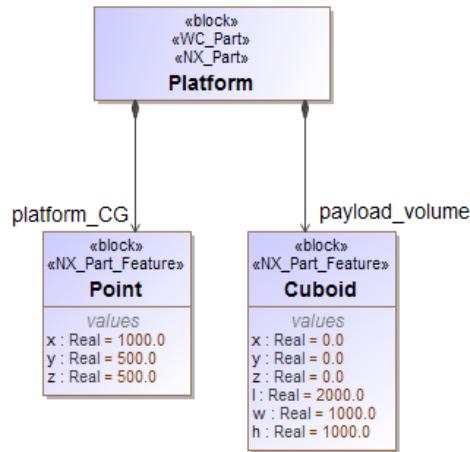


### 3. Spectrum of Model-Based Connections

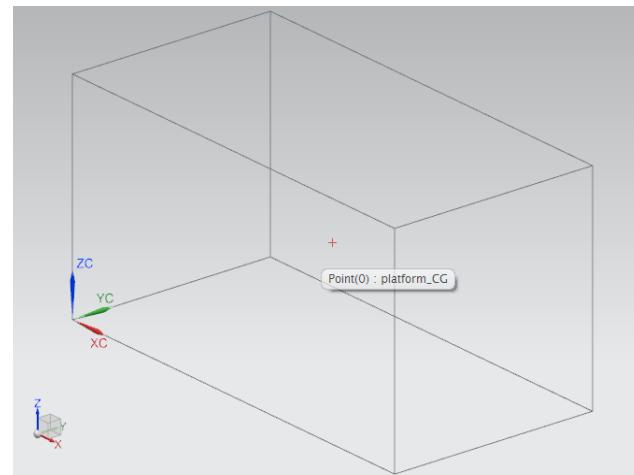
(Screenshots from Syndeia – 3/4)



Model Transform connection to seed sub-system  
bounding boxes from property-based requirements



Seed system  
constraints (bounding  
boxes, keepout-  
zones,...) from the  
architecture



### 3. Spectrum of Model-Based Connections

(Screenshots from Syndeia – 4/4)



Compare and bi-directional sync across connections

Syndeia screenshot showing the Connection Browser interface. The interface includes a toolbar with Repository Manager, Connection Manager, Connection Browser (selected), Connection Summary, Comparison Result, and Settings. A search bar and buttons for Clear and Export to Excel are also present. The main table displays connections between various components, with the first row highlighted in yellow. The table columns are Conn ID, Source, Target, Latest Target, and Comment. The table shows multiple connections for a single component, such as 'Unmanned Aerial Vehicle' and 'thermal camera'. The bottom status bar shows the message "[11:56:22] INFO Comparing SysML part property and Teamcenter part occurrence (BOM line with ref des) thermal camera." and the time 11:56:55 AM.

Conn ID	Source	Target	Latest Target	Comment
e3f03...	Unmanned Aerial Vehicle wimax module : WiMax Module visual camera : Visual Camera trackers : Sensor	000464/C;2-Unmanned Aerial Vehicle wimax module : 000472/A;1-WiMa... visual camera : 000475/A;1-Visual ... thermal camera : Thermal Camera	000464/C;2-Unmanned Aerial Vehicle wimax module : 000472/A;1-WiMa... visual camera : 000475/A;1-Visual Ca... thermal camera : 000476/A;1-Ther...	The block Unmanned Aerial Vehic... Part property wimax module and... Part property visual camera and ... Part property trackers has no co...
	software : Software System	software : 000487/B;1-Software S...	software : 000487/B;1-Software Syst...	Part property software and part...
	payload controller : Payload Controller	payload controller : 000470/A;1-P...	payload controller : 000470/A;1-Payl...	Part property payload controller ...
	modem : Spread Spectrum Radio M...	modem : 000474/A;1-Spread Spec...	modem : 000474/A;1-Spread Spectru...	Part property modem and part o...
	ir detector : Wide Angle IR Detector	ir detector : 000477/A;1-Wide Ang...	ir detector : 000477/A;1-Wide Angle I...	Part property ir detector and pa...
	gps : GPS	gps : 000466/A;1-GPS	gps : 000466/A;1-GPS	Part property gps and part occu...
	gprs module : GPRS UMTS Module	gprs module : 000473/A;1-GPRS U...	gprs module : 000473/A;1-GPRS UMT...	Part property gprs module and p...
	flight controller : Flight Controller	flight controller : 000469/A;1-Fligh...	flight controller : 000469/A;1-Flight C...	Part property flight controller an...

# 4. Unified Framework for Model-Based Connections

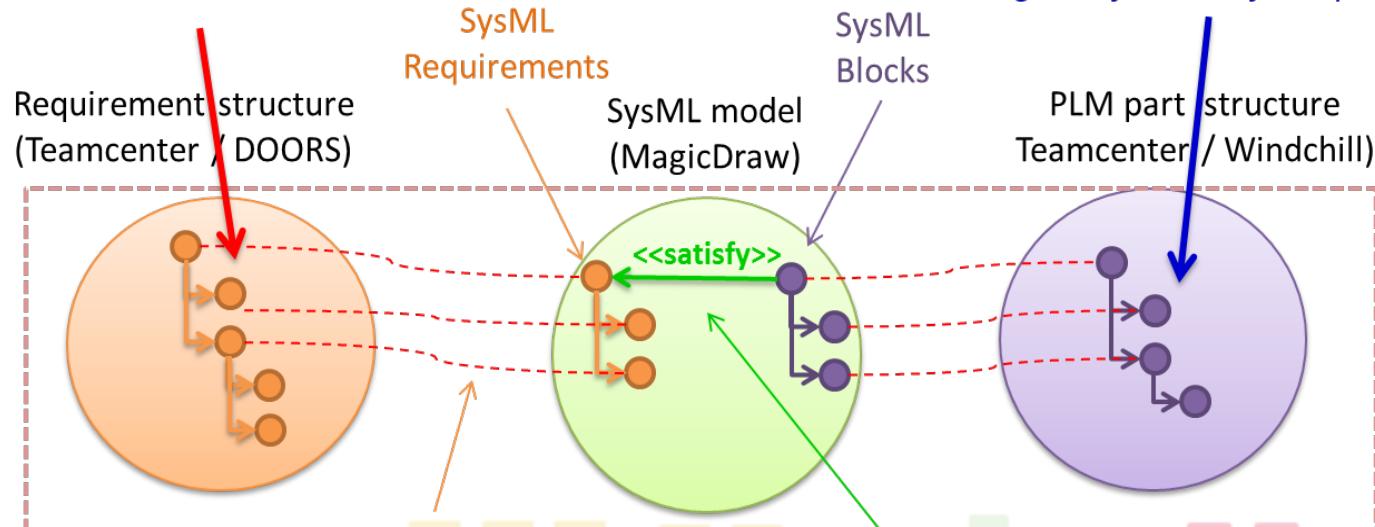


- A unified model-based engineering framework is needed to traverse both:
  - Inter-model connections (across model boundaries)
  - Intra-model connections (within model boundaries)

# 4. Unified Framework for Model-Based Connections

- Use Cases (example)

*If I change this requirement, what is the downstream impact, e.g. to CAD models in PLM*



# 5. From Traceability to Impact



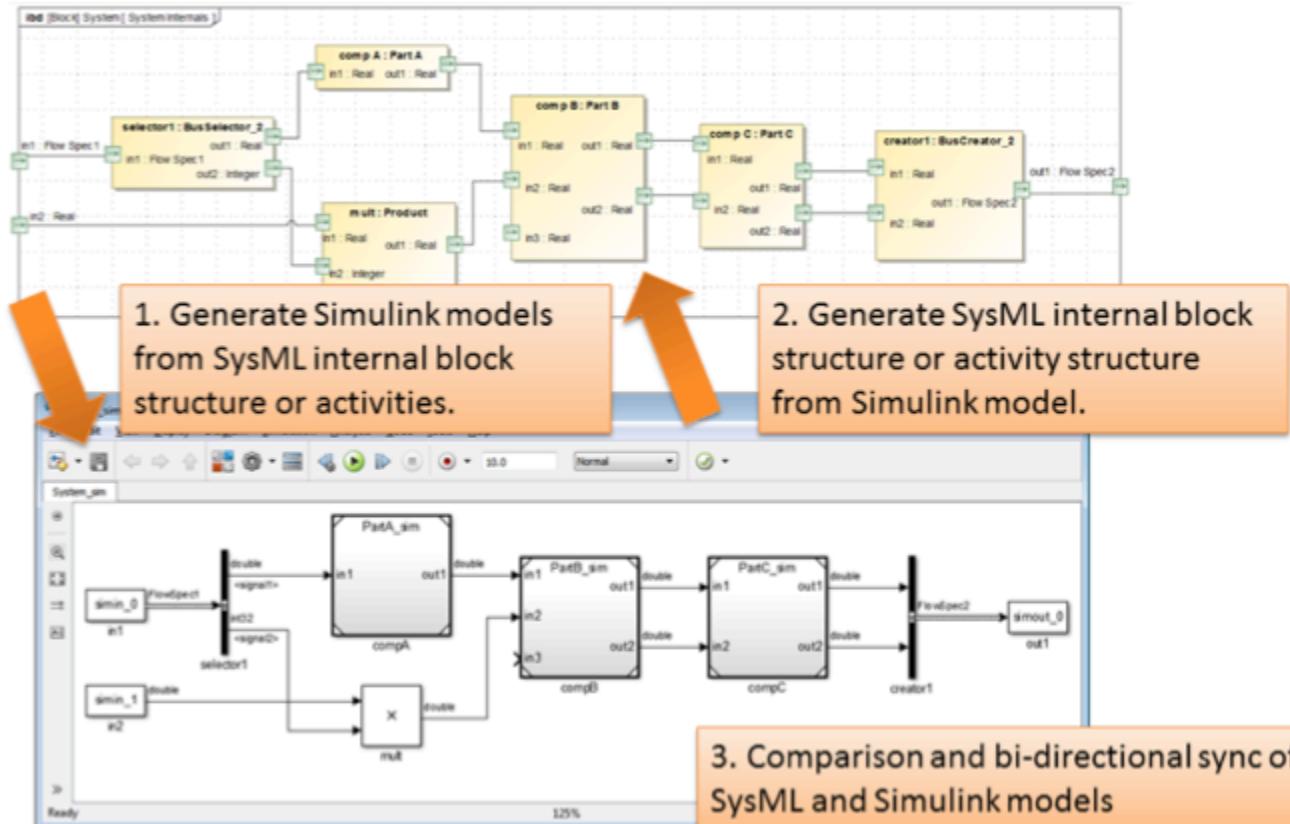
- Traceability is a starting point but not sufficient
- How do we create and manage millions of model-based connections for a real system?
  - Model transformations > Generate connections
- How do we propagate changes in one model to another model - quantitatively beyond suspect links?
  - Executable connections propagate changes

# 5. From Traceability to Impact

(Screenshot from *Syndesia transformations*)



System internal structure (SysML) used for generating and sync'ing executable simulation models (Simulink) and inter-model connections



## 6. Many Users, Many Views

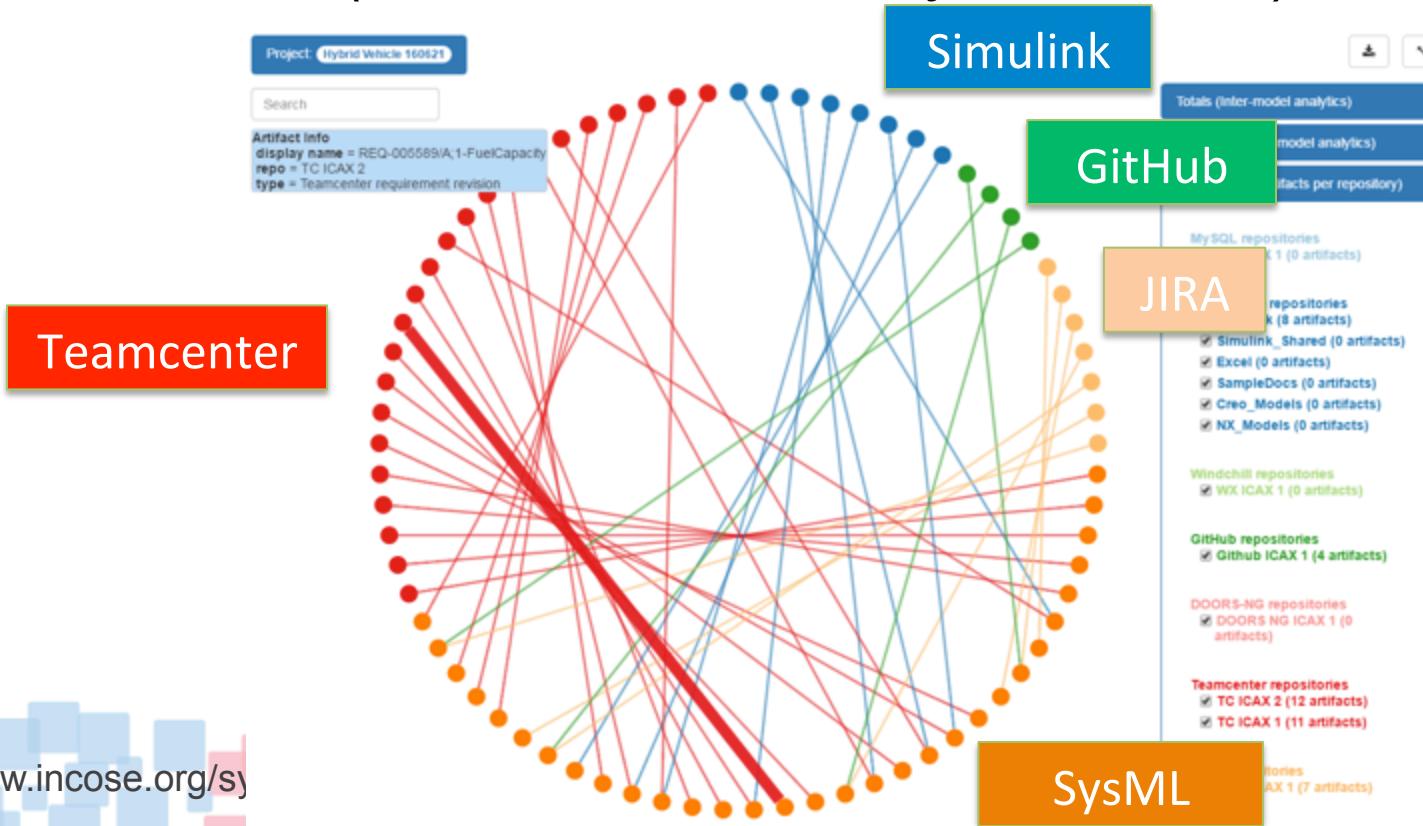


- Stakeholders need to visualize and query the Total System Model for different purposes
  - What system functions are planned to satisfy a reqt.?
  - What system elements implement a given function?
  - What test cases are planned to verify a requirement?
  - What functions would be affected if a part fails?
  - Is there a traceability for reqt. R to mechanical part M

# 6. Many Users, Many Views

## *Viewing all inter-model connections*

(Screenshots from *Syndesia* – 1/3)



# 6. Many Users, Many Views

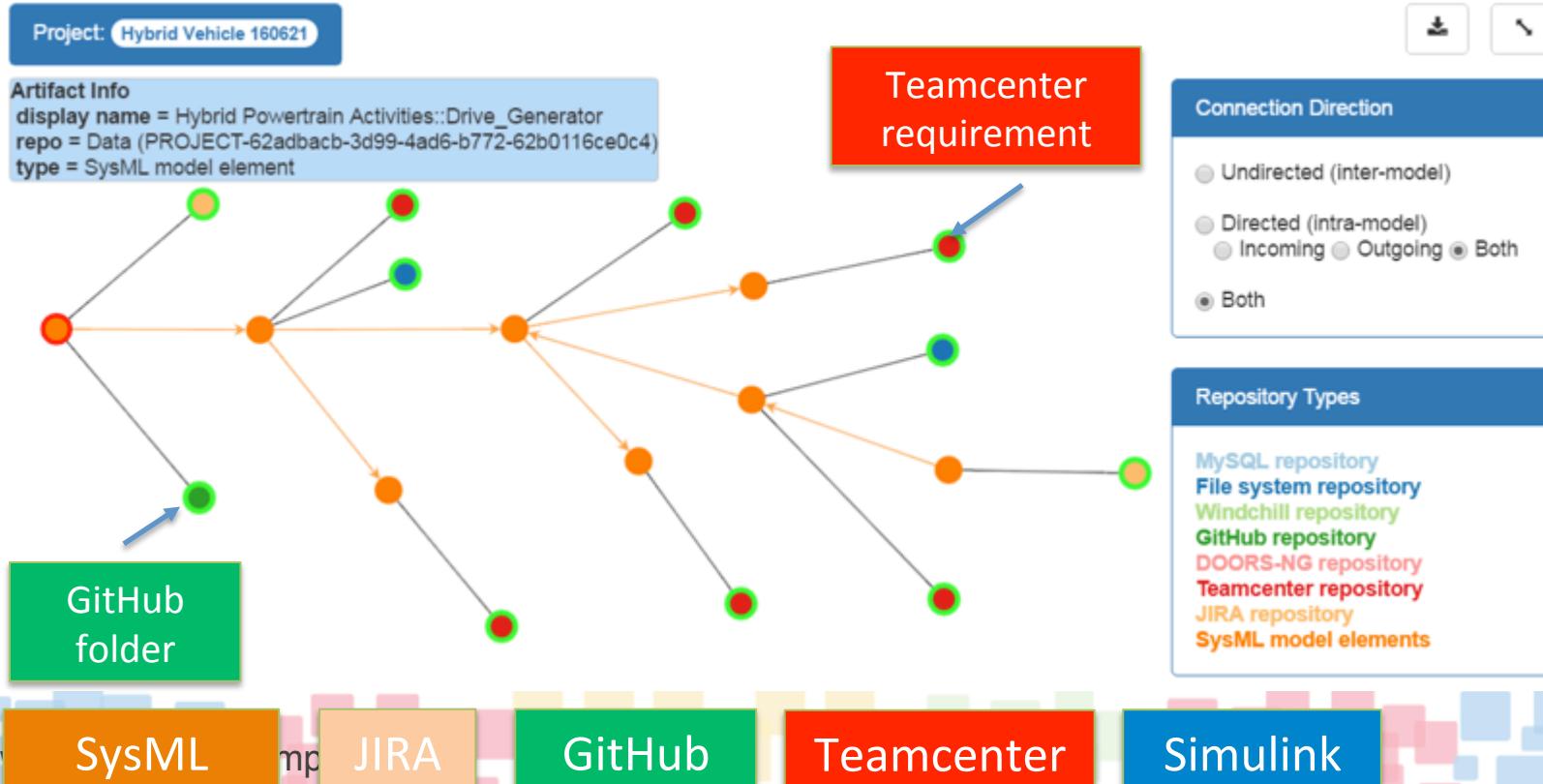
## Explore inter- and intra-model connections



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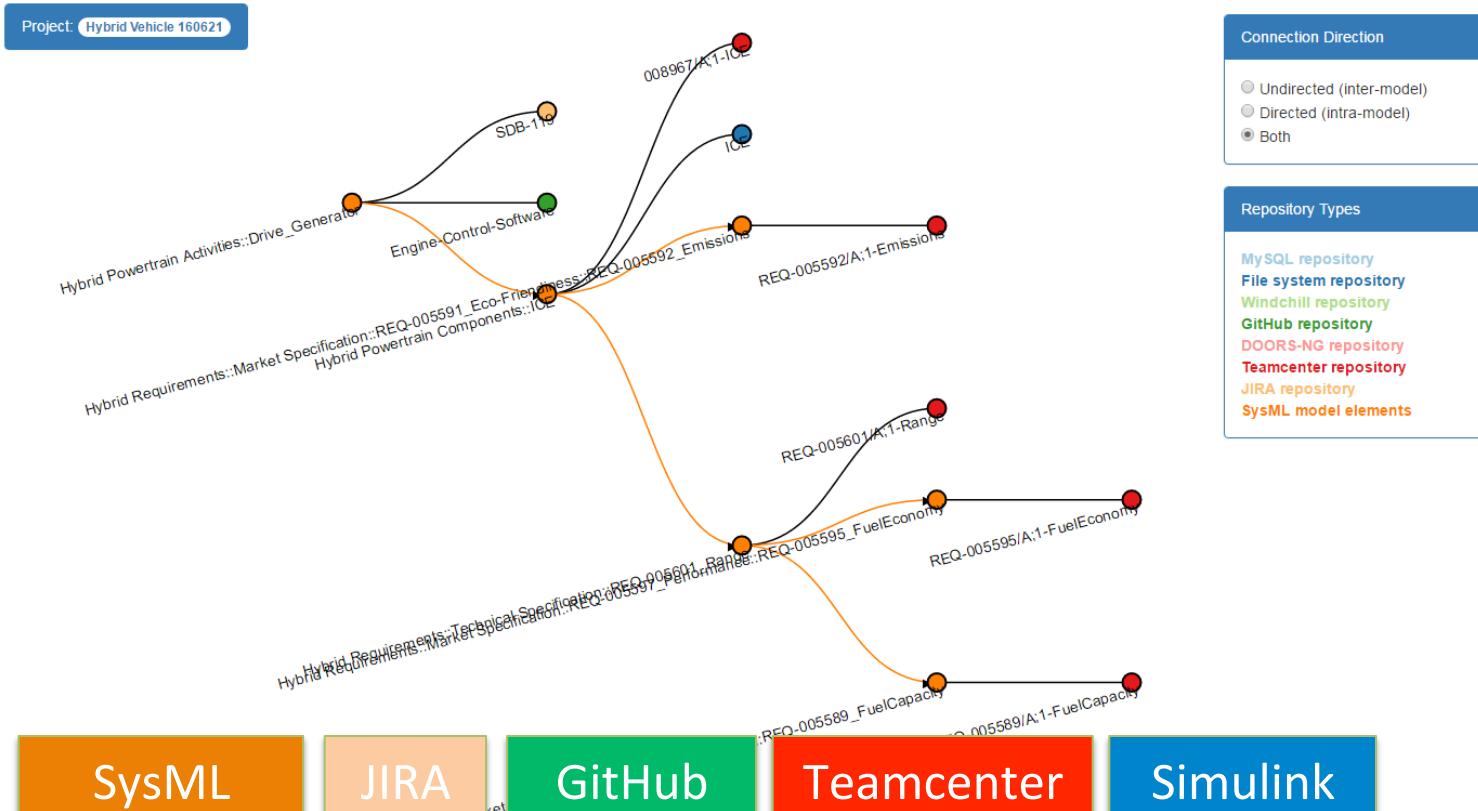
(Screenshots from Syndeia – 2/3)



# 6. Many Users, Many Views

## *Explore inter- and intra-model connections*

(Screenshots from Syndeia – 3/3)



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# MBSE++ Illustration using Syndeia



- YouTube Video

<https://youtu.be/SHsNrrWiFDE>

# Summary



- *Graphs* are a fundamental abstraction for MBSE++ (nodes = model elements, and edges = inter-/intra-model relationships)
- *Total System Model* is a graph connecting all engineering disciplines across the lifecycle, a key enabler for MBSE++
- Presented 6 fundamental principles of MBSE++
- *Syndeia* = Software platform for MBSE++

# Questions and Comments

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