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Axel Reichwein, Koneksys

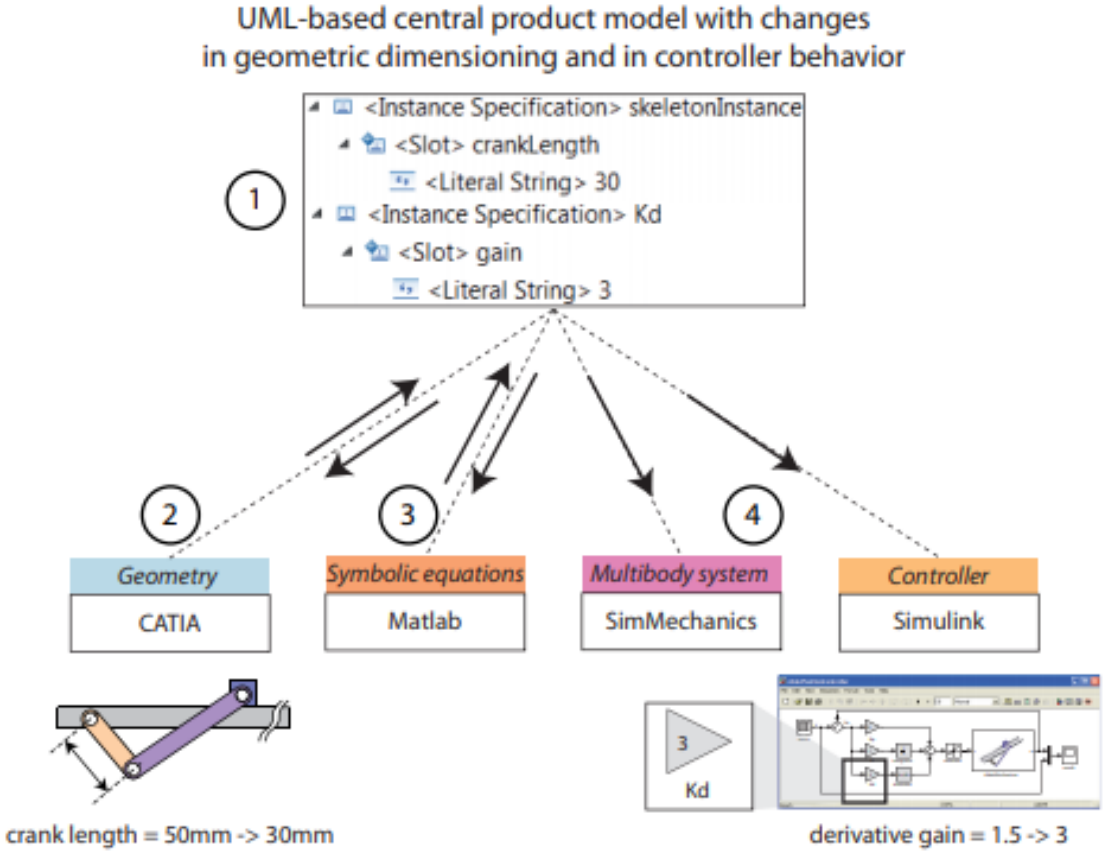
Modular Architecture Principles for Model-Based Systems Engineering

Axel Reichwein

- Background in aerospace engineering
- Focus on data integration and Open Services for Lifecycle Collaboration (OSLC)
- Previously involved in standardization efforts related to SysML (Systems Modeling Language)

My engineering background

- PhD and postdoc focused on tradeoff studies
- Reconfiguring architecture model to then automatically sync detailed discipline-specific models
- Applying rule-based design in engineering

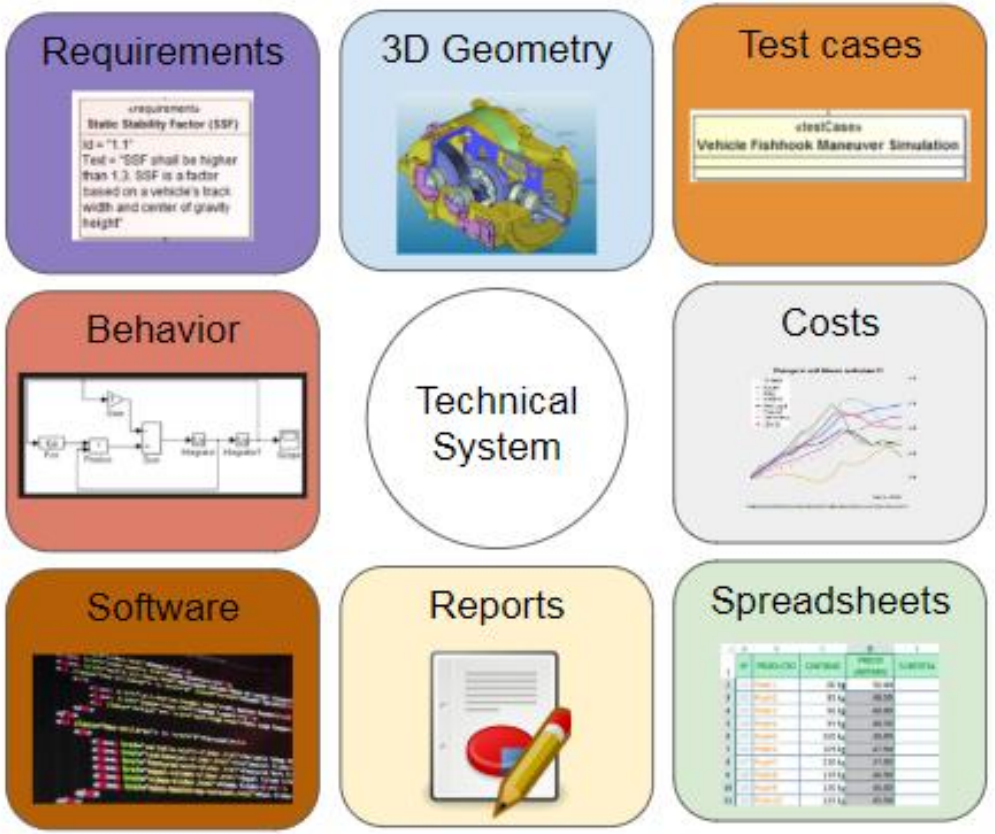


Overview

- Challenges in Systems Engineering in addressing cross-cutting issues
- Future SE = Network-Based Model-Based Systems Engineering
- Modular Architecture Principles for MBSE

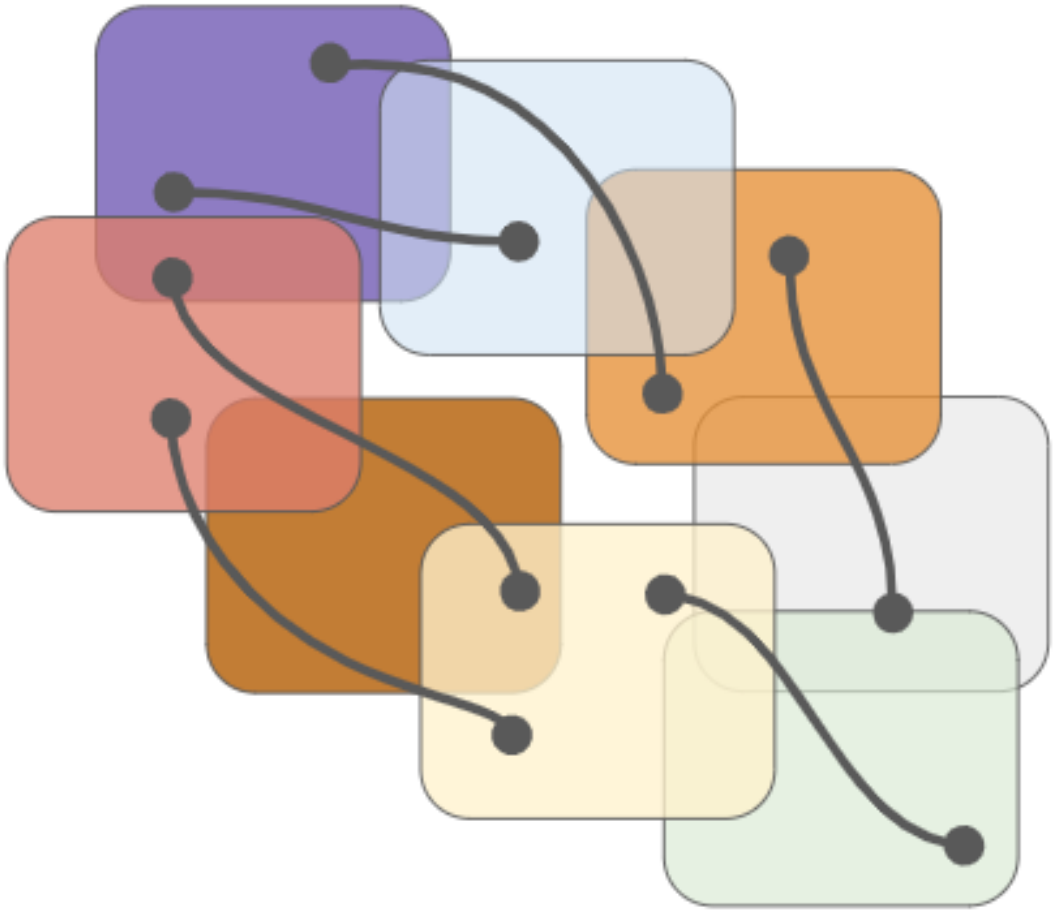
Distributed Engineering Information

- 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 Information

- 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 Systems 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

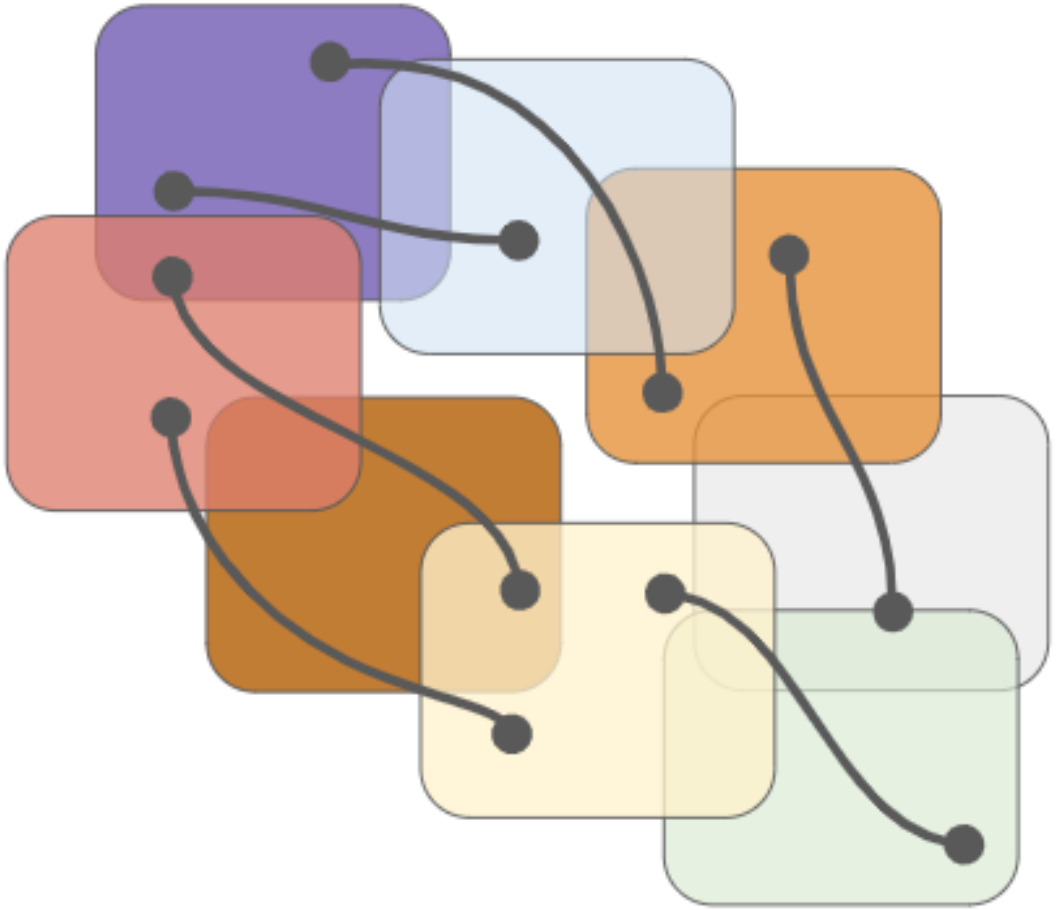
According to David Meza, Head of Knowledge Management at NASA

- "**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**"

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

What is Network-Based MBSE?

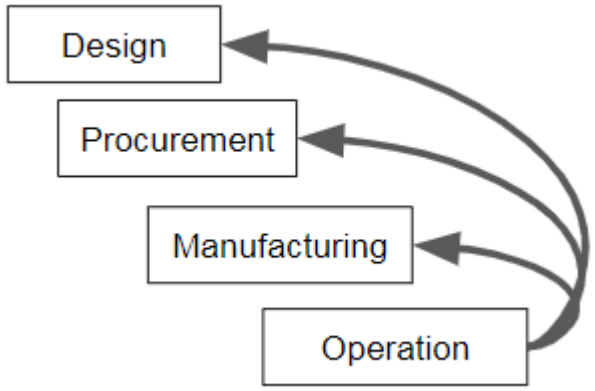
- Capturing relationships between engineering data across disciplines and across software applications
- Addressing cross-cutting issues efficiently by knowing cross-disciplinary relationships



2 Trends requiring Network-Based MBSE

IoT

New feedback loops needed to make sense of recorded operational data



Autonomy

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

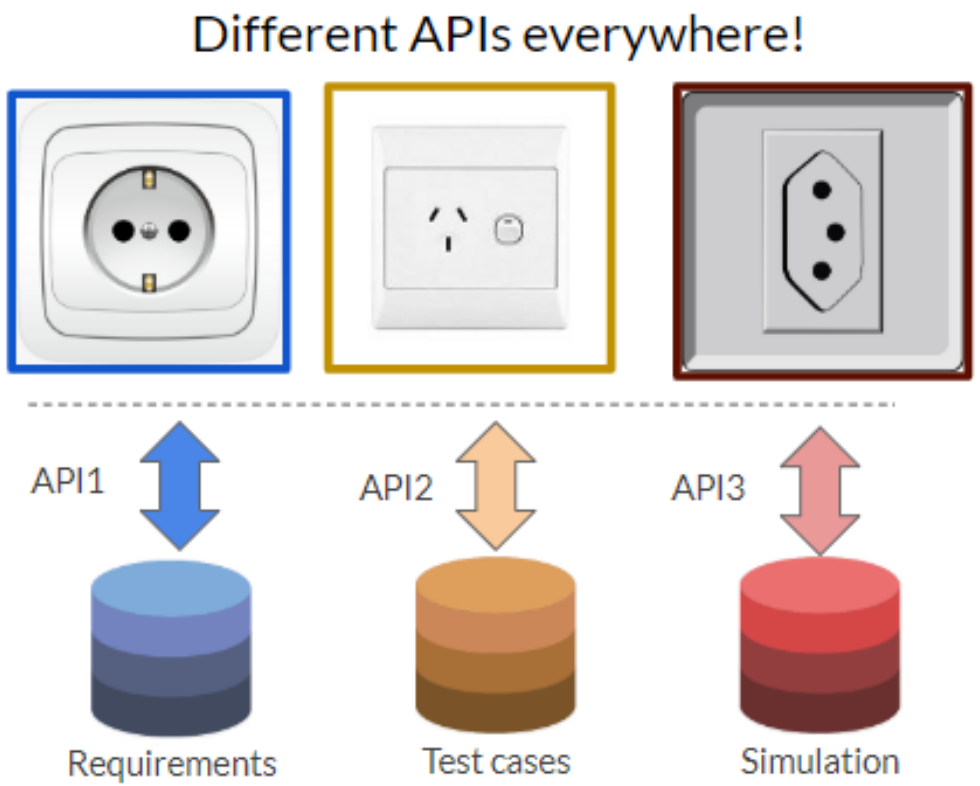
What does it mean to connect data?

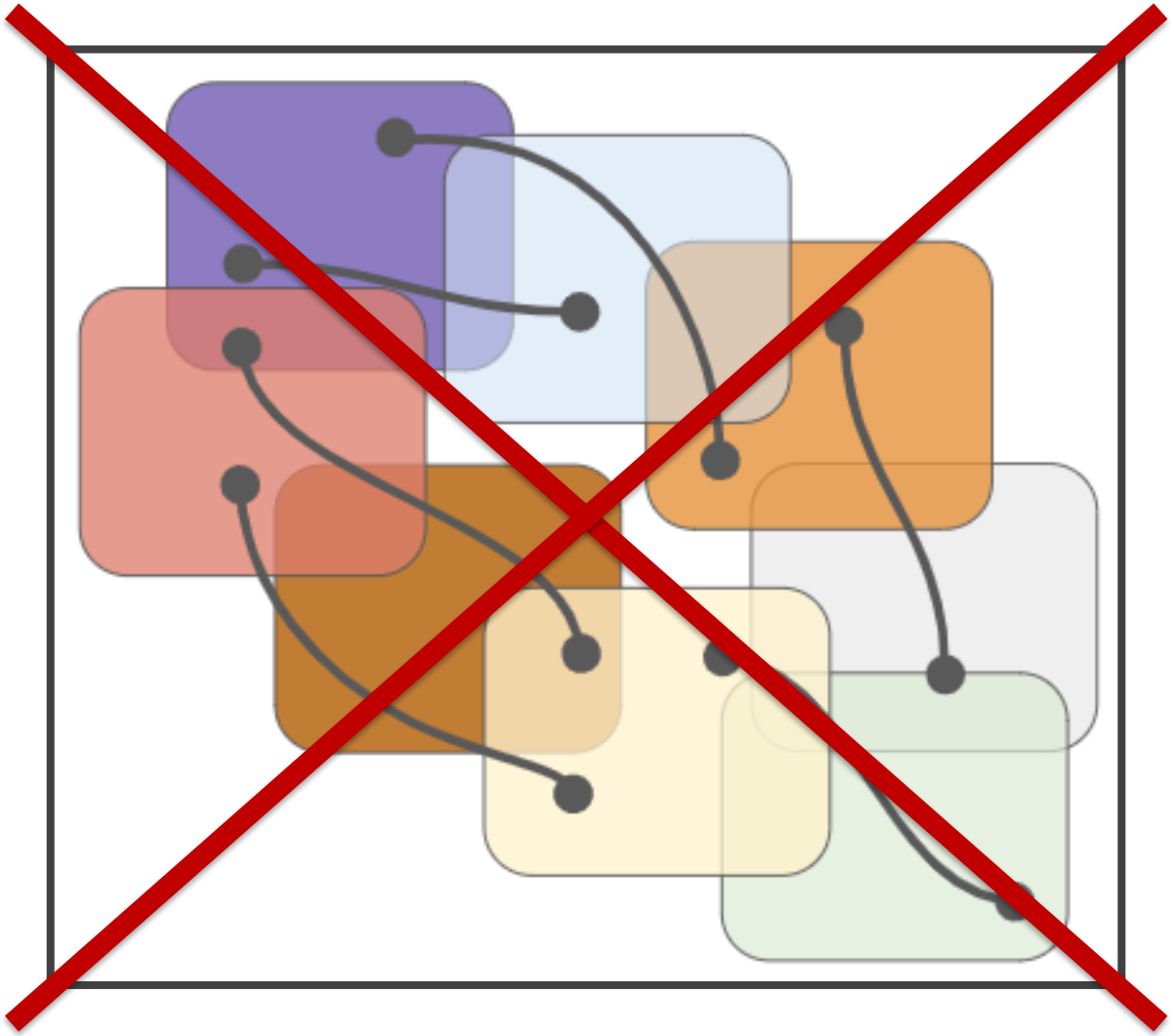
- Example: Requirement identifier <- link type -> Simulation parameter identifier
- Connection is between IDENTIFIERS of data
- Example: Power budget requirement will have identifier Req-PX-123456
- Example: Power parameter in simulation model has identifier Par-PX-7890
- Analogy: phone call between 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

Network-Based MBSE 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

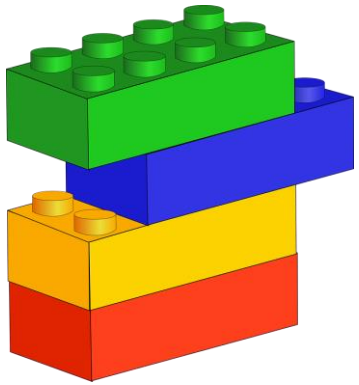
- Different protocols to access documents on the internet (Gopher, WAIS, etc...)
- No connected documents (hierarchical document structure, no hyperlinks)
- Not many persons used the internet
- Hypertext existed since 1965, 25 years before the invention of the Web
- Lack of standards for Hypertext hindered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

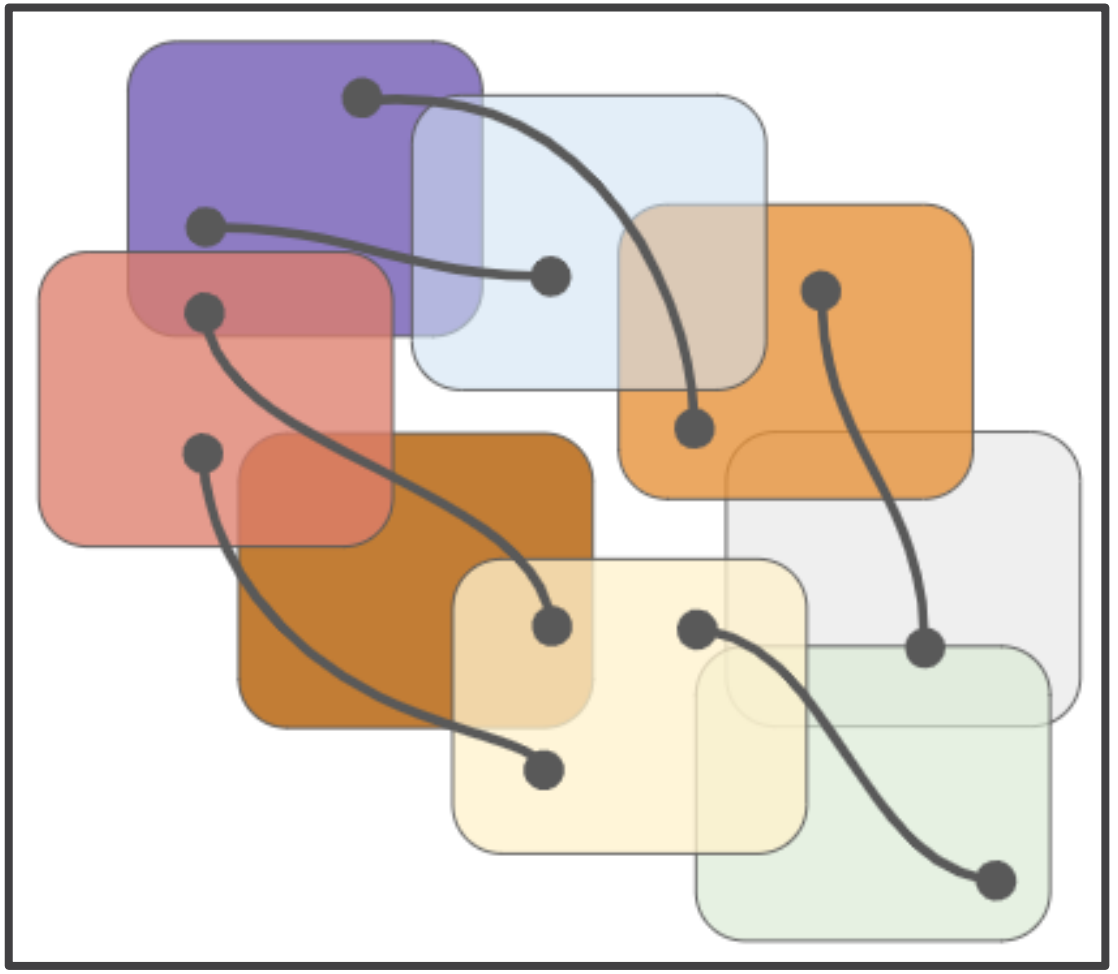
Lessons learned from the Web

- 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

Modular Architecture Principles for Network-based MBSE

- Modularity = Supporting exchangeability of components through standard interfaces





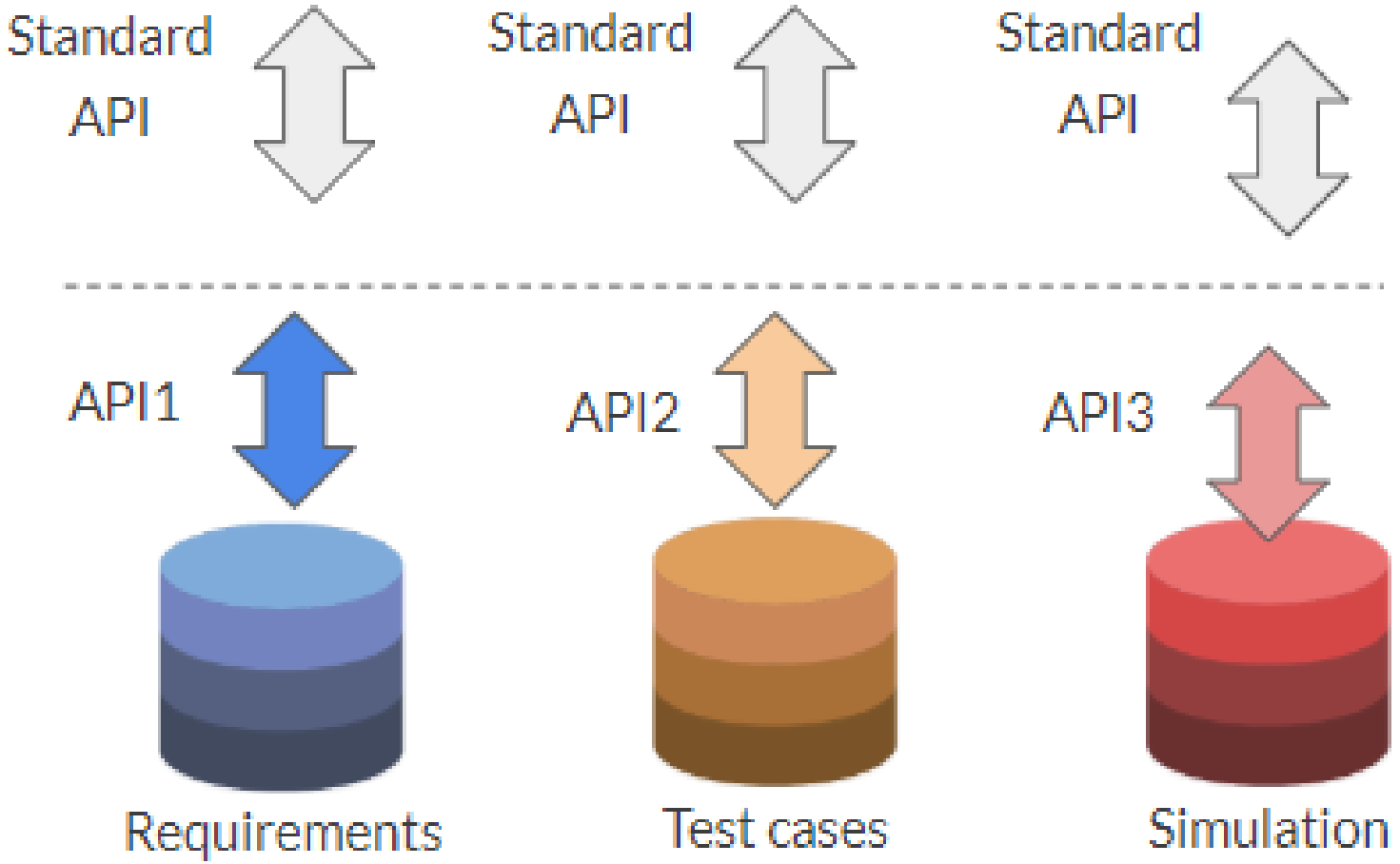
Modularity applied to engineering data

- Data has many “faces”
  - Data access protocols
  - Data types
  - Data structures
  - Data connections
  - Data formats
  - Version-management concepts

- For modularity, different “faces” of data need to be standardized

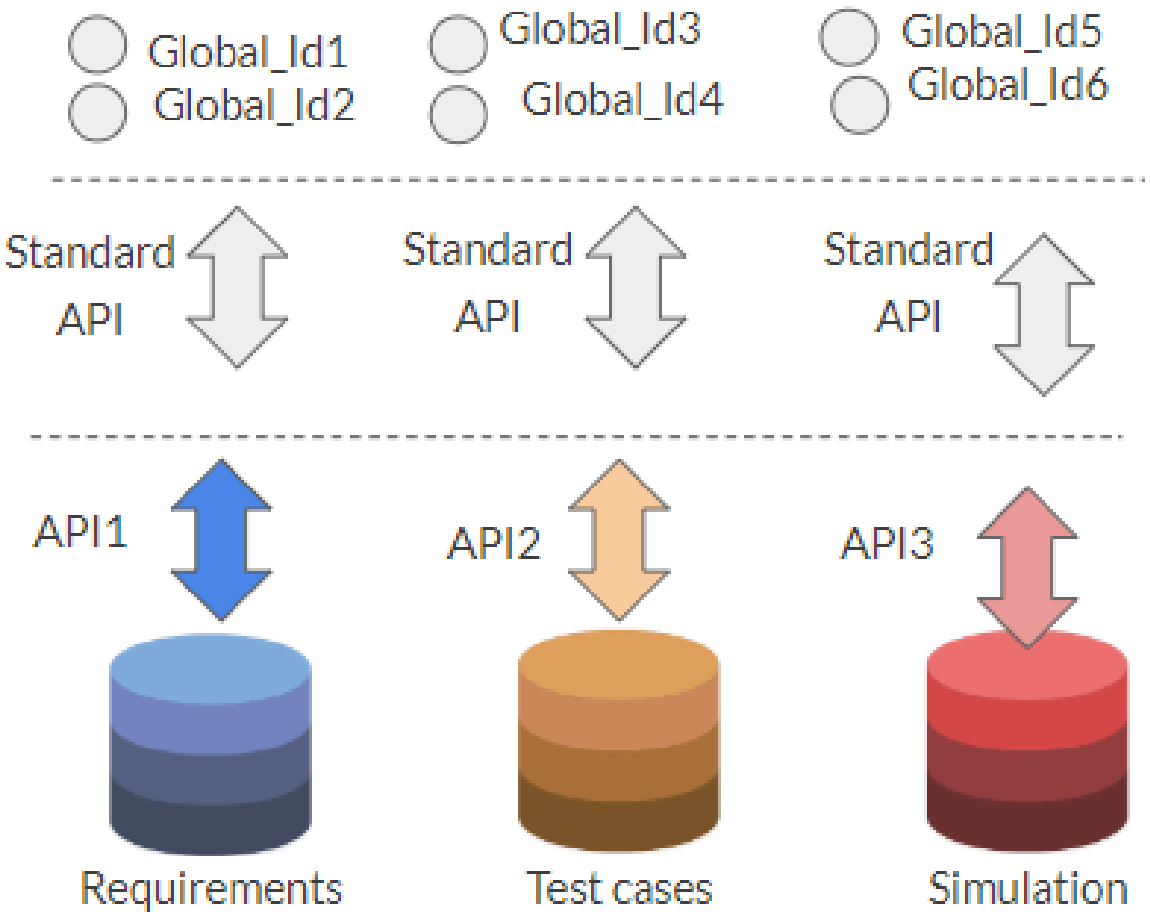
Principle 1: Standard API

Data is accessible through a standard API



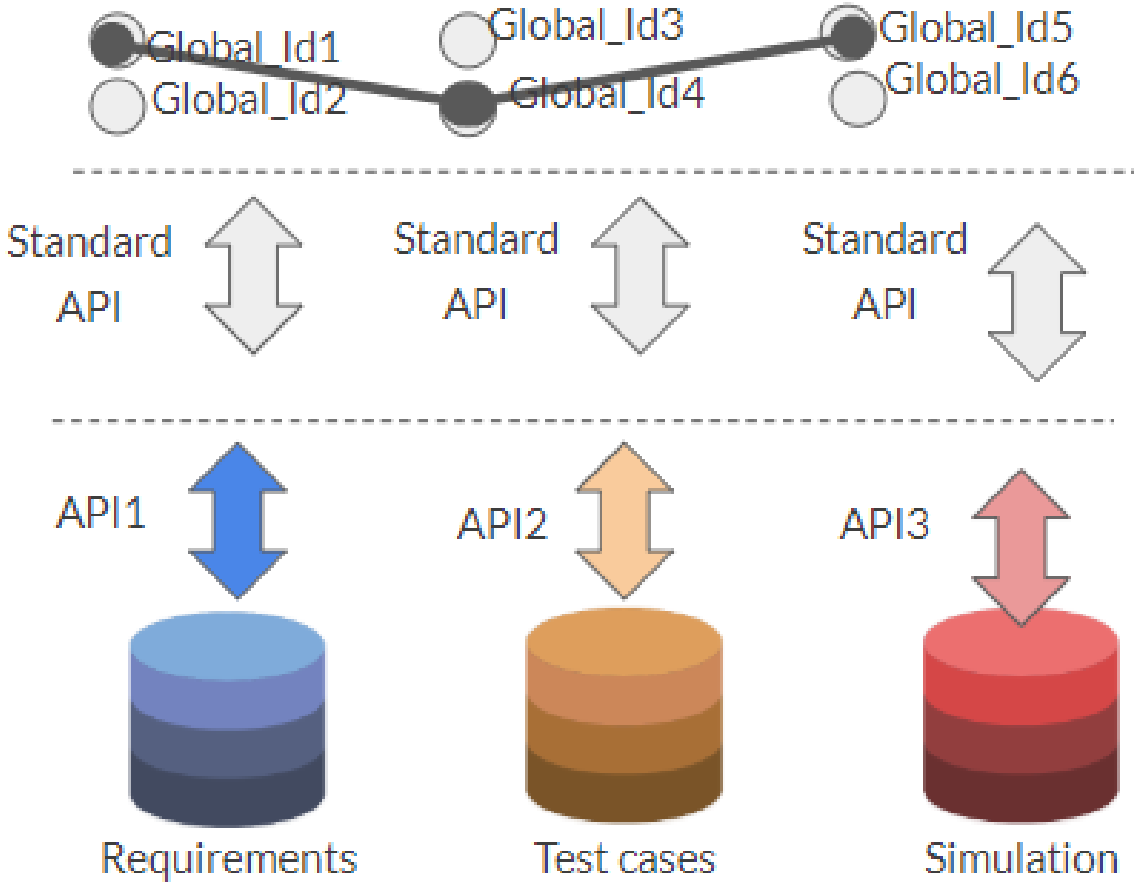
Principle 2: Unique Global identifiers

Data has unique global identifiers



Principle 3: Connections across silos

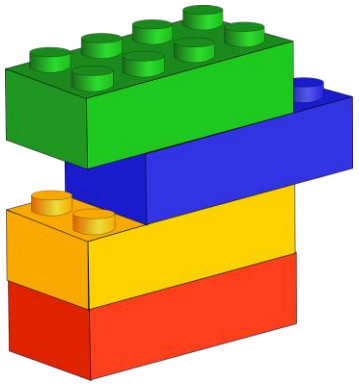
Data is connected

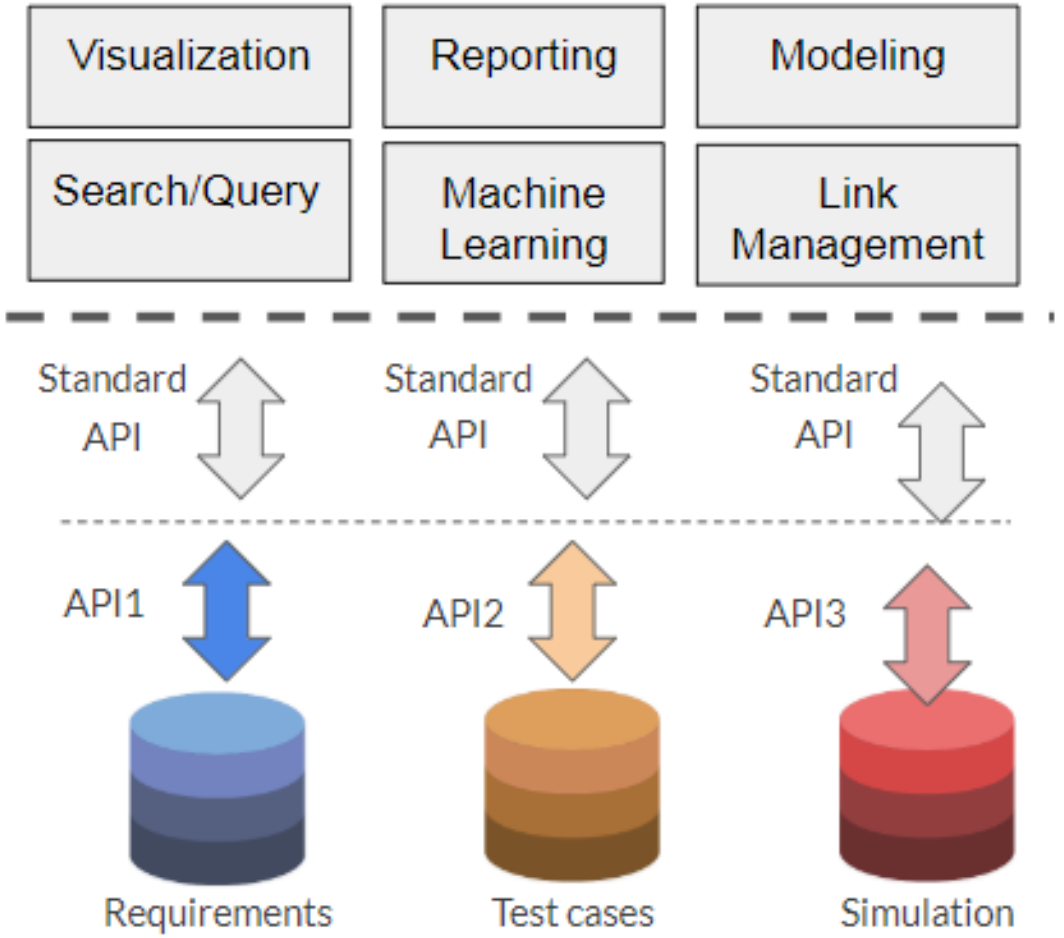


Principle 4: Applications decoupled from data

Applications decoupled from data

- True data ownership
- Reusing existing data

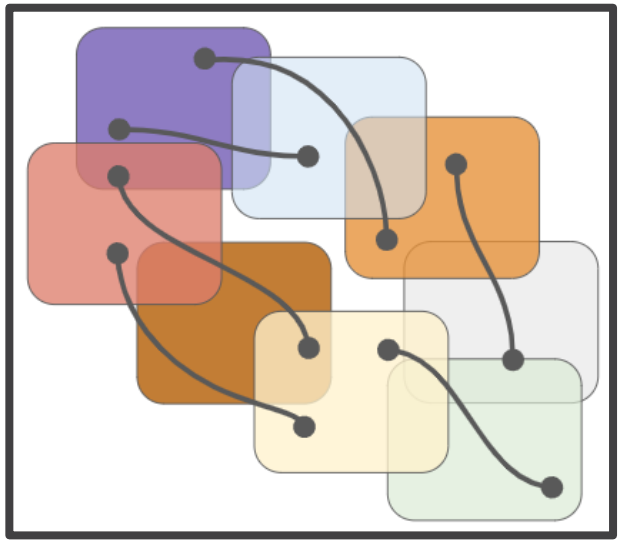




From Model-Based to Network-based SE

MBSE

Network-based MBSE



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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