



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

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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
 - **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

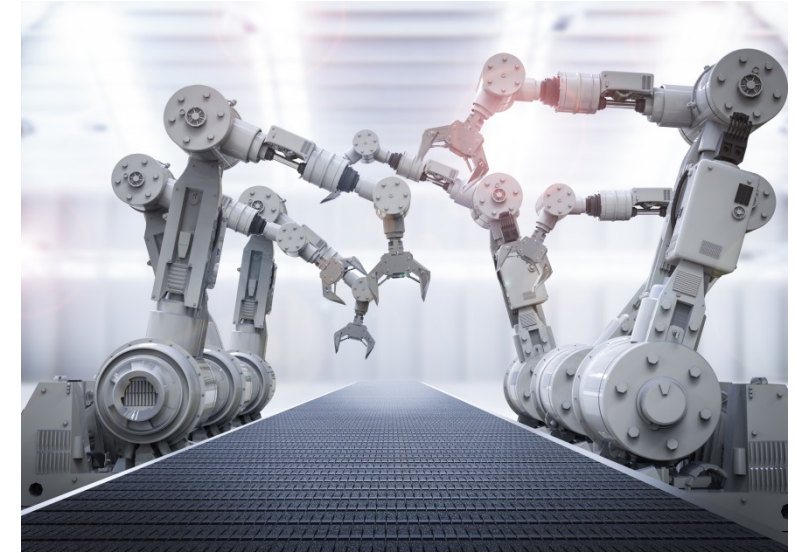
Systems – Cyber-physical, Multi-Disciplinary, System-of-Systems



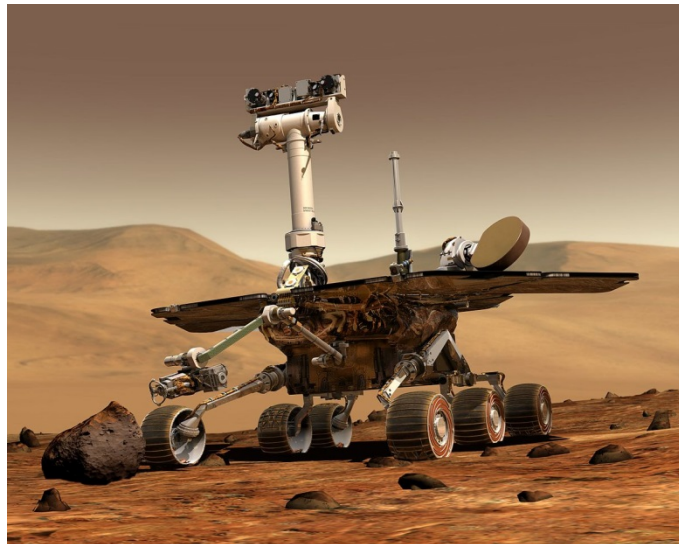
Smart Home



Hybrid/Electric/Self-Driving Cars



Robotic / Smart Manufacturing



Rovers



Smart Energy Grids



Healthcare

What is common across all these systems?

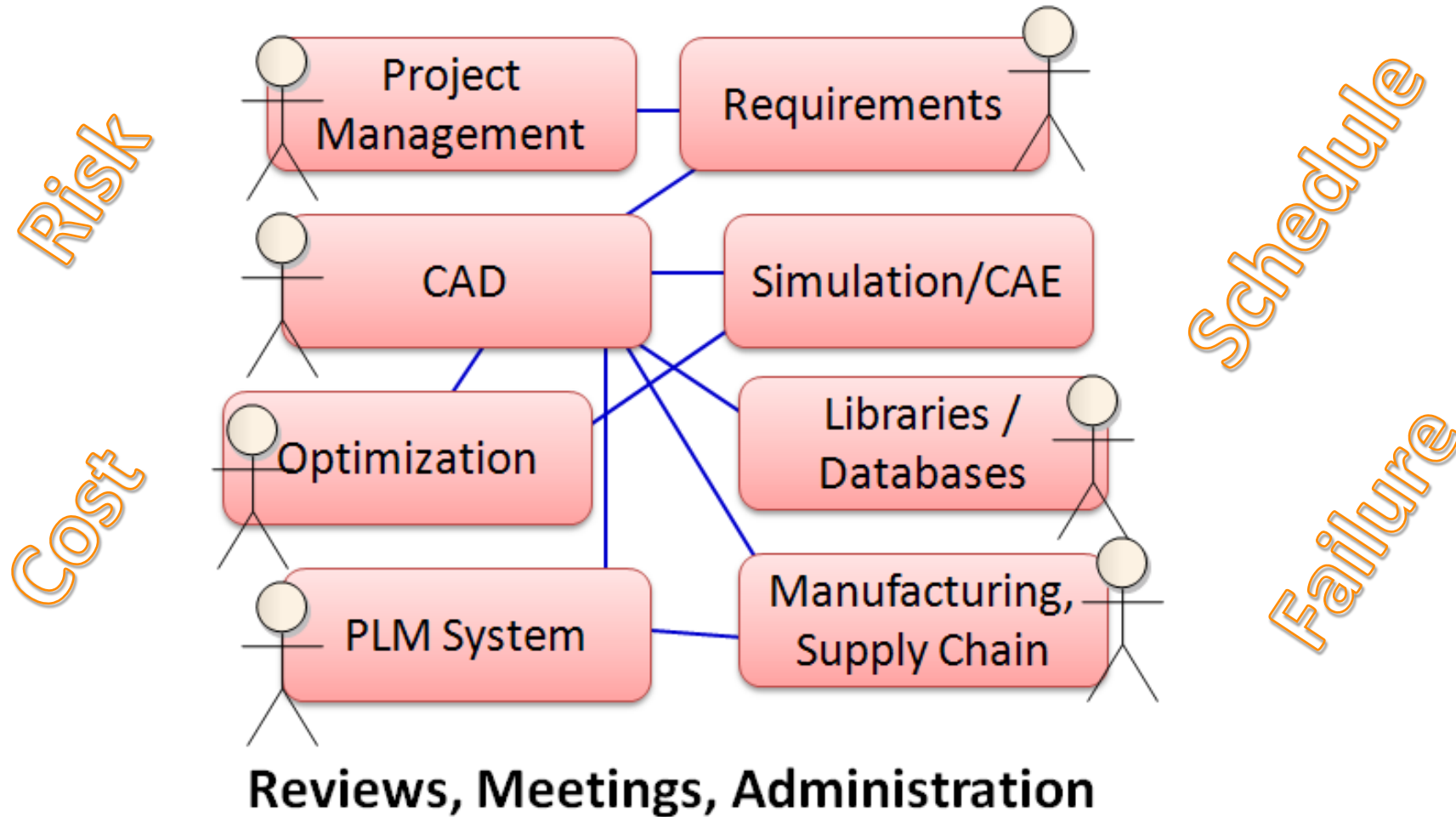


- **What is common to all these systems?**
 - Multi-disciplinary, many teams of engineers, project managers, suppliers, and more
 - Hardware, software, human, robotic sub-systems
 - Many software tools & databases (Systems, PLM, CAD, ALM, Simulation, and more)
 - Manage across lifecycle (conceptual -> 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?

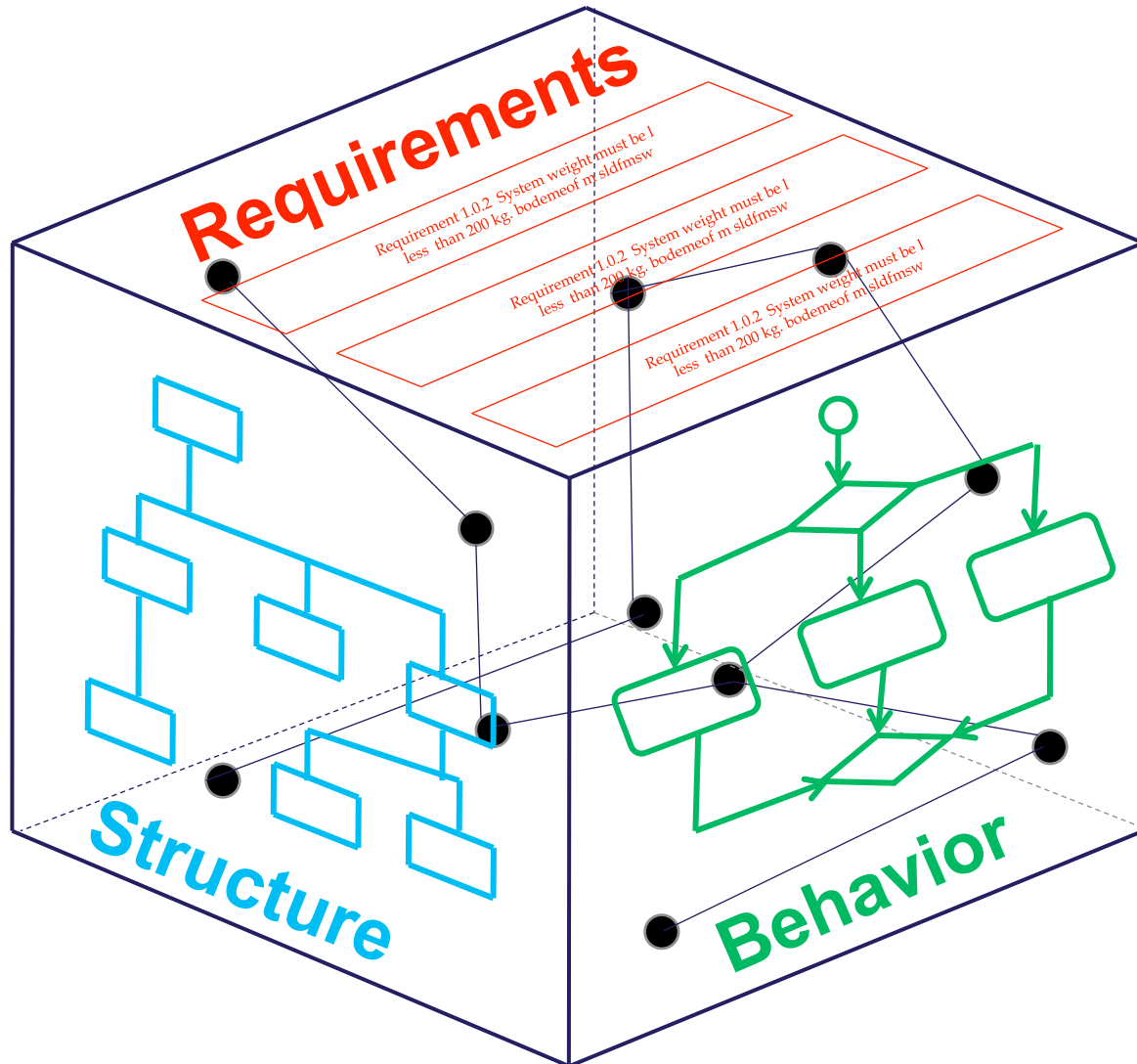


Point-to-point ad-hoc information flows
without a common architecture model



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

What is Model-Based Systems Engineering?

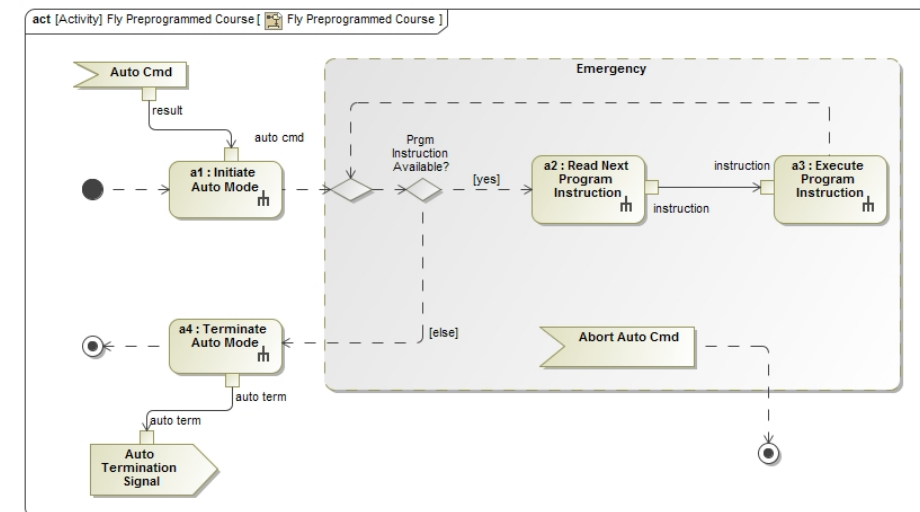
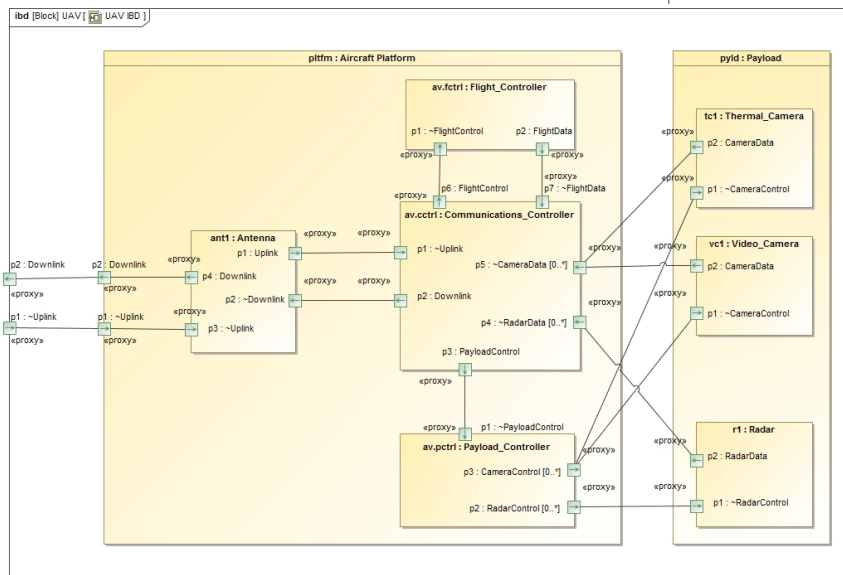
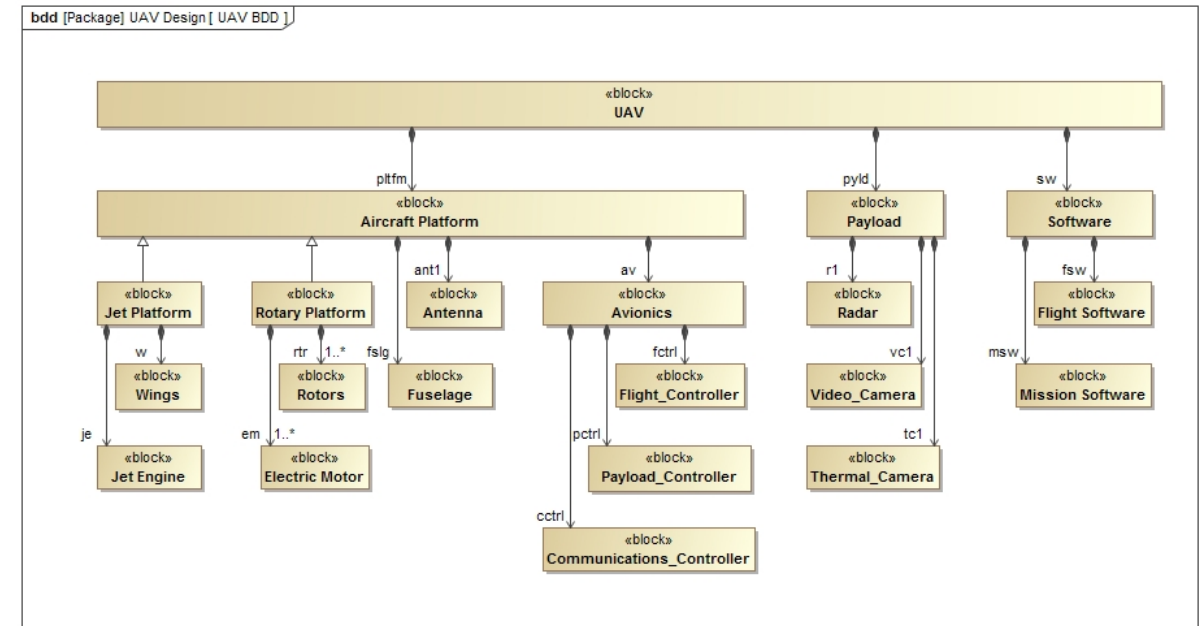
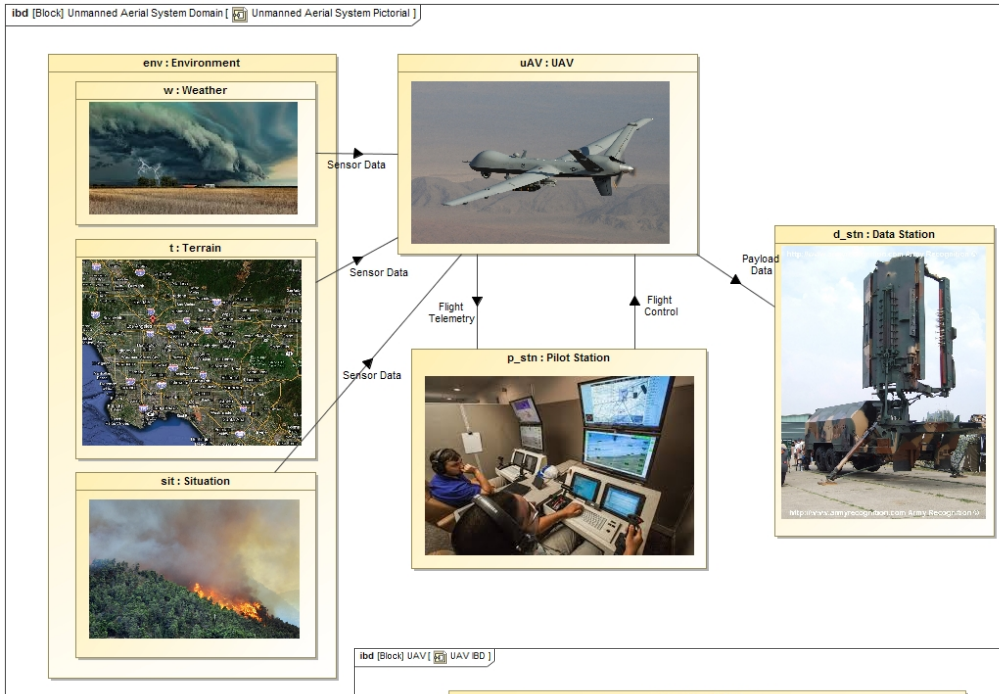


- MBSE = Unified model of the system versus series of disconnected documents or document-based flows between models (DBSE)
- System docs and views can be generated from this unified model
- DBSE > MBSE \Leftrightarrow 2D > 3D CAD
- Models in SE \neq MBSE



- **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

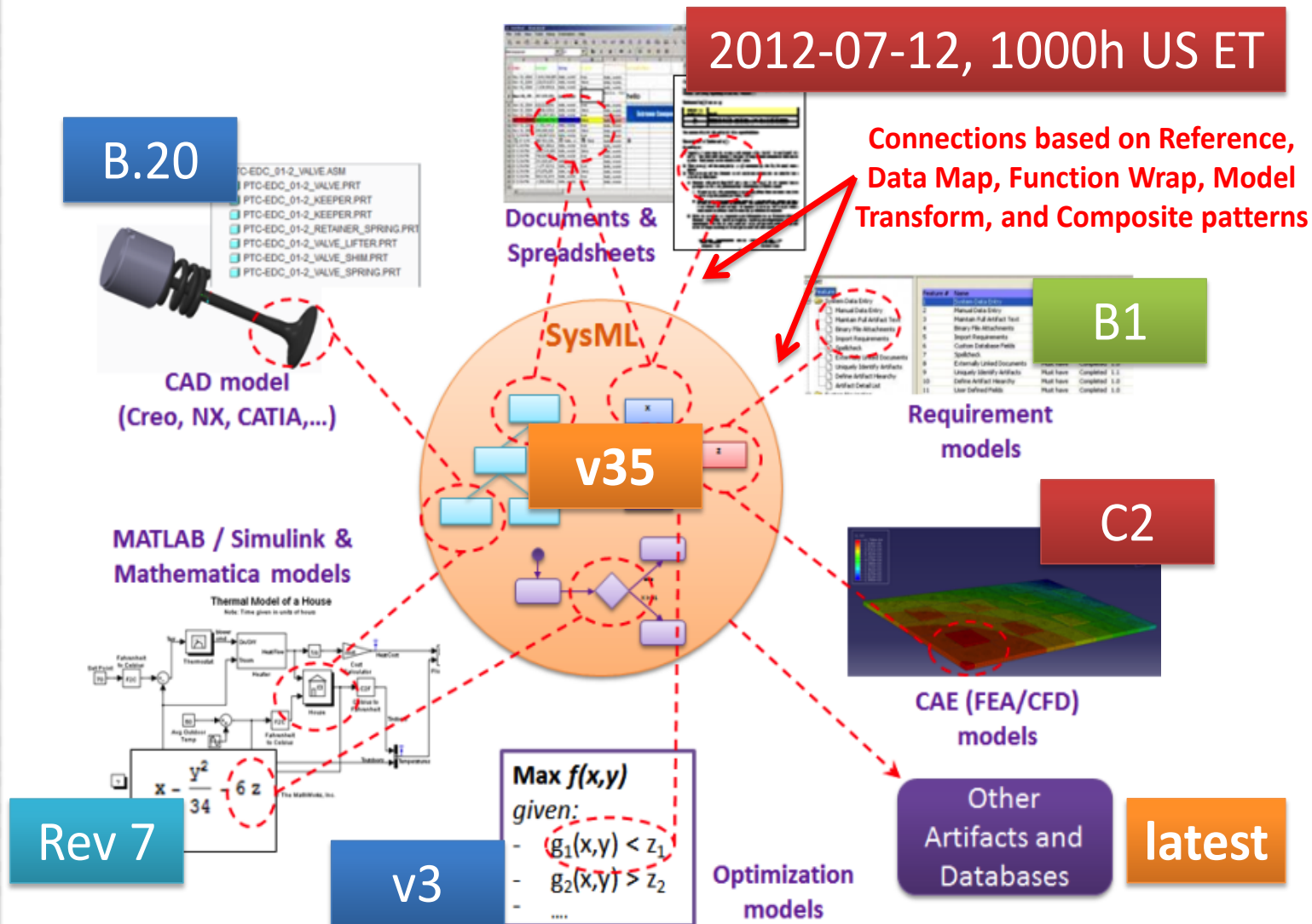
Example views (diagrams) in a SysML model



Total System Model – A Federated *Graph*



TOTAL SYSTEM MODEL (TSM)



Connect architecture model (SysML) with domain-specific models

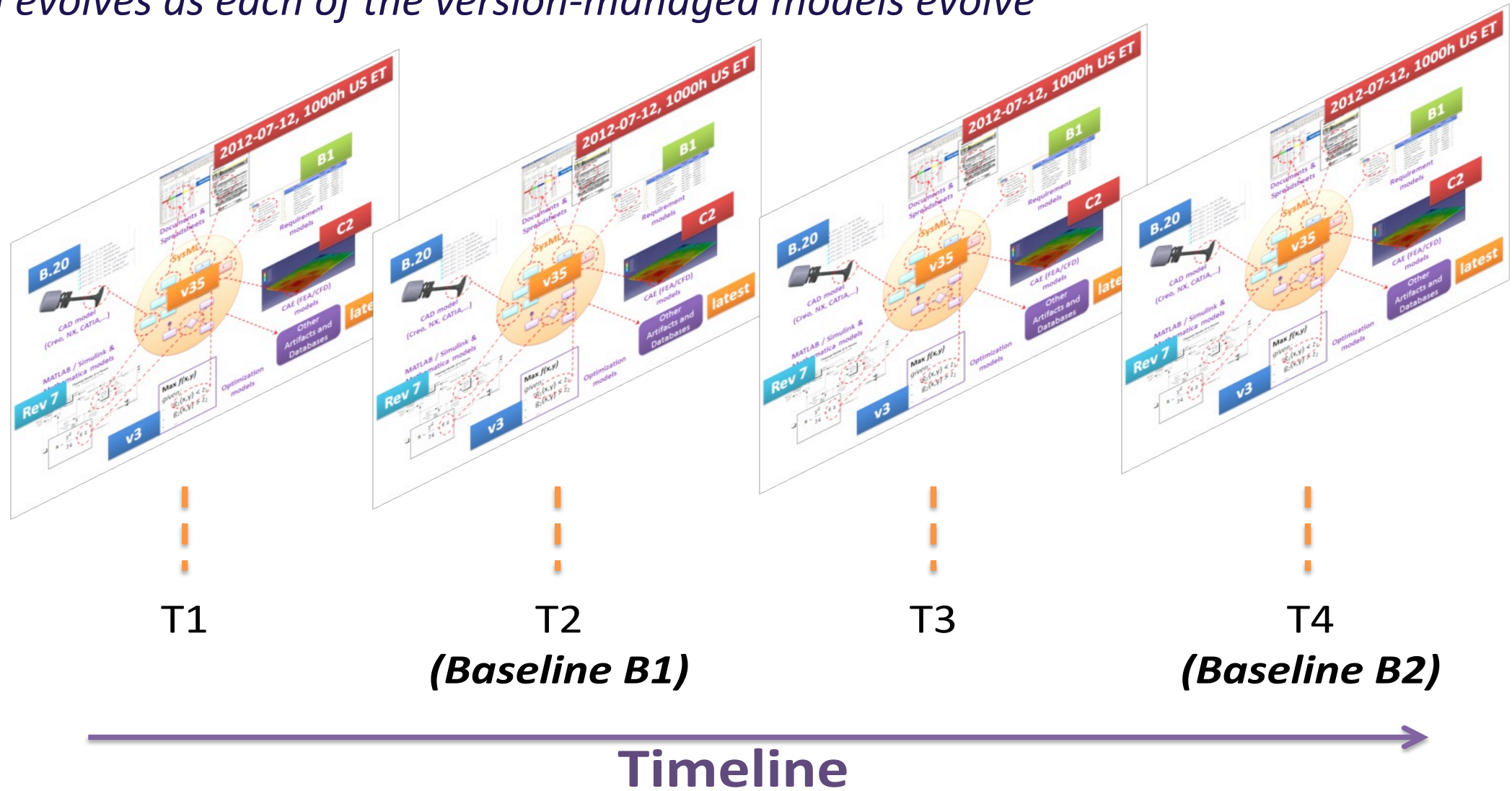
Total System Model (TSM) as a digital blueprint of the system connecting models across disciplines, tools, and version-management systems

Goal: Seamless traceability between disciplines across the system lifecycle

Total System Model (TSM)



TSM evolves as each of the version-managed models evolve

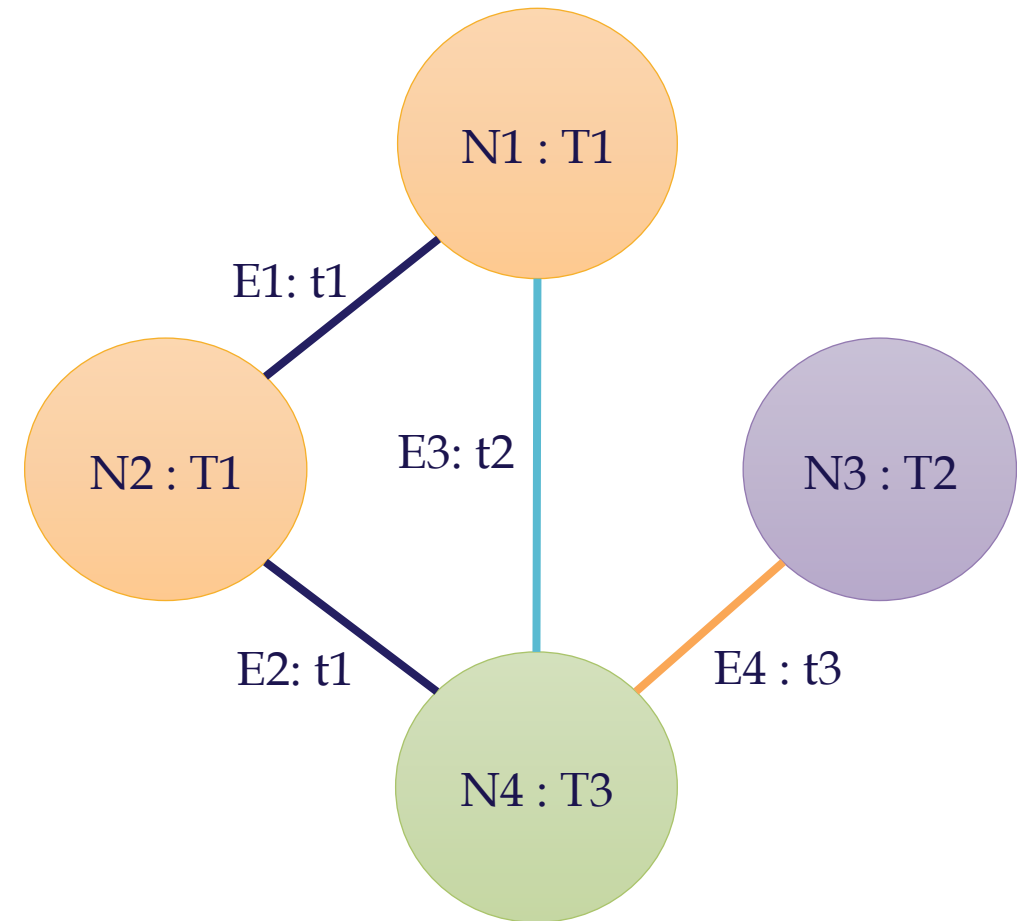




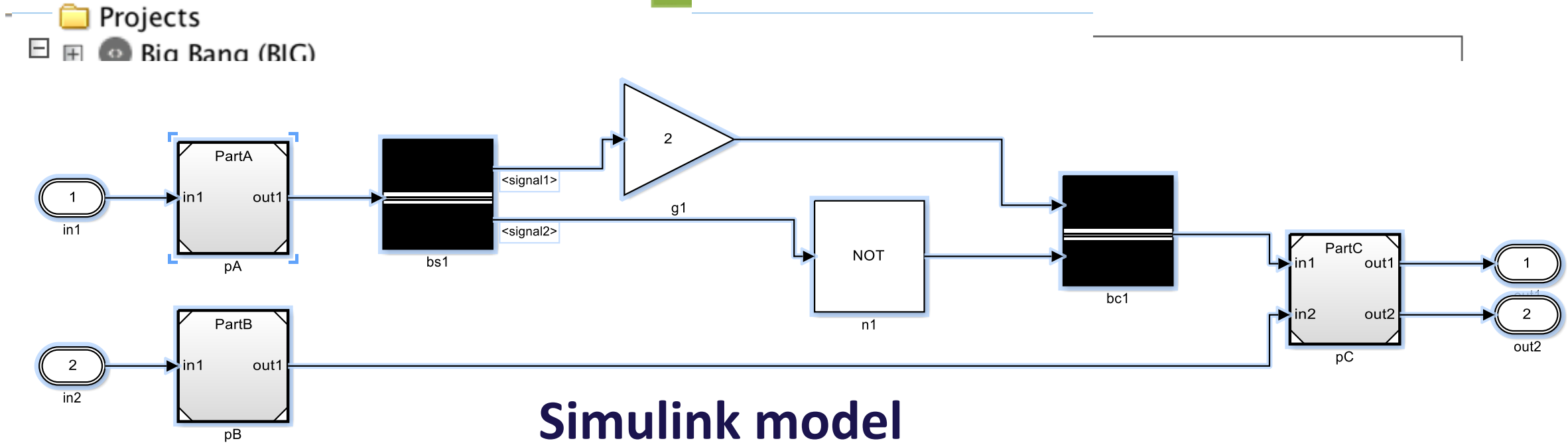
Total System Model is a Graph-based Digital Blueprint of a System



- 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



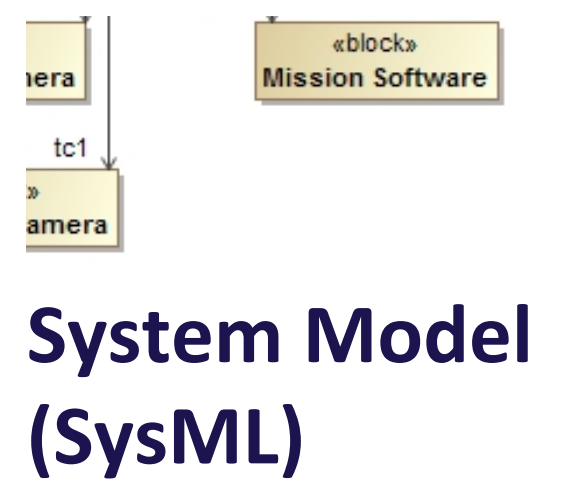
Information models can be abstracted as graphs



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

artifacts
Specification Module
ge Load

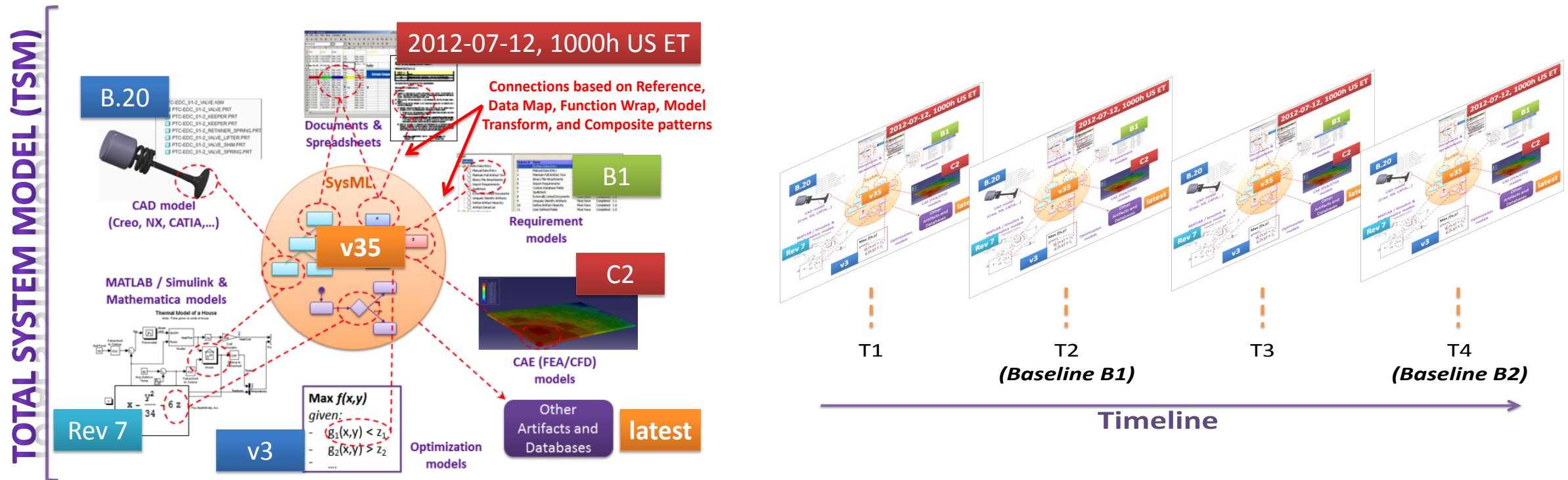


Total System Model Graph



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

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

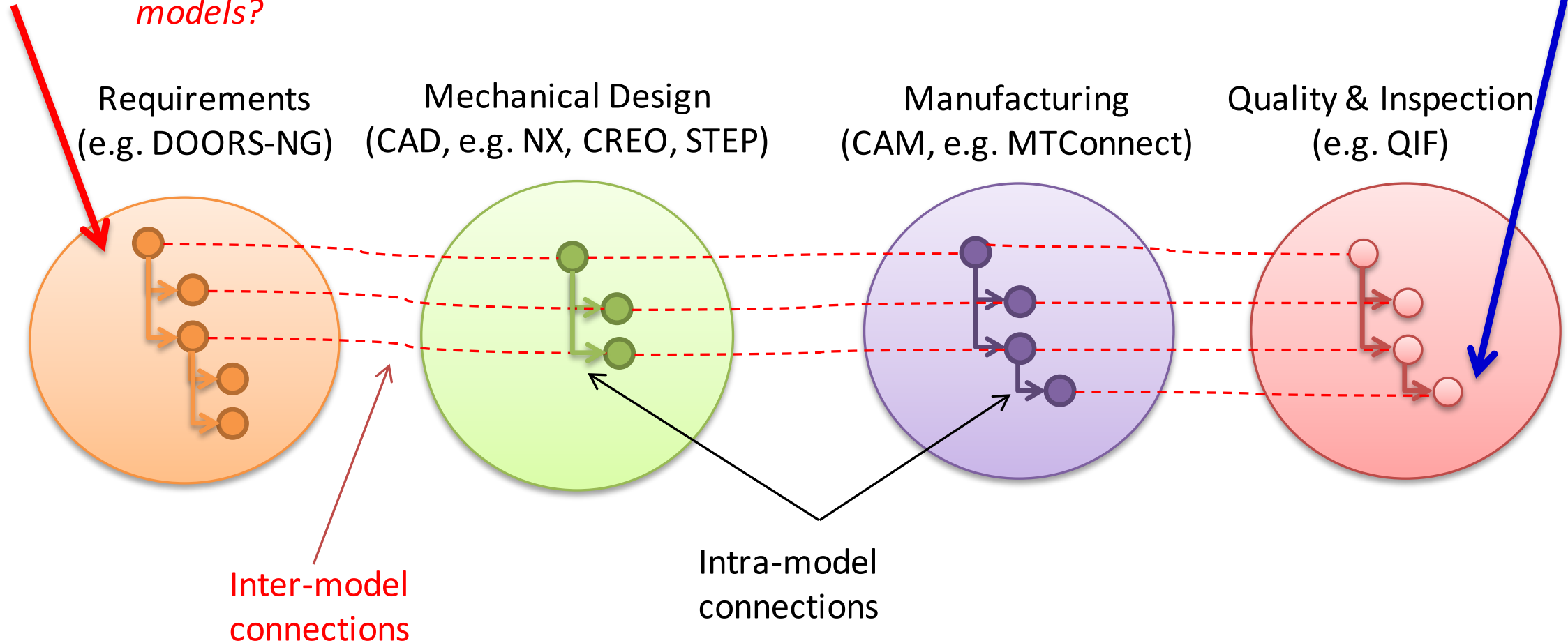


Intra-Model and Inter-Model Connections



*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?

 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)



Building and Visualizing the Total System Model Graph

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



The screenshot shows the 'Repository Manager' application with several tabs: 'Repository Manager', 'Connection Manager', 'Connection Browser', 'Connection Summary', 'Comparison Result', and 'Settings'. The 'Repository Manager' tab is active, displaying a list of repositories on the left and a hierarchical tree view of an 'Unmanned Aerial Vehicle' model on the right.

Repositories List:

- 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

Model Structure (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_UMTS (A.1)
 - gps : GPS (A.1)
 - pltfrm1 : Aircraft_Platform (A.1)
 - pyld_con1 : PayloadController (A.1)
 - ssr1 : SpreadSpectrum (A.1)
 - sw : UAS_Software (A.1)
 - therm1 : Thermal_Camera (A.1)
 - therm2 : WideAngleIR (A.1)
 - vis1 : Visual_Camera (A.1)
 - wifi1 : WiFi_WiMax (A.1)
 - Folders
 - Hardware Component
 - Aircraft Platform (00000000000000000000000000000000)
 - Aircraft_Platform (00000000000000000000000000000000)
 - Autopilot (00000000000000000000000000000000)
 - CommunicationsController (00000000000000000000000000000000)
 - Data_Bus (00000000000000000000000000000000)
 - FlightController (00000000000000000000000000000000)
 - GPRS_UMTS_Module (00000000000000000000000000000000)
 - GPS (00000000000000000000000000000000)
 - PayloadController (00000000000000000000000000000000)

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

Teamcenter

MySQL

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



The screenshot displays the Syndeia Dashboard (2.0.0) interface for an Unmanned Aerial Vehicle. The interface is divided into several panes:

- SysML Model:** A tree view showing the structure of the Unmanned Aerial Vehicle model, including components like Aircraft Platform, blackbox, body, elec assembly, engine, fuel system, powertrain, rotor, tail assembly, Analysis Manager, APU, Autopilot, Battery, BlackBox, Body, Communications Controller, Communications Interface, and Cowling.
- Connection Type:** A panel with radio buttons for Reference, Function Wrap, Data Map, and Model Transform (selected).
- TC91:** A tree view showing the structure of the TC91 repository, including Requirements, Satellite (Precise BOM), TraceLinks, UAV (Imprecise BOM), and various sub-components like 000464/A; 1-Unmanned Aerial Vehicle, 000464/B; 1-Unmanned Aerial Vehicle, and 000464/C; 2-Unmanned Aerial Vehicle.
- Local File System Repositories:** A list of repositories including Creo, NX, Simulink, MySQL Repositories, Teamcenter Repositories, and Windchill Repositories. The TC91 repository is highlighted.

A red dashed arrow labeled "Drag-n-Drop" points from the SysML Model tree to the TC91 repository tree. A red dashed arrow labeled "Switch repos" points from the TC91 repository tree to the Local File System Repositories list.

At the bottom of the interface, there is a status bar showing the time (10:54:22 AM) and memory usage (442M of 791M).

Example using Syndeia
(www.syndeia.com)

Compare and synchronize across inter-model connections



Repository Manager Connection Manager Connection Browser Connection Summary Comparison Result Settings

Q Type here to filter connections Clear Export to Excel

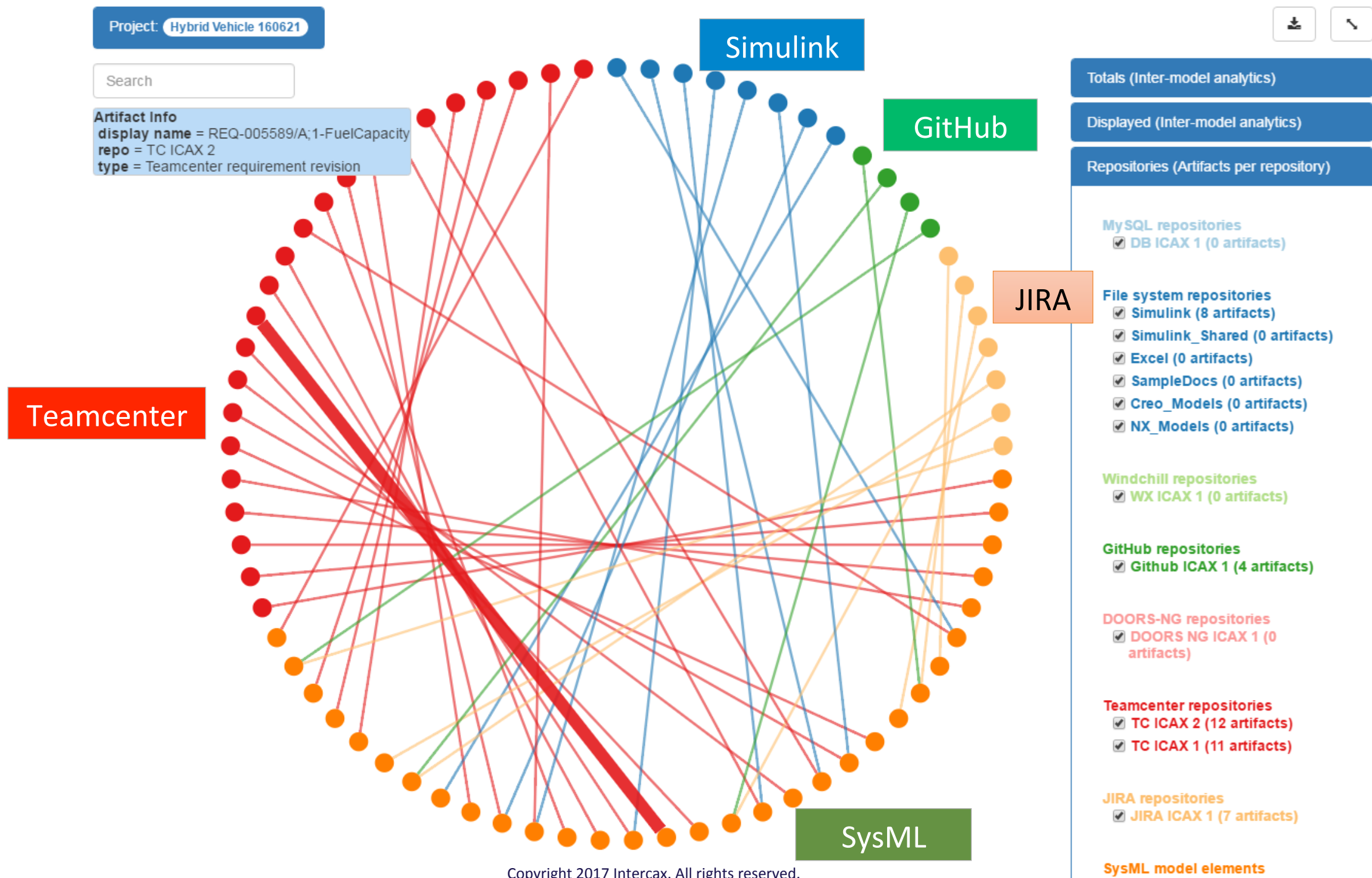
Conn ID	Source	Target	Latest Target	Comment
e3f03...	Unmanned Aerial Vehicle	000464/C;2-Unmanned Aerial Vehicle	000464/C;2-Unmanned Aerial Vehicle	The block Unmanned Aerial Vehic...
	wimax module : WiMax Module	wimax module : 000472/A;1-WiMa...	wimax module : 000472/A;1-WiMax M...	Part property wimax 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...

[11:56:22] INFO Comparing SysML part property and Teamcenter part occurrence (BOM line with ref des) thermal camera.

Ready 11:56:55 AM 549M of 735M

Example using Syndeia
(www.syndeia.com)

Interactive Graph of Total System Model





Teamcenter requirement

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

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

GitHub
folder

JIRA

Teamcenter

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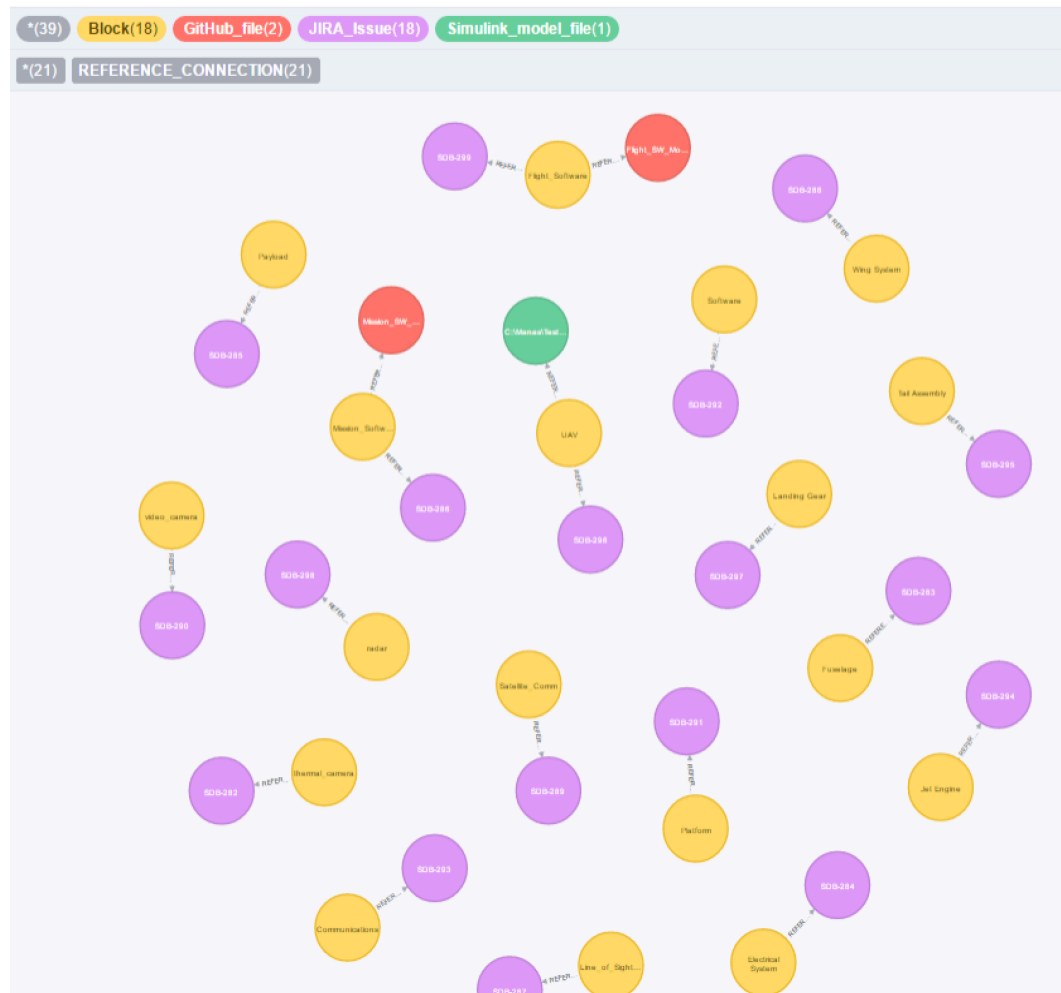


Querying the Total System Model Graph

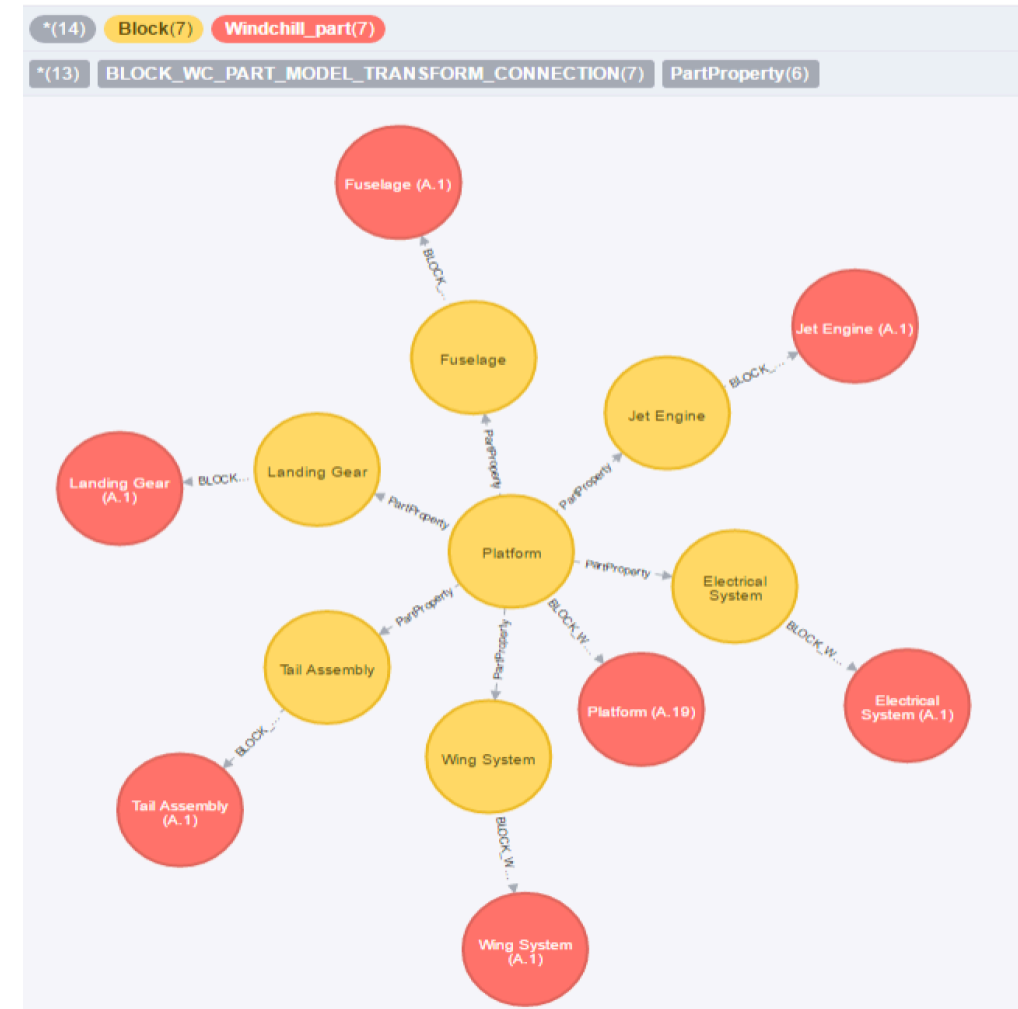
Graph Queries on the Total System Model (1/2)



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

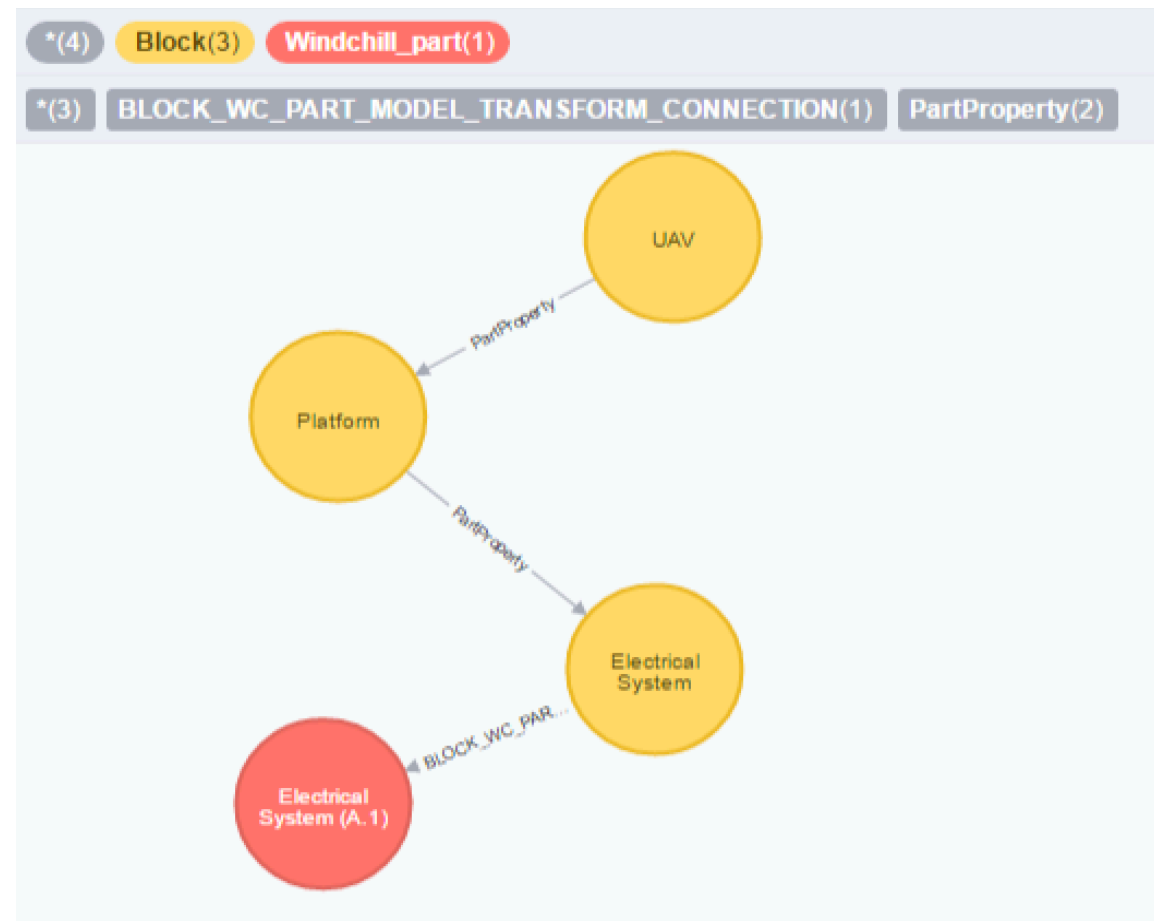


2. Get all connections between system architecture (SysML) and hardware parts (PLM)

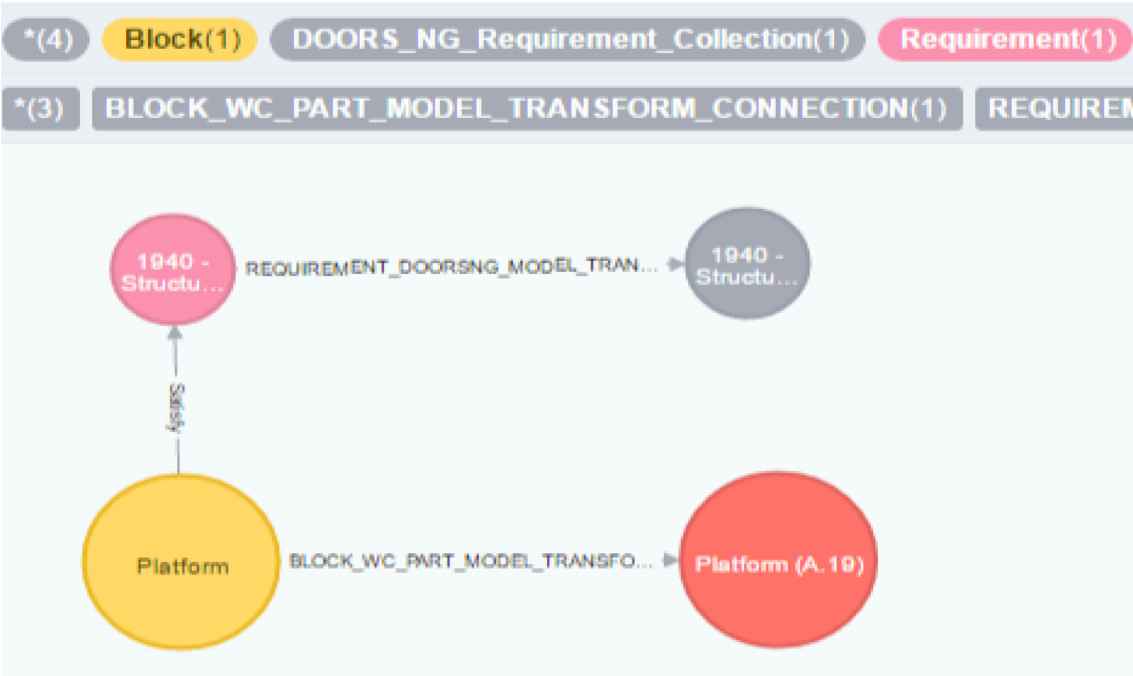




3. How does a failure in the Electrical System assembly (PLM) affect the overall UAV architecture (SysML)?



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



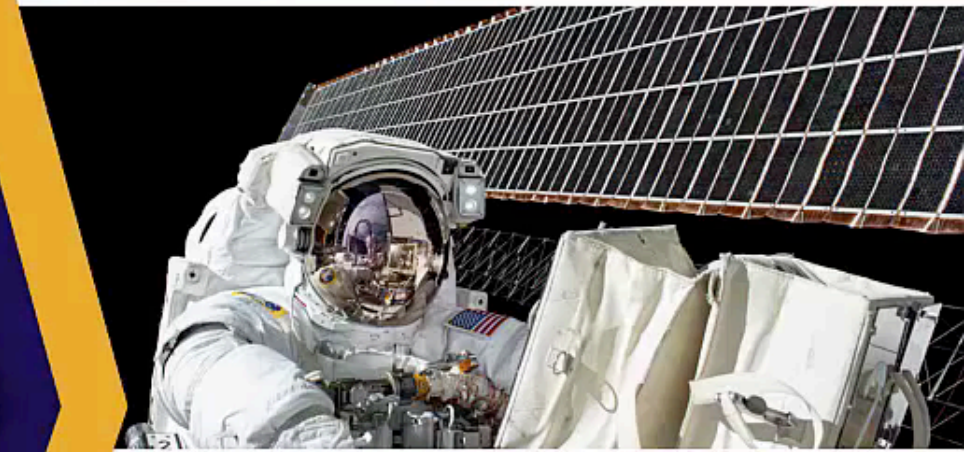


Demonstration



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/

Neo4j

Manas

100% Sun 10:13 PM

Favorites
Synced a minute ago
Connected

+ New folder

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

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?

Start Learning

Jump into code
Use Cypher, the graph query language.

- Code walk-throughs
- RDBMS to Graph
- Query templates

Write Code

Monitor the system
Key system health and status metrics.

- Disk utilization
- Cache activity
- Cluster health and status

Monitor

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

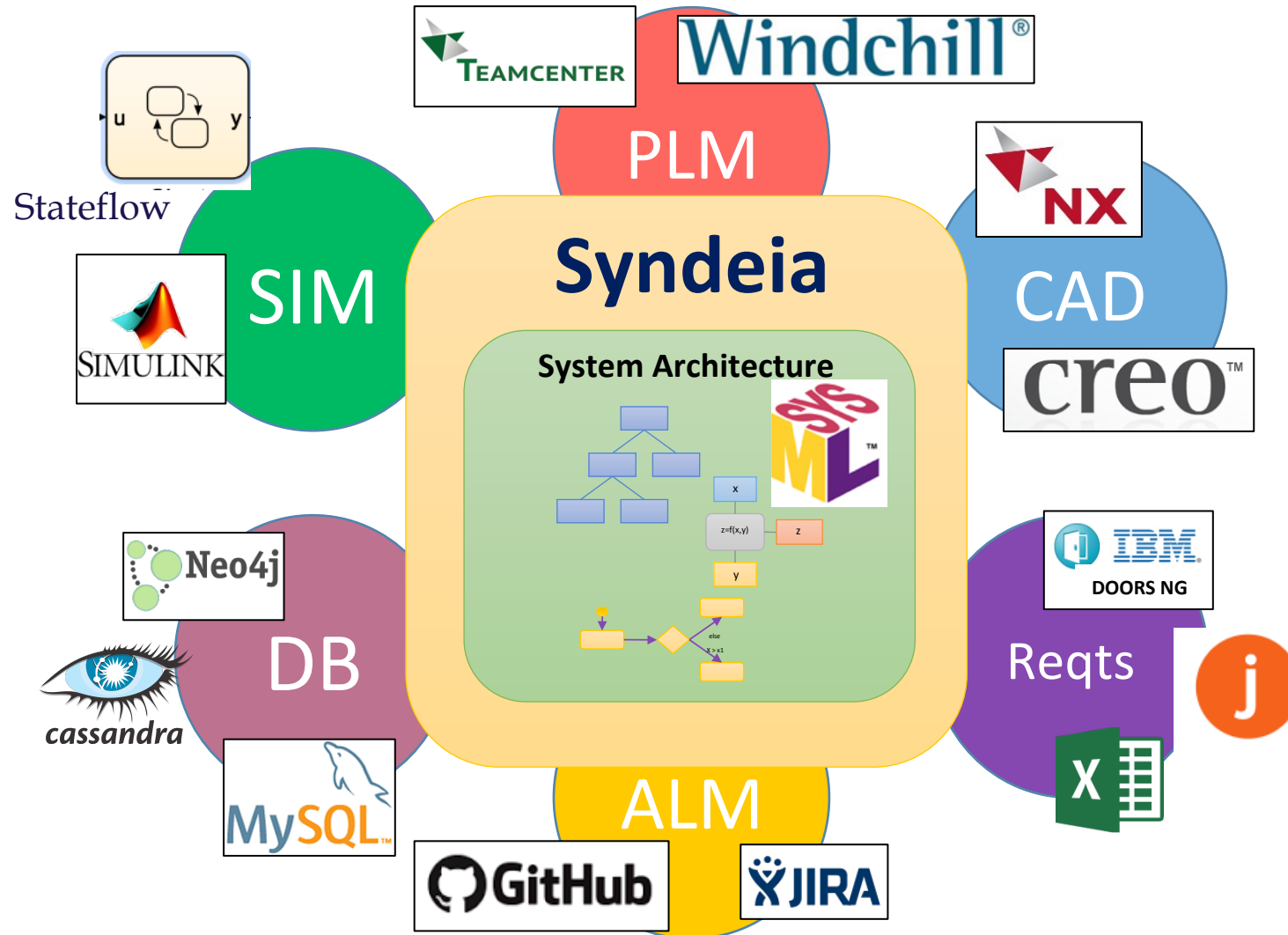
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Syndeia 1.0 (SLIM)
Jul 2014

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)



- 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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