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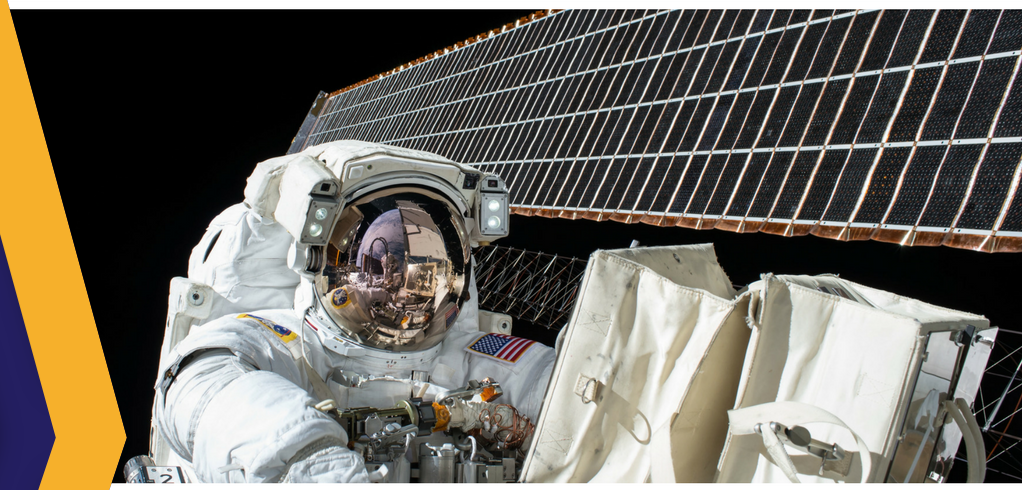
Graph-Based Digital Blueprint for Model Based Engineering of Complex Systems

INCOSE International Symposium, Jul 15-20, Adelaide

Session 2.1.2, Hall L



Authors

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Lockheed Martin – Jonathan Backhaus, Timothy Walden, Chris Schreiber

About Intercax

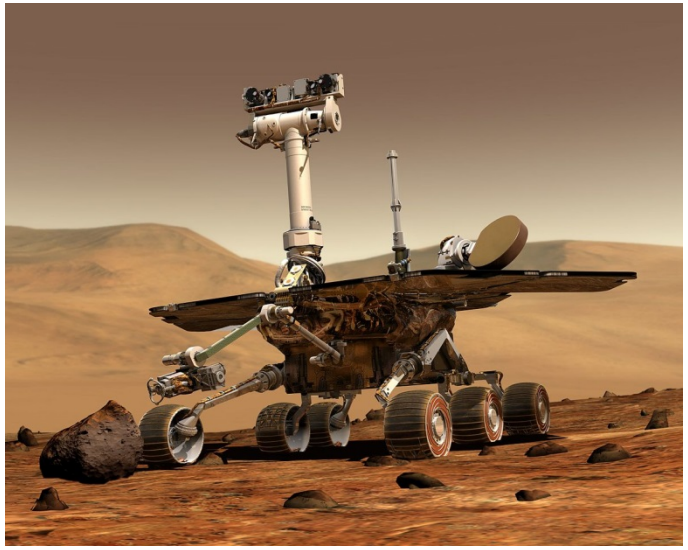
- Georgia Tech spin-off 2008
- Atlanta, US (HQ) and Pune, India
- **Focus**: Software for MBE/MBSE
  - **Syndeia –** MBSE (SysML) + PLM/ CAD/CAE/Data/Simulations
  - SysML parametric solvers (**ParaMagic**, **Melody**, **Solvea**, & **ParaSolver**)
- Training, consulting, custom apps
  - 4500+ participants since 2008
- Customers
  - Gov.: NASA, DoD, DoE, DoC
  - Commercial: aero, auto, transportation, consumer goods, energy, mfg., healthcare

Systems – Cyber-physical, Multi-Disciplinary, System-of-Systems

Smart Home

Hybrid/Electric/Self-Driving Cars

Robotic / Smart Manufacturing



Rovers

Smart Energy Grids

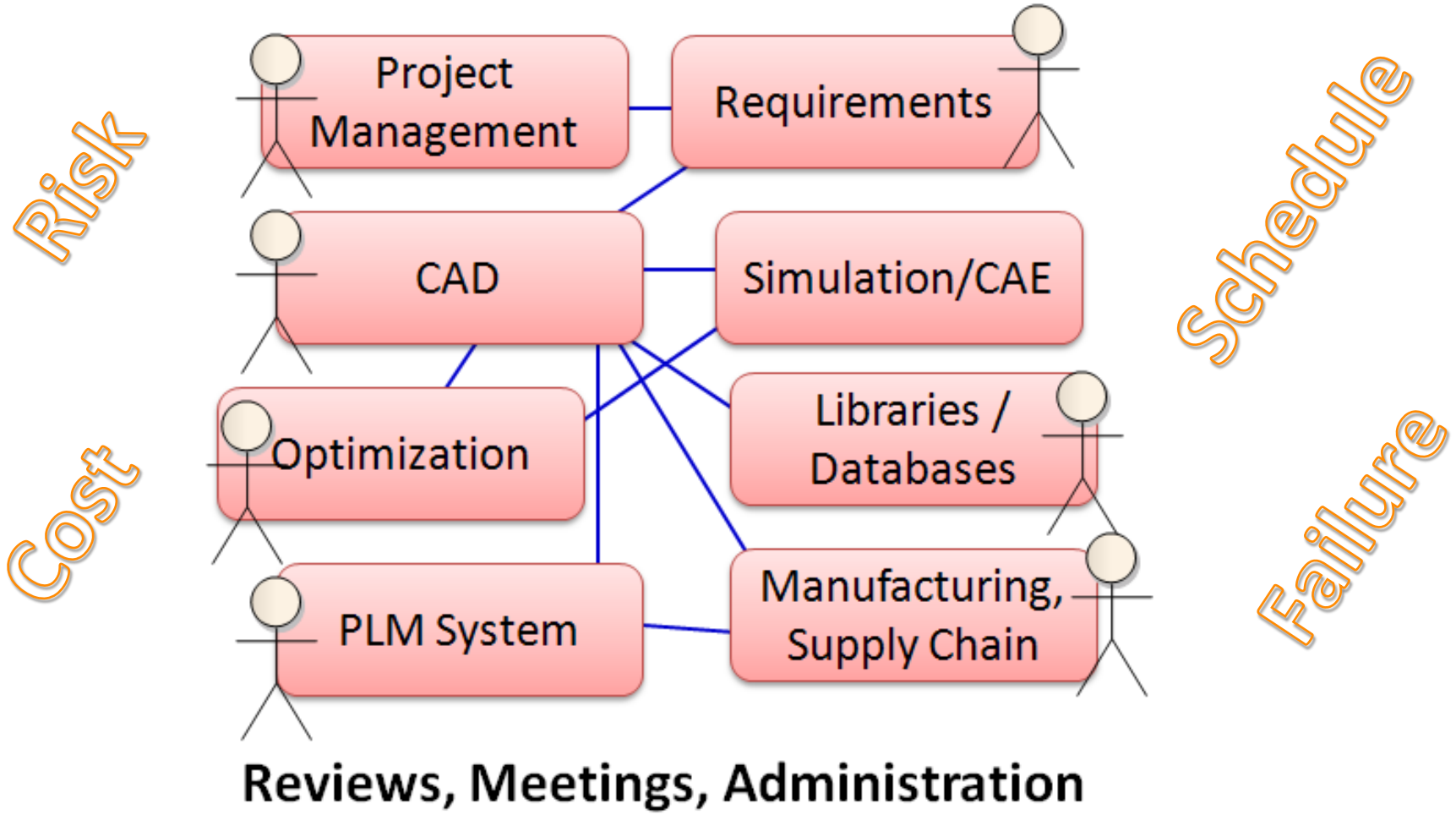
Healthcare

What is common across all these systems?

- **What is common to all these systems?**
  - Multi-disciplinary, many teams of engineers, project managers, suppliers, and more
  - Hardware, software, human, robotic sub-systems
  - Many software tools & databases (Systems, PLM, CAD, ALM, Simulation, and more)
  - Manage across lifecycle (conceptual -> design -> manufacturing -> service -> disposal)
- **Where are the biggest challenges in developing these systems?**
  - Managing interfaces between sub-systems
  - Assessing impact of changes, “what-if” analyses and trade-offs
  - Managing variants and options
  - Resilience to failure
  - Reducing margins for error (0 margin for mission- and life-critical systems)
  - Cost, time-to-market and competition

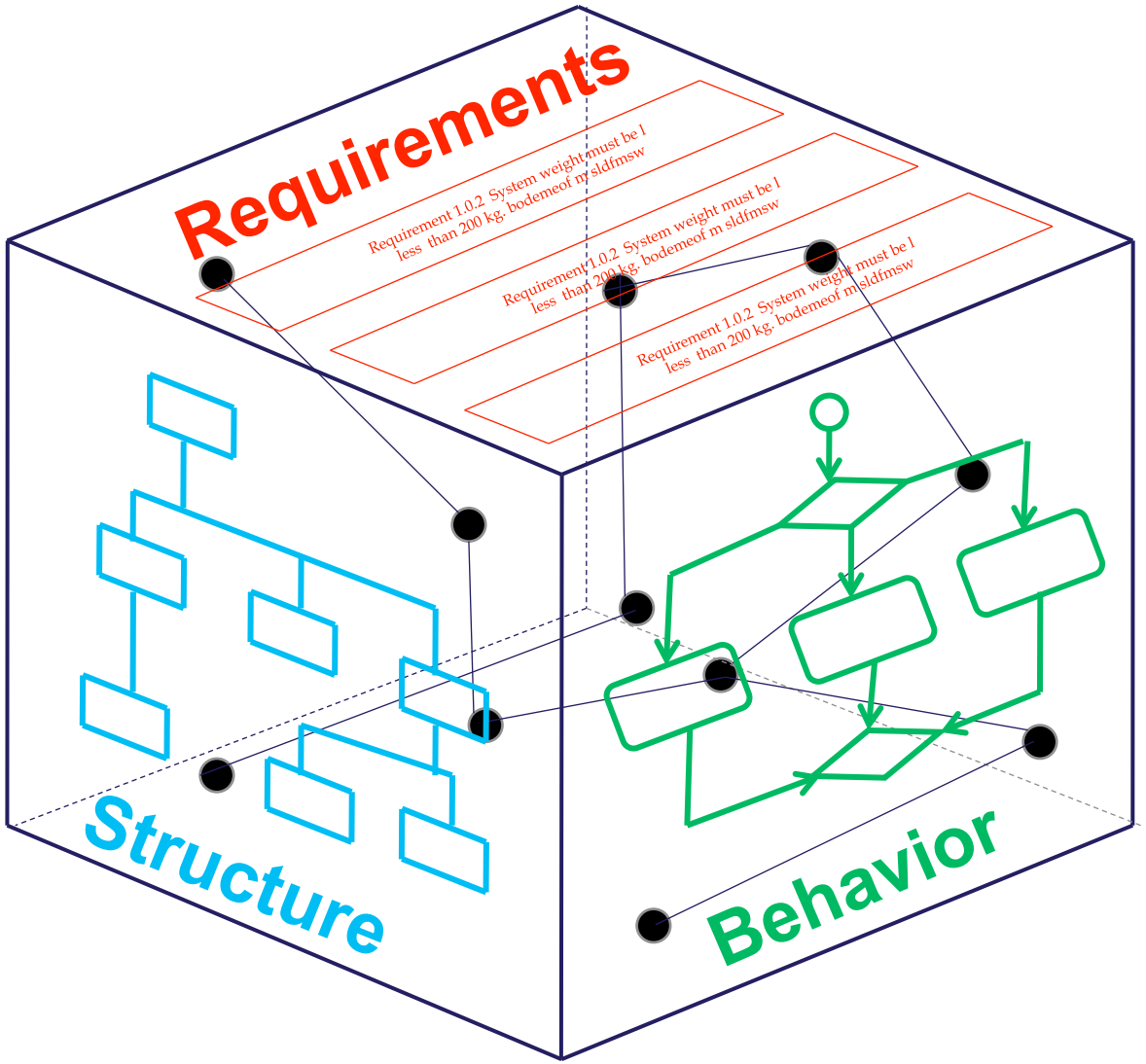
Where is the system architecture / blueprint?

Point-to-point ad-hoc information flows without a common architecture model



Use of models in each engineering discipline is not model-based systems engineering

What is Model-Based Systems Engineering?

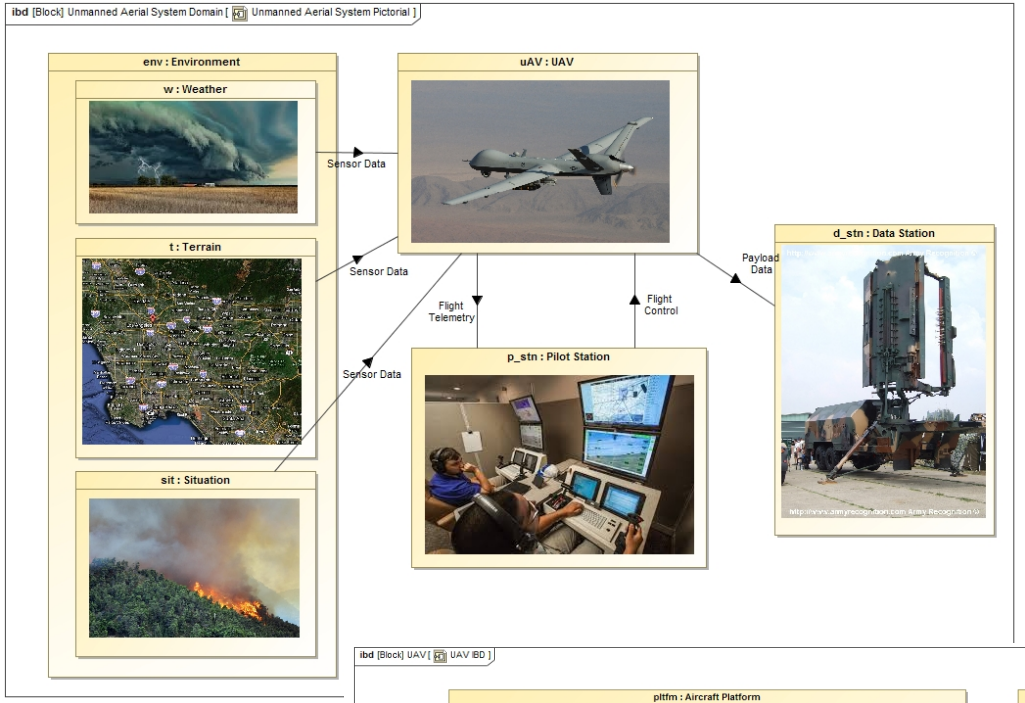


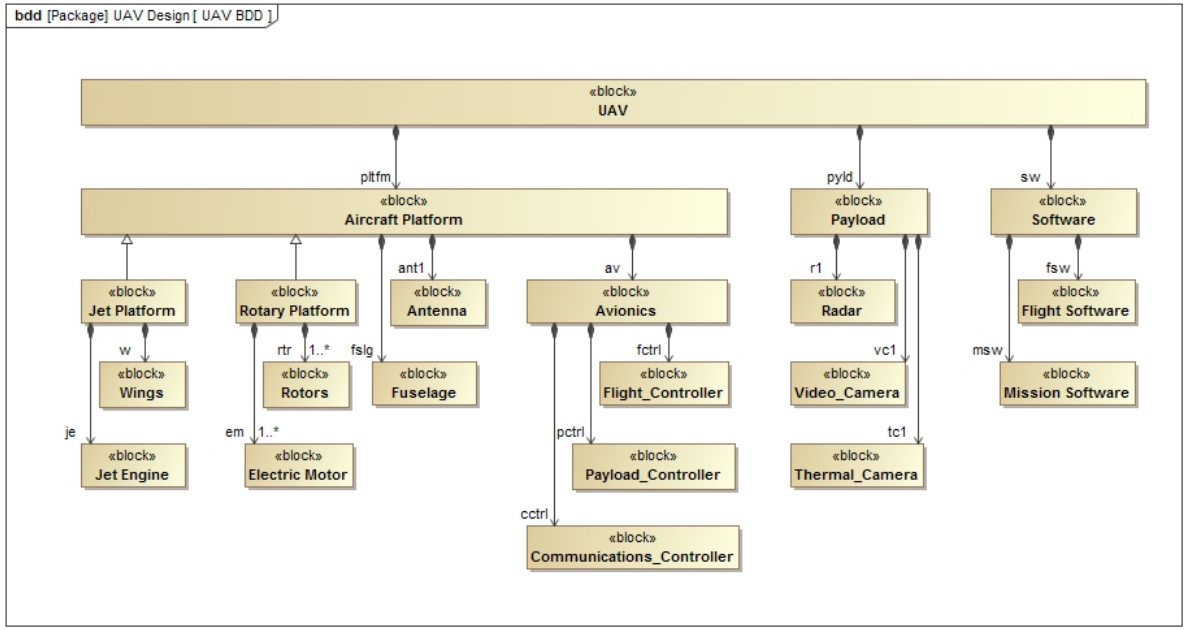
- MBSE = Unified model of the system versus series of disconnected documents or document-based flows between models (DBSE)
- System docs and views can be generated from this unified model
- DBSE > MBSE ⇔ 2D > 3D CAD
- Models in SE ≠ MBSE

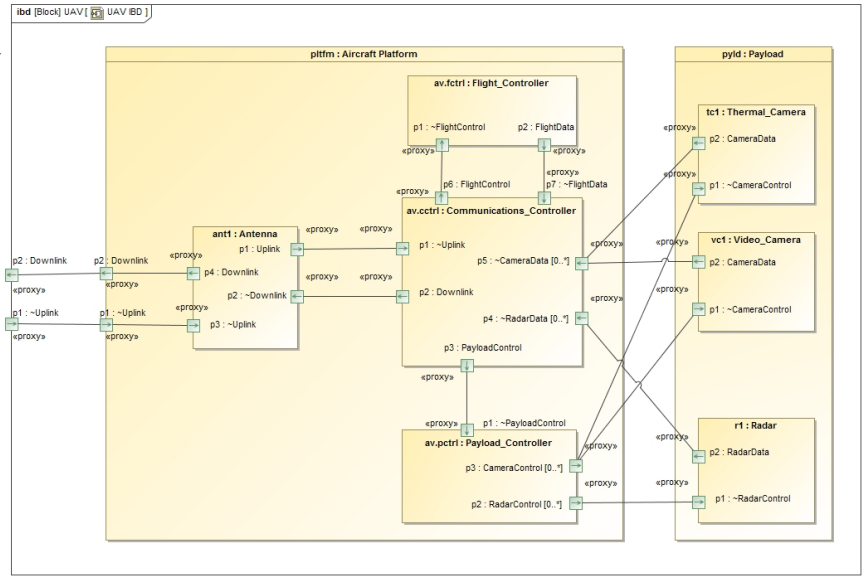
Systems Modeling Language (SysML) – Object Management Group

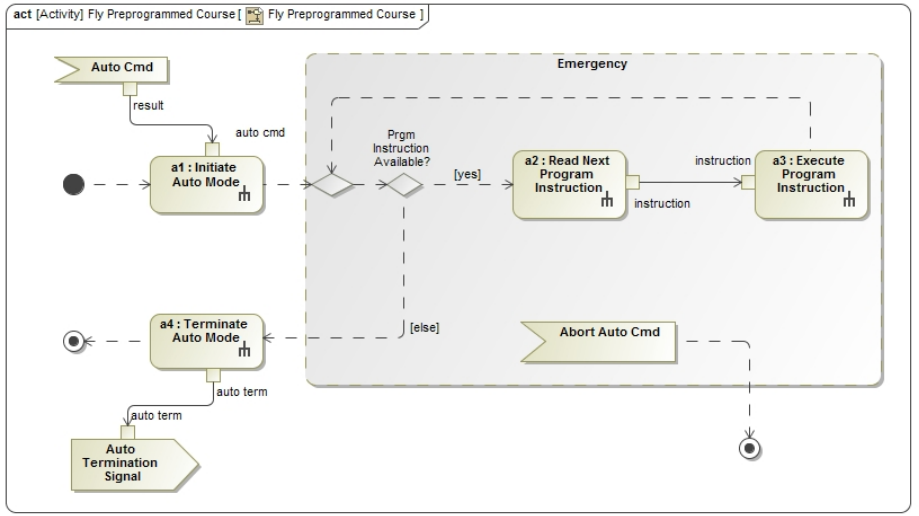
- **SysML is a visual modeling language** that provides:
  - **Semantics** = meaning
  - **Notation** = representation of meaning
- SysML is *not* a methodology or a software tool
  - SysML is methodology-independent & tool-independent
  - Multiple vendor tools support the SysML language
- Supports the specification, analysis, design, verification, and validation of systems that include hardware, software, data, personnel, procedures, and facilities
- History
  - 2003 - UML for Systems Engineering RFP by OMG, INCOSE and ISO 10303 AP233
  - 2007 - SysML 1.0 released
  - 2017 - SysML 1.5 released in May 2017
  - 2019 - SysML 2.0 planned release
- http://www.omgsysml.org/ for more information on OMG / ISO IEC SysML standard
- http://www.omgsysml.org/news-articles.htm - publications demonstrating real production use

Example views (diagrams) in a SysML model

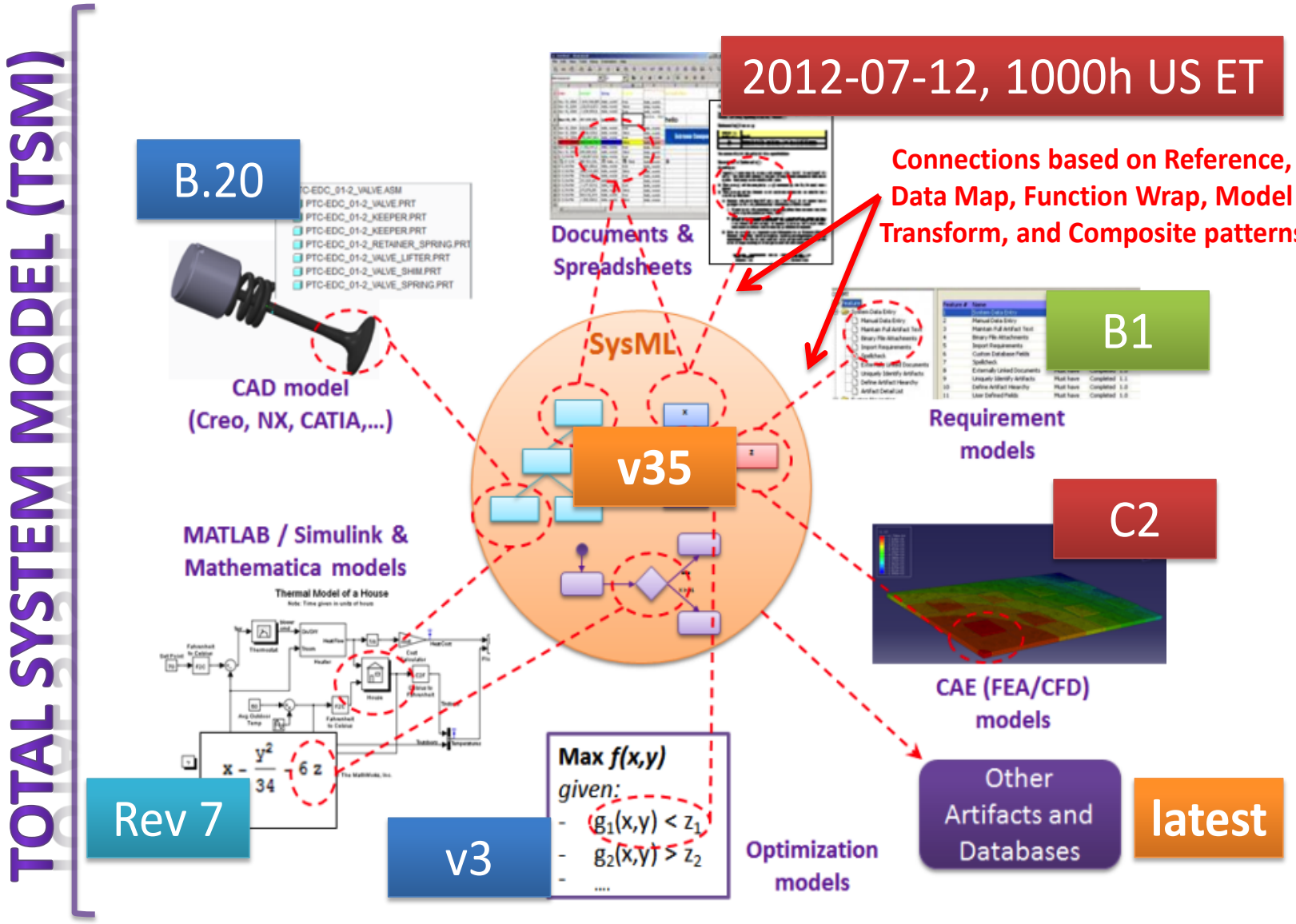








Total System Model – A Federated *Graph*



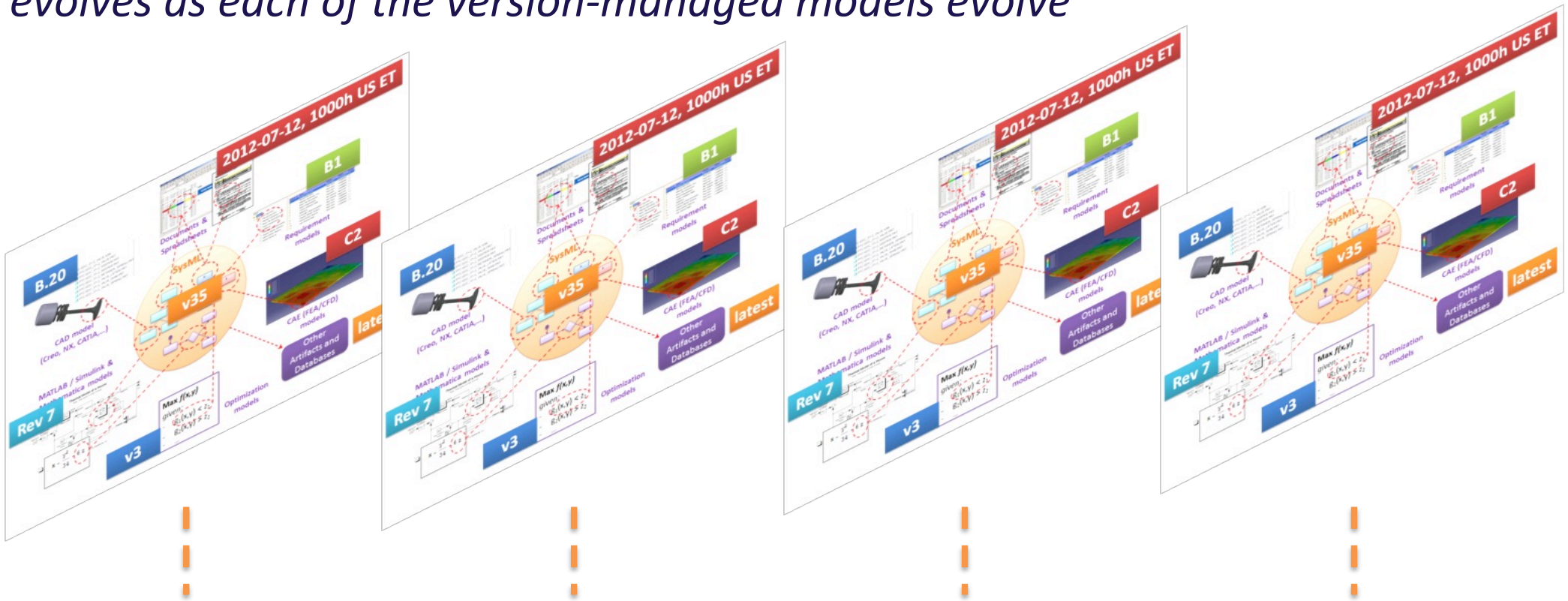
Connect architecture model (SysML) with domain-specific models

Total System Model (TSM) as a digital blueprint of the system connecting models across disciplines, tools, and version-management systems

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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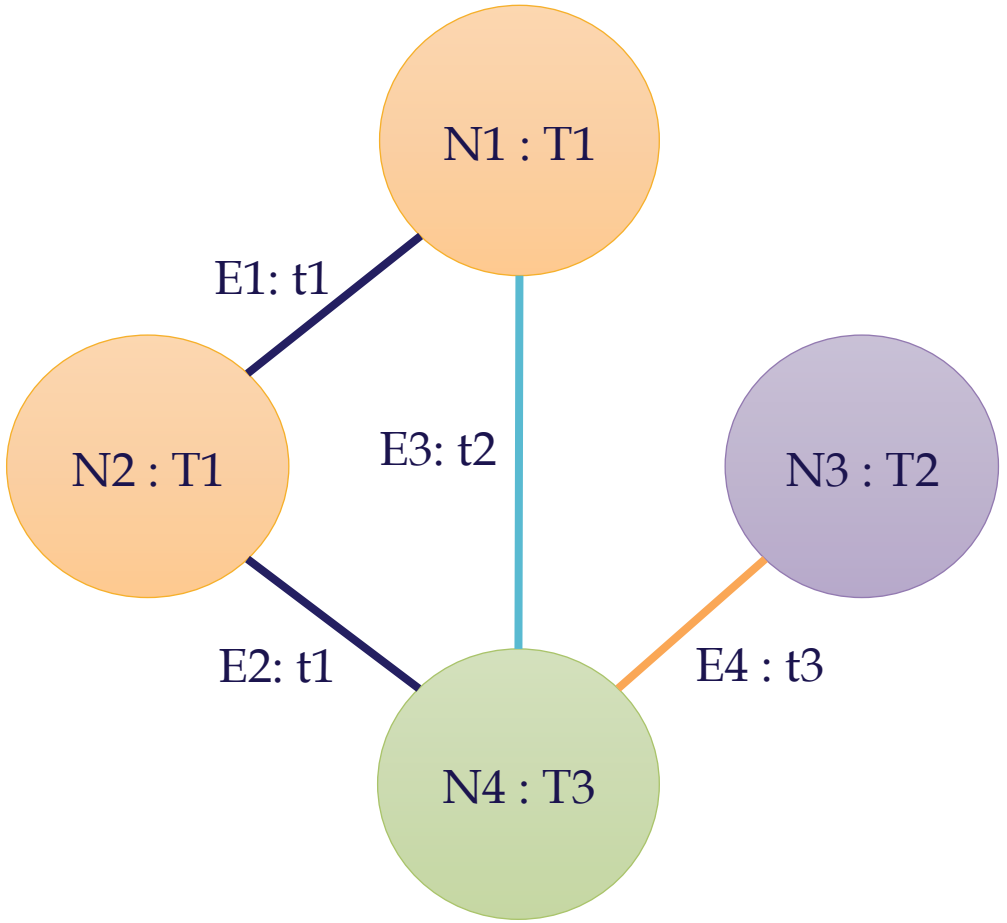
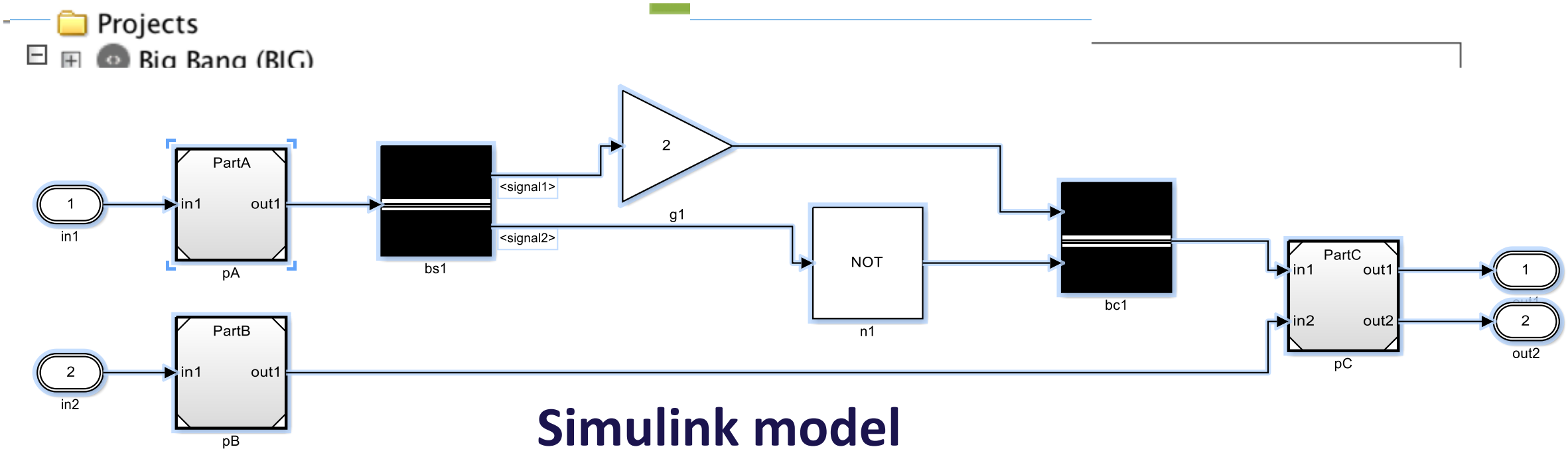
Total System Model is a Graph-based Digital Blueprint of a System

Graph

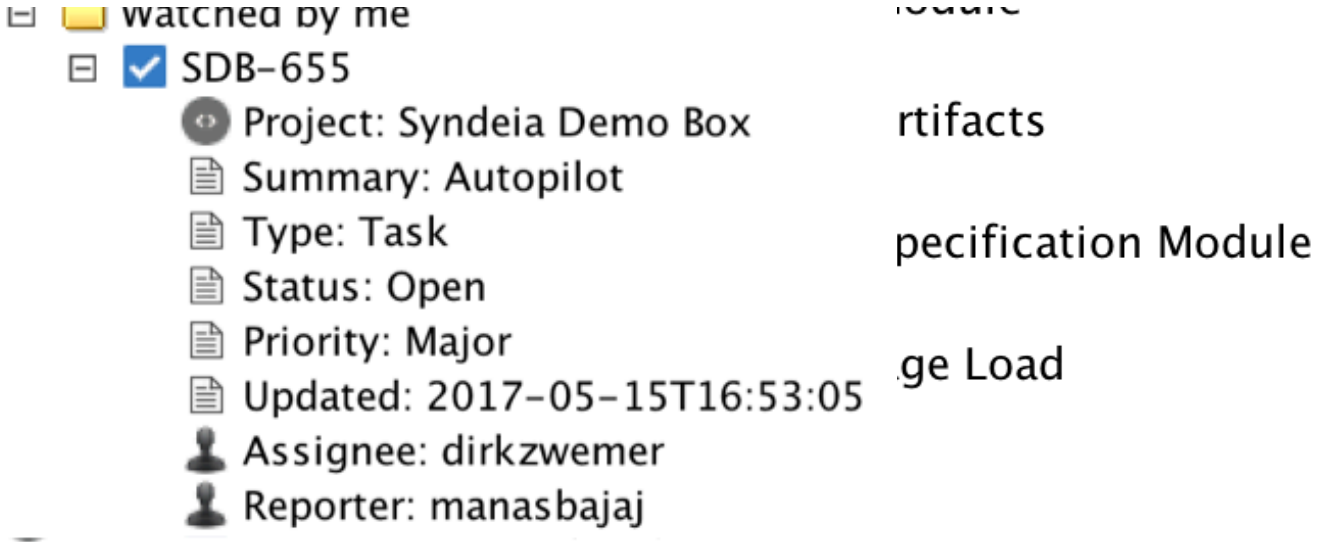
- Graph – Nodes and Edges
- Nodes and Edges may have
  - Name
  - Type (Typed Graph)
  - Properties (Property Graph)
- Edges may have
  - Direction (Directed vs. Undirected Graph)
- Graphs can be
  - Stored
  - Queried (Pattern matching)
  - Traversed (e.g. Breadth-first, Depth-first)
  - Generated and Transformed
  - Analyzed

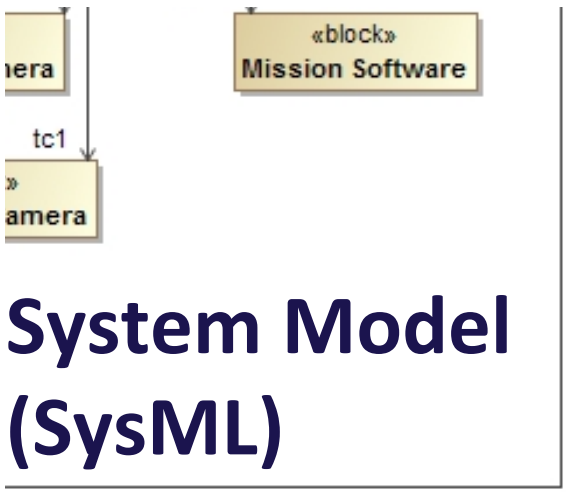


Information models can be abstracted as graphs



Simulink model



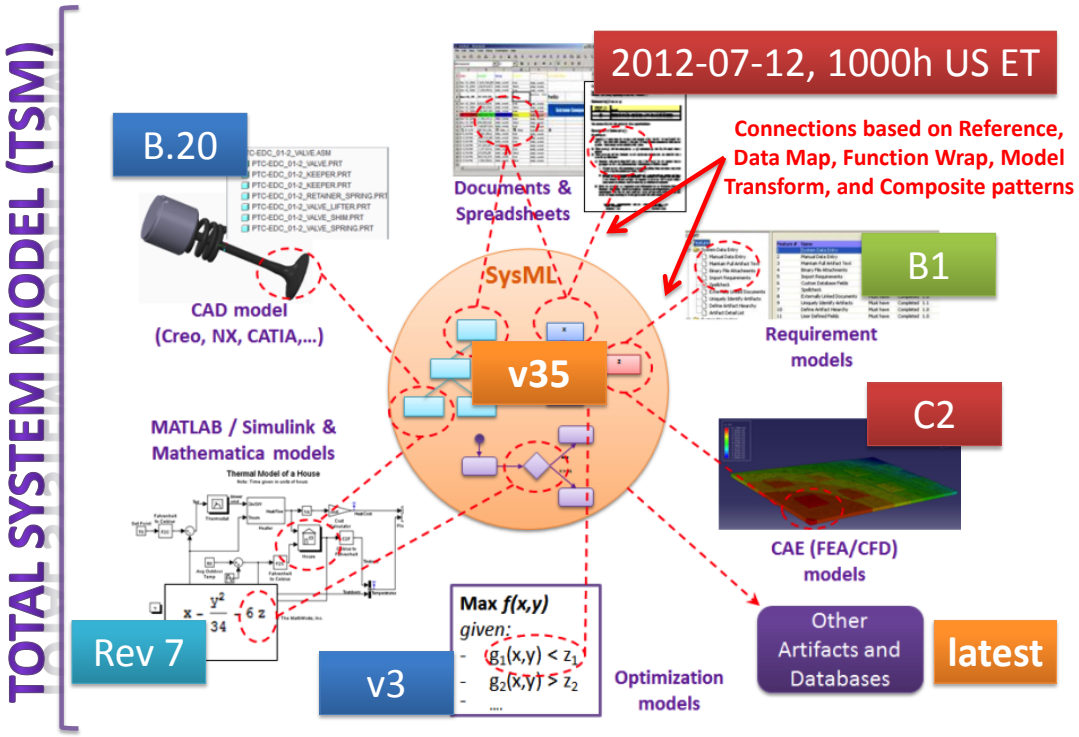


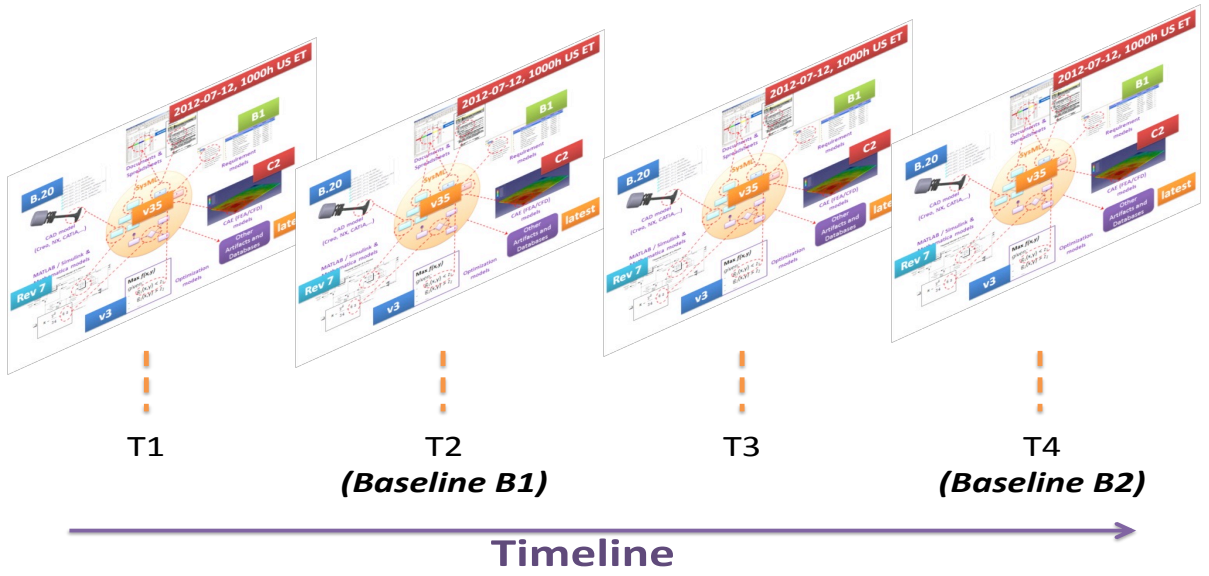
System Model (SysML)

Total System Model Graph

Total System Model (TSM) = Graph of models (graphs)

TSM graph evolves over time as each sub-graph (model) is evolving, often concurrently

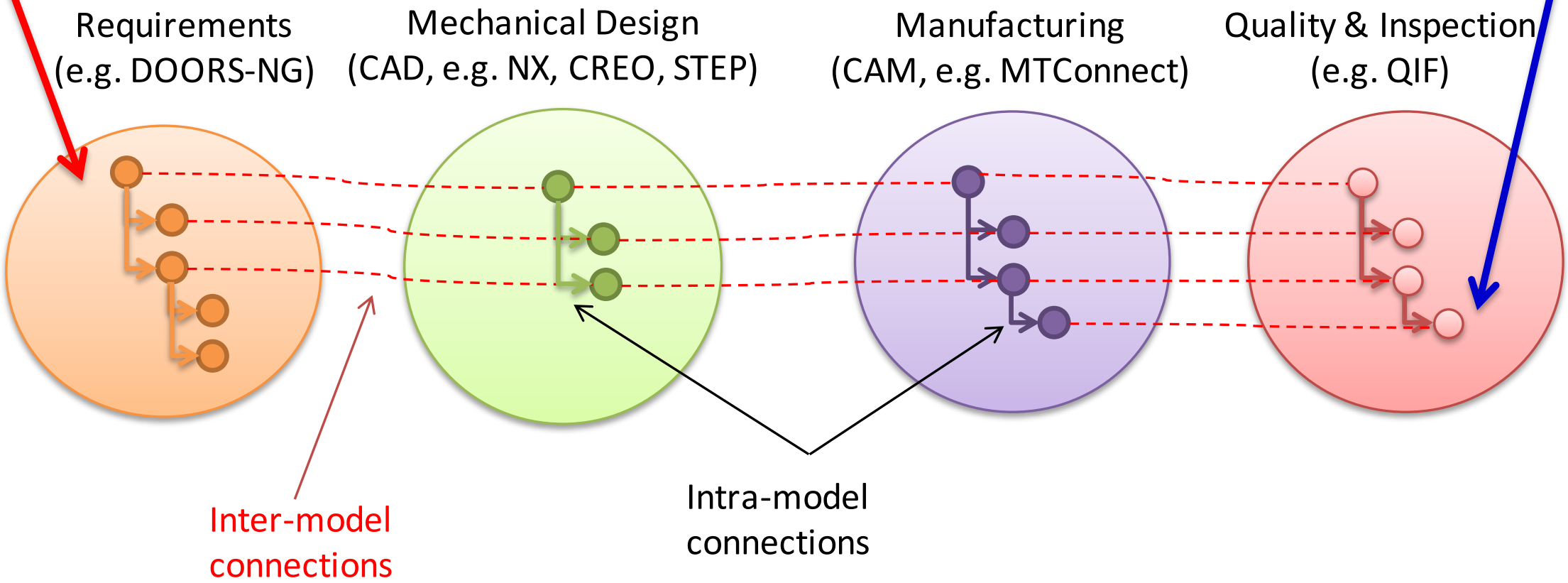




Intra-Model and Inter-Model Connections

If I change this requirement, what is the downstream impact, e.g. to CAD and CAM models?

Trace the CAD and CAM models for this part and compare attributes against test results



Model-Based Connection Patterns

- 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)

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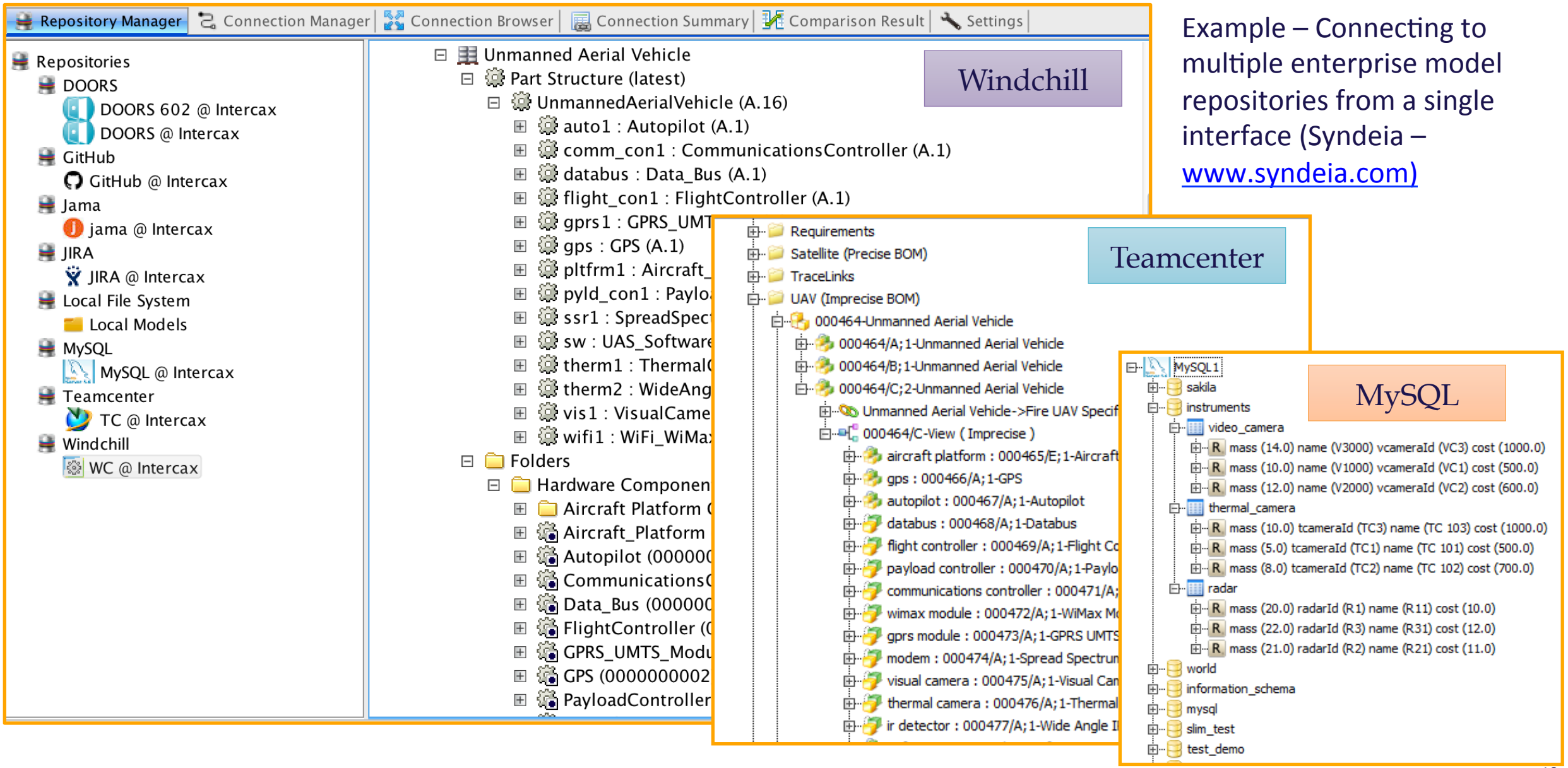
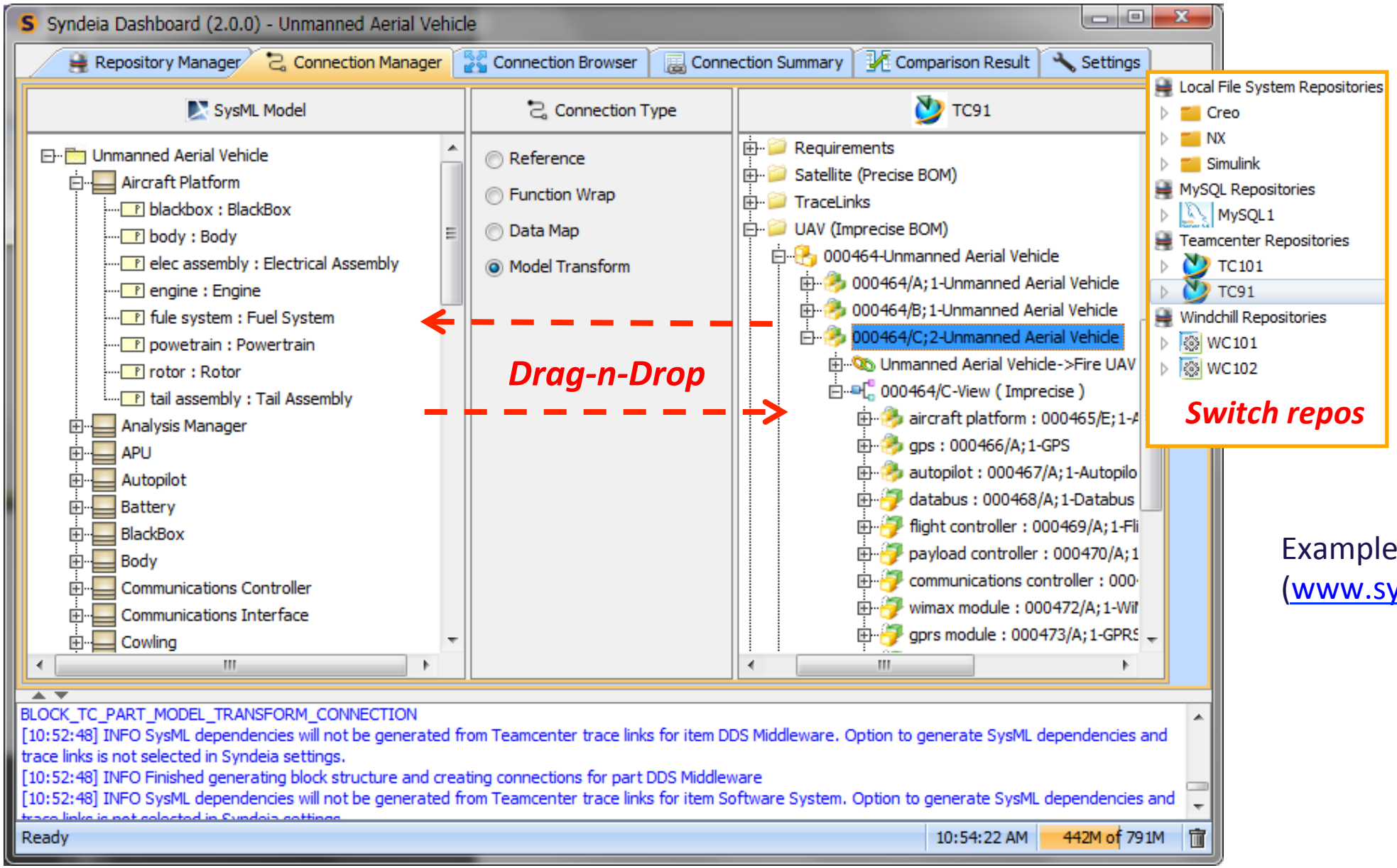
Building and Visualizing the Total System Model Graph

Connect to enterprise repositories (PLM, ALM, DB,…)



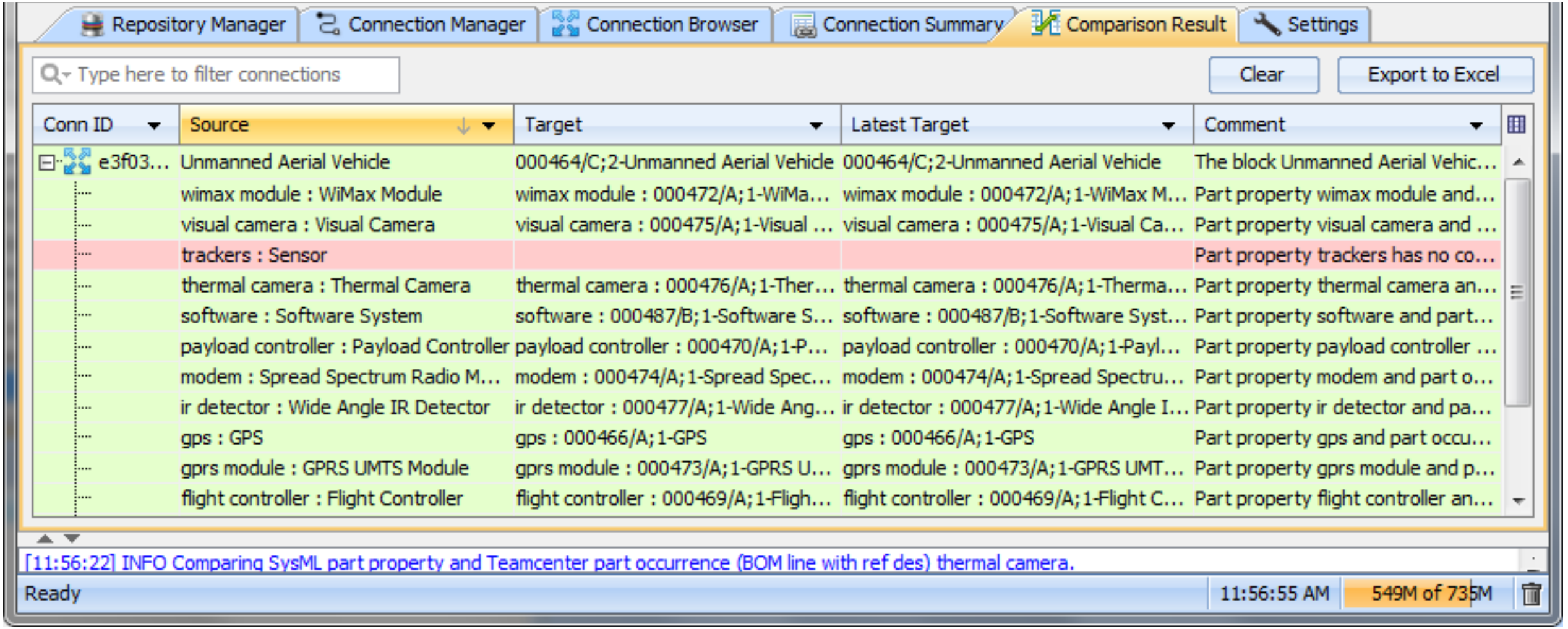
Example – Connecting to multiple enterprise model repositories from a single interface (Syndeia – www.syndeia.com)

Drag-n-Drop to connect existing or generate new models (or elements)



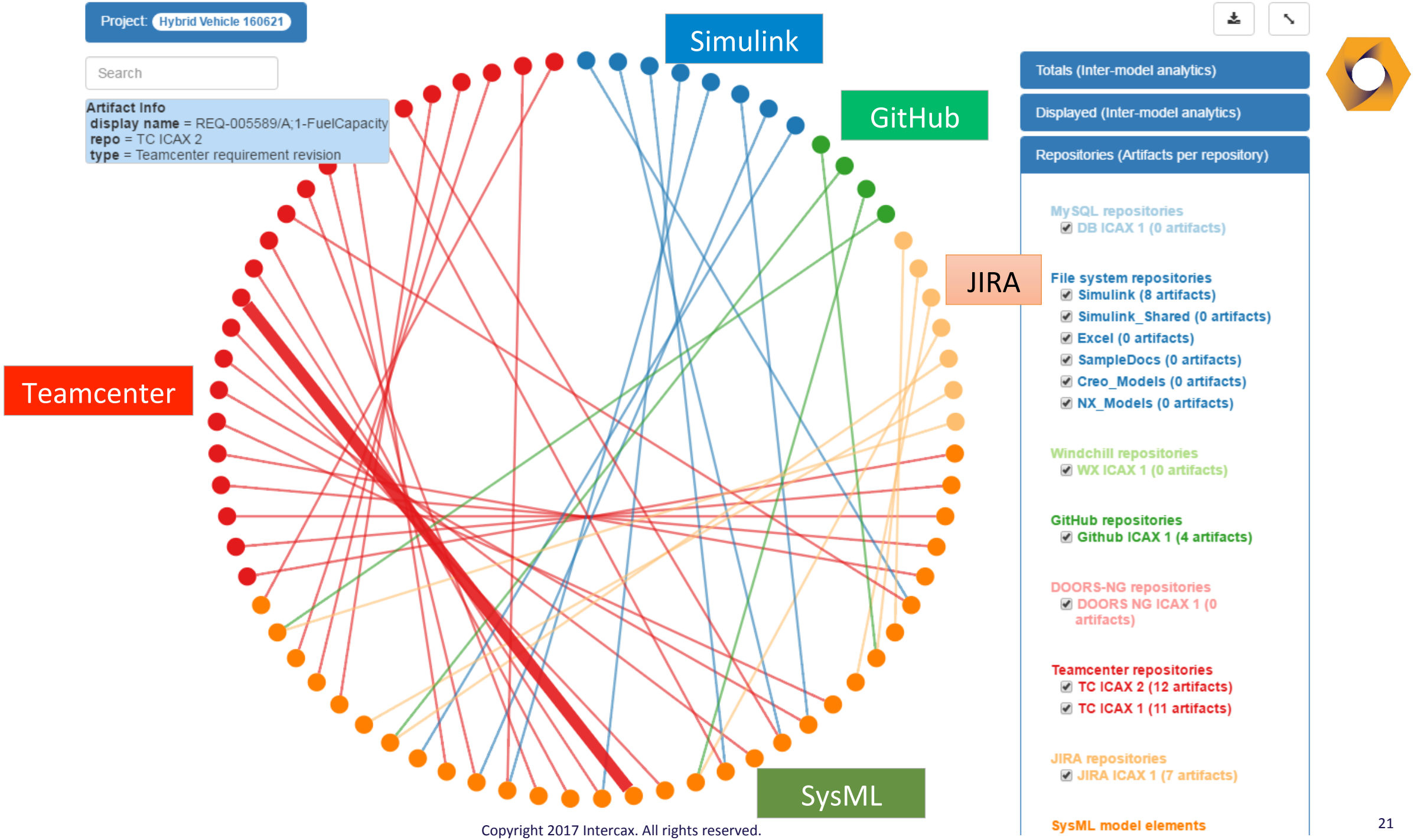
Example using Syndeia (www.syndeia.com)

Compare and synchronize across inter-model connections

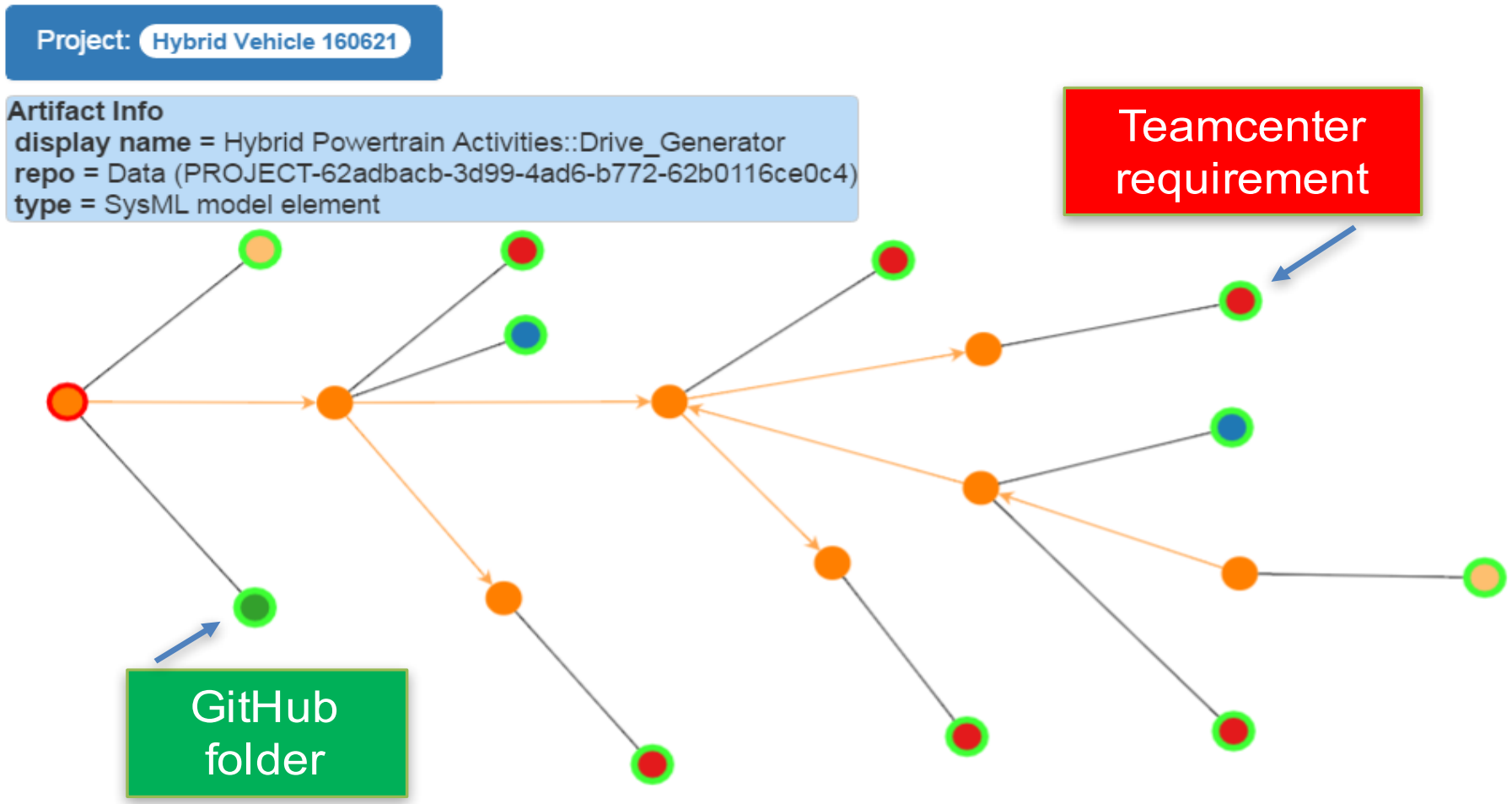


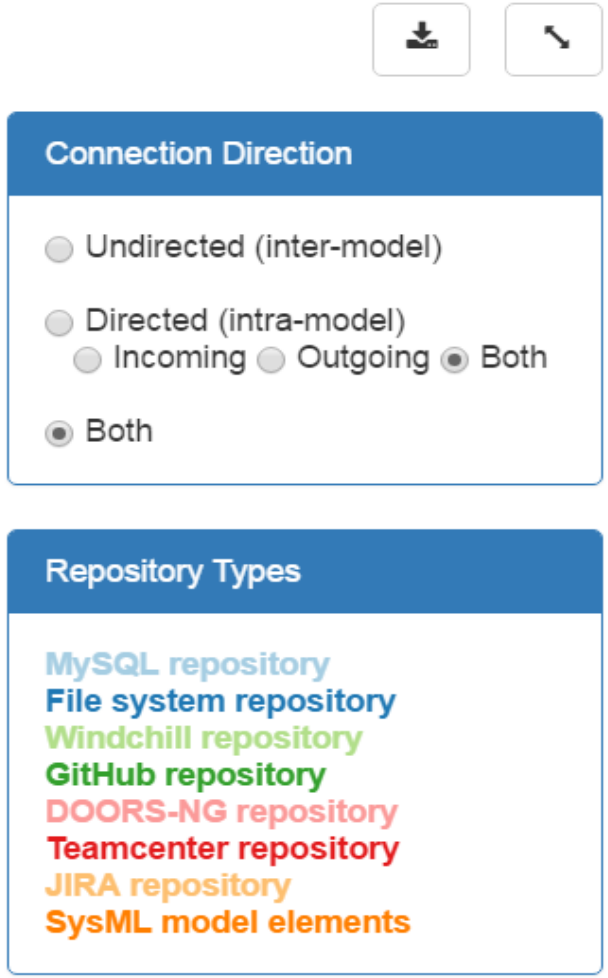
Example using Syndeia (www.syndeia.com)

Interactive Graph of Total System Model



Exploring intra- and inter-model connections





SysML | JIRA | GitHub | Teamcenter | Simulink

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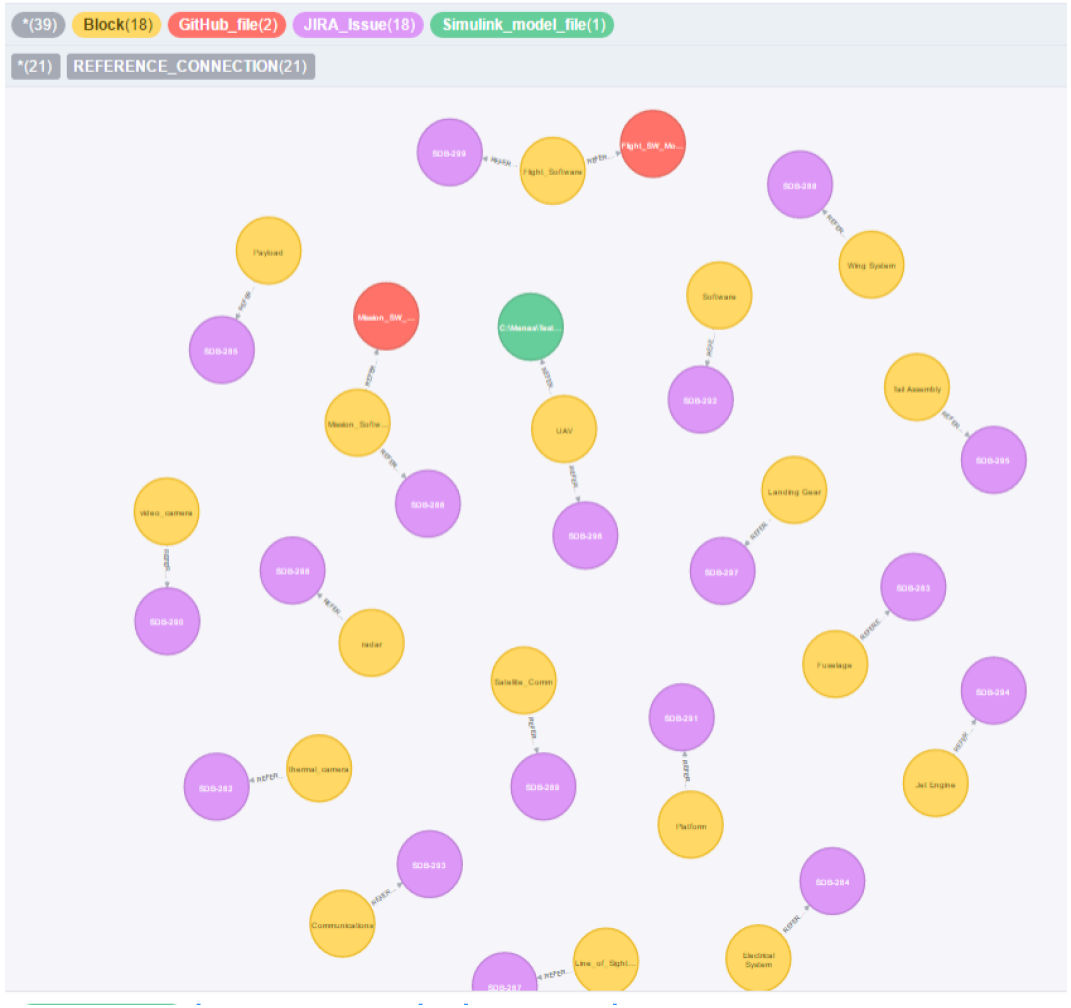
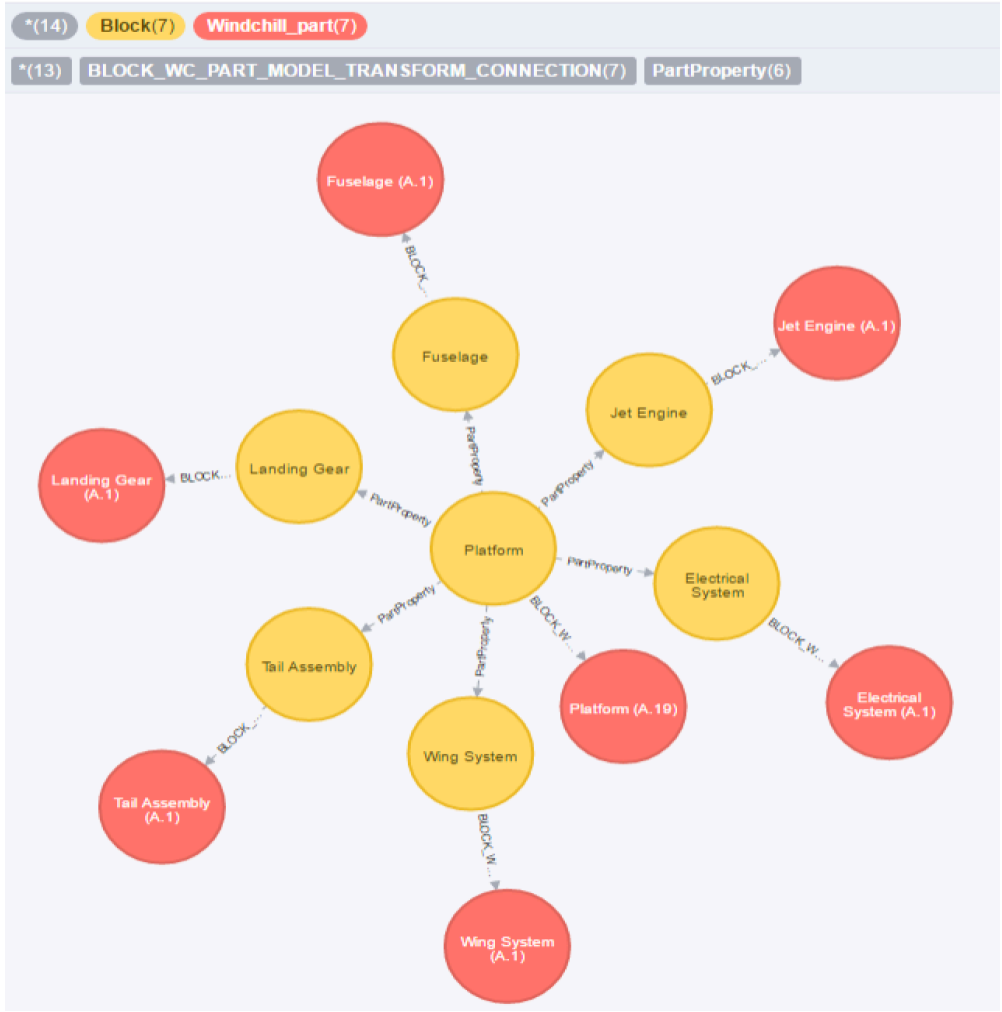
Querying the Total System Model Graph

Graph Queries on the Total System Model (1/2)

1. Get all connections between system architecture, software, project tasks, & simulations

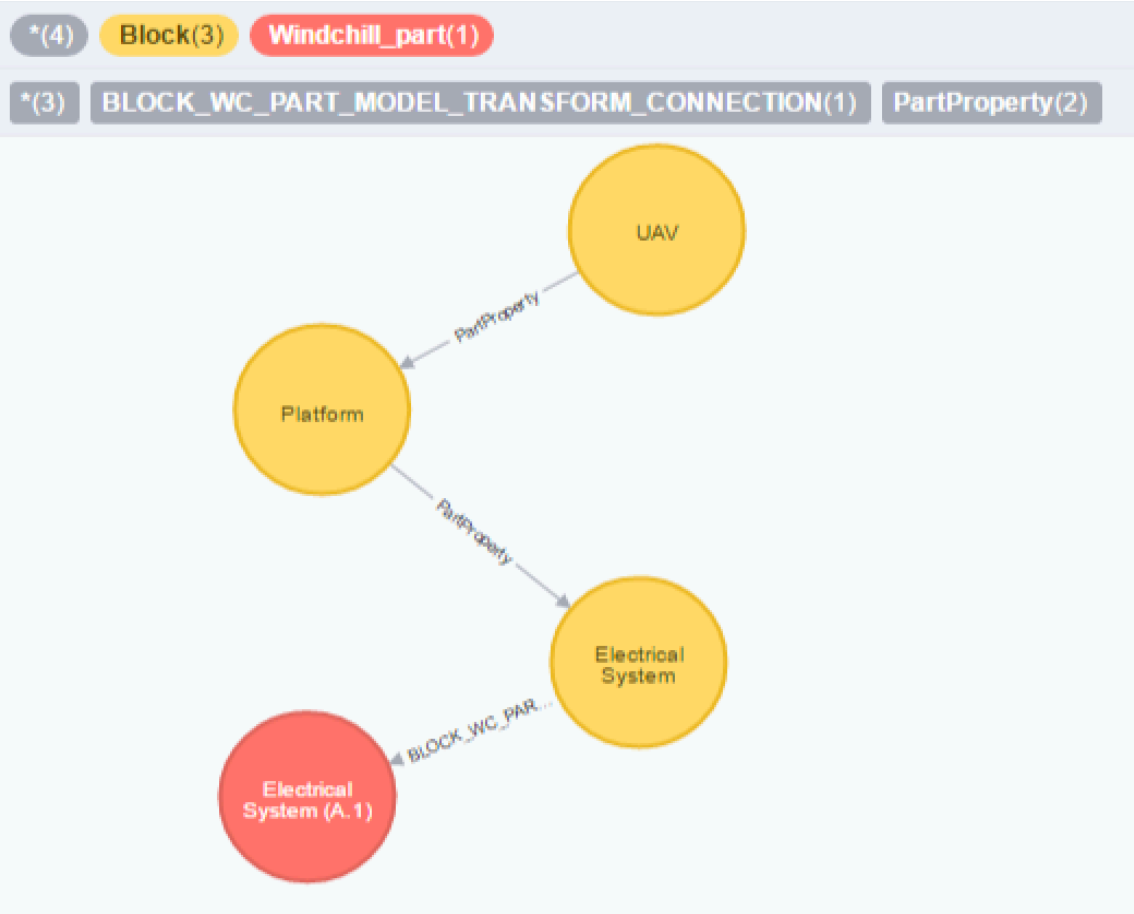


2. Get all connections between system architecture (SysML) and hardware parts (PLM)

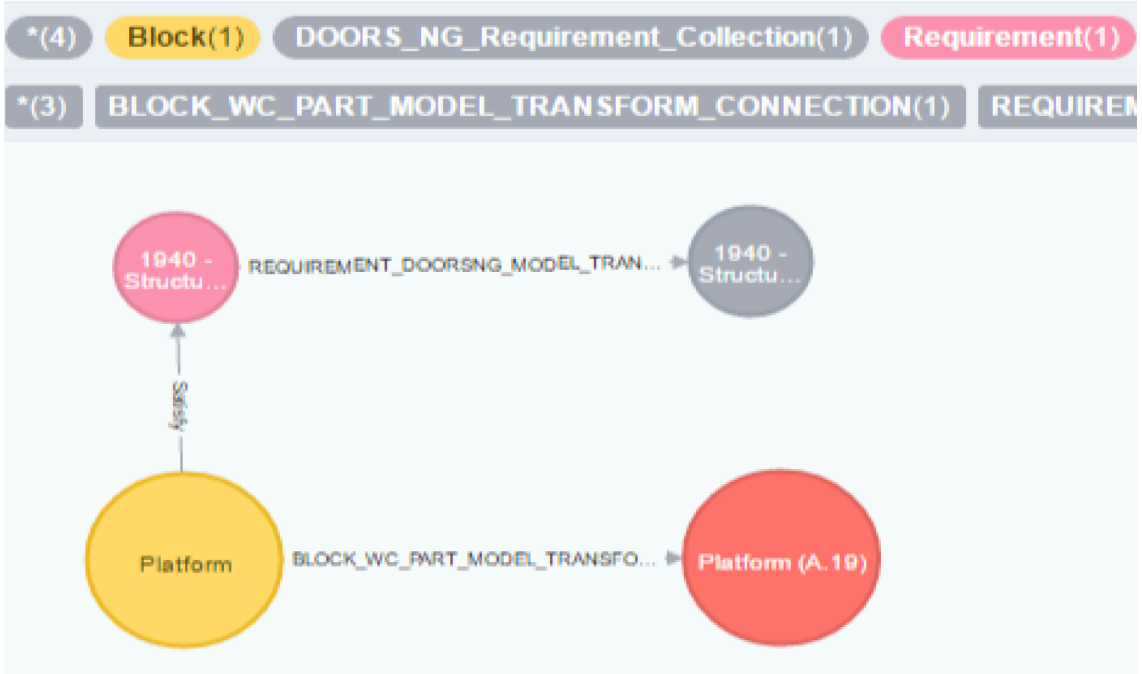


Graph Queries on the Total System Model (2/2)

3. How does a failure in the Electrical System assembly (PLM) affect the overall UAV architecture (SysML)?



4. What hardware parts (PLM) may get affected if a requirement is changed (DOORS-NG)?



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Demonstration

Demo 1 – Building and visualizing the Total System Model graph

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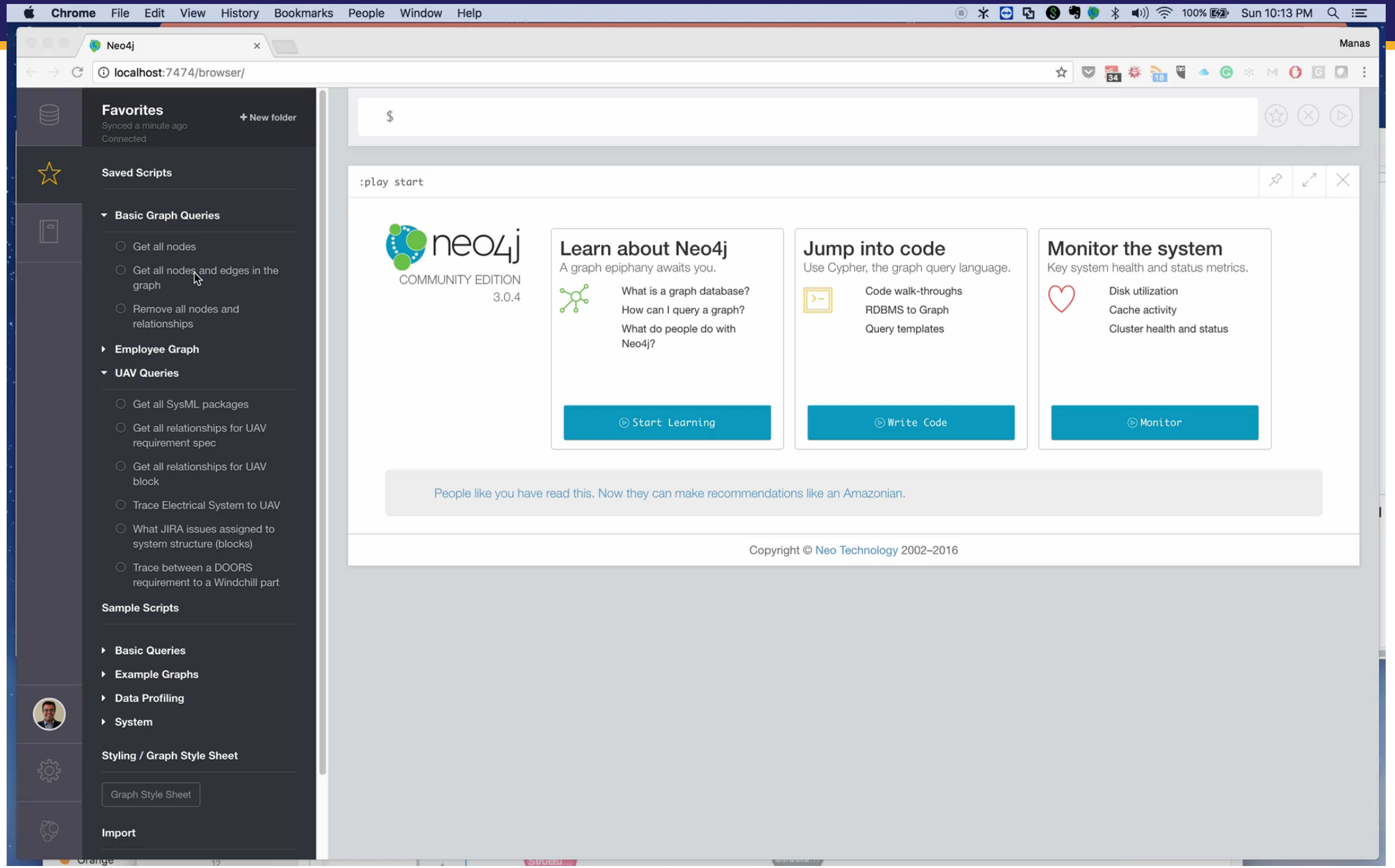
Syndeia 3.1 for MagicDraw

The Next Generation of Model-Based Engineering

Demo 2 - Graph Queries on the Total System Model graph

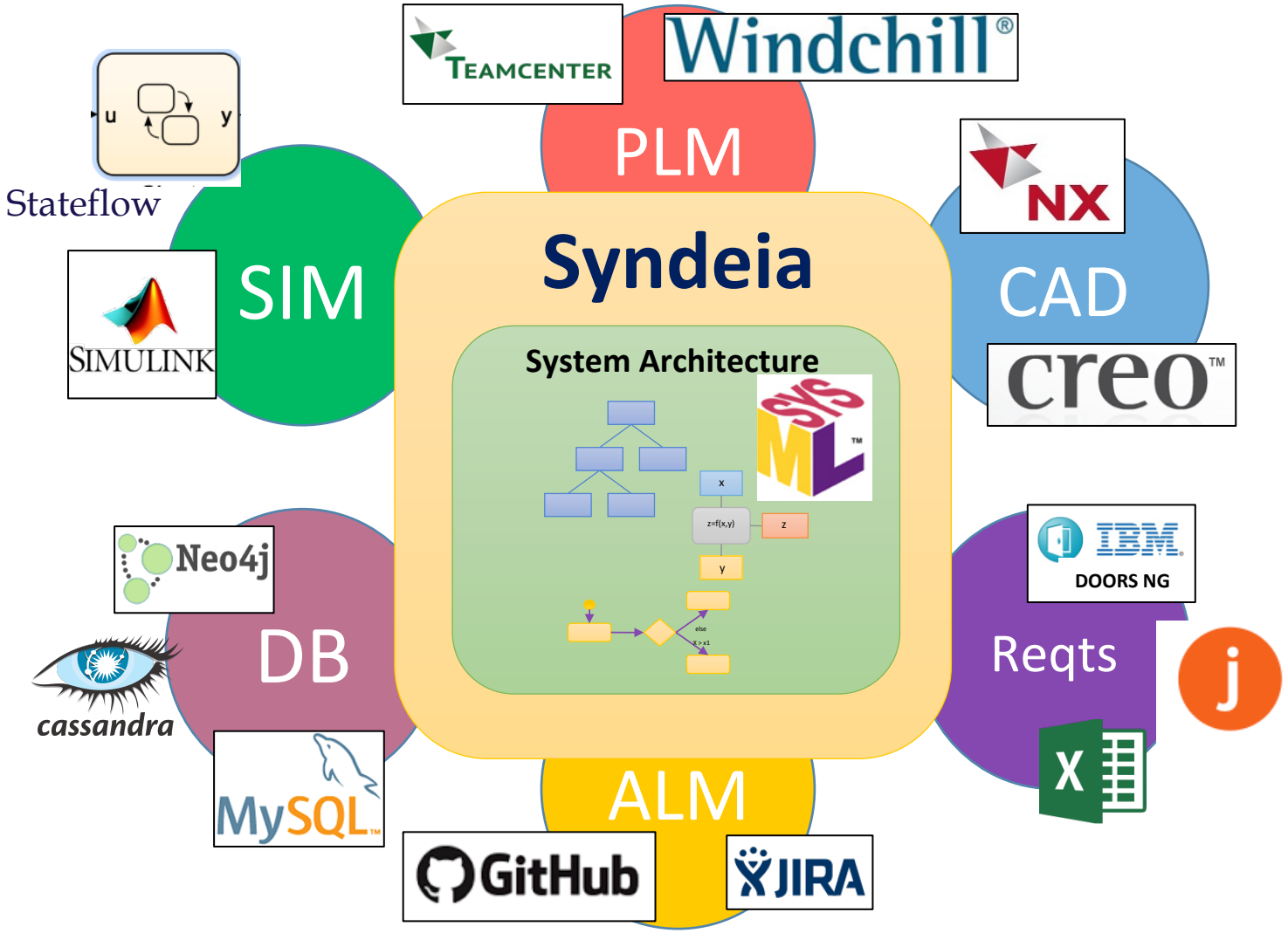


Syndeia 1.0 (SLIM)
Jul 2014

Syndeia 2.0
Jul 2015

Syndeia 3.0
Jul 2016

Syndeia 3.1
May 2017



Syndeia

- www.syndeia.com
- YouTube demo video www.intercax.com/products/syndeia/demos/
- Download a free evaluation www.intercax.com/products/syndeia/download/

Syndeia 3.1 Interfaces

Syndeia 3.1 Interfaces	
SysML	MagicDraw (No Magic), Rhapsody (IBM)
PLM	Teamcenter (Siemens), Windchill (PTC)
CAD	Creo (PTC), NX (Siemens)
Simulation	Simulink (The Mathworks), Stateflow (The Mathworks)
Database	MySQL (Oracle), Excel (Microsoft), Apache Cassandra, Neo4j (Neo Tech)
Requirements	DOORS NG (IBM), Teamcenter (Siemens), Jama (Jama Software)
Project Management	JIRA (Atlassian)
ALM	GitHub (GitHub), JIRA (Atlassian)

Leverages open standards, open frameworks, and open APIs

- Systems Modeling Language (OMG SysML)
- REST (over http)
- JSON
- JDBC
- openCypher
- ISO STEP 10303
- Apache projects (multiple)
- OSLC
- FMI
- … and others

Future Work

- Library of graph patterns for frequently asked questions in systems engineering
- Continuous V&V using the TSM graph
- Visualizing evolution history of the TSM graph
- Generating sub-graphs that can be shared across organization boundaries
- Parametric constraints on graph edges

Questions / Comments

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