



intercax

# 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*





- Georgia Tech spin-off 2008
- Atlanta, US (HQ) and Pune, India
- **Focus:** Software for MBE/MBSE
  - **Syndea** – 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**



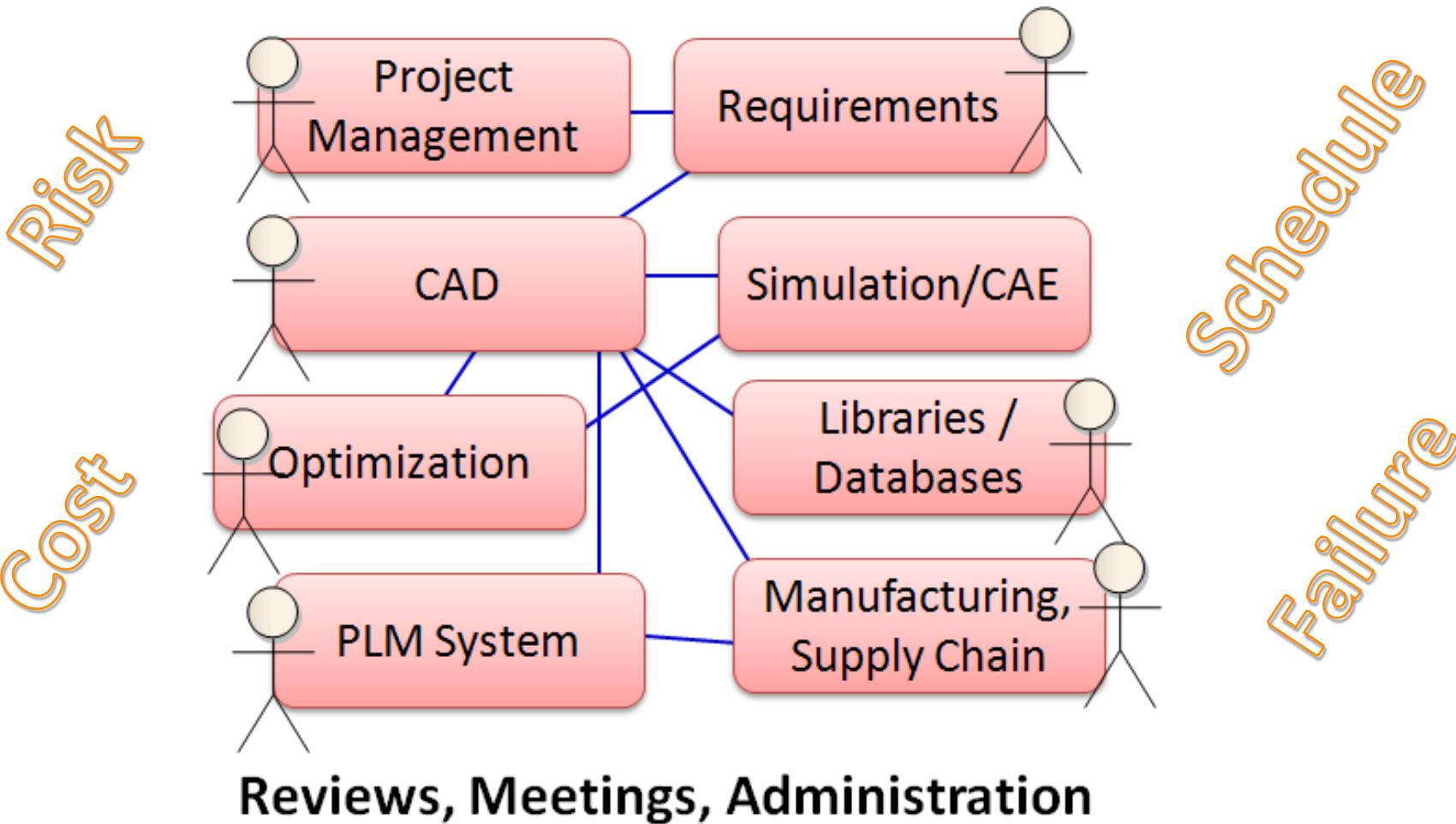
**Healthcare**



- **What is common 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

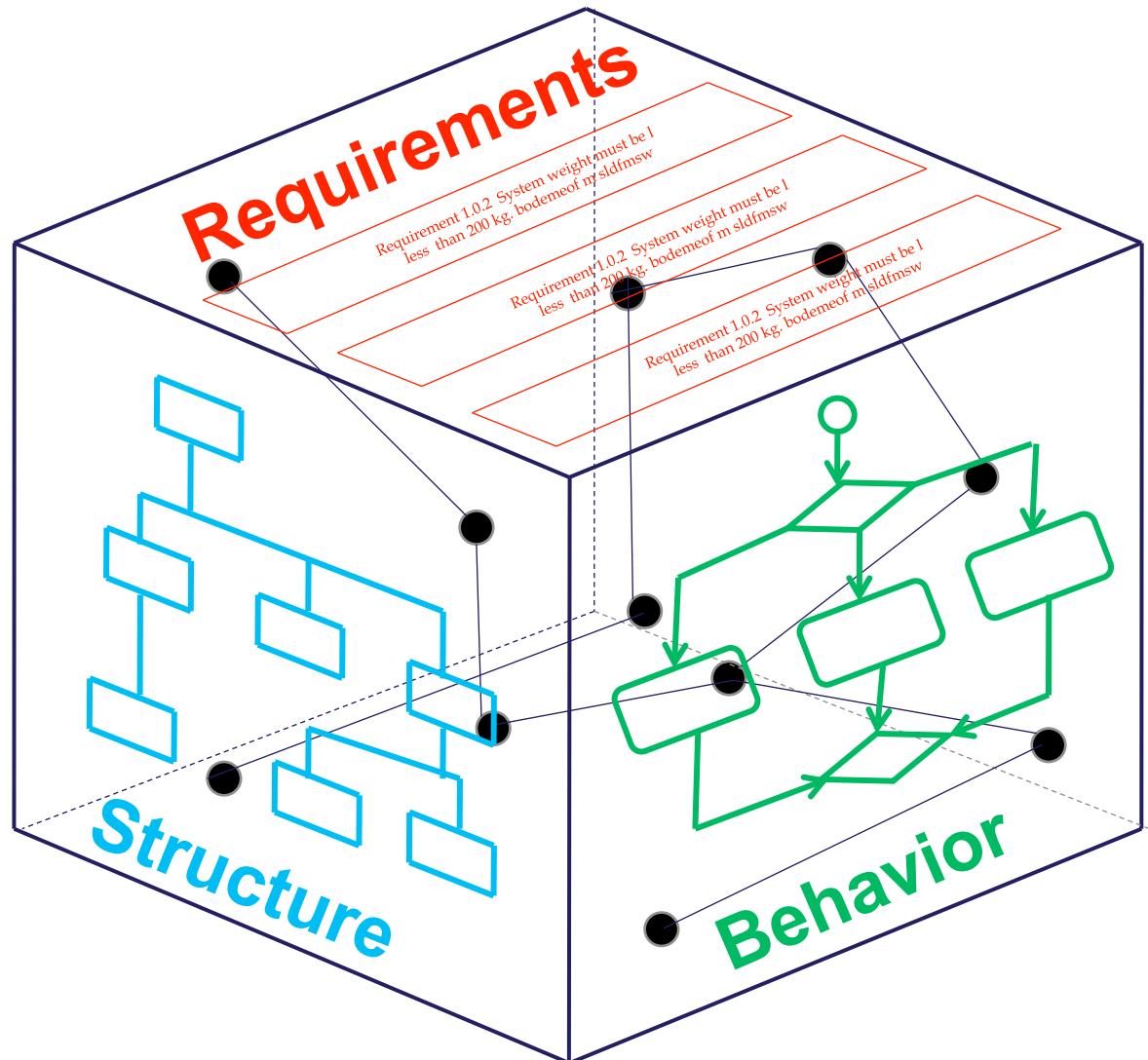


Point-to-point ad-hoc information flows  
without a common architecture model



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

# What is Model-Based Systems Engineering?

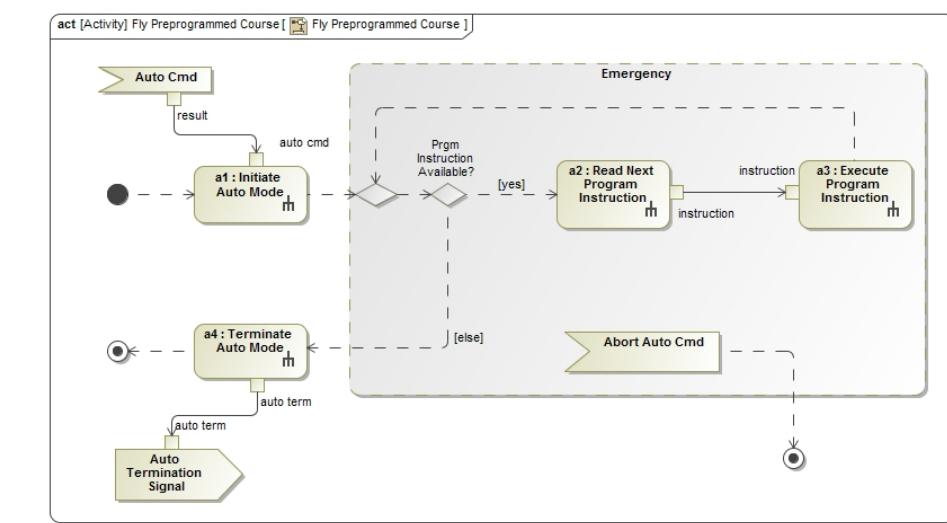
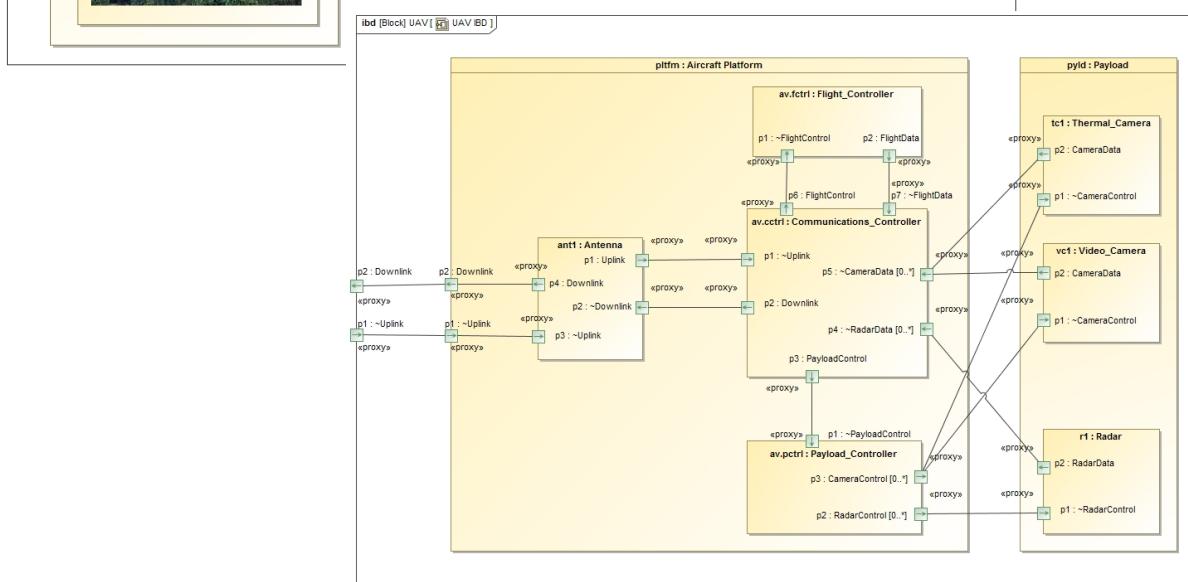
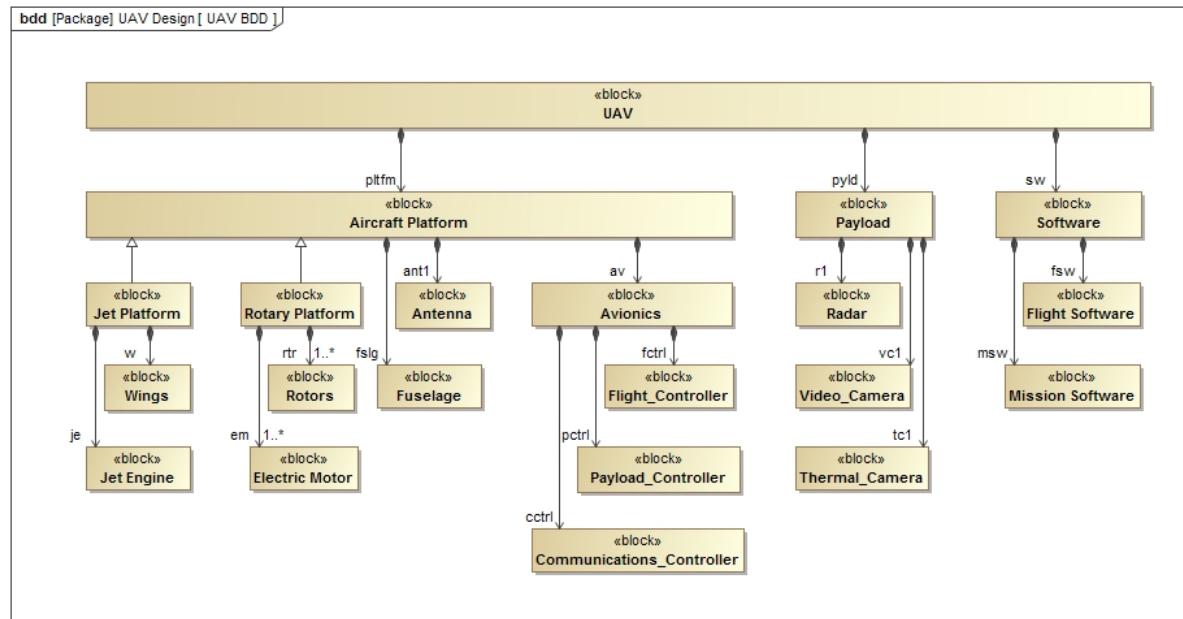
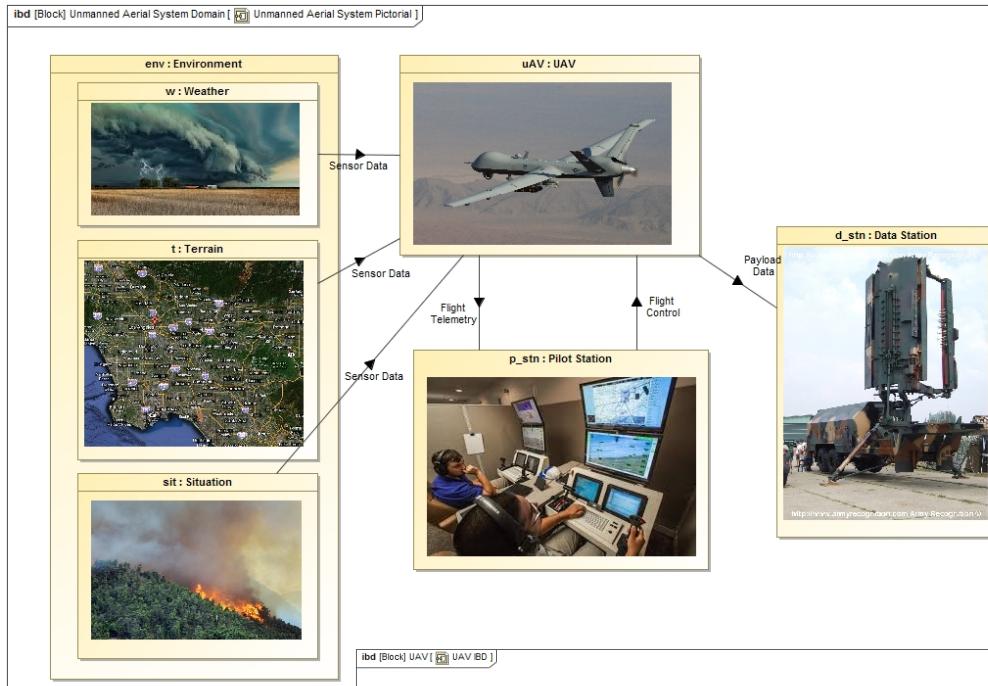


- MBSE = Unified model of the system versus series of disconnected documents or document-based flows between models (DBSE)
- System docs and views can be generated from this unified model
- DBSE > MBSE  $\Leftrightarrow$  2D > 3D CAD
- Models in SE  $\neq$  MBSE



- **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.omg.sysml.org/> for more information on OMG / ISO IEC SysML standard
- <http://www.omg.sysml.org/news-articles.htm> - publications demonstrating real production use

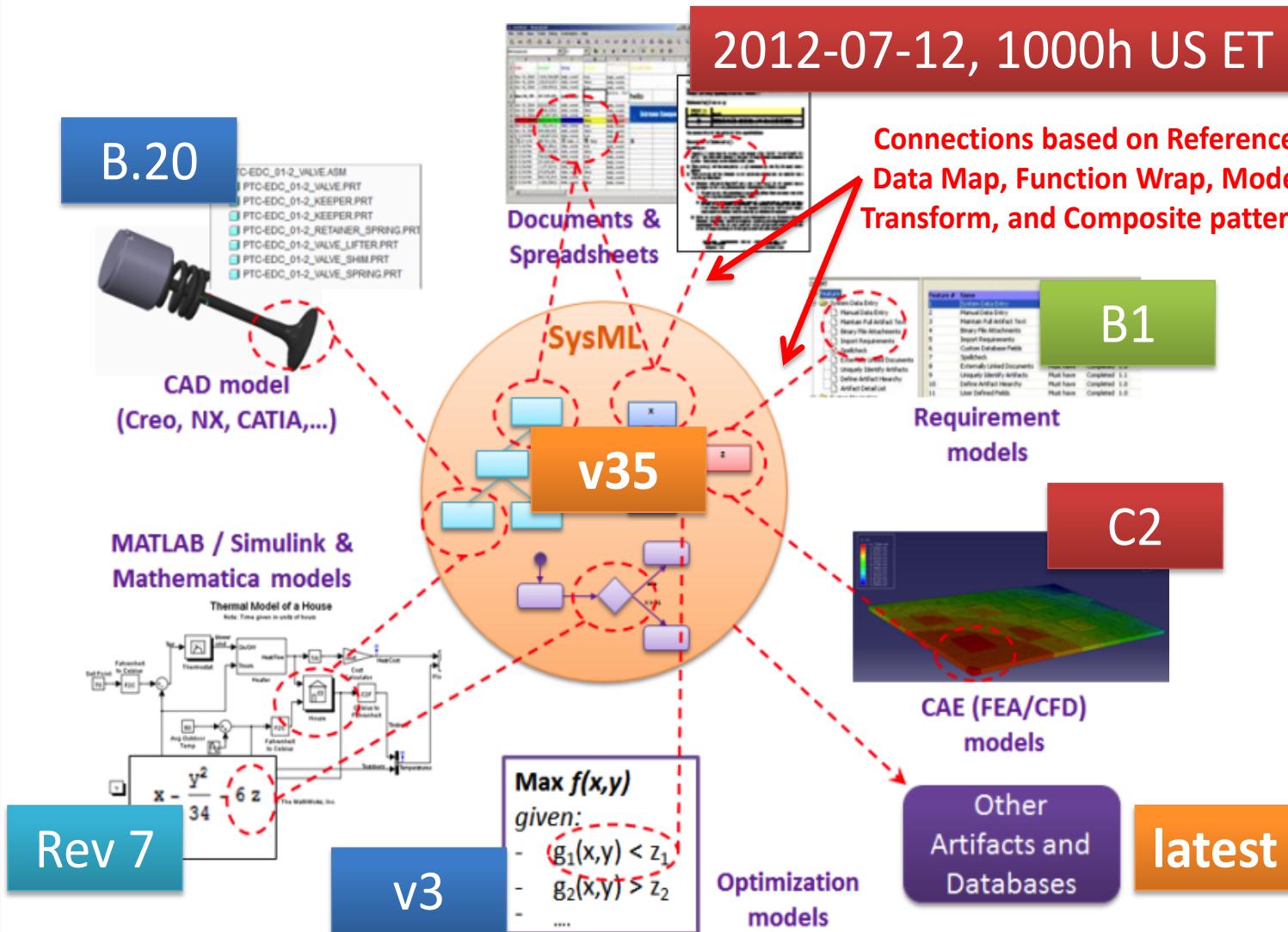
# Example views (diagrams) in a SysML model





# Total System Model – A Federated *Graph*

## TOTAL SYSTEM MODEL (TSM)



Connect architecture model (SysML) with domain-specific models

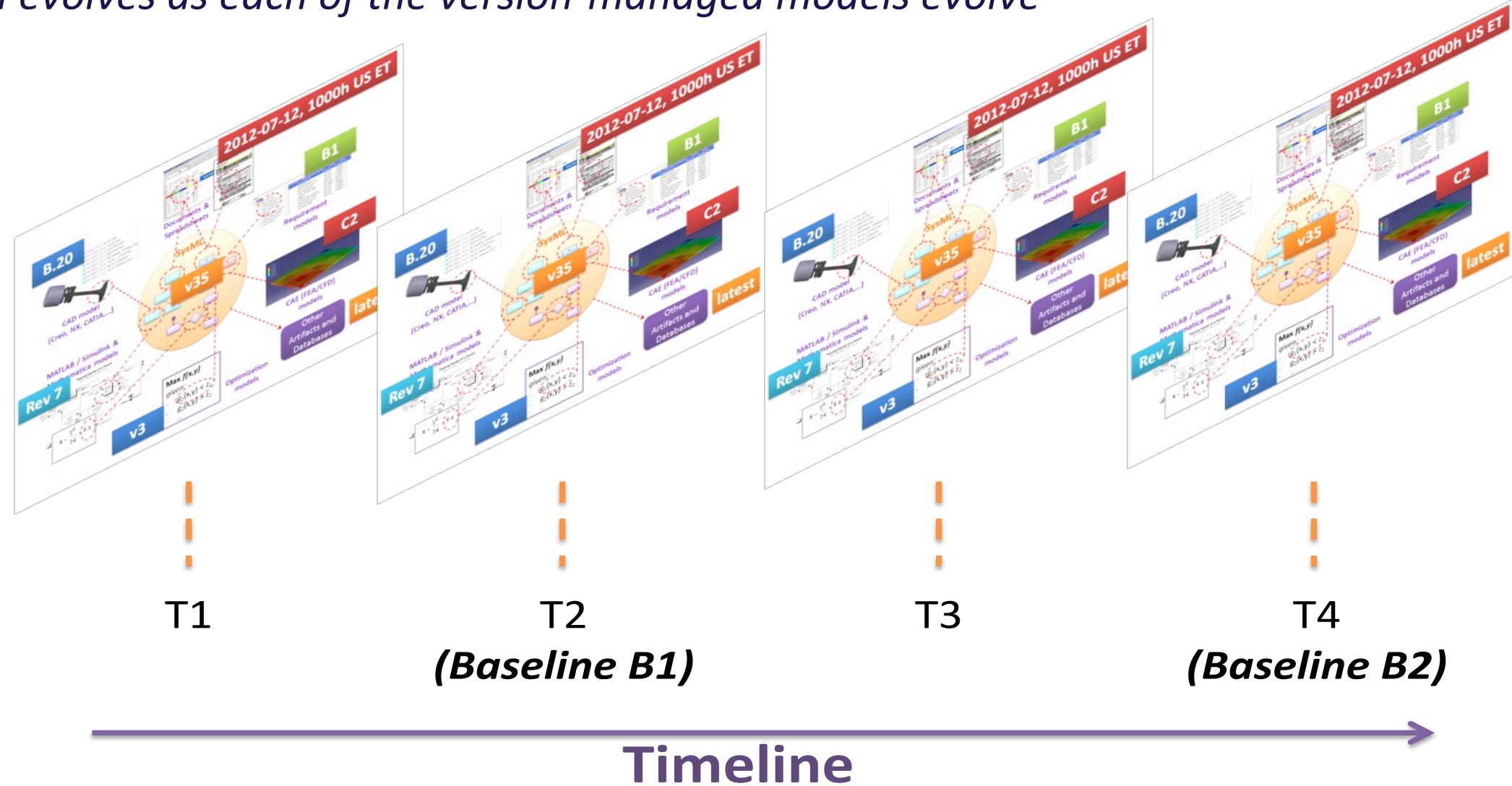
Total System Model (TSM) as a digital blueprint of the system connecting models across disciplines, tools, and version-management systems

Goal: Seamless traceability between disciplines across the system lifecycle

# Total System Model (TSM)



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

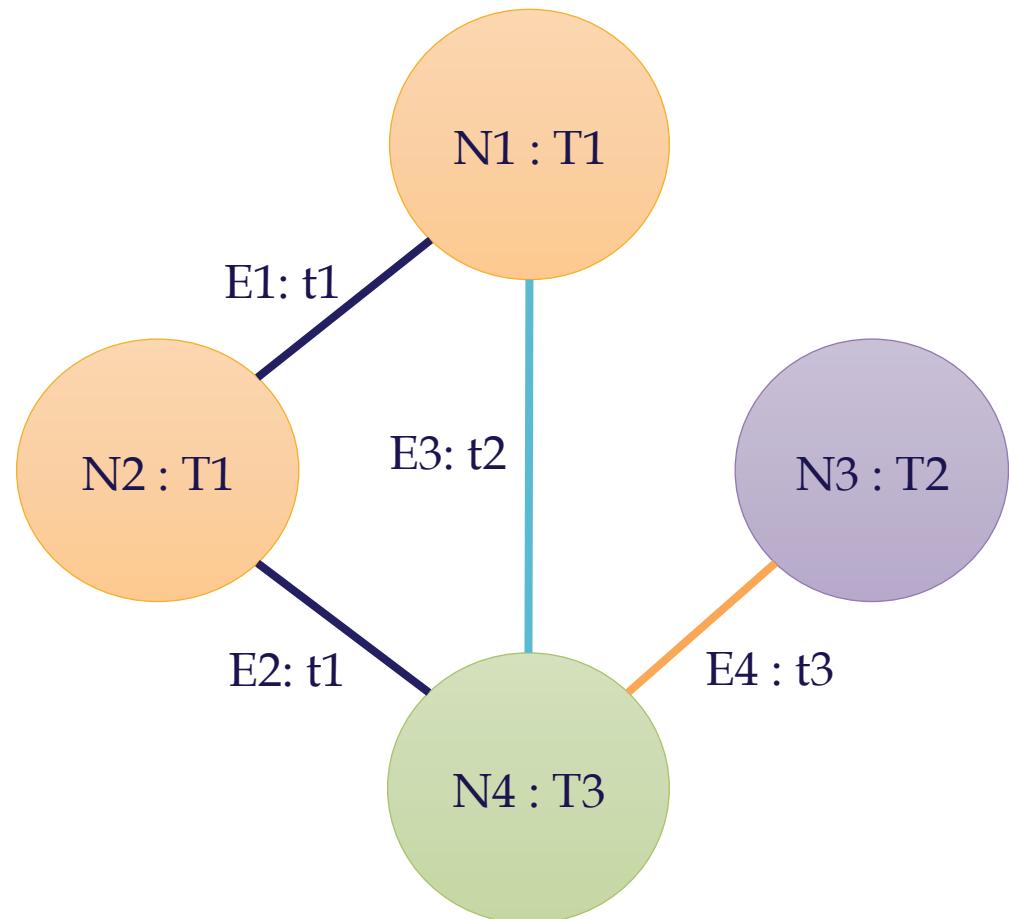




**Total System Model is a  
Graph-based Digital Blueprint of a  
System**



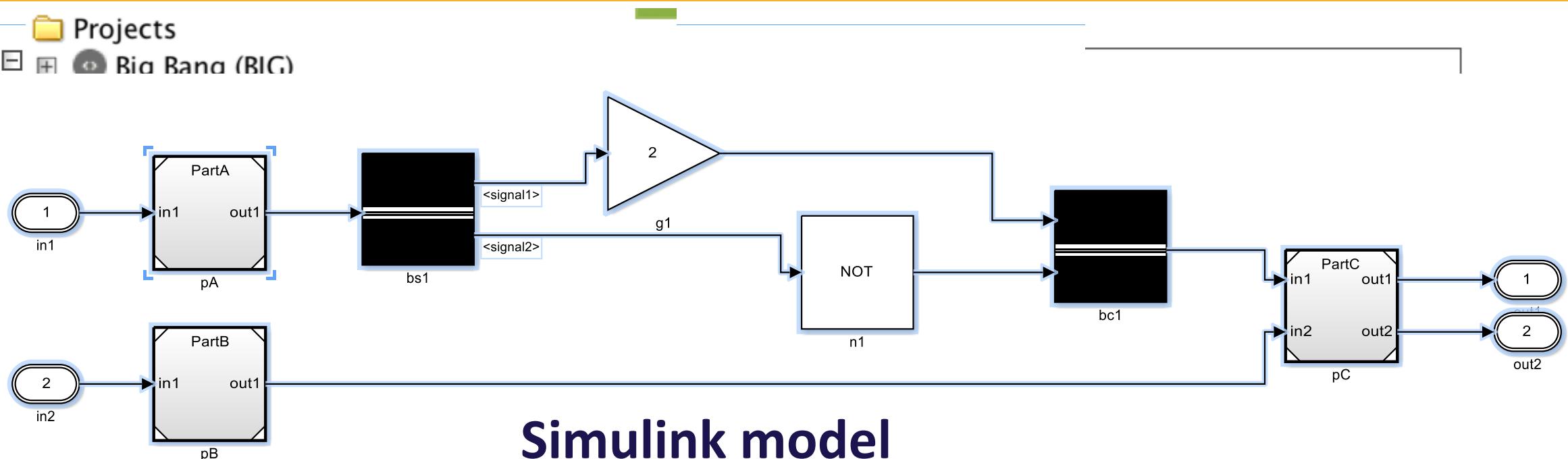
- Graph – Nodes and Edges
- Nodes and Edges may have
  - Name
  - Type (Typed Graph)
  - Properties (Property Graph)
- Edges may have
  - Direction (Directed vs. Undirected Graph)
- Graphs can be
  - Stored
  - Queried (Pattern matching)
  - Traversed (e.g. Breadth-first, Depth-first)
  - Generated and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



# Information models can be abstracted as graphs



Projects  
Ria Rana (BIG)



## Simulink model

watched by me  
 SDB-655  
Project: Syndeia Demo Box  
Summary: Autopilot  
Type: Task  
Status: Open  
Priority: Major  
Updated: 2017-05-15T16:53:05  
Assignee: dirkzwemer  
Reporter: manasbajaj

rtifacts  
pecification Module  
ge Load



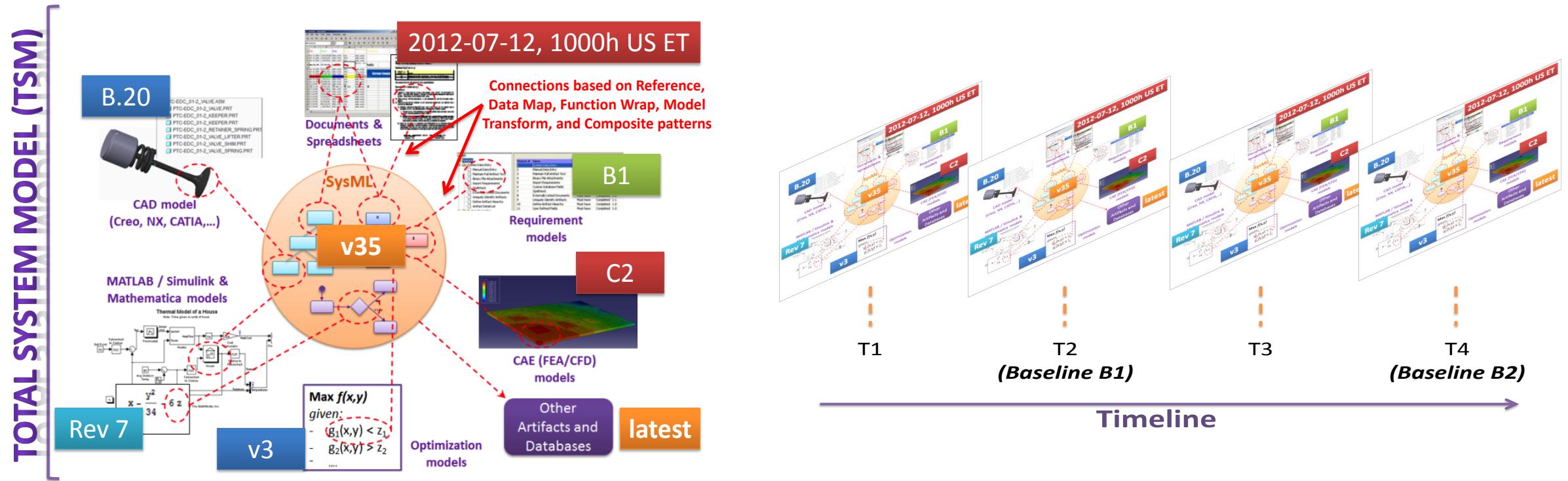
## System Model (SysML)

# 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

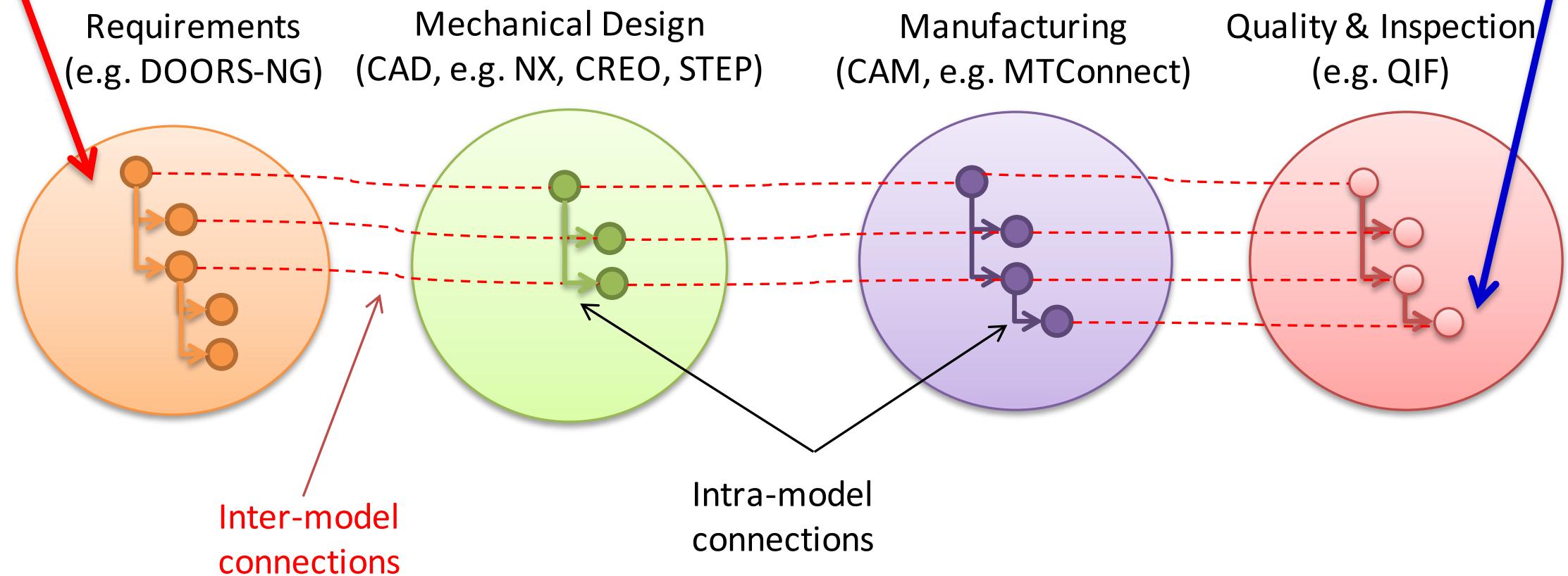


# Intra-Model and Inter-Model Connections



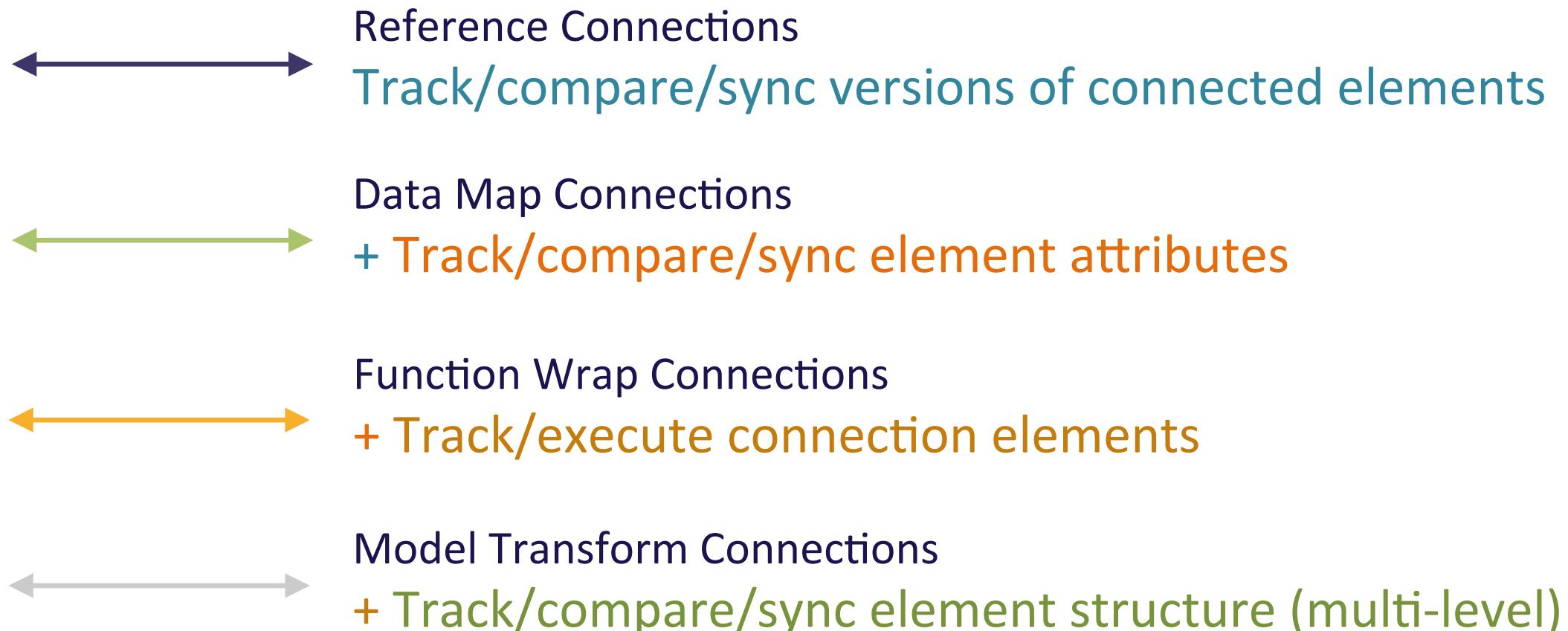
*If I change this requirement,  
what is the downstream  
impact, e.g. to CAD and CAM  
models?*

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





- What is the purpose of model-based connections?





# Building and Visualizing the Total System Model Graph

# Connect to enterprise repositories (PLM, ALM, DB,...)



Repository Manager | Connection Manager | Connection Browser | Connection Summary | Comparison Result | Settings

**Repositories**

- DOORS
- DOORS 602 @ Intercax
- DOORS @ Intercax
- GitHub
- GitHub @ Intercax
- Jama
- jama @ Intercax
- JIRA
- JIRA @ Intercax
- Local File System
- Local Models
- MySQL
- MySQL @ Intercax
- Teamcenter
- TC @ Intercax
- Windchill
- WC @ Intercax

**Windchill**

Unmanned Aerial Vehicle

- Part Structure (latest)
- UnmannedAerialVehicle (A.16)
  - auto1 : Autopilot (A.1)
  - comm\_con1 : CommunicationsController (A.1)
  - databus : Data\_Bus (A.1)
  - flight\_con1 : FlightController (A.1)
  - gprs1 : GPRS\_UMT
  - gps : GPS (A.1)
  - pltfrm1 : Aircraft
  - pyld\_con1 : PayloadController
  - ssr1 : SpreadSpec
  - sw : UAS\_Software
  - therm1 : Thermal
  - therm2 : WideAngle
  - vis1 : VisualCamera
  - wifi1 : WiFi\_WiMa

**Teamcenter**

000464-Unmanned Aerial Vehicle

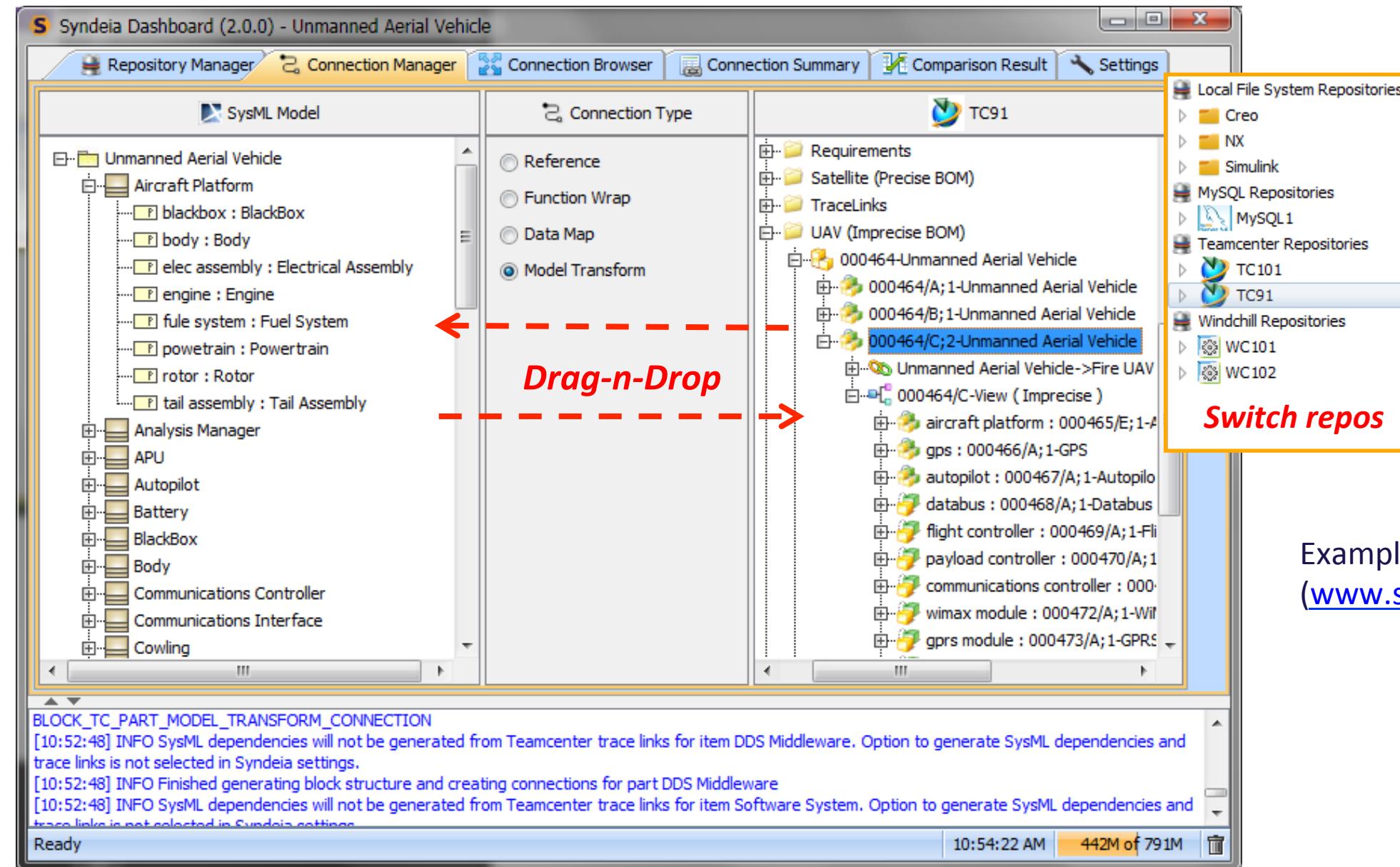
- 000464/A;1-Unmanned Aerial Vehicle
- 000464/B;1-Unmanned Aerial Vehicle
- 000464/C;2-Unmanned Aerial Vehicle
  - Unmanned Aerial Vehicle->Fire UAV Specification
  - 000464/C-View (Imprecise)
    - aircraft platform : 000465/E;1-Aircraft
    - gps : 000466/A;1-GPS
    - autopilot : 000467/A;1-Autopilot
    - databus : 000468/A;1-Databus
    - flight controller : 000469/A;1-Flight Controller
    - payload controller : 000470/A;1-PayloadController
    - communications controller : 000471/A;1-CommunicationsController
    - wimax module : 000472/A;1-WiMax Module
    - gprs module : 000473/A;1-GPRS UMTS
    - modem : 000474/A;1-Spread Spectrum
    - visual camera : 000475/A;1-Visual Camera
    - thermal camera : 000476/A;1-Thermal Camera
    - ir detector : 000477/A;1-Wide Angle IR

**MySQL**

- MySQL1
  - sakila
  - instruments
    - video\_camera
      - mass (14.0) name (V3000) vcameraId (VC3) cost (1000.0)
      - mass (10.0) name (V1000) vcameraId (VC1) cost (500.0)
      - mass (12.0) name (V2000) vcameraId (VC2) cost (600.0)
    - thermal\_camera
      - mass (10.0) tcameraId (TC3) name (TC 103) cost (1000.0)
      - mass (5.0) tcameraId (TC1) name (TC 101) cost (500.0)
      - mass (8.0) tcameraId (TC2) name (TC 102) cost (700.0)
    - radar
      - mass (20.0) radarId (R1) name (R11) cost (10.0)
      - mass (22.0) radarId (R3) name (R31) cost (12.0)
      - mass (21.0) radarId (R2) name (R21) cost (11.0)
  - world
  - information\_schema
  - mysql
  - slim\_test
  - test\_demo

Example – Connecting to multiple enterprise model repositories from a single interface (Syndesia – [www.syndesia.com](http://www.syndesia.com))

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



## Example using Syndeia ([www.syndeia.com](http://www.syndeia.com))

# Compare and synchronize across inter-model connections



Screenshot of the Syndesia software interface showing a comparison between SysML part properties and Teamcenter part occurrences.

The interface includes a top navigation bar with tabs: Repository Manager, Connection Manager, Connection Browser, Connection Summary, Comparison Result (selected), and Settings. Below the navigation bar is a search bar labeled "Type here to filter connections" and buttons for "Clear" and "Export to Excel".

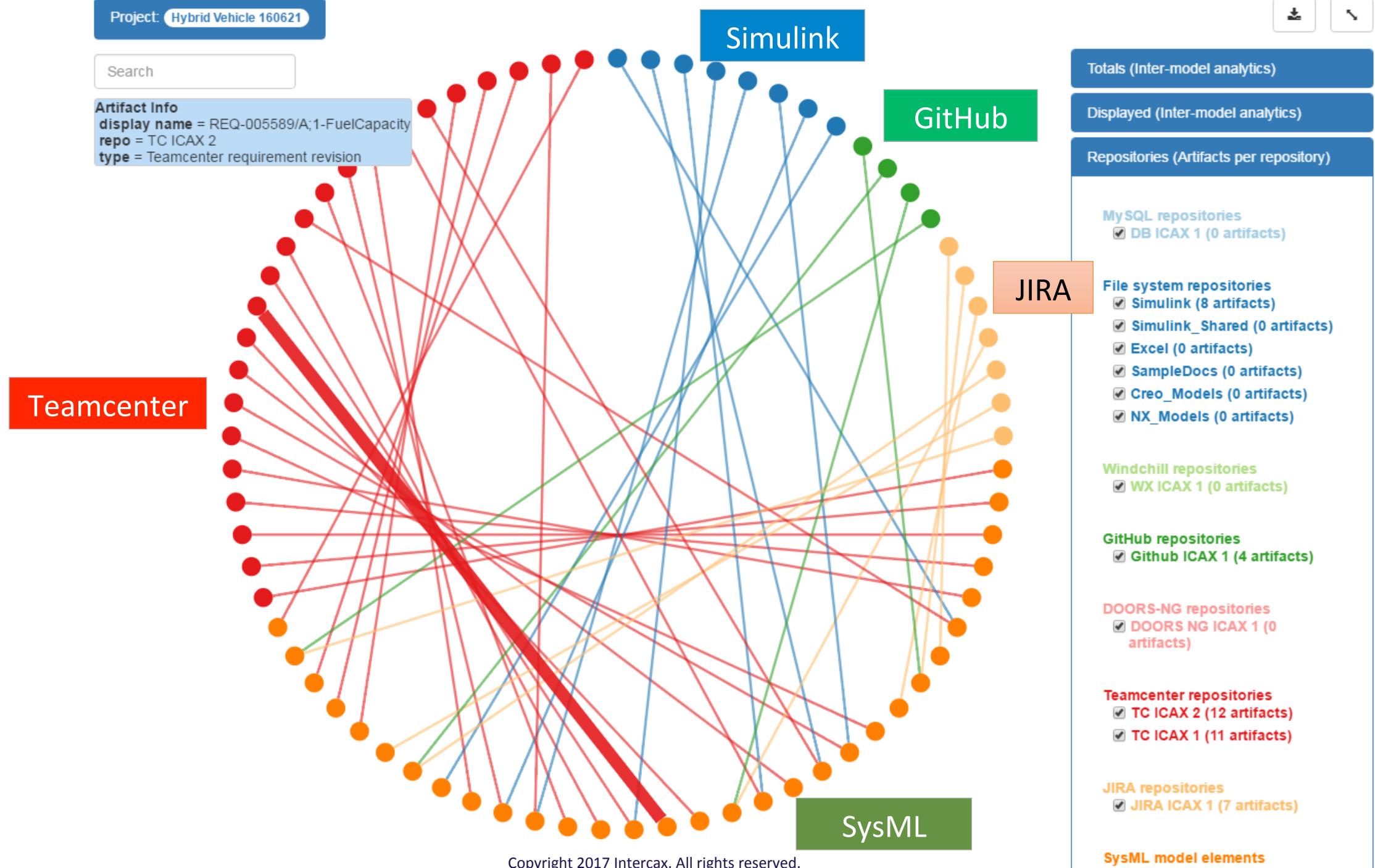
The main content area is a table with the following columns: Conn ID, Source, Target, Latest Target, and Comment. The table lists various components and their relationships:

Conn ID	Source	Target	Latest Target	Comment
e3f03...	Unmanned Aerial Vehicle	000464/C;2-Unmanned Aerial Vehicle	000464/C;2-Unmanned Aerial Vehicle	The block Unmanned Aerial Vehic...
	wimax module : WiMax Module	wimax module : 000472/A;1-WiMa...	wimax module : 000472/A;1-WiMax M...	Part property wimax module and...
	visual camera : Visual Camera	visual camera : 000475/A;1-Visual ...	visual camera : 000475/A;1-Visual Ca...	Part property visual camera and ...
	trackers : Sensor			Part property trackers has no co...
	thermal camera : Thermal Camera	thermal camera : 000476/A;1-Ther...	thermal camera : 000476/A;1-Therma...	Part property thermal camera an...
	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...

At the bottom of the interface, a status bar displays the message "[11:56:22] INFO Comparing SysML part property and Teamcenter part occurrence (BOM line with ref des) thermal camera.", the status "Ready", the timestamp "11:56:55 AM", the file size "549M of 735M", and a trash bin icon.

Example using Syndesia  
([www.syndesia.com](http://www.syndesia.com))

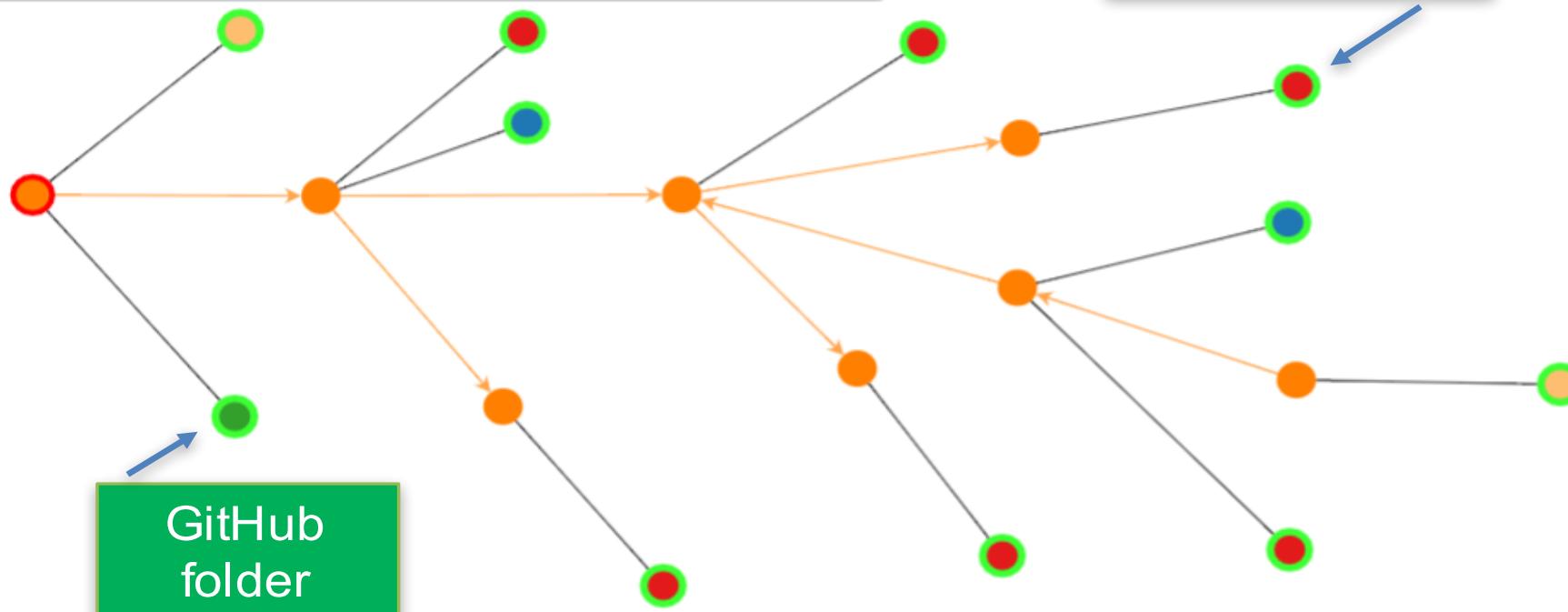
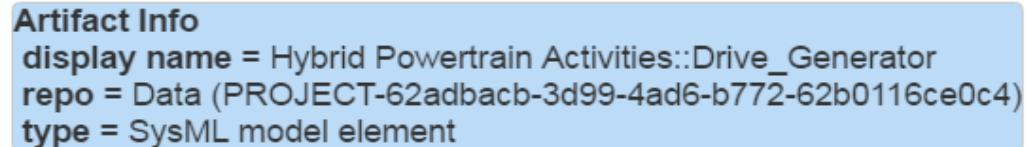
# Interactive Graph of Total System Model



# Exploring intra- and inter-model connections



Project: Hybrid Vehicle 160621



# Teamcenter requirement

## Connection Direction

- Undirected (inter-model)
- Directed (intra-model)
  - Incoming
  - Outgoing
  - Both
- Both

## Repository Types

- MySQL repository
- File system repository
- Windchill repository
- GitHub repository
- DOORS-NG repository
- Teamcenter repository
- JIRA repository
- SysML model elements

# SysML

# JIRA

# GitHub

# Teamcenter

# Simulink

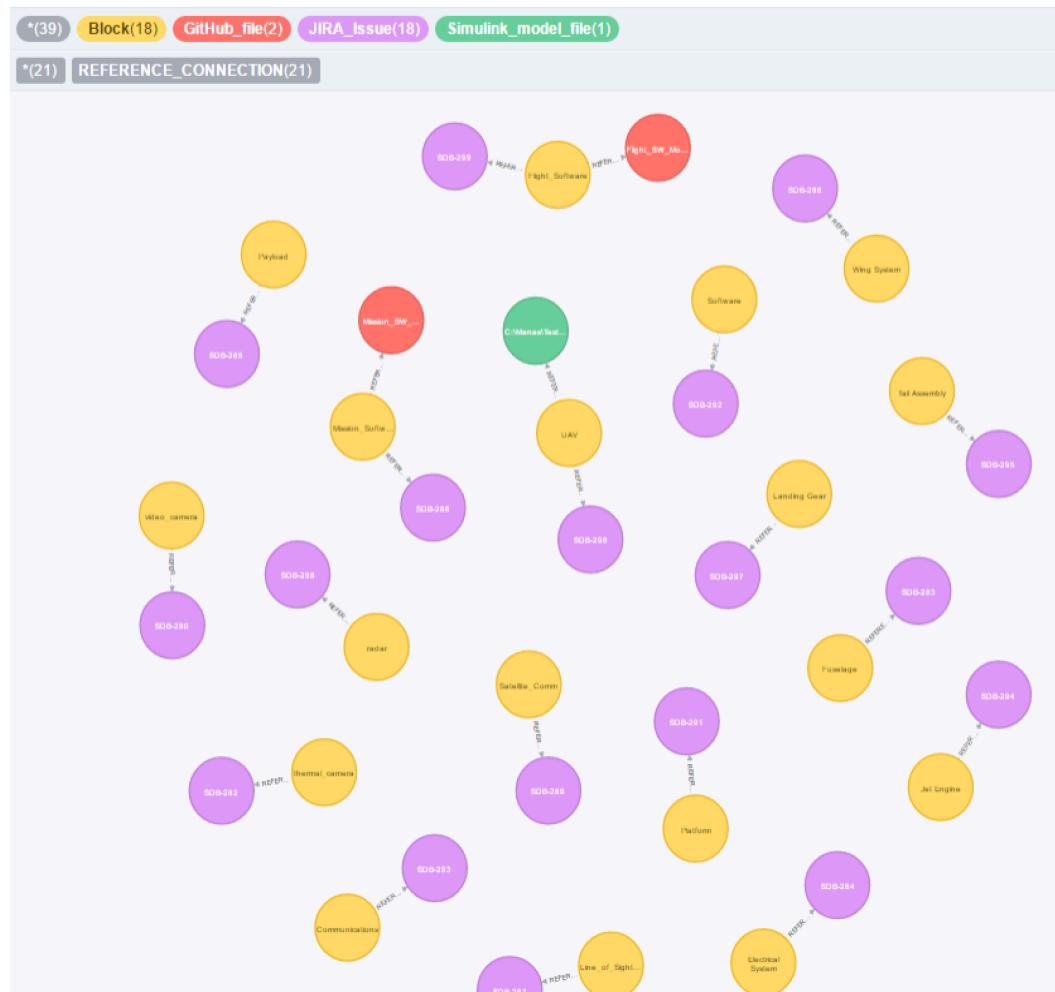


# Querying the Total System Model Graph

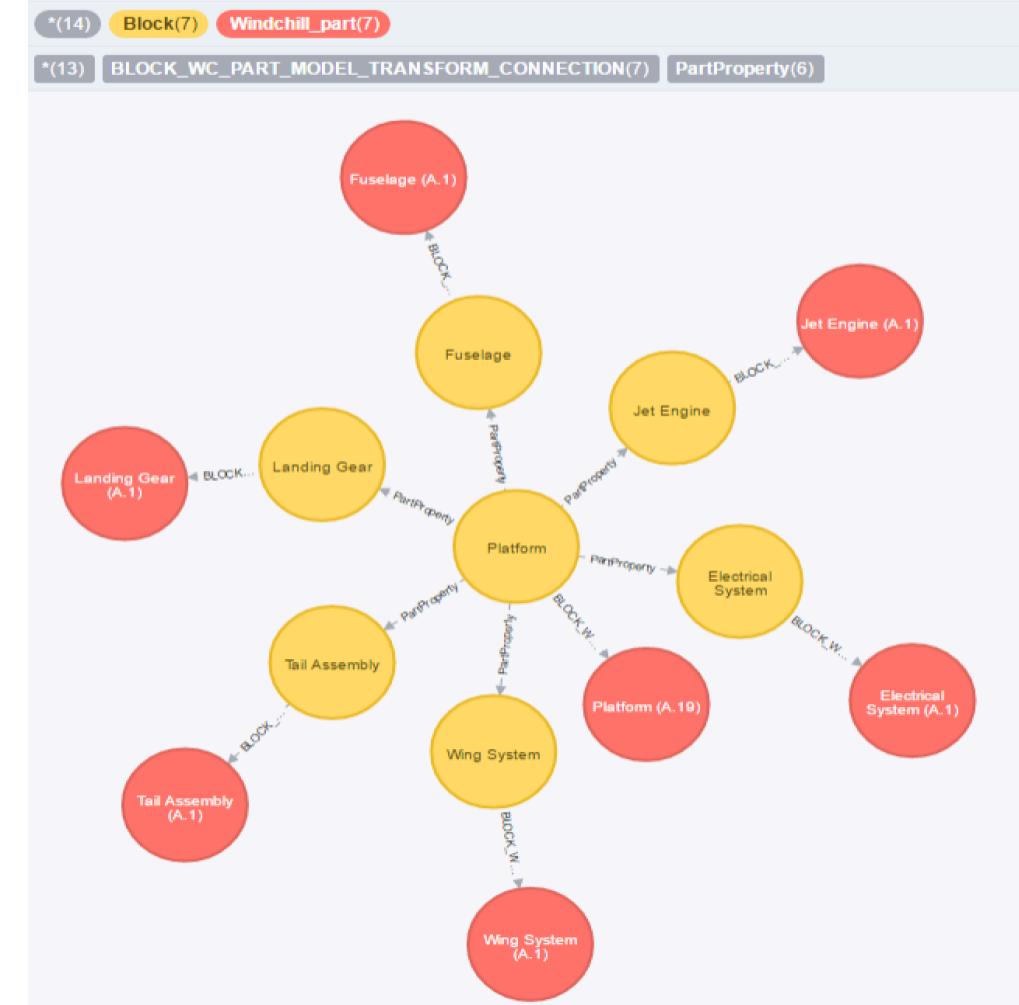
# Graph Queries on the Total System Model (1/2)



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



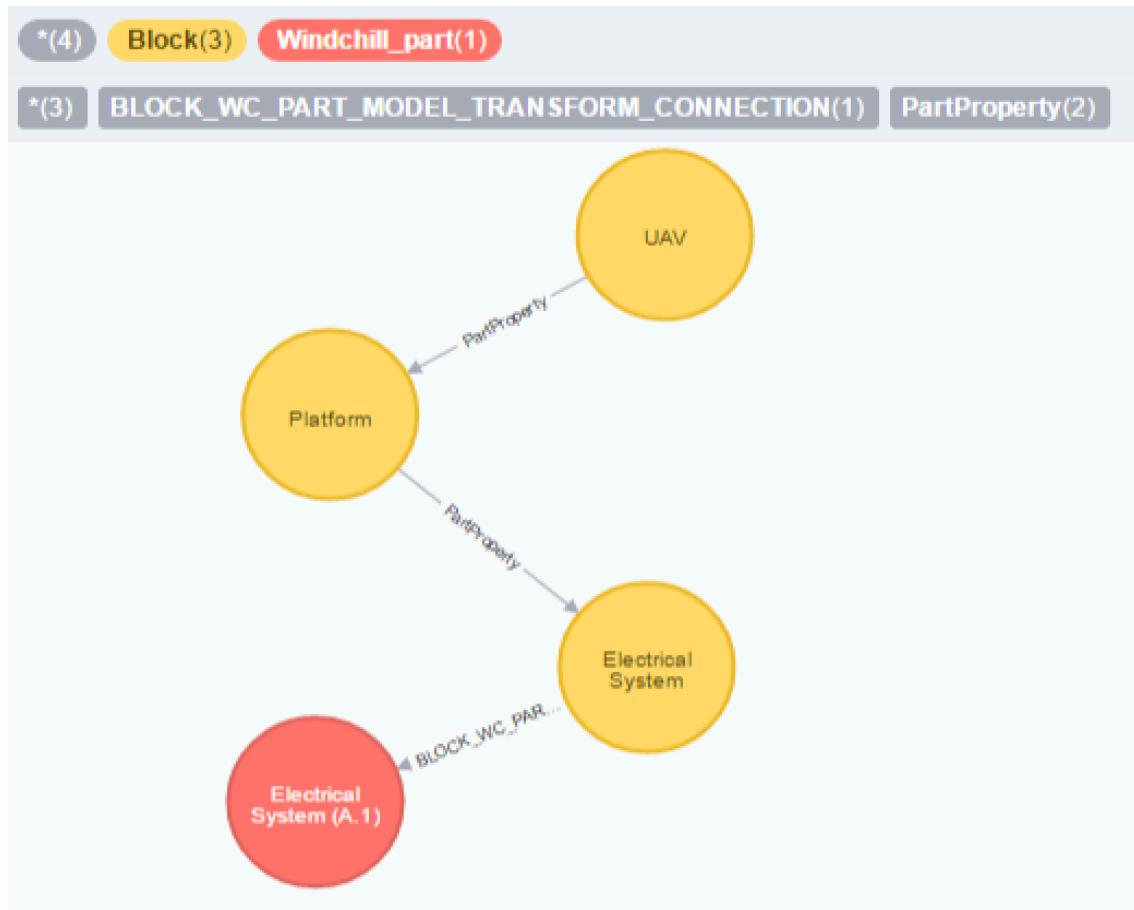
## 2. Get all connections between system architecture (SysML) and hardware parts (PLM)



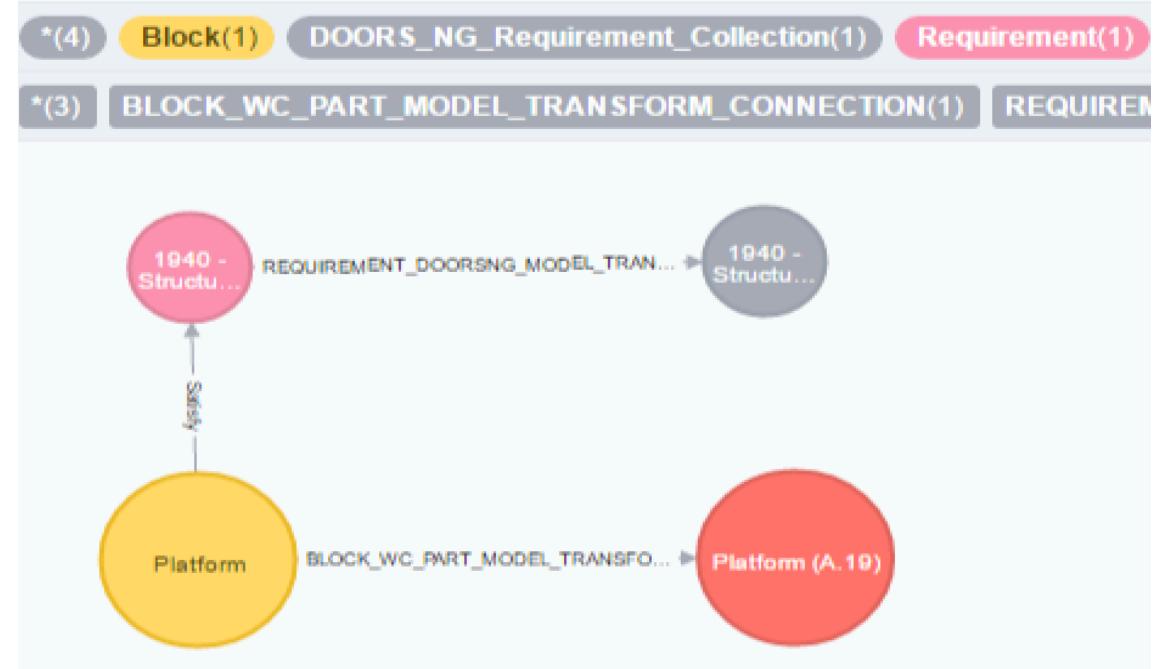
# Graph Queries on the Total System Model (2/2)



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)?





# Demonstration



## Syndeia 3.1 for MagicDraw

*The Next Generation of  
Model-Based Engineering*



# Demo 2 - Graph Queries on the Total System Model graph



Chrome File Edit View History Bookmarks People Window Help

localhost:7474/browser/

Favorites

Connected

Saved Scripts

- Basic Graph Queries
  - Get all nodes
  - Get all nodes and edges in the graph
  - Remove all nodes and relationships
- Employee Graph
- UAV Queries
  - Get all SysML packages
  - Get all relationships for UAV requirement spec
  - Get all relationships for UAV block
  - Trace Electrical System to UAV
  - What JIRA issues assigned to system structure (blocks)
  - Trace between a DOORS requirement to a Windchill part

Sample Scripts

- Basic Queries
- Example Graphs
- Data Profiling
- System

Styling / Graph Style Sheet

Graph Style Sheet

Import

Orange 12

\$

:play start

 neo4j  
COMMUNITY EDITION  
3.0.4

**Learn about Neo4j**  
A graph epiphany awaits you.  
 What is a graph database?  
How can I query a graph?  
What do people do with Neo4j?

**Jump into code**  
Use Cypher, the graph query language.  
 Code walk-throughs  
RDBMS to Graph  
Query templates

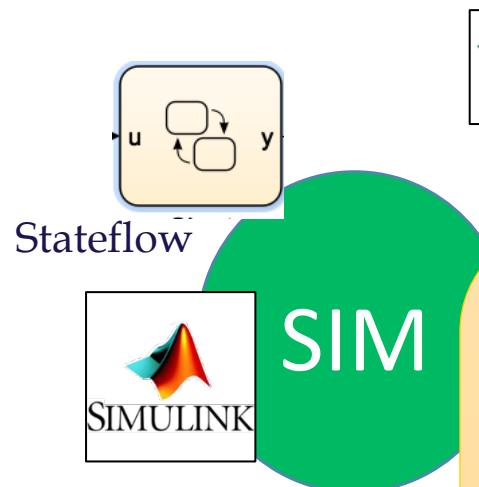
**Monitor the system**  
Key system health and status metrics.  
 Disk utilization  
Cache activity  
Cluster health and status

People like you have read this. Now they can make recommendations like an Amazonian.

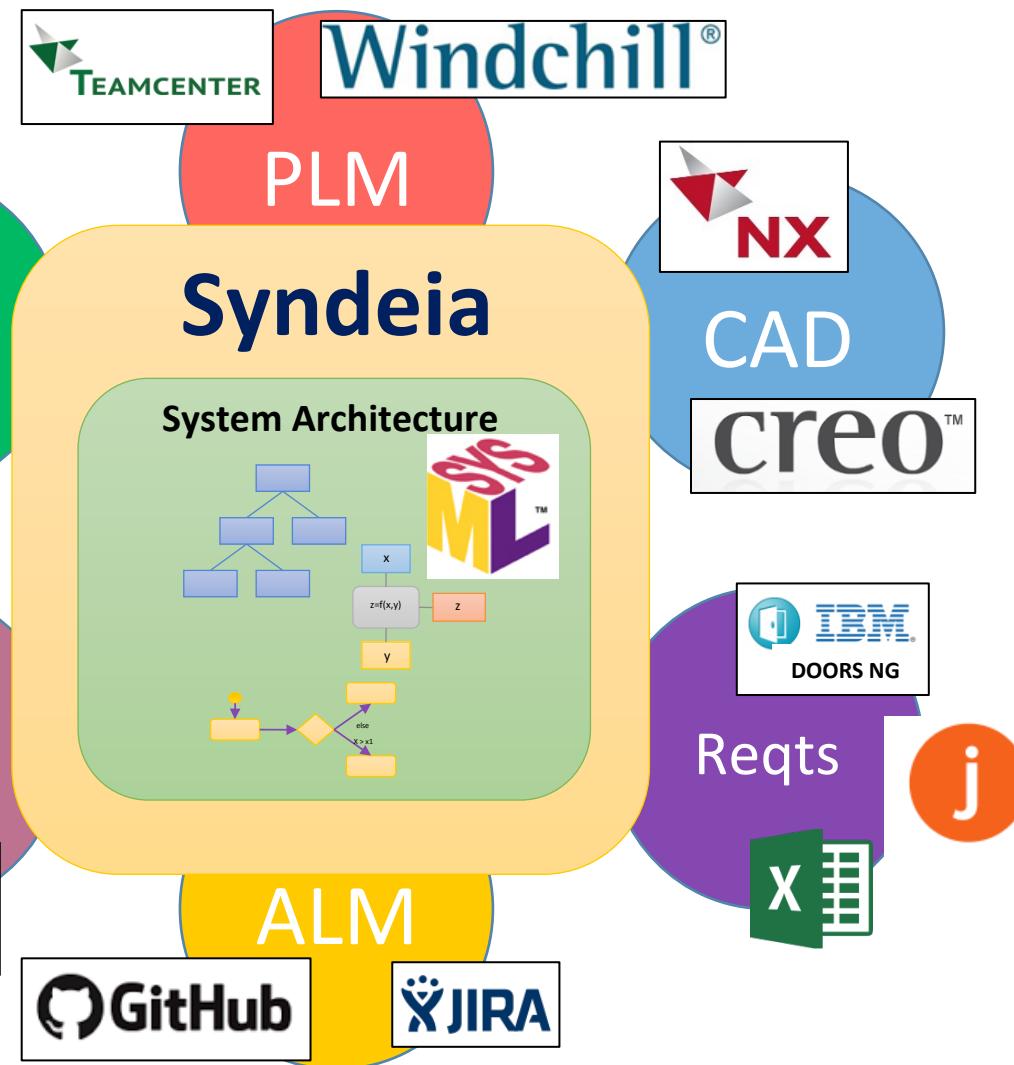
Copyright © Neo Technology 2002–2016

Manas

## 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](http://www.syndeia.com)
- YouTube demo video  
[www.intercax.com/products/syndeia/demos/](http://www.intercax.com/products/syndeia/demos/)
- Download a free evaluation  
[www.intercax.com/products/syndeia/download/](http://www.intercax.com/products/syndeia/download/)



## Syndea 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)



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



- 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



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