



intercax

NIST
National Institute of
Standards and Technology
U.S. Department of Commerce

System Lifecycle Handler – *Spinning a Digital Thread for Manufacturing*

INCOSE IS, Washington DC / July 12, 2018

Manas Bajaj, PhD

Chief Systems Officer, Intercax

Thomas Hedberg, Jr.

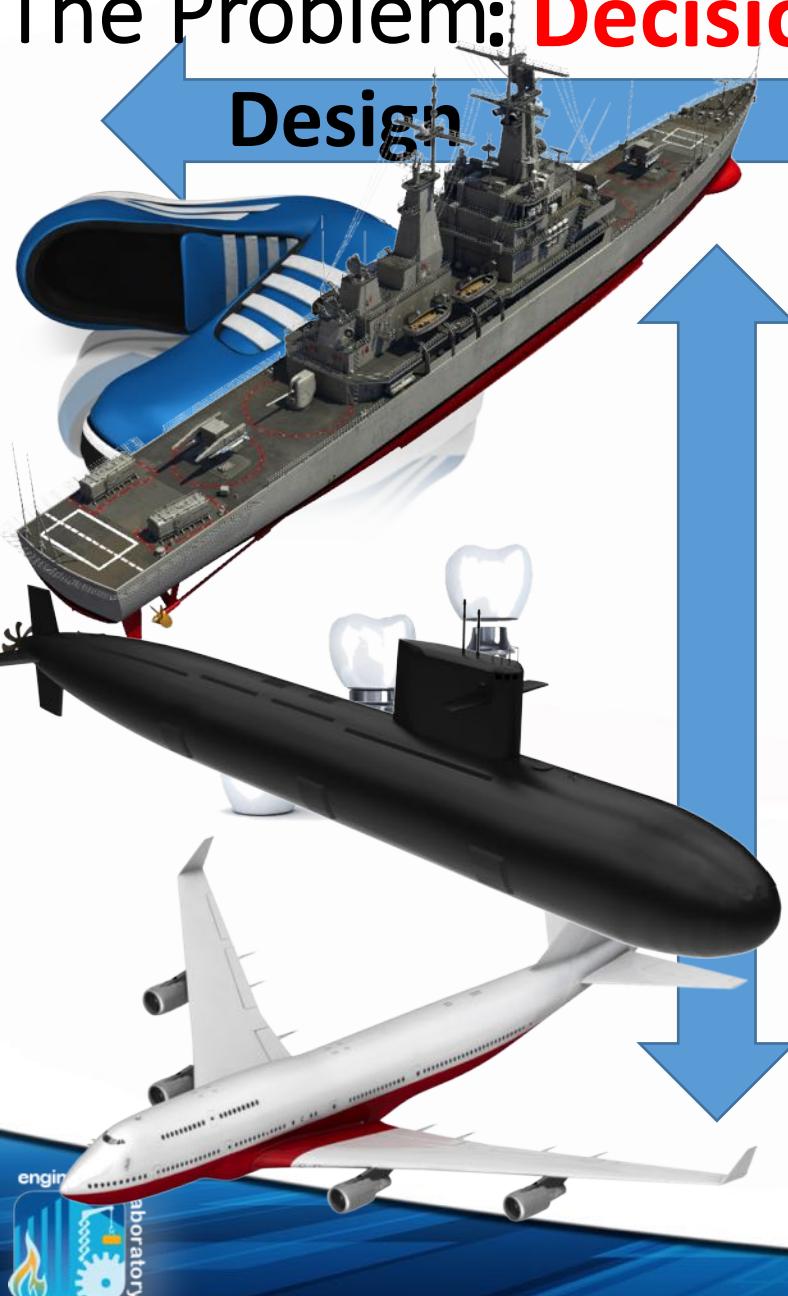
Project Leader, Digital Thread for Smart
Manufacturing, NIST



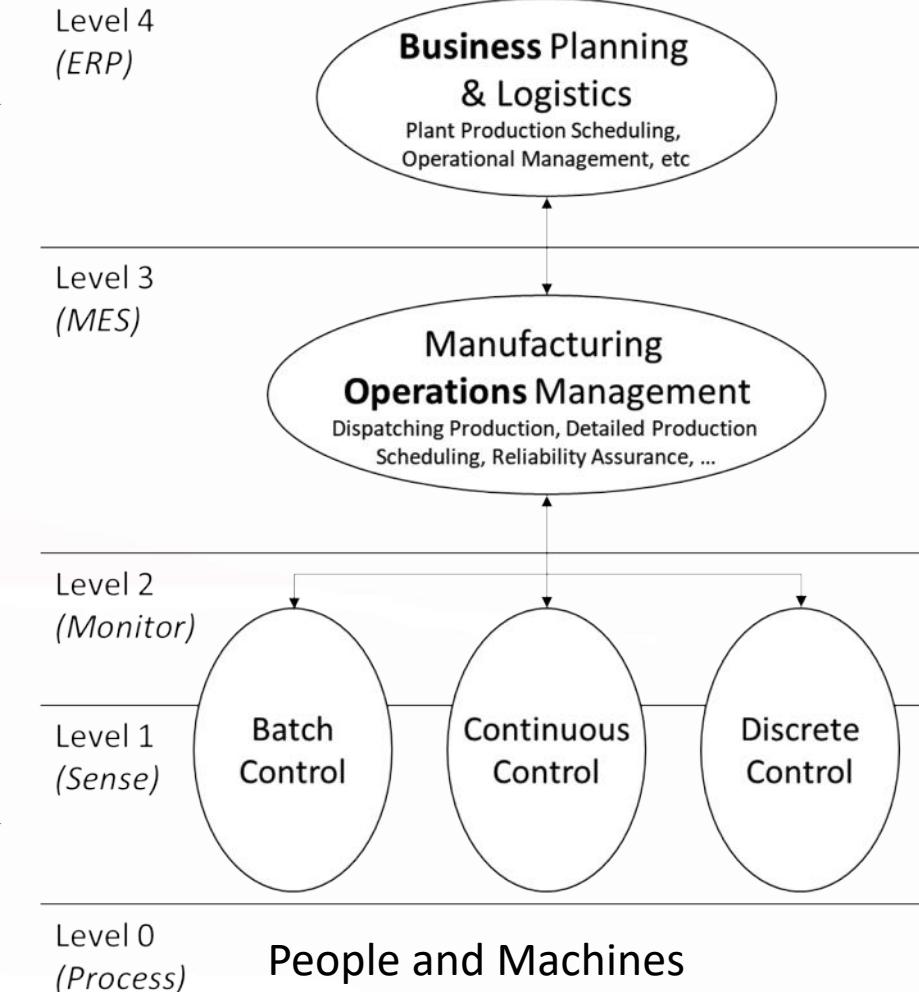
- **Digital Thread for Smart Manufacturing**
- System Lifecycle Handler - Foundations
 - Project goals
 - Use Cases
 - Graph foundations
- System Lifecycle Handler – Proof-of-concept demonstrations
 - Querying the digital thread
 - Building the digital thread
 - Maintaining the digital thread
 - API for the digital thread
 - Tools, APIs, and open standards used in the PoC
- Next steps
- Questions and Comments

The Problem: Decision Making in Distributed Environments

Design



Manufacturing



Sustainment



Why?

- Decentralized manufacturing → OEMs = system integrators
- Industry wants and needs agility and flexibility [1]
- Simplicity through distributed complexity [2]
- Change in demand (lot size one, make it next door, on-demand ordering) [1, 3, 4]
- MRO/Sustainment needs distributed manufacturing to figure out what capabilities & capacities are located where and what is the topology of that distributed network
- Increased opportunities for MFGaaS → \$57 Million Annual Opportunity in simply better sensing and monitoring [5]

1. Gallaher, M. P., Oliver, Z. T., Rieth, K. T., and O'Connor, A. C., 2016. Economic analysis of technology infrastructure needs for advanced manufacturing: Smart manufacturing. Report NIST GCR 16-007, RTI International.
2. Mocker, M., Weill, P., & Woerner, S. (2014). Revisiting Complexity in the Digital Age. *MIT Sloan Management Review*. Retrieved from <https://sloanreview.mit.edu/article/revisiting-complexity-in-the-digital-age/>
3. Quan, T. and Williams, K., Product Variety, Across-Market Demand Heterogeneity, and the Value of Online Retail (November 17, 2016). Cowles Foundation Discussion Paper No. 2054. DOI: 10.2139/ssrn.2871513
4. Quan, T. and Williams, K., Product Variety, Across-Market Demand Heterogeneity, and the Value of Online Retail (June 26, 2017). Cowles Foundation Discussion Paper No. 2054R. DOI: 10.2139/ssrn.2993236
5. Anderson, G. (2016). *The Economic Impact of Technology Infrastructure for Smart Manufacturing* (NIST Economic Analysis Briefs 4). Retrieved from Gaithersburg MD: <http://nvlpubs.nist.gov/nistpubs/eab/NIST.EAB.4.pdf>

Enter Digital Thread and Digital ~~Twins~~ *Surrogates*

- Digital Thread, *noun*
 - A connected information flow between standard interfaces for activities across the product lifecycle
- Digital Surrogate, *noun*
 - An application of the digital thread to an environment where integrated information flows are leveraged to digitize systems and apply modeling and simulation to enable dynamic control

Lifecycle Information Framework and Technology

FROM INFORMATION SILOS...

Design

Analysis

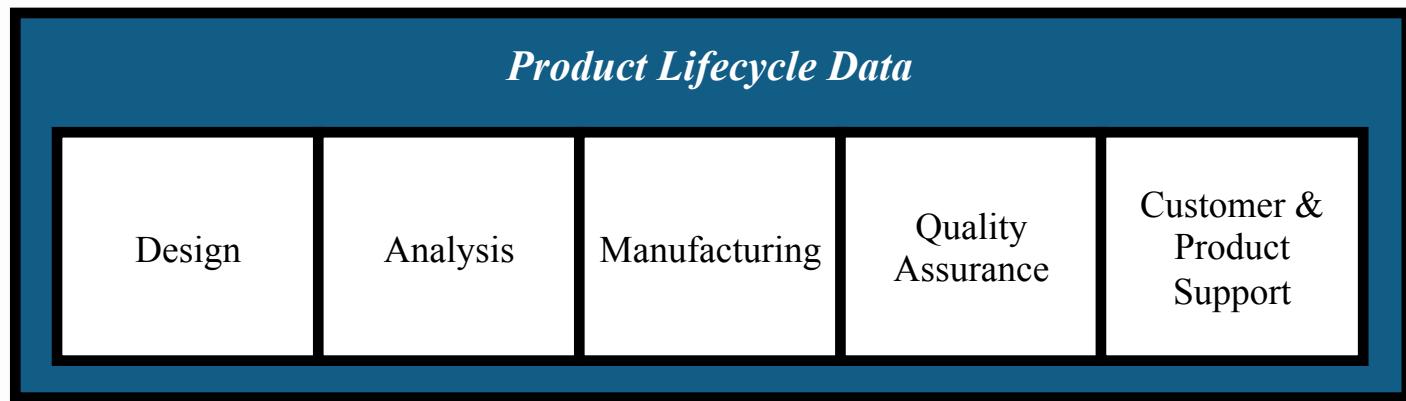
Manufacturing

Quality
Assurance

Customer &
Product
Support

Hedberg Jr, T., Barnard Feeney, A., Helu, M., & Camelio, J. A. (2017). Towards a Lifecycle Information Framework and Technology in Manufacturing. *Journal of Computing and Information Science in Engineering*, 17(2), 021010-021010-021013. doi:10.1115/1.4034132

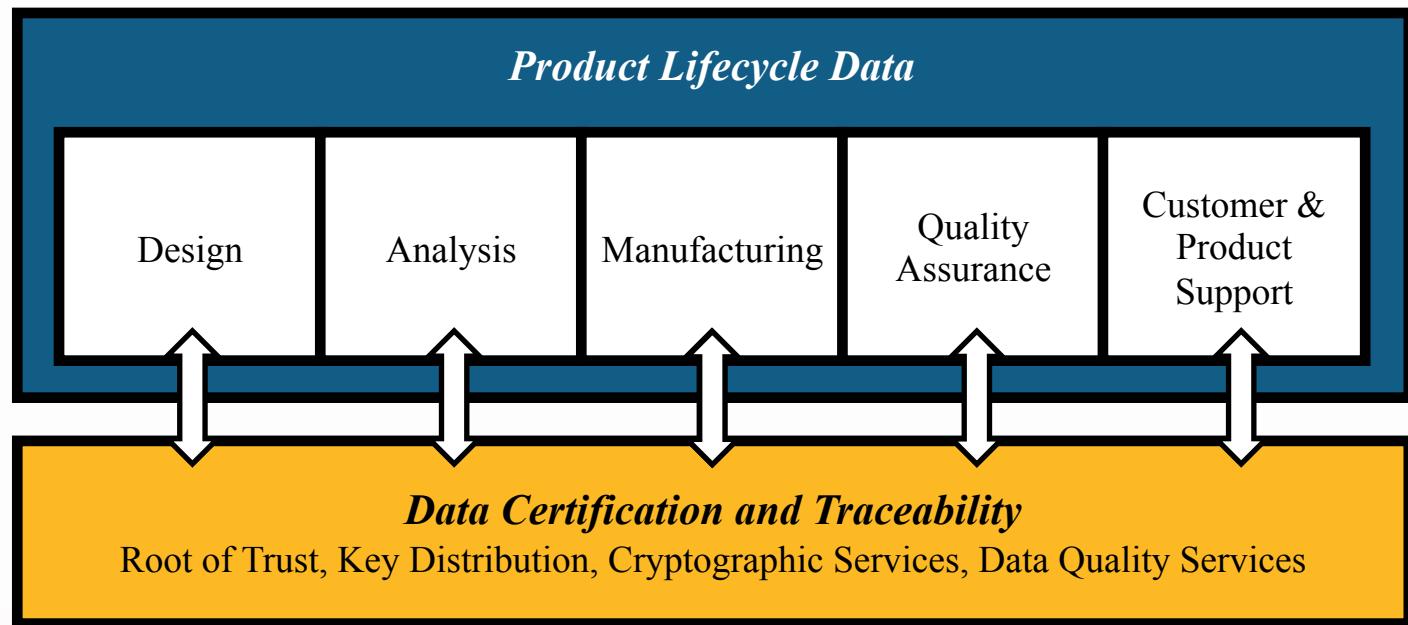
Lifecycle Information Framework and Technology



...TO LINKED DATA...

Hedberg Jr, T., Barnard Feeney, A., Helu, M., & Camelio, J. A. (2017). Towards a Lifecycle Information Framework and Technology in Manufacturing. *Journal of Computing and Information Science in Engineering*, 17(2), 021010-021010-021013. doi:10.1115/1.4034132

Lifecycle Information Framework and Technology

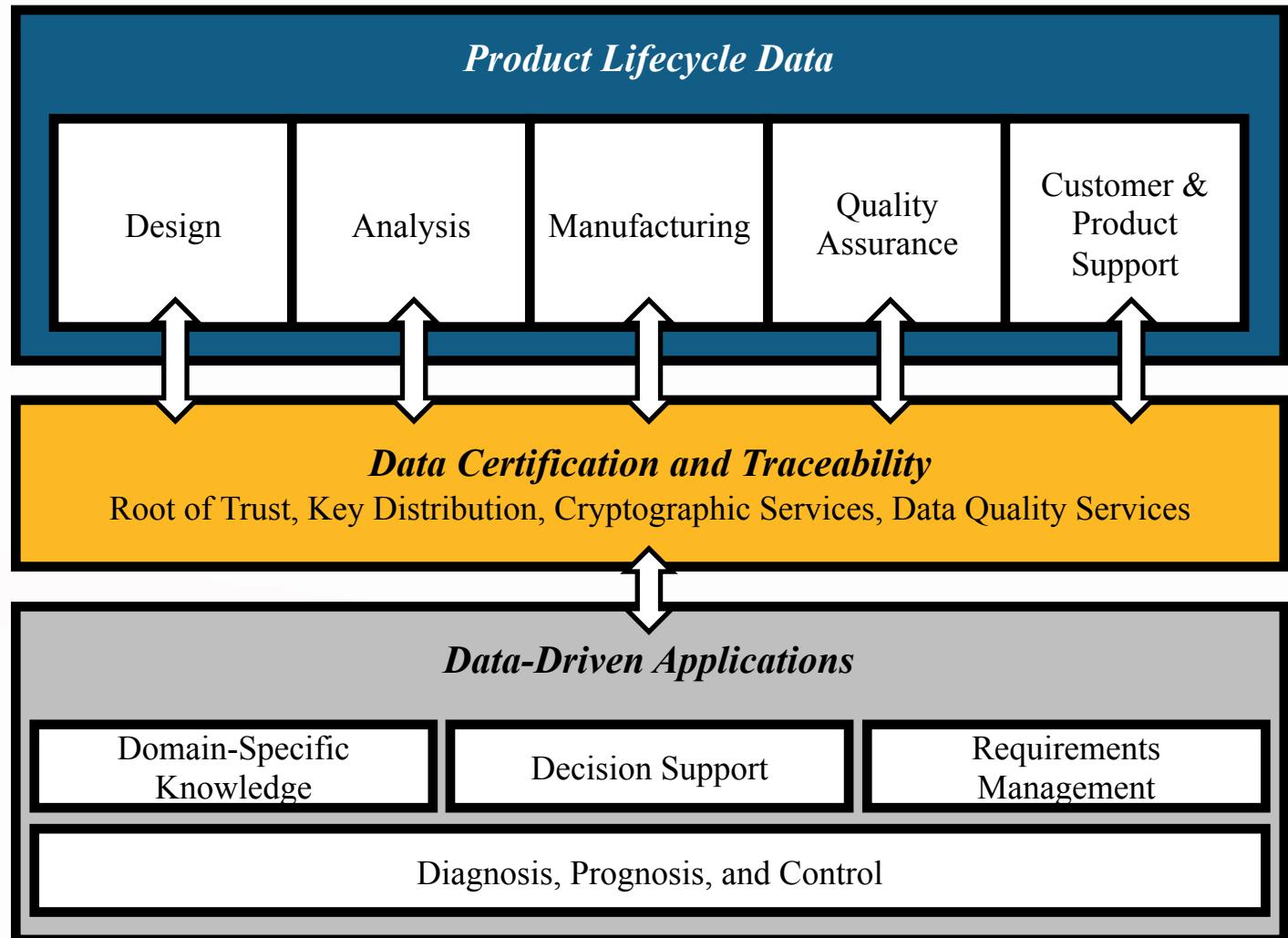


...WITH BUILT IN TRUST AND TRACEABILITY...

Hedberg Jr, T., Barnard Feeney, A., Helu, M., & Camelio, J. A. (2017). Towards a Lifecycle Information Framework and Technology in Manufacturing. *Journal of Computing and Information Science in Engineering*, 17(2), 021010-021010-021013. doi:10.1115/1.4034132

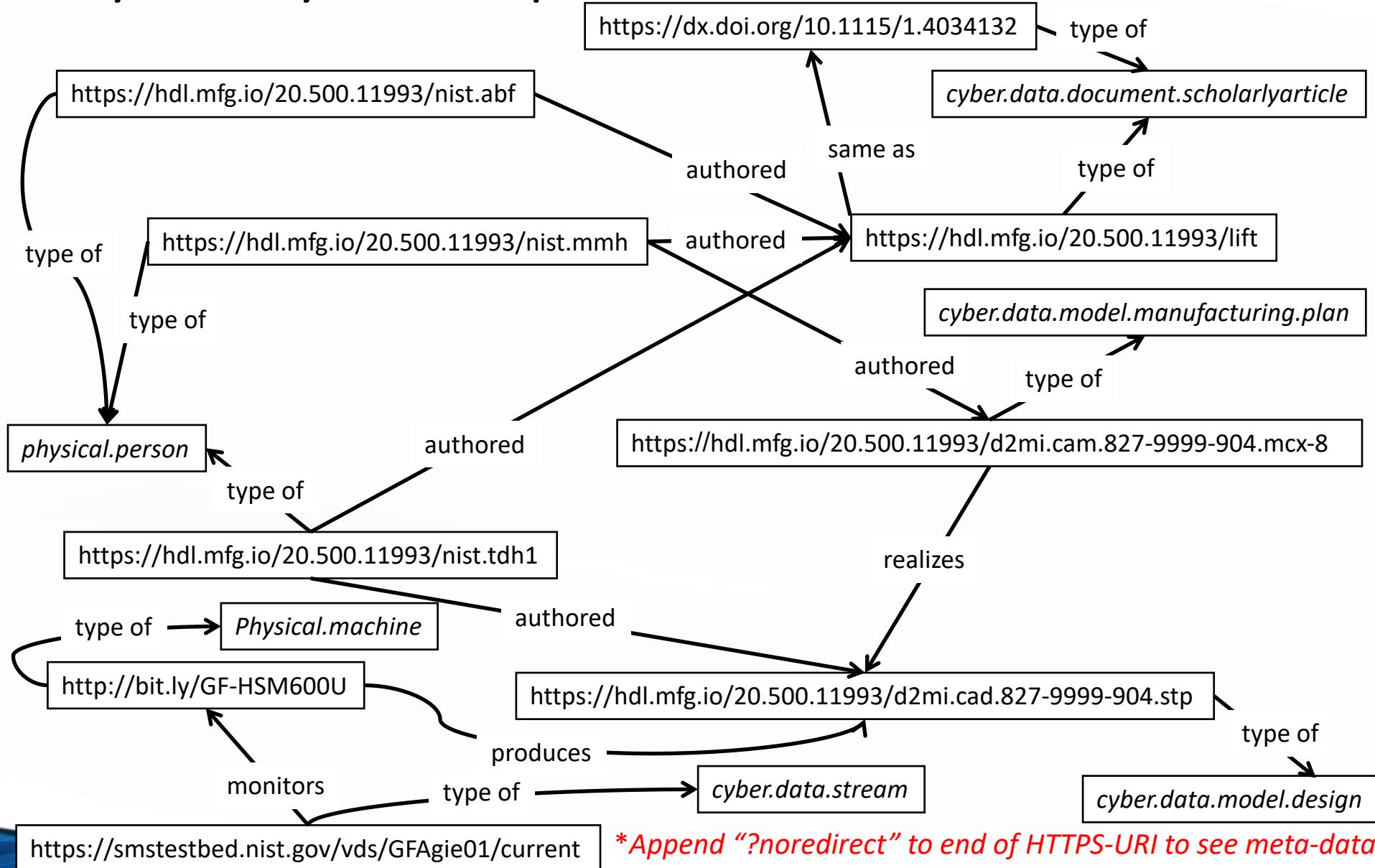
Lifecycle Information Framework and Technology

...FOR DRIVING APPLICATION WITH DATA!

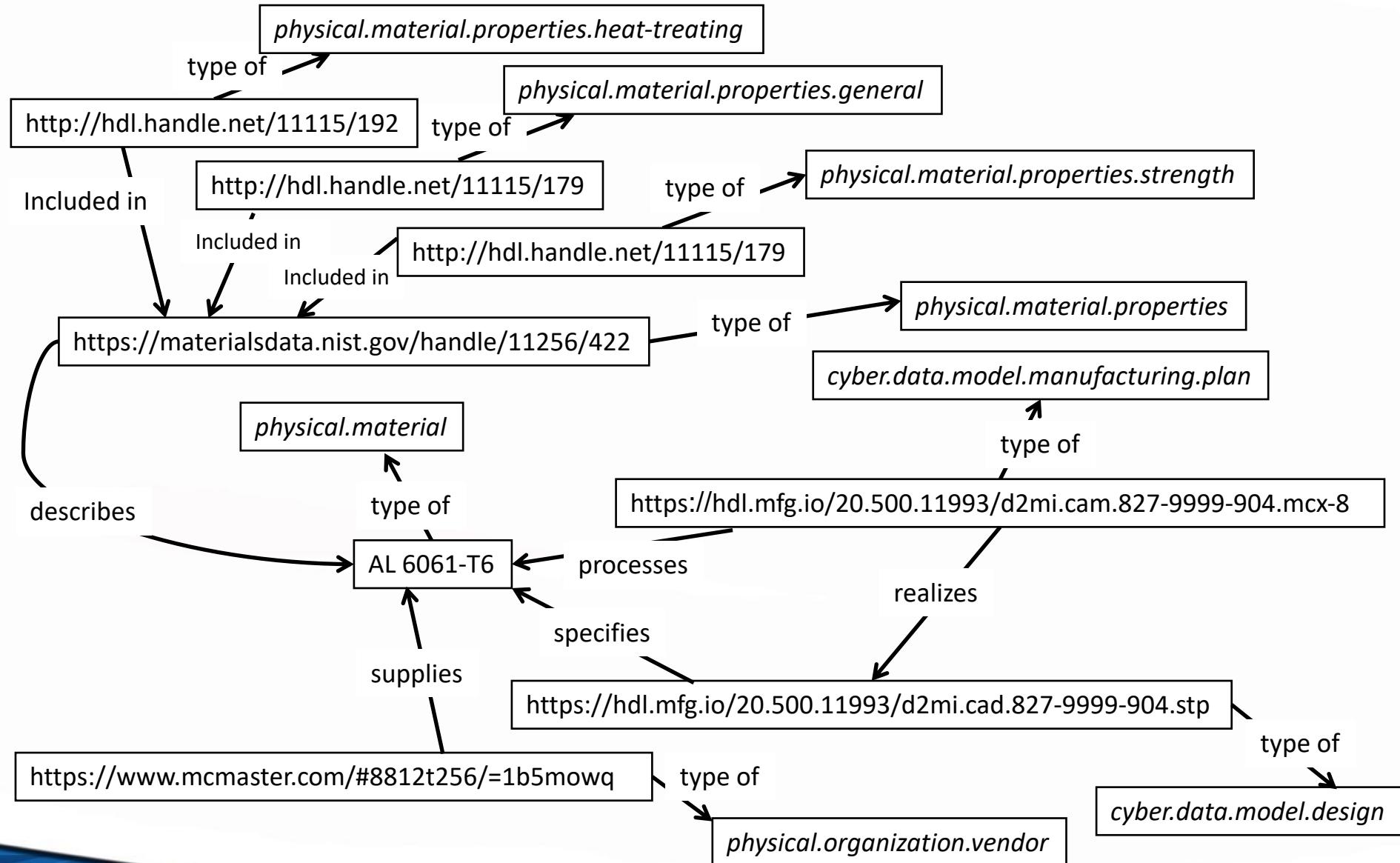


Hedberg Jr, T., Barnard Feeney, A., Helu, M., & Camelio, J. A. (2017). Towards a Lifecycle Information Framework and Technology in Manufacturing. *Journal of Computing and Information Science in Engineering*, 17(2), 021010-021010-021013. doi:10.1115/1.4034132

Cyber-Physical Graph: Fabrication Context



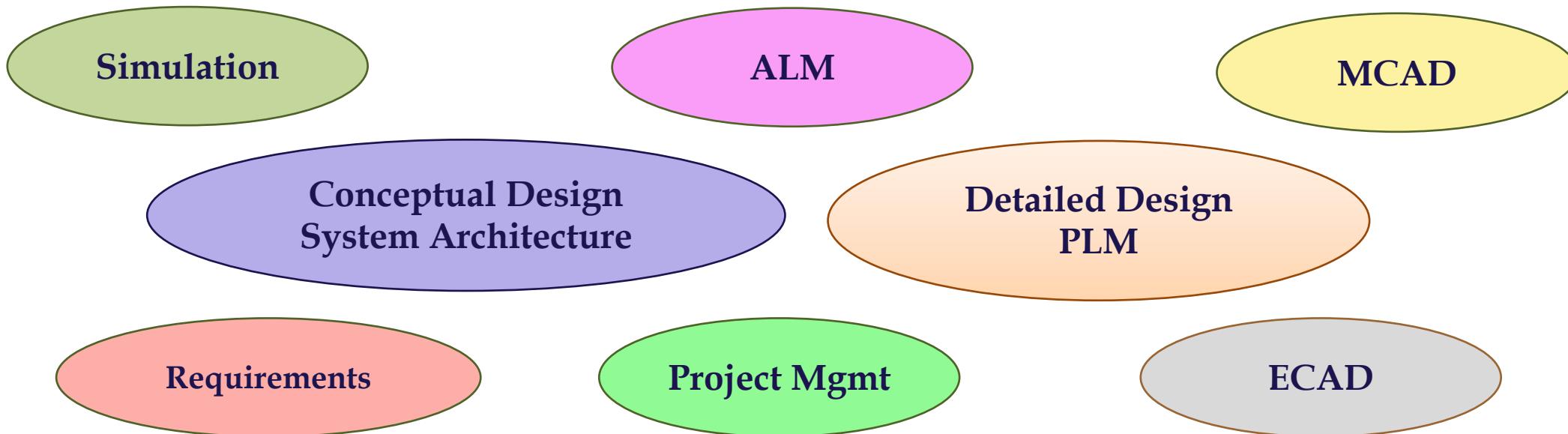
Cyber-Physical Graph: Materials Context



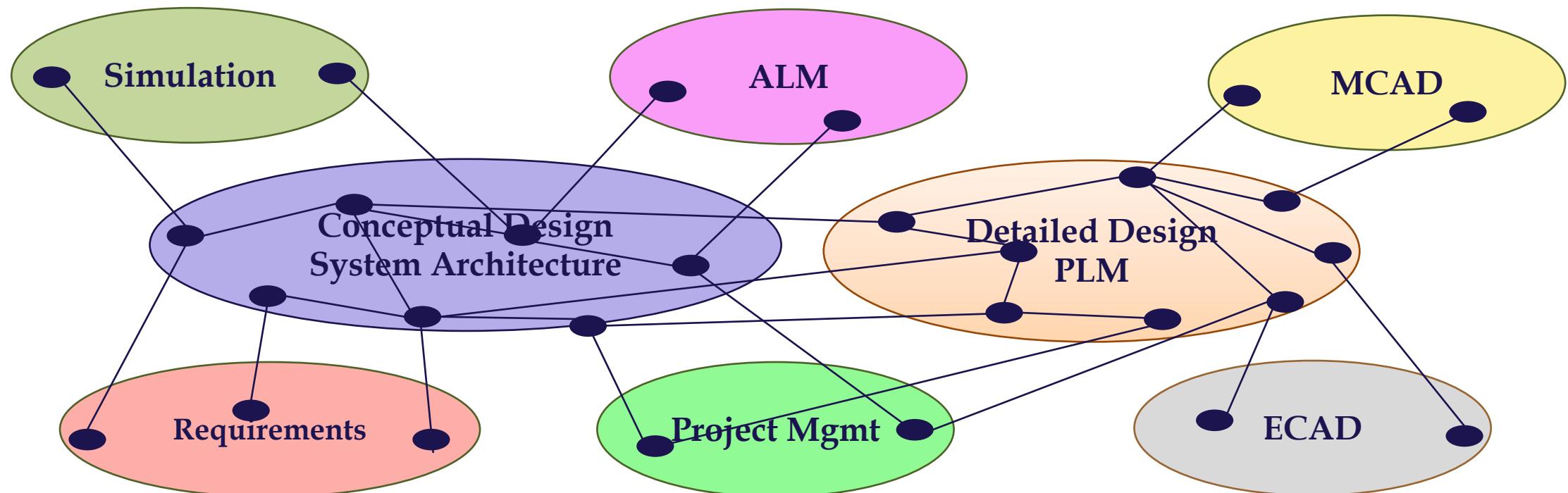
- Digital Thread for Smart Manufacturing
- **System Lifecycle Handler - Foundations**
 - Project goals
 - Use Cases
 - Graph foundations
- System Lifecycle Handler – Proof-of-concept demonstrations
 - Querying the digital thread
 - Building the digital thread
 - Maintaining the digital thread
 - API for the digital thread
 - Tools, APIs, and open standards used in the PoC
- Next steps
- Questions and Comments

- ***Build*** digital thread for systems
 - ***Connect*** to data across the enterprise (Systems, PLM, CAD, ALM, Project management, Manufacturing, Operations) and spin a digital thread
 - ***Generate*** models as information moves across disciplines
- ***Query and search*** the digital thread
- ***Manage*** the digital thread
 - ***Track changes*** in versioned models connected in the digital thread
 - ***Compare, synchronize, repair*** connections and models
- ***Visualize*** the digital thread

- Organizations deal with a diverse, multi-vendor engineering toolset.
- They create and store product/system data in a variety of tools, models and repositories: PLM, ALM, CAD, spreadsheets, databases, SysML models...



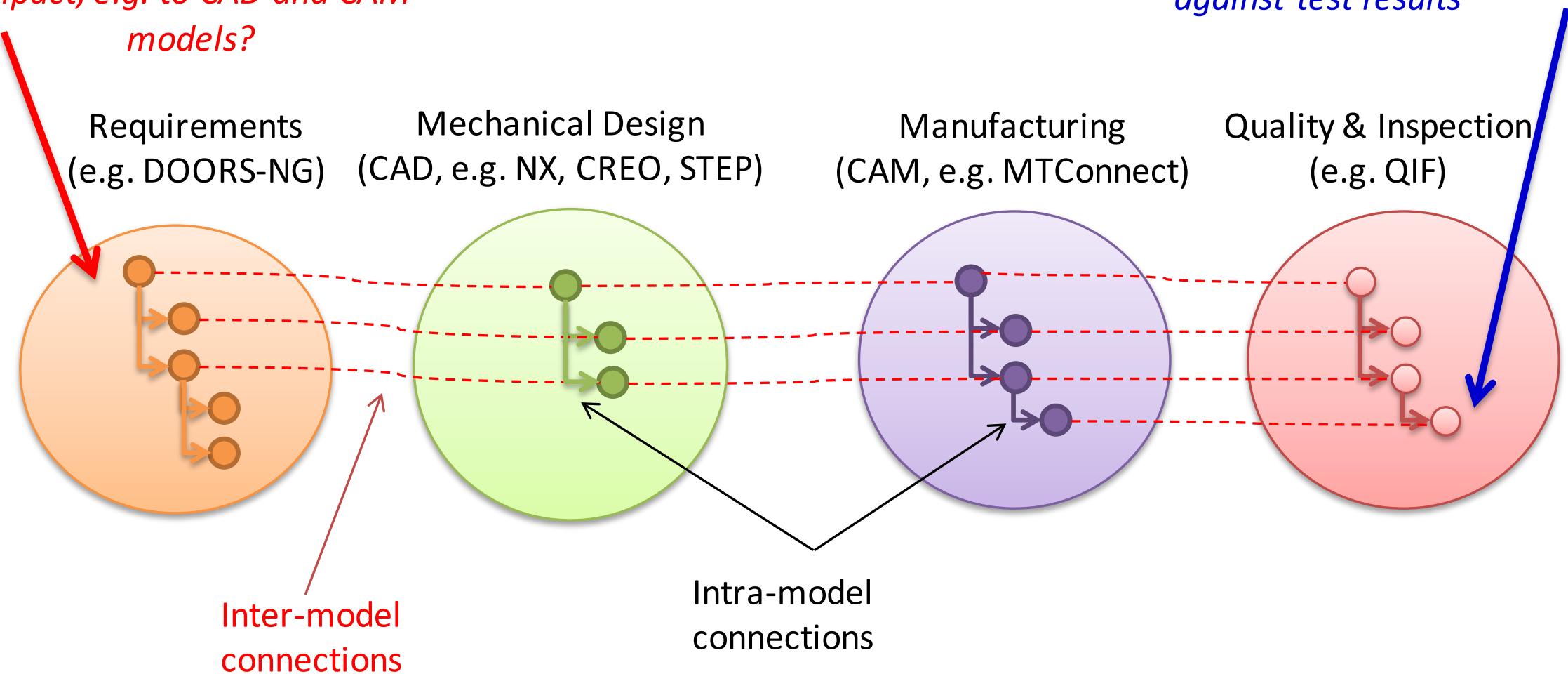
- Federating data and models across disciplines
- Connecting model elements and data at different levels of abstractions



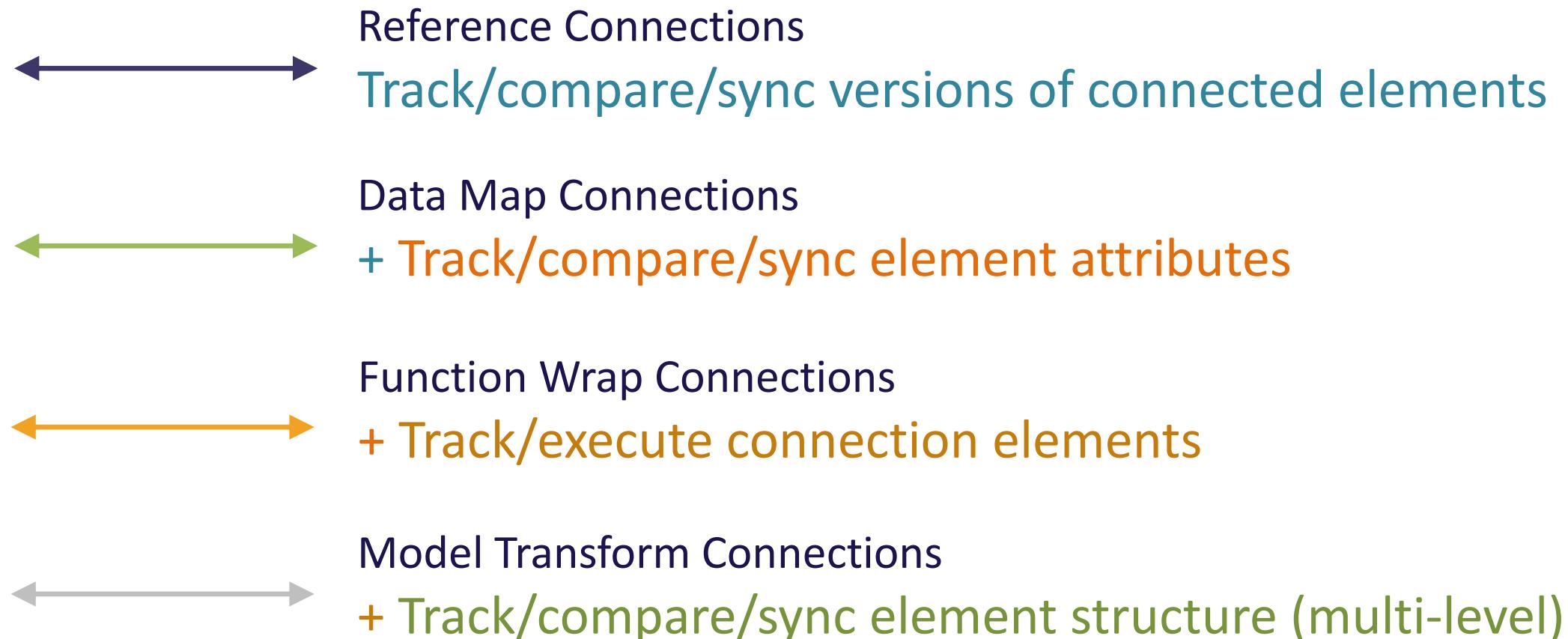
Digital Thread – Example showing artifacts and connections

*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*

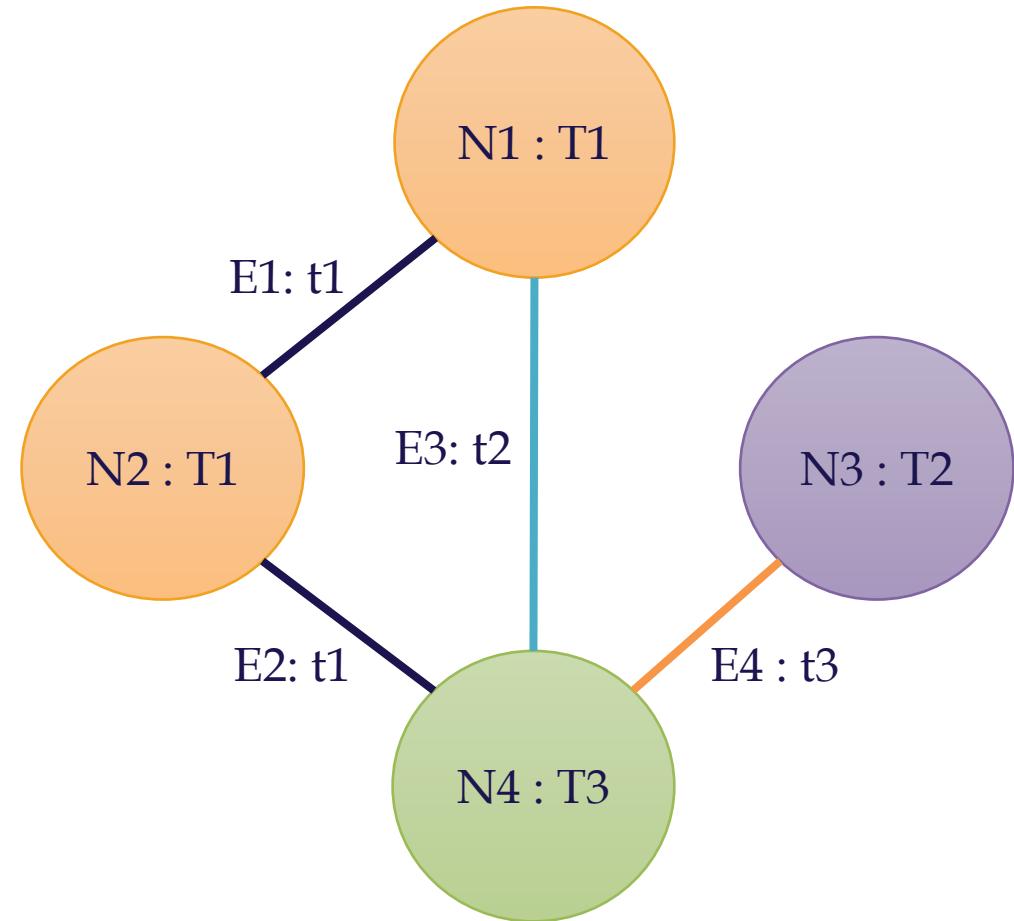


- What is the purpose of model-based connections?



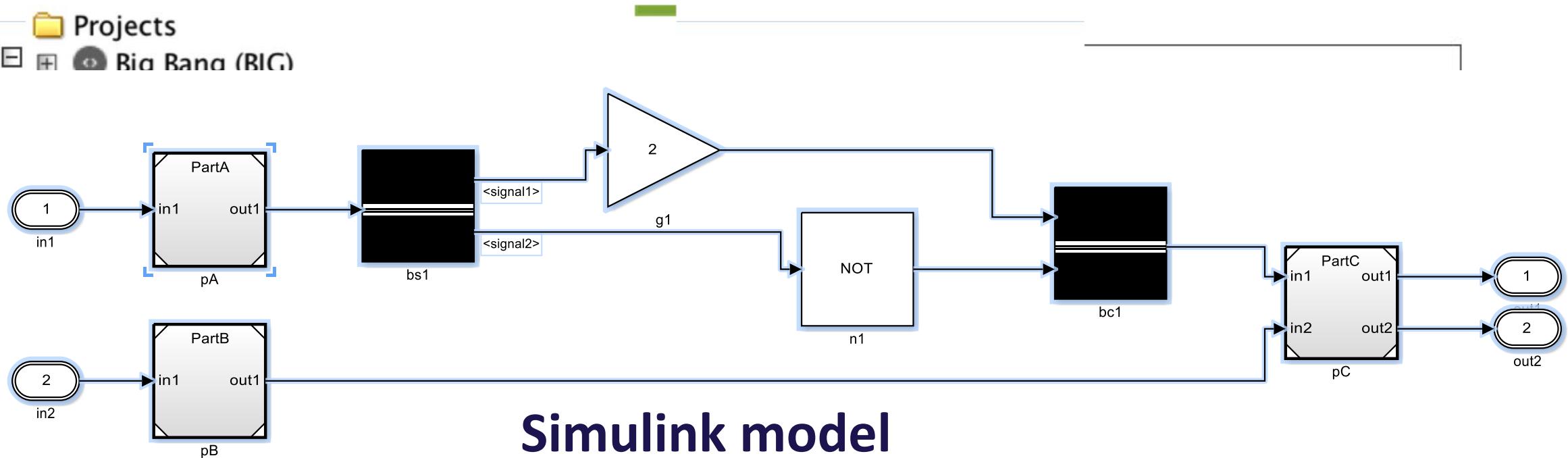
Digital Thread is a *Graph*

- 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

Projects
Ria Rang (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

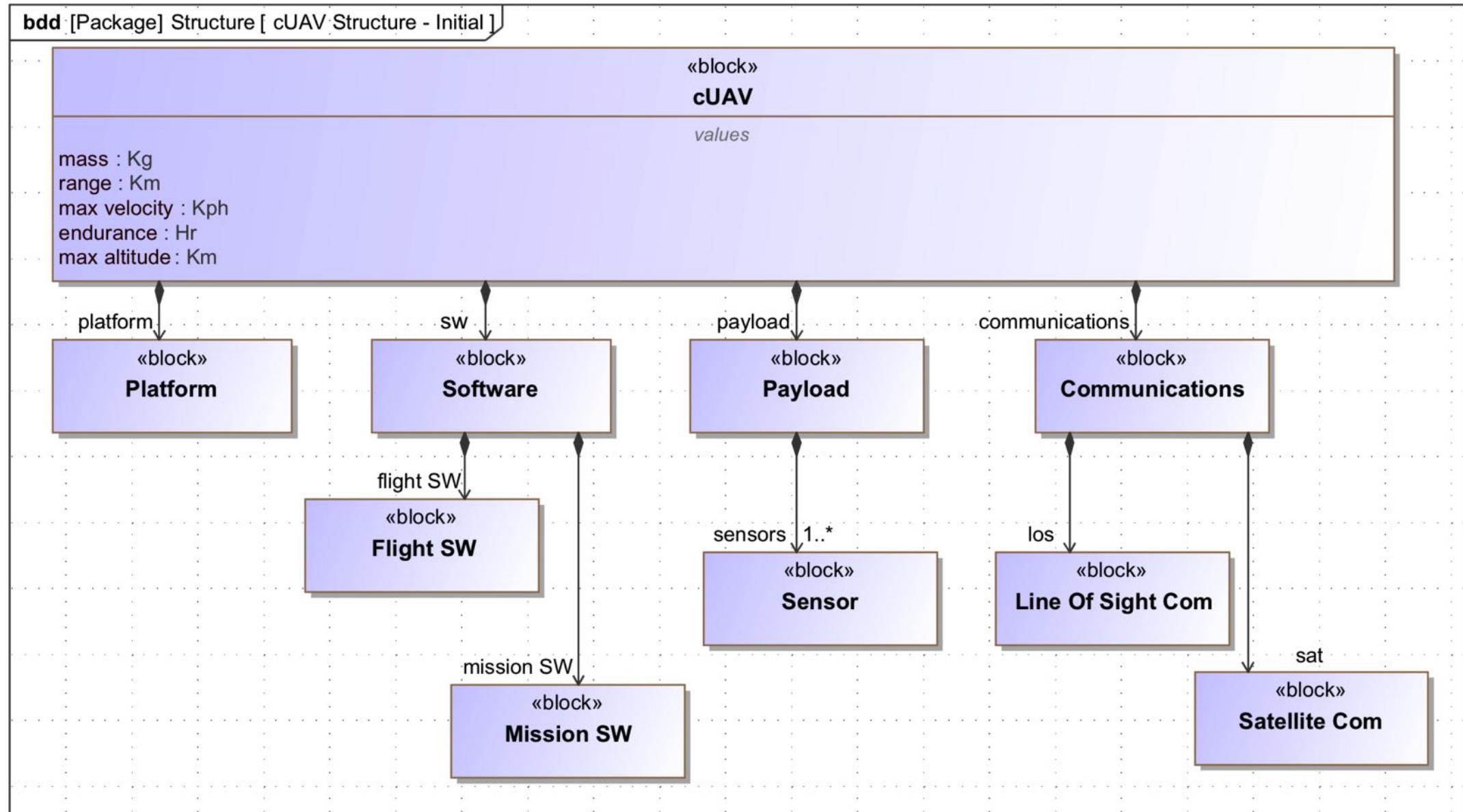
rtifacts
pecification Module
ge Load



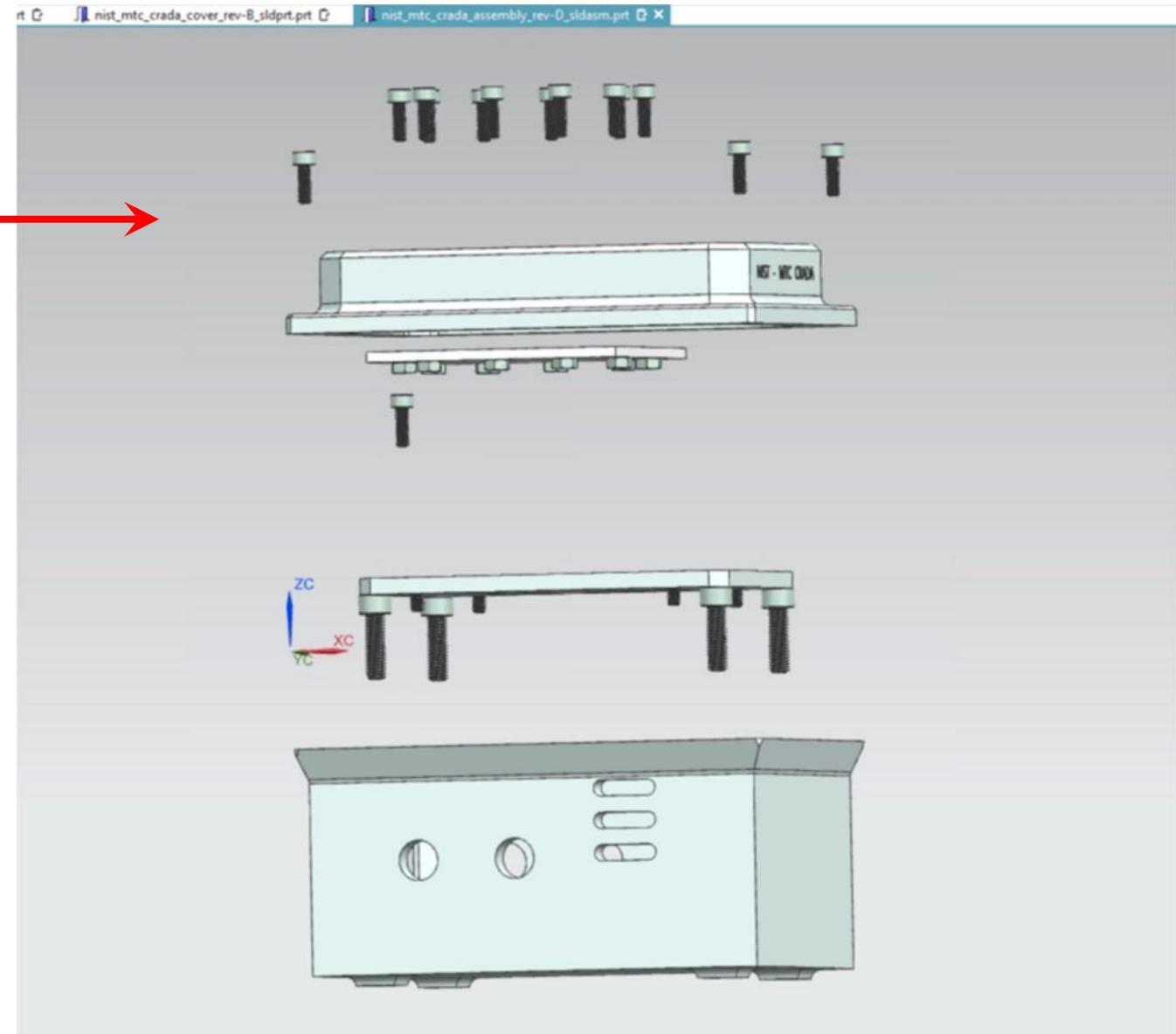
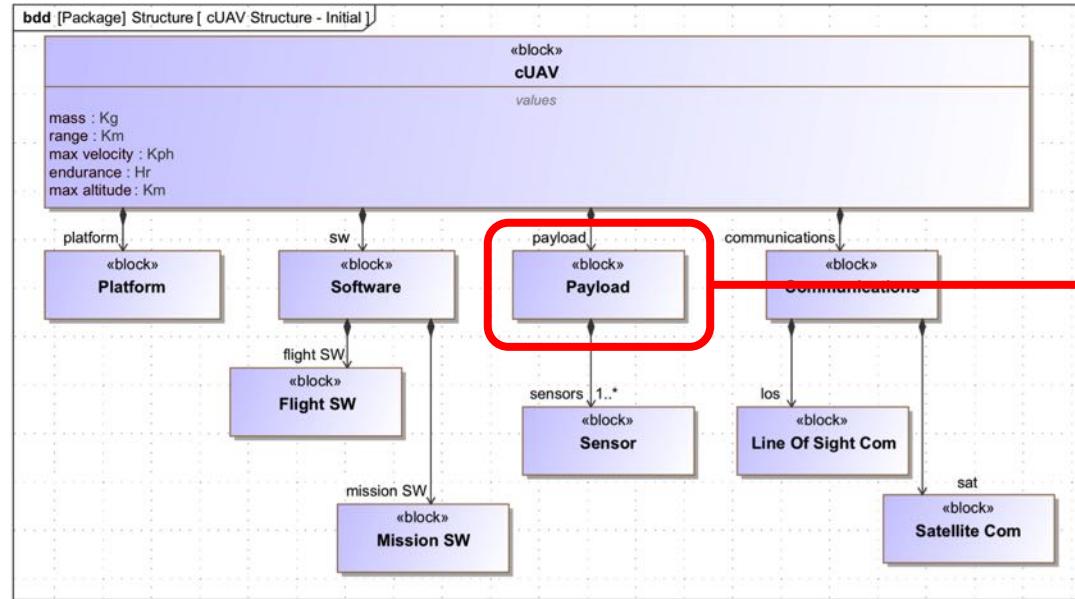
System Model (SysML)

- Digital Thread for Smart Manufacturing
- System Lifecycle Handler - Foundations
 - Project goals
 - Use Cases
 - Graph foundations
- **System Lifecycle Handler – Proof-of-concept demonstrations**
 - Querying the digital thread
 - Building the digital thread
 - Maintaining the digital thread
 - API for the digital thread
 - Tools, APIs, and open standards used in the PoC
- Next steps
- Questions and Comments

Testbed model for proof-of-concept – Configurable UAV



Testbed model for proof-of-concept – Configurable UAV

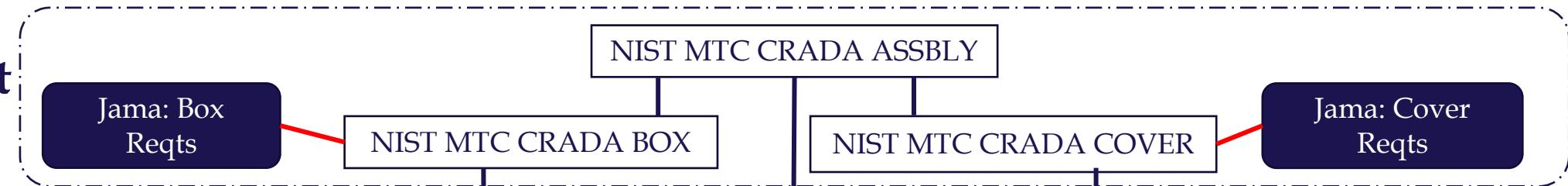


Enclosure Box for an
Avionics assembly used
in the Configurable
UAV

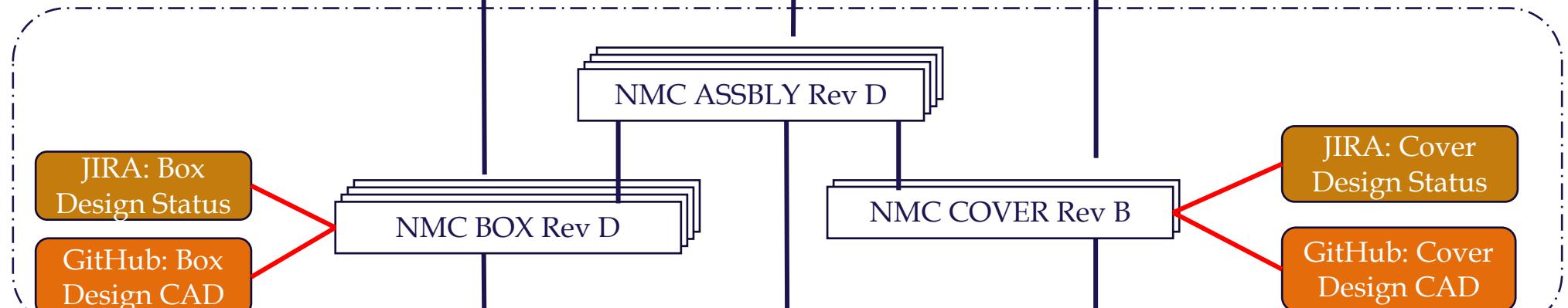
- **SysML** model of the UAV and the payload
- CAD models for multiple variants and revisions of the Box
(SolidWorks files on GitHub)
- Design flow management in **JIRA**
- 20 instances of each part are manufactured. For each instance:
 - Machine sensor data streams for each part instance (**MTConnect 1.3 XML on GitHub**)
 - NC code data - ISO 6983 (**G-code files on GitHub**)
 - First article inspection reports (**QIF 2.1 XML on GitHub**)
 - Receiving inspection reports (**QIF 2.1 XML on GitHub**)

Approach for organizing the digital thread

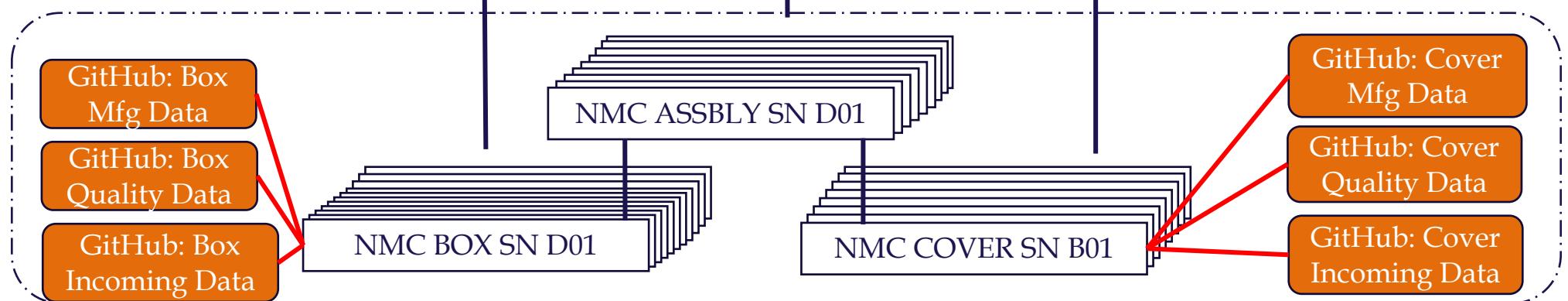
Product Concept Level



Design Variant Level



Part Instance Level





Demo video #1 – Querying the digital thread for the simple avionics box assembly

See video **DigitalThreadQuery.mp4**



Demo video #2 - Building the digital thread for the simple avionics box assembly

See video **DigitalThreadBuildManage.mp4**

Model Transformations – Automatically spinning the digital thread



SysML Model

- Unmanned Aerial Vehicle
 - Aircraft Platform
 - blackbox : BlackBox
 - body : Body
 - elec assembly : Electrical Assembly
 - engine : Engine
 - fuel system : Fuel System
 - powetrain : Powertrain
 - rotor : Rotor
 - tail assembly : Tail Assembly
 - Analysis Manager
 - APU
 - Autopilot
 - Battery
 - BlackBox
 - Body
 - Communications Controller
 - Communications Interface
 - Cowling

Connection Type

- Reference
- Function Wrap
- Data Map
- Model Transform

TC91

- Requirements
- Satellite (Precise BOM)
- TraceLinks
- UAV (Imprecise BOM)
 - 000464-Unmanned Aerial Vehicle
 - 000464/A;1-Unmanned Aerial Vehi
 - 000464/B;1-Unmanned Aerial Vehi
 - 000464/C;2-Unmanned Aerial Vehi
 - Unmanned Aerial Vehicle->Fire
 - 000464/C-View (Imprecise)
 - aircraft platform : 000466
 - gps : 000466/A;1-GPS
 - autopilot : 000467/A;1-Autopilo
 - databus : 000468/A;1-Databus
 - flight controller : 000469/A;1-Fli
 - payload controller : 000470/A;1
 - communications controller : 000
 - wimax module : 000472/A;1-Wil
 - gprs module : 000473/A;1-GPRS

Local File System Repositories

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

Generate Models (System <-> PLM)

Switch repos

BLOCK_TC_PART_MODEL_TRANSFORM_CONNECTION

[10:52:48] INFO SysML dependencies will not be generated from Teamcenter trace links for item DDS Middleware. Option to generate SysML dependencies and trace links is not selected in Syndeia settings.

[10:52:48] INFO Finished generating block structure and creating connections for part DDS Middleware

[10:52:48] INFO SysML dependencies will not be generated from Teamcenter trace links for item Software System. Option to generate SysML dependencies and trace links is not selected in Syndeia settings.

Ready 10:54:22 AM 442M of 791M

Digital Thread as a conduit for information flow



*Requirements
(SE -> ME)*

*Mass properties
(ME -> SE)*

SysML Model

Connection Type

Creo

Search Repository

Requirements (SE -> ME)

Mass properties (ME -> SE)

Creo Race Car

The screenshot illustrates the digital thread between a SysML model and a Creo assembly. The interface includes:

- SysML Model:** Shows a tree view of the "Automobile System" containing various components like 1_FORMULA_SAE_RACECAR, 20_6950_10, 20_6950_10_MIR, etc.
- Connection Type:** A dropdown menu showing "Reference", "Function Wrap", "Data Map", and "Model Transform".
- Creo:** Shows a tree view of the "1_FORMULA_SAE_RACECAR" assembly with components: MANIFOLD, SUSPENSION, DIFFERENTIAL, RR_CORNER, CENTER_SUPPORT, FRONT_FAIRING_COMPLETE, LF_CORNER, FRONT_PAN, FRONT_FAIRING, FLOORBOARD, SEAT, LR_CORNER, RF_CORNER, REAR_MOUNT, MOTOR, CHASSIS, and FRONT_WING.
- Requirements (SE -> ME):** A box containing the requirements for the 1_FORMULA_SAE_RACECAR block, including parts like MANIFOLD, SUSPENSION, DIFFERENTIAL, RR_CORNER, CENTER_SUPPORT, FRONT_FAIRING_COMPLETE, LF_CORNER, FRONT_PAN, FRONT_FAIRING, FLOORBOARD, SEAT, LR_CORNER, RF_CORNER, REAR_MOUNT, MOTOR, CHASSIS, and FRONT_WING.
- Mass properties (ME -> SE):** A box containing the mass properties values for the Creo Mass Property block, including mass, volume, density, surface area, and coordinates for lower_left_x, lower_left_y, lower_left_z, upper_right_x, upper_right_y, and upper_right_z.
- Creo Race Car:** A 3D rendering of the race car assembly.

Tracking changes in connected models in the digital thread



Screenshot of a software interface for tracking changes in connected models in the digital thread. The interface includes a toolbar with tabs: Repository Manager, Connection Manager, Connection Browser, Connection Summary, Comparison Result (selected), and Settings. A search bar and buttons for Clear and Export to Excel are also present. The main area is a table showing connections between source and target components, with a 'Latest Target' column and a 'Comment' column. The table has columns for Conn ID, Source, Target, Latest Target, and Comment. A summary message at the bottom indicates a comparison between SysML part properties and Teamcenter part occurrences.

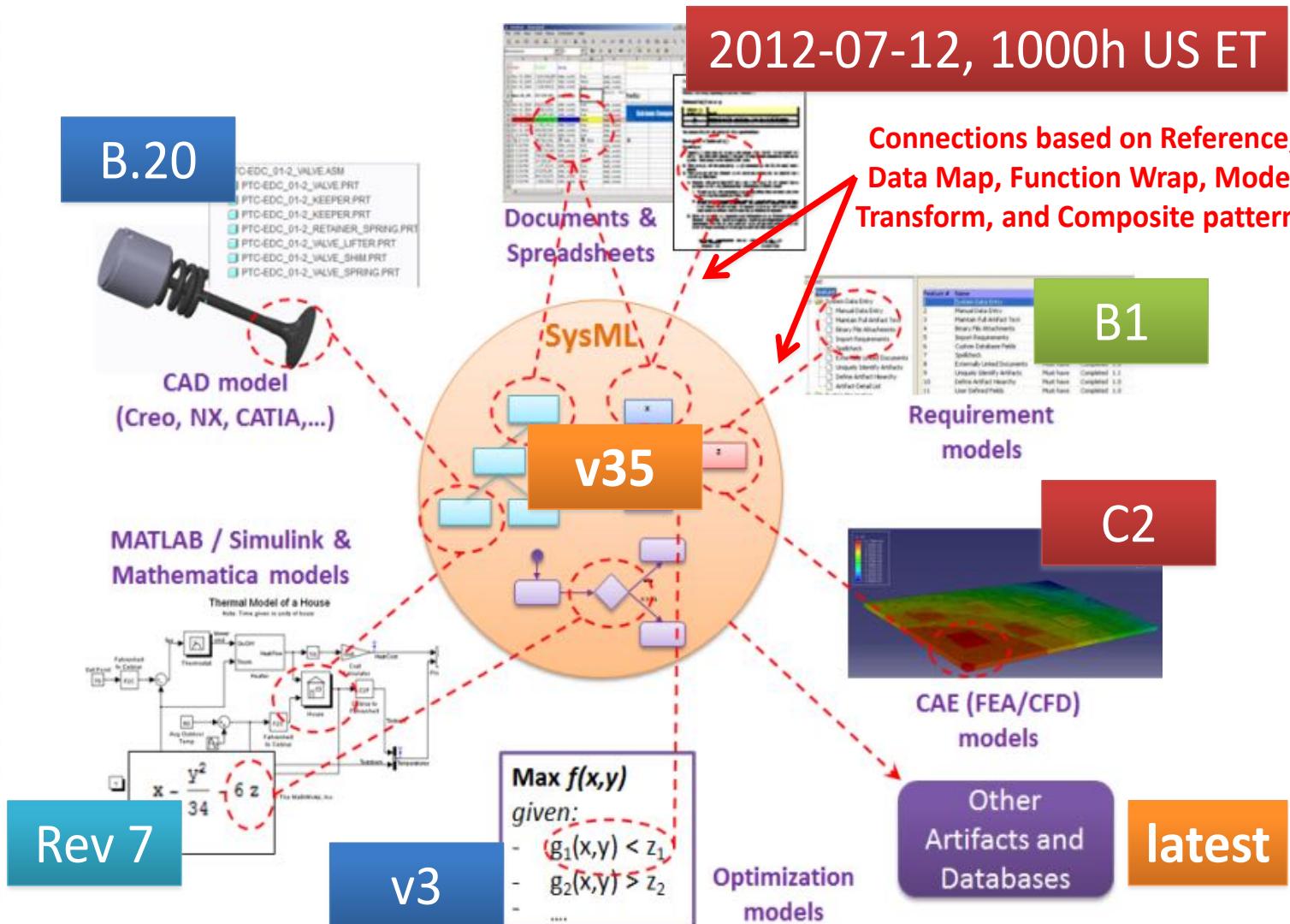
Conn ID	Source	Target	Latest Target	Comment
e3f03...	Unmanned Aerial Vehicle	000464/C;2-Unmanned Aerial Vehicle	000464/C;2-Unmanned Aerial Vehicle	The block Unmanned Aerial Vehic...
	wimax module : WiMax Module	wimax module : 000472/A;1-WiMa...	wimax module : 000472/A;1-WiMax M...	Part property wimax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

Total System Model – A snapshot of the digital thread

TOTAL SYSTEM MODEL (TSM)



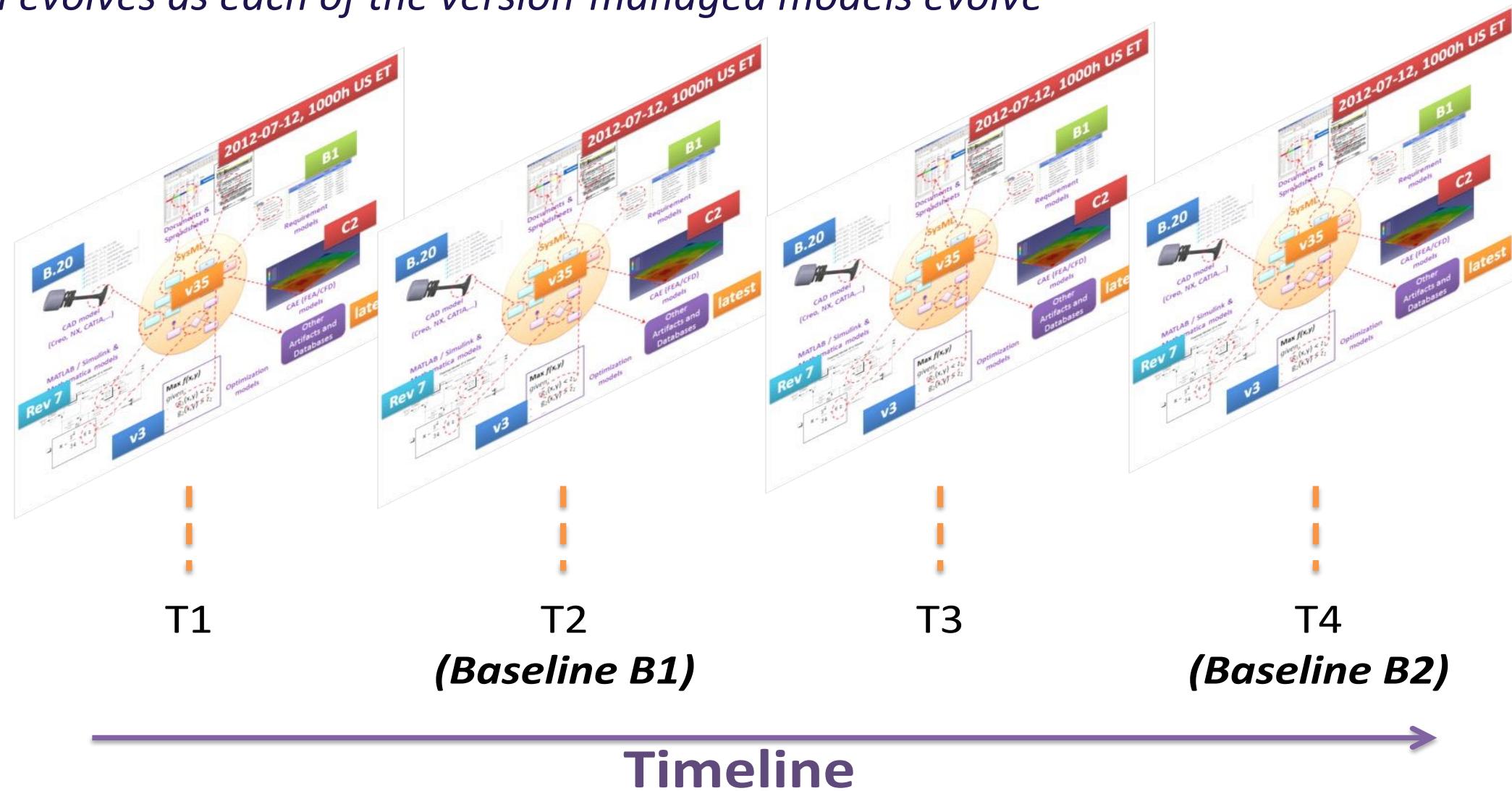
Connect architecture model (SysML) with domain-specific models

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 maturing though the lifecycle

TSM evolves as each of the version-managed models evolve



- Provides a unique registry for all artifacts in the digital thread (similar to DOI)
- Global ID system to identify artifacts (part, sensor, data, machines, ...)
 - chain of addresses {A1, A2, A3, ...} similar to postal address. Addresses may be URIs.
- Basic meta-data for each artifact (full artifact data in native repository – PLM, ALM,...)
- Uses Handle.Net system



Example entry in the Handle System for a Heat Sink part

Handler system
<https://hdl.mfg.io>

Entry for he Heat Sink part
<https://hdl.mfg.io/20.500.11993/d2mi.cad.827-9999-904.stp?noredirect>

Secure | <https://hdl.mfg.io/20.500.11993/d2mi.cad.827-9999-904.stp?noredirect>

Handle.Net®

Handle Values for: 20.500.11993/d2mi.cad.827-9999-904.stp

Index	Type	Timestamp	Data
1	URL	2017-08-31 03:29:03Z	https://smstestbed.nist.gov/tdp/d2mi/CAD/827-9999-904.stp
2	TYPE	2017-08-31 03:29:03Z	cyber.data.model.design
3	SCHEMA	2017-08-31 03:29:03Z	http://schema.org/ProductModel
4	DATE_CREATE	2017-08-31 03:29:03Z	2017-07-06
5	ATTRIBUTE	2017-08-31 03:52:13Z	<pre> "@context": "http://schema.org", "@graph": [{ "@id": "#model", "@type": "ProductModel", "additionalType": "http://www.productontology.org/id/heat_sink", "description": "A heat sink for an aerospace avionics printed circuit board", "gtin13": "6921407390089", "name": "Aluminum Heatsink" }, { "@type": "DigitalDocument", "fileFormat": "application/step", "about": "Design model for a heat sink for an aerospace avionics printed circuit board", "author": "https://hdl.mfg.io/20.500.11993/nist.tdh1", "additionalType": "http://www.productontology.org/id/heat_sink", "hasDigitalDocumentPermission": [{ "@type": "DigitalDocumentPermissionType", "permissionType": "http://schema.org/WritePermission", "grantee": { "@type": "Person", "name": "Thomas Hedberg", "identifier": "https://hdl.mfg.io/20.500.11993/nist.tdh1" } }, { "@type": "DigitalDocumentPermissionType", "permissionType": "http://schema.org/ReadPermission", "grantee": { "@type": "Audience", "audienceType": "public" } }] }] }</pre>

API for the digital thread

Request URL

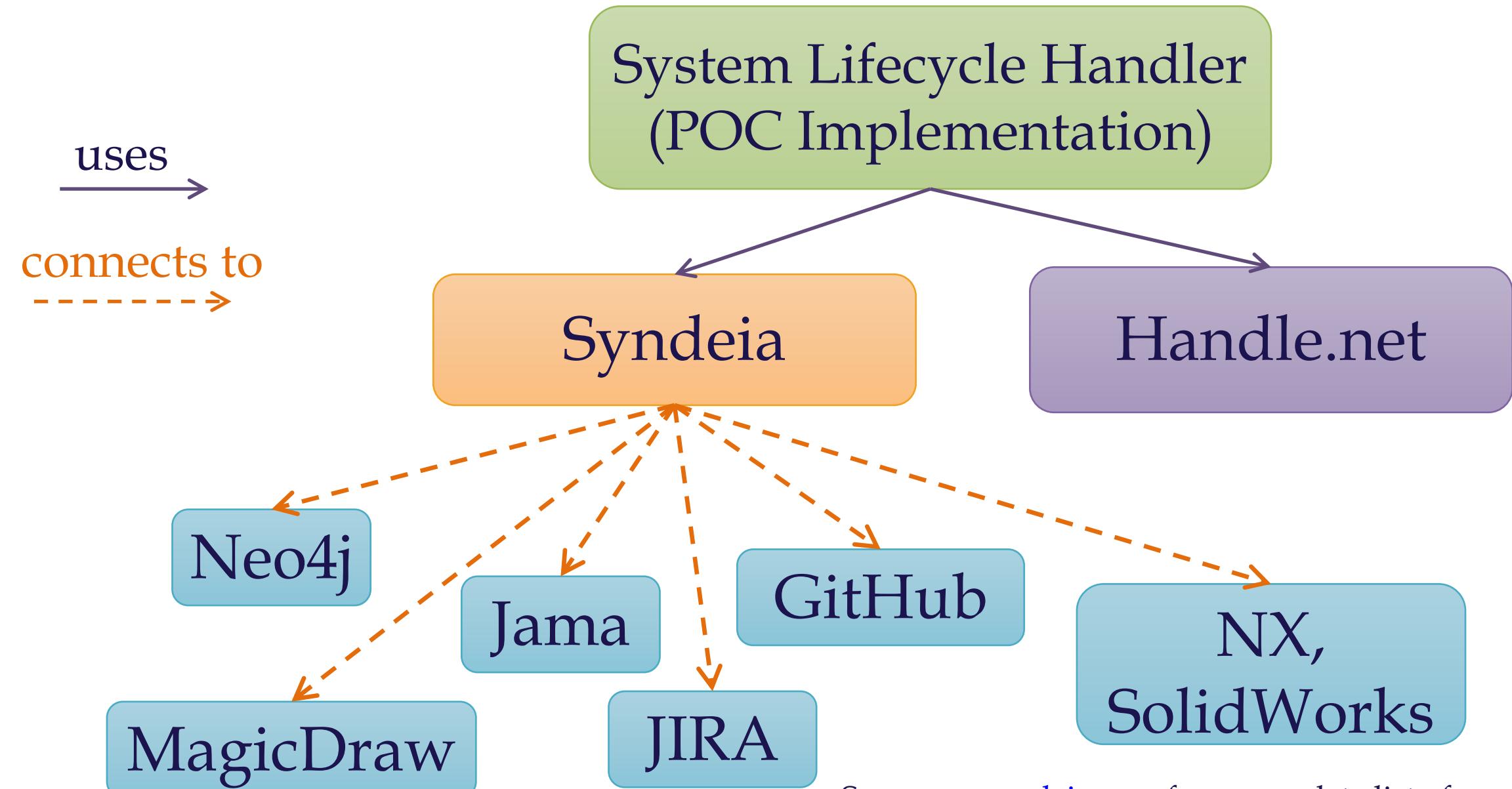
```
http://localhost:9000/api/v1/repositories
```

Server response

Code	Details
200	<p>Response body</p> <pre>{ "statusCode": 200, "headers": {}, "pageInfo": { "startIndex": 0, "resultCount": 38, "totalResults": 0 }, "resources": [{ "id": "63bd28f1-2fd9-11e8-9021-336807f93a57", "createdBy": "af860442-f78b-11e7-b394-c9ef258a9419", "createdDate": "2018-03-24 23:05:36.252-0400", "modifiedBy": "af860442-f78b-11e7-b394-c9ef258a9419", "modifiedDate": "2018-03-24 23:05:36.252-0400", "key": "JAMA-30", "gid": "eXd1cVIVVLa8__Q9kW6ELozkLqCIHitQ", "name": "Jama 3 @ Intercax", "description": "", "attributes": { "RESTFUL_REQUESTS": "[]" }, "type": { "id": "63bd28f3-2fd9-11e8-9021-336807f93a57", "name": "Jama repository" }, "host": "https://intercax.jamacloud.com", "authentication": {} }, { "id": "63bd28f1-2fd9-11e8-9021-336807f93a57", "createdBy": "af860442-f78b-11e7-b394-c9ef258a9419", "createdDate": "2018-03-24 23:05:36.252-0400", "modifiedBy": "af860442-f78b-11e7-b394-c9ef258a9419", "modifiedDate": "2018-03-24 23:05:36.252-0400", "key": "JAMA-30", "gid": "eXd1cVIVVLa8__Q9kW6ELozkLqCIHitQ", "name": "Jama 3 @ Intercax", "description": "", "attributes": { "RESTFUL_REQUESTS": "[]" }, "type": { "id": "63bd28f3-2fd9-11e8-9021-336807f93a57", "name": "Jama repository" }, "host": "https://intercax.jamacloud.com", "authentication": {} }] }</pre>

- REST/HTTP API to access data in the digital thread, such as:
 - Repositories, projects, model elements, and connections
 - Query capabilities to search for connections given type, source, target, etc. (basic graph navigation)
- Foundation for new apps that can be built to access, analyze, enhance the digital thread

Tools used in this proof-of-concept (POC)



Open Standards and APIs used in this POC

- SysML
- MTConnect
- QIF
- JSON
- REST/HTTP
- OSLC
- OAuth
- JDBC
- Other relevant open standards – STEP, FMI
- Native APIs, and Multiple open source Apache and Google libraries

- Common schema(s) for the artifacts and relationships in the digital thread
- Library of queries (FAQs) for the digital thread
- Tracking active lifecycle states – design, make, ops, service
- Explore multi-level change management scenarios, e.g. replay cascading changes that may happen if one artifact changes
- Test suites for V&V of the digital thread, automated testing and release builds (Technical Data Packages) of the digital thread

Manas Bajaj, PhD -- manas.bajaj@intercax.com

Dirk Zwemer, PhD -- dirk.zwemer@intercax.com

Intercax

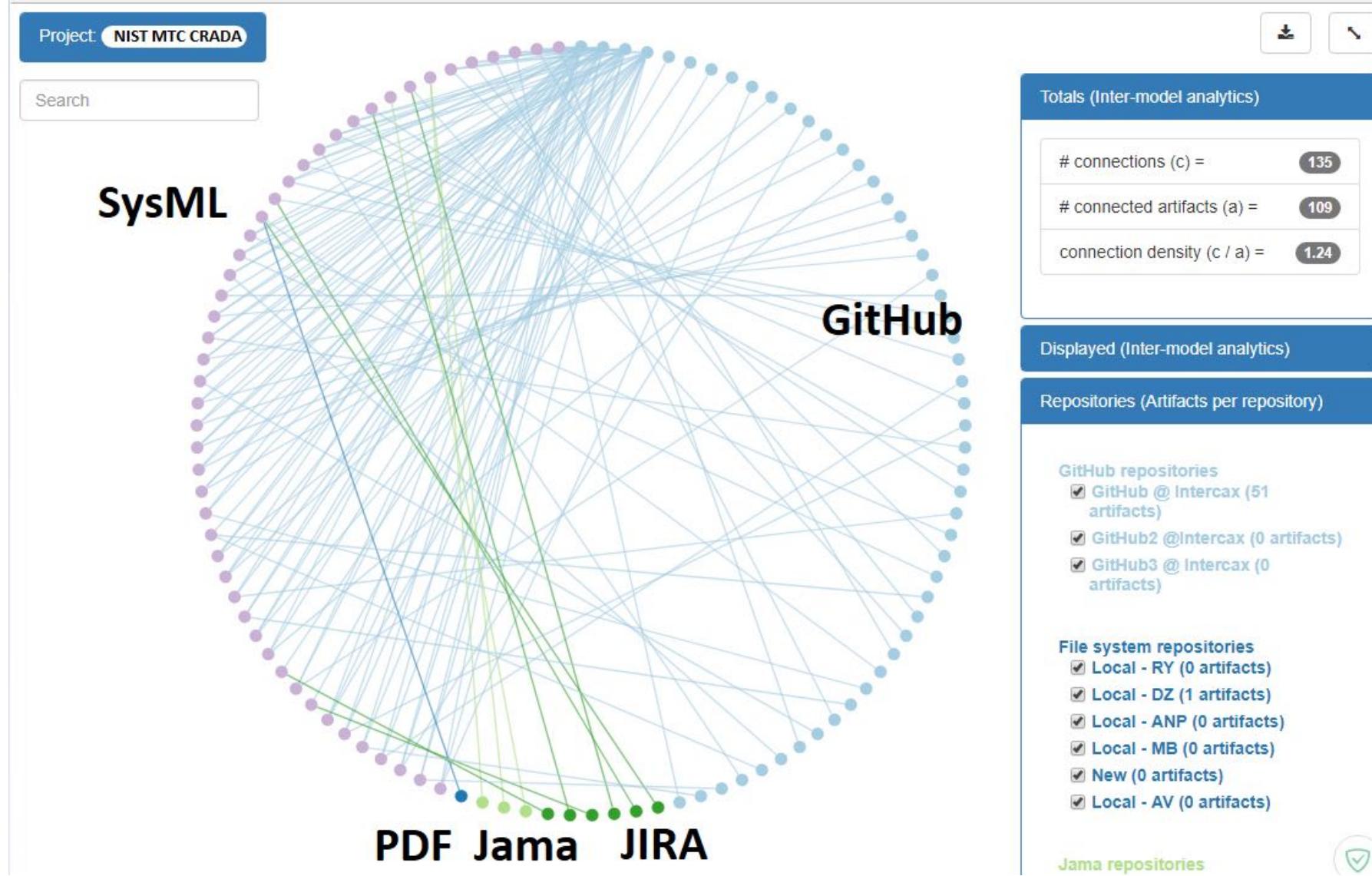
Thomas Hedberg -- thomas.hedberg@nist.gov

NIST



Screenshots of the key visualizations shown in
the demonstration videos

Syndeia Chord Plot Visualization



Chord Plot

Syndeia
Inter-Model
Connections

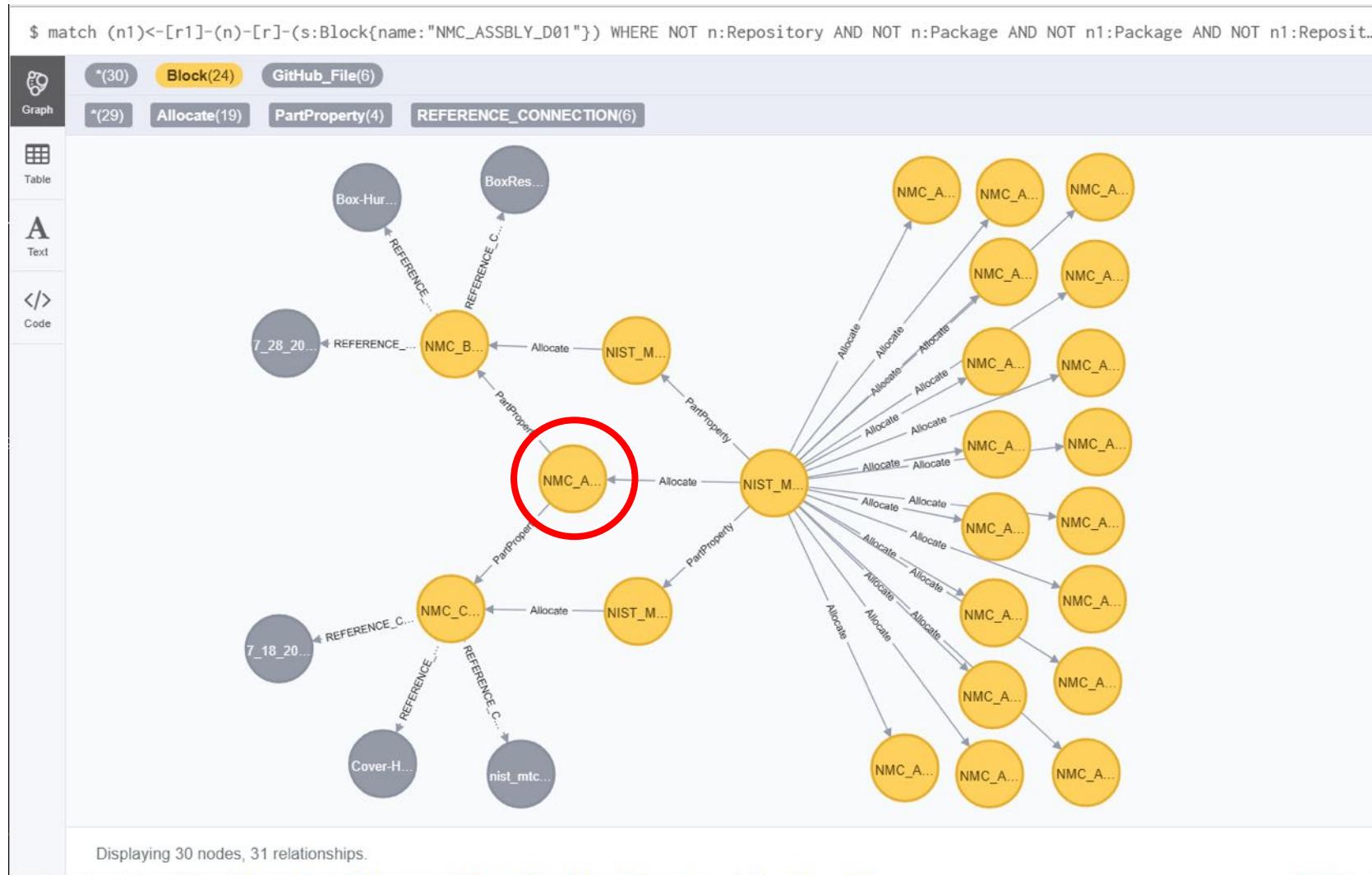
Syndemia Tree Layout Visualization



Tree Expansion from Product Concept 'NIST_MTC _CRADA_Cover'

```
graph TD; A[Product Concept] --> B[Design Variants]; B --> C[Part Instances]; C --> D[Mfg & Quality Data Files]; D --> E[Quality Data Files];
```

Graph Database Queries



Show all
nearest and
next-nearest
neighbors to
Part Instance
'NMC_ASSBLY_
D01'

Graph Database Queries

```
$ match (n:JIRA_Task)-[r]-(s1)-[r1]-(s:Block{name:"NMC_Box_D01"}) return n,r,s1,r... 
```

Graph

*(3) JIRA_Task(1) Block(2)

*(2) REFERENCE_CONNECTION(1) Allocate(1)

Table

A Text

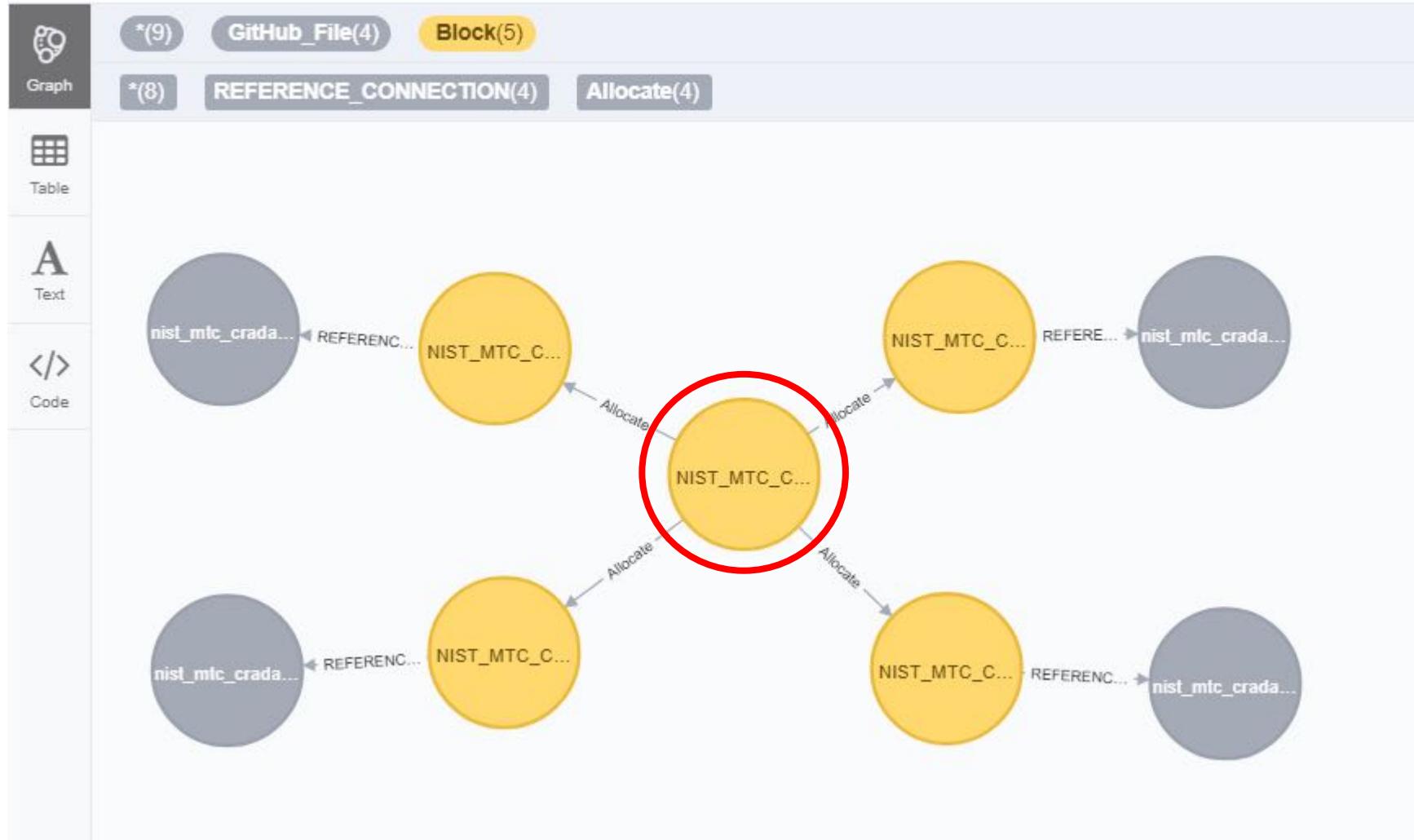
</> Code

"n"	"r"
{"gid":"JIRA @ Intercax {\n \"id\": \"35867\",\\n \"key\": \"SDB-1326\",\\n \"self\": \"https://intercax.atlassian.net/rest/api/2/issue/35867\",\\n \"type\": \"JIRA Issue\",\\n \"version\": \"2018-03-27T11:26:53\\n\",\\n \"name\": \"SDB-1326\"}","name": "SDB-1326"}	{"gid":"48dbe071-31d3-11e8-be64-11ac61647dd8","name": "NIST_CRADA Model::Structure::Box::NIST_MTC_CRADA_BOX RevD - SDB-1326"}

Show all JIRA Tasks connected to Part Instance 'NMC_Box_D01'

Graph Database Queries

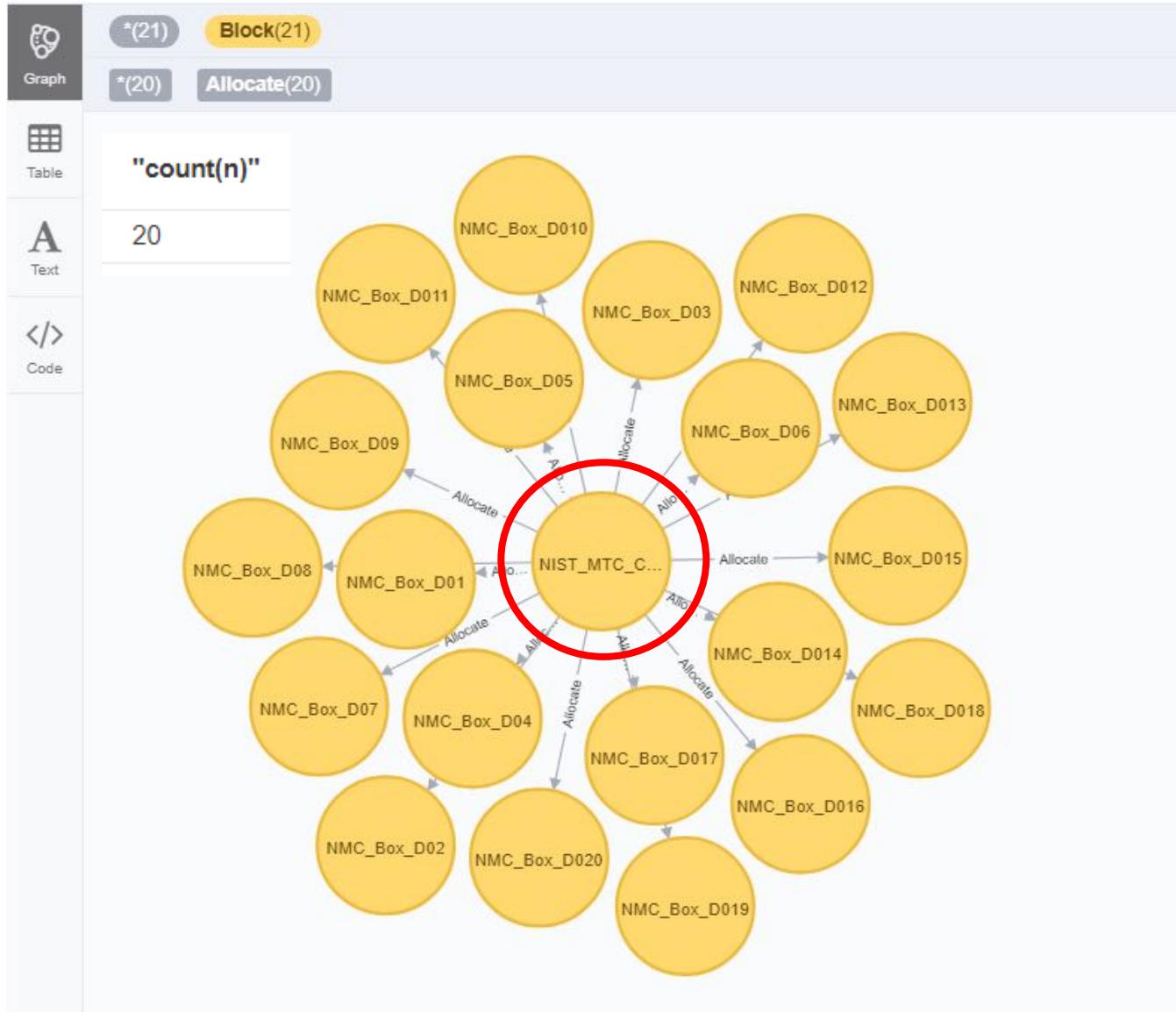
```
$ match (m:GitHub_File)-[t]-(n:Block)-[r]-(s:Block{name: "NIST_MTC_CRADA_BOX"}) RETURN m,t,n,r,s
```



Show all Design Variants of Product Concept 'NIST_MTC_CRADA_Box' and associated CAD files

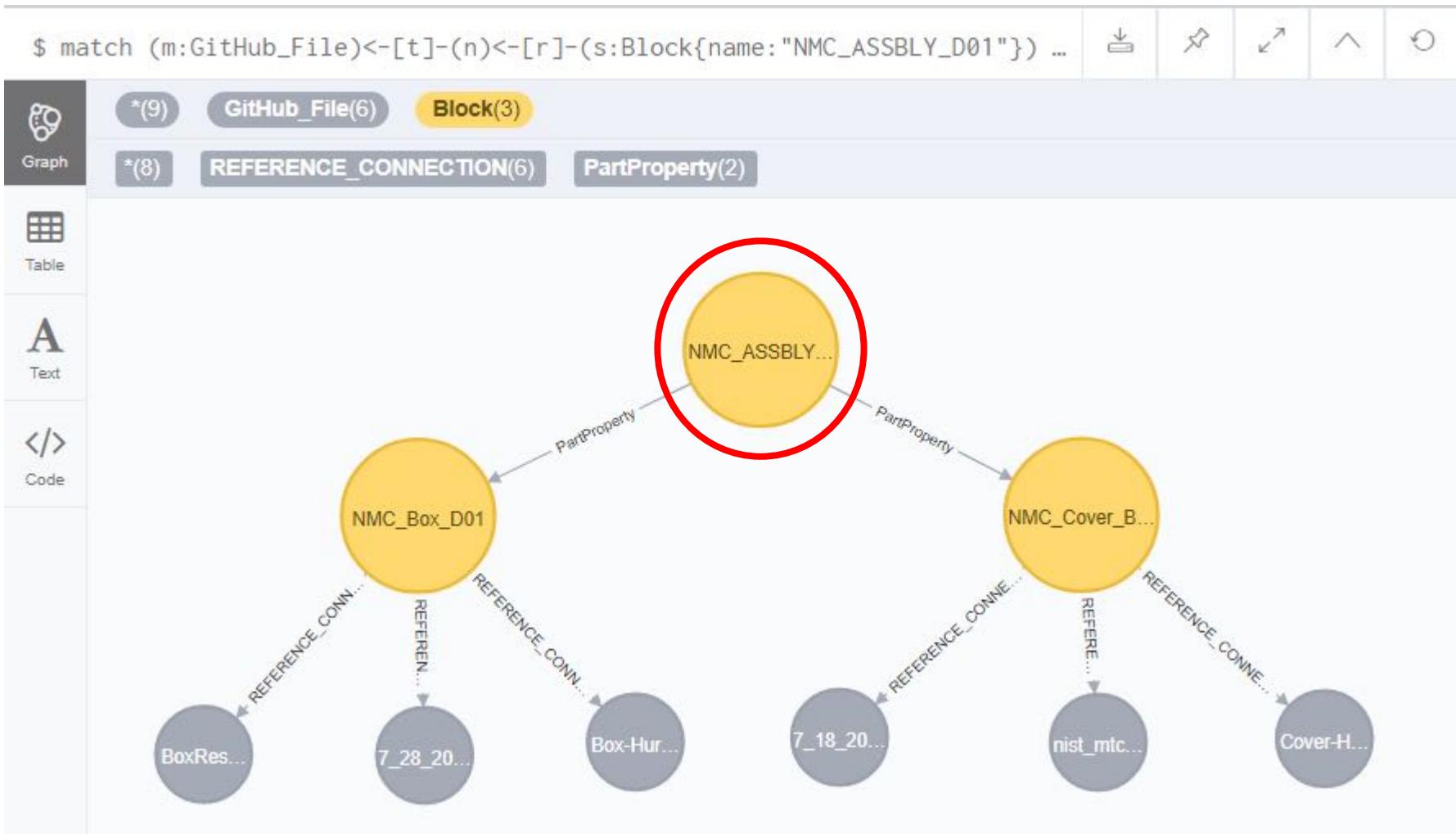
Graph Database Queries

```
$ MATCH (n:Block)<-[r:Allocate]-(m:Block{name: 'NIST_MTC_CRADA_BOX RevD'}) RETURN n,r,m
```



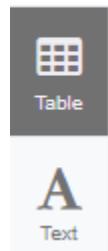
Show all Part Instances of Design Variant block 'NIST_MTC_CRADA_Box_RevD'

Graph Database Queries



Show all Mfg and Quality files in GitHub associated with Part Instance 'NMC_ASSBLY_D01'

```
$ MATCH (m:Block)-[t:Allocate]-(n:Block)-
```



"count(m)"

20

```
$ MATCH (n1:GitHub_File{name: 'BoxResults_19_
```



"count(m)"

19

```
$ MATCH (n1:GitHub_File{name: 'BoxResults_19_samples.QIF'})-[r1:REFERENC
```



"m"

```
{"gid":"PROJECT-b11f2583-da67-4515-b8d9-1304d22c06a7 |  
_18_5_3_63e021c_1521994265350_944094_15411","name":"NMC_Box_D019"}  
{"gid":"PROJECT-b11f2583-da67-4515-b8d9-1304d22c06a7 |  
_18_5_3_63e021c_1521994264434_175058_15408","name":"NMC_Box_D018"}
```

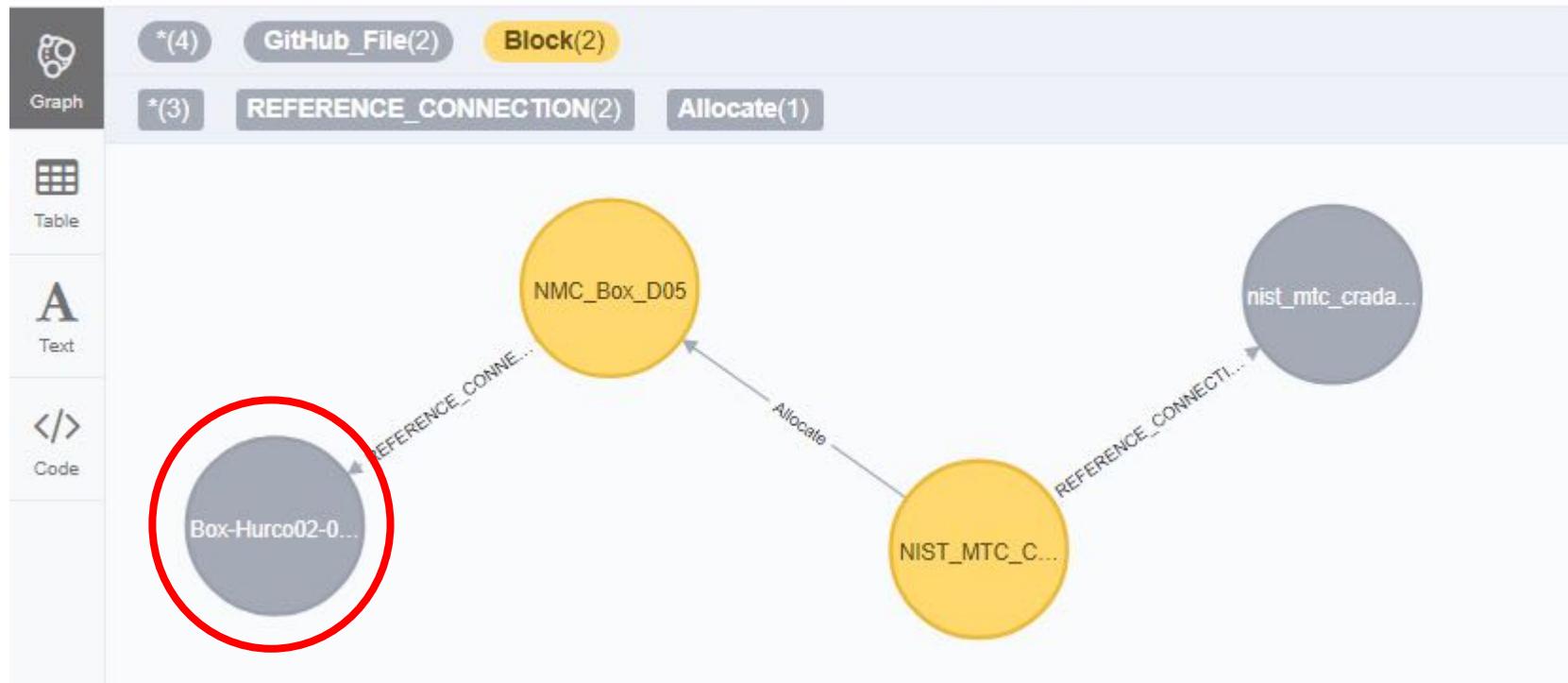
How many instances of Box
have been manufactured?

How many instances of Box
have been through
incoming inspection?

List them

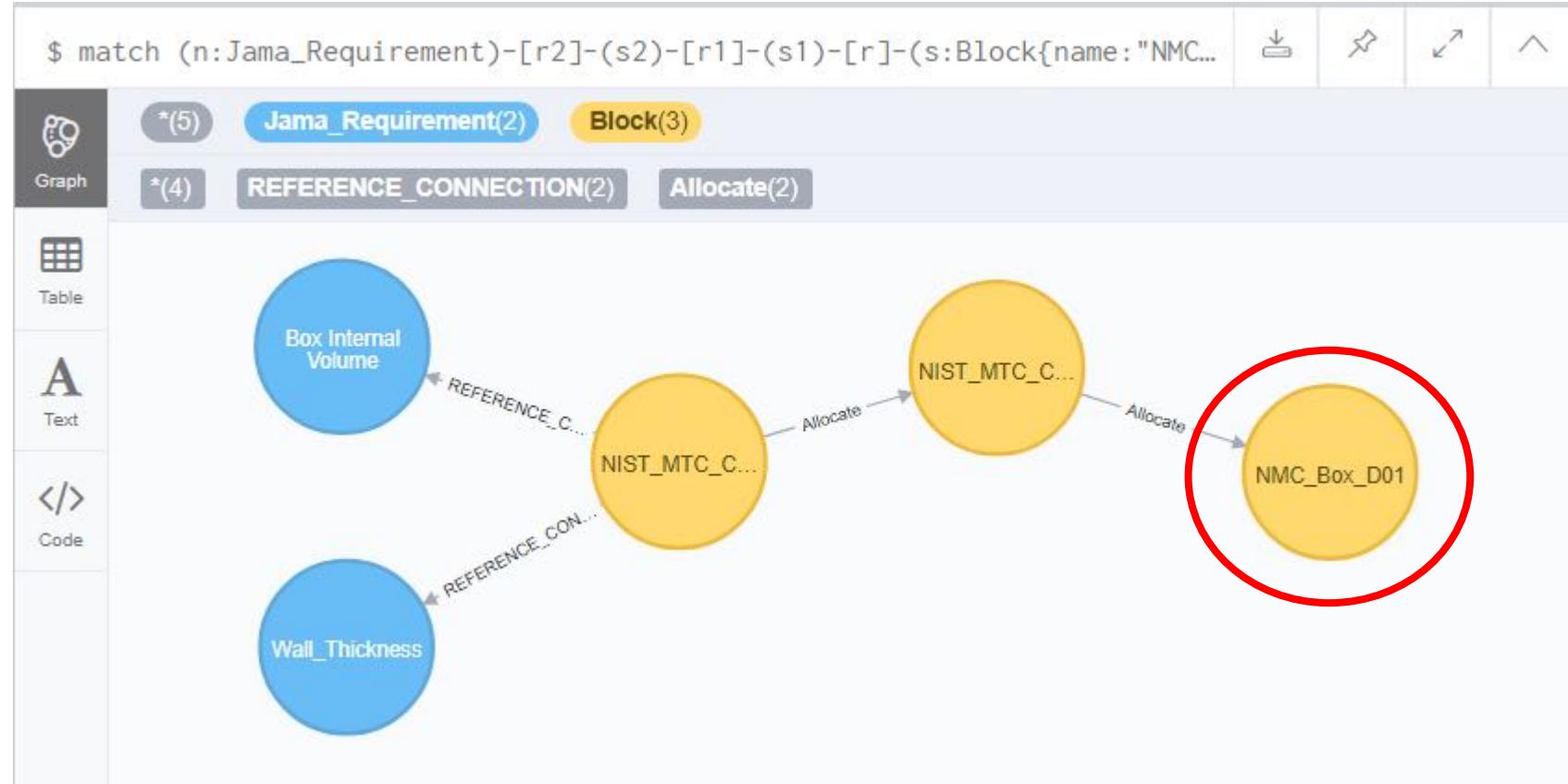
Graph Database Queries

```
$ match (m:GitHub_File)-[t1]-(n1)-[t]->(n)-[r]->(s:GitHub_File{name:"Box-Hurco02-05of20.txt"})
```



Show the CAD file in GitHub associated with Mfg Data 'Box-Hurco02-05of20.txt'

Graph Database Queries



Show all Jama Requirements connected to Part Instance 'NMC_Box_D01'