Model Based Space Systems and Software Engineering MBSE2021
Virtual event. 29-30 September 2021

Using Semantic Systems Engineering Techniques to Verify the 'Large Aperture Space Telescope' Mission - *Current Status*

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1. Challenge of the Digital Thread
2. Introduction to Semantic Technologies
3. The ‘Semantic Systems Engineering Ontology’ (SESO)
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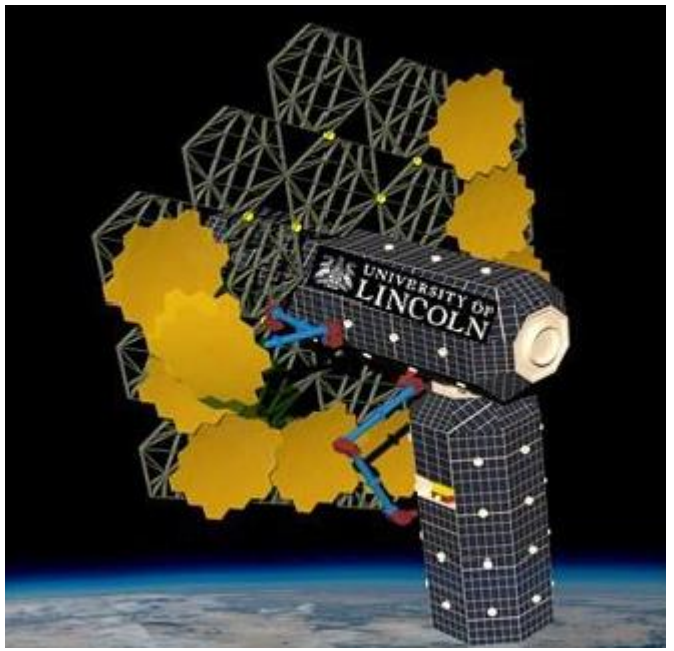
Challenge of Digital Thread

"The challenge is to implement Digital Continuity between data stored in different artefacts, by use of model based techniques. These links need to be created in the three dimensions of system engineering:

1. *across disciplines*
2. *throughout the life cycle*
3. *along the supply chain."*

European Space Agency (ESA), Technology Harmonisation Advisory Group, March 2020



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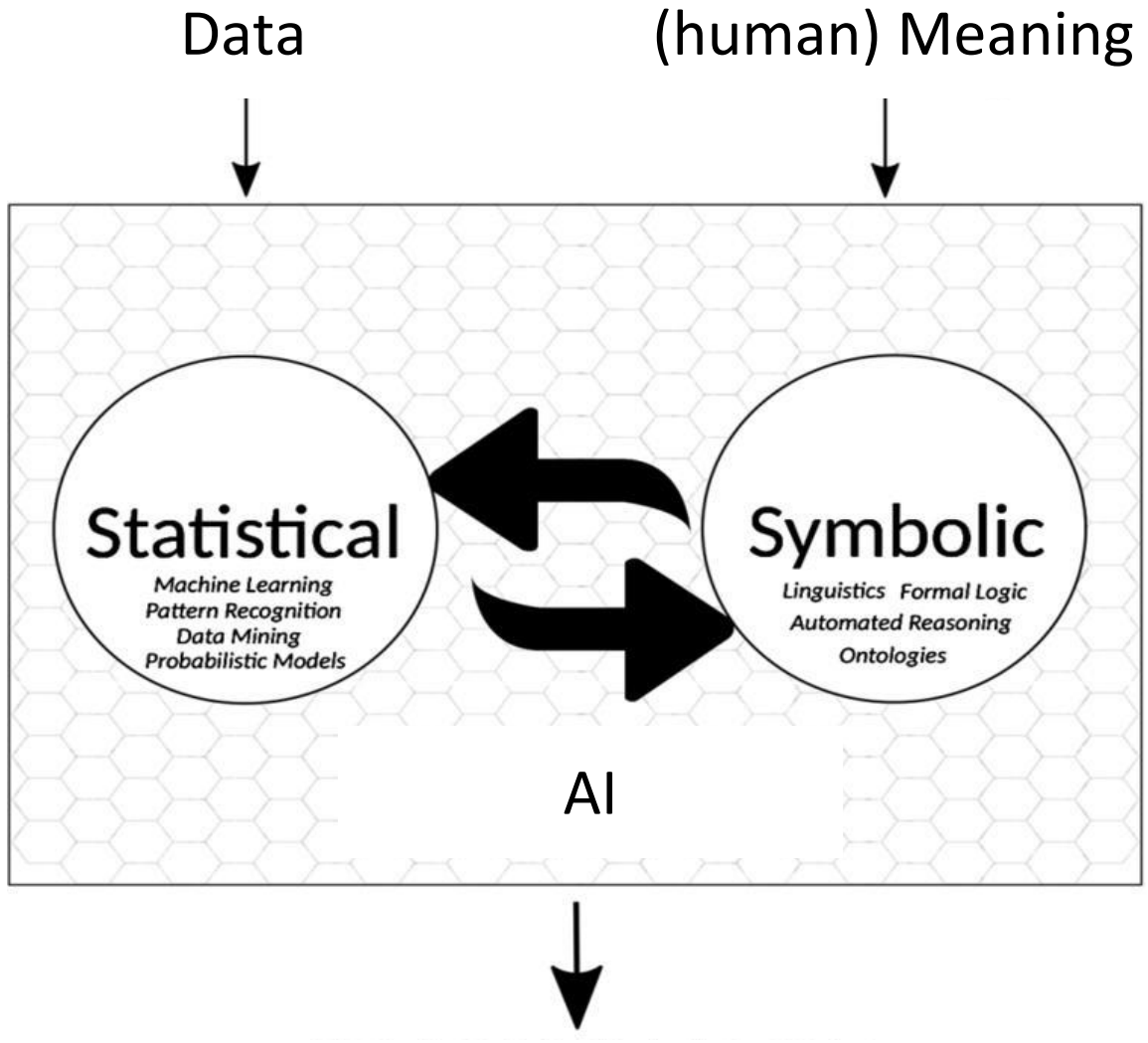
Introduction to Semantic Technologies



Introduction to Semantic Technologies

Parallels between Semantic Web and Systems Engineering

The Web	Systems Engineering
Web of Documents	Document-Centric Systems Engineering
↓	↓
Web of Data	Model-Based / Data-Centric Systems Engineering
↓	↓
Semantic Web	Semantic Systems Engineering

- Systems Engineering is following in the footsteps of the Semantic Web
- Other disciplines are further ahead (e.g. biomedical)
- We can learn to adopt ‘Semantic Web Technologies’ in Systems Engineering

Introduction to Semantic Technologies

Why is Ontology Needed?

We want to ensure we have a **consistent**, **formal** understanding of the terms and relationships allowed.

So – provide rules of what is allowed

e.g.

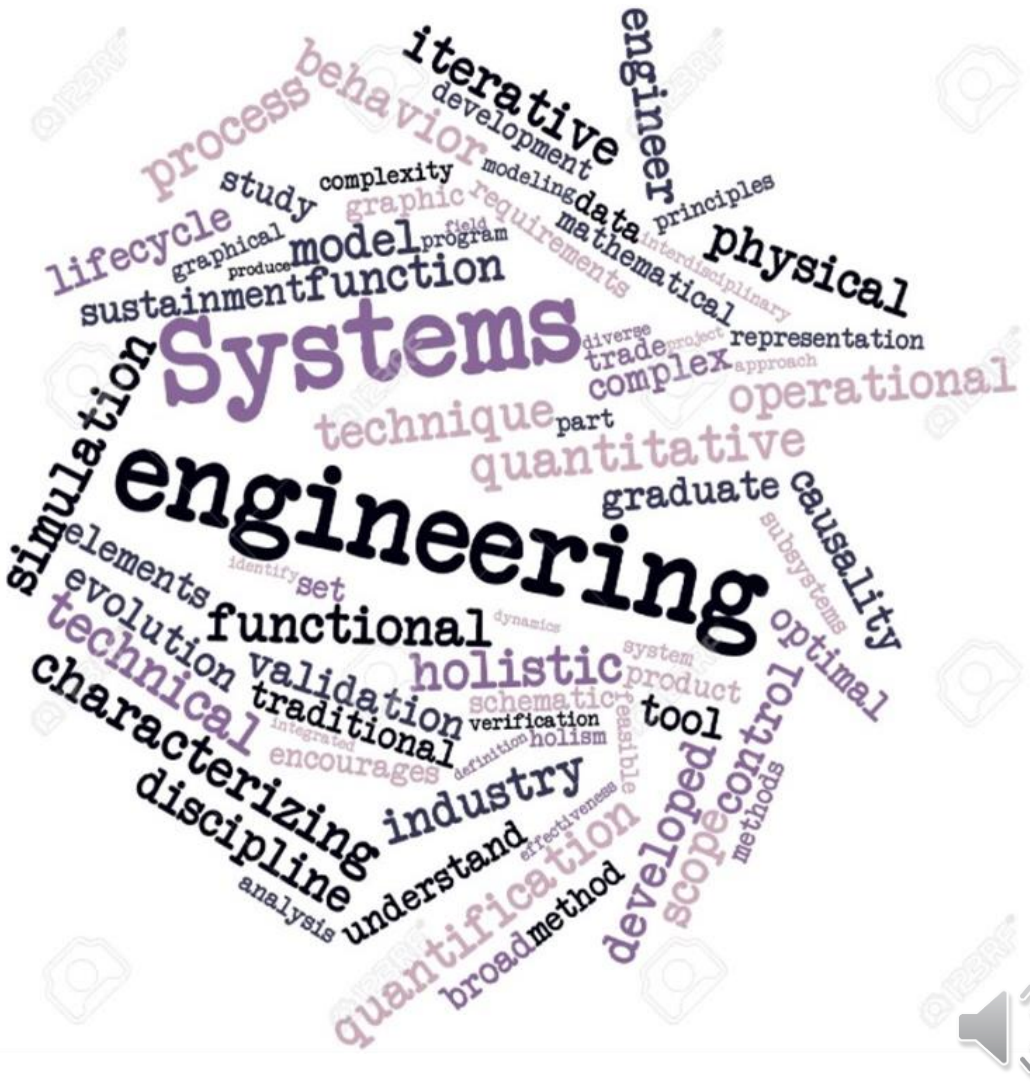
A simulation produces results.

A function has at least one input and at least one output.

A functional requirement can only be satisfied by a function.

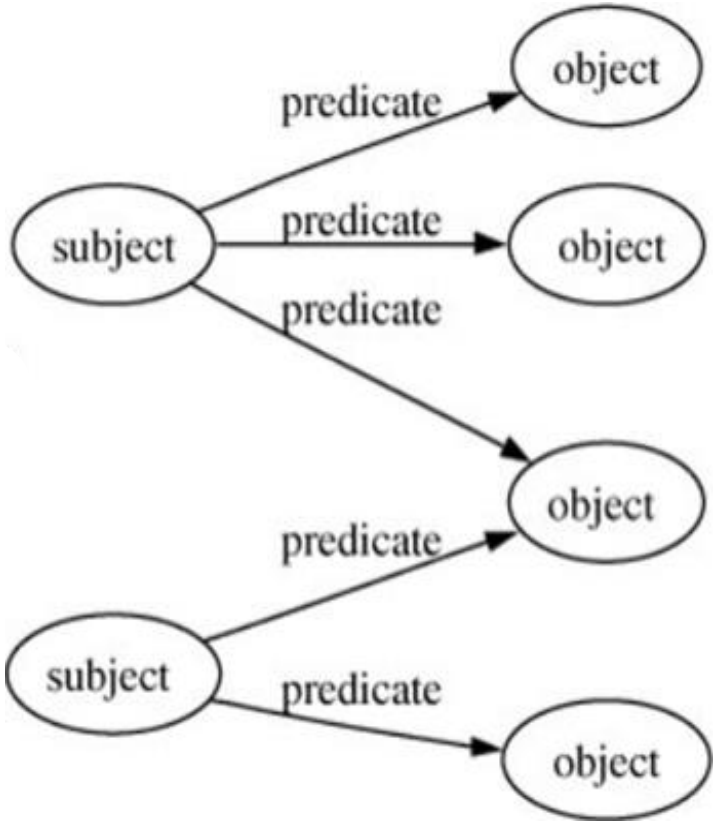
A requirement is verified by a verification method.

A verification method is a type of process.



Introduction to Semantic Technologies

How do we adopt ‘Semantic Web Technologies’
in Systems Engineering?



Resource Description Framework

- Makes information machine-readable
- Replicated sentence structure
- Built on RDF ‘triples’

Web Ontology Language

- “a formal, explicit specification of a shared conceptualisation”

Tom Gruber

- Enables the building of ontologies to provide context to information

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Semantic Systems Engineering Ontology - Methodology [1]

1. Determine the domain and scope of the ontology,

2. Consider reusing existing ontologies,
   - Basic Formal Ontology (with guidance from IOF) [2]
   - Common Core Ontologies (CUBRC) [3]
   - The Ontology of Systems Engineering [4]

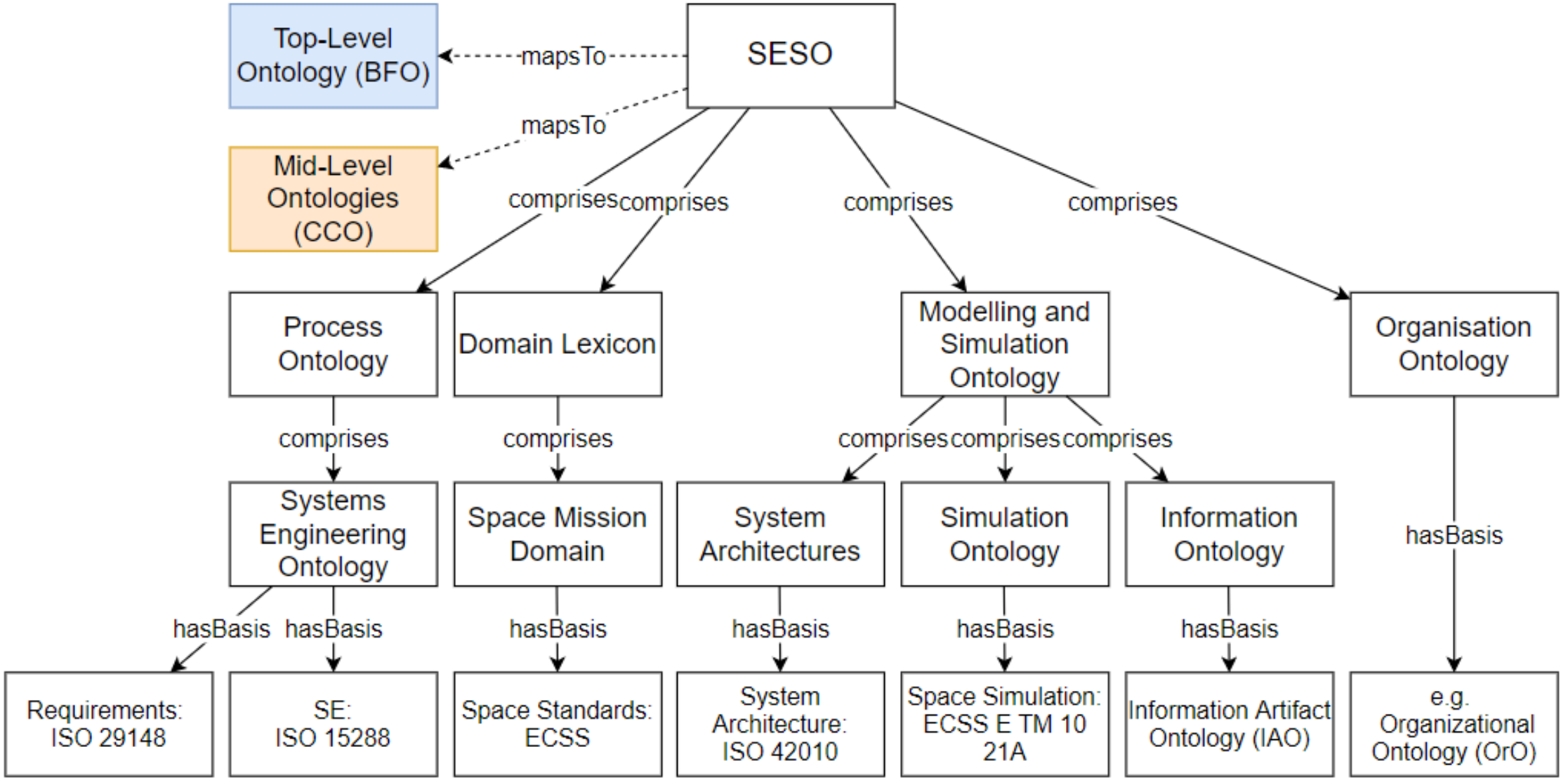
3. Enumerate important terms in the ontology,

4. Define the classes and class properties,

5. Create instances.

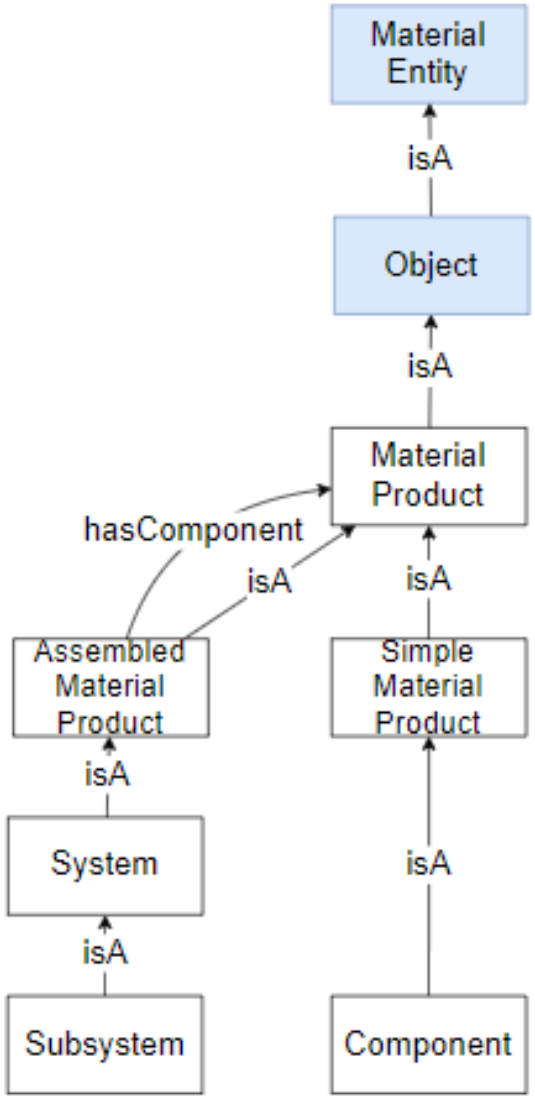
[1] N. F. Noy and D. McGuiness, "Ontology Development 101: A Guide to Creating Your First Ontology," Knowl. Syst. Lab. Stanford Univ., 2001.
[2] https://basic-formal-ontology.org/
[3] https://www.cubrc.org/index.php/data-science-and-information-fusion/ontology
[4] D. Orellana and W. Mandrick, "The Ontology of Systems Engineering: Towards a Computational Digital Engineering Semantic Framework," Procedia Comput. Sci., vol. 153, pp. 268–276, 2019.

Semantic Systems Engineering Ontology - Structure

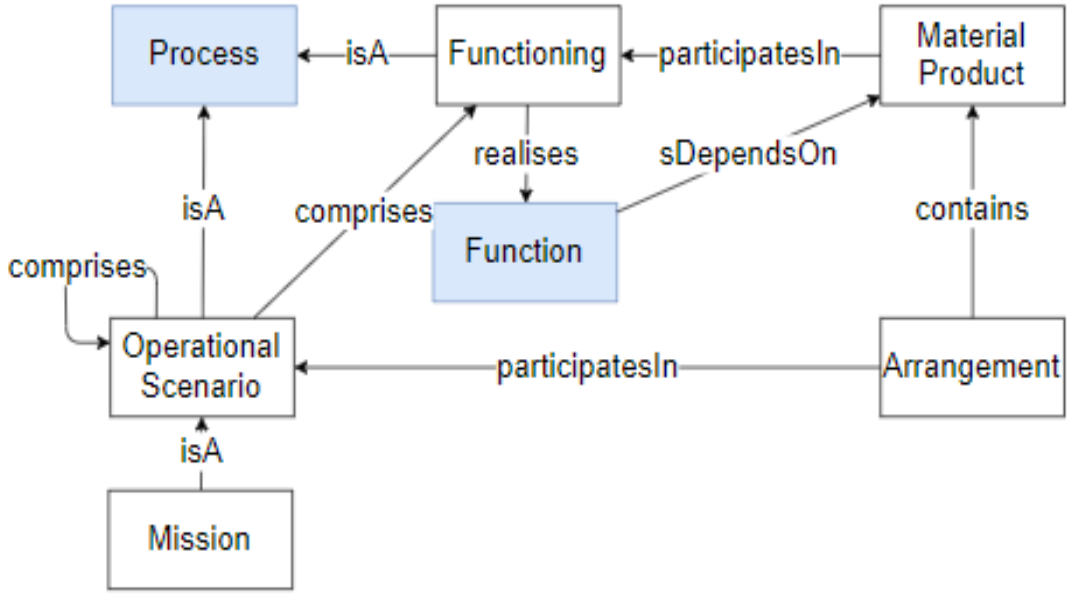


Semantic Systems Engineering Ontology - Patterns

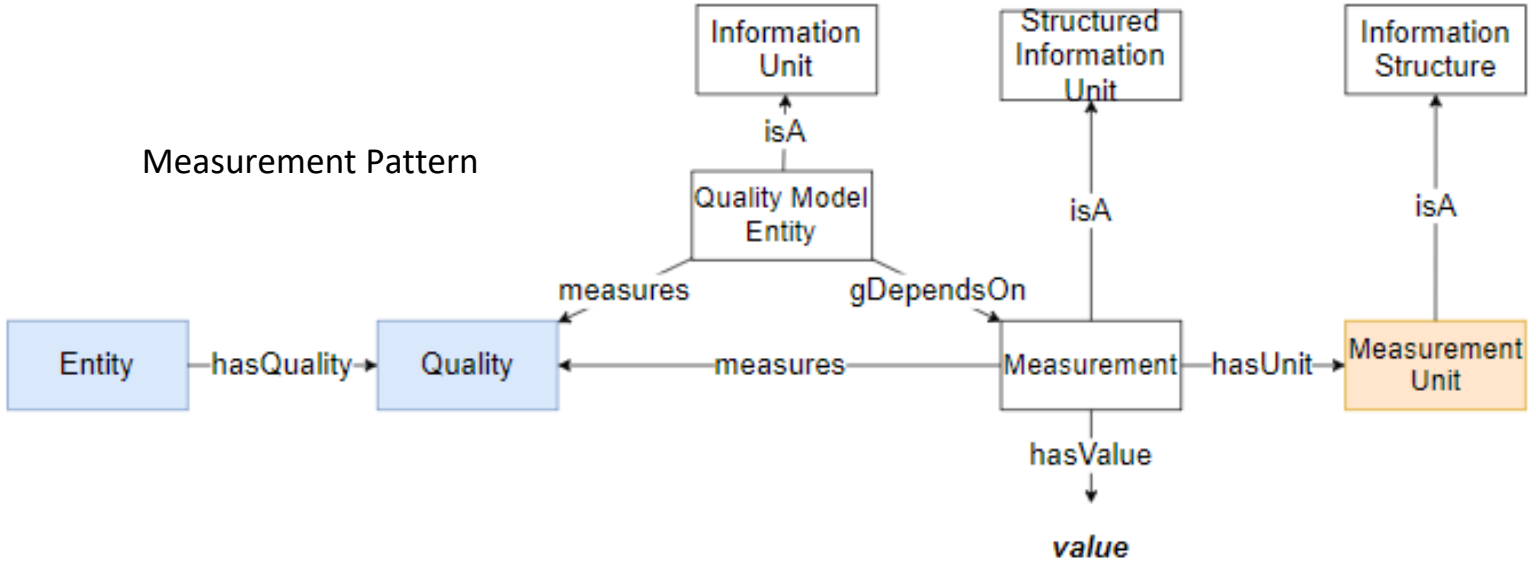
Material Product Pattern



Operational Scenario Pattern



Measurement Pattern



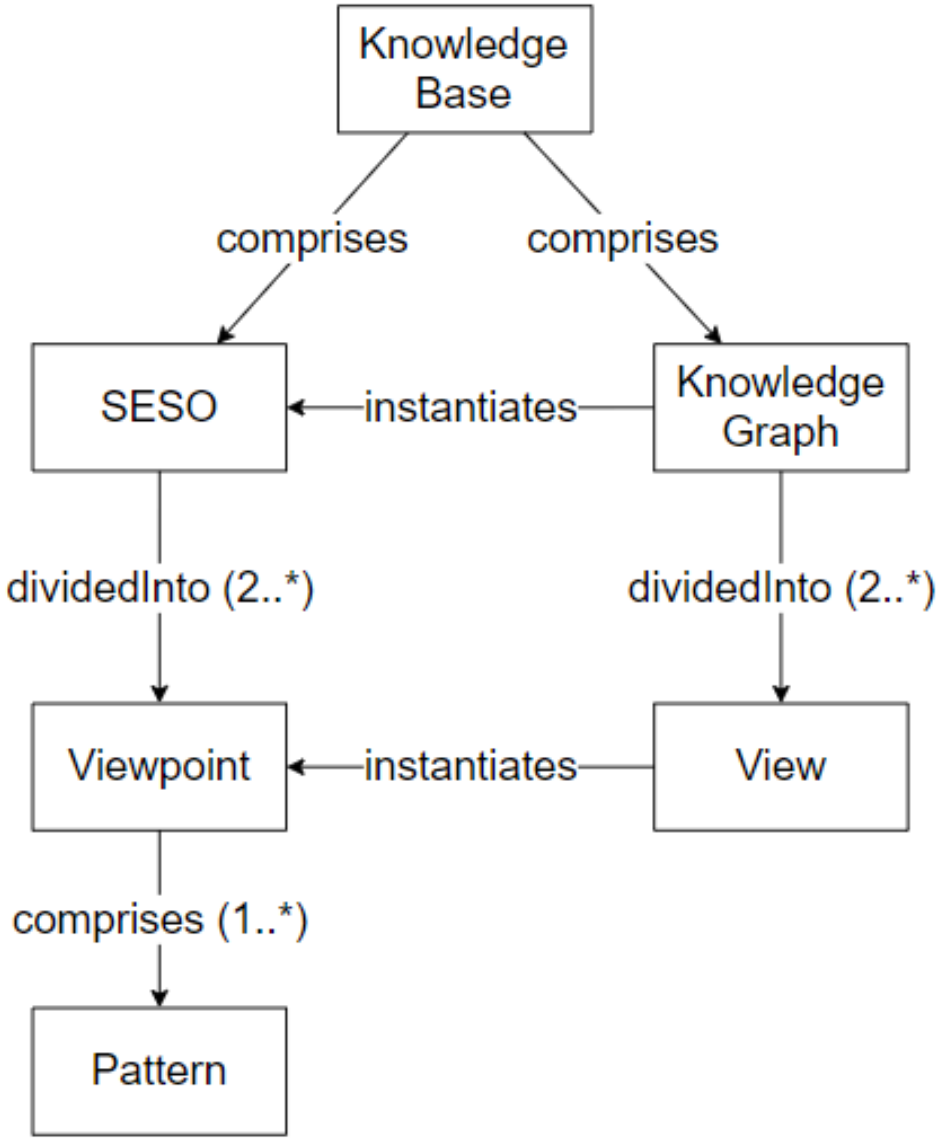
Semantic Systems Engineering Ontology - Overview

25 Patterns
- Organisation Pattern
- Interfaces Pattern
- Functions and Modes Pattern
- Activity Pattern
- Architecture Pattern
- Requirement Satisfaction Pattern
- *etc*

141 Classes

53 Object Properties

577 Logical Axioms



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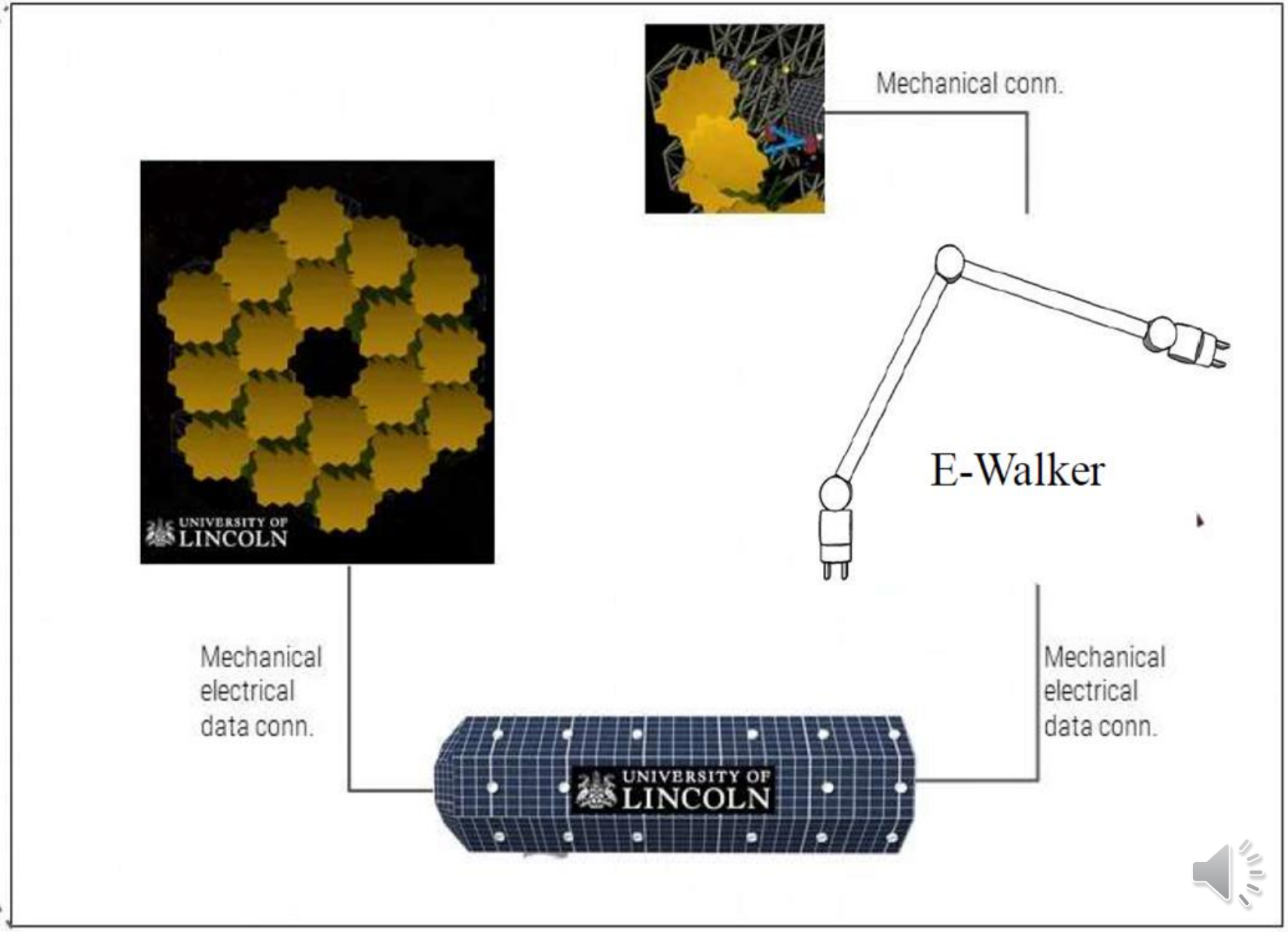
Application to the LAST Mission - Mission Overview



Application to the LAST Mission - Requirements

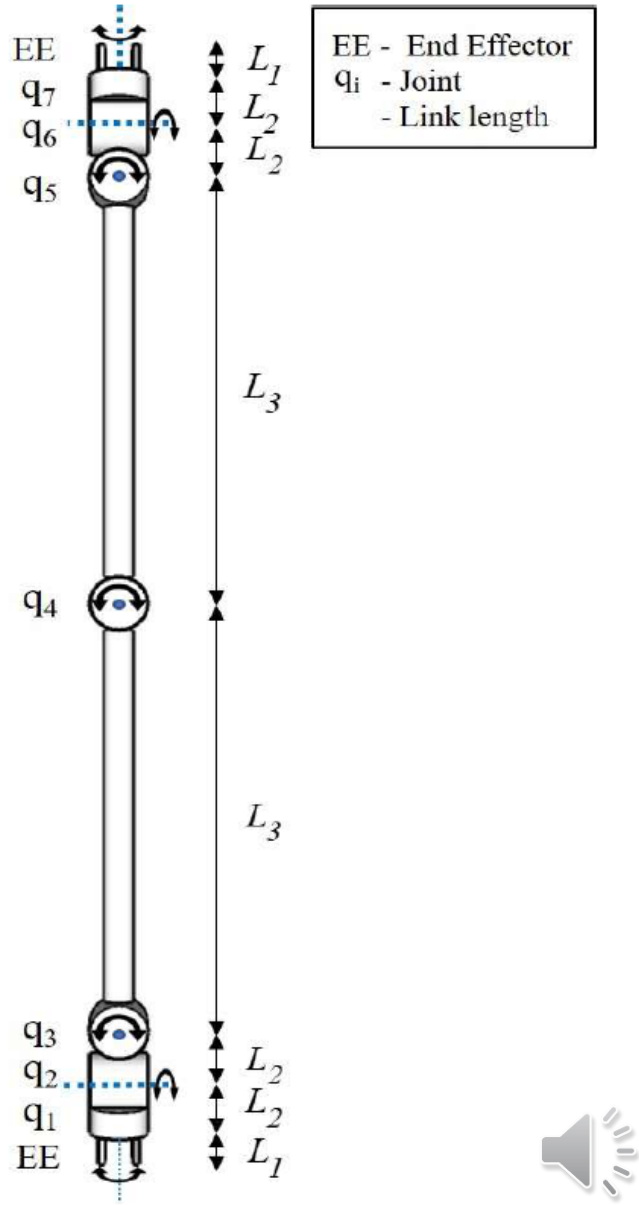
E-Walker Requirements:

R1. In all configurations, the E-Walker shall be capable of moving from the current connector port to the nearest connector port.

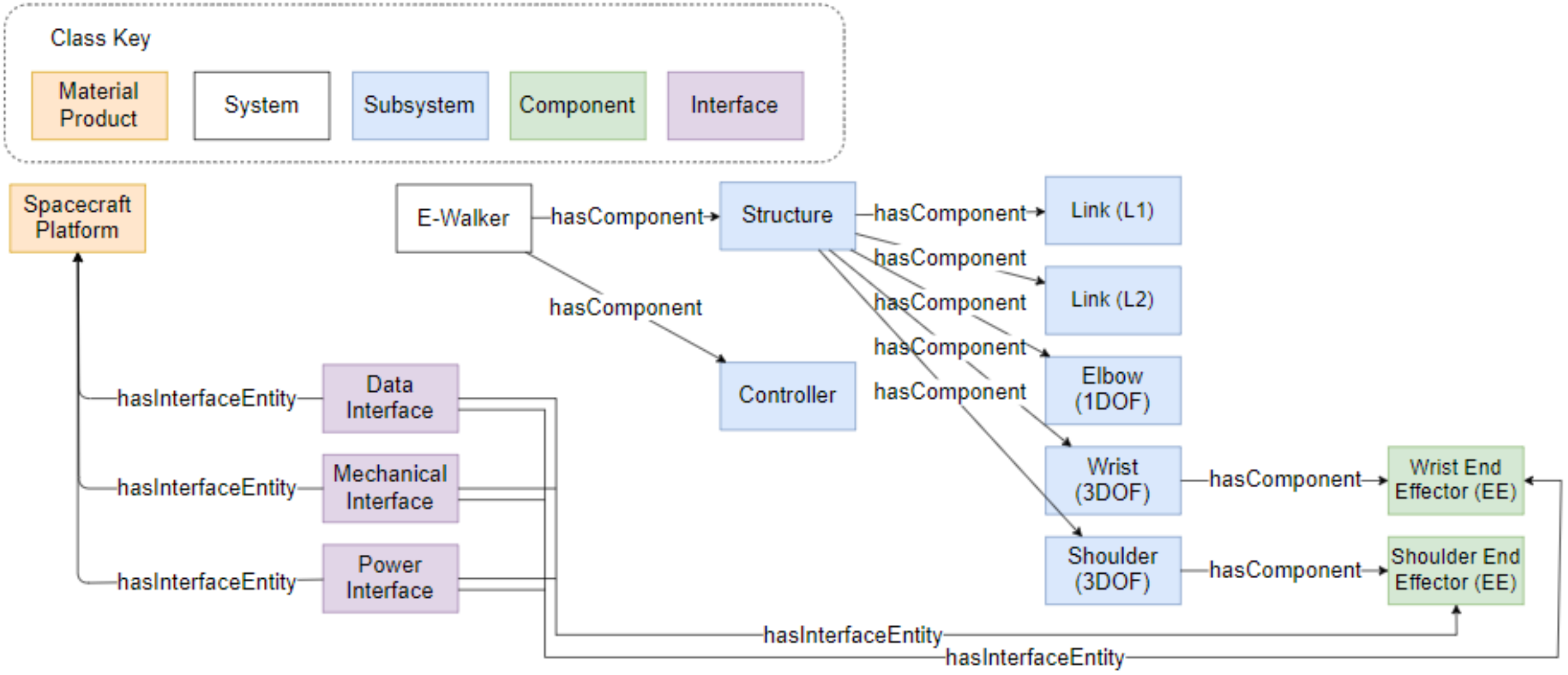
R2. The E-Walker shall have the following interfaces with the spacecraft platform: - Mechanical; Power; Data

R3. The E-Walker Latching End Effector (LEE) shall maintain an accuracy of 5mm in all axes throughout its motion and during latching.

R4. The E-Walker power consumption shall not exceed 80% of the 'available power' supplied by the spacecraft platform.

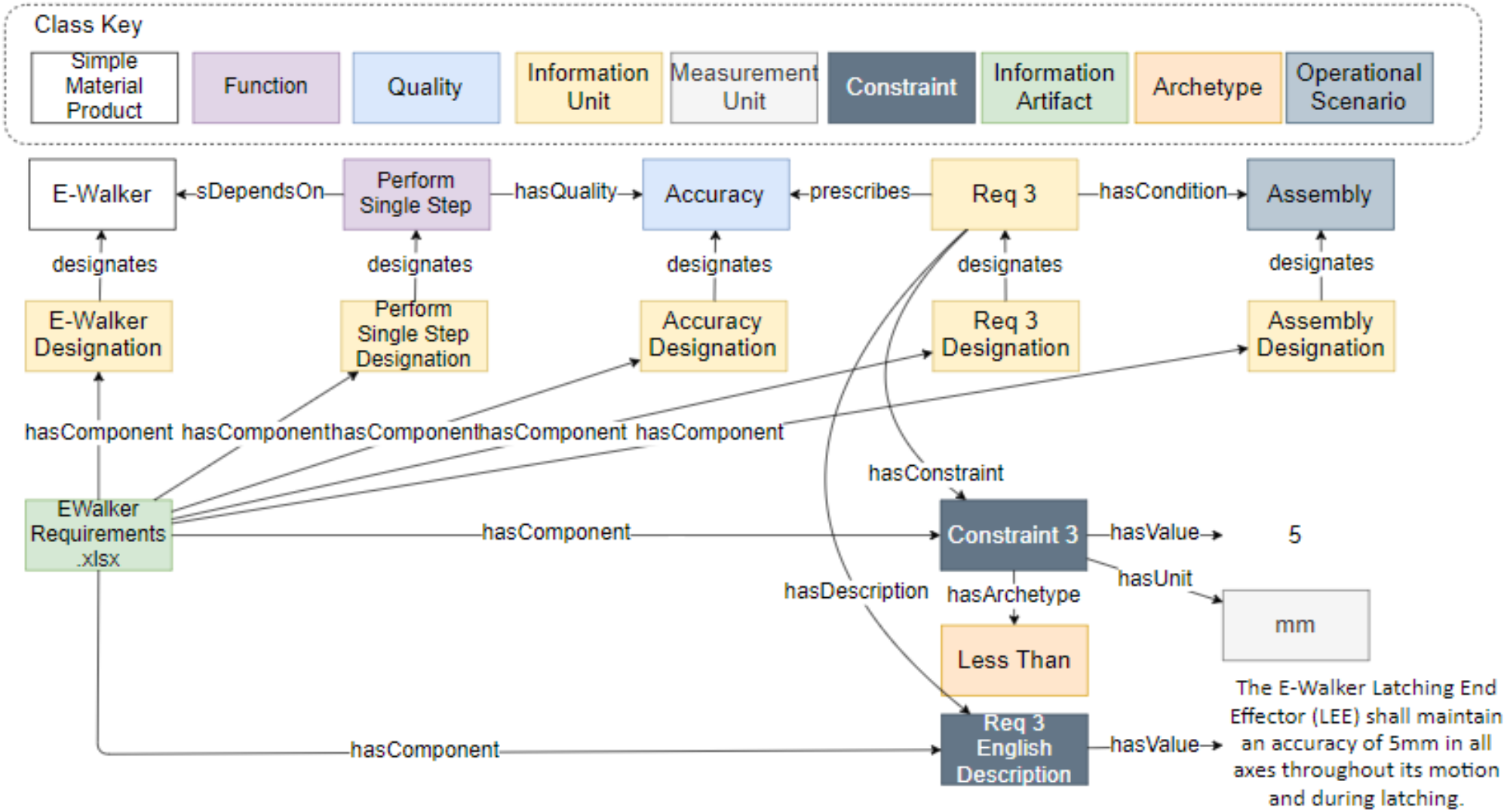


Application to the LAST Mission - Physical Architecture



Application to the LAST Mission - Requirements Traceability

	A	B	C	D	E	F	G
1	ID	Description	Prescribes	Constraint Type	Value	Unit	Condition
6	R3	The E-Walker Latching End Effector (LEE) shall maintain an accuracy of 5mm in all axes throughout its motion and during latching.	Perform Single Step - Accuracy	LessThan	5	mm	Assembly



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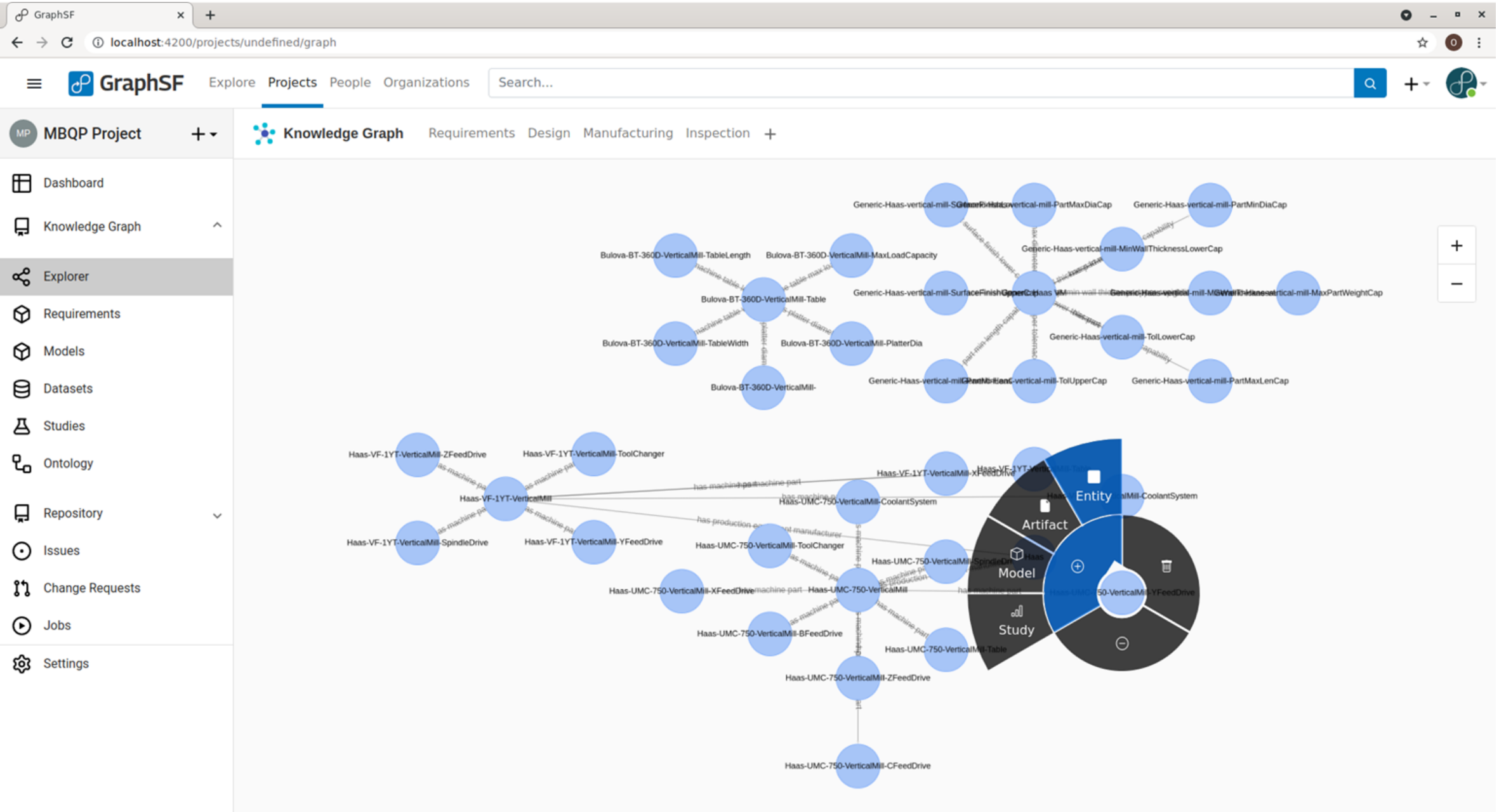
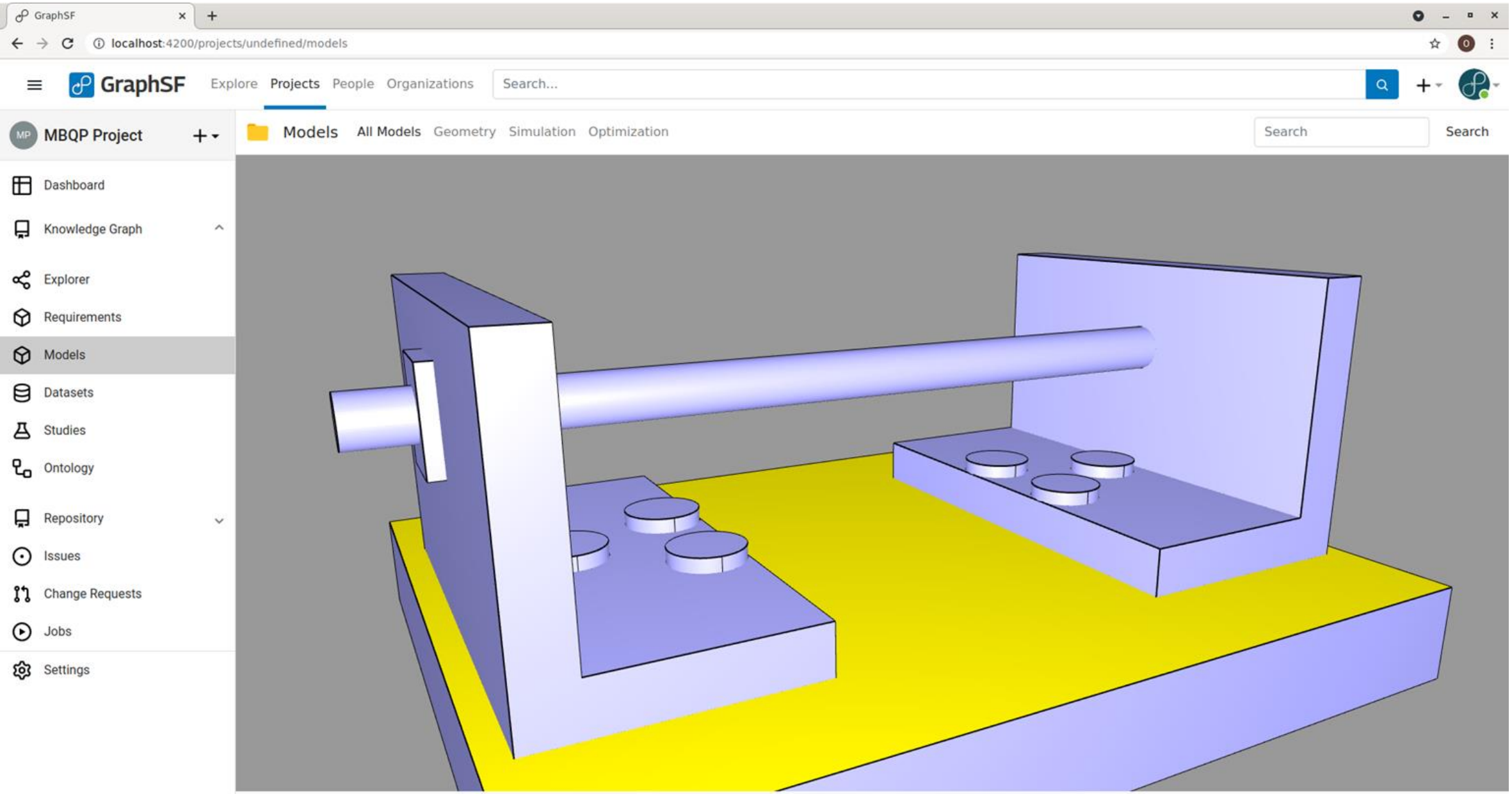
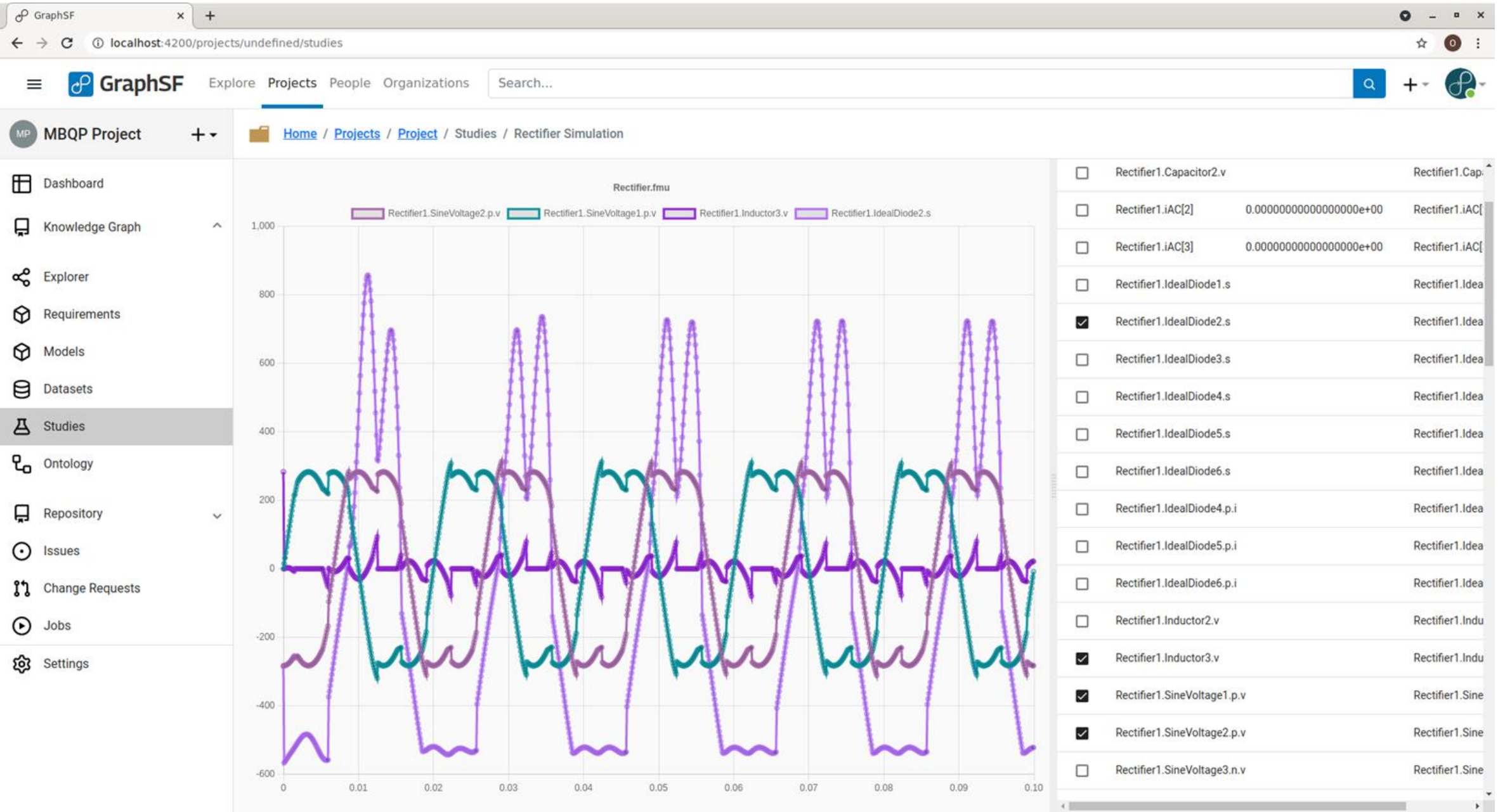
GraphSF - Knowledge Graph



GraphSF - 3D Model Viewer



GraphSF - Study Results



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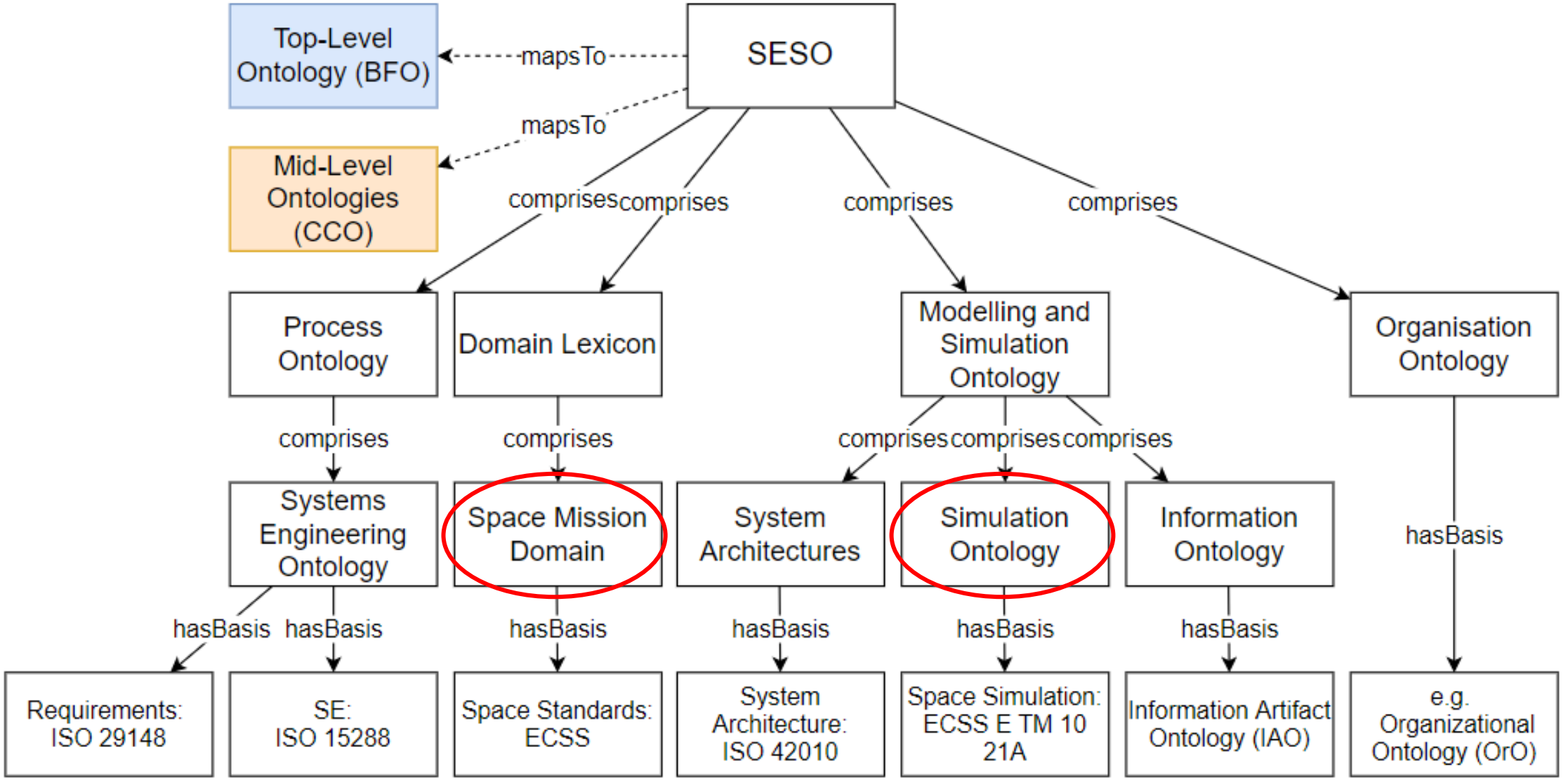
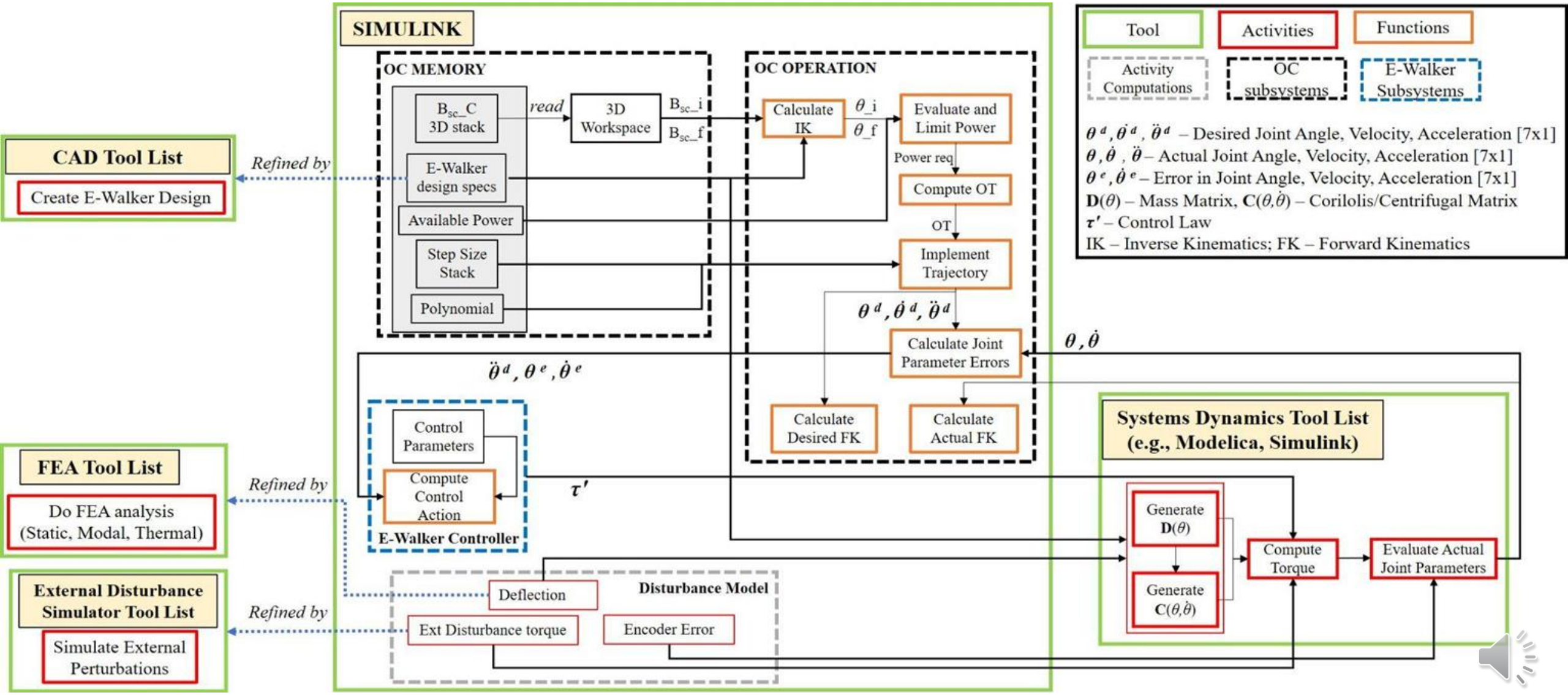
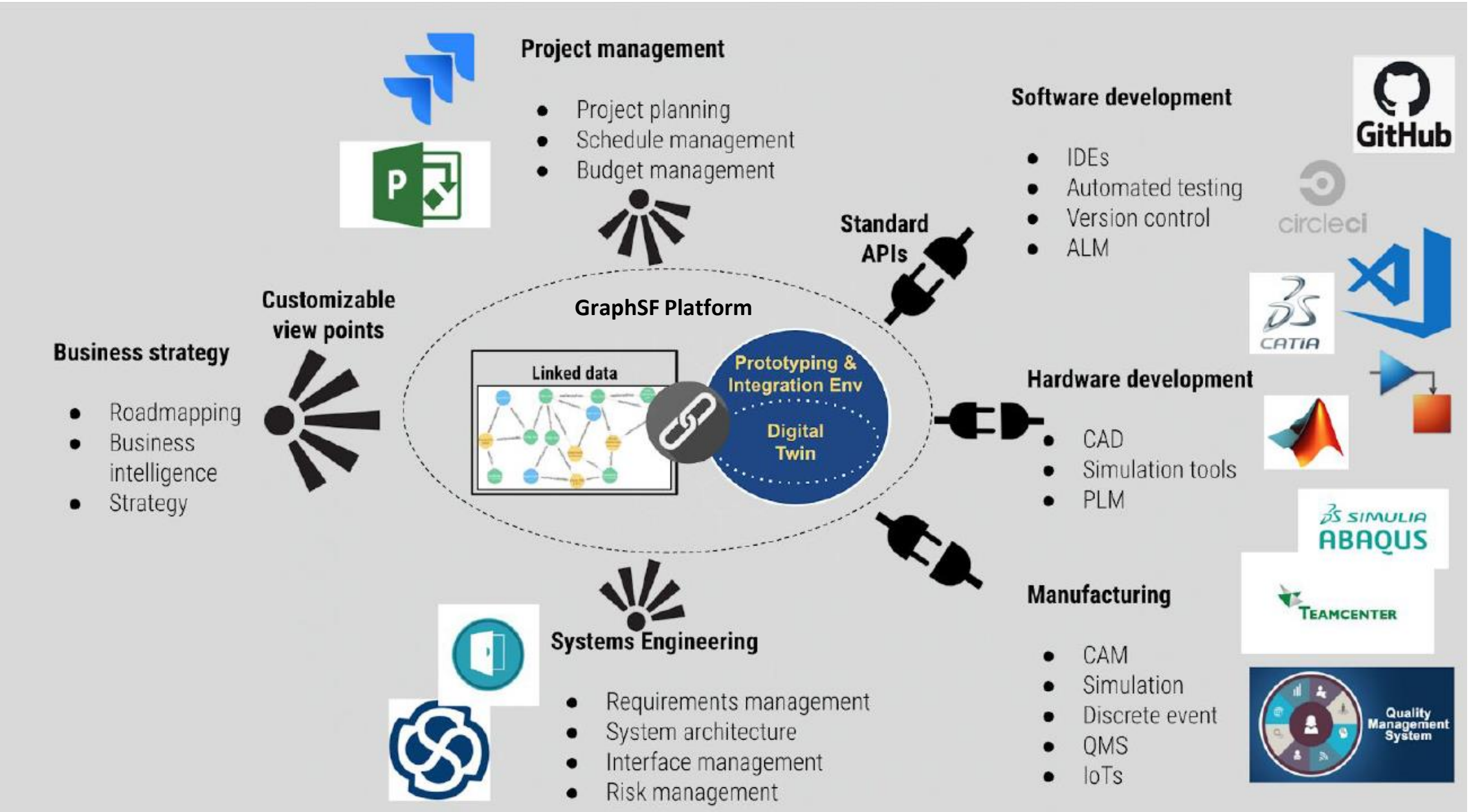
Next Steps


Top-Level Ontology (BFO)
mapsTo
SESO
mapsTo
Mid-Level Ontologies (CCO)
comprises
comprises
comprises
comprises
Process Ontology
Domain Lexicon
Modelling and Simulation Ontology
Organisation Ontology
comprises
comprises
comprises
comprises
comprises
Systems Engineering Ontology
Space Mission Domain
System Architectures
Simulation Ontology
Information Ontology
hasBasis
hasBasis
hasBasis
hasBasis
hasBasis
hasBasis
hasBasis
Requirements: ISO 29148
SE: ISO 15288
Space Standards: ECSS
System Architecture: ISO 42010
Space Simulation: ECSS E TM 10 21A
Information Artifact Ontology (IAO)
e.g. Organizational Ontology (OrO)

Next Steps - LAST Model-Based Architecture



Next Steps - GraphSF Extended Enterprise Platform



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Thank you for your attention

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