26th annual INCOSE international symposium

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

Authors: Manas Bajaj[1], Dirk Zwemer[1], Rose Yntema[1], Alex Phung[1], Amit Kumar[1], Anshu Dwivedi[1], Manoj Waikar[1]

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

1 intercax www.intercax.com

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

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Interconnected

Interdependent

Complex

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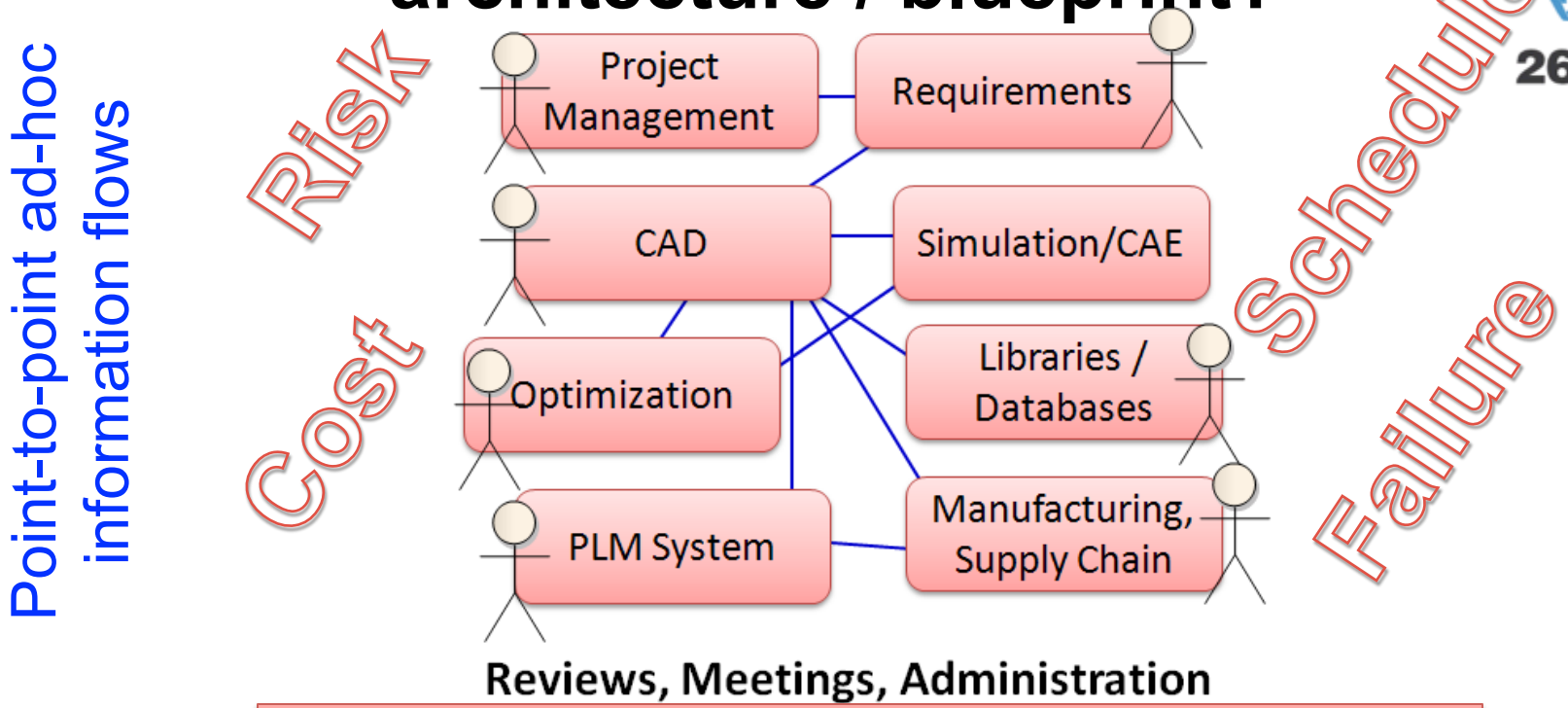
http://goo.gl/uE5OS9

Challenge – Where is the system architecture / blueprint?



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

Transition from Document-Based to Model-Based Systems Engineering

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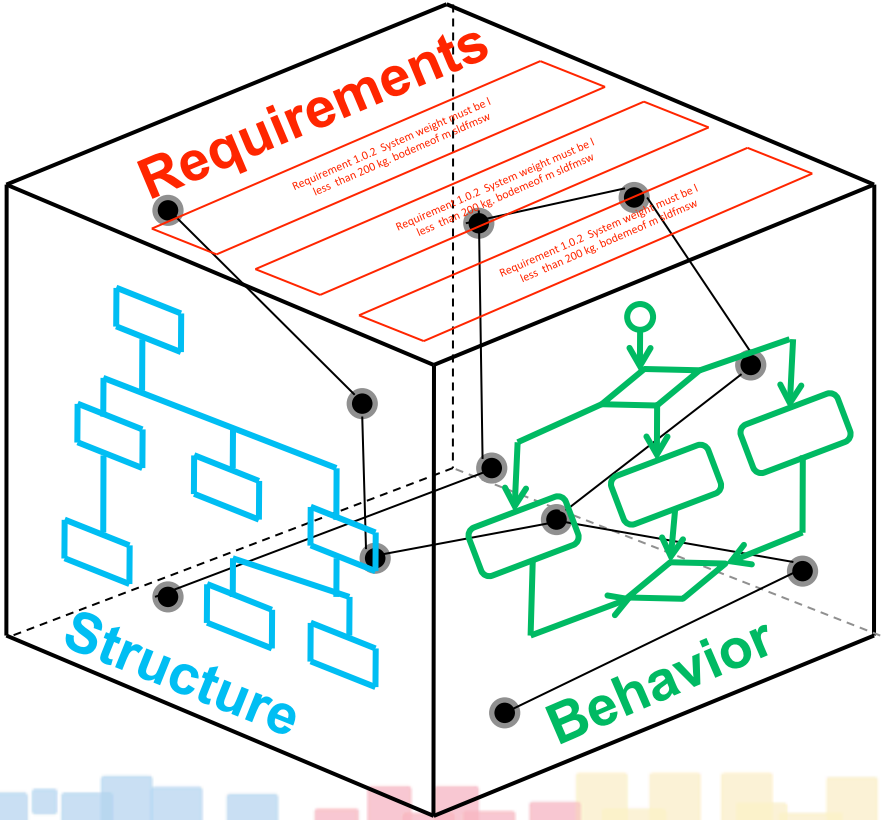


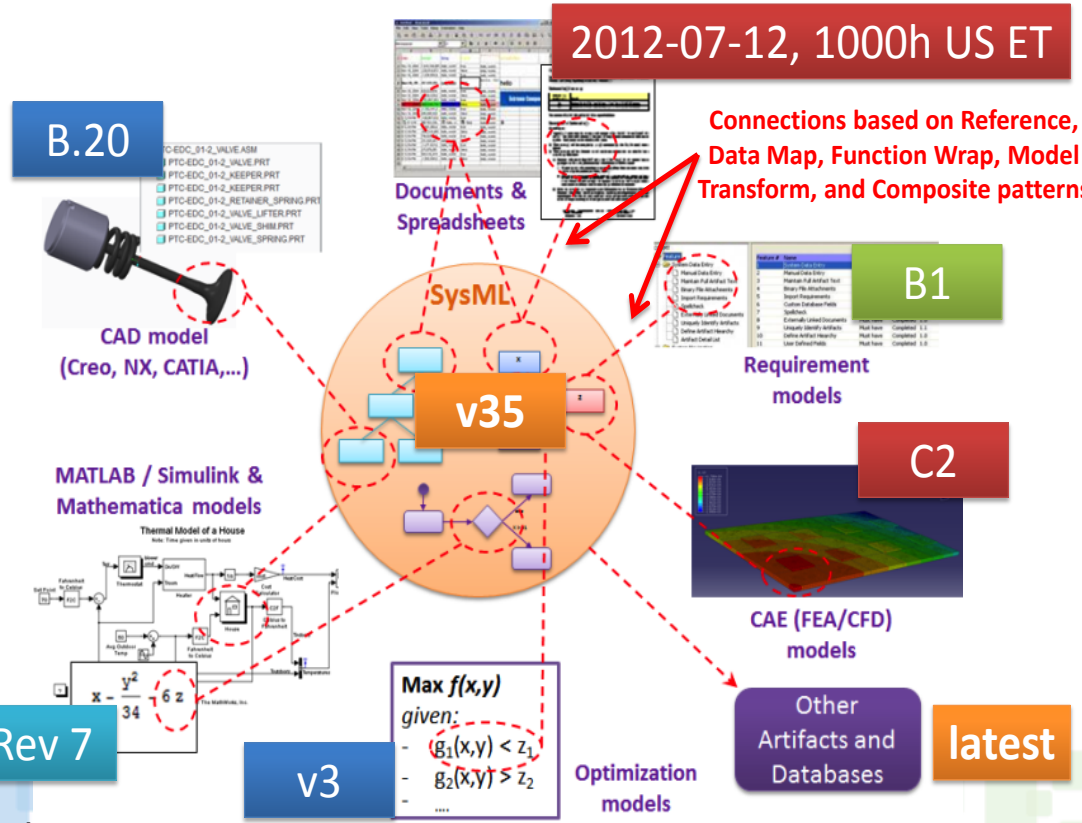
- MBSE = Unified model of the system versus series of disconnected documents (DBSE)
- System docs and views can be generated from this unified model
- DBSE > MBSE ⇔ 2D > 3D CAD
- Models in SE ≠ MBSE

DBSE > MBSE > MBSE++

- OMG SysML – 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++

TOTAL SYSTEM MODEL (TSM)



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

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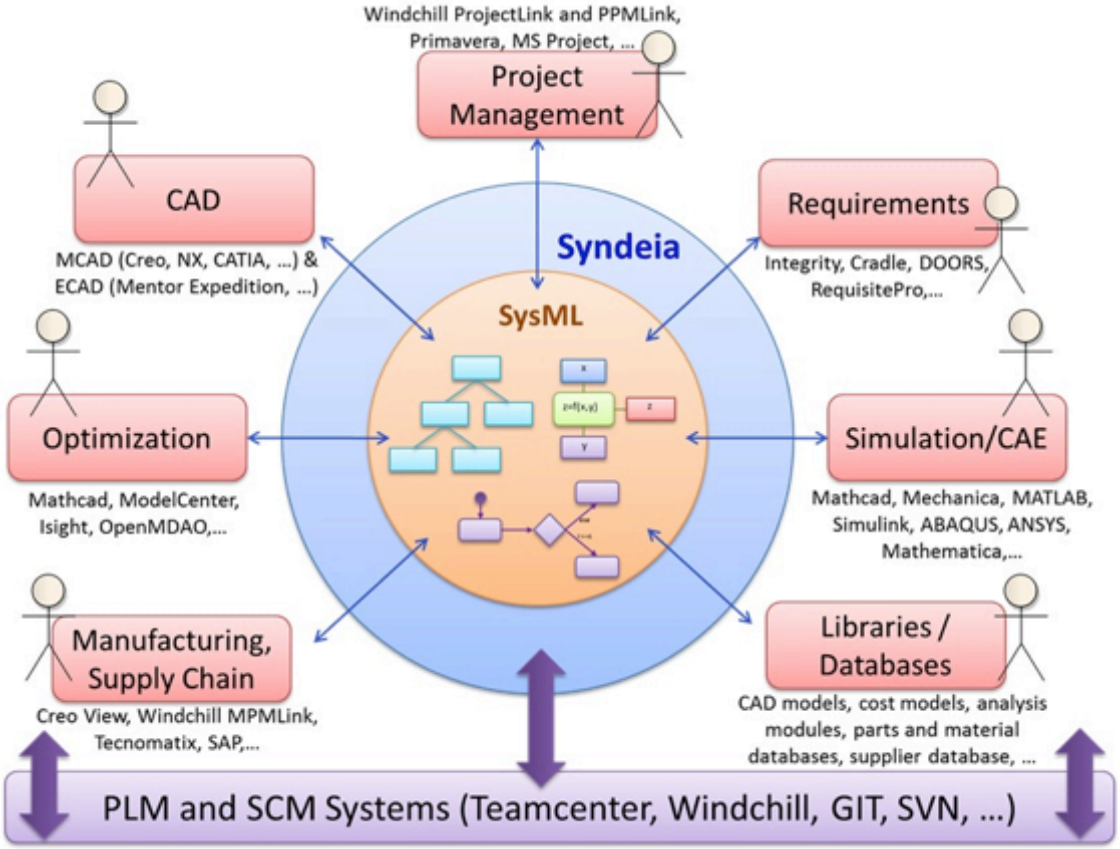
Syndeia = Software Platform for MBSE++



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

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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

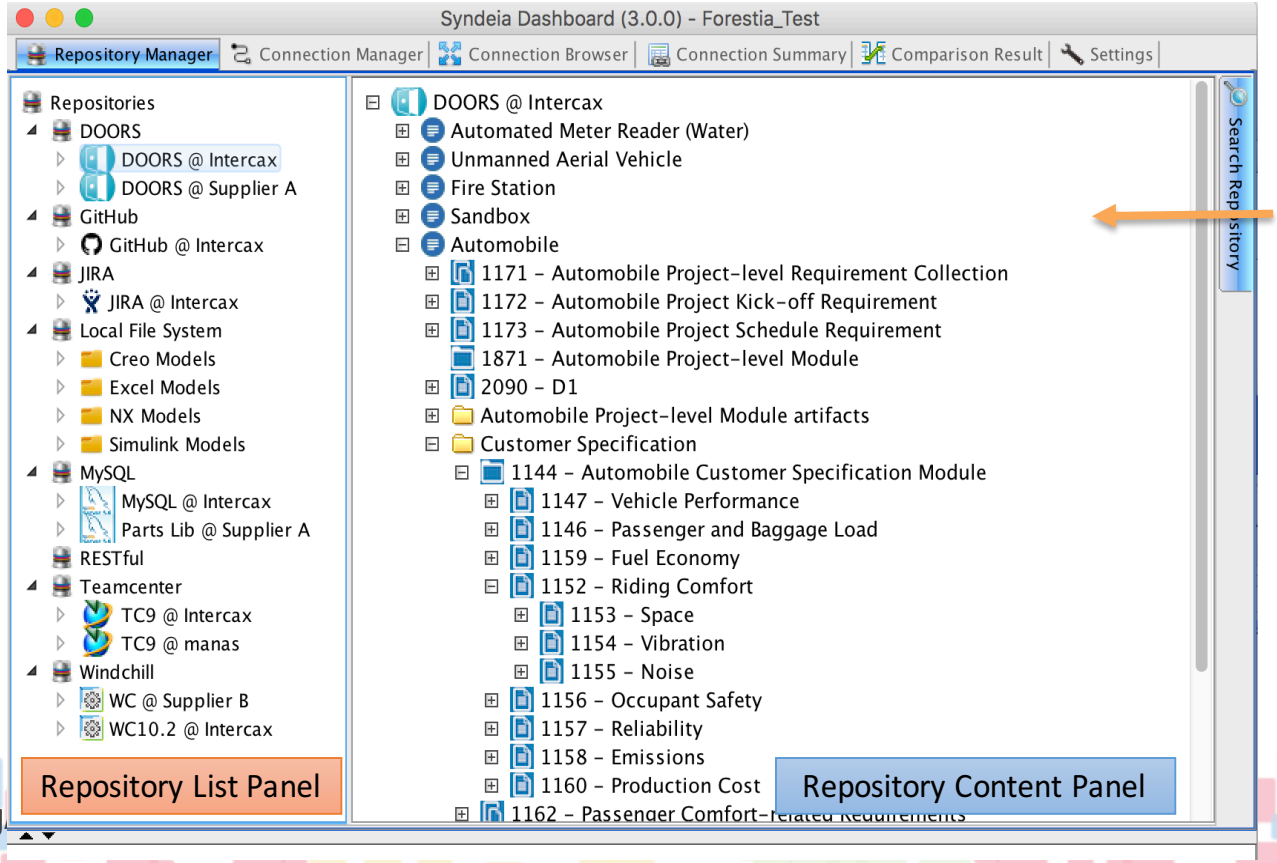
- Wide range of:
  - Modeling languages (SysML, Modelica, Simscape, XML, EXPRESS,...)
  - Data formats (XML, JSON,...)
  - APIs
  - Standards (ISO STEP, JDBC, FMI, OSLC,...)
  - Communication modes (Web services – REST, SOAP, File exchange,...)

1. Heterogeneous and Decentralized Data

(Screenshots from Syndeia -1/2)

Access multiple enterprise repositories

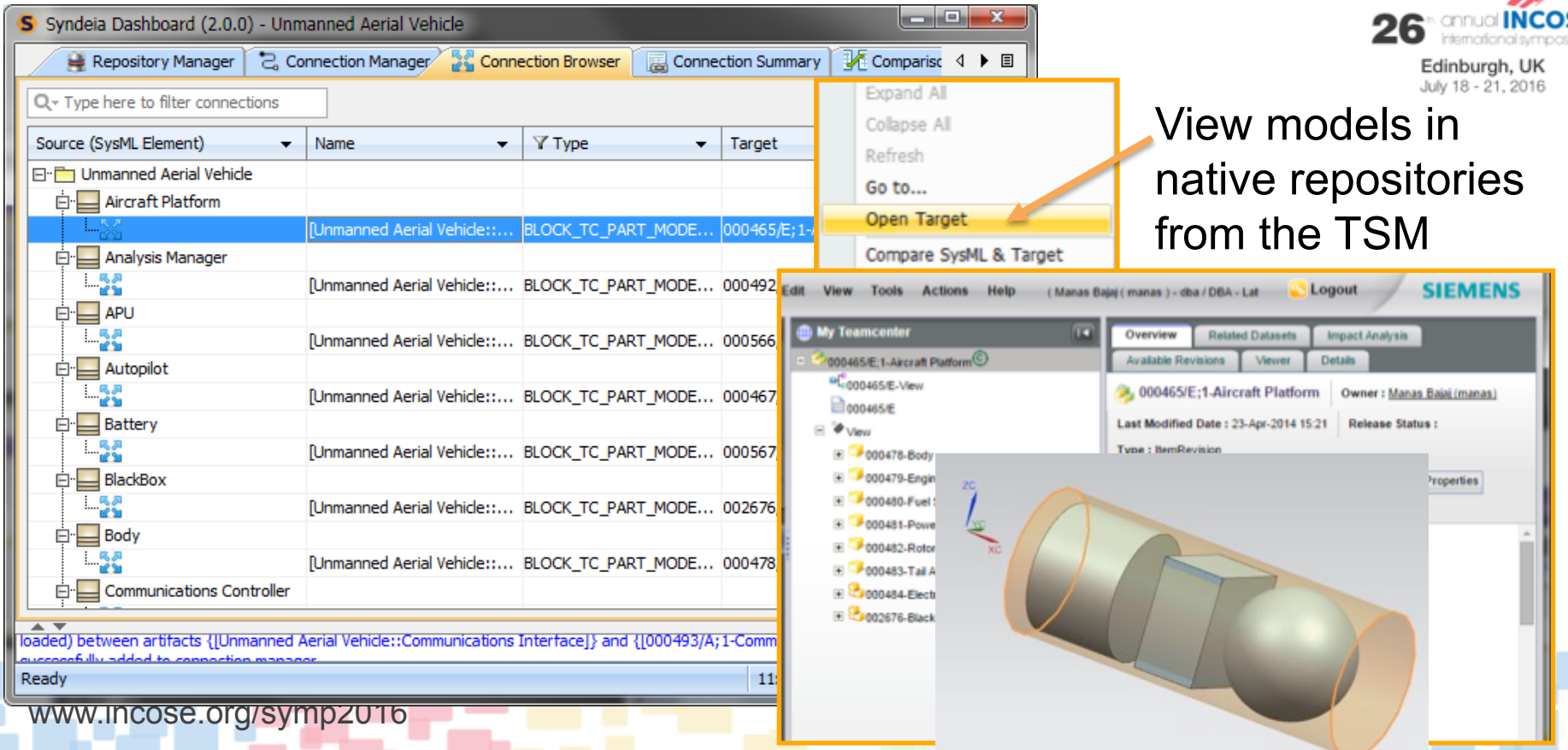
(PLM, ALM, Databases, Req. Mgt, Project Mgt, Drives)



Browse and search repository contents

1. Heterogeneous and Decentralized Data

(Screenshots from Syndeia -2/2)



View models in native repositories from the TSM

2. Capturing & Maintaining the High-level System Architecture

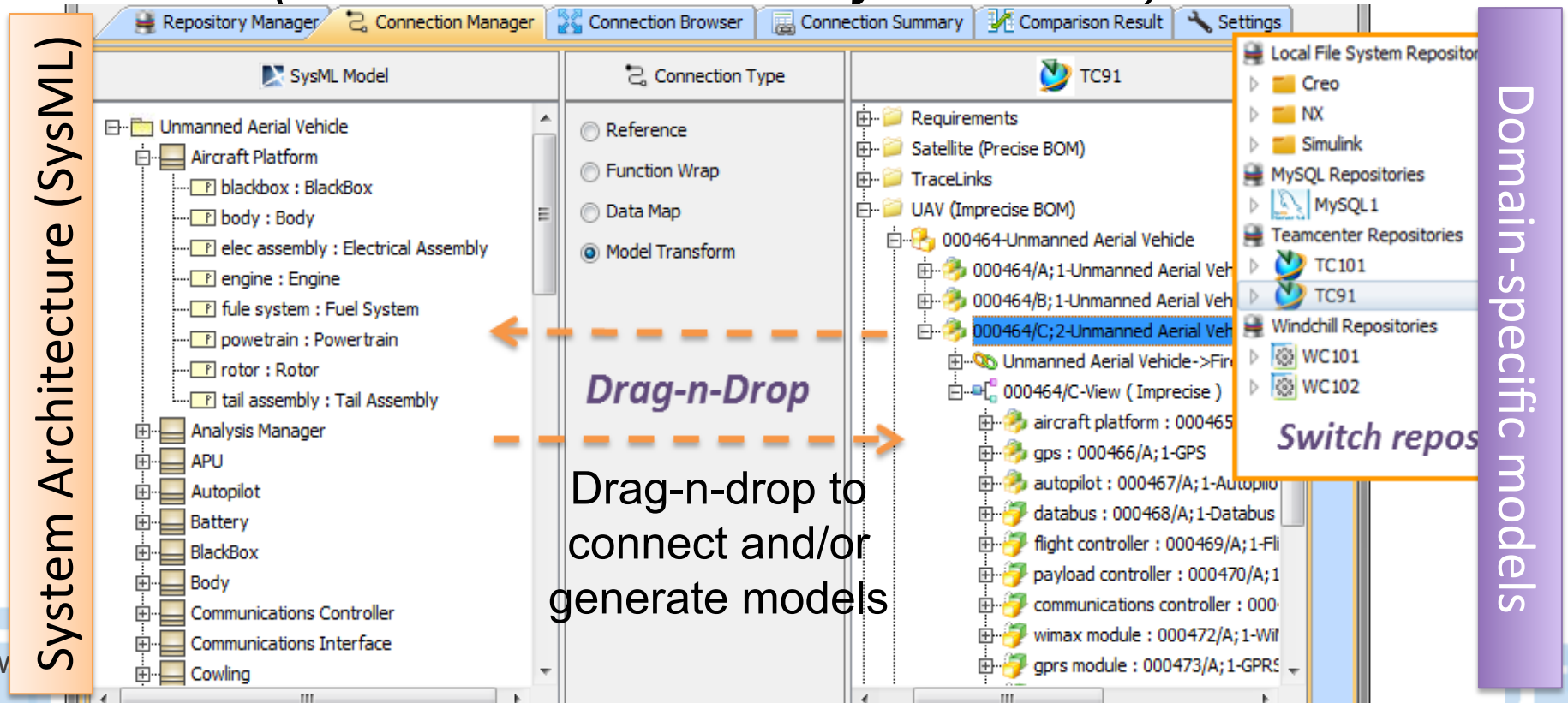
- Challenges
  - High-level system definition to coordinate and orchestrate disciplines – project management, mechanical/electrical design, simulation, software, part suppliers, and other vendors
  - Domain-specific models / specifications should be derived from system architecture, or vice versa, and 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

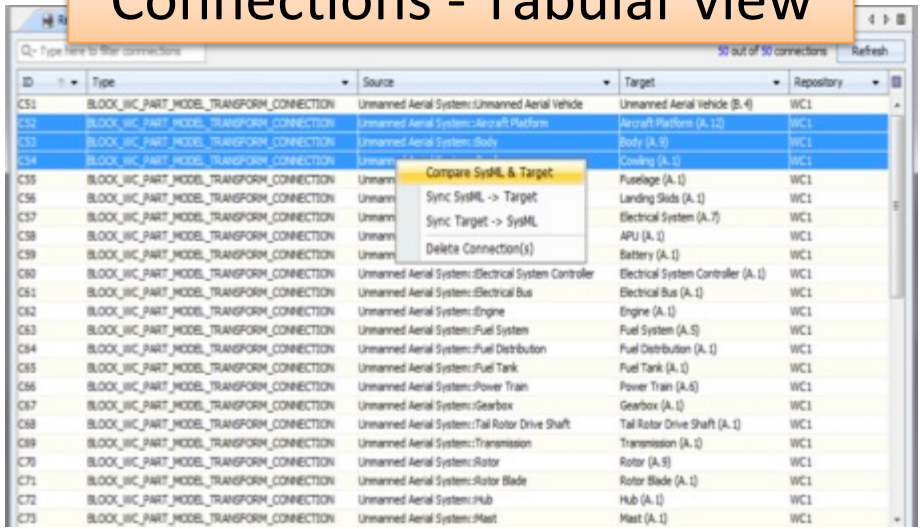
(Screenshots from Syndeia 1/2)



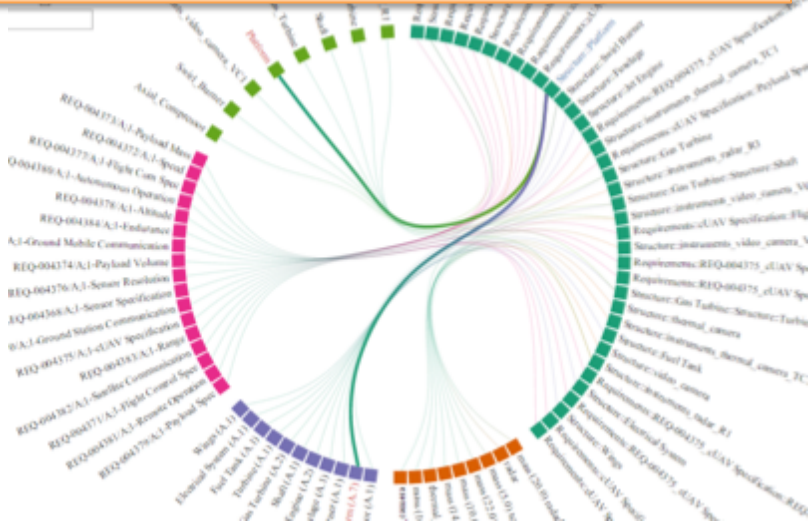
2. Capturing & Maintaining the High-level System Architecture

(Screenshots from Syndeia – 2/2)

Connections - Tabular view

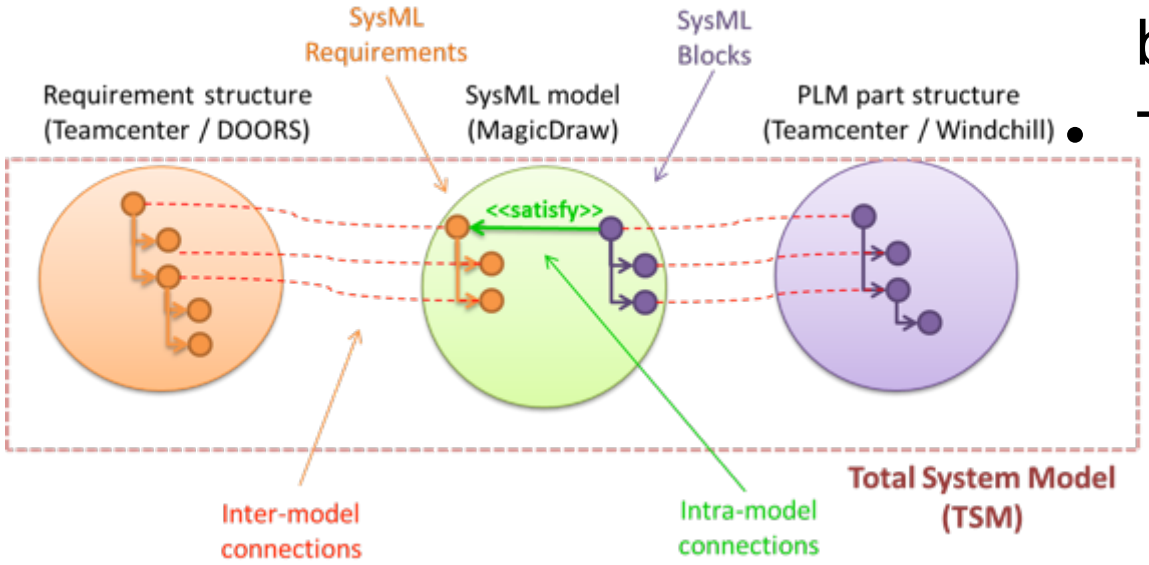


Connections – Graphical view



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

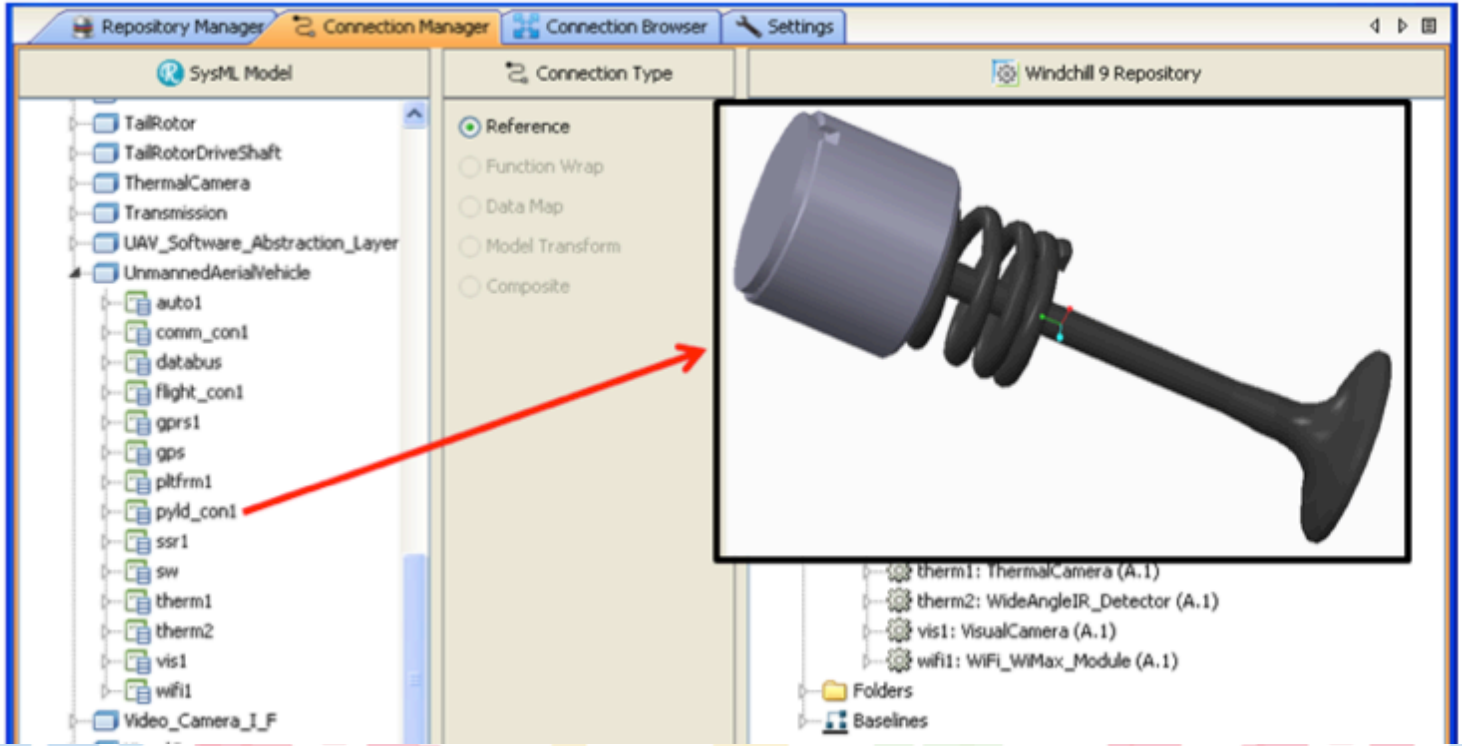
Function Wrap Connections
+ Track/execute connection elements

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

3. Spectrum of Model-Based Connections

(Screenshots from Syndeia – 1/4)

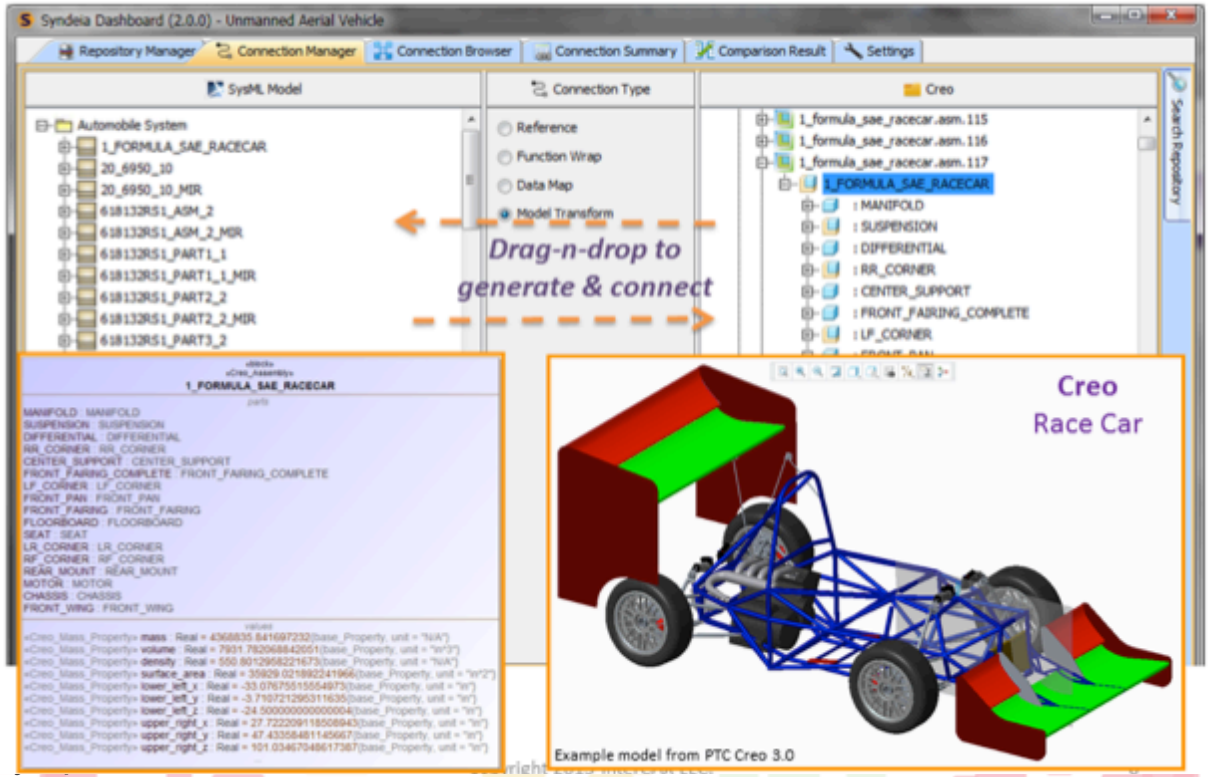
Reference connection between SysML and CAD to track/view 3D geometry



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)

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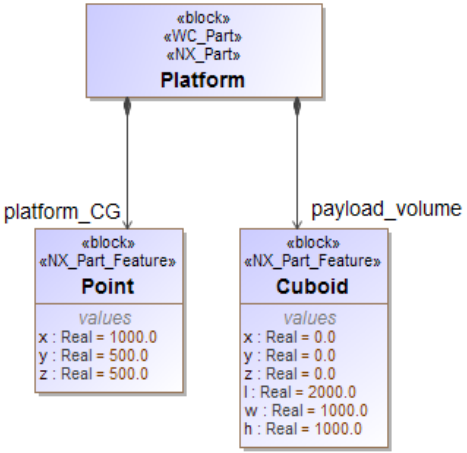
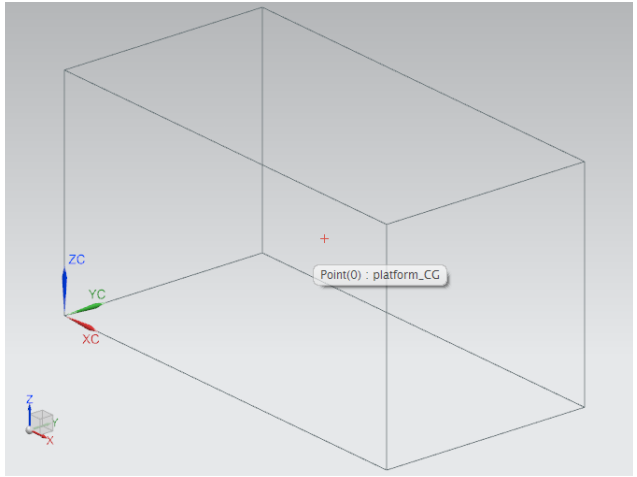
Model Transform connection to seed sub-system bounding boxes from property-based requirements



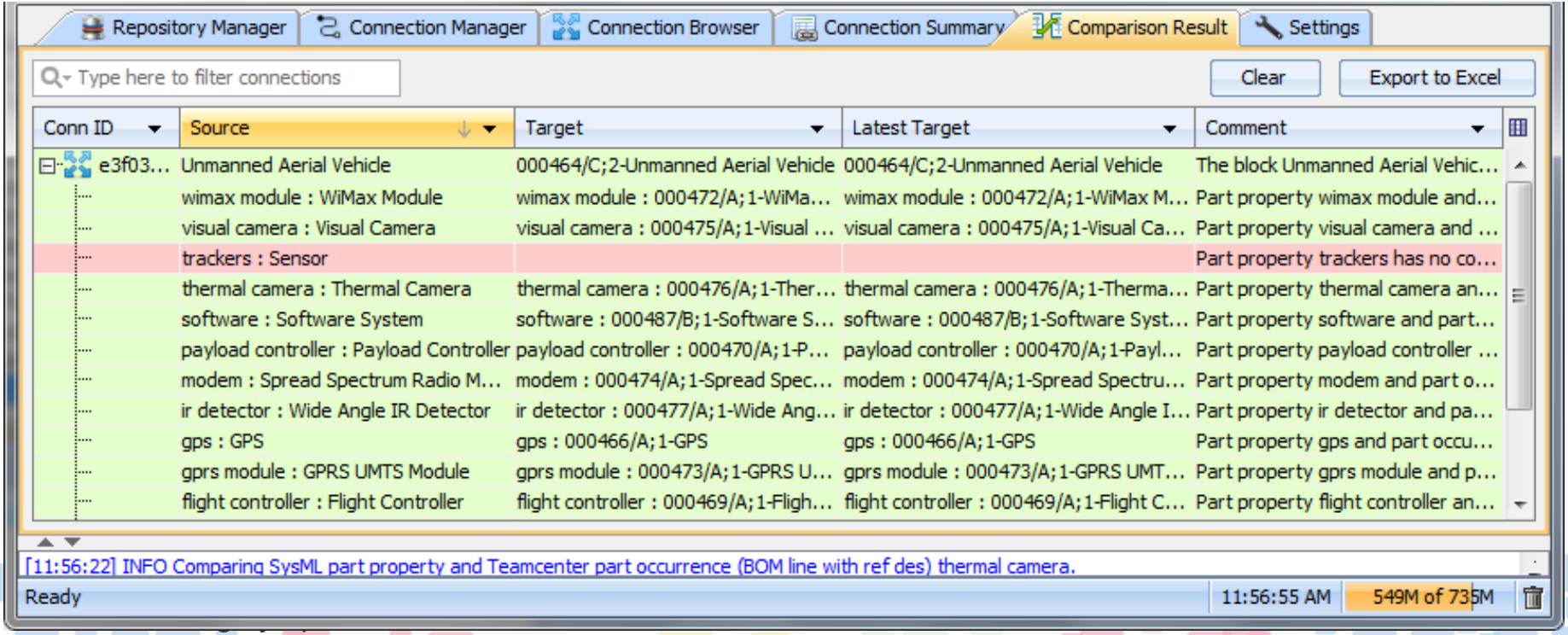
Seed system constraints (bounding boxes, keepout-zones,…) from the architecture



3. Spectrum of Model-Based Connections

(Screenshots from Syndeia – 4/4)

Compare and bi-directional sync across connections



4. Unified Framework for Model-Based Connections

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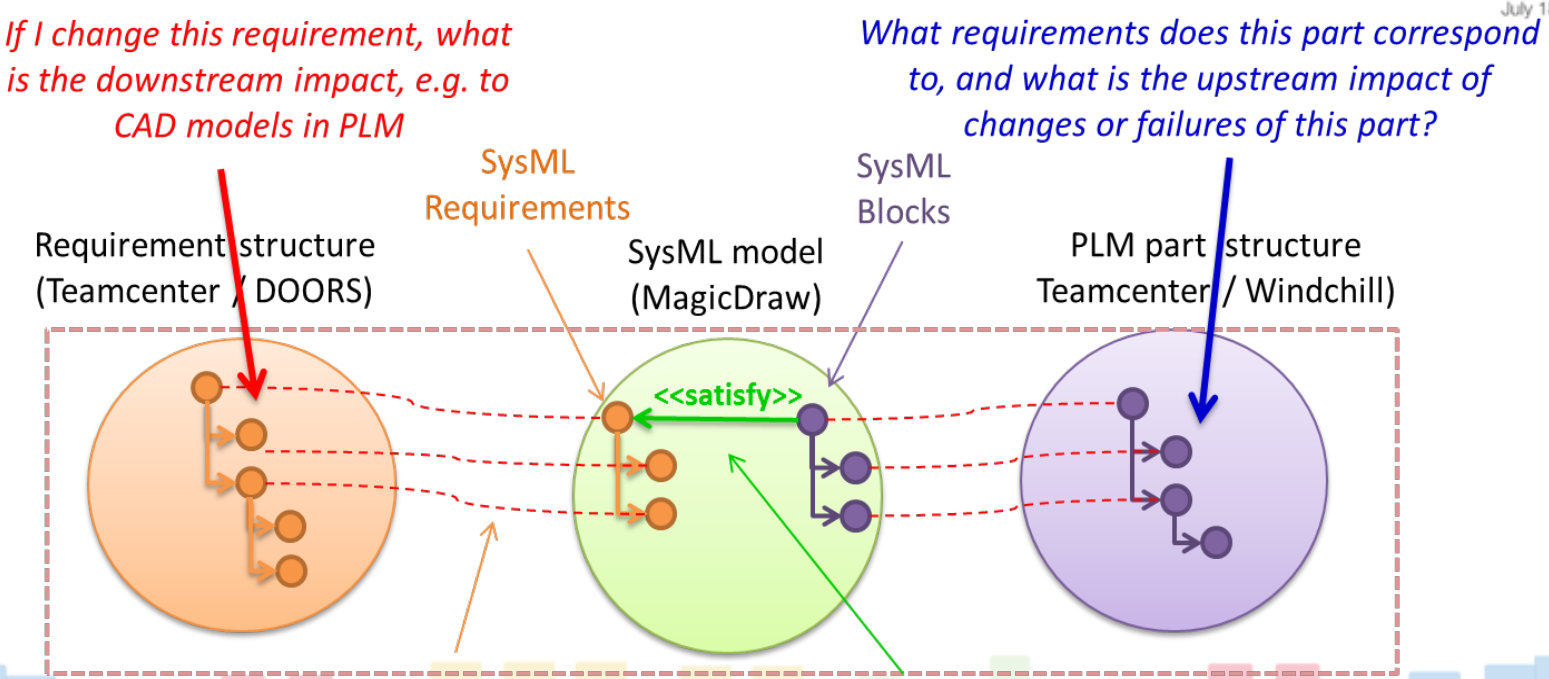
- A unified model-based engineering framework is needed to traverse both:
  - Inter-model connections (across model boundaries)
  - Intra-model connections (within model boundaries)

4. Unified Framework for Model-Based Connections

- Use Cases (example)



5. From Traceability to Impact

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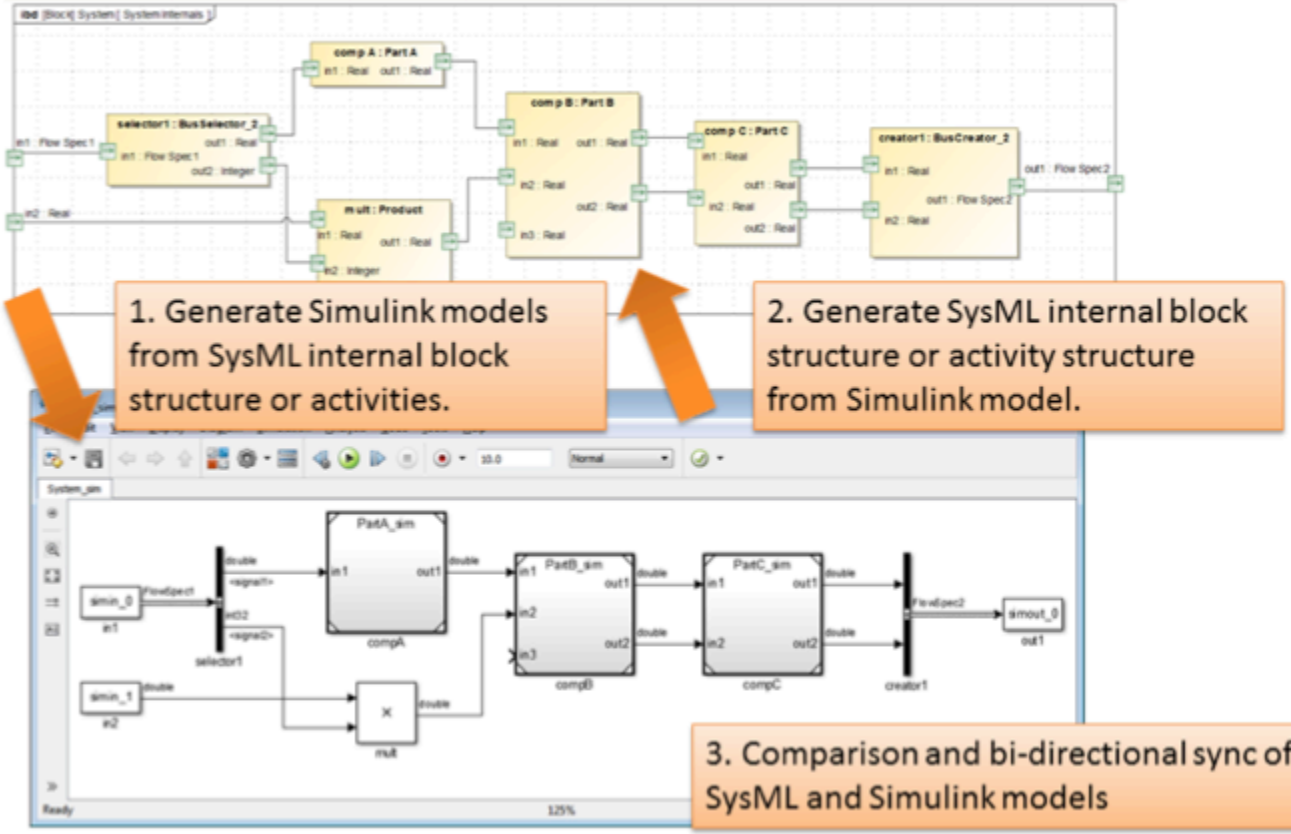
- Traceability is a starting point but not sufficient
- How do we create and manage millions of model-based connections for a real system?
  - Model transformations > Generate connections
- How do we propagate changes in one model to another model - quantitatively beyond suspect links?
  - Executable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

5. From Traceability to Impact

(Screenshot from Syndeia transformations)

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



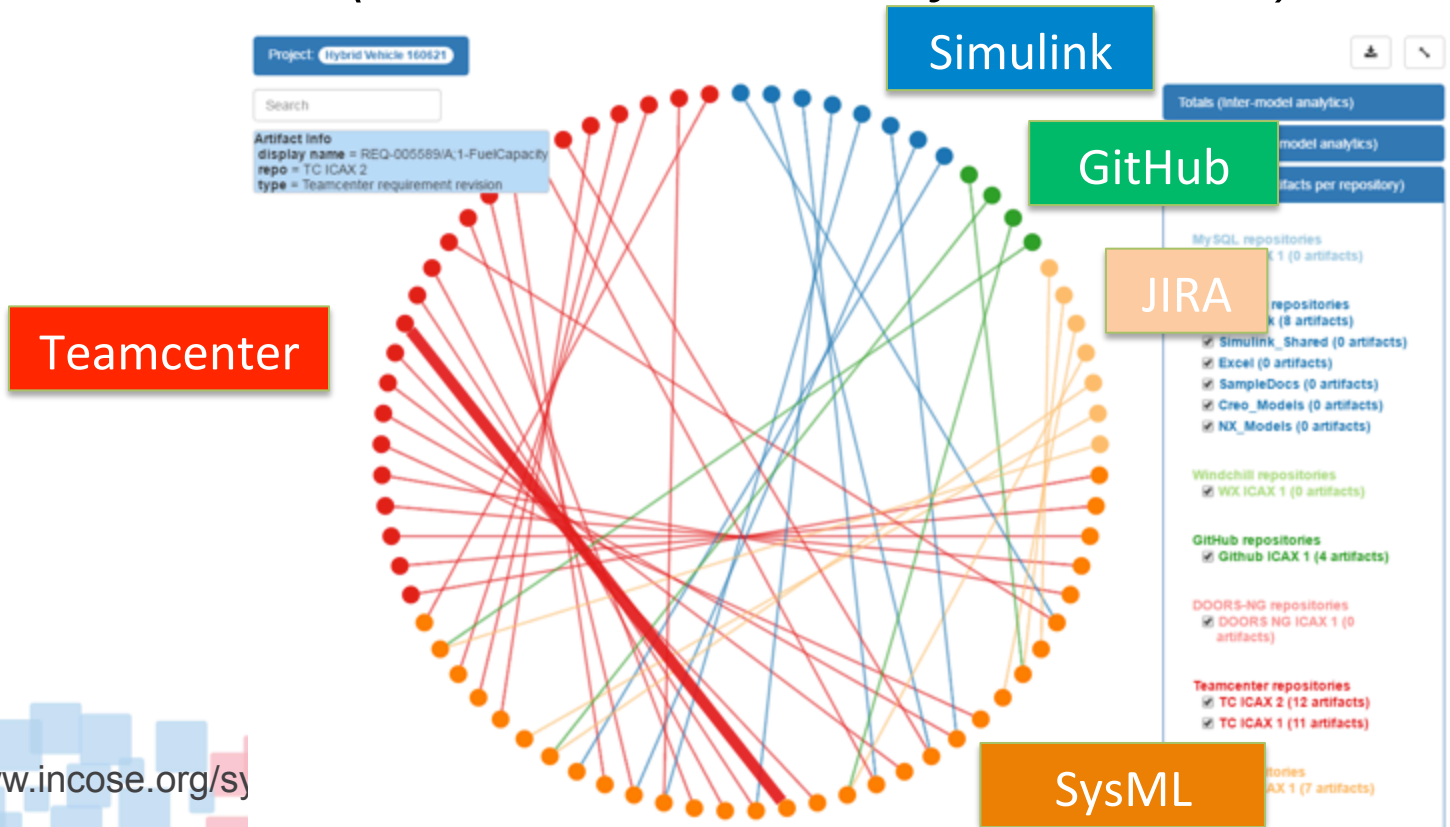
6. Many Users, Many Views

- 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

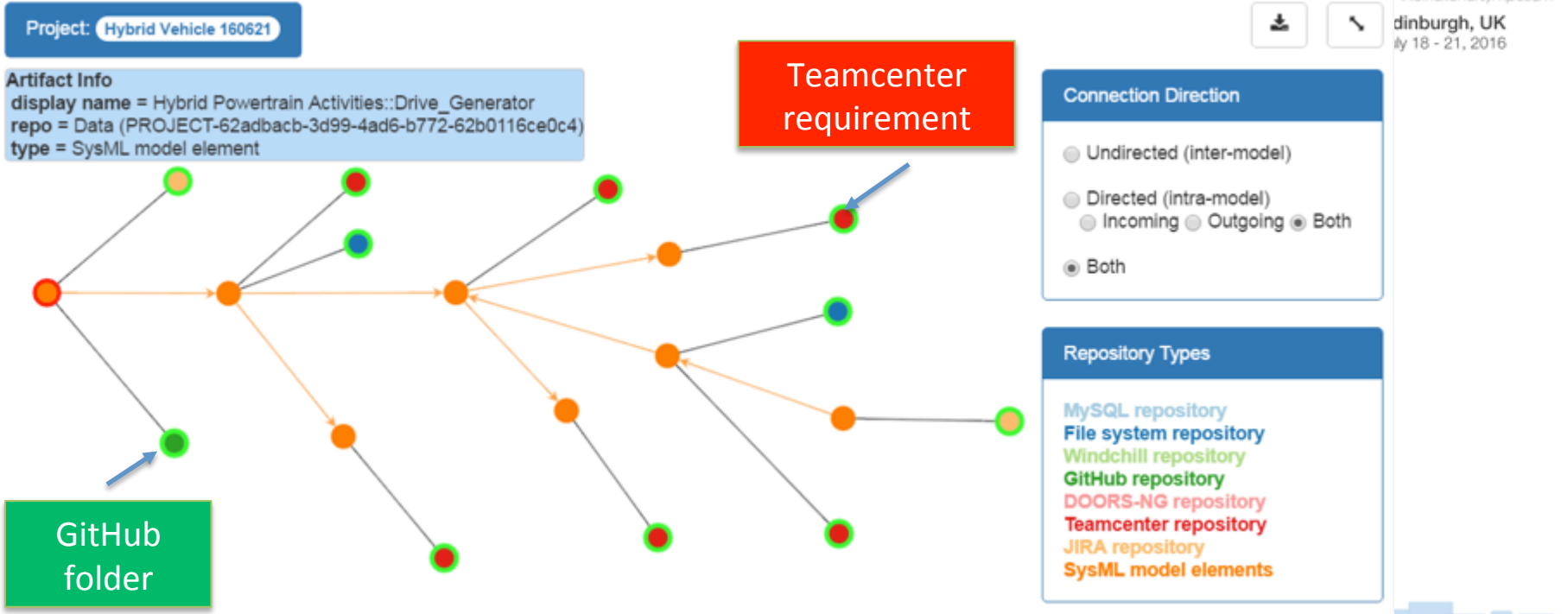
(Screenshots from Syndeia – 1/3)



6. Many Users, Many Views

Explore inter- and intra-model connections

(Screenshots from Syndeia – 2/3)

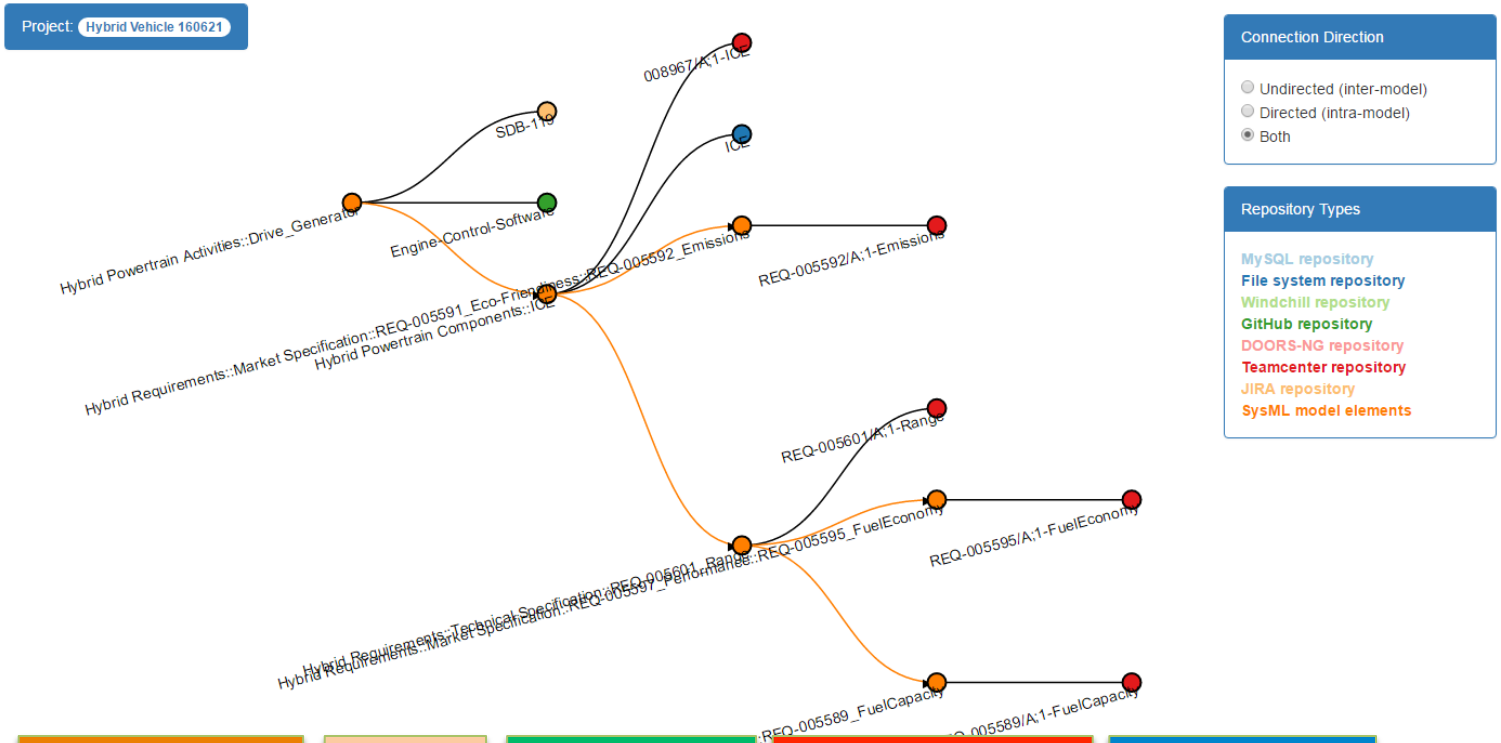


SysML | JIRA | GitHub | Teamcenter | Simulink

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

Corresponding Author

Manas Bajaj, PhD

manas.bajaj@intercax.com

+1-404-775-4287

www.linkedin.com/in/manasbajaj

intercax syndeia /company/intercax-llc

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