Standard APIs & Link Prediction for the Digital Thread

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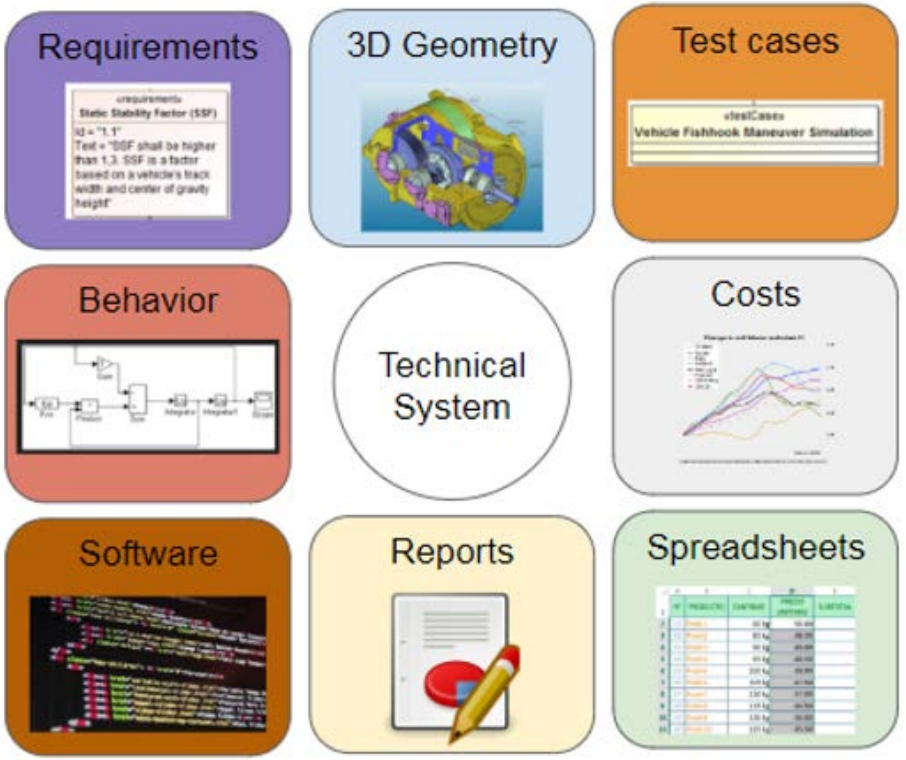
Overview

- Challenges in addressing cross-cutting concerns in Engineering
- Engineering of the Future = Digital Thread
- AI for link prediction

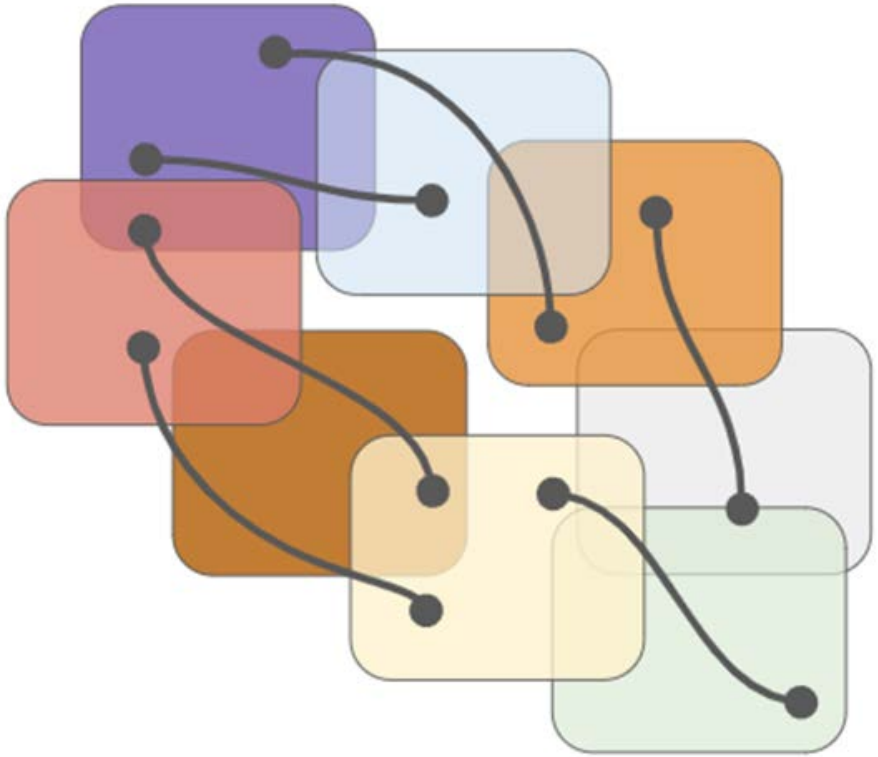
Distributed Engineering Information

- One technical system described from different perspectives
- One technical system, but a lot of distributed information
- Distributed information is challenging for collaboration



Overlaps and Relationships in Engineering

- Overlaps due to data duplication (e.g. same parameter used in different models or reports)
- Logical relationships such as a requirement verified by a test case
- The more complex a system is, the more relationships exist between engineering information



Tough Questions for Engineers

[**traceability**] is this requirement tested/satisfied? By which architecture/simulation/cad model?

[**change management**] If we change this requirement, what is the impact for downstream models? How many tests need to be performed again? On the other hand, if a downstream model changes (simulation/cad), what are the upstream impacts on requirements and the system architecture?

[**reuse**] I have the same requirement in a new project, which elements of the old project can I reuse in the new project (which test cases, which architecture/simulation/cad models)?

Status Quo

According to David Meza, Head of Knowledge Management at NASA

“Most engineers have to look at 13 different sources to find the information they are looking for”

“46% of workers can’t find the information about half the time”

“30% of total R&D funds are spent to redo what we’ve already done once before”

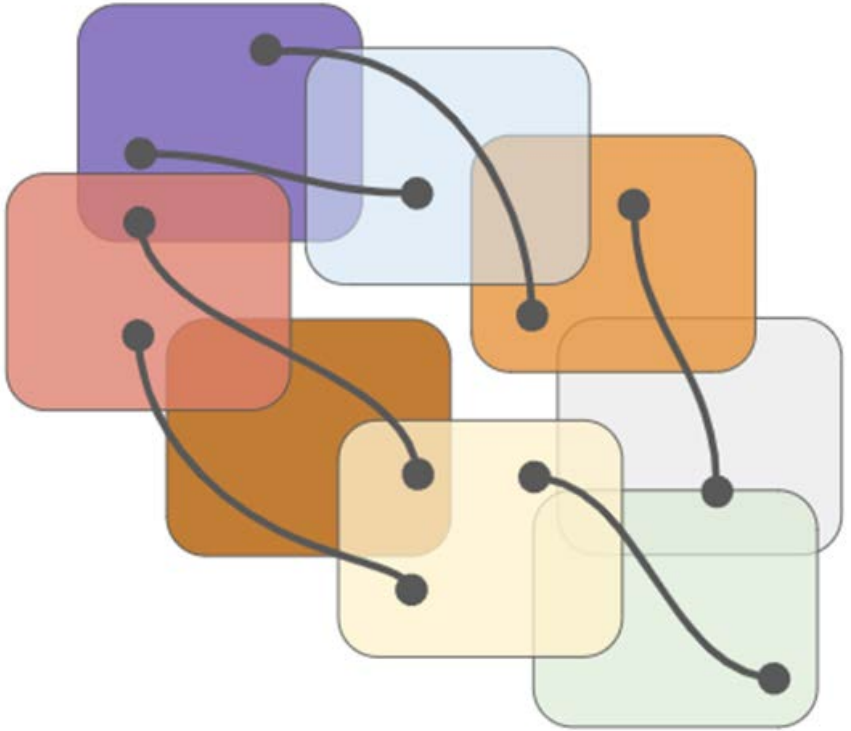
“54% of our decisions are made with inconsistent, or incomplete, or inadequate information”

Quote from https://www.youtube.com/watch?v=QEBVoultYJg

What is the Digital Thread?

Capturing relationships between engineering data across disciplines and across software applications

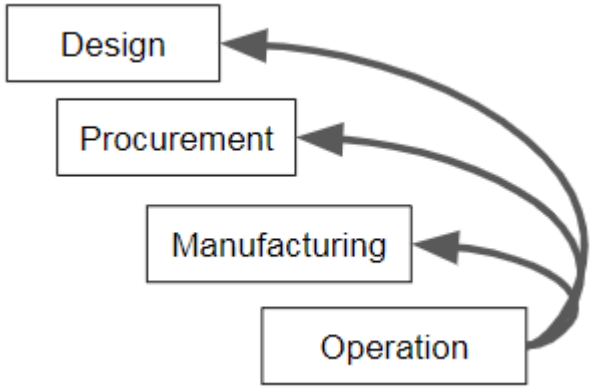
Addressing cross-cutting issues efficiently by knowing cross-disciplinary relationships



2 Trends requiring the Digital Thread

IoT/Digital Twin

New feedback loops needed to make sense of recorded operational data



Complexity of Autonomous Systems

Explosion of number of test scenarios
Need to link experienced auton. vehicle behavior (e.g. saved in data lakes) with test scenarios (e.g. saved in systems engineering applications) to assess coverage of test scenarios and overall vehicle safety

What does it mean to connect data?

Example:

Requirement **identifier** <- link type **identifier** -> Simulation parameter **identifier**
Connection is between **IDENTIFIERS** of data

Example: Power budget requirement will have identifier Req-PX-123456
Example: Power parameter in simulation model has identifier Par-PX-7890

Analogy: phone call between 2 persons identified by their phone number

Accessing data identifiers through APIs

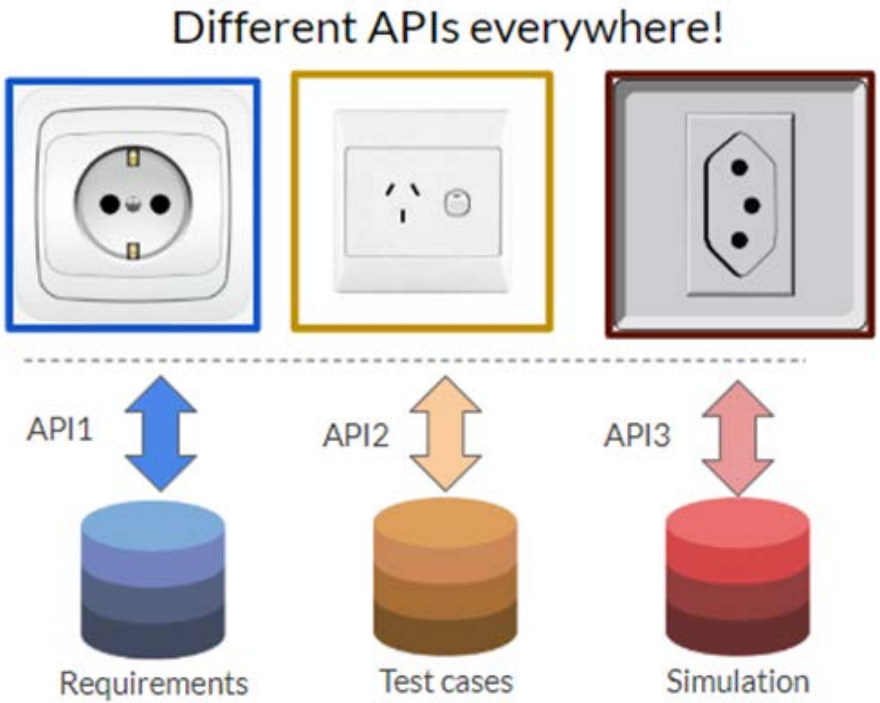
Identifiers need to be retrieved from the Application Programming Interface (API) of the data source

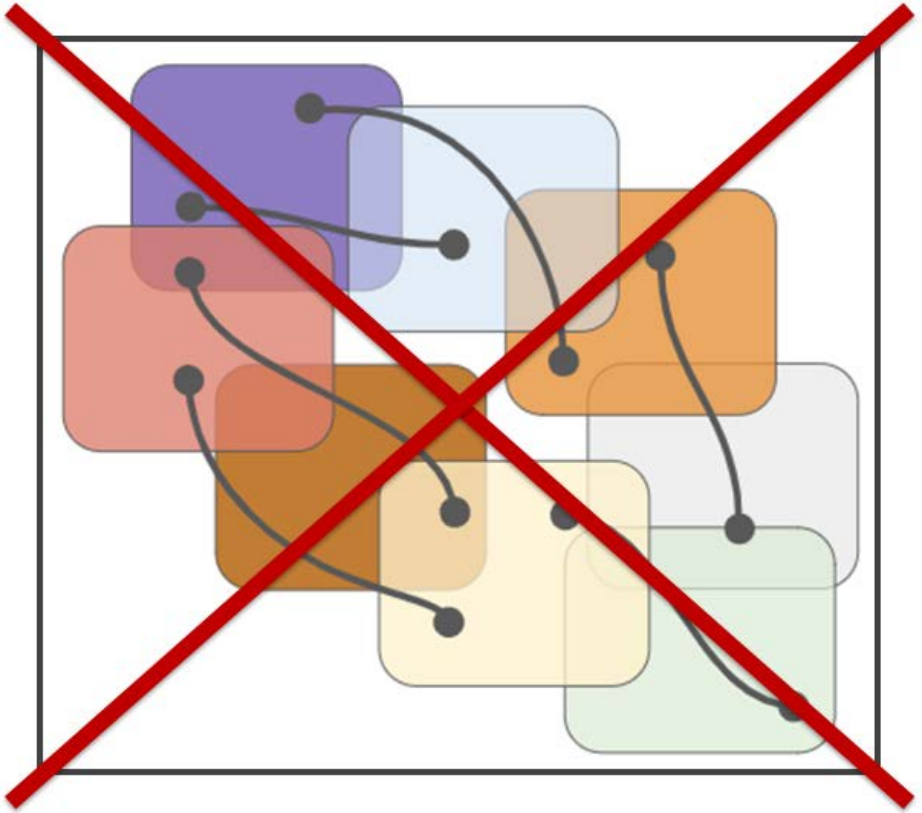
Different data sources have different APIs

Example: REST API, Web API, SQL, Java/Python library etc.

Analogy: Different APIs like different power outlets

Digital Thread is currently impossible!





Different API = vendor lock-in

Proprietary APIs and Data Formats

Your Data

Your Software Application Vendor

Once Upon a Time – Before the Web

- Different protocols to access documents on the internet (Gopher, WAIS, etc...)
- No connected documents (hierarchical document structure, no hyperlinks)
- Not many persons used the internet
- Hypertext existed since 1965, 25 years before the invention of the Web
- Lack of standards for Hypertext hindered adoption of Hypertext - no compatibility between different Hypertext systems

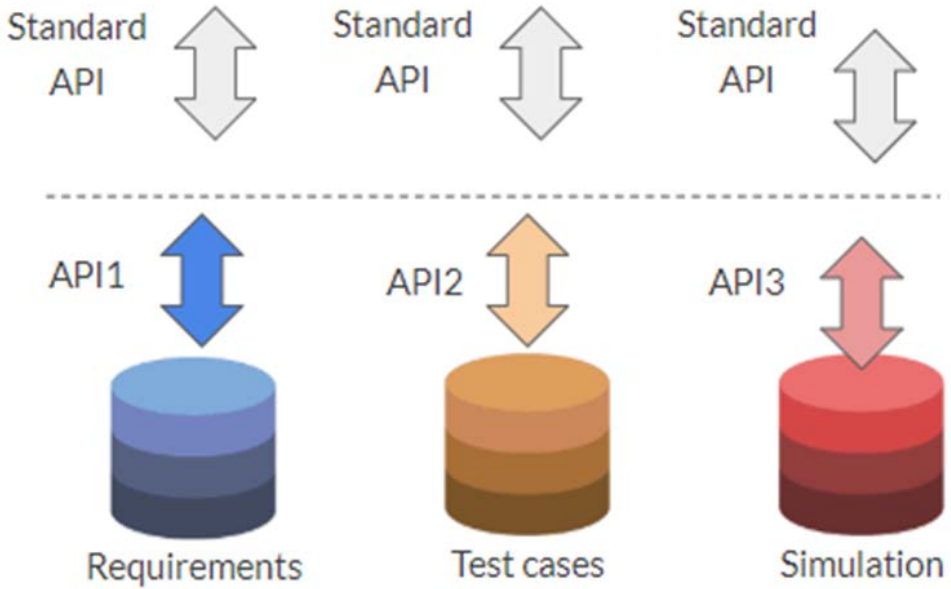
Lessons learned from the Web

- Seeds for innovation: Open standards + open-source
- Web not owned by a software vendor
- Any document can connect to any other document
- Improved knowledge sharing and collaboration
- OSLC driven by similar values than World Wide Web

Principle 1: Standard API

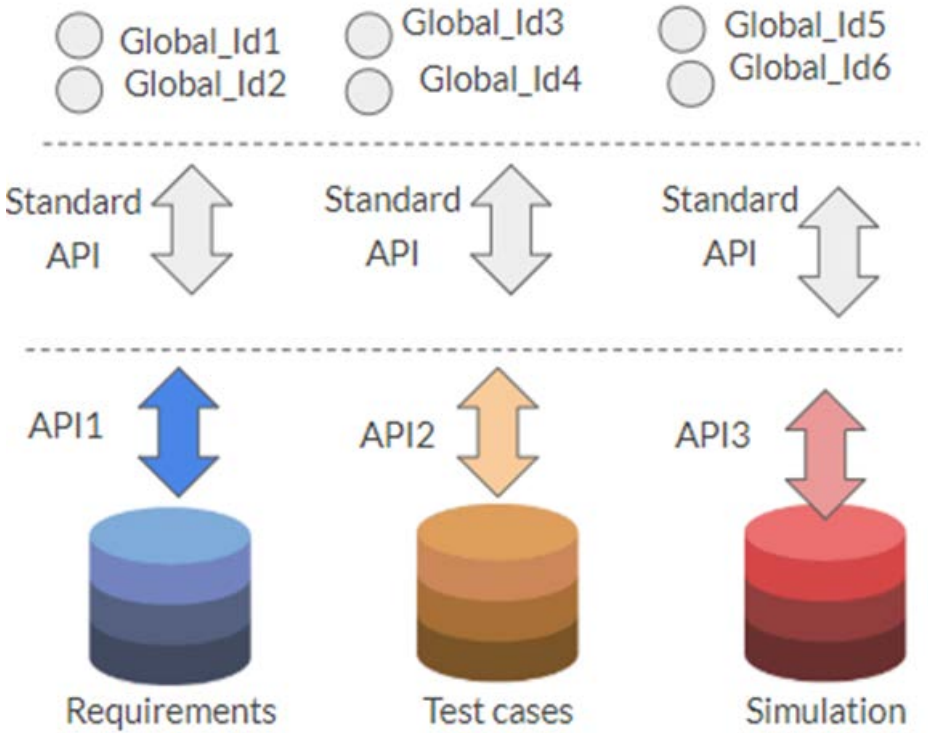
Data is accessible through a standard API

- Versioning of resources
- Discovery of resources
- Constraints on resources
- Change events impacting resources



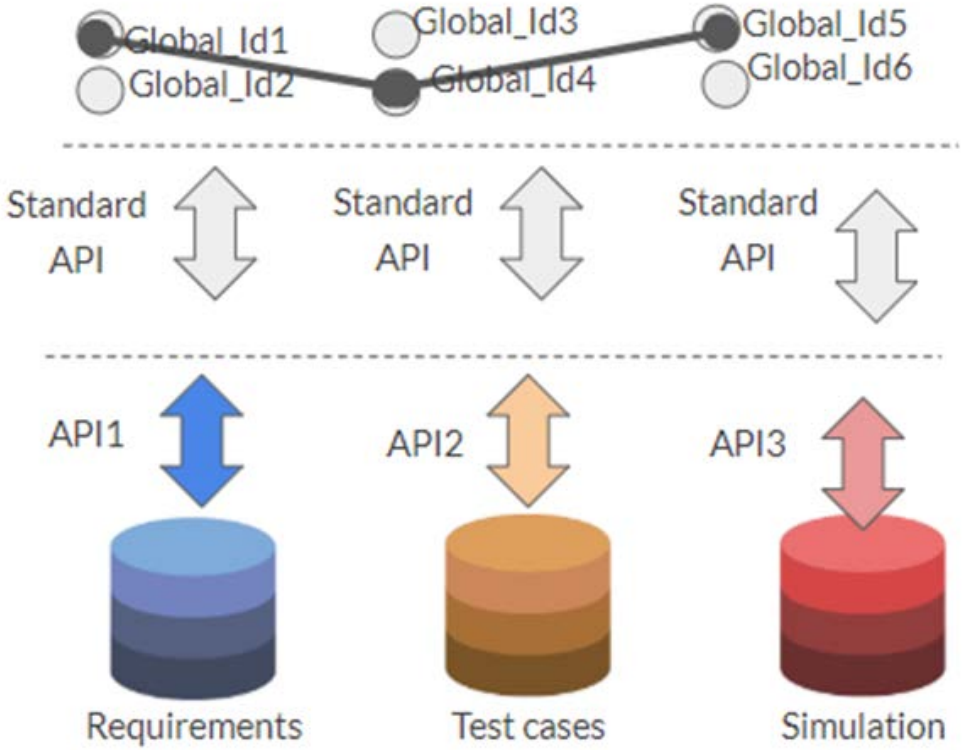
Principle 2: Unique Global identifiers

Data has unique global identifiers



Principle 3: Connections across silos

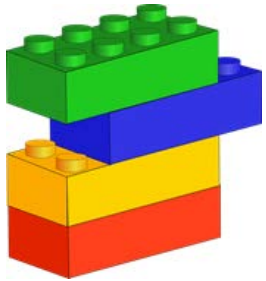
Data is connected

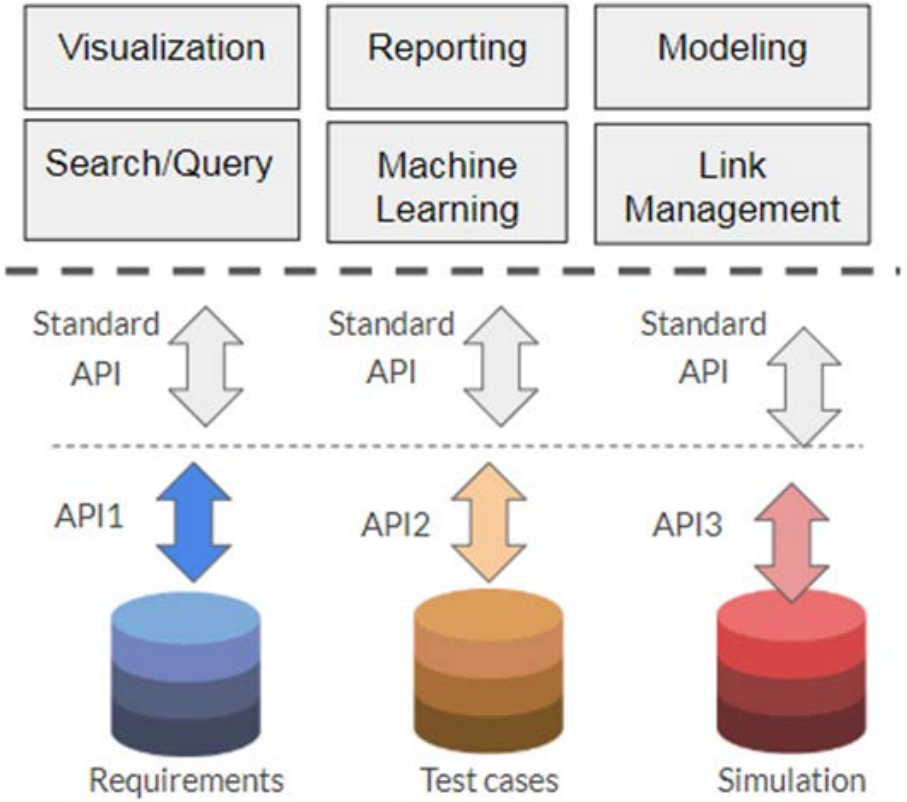


Principle 4: Applications decoupled from data

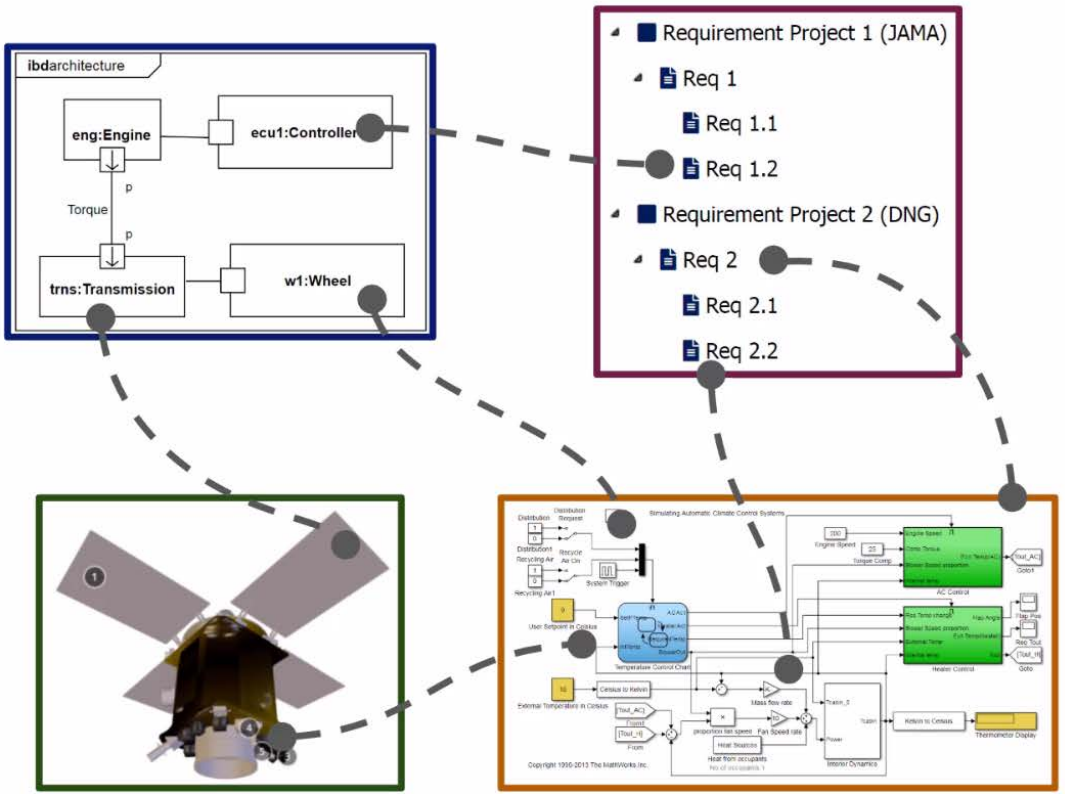
Applications decoupled from data

- True data ownership
- Reusing existing data





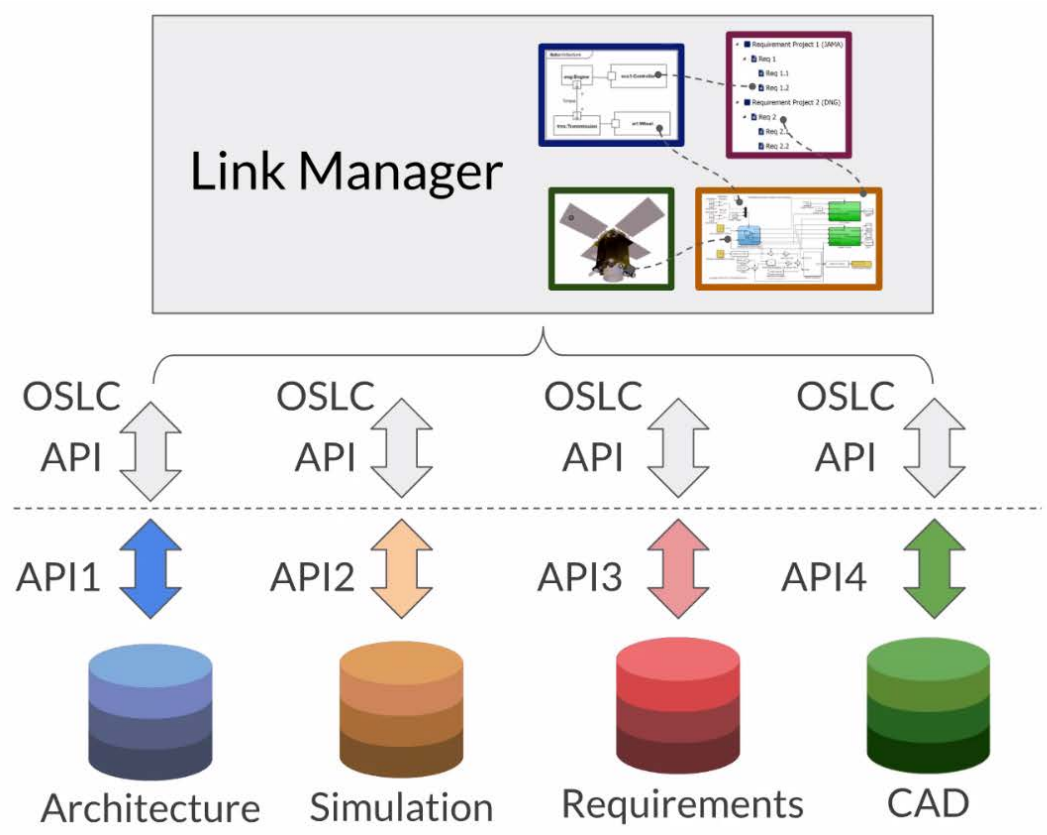
Link Manager Goal



Goal

Connect requirements, architecture, simulation and CAD information with links

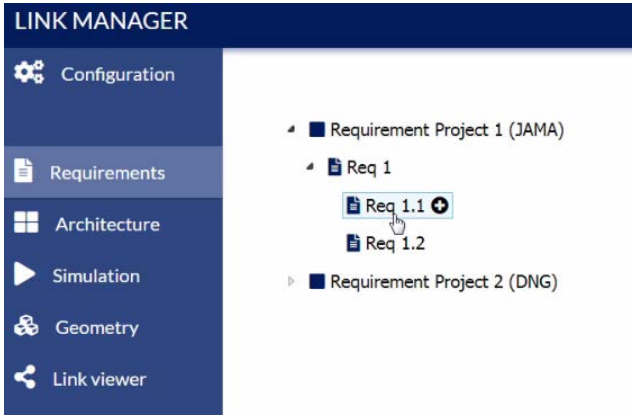
Link Manager Architecture

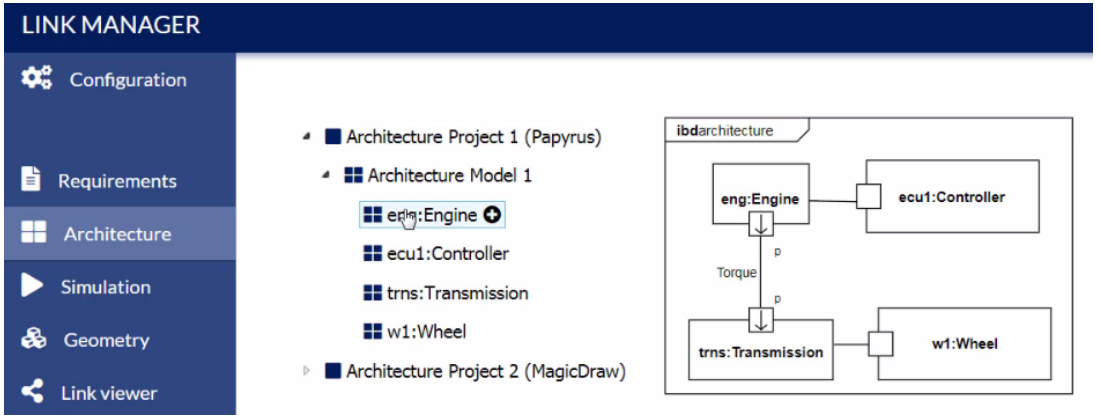


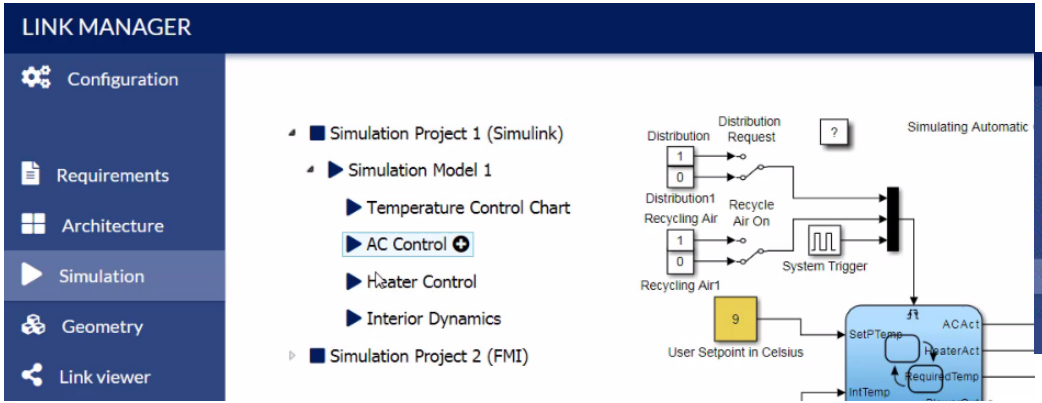
Architecture

Link creation in separate neutral application **Link Manager** using standard OSLC APIs

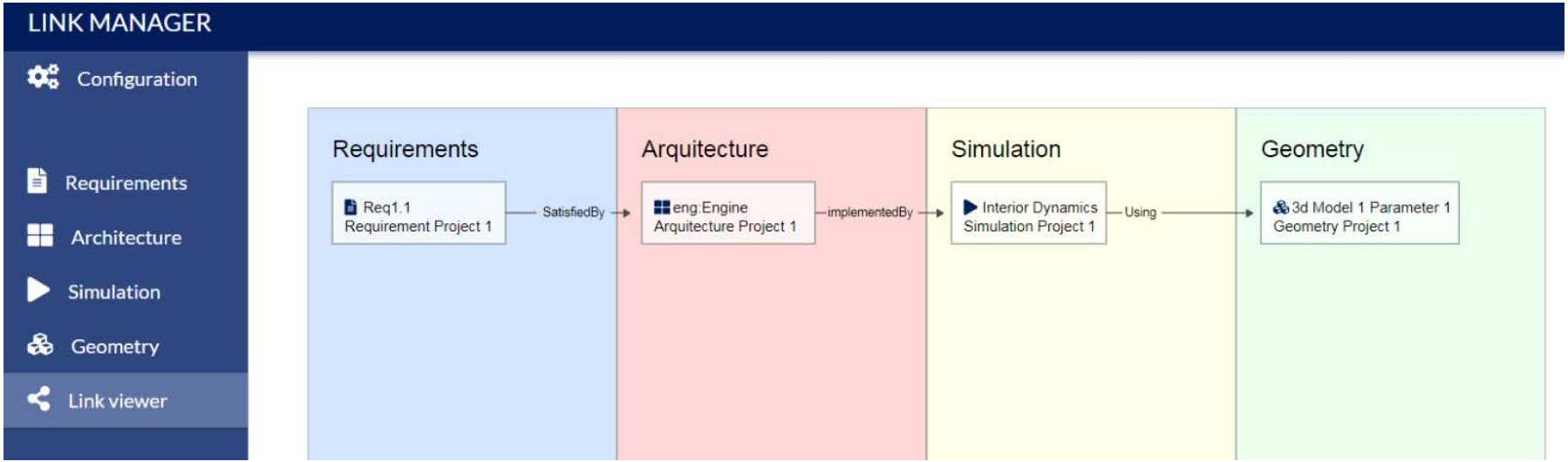
Link Manager Views





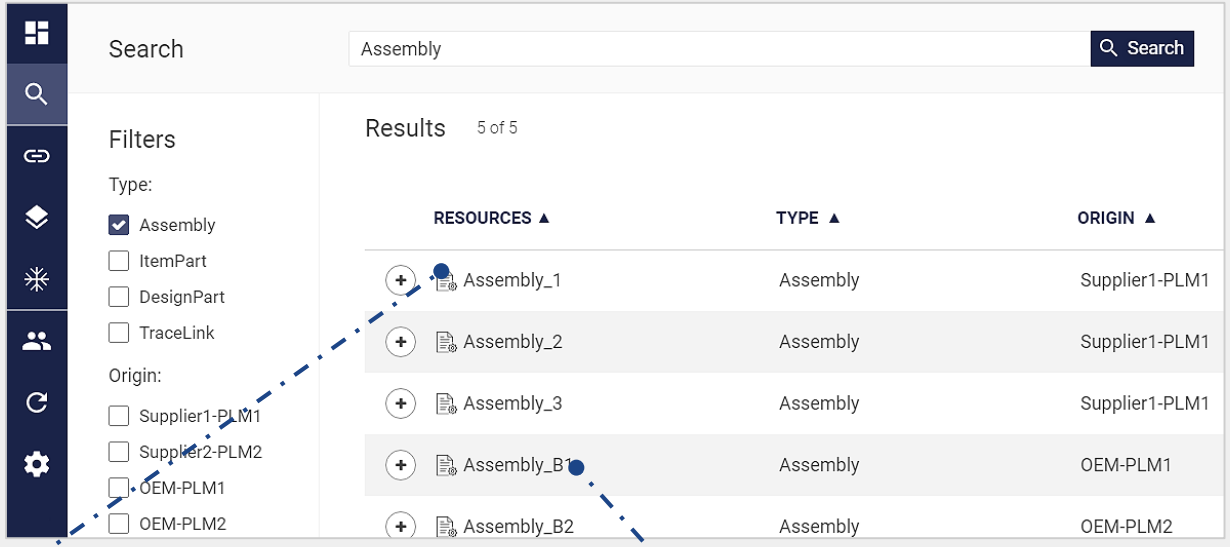


Link Viewer

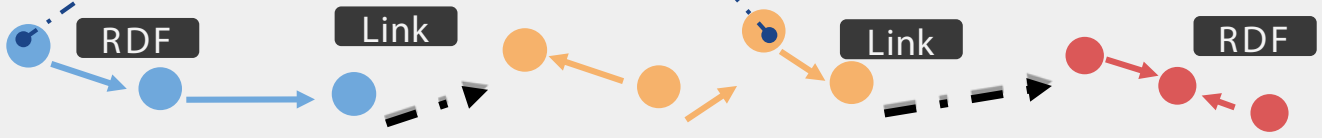

LINK MANAGER
Configuration
Requirements
Architecture
Simulation
Geometry
Link viewer
Requirements
Req1.1
Requirement Project 1
SatisfiedBy
Arquitecture
eng:Engine
Arquitecture Project 1
implementedBy
Simulation
Interior Dynamics
Simulation Project 1
Using
Geometry
3d Model 1 Parameter 1
Geometry Project 1

Data Web Application Example

Google-like Search



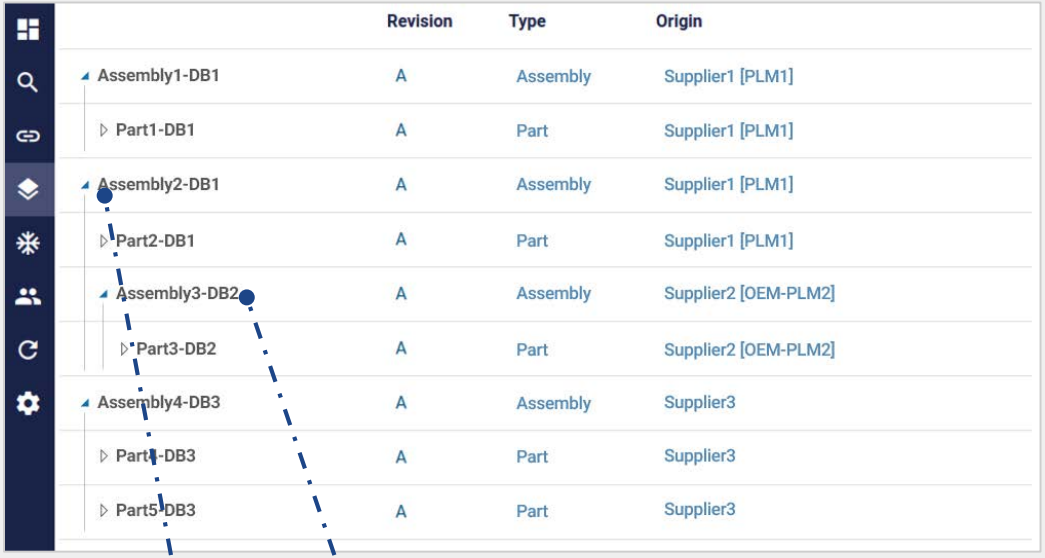
Private/public Data Web



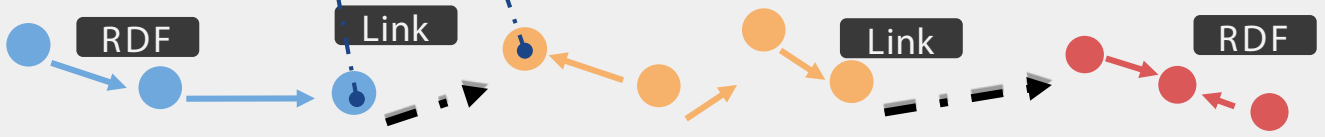
Distributed Data Silos

Data Web Application Example

Tree (BOM-like) Viewers

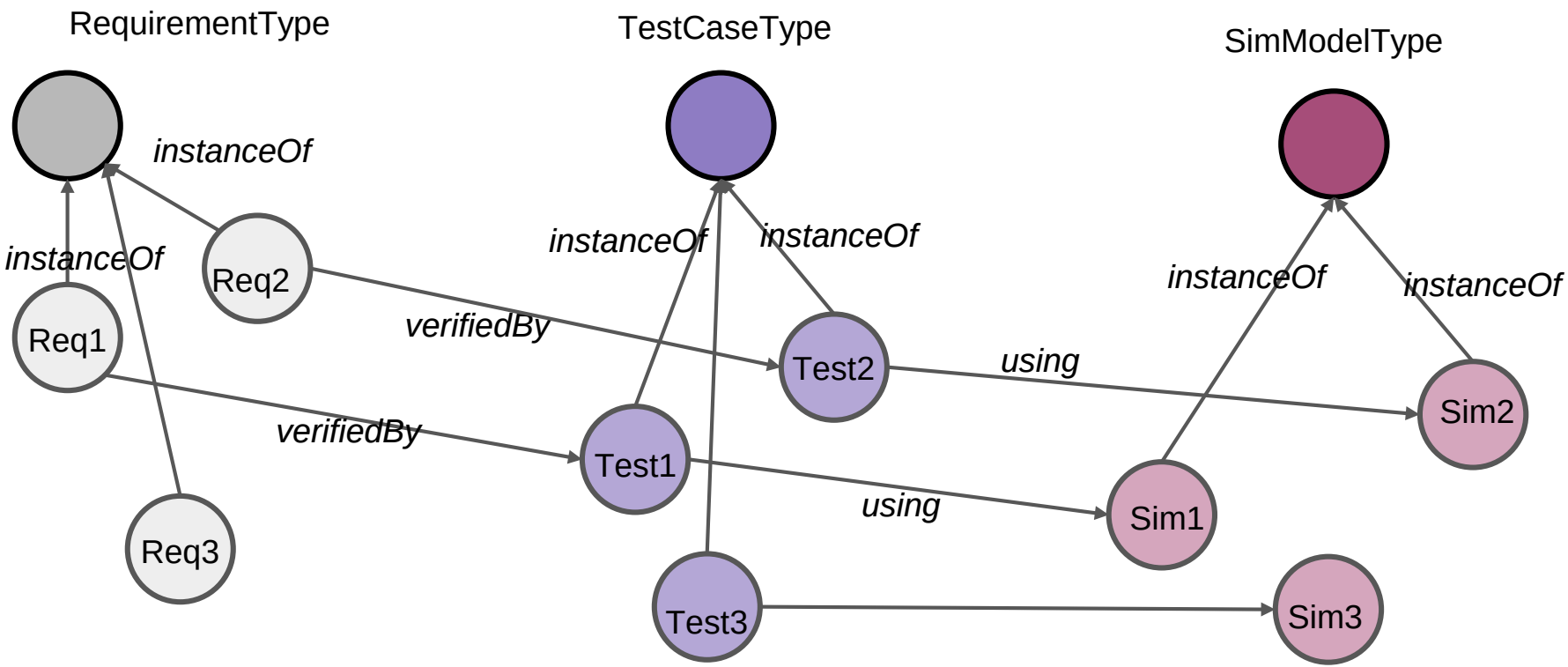


Private/public Data Web

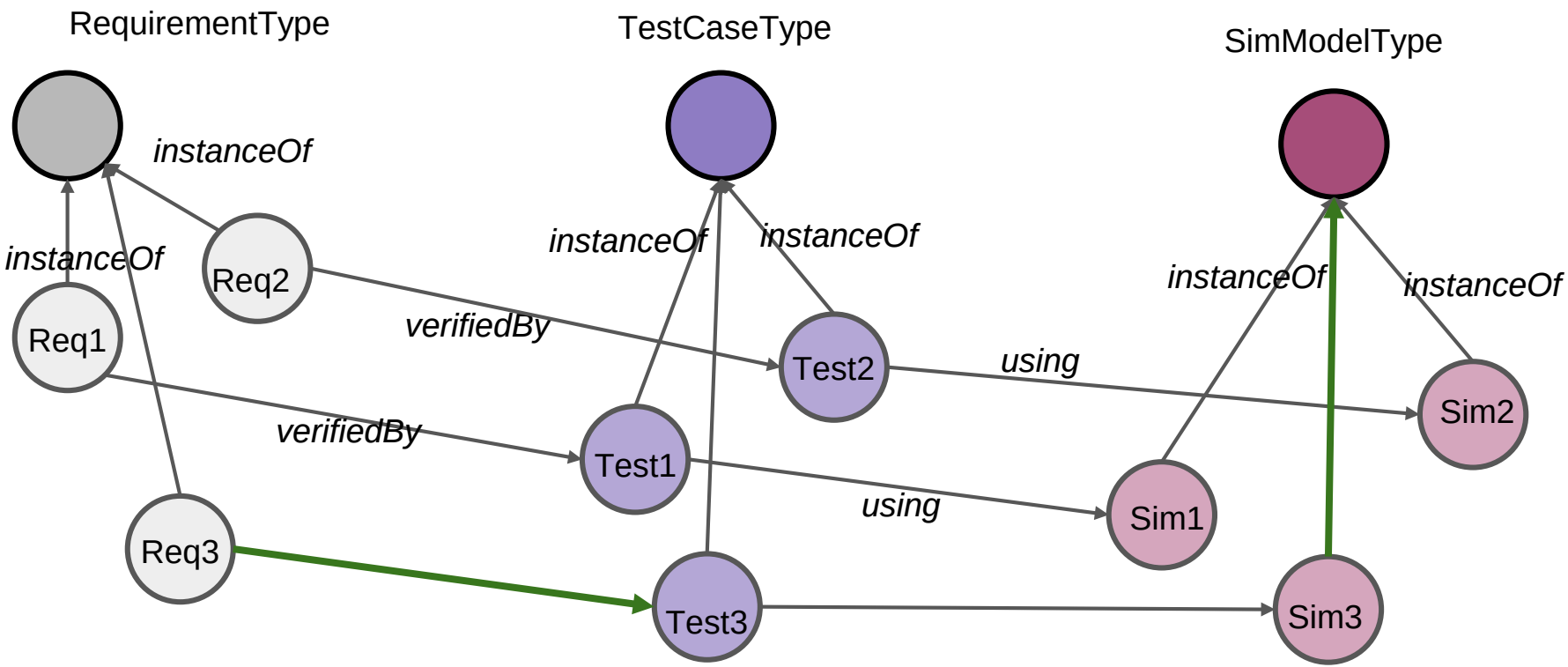


Distributed Data Silos

Digital Thread is a Graph

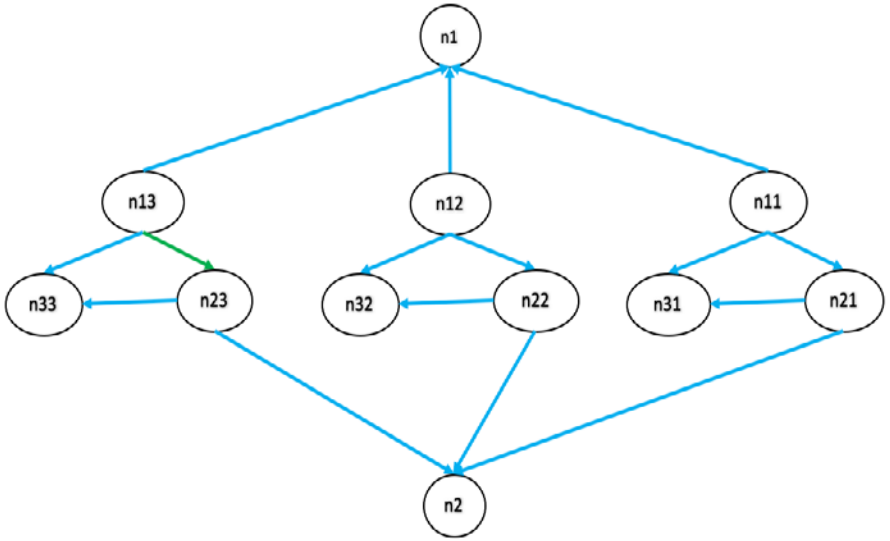


Graphs have patterns-> Link Prediction

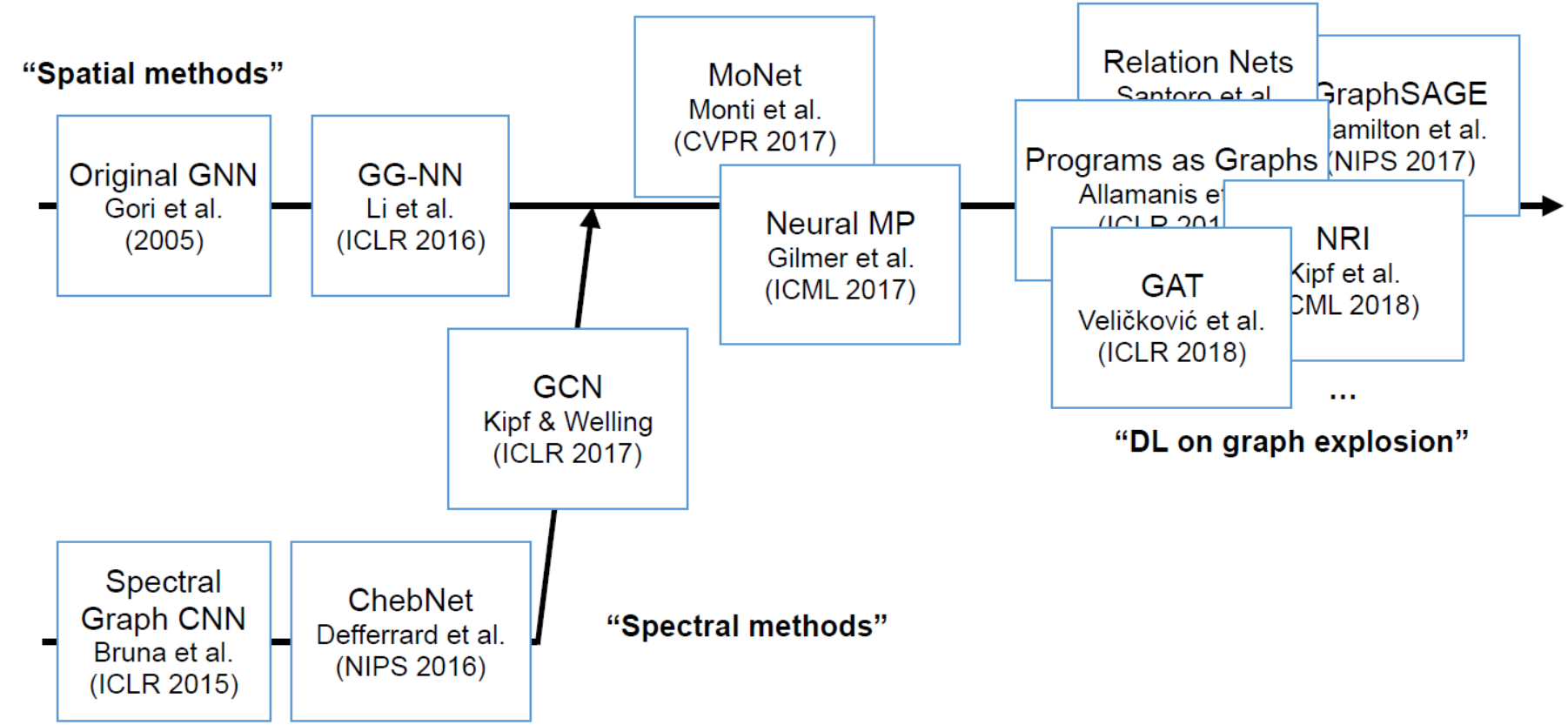


Link Prediction

- Manual link definition is time-consuming
- Based on patterns in existing links, additional links can be predicted through machine learning, graph mining, and heuristics



Brief History of graph neural nets



3 Investigated Link Prediction Approaches

1. Deep learning
2. Heuristics
3. Graph mining

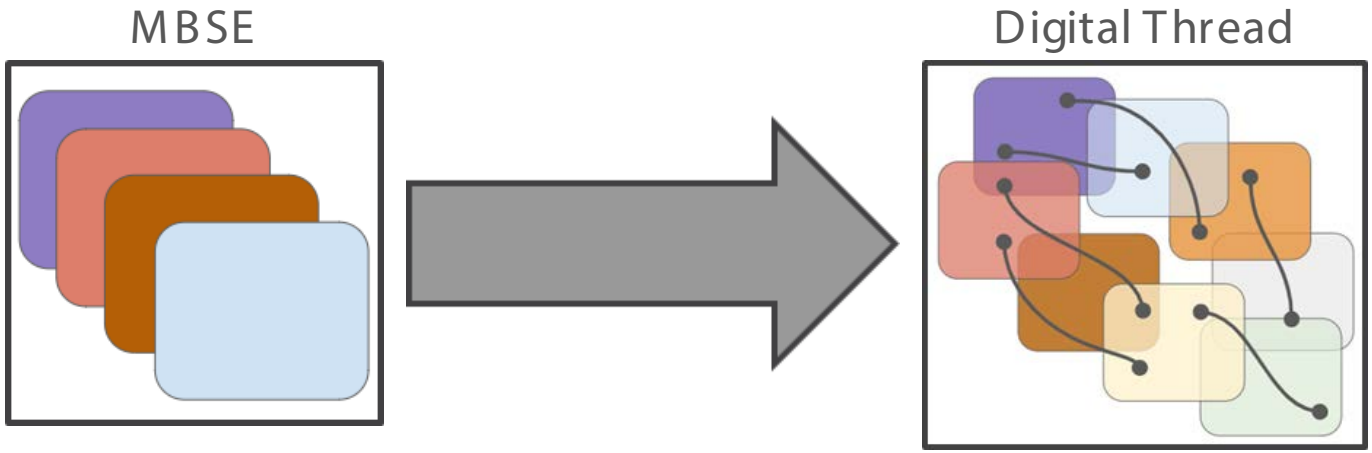
The digital thread graph is **relatively small** (compared to social network graphs) and contains **complex patterns**

No link prediction approach yet found suitable for digital thread graphs

Comparison of 3 link prediction approaches

Approach	Identification of complex patterns	Applicable to small graphs	Computational effort
Deep learning			
Heuristics			
Graph mining			

From Model-Based to the Digital Thread



Focused on specific models, specific data types, specific data structures, specific engineering disciplines

Focused on viewing data as a universal asset, and getting the most value out of ALL the data

Viewing Data as Universal Asset

Electricity played a big role in the Industrial Revolution

Different devices can connect to electric power through a standard power outlet

Data is the new source of power

We need standard APIs to access data, just like we have standard power outlets to access electric power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Thanks and get in touch!

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