

# A Digital Engineering Factory for Students

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## GLOBAL PRODUCT DATA INTEROPERABILITY SUMMIT 2023



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# Agenda

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- DE for Students
- The Problem
- A Possible Solution (Semantic Hub and Spoke)
- Digital Engineering Factory
- Use Cases
- Example
- Future Work and Lessons Learned

## Digital Engineering

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Digital engineering is defined as:

“an integrated digital approach that uses authoritative sources of systems’ data and models as a continuum across disciplines to support lifecycle activities from concept through disposal [1].”

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## Digital Engineering *for Students*

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## Digital Engineering *for Students*

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“an integrated **digital** approach that uses **authoritative sources** of systems’ data and models as a continuum **across disciplines** to support lifecycle activities from **concept through disposal** [1].”

Goal is to develop a ‘Digital Environment’ to support students during class and on projects, that can:

- support authoritative representation of system description and simulation,
- host tools to support students across all engineering courses,
- connect this data across courses (lifecycle phases).

## Courses – Software Engineering (SFWE), Systems and Industrial Engineering (SIE)

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Code	Name	Description	Tools
SFWE-301	Software Requirements Analysis and Test	Students learn how to develop high-quality software requirements, test plans and test procedures. Students also learn the importance of traceability.	<b>Requirements Test Strategy</b>
SFWE-302	Software Architecture & Design	Students learn how to build, test, and deploy software applications. Students will automate test cases and run static code analysis on their code.	<b>IDE Static Code Analyzer</b>
SFWE-403	Software Project Management	Students learn how to plan, manage and track the progress of an Agile software management project.	<b>Project Management</b>
SIE-431	Simulation Modeling and Analysis	Students learn how to conduct simulations on candidate system architectures. Discrete event simulation, model development, statistical design and analysis of simulation experiments, variance reduction, random variate generation, Monte Carlo simulation.	<b>Requirements System Architecture Physics Simulation Statistics Tool</b>
SIE-458	Model-Based Systems Engineering	Students learn how to use a SysML v1 modeling tool to exercise the systems engineering process.	<b>SysML v1</b>
SIE-498	Senior Design Project	The Senior Design Project pulls much of this together. Students use material taught across the curriculum to address a customer's needs and help a real-world client design or improve a system.	<b>Requirements Software Architecture Test Strategy Code Test</b>
...	...	...	...

# Tool Examples

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## Software Development Tools

Requirements Analysis



Visual Paradigm

SW Design and Modeling



MathWorks

Code and Unit Test



Visual Studio

Continuous Integration



VERACODE

Verification / Validation



Continuous Deployment & Operations

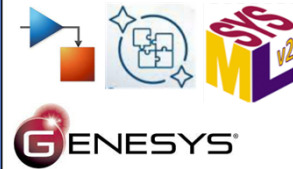


## Systems Development Tools

Requirements Engineering



System Architecture



Domain-Specific Analysis



Design and Manufacture



Trade-Offs and Optimization

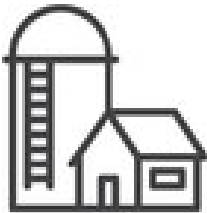


PLM



# Silos in Engineering Education

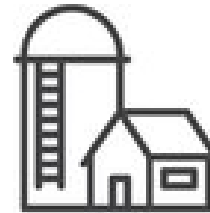
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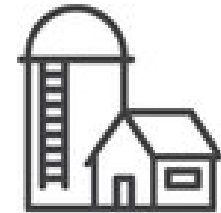
Software



Electronics



Aerodynamics



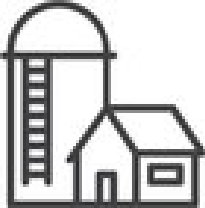
Mechanical

This is not good enough in industry!

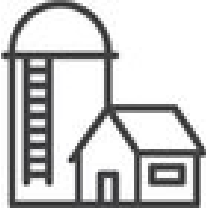
But what do we do across engineering curricula?

# Silos in Engineering Education

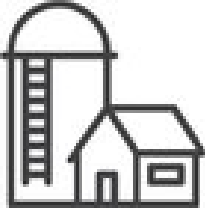
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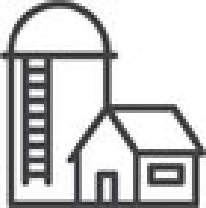
SIE 431



SFWE 302



SIE 458



SFWE 403

## Silos in Engineering Education

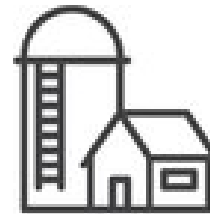
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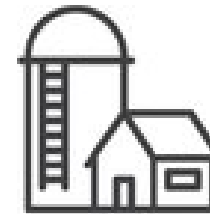
SIE 431



SFWE 302



SIE 458



SFWE 403

Engineering courses are **silos**

- Students do not observe effects downstream
- Students do not gain experience of working in a DE environment
- Data / effort duplication across courses
- There is limited scope for collaborative work

## What are the Possible Benefits of DE in Engineering Curricula?

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Students no longer submit homework, they **commit models**.

Students have access to data and tools through a single **integrated** environment.

Digital Engineering is **embedded** into the engineering curriculum.

Potential **benefits** include:

- Over multiple courses, students see a complete **end-to-end** process,
- Students see the **consequences** of their decisions downstream,
- Students gain experience working **collaboratively** in a digital environment,
- Instructors (and students) can **evaluate / grade** work more effectively.

# Tool Map

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Requirements  
Tool



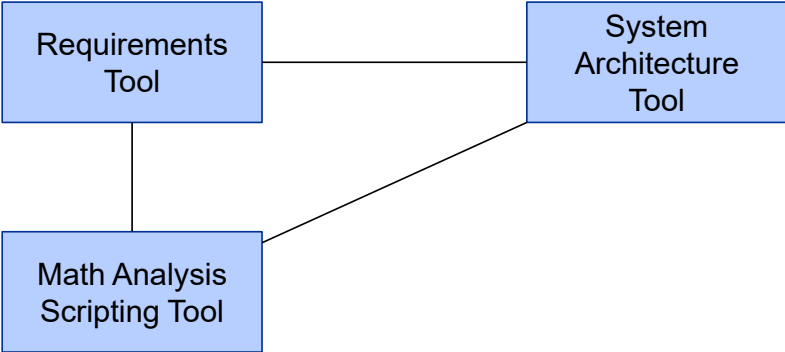
# Tool Map

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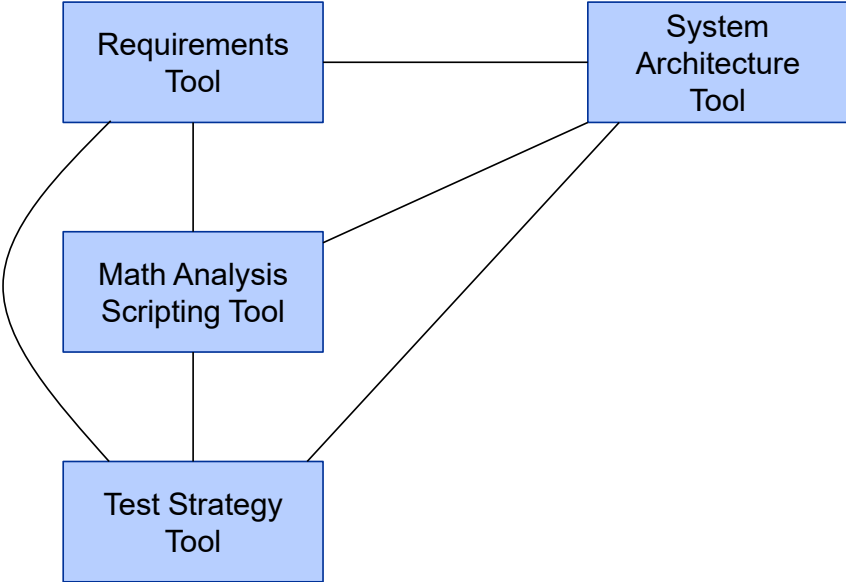
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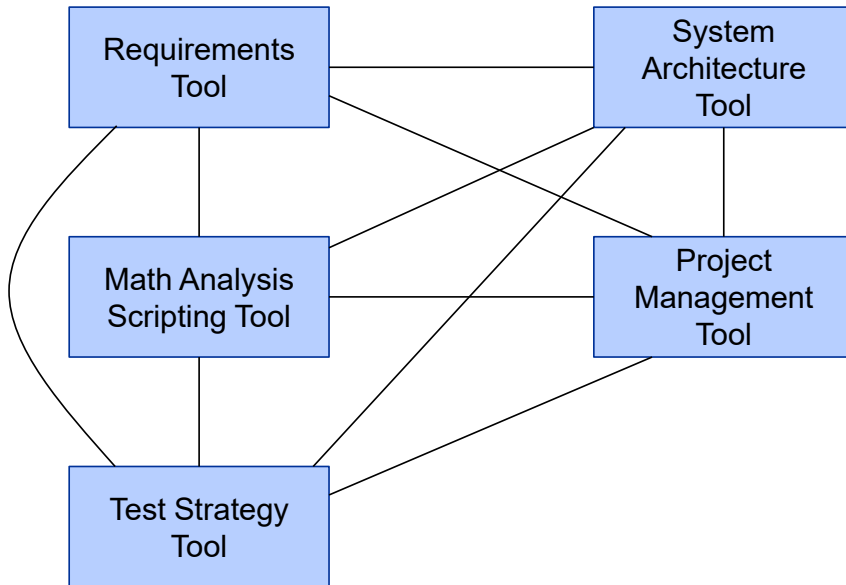
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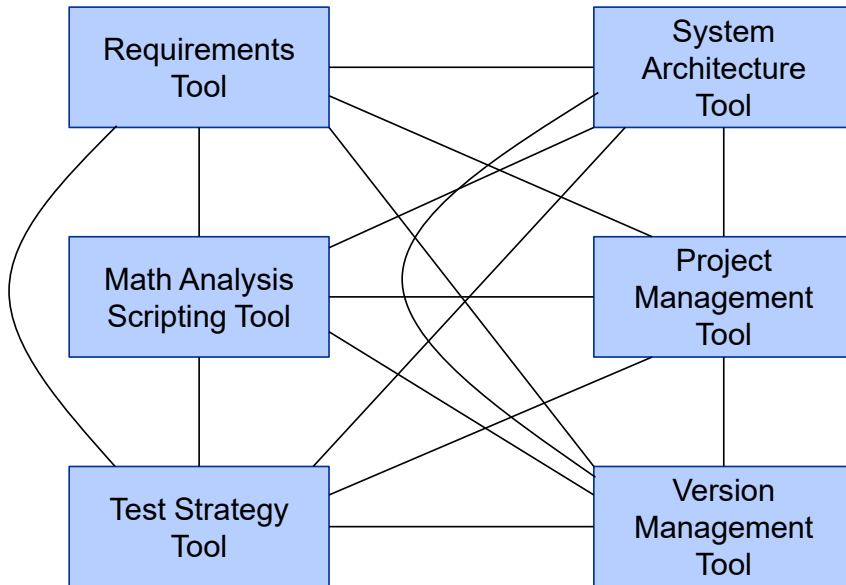
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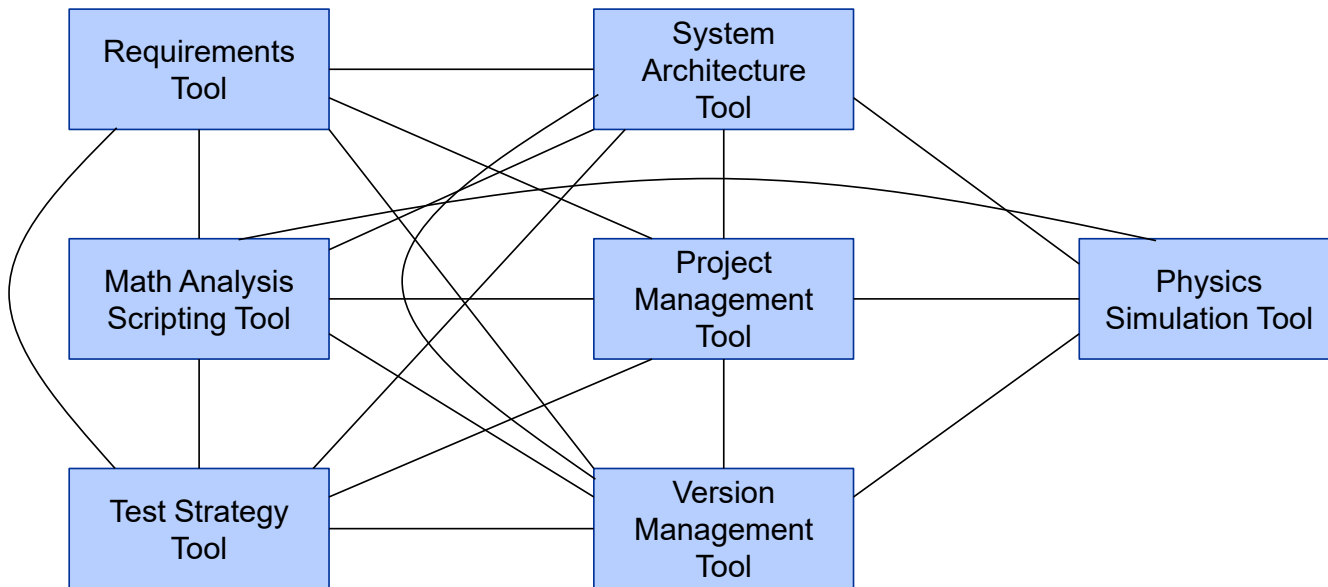
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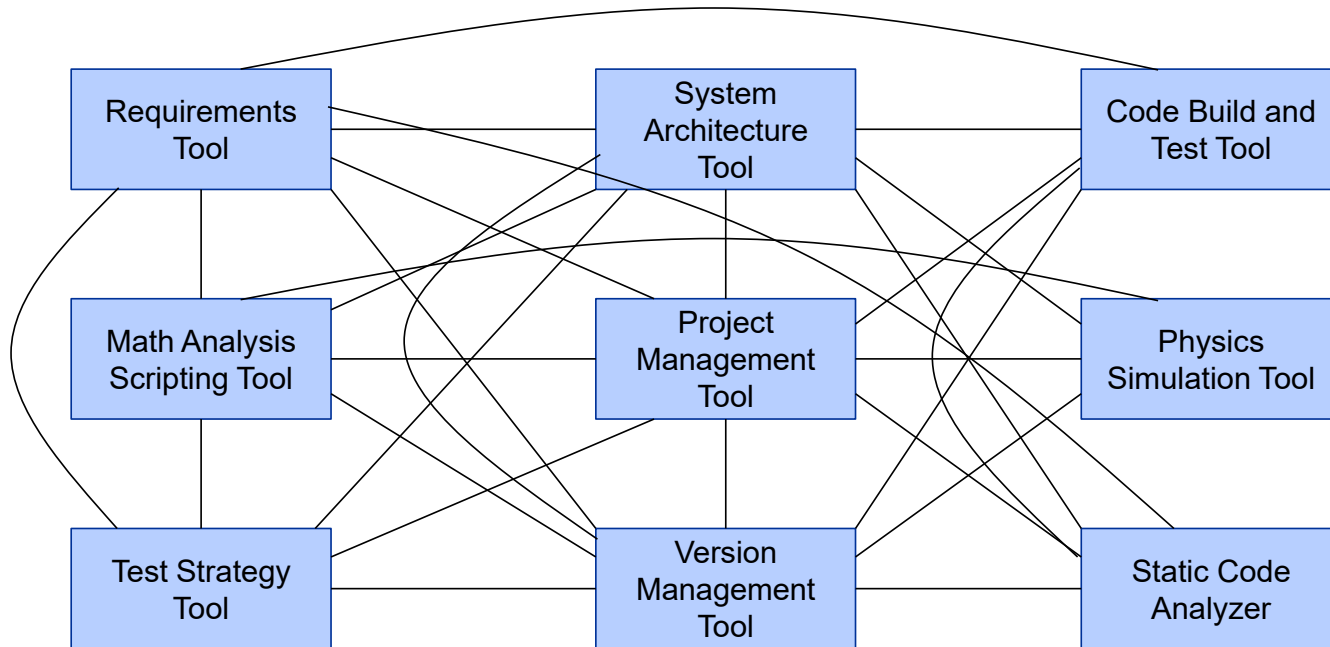
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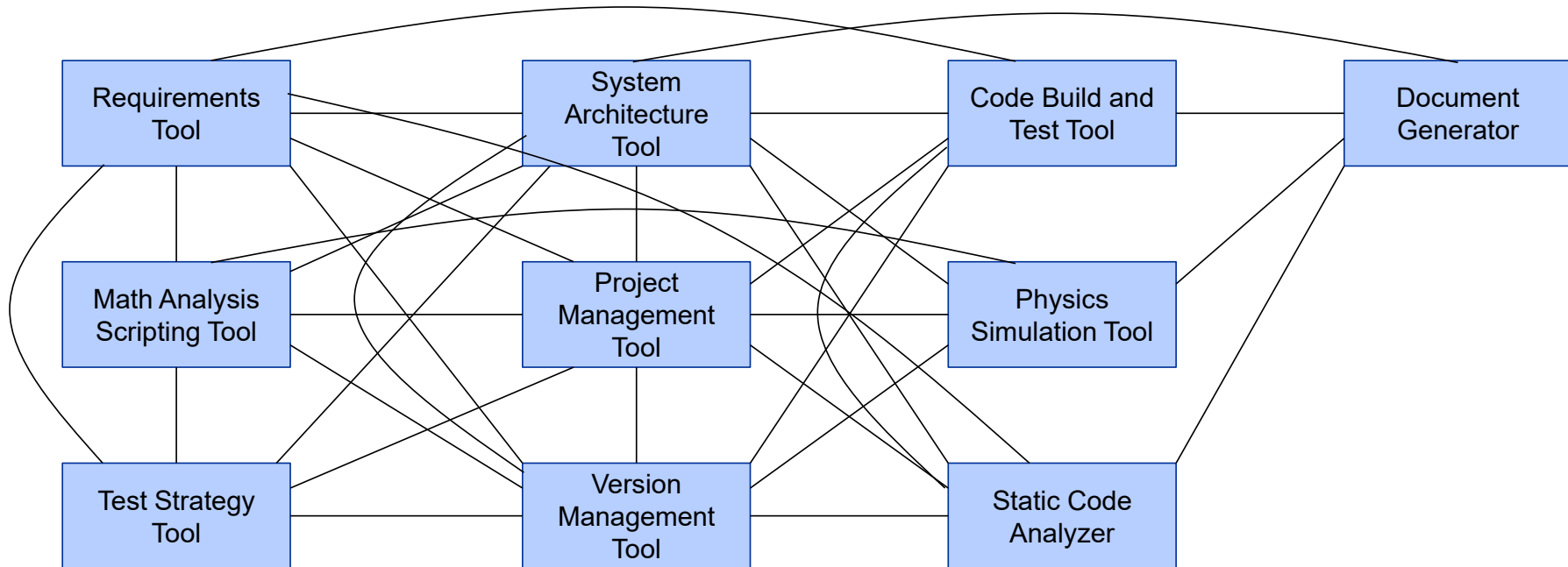
# Tool Map

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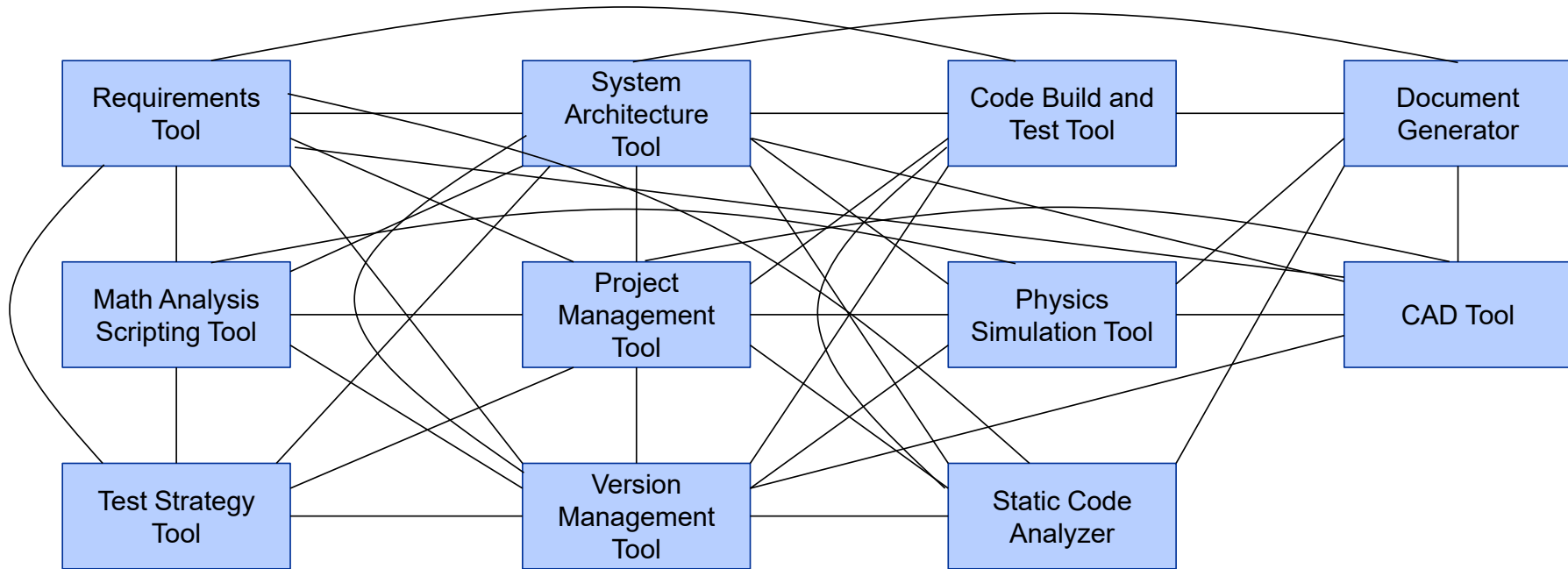
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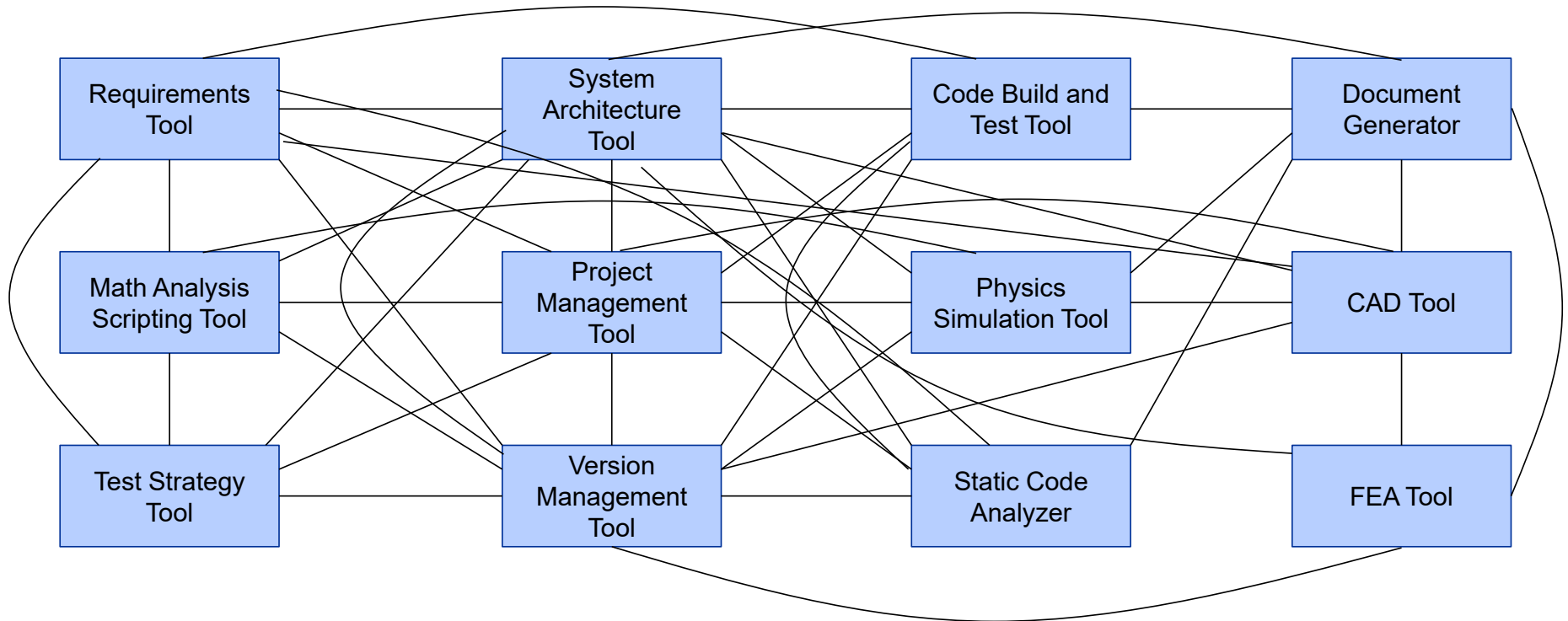
# Tool Map

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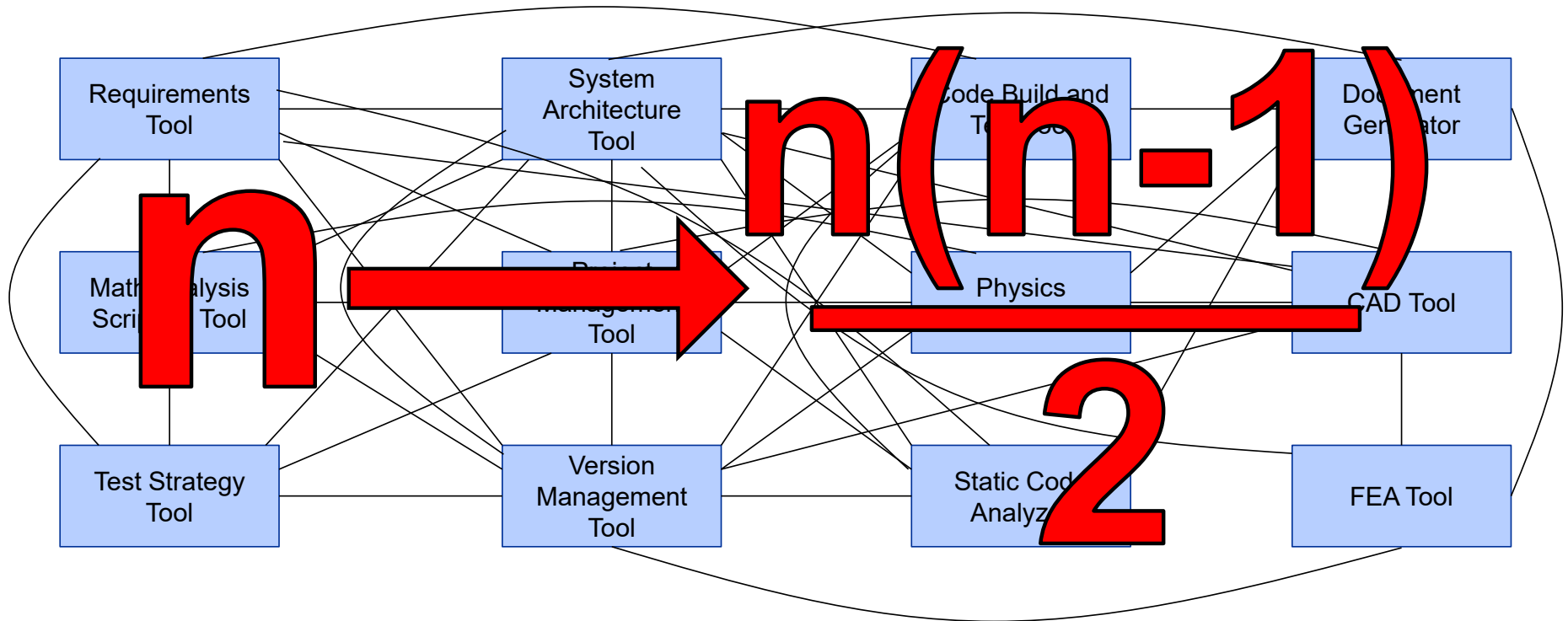
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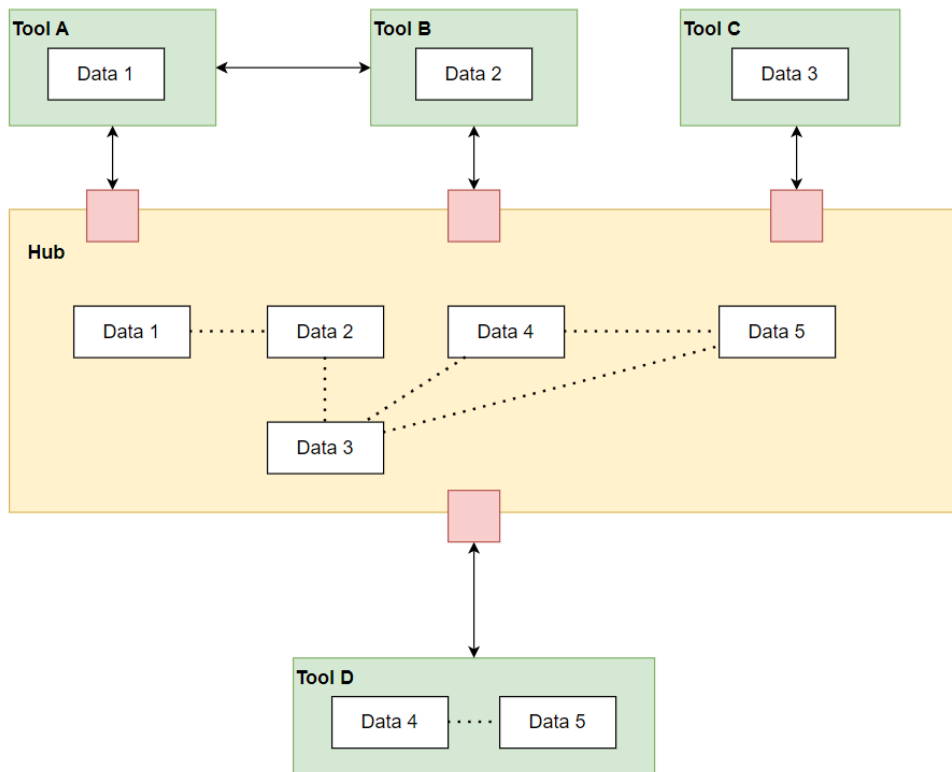
# Tool Map

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# Hub and Spoke

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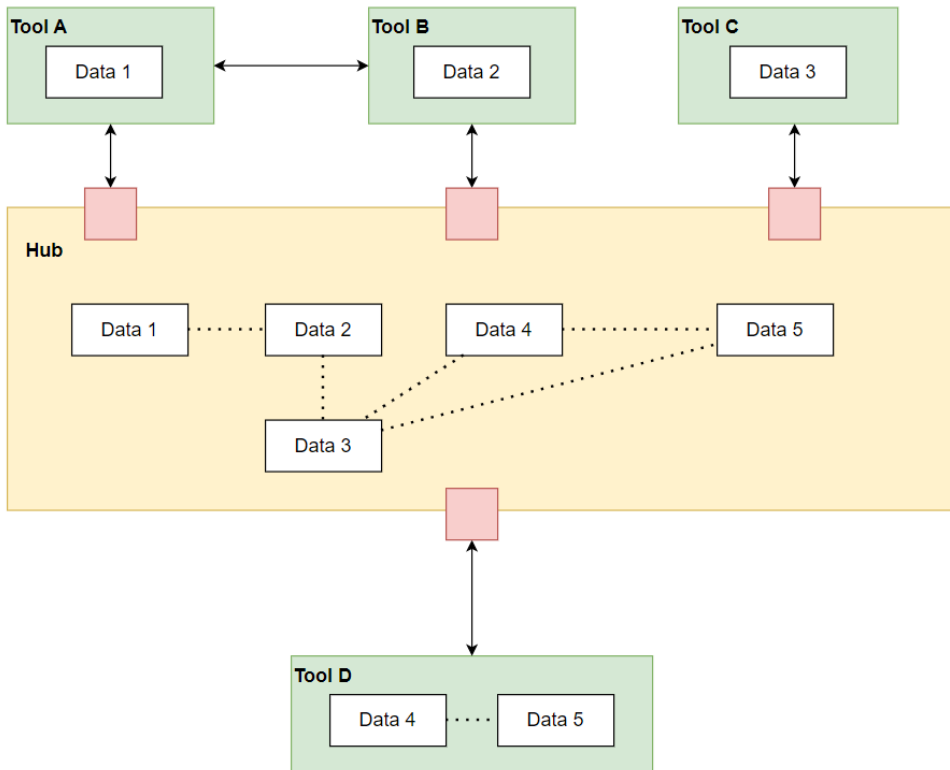


## • Hub and Spoke approach

- The 'Hub' enables integrations from multiple tools
- Data is connected within the Hub
- Intra-tool relations are carried
- Inter-tool relations can be added
- Comprehensive representation of **entire** dataset in **one** place

# Hub and Spoke

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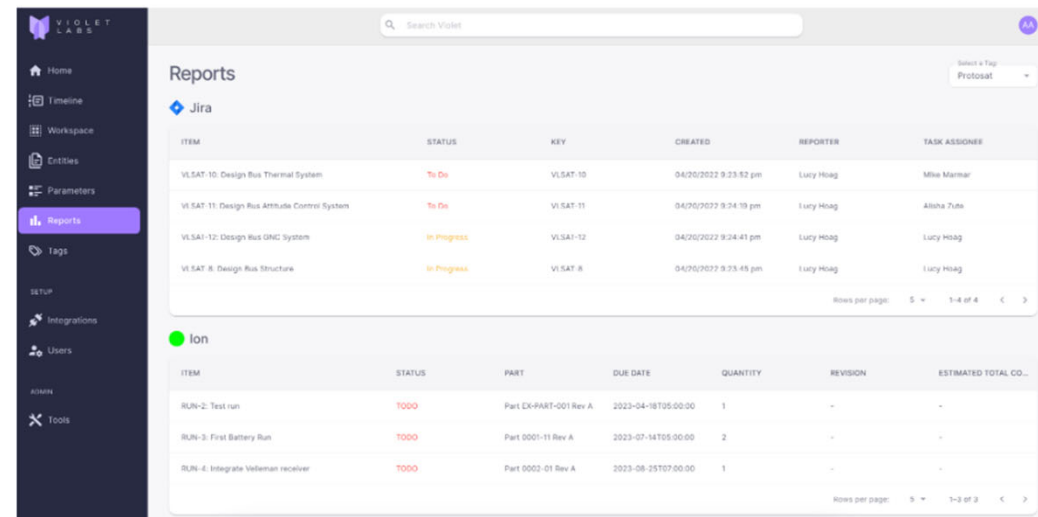
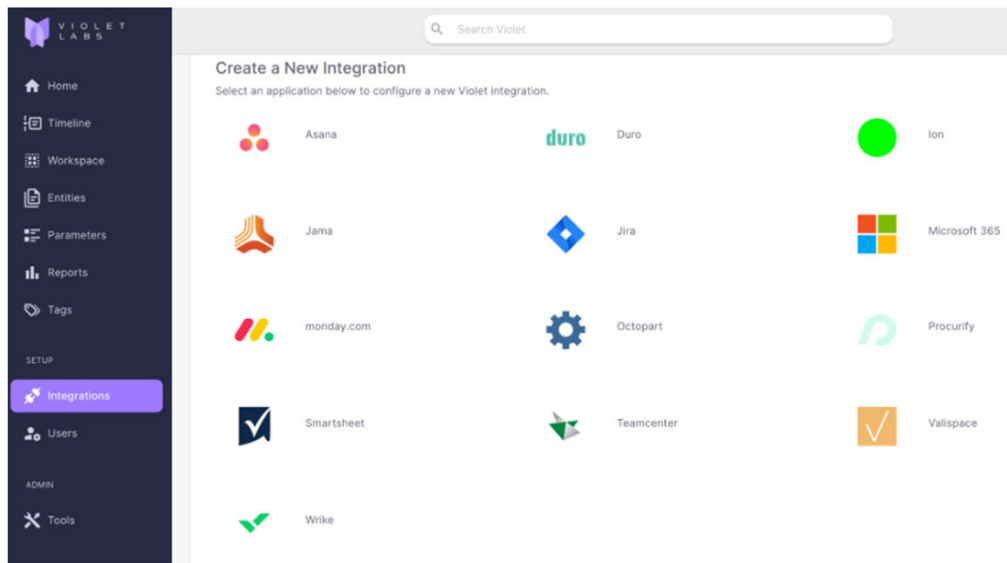
**n** → **n**

# The Hub – Violet Labs [2]

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1 Connect tools

2 Violet continuously fetches and structures the data



3

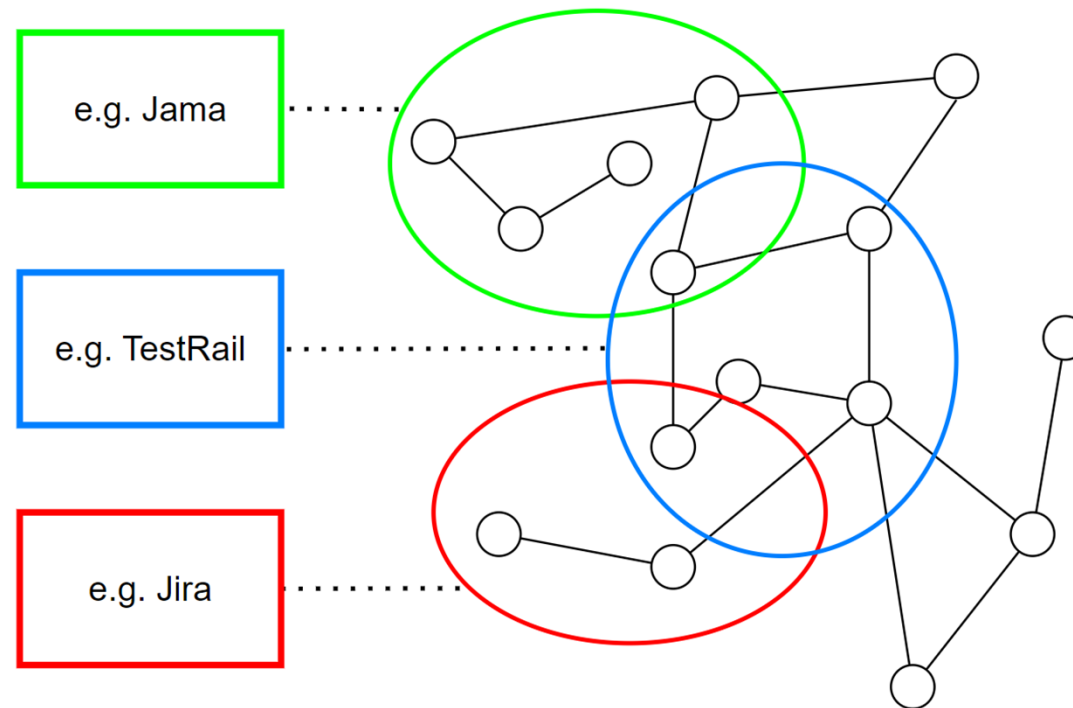
Enables bi-directional data sync, parameter backbone, report generation

[www.violetlabs.com](http://www.violetlabs.com)

## The Hub – Violet Labs [2]

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*So, we have a graph representation of the data...*



*How can we add value?*

## The Hub – OML Rosetta [3]

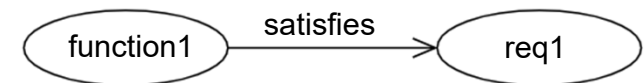
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### Semantic Web Technologies (SWTs)

- provide an approach to the structuring and understanding of data [4].

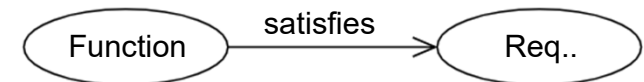
- Resource Description Framework (RDF) [5]

- *Makes information machine-readable*



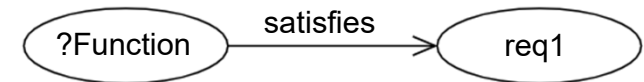
- Web Ontology Language (OWL) [6]

- *Provides context to information, enables validation*



- SPARQL [7]

- *Enables users to query RDF graphs*



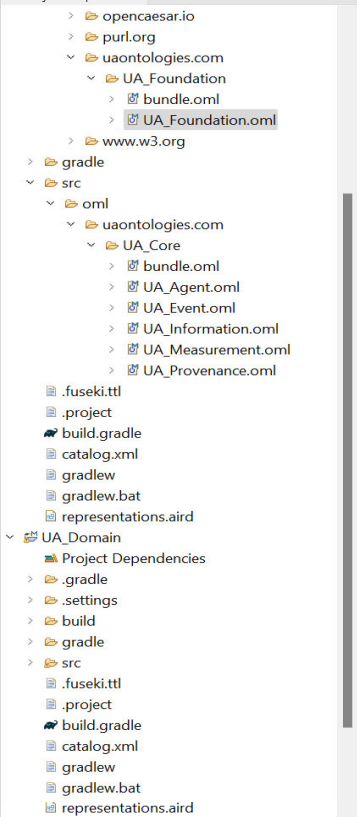


## The Hub – OML Rosetta [3]

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- The Ontological Modeling Language (OML) is a thin extension to OWL 2 DL
  - Part of the ‘OpenCAESAR’ project [3]
  - enables reification of relations and convenient use of mixin classes (as aspects).
  - enables representation of data as RDF and therefore SPARQL querying.
- OML uses the concept of ‘**bundles**’
  - these allow the modeler to group together multiple descriptions into a closed-world dataset.
  - the **closed-world assumption** allows the reasoner to highlight the absence of expected information.
- OML Ontologies and Descriptions can be modeled using OML Rosetta
- OML Rosetta is Eclipse-based
  - supports textual notation
  - supports graphical representation





```
@rdfs:label "IdentifiedEntity"  
concept IdentifiedEntity  
  
@rdfs:label "Occurrent"  
concept Occurrent :> IdentifiedEntity, ContainedElement  
  
@rdfs:label "Continuant"  
concept Continuant :> IdentifiedEntity  
  
@rdfs:label "Temporal Region"  
concept TemporalRegion :> Occurrent, Container, ContainedElement [  
  restricts all relation contains to TemporalRegion  
  restricts all relation isContainedIn to TemporalRegion  
]  
  
@rdfs:label "Process"  
concept Process :> Occurrent, Container, ContainedElement [  
  restricts all relation contains to Process  
  restricts all relation isContainedIn to Process  
]  
  
@rdfs:label "Independent Continuant"  
concept IndependentContinuant :> Continuant, SDCCCarrier  
  
@rdfs:label "Specifically Dependent Continuant"  
concept SpecificallyDependentContinuant :> Continuant [  
  restricts some relation specificallyDependentOn to SDCCCarrier  
]  
  
@rdfs:label "Generically Dependent Continuant"  
concept GenericallyDependentContinuant :> Continuant  
  
@rdfs:label "Realizable Entity"  
concept RealizableEntity :> SpecificallyDependentContinuant  
  
@rdfs:label "Quality"  
concept Quality :> SpecificallyDependentContinuant  
  
@rdfs:label "Disposition"  
concept Disposition :> RealizableEntity  
  
@rdfs:label "Function"  
concept Function :> Disposition, Container, ContainedElement [  
  restricts all relation contains to Function  
  restricts all relation isContainedIn to Function  
]  
  
@rdfs:label "Material Entity"  
concept MaterialEntity :> IndependentContinuant, ContainedElement
```

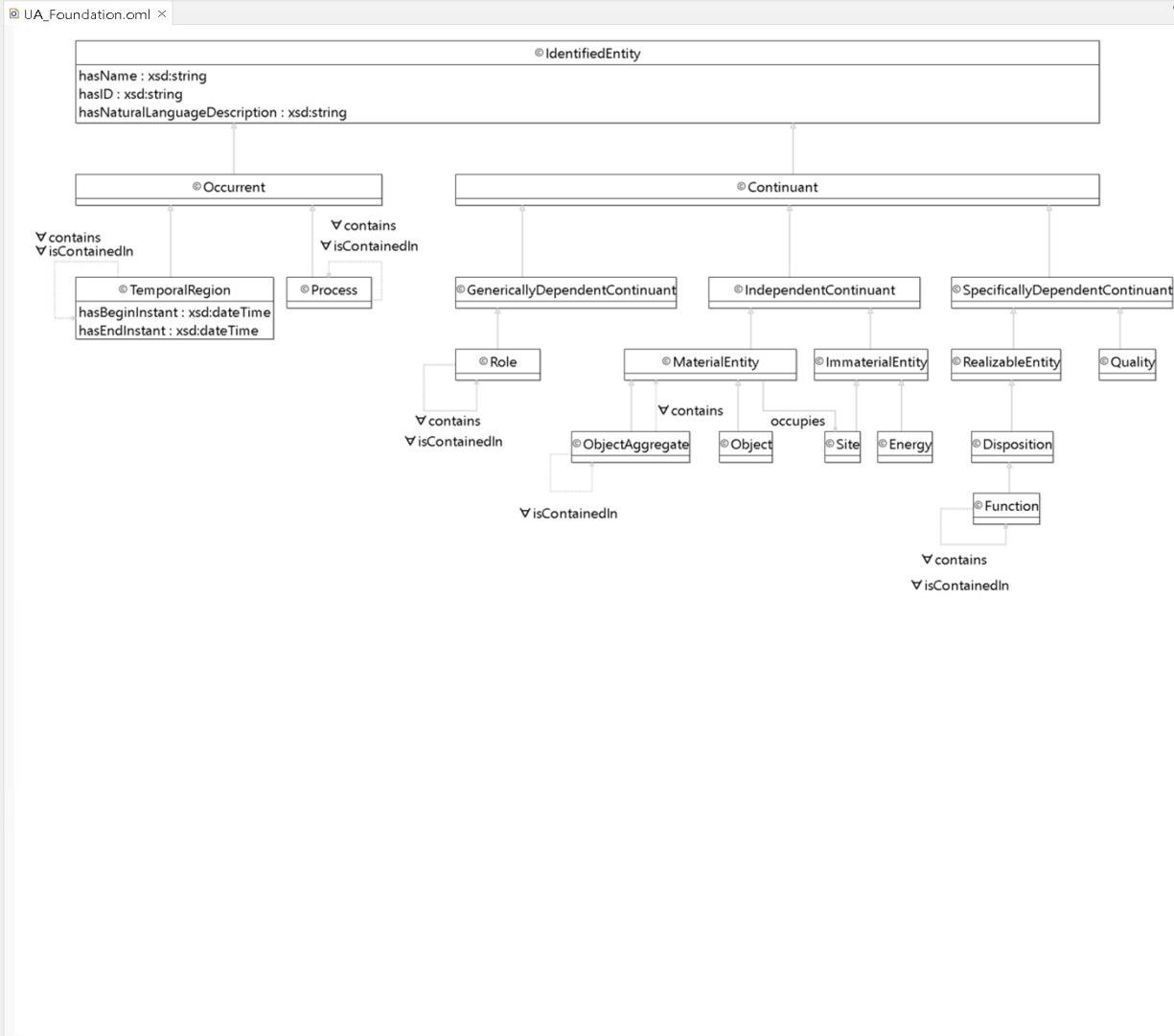
Runs: 0/0 Errors: 0 Failures: 0

Failure Trace

http://uaontologies.com/UA\_Foundation/UA\_F

Project Explorer

- opencasuar.io
- purl.org
- uaontologies.com
  - UA\_Foundation
    - bundle.oml
    - UA\_Foundation.oml
- www.w3.org
- gradle
- src
  - oml
    - uaontologies.com
      - UA\_Core
        - bundle.oml
        - UA\_Agent.oml
        - UA\_Event.oml
        - UA\_Information.oml
        - UA\_Measurement.oml
        - UA\_Provenance.oml
- .fuseki.ttl
- .project
- build.gradle
- catalog.xml
- gradlew
- gradlew.bat
- representations.aird

- UA\_Domain
- Project Dependencies
- .gradle
- .settings
- build
- gradle
- src
  - .fuseki.ttl
  - .project
  - build.gradle
  - catalog.xml
  - gradlew
  - gradlew.bat
  - representations.aird


JUnit x Gradle Tasks x Gradle Exec... x Console x Tasks

Runs: 0/0   Errors: 0   Failures: 0

Failure Trace

Outline

- http://uaontologies.com/UA\_Foundation/UA\_F...

# The Hub – Violet Labs [2] and OML Rosetta [4]

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**Entities / doro VL-958 910-00001: Solar Panel Assembly**

**Description**  
Deployable Solar Panel Assembly

<b>CPN</b> 910-00001	<b>Procurement</b> Buy	<b>Status</b> PROTOTYPE
<b>Mass</b> 50000 kg	<b>Revision</b> 1	<b>Name</b> Solar Panel Assembly

**Dependents**

- 999-00004: Minnesota SAR-Sat (1 dependents) [VIEW](#)
- 910-00001: Solar Panel Assembly (3 dependents) [VIEW](#)
  - 912-00001: Solar Panel [VIEW](#)
  - 913-00001: PCBA (2 dependents) [VIEW](#)
  - 920-00001: CABLE 14 COAX HDMI [VIEW](#)

[VIEW RELATIONSHIPS](#)

## Generate OML/RDF

**Download File**

Lang: turtle Theme: cobalt prefix omit rdf:type subjects

Subjects: viEntity:6334909d75edc20008485354  
viEntity:62633b4401d8400091d4328  
viEntity:6334909d75edc20008485354

Select to draw

URL: https://raw.githubusercontent.com/violetlabs/oml-rosetta/main/...  
[Load URL](#) [To JSON-LD](#) [To Turtle](#) [Show Facts](#) [\[xpo\]](#)

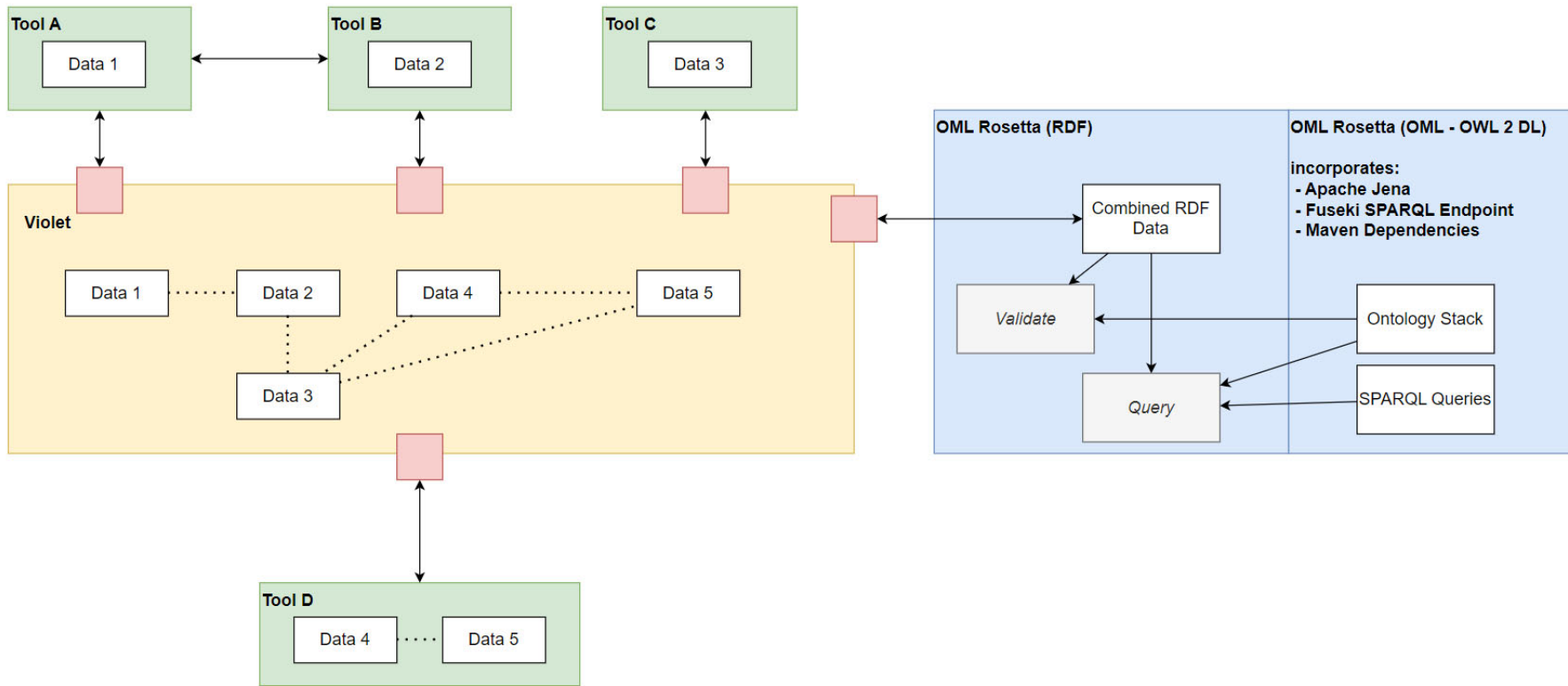
**SPARQL Pane (results in console)**  
select \* (2a 7p 7o)

Graph visualization showing relationships between entities and properties:

- viEntity:6334909d75edc20008485354 (Barry's Drone)
- viEntity:62633b4401d8400091d4328 (Minnesota SAR-Sat)
- viEntity:6334909d75edc20008485354 (PCBA)
- viEntity:63348f22b3d1eb0009a212ac (Cable)
- viEntity:6334909d75edc20008485354 (Solar Panel Assembly)
- viProp:cpn: 999-00048
- viProp:name: Barry's Drone
- viProp:mass: 29404
- viProp:status: OBSOLETE
- viProp:revision: A

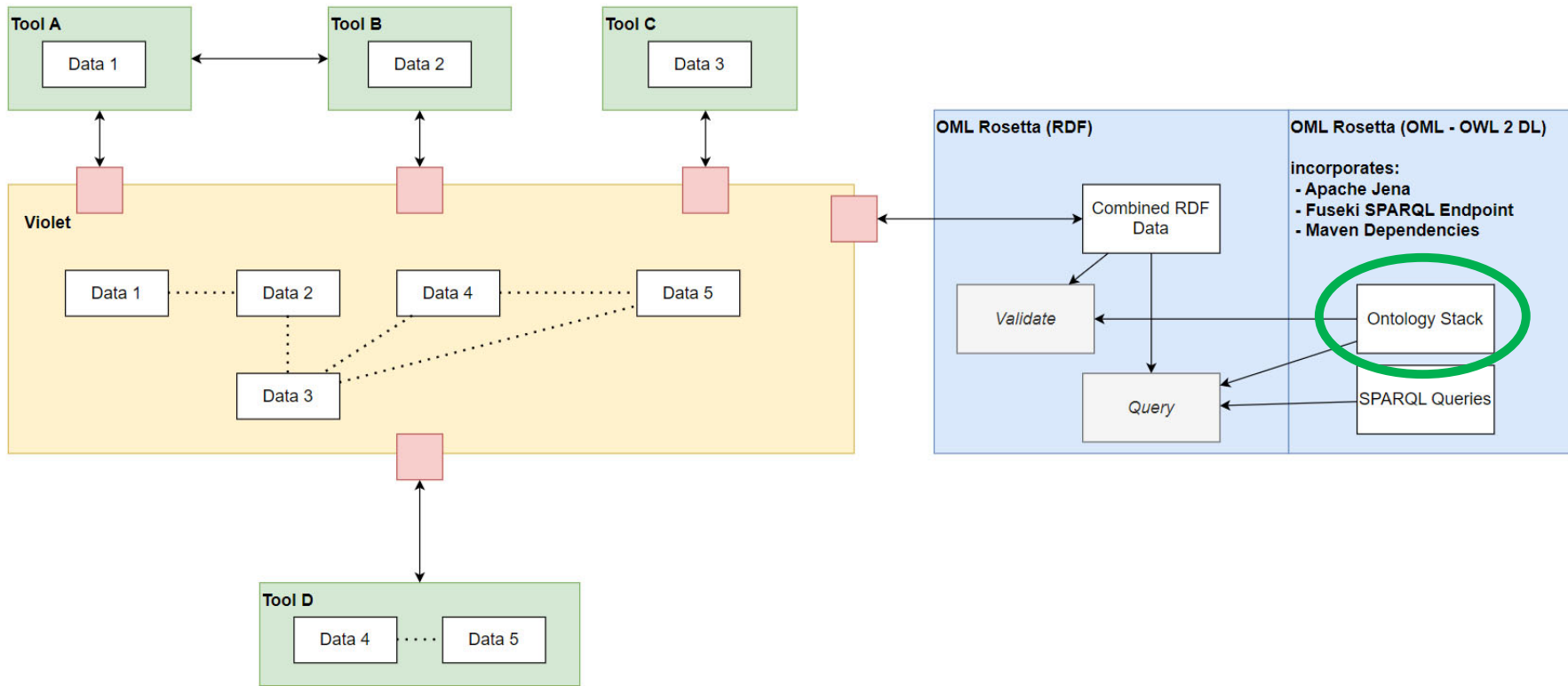
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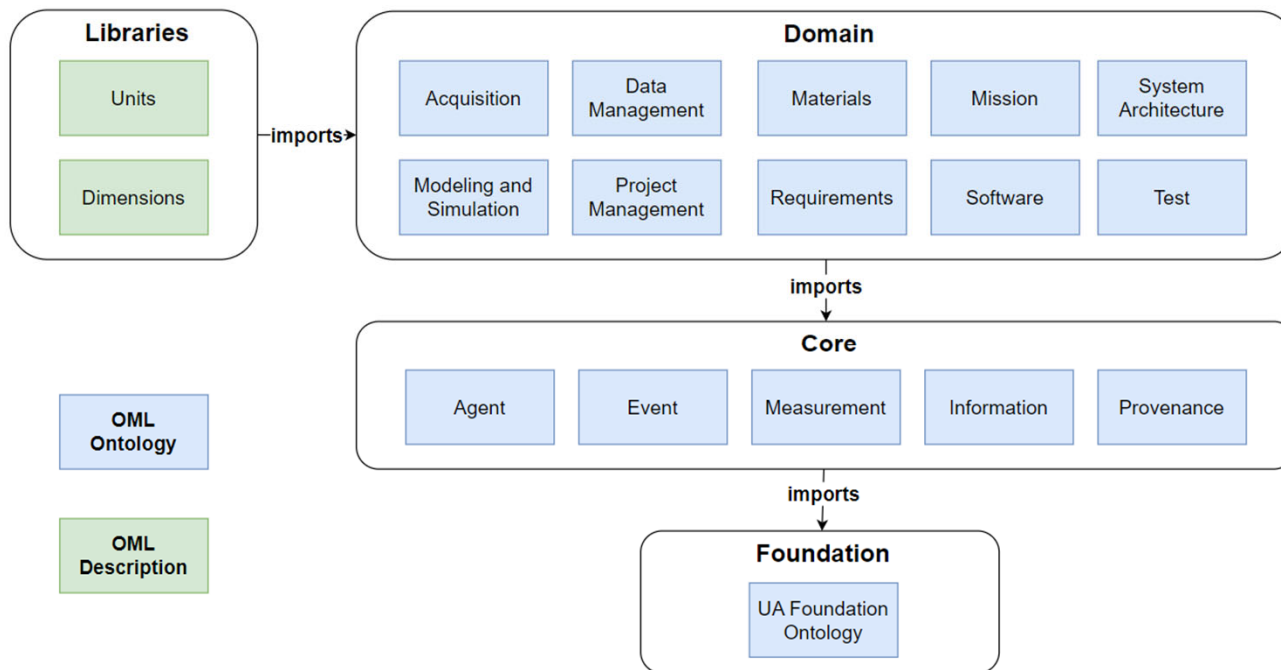
# The Hub – Violet Labs [2] and OML Rosetta [4]

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# The Hub – UA OML Ontology Stack

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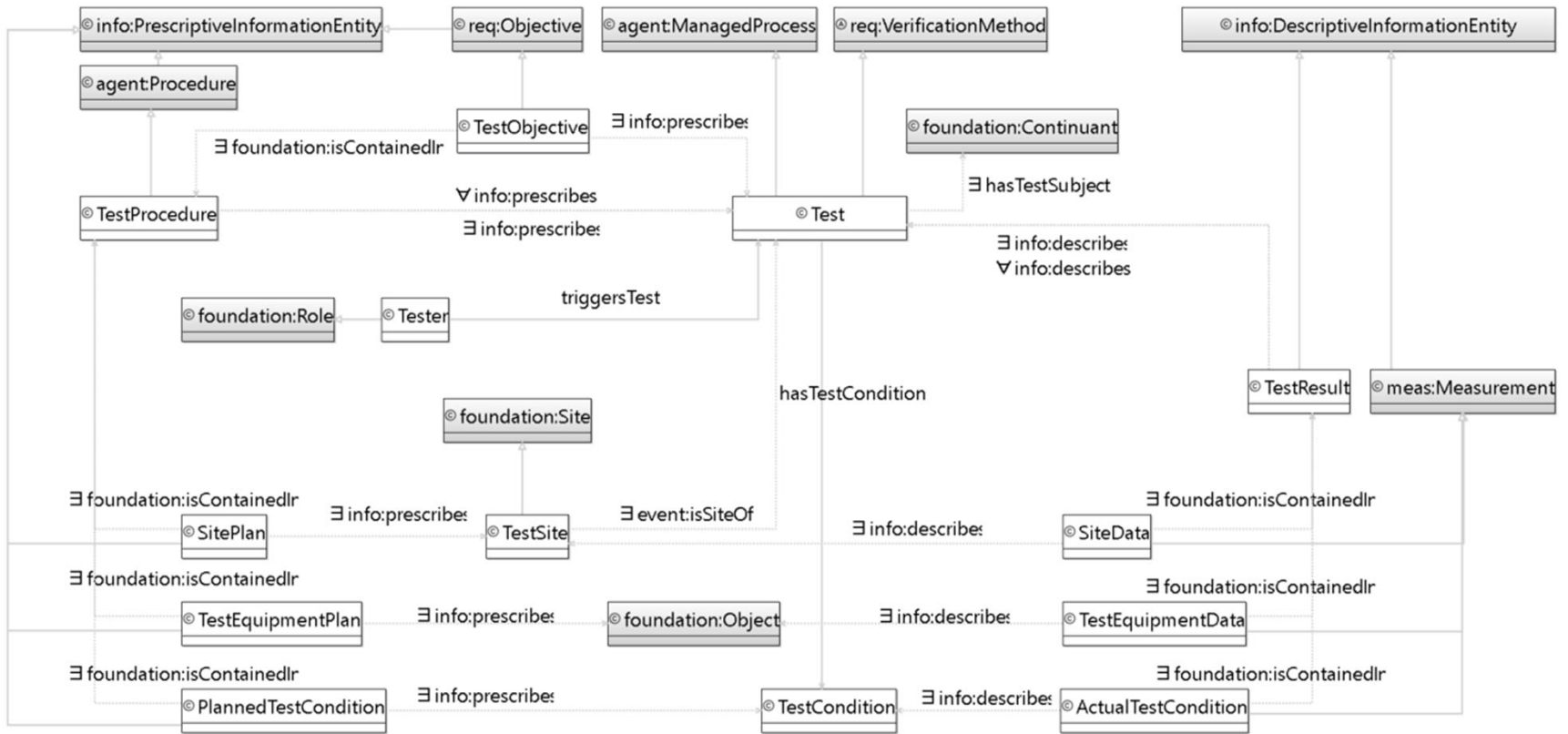


- **Foundation Ontology**
  - uses Basic Formal Ontology (BFO) [8]
- **Core Ontologies**
  - uses Common Core Ontologies (CCO) [9]
- **Domain Ontologies**
  - identified as key to support student work
  - draws from relevant standards and theory (e.g. ISO 42010 [10], VIM4 [11])
- **Libraries**
  - draws from existing libraries

**Reuse wherever possible!**

# The Hub – Domain-Level ‘Test’ OML Ontology

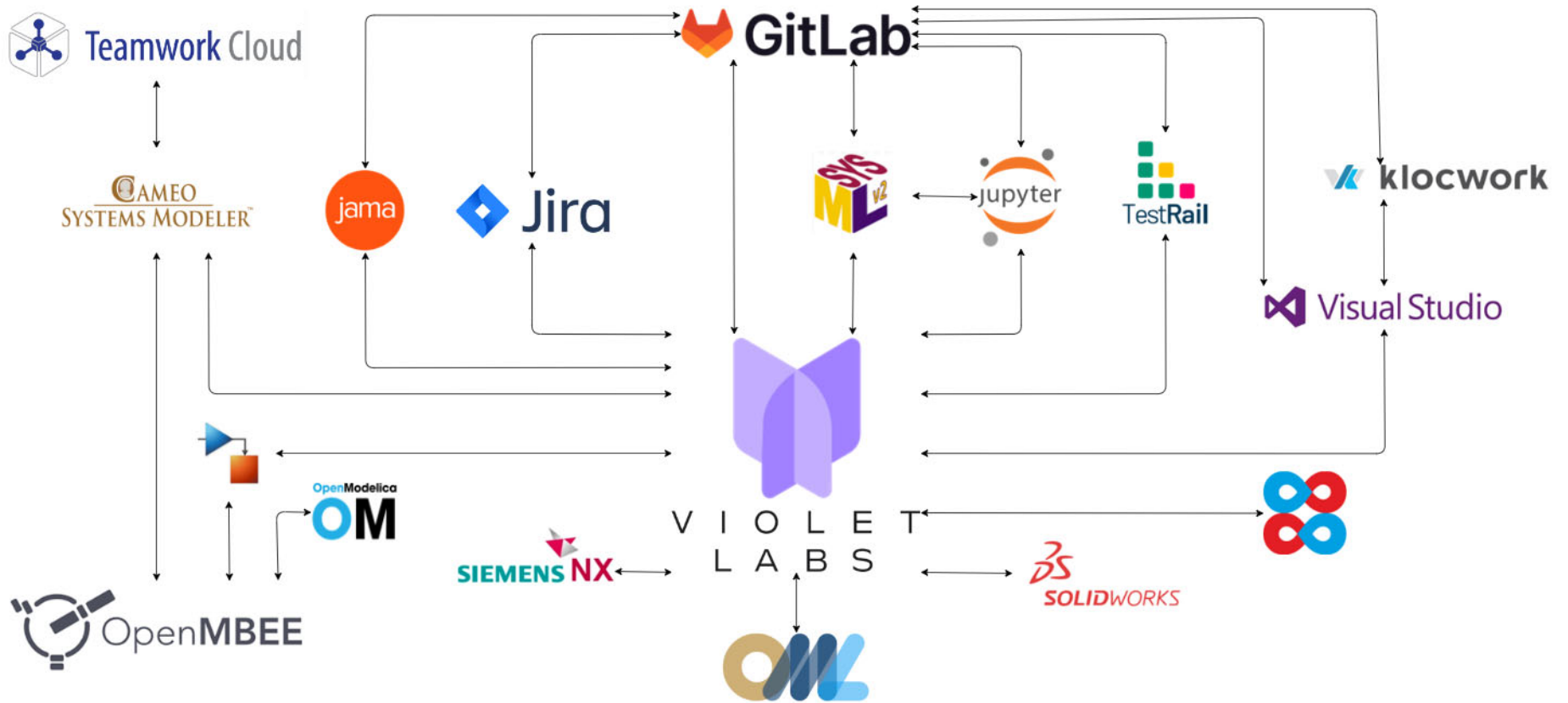
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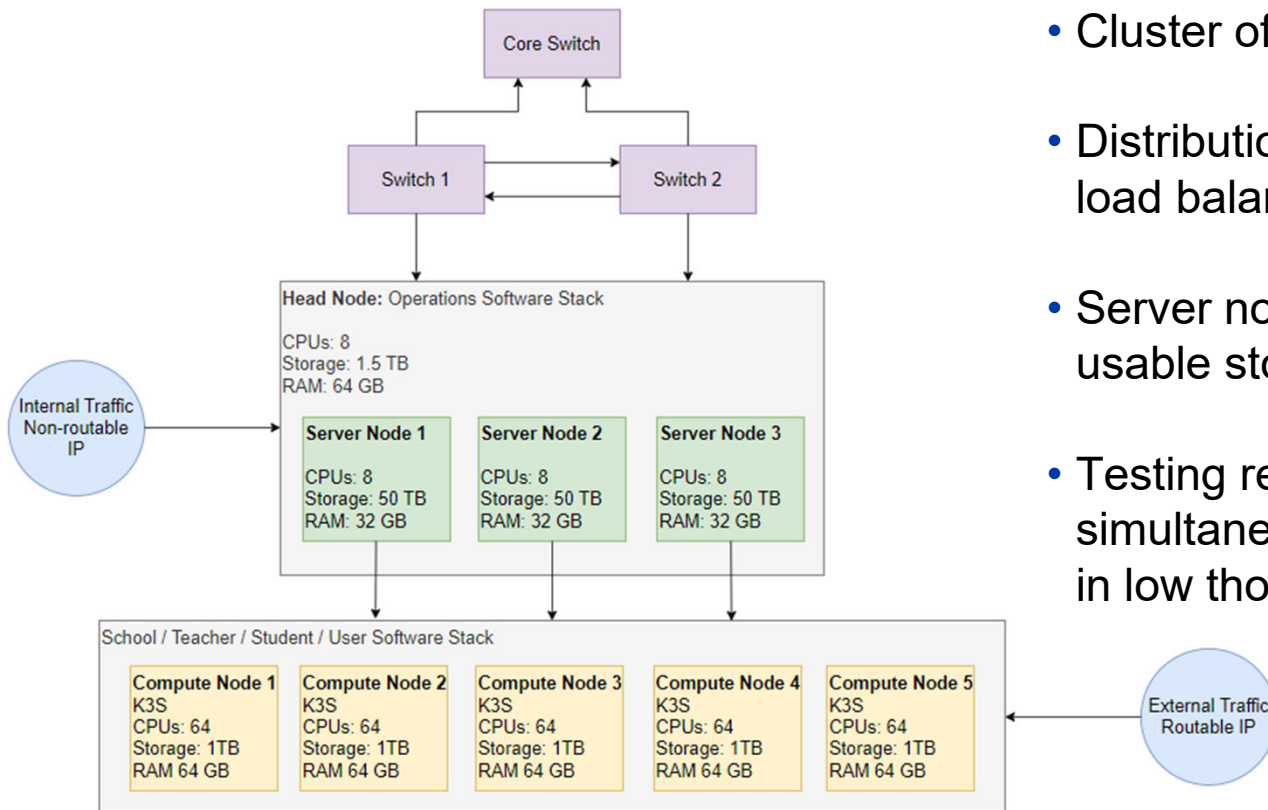
# Digital Engineering Factory

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# Digital Engineering Factory

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- Cluster of 320 CPUs to support students
- Distribution to support high-availability load balancing and ease of maintenance
- Server nodes will provide ~100TB of usable storage for installations
- Testing required to determine number of simultaneous users supported (expected in low thousands)

# Use Case 1 – Transferring Project Data Between Courses

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**Spacecraft mass** v2

System Requirement - Modified 06/27/2022 09:39:16 pm

PROJECT ID: VLSAT-BUSRQ-4

GLOBAL ID: GID-55892

NAME: Spacecraft mass

DESCRIPTION: Spacecraft mass including payload shall be no more than 400kg.

DISCIPLINE(S): Hardware

VERIFICATION METHOD(S): Analysis

STATUS: Draft

RATIONALE: -

VL VALUE: -



**Entities / dero VL-958 910-00001: Solar Panel Assembly**

ADD TAG

DOWNLOAD AS SYSML

Download as SysML

Download as RDF/TTL

Description: Deployable Solar Panel Assembly

CPN: 910-00001	Procurement: Buy	Status: PROTOTYPE
Mass: 50000 kg	Revision: 1	Name: Solar Panel Assembly

Dependents

- 999-00004: Minnesota SAR-Sat (1 dependents) [VIEW](#)
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[VIEW RELATIONSHIPS](#)

# Use Case 1 – Transferring Project Data Between Courses

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```
SysMLv2Demo.ipynb  
[50]:  
1 package VehicleQuantities {  
2   import Quantities::*;  
3   import MeasurementReferences::DerivedUnit;  
4   import ISQ::*;  
5   import SI::*;  
6   import SIPrefixes::kilo;  
7  
8   distancePerVolume >: tensorQuantities = distance/volume;  
9   timePerDistance >: tensorQuantities = time/distance;  
10  volumePerDistance >: tensorQuantities = volume/distance;  
11  volumePerTime >: tensorQuantities = volume/time;  
12  
13  kpl : DerivedUnit = km/L;  
14  rpm : DerivedUnit = 1/min;  
15  kW : DerivedUnit = kilo*W;  
16 }  
[50]: Package VehicleQuantities (796337d9-7b58-4ad7-8a29-e86334ff6acc)
```

```
[51]:  
1 package VehiclePartDefinitions {  
2   import ScalarValues::*;  
3   import VehicleQuantities::*;  
4  
5   item def Fuel {  
6     attribute mass >: ISQ::mass;  
7   }  
8  
9   item def FuelCmd {  
10    attribute throttleLevel : Real;  
11  }  
12  
13  part def Vehicle {  
14    attribute mass >: ISQ::mass;  
15    attribute dryMass >: ISQ::mass;  
16    attribute cargoMass >: ISQ::mass;  
17    attribute fuelMass >: ISQ::mass;  
18    attribute fuelCapacity >: ISQ::mass;  
19  
20    attribute electricalPower >: ISQ::power;  
21    attribute avgFuelEconomy >: distancePerVol  
22  
23    attribute brakePedalDepressed : Boolean;  
24  
25    perform action providePower {  
26      in item fuelCmd : FuelCmd;  
27      out wheelToRoadTorque >: ISQ::torque [  
28    }  
29  }  
30 }
```



```
SimplePythonAnalysis.ipynb  
2  
3 count = 0;  
4 cost_value_array = [];  
5 for i in data:  
6   if i.get('name') == 'cost':  
7     cost_value_id = i.get('ownedElement')  
8     cost_value_id_formatted = str(cost_value_id)[10:46]  
9     cost_value_array.append(cost_value_id_formatted)  
10    print("Cost Element ID:", count, cost_value_array[count])  
11    count +=1;  
12  
13 count = 0;  
14 owner_id_array = [];  
15 for i in data:  
16   if i.get('name') == 'cost':  
17     owner_id = i.get('owner')  
18     owner_id_formatted = str(owner_id)[9:45]  
19     owner_id_array.append(owner_id_formatted)  
20     print("Owner ID:", count, owner_id_array[count])  
21     count +=1;  
22  
23 owner_name_array = [];  
24 for j in range(3):  
25   for i in data:  
26     if i.get('elementId') == owner_id_array[j]:  
27       owner_name = i.get('name')  
28       owner_name_array.append(owner_name)  
29       print("Owner Name:", j, owner_name)  
30  
31 cost_value_literal_array = [];  
32 for j in range(3):  
33   for i in data:  
34     if i.get('elementId') == cost_value_array[j]:  
35       cost_value_literal = i.get('value')  
36       cost_value_literal_array.append(cost_value_literal)  
37       print("Cost Value Literal:", j, cost_value_literal)
```

**VIOLET LABS**

Entities | [View](#) **VL-958** 910-0001: Solar Panel Assembly

ADD TAG

Description  
Deployable Solar Panel Assembly

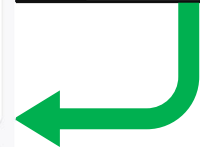
CPN	Procurement	Status
910-0001	Buy	PROTOTYPE

Mass	Revision	Name
50000 kg	1	Solar Panel Assembly

Dependents

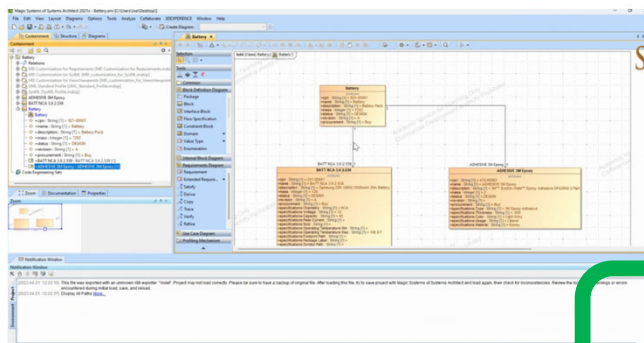
- 999-00004: Minnesota SAR-Sat (1 dependents) [VIEW](#)
- 910-00001: Solar Panel Assembly (3 dependents)
  - 912-00001: Solar Panel [VIEW](#)
  - 913-00001: PCBA (2 dependents) [VIEW](#)
  - 920-00001: CABLE 14 COAX HDMI [VIEW](#)

[VIEW RELATIONSHIPS](#)

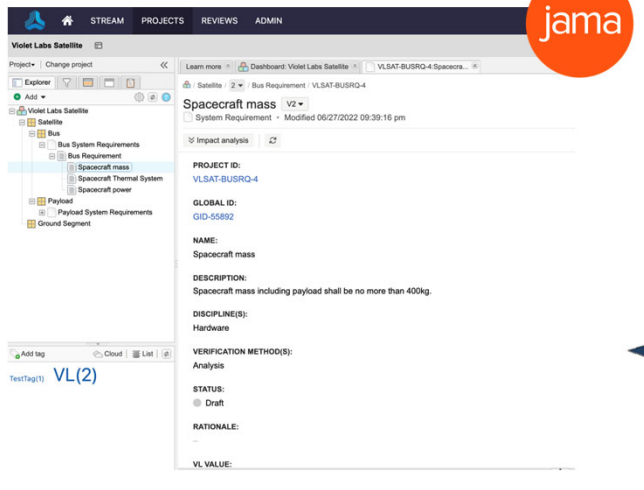


# Use Case 2 – Static Data Integration and Evaluation

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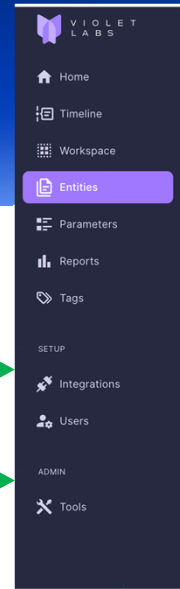
CAMEO SYSTEMS MODELER™



jama



SIEMENS NX



Entities / **durv VL-958** 910-00001: Solar Panel Assembly

DOWNLOAD AS SYXML  
Download as SysML  
Download as RDF/TTL

Description  
Deployable Solar Panel Assembly

CPN 910-00001	Procurement Buy	Status PROTOTYPE
Mass 50000 kg	Revision 1	Name Solar Panel Assembly

Dependents

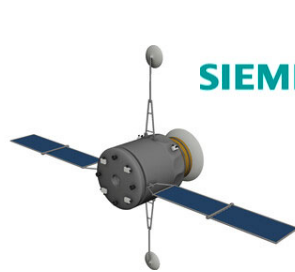
- 999-00004: Minnesota SAR-Sat (1 dependents) VIEW
- 910-00001: Solar Panel Assembly (3 dependents) VIEW
  - 912-00001: Solar Panel VIEW
  - 913-00001: PCBA (2 dependents) VIEW
    - 920-00001: CABLE 14 COAX HDMI VIEW

VIEW RELATIONSHIPS

```
graph TD
    subgraph "IA Foundation"
        direction TB
        IA_Entity["#Rdfs:label \"IdentifiedEntity\"  
concept IdentifiedEntity"]
        IA_Container["#Rdfs:label \"Container\"  
concept Container -> IdentifiedEntity"]
        IA_TemporalRegion["#Rdfs:label \"Temporal Region\"  
concept TemporalRegion -> Occurrent, Container, ContainedElement  
restricts all relation contains to TemporalRegion  
restricts all relation isContainedIn to TemporalRegion"]
        IA_Process["#Rdfs:label \"Process\"  
concept Process -> Occurrent, Container, ContainedElement  
restricts all relation contains to Process  
restricts all relation isContainedIn to Process"]
        IA_IndependentContaintant["#Rdfs:label \"Independent Containtant\"  
concept IndependentContaintant -> Containtant, SDCCarrier"]
        IA_SpecificallyDependentContaintant["#Rdfs:label \"Specifically Dependent Containtant\"  
concept SpecificallyDependentContaintant -> Containtant  
restricts some relation specificallyDependent to SDCCarrier"]
        IA_GenericallyDependentContaintant["#Rdfs:label \"Generically Dependent Containtant\"  
concept GenericallyDependentContaintant -> Containtant"]
        IA_RealizableEntity["#Rdfs:label \"Realizable Entity\"  
concept RealizableEntity -> SpecificallyDependentContaintant"]
        IA_Quality["#Rdfs:label \"Quality\"  
concept Quality -> SpecificallyDependentContaintant"]
        IA_Disposition["#Rdfs:label \"Disposition\"  
concept Disposition -> RealizableEntity"]
        IA_Function["#Rdfs:label \"Function\"  
concept Function -> Disposition, Container, ContainedElement  
restricts all relation contains to Function  
restricts all relation isContainedIn to Function"]
        IA_MaterialEntity["#Rdfs:label \"Material Entity\"  
concept MaterialEntity -> IndependentContaintant, ContainedElement"]
    end
```

# Use Case 3 – Continuous Requirement Verification

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**Spacecraft mass** V2

System Requirement - Modified 06/27/2022 09:39:16 pm

PROJECT ID: VLSAT-BUSRQ-4

GLOBAL ID: GID-55892

NAME: Spacecraft mass

DESCRIPTION: Spacecraft mass including payload shall be no more than 400kg.

DISCIPLINE(S): Hardware

VERIFICATION METHOD(S): Analysis

STATUS: Draft

RATIONALE: -

VL VALUE: -

- Home
- Timeline
- Entities
- Tags
- SETUP
  - Integrations
  - Users
- ADMIN
  - Applications
  - Tools

Entities / VLSAT-BUSRQ-5: Spacecraft Mass

DOWNLOAD AS SYSML

	<b>Description</b> Spacecraft mass including payload shall be no more than 400kg.	<b>Project I D</b> VLSAT-BUSRQ-5	<b>Global I D</b> GID-55925
<b>Item Type</b> 86	<b>Project</b> 52	<b>Name</b> Spacecraft Mass	<b>Fields</b> Spacecraft Mass
<b>Fields Key</b> VLSAT-BUSRQ-5	<b>Fields id</b> GID-55925	<b>Fields</b> Spacecraft mass including payload shall be no more than 400kg.	<b>Fields</b> 400.0000000
<b>Fields</b> kg	<b>Fields</b> 292		

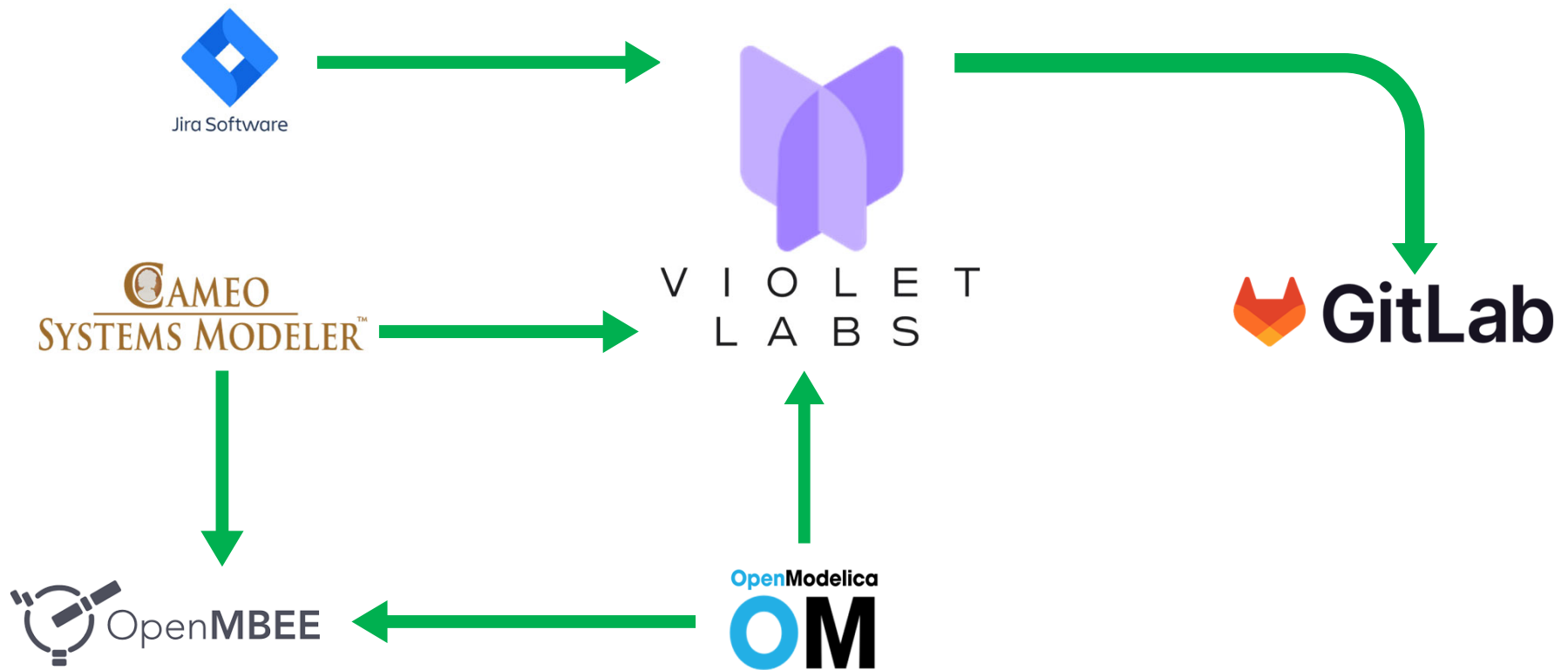
ADD TAG

Activity Stream



# Use Case 4 – Team Project Submission



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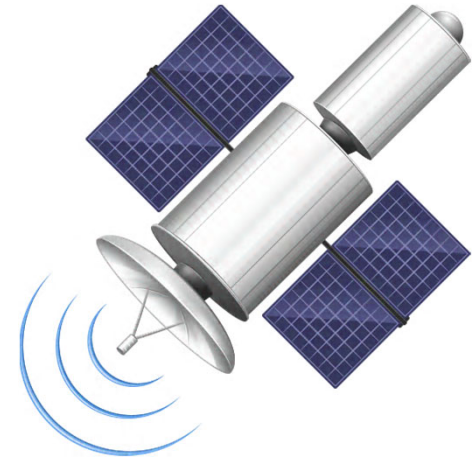


## Example – Overview

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### “Arizona Sat”

- Students are developing a Low-Earth Orbit satellite
- Students have requirements defined in  jama
- Students have components defined in  duro
- Students wish to review and submit their entire dataset





## Example – Sign-on

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Students will log into the DEF to:

- Access tools
- Access projects
- Work collaboratively

SFWE students are currently helping to develop the DEF Landing Page

The screenshot shows the Digital Engineering Factory (DEF) landing page. At the top is a red header with the 'A' logo and the text 'Digital Engineering Factory'. Below the header are two main sections: 'My Tools' and 'Projects'. The 'My Tools' section contains icons for Jira, Jama software, and SolidWorks. The 'Projects' section contains three folder icons labeled 'SFWE301-Sem...', 'SIELab2', and 'SIESemProj'. To the right of these sections is an 'Updates' section with two announcements: 'Ansys STK Now Supported!' and 'Co-op support for VSCode Added'. A vertical line separates the main content from the updates section.

**My Tools**

- Jira
- Jama software
- SOLIDWORKS

**Projects**

- SFWE301-Sem...
- SIELab2
- SIESemProj

**Updates**

- Ansys STK Now Supported!**  
The DEF has recently been updated to support the Ansys STK suite of tools! You can export files to have them work with Solidworks and ...
- Co-op support for VSCode Added**  
Support for project folders of VSCode has been implemented to the DEF. Here are a few ways this feature can be used.

\*This section looks like the D2L announcements section\*

# Example – Student Project Data

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The screenshot displays the JAMA software interface for the 'Arizona Satellite' project. The top navigation bar includes 'STREAM', 'PROJECTS', 'REVIEWS', and 'ADMIN'. The left sidebar shows a project tree with 'Satellite' expanded to show 'Bus' and its sub-components: 'Attitude Determination and Control System', 'Propulsion Subsystem Requirements', 'Power Subsystem Requirements', 'Solar Power', and 'Battery'. The main content area shows the 'Bus' component details, including a table of items.

ID	Name	Person	Messages	Relationship St...
AZSAT-SET-7	ADCS Subsystem Requirements	1	0	[Icons]
AZSAT-SET-9	Propulsion Subsystem Requirements	1	0	[Icons]
AZSAT-SET-10	Power Subsystem Requirements	1	0	[Icons]

# Example – Student Project Data

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**Products**

999-00051 Arizona Sat

- ▶ 910-00001 Solar Panel Assembly
- ▶ 910-00002 Propulsion System
- 991-00002 C&DH Assembly
- ▶ 991-00003 Payload Assembly
- ▶ 991-00004 ADCS

## Arizona Sat

### PRODUCT OVERVIEW

CPN **999-00051**

EID

REVISION **A**

STATUS **DESIGN**

### DETAILS

University of Arizona satellite

**PRIMARY SOURCE**

MPN **999-00051**

MFR **Violet Labs**

MIN QTY **1**

UNIT PRICE **\$0.0000**

LEAD TIME **0 DAYS**

MASS (g) **175,255.00**

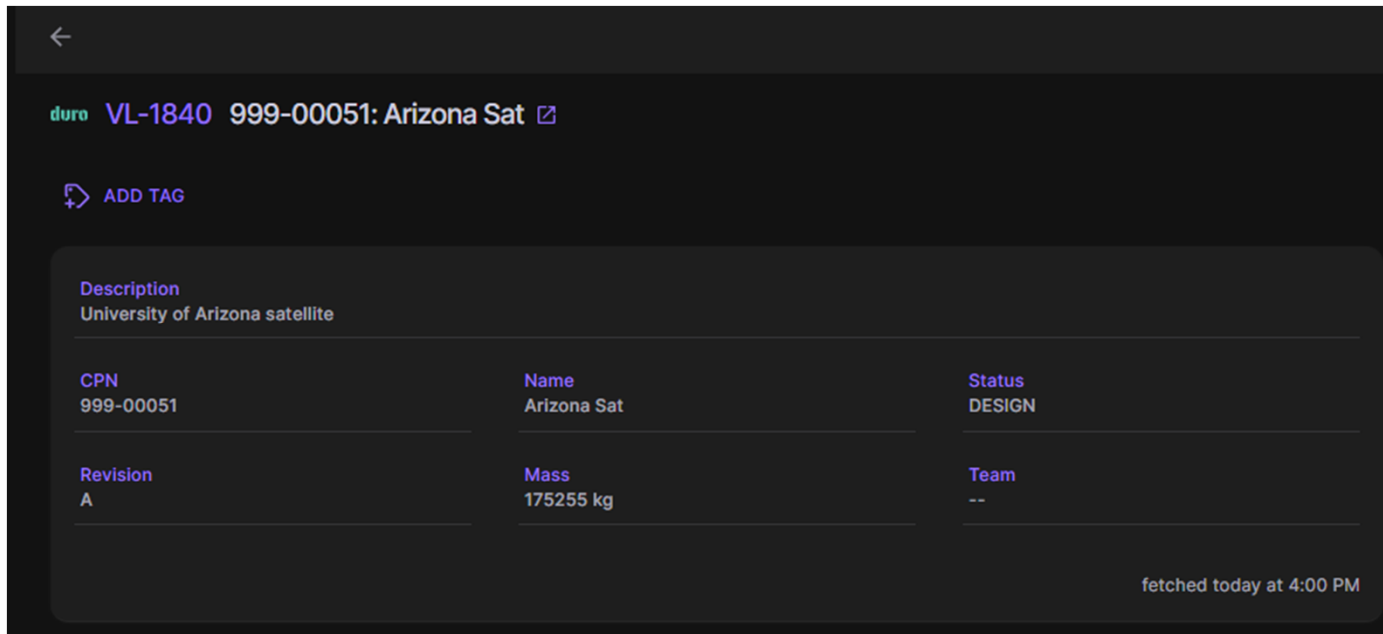
PROCUREMENT

CREATED **Aug 31, 2023 03:15 PM**

MODIFIED

## Example – Student Project Data

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The screenshot shows a mobile application interface with a dark theme. At the top left is a back arrow. Below it, the product name 'VL-1840 999-00051: Arizona Sat' is displayed in green and white, with a checkmark icon. Underneath is an 'ADD TAG' button with a tag icon. The main content area is a rounded rectangle containing a 'Description' section with the text 'University of Arizona satellite'. Below this is a table with three columns: CPN, Name, and Status. The first row contains '999-00051', 'Arizona Sat', and 'DESIGN'. The second row contains 'Revision A', 'Mass 175255 kg', and 'Team --'. At the bottom right of the table area, it says 'fetched today at 4:00 PM'.

CPN	Name	Status
999-00051	Arizona Sat	DESIGN
Revision	Mass	Team
A	175255 kg	--



# Example – Student Project Data

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←

**VL-1840** 999-00051: Arizona Sat [🔗](#)

ADD TAG

**Description**  
University of Arizona satellite

CPN	Name	Status
999-00051	Arizona Sat	DESIGN

Revision	Mass
A	175255 kg



### Dependents

- VL-1840 999-00051: Arizona Sat [🔗](#) (5 dependents) [VIEW](#)
- > VL-1623 991-00003: Payload Assembly [🔗](#) (2 dependents) [VIEW](#)
- VL-1627 991-00002: C&DH Assembly [🔗](#) [VIEW](#)
- > VL-1643 910-00002: Propulsion System [🔗](#) (2 dependents) [AZSat](#) [HITL](#) [VIEW](#)
- > VL-1645 910-00001: Solar Panel Assembly [🔗](#) (3 dependents) [AZSat](#) [HITL](#) [VIEW](#)
- > VL-1885 991-00004: ADCS [🔗](#) (2 dependents) [AZSat](#) [VIEW](#)

[VIEW RELATIONSHIPS](#)

# Example – Student Project Data

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### Dependents

- VL-1840 999-00051: Arizona Sat (1 dependents) [VIEW](#)
- VL-1643 910-00002: Propulsion System (2 dependents) [AZSat](#) [HITL](#) [VIEW](#)
  - VL-1637 422-00001: MOTOR Engine N/A RP-1 [VIEW](#)
  - VL-1638 463-00001: NOZZLE [VIEW](#)

[VIEW RELATIONSHIPS](#)

### Relationships

**Satisfies**

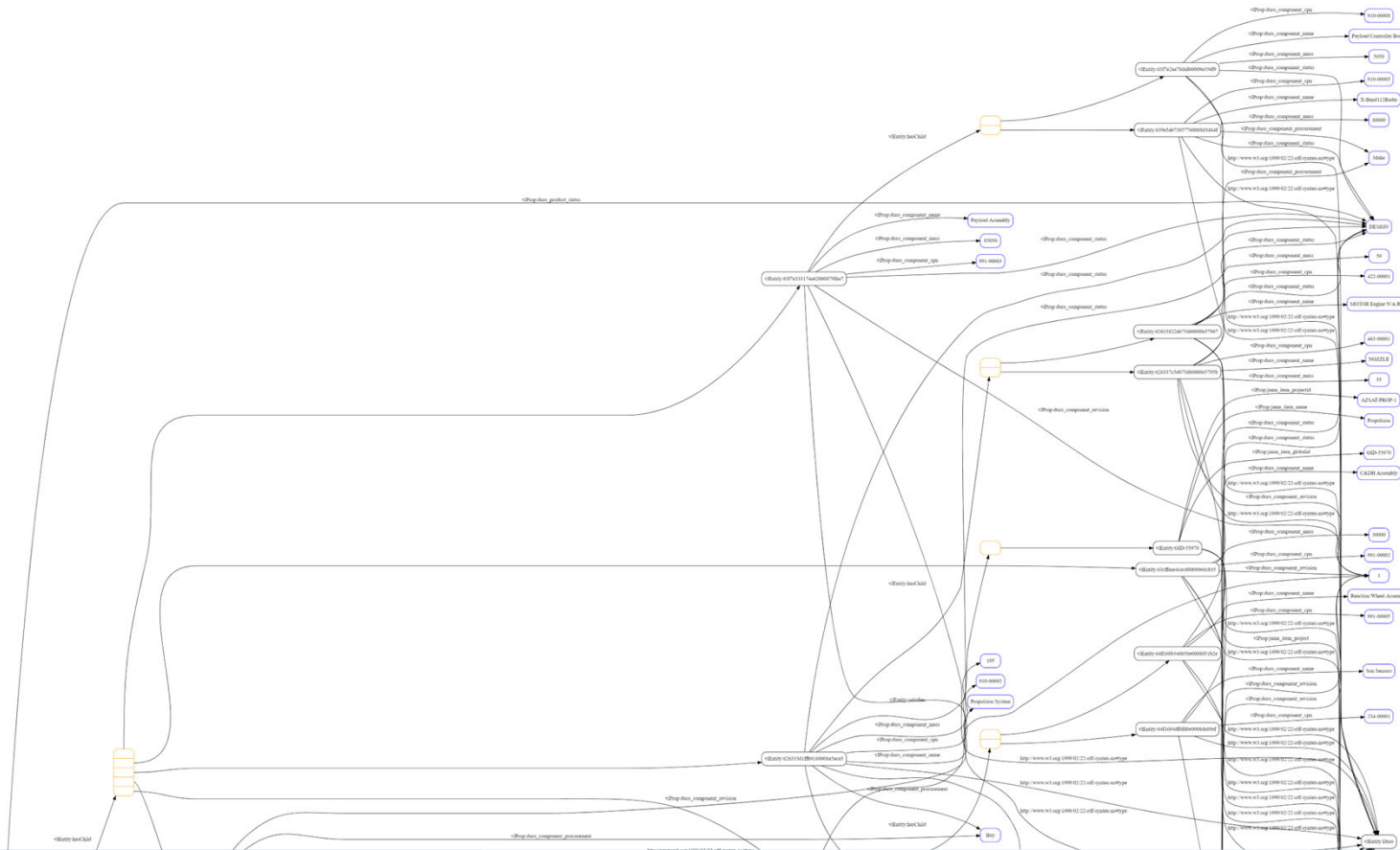
-  VL-1850 AZSAT-PROP-1: Propulsion [VIEW](#)

Tags / [AZSat](#) [DOWNLOAD AS RDF/TTL](#)



# Example – RDF Representation

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# Example – Validation

Global Product Data Interoperability Summit | 2023



## Example – Validation

Global Product Data Interoperability Summit | 2023

### Initial issue with build – validation failed

Operation	Duration
▼ ● Run build	1.401 s
> ● Configure build	0.196 s
> ● Calculate build tree task graph	0.016 s
> ● Load build	0.010 s
● Build finished for file system watching	0.001 s
▼ ● Run main tasks	1.156 s
> ● Run tasks	1.155 s
● Build started for file system watching	0.013 s

## Example – Validation

Global Product Data Interoperability Summit | 2023

⚠️ Antisymmetric property isAbout

```
<?xml version="1.0"?>
<rdf:RDF xmlns="urn:unnamed:ontology#ont395285532729201#"
  xml:base="urn:unnamed:ontology#ont395285532729201"
  xmlns:owl="http://www.w3.org/2002/07/owl#"
  xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  xmlns:xml="http://www.w3.org/XML/1998/namespace"
  xmlns:xsd="http://www.w3.org/2001/XMLSchema#"
  xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
  xmlns:swrl="http://www.w3.org/2003/11/swrl#"
  xmlns:swrlb="http://www.w3.org/2003/11/swrlb#"
  xmlns:UA_Foundation="http://uaontologies.com/UA_Foundation/UA_Foundation#"
  xmlns:UA_Information="http://uaontologies.com/UA_Core/UA_Information#">
<owl:Ontology rdf:about="urn:unnamed:ontology#ont395285532729201"/>
```

## Example – Validation

Global Product Data Interoperability Summit | 2023

⚠️ Antisymmetric property isAbout

```
<?xml version="1.0"?>
<rdf:RDF xmlns="urn:unnamed:ontology#ont395285532729201#"
  xml:base="urn:unnamed:ontology#ont395285532729201"
  xmlns:owl="http://www.w3.org/2002/07/owl#"
  xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  xmlns:xml="http://www.w3.org/XML/1998/namespace"
  xmlns:xsd="http://www.w3.org/2001/XMLSchema#"
  xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
  xmlns:swrl="http://www.w3.org/2003/11/swrl#"
  xmlns:swrlb="http://www.w3.org/2003/11/swrlb#"
  xmlns:UA_Foundation="http://uaontologies.com/UA_Foundation/UA_Foundation#"
  xmlns:UA_Information="http://uaontologies.com/UA_Core/UA_Information#">
<owl:Ontology rdf:about="urn:unnamed:ontology#ont395285532729201"/>
```

```
<!-- http://uavl.com/UAVL_Example/tag1#AZSAT-SET-7 -->
```

```
<owl:NamedIndividual rdf:about="http://uavl.com/UAVL_Example/tag1#AZSAT-SET-7">
  <UA_Information:prescribes rdf:resource="http://uavl.com/UAVL_Example/tag1#Arizona_Sat"/>
</owl:NamedIndividual>
```

```
<!-- http://uavl.com/UAVL_Example/tag1#Arizona_Sat -->
```

```
<owl:NamedIndividual rdf:about="http://uavl.com/UAVL_Example/tag1#Arizona_Sat">
  <UA_Foundation:contains rdf:resource="http://uavl.com/UAVL_Example/tag1#AZSAT-SET-7"/>
</owl:NamedIndividual>
```

## Example – Validation

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After identifying the issue using the Reasoning report, the issue is rectified

Operation	Duration
▼ ● Run build	0.272 s
> ● Calculate build tree task graph	0.016 s
> ● Configure build	0.180 s
● Build finished for file system watching	0.001 s
● Build started for file system watching	0.012 s
▼ ● Run main tasks	0.042 s
> ● Run tasks	0.042 s
> ● Load build	0.013 s

# Example – Querying (as Grading)

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## Example – Querying (as Grading)

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### Prefixes – UA Ontology Stack

```
PREFIX foundation: <http://uaontologies.com/UA_Foundation/UA_Foundation#>

PREFIX agent: <http://uaontologies.com/UA_Core/UA_Agent#>
PREFIX event: <http://uaontologies.com/UA_Core/UA_Event#>
PREFIX info: <http://uaontologies.com/UA_Core/UA_Information#>
PREFIX meas: <http://uaontologies.com/UA_Core/UA_Measurement#>
PREFIX prov: <http://uaontologies.com/UA_Core/UA_Provenance#>

PREFIX acq: <http://uaontologies.com/UA_Domain/UA_Acquisition#>
PREFIX data: <http://uaontologies.com/UA_Domain/UA_DataManagement#>
PREFIX mission: <http://uaontologies.com/UA_Domain/UA_Mission#>
PREFIX ms: <http://uaontologies.com/UA_Domain/UA_ModelingAndSimulation#>
PREFIX pm: <http://uaontologies.com/UA_Domain/UA_ProjectManagement#>
PREFIX req: <http://uaontologies.com/UA_Domain/UA_Requirements#>
PREFIX sw: <http://uaontologies.com/UA_Domain/UA_Software#>
PREFIX sa: <http://uaontologies.com/UA_Domain/UA_SystemArchitecture#>
PREFIX test: <http://uaontologies.com/UA_Domain/UA_Test#>
PREFIX mat: <http://uaontologies.com/UA_Domain/UA_Materials#>
```

## Example – Querying (as Grading)

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List all entities, their IDs and their sources:

```
SELECT DISTINCT ?EntityName ?EntityID ?EntitySource

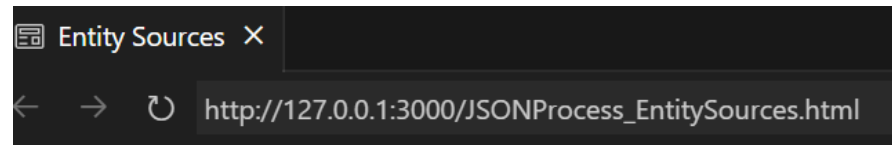
WHERE {
    ?Entity sw:hasEntitySource ?EntitySource .
    ?Entity foundation:hasName ?EntityName .
    ?Entity foundation:hasID ?EntityID .
}
```

## Example – Querying (as Grading)

Global Product Data Interoperability Summit | 2023

List all entities, their IDs and their sources:

```
SELECT DISTINCT ?EntityName ?EntityID ?EntitySource
WHERE {
  ?Entity sw:hasEntitySource ?EntitySource .
  ?Entity foundation:hasName ?EntityName .
  ?Entity foundation:hasID ?EntityID .
}
```



Entity Name	Entity ID	Entity Source
Payload Assembly	991-00003	Duro
Arizona Sat	999-00051	Duro
CDH Assembly	991-00002	Duro
Propulsion System	910-00002	Duro
ADCS	991-00004	Duro
Solar Panel Assembly	910-00001	Duro
Propulsion	AZSAT-PROP-1	Jama
ADCS Subsystem Pointing	AZSAT-ADCS-1	Jama
Power Generation	AZSAT-POWER-1	Jama



## Example – Querying (as Grading)

Global Product Data Interoperability Summit | 2023

List all components, their descriptions and their masses:

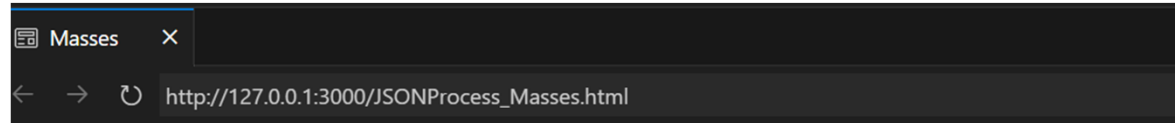
```
SELECT DISTINCT ?SystemName ?SystemDescription ?MassValue ?MassUnit
WHERE {
  ?System a sa:System .
  ?System foundation:hasName ?SystemName .
  ?System foundation:hasNaturalLanguageDescription ?SystemDescription .
  ?SystemMass a meas:Quantity .
  ?SystemMass foundation:specificallyDependentOn ?System .
  ?SystemMassMeasurement a meas:SimpleMeasurement .
  ?SystemMassMeasurement meas:measurementOf ?SystemMass .
  ?SystemMassMeasurement meas:hasValue ?MassValue .
  ?SystemMassMeasurement meas:hasUnit ?MassUnit .
}
ORDER BY ASC (?SystemName)
```

## Example – Querying (as Grading)

Global Product Data Interoperability Summit | 2023

List all components, their descriptions and their masses:

```
SELECT DISTINCT ?SystemName ?SystemDescription ?MassValue ?MassUnit
WHERE {
  ?System a sa:System .
  ?System foundation:hasName ?SystemName .
  ?System foundation:hasNaturalLanguageDescription ?SystemDescription .
  ?SystemMass a meas:Quantity .
  ?SystemMass foundation:specificallyDependentOn ?System .
  ?SystemMassMeasurement a meas:SimpleMeasurement .
  ?SystemMassMeasurement meas:measurementOf ?SystemMass .
  ?SystemMassMeasurement meas:hasValue ?MassValue .
  ?SystemMassMeasurement meas:hasUnit ?MassUnit .
}
ORDER BY ASC (?SystemName)
```



Component Name	Component Description	Component Mass	Mass Unit
ADCS	ADCS for University of Arizona satellite	100	kilogram
Arizona Sat	University of Arizona satellite	175255	kilogram
CDH Assembly	CDH assembly for University of Arizona satellite	30000	kilogram
Payload Assembly	Payload assembly for University of Arizona satellite	85050	kilogram
Propulsion System	Propulsion system for University of Arizona satellite	105	kilogram
Solar Panel Assembly	Solar panel assembly for University of Arizona satellite	60000	kilogram

## Example – Querying (as Grading)

Global Product Data Interoperability Summit | 2023

List all requirements and the entities that satisfy them:

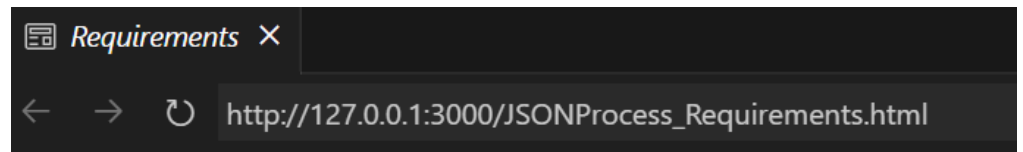
```
SELECT DISTINCT ?ReqID ?ReqName ?SystemName
WHERE {
  ?Requirement a req:Requirement .
  ?Requirement foundation:hasID ?ReqID .
  ?Requirement foundation:hasName ?ReqName .
  ?Requirement req:isSatisfiedBy ?System .
  ?System foundation:hasName ?SystemName .
}
```

## Example – Querying (as Grading)

Global Product Data Interoperability Summit | 2023

List all requirements and the entities that satisfy them:

```
SELECT DISTINCT ?ReqID ?ReqName ?SystemName
WHERE {
  ?Requirement a req:Requirement .
  ?Requirement foundation:hasID ?ReqID .
  ?Requirement foundation:hasName ?ReqName .
  ?Requirement req:isSatisfiedBy ?System .
  ?System foundation:hasName ?SystemName .
}
```



Requirement ID	Requirement Name	Satisfied By
AZSAT-PROP-1	Propulsion	Propulsion System
AZSAT-ADCS-1	ADCS Subsystem Pointing	ADCS
AZSAT-POWER-1	Power Generation	Solar Panel Assembly

## Future Work

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We are at the beginning of this journey!

- We have tools ready to go:    **GitLab** 
- Others will be online soon:   **MathWorks**  **Visual Studio**
- And we are in the process of developing the automation pipelines
  - Elaborating use cases: change management, consistency checking, student submission.
  - Reviewing IncQuery.

We are interested in your **use cases**!

- What would **you** like your future engineering grads to have experience with?
- How can we use the DEF to provide those opportunities?

## Lessons Learned

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- Selection of hub 'type' and data representation is key
  - Are you interested in workflows?
  - Are you interested in mappings?
  - Are you interested in translations?
- Not all of the *n* connections are necessary
  - Leverage existing connections
  - OpenMBEE, Plug-ins, Repositories
- Tool selection criteria
  - Open-source?
  - License availability?
  - Existing integrations with other tools to be exploited?
- HW Considerations
  - Implement locally, or use a service?
  - Data volume, port requirements, etc. impacts configuration

## Acknowledgments

Global Product Data Interoperability Summit | 2023

- This material has been produced using funds provided by the *Arizona Technology and Research Initiative Fund*
  
- Violet Labs
  - for continued support of the DEF project
  - [www.violetlabs.com](http://www.violetlabs.com)
  - [hello@violetlabs.com](mailto:hello@violetlabs.com)
  
- UA IT Team
  - for continued work on hardware configuration
  
- UA SFWE Students
  - for continued work on DEF development

## References

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**Thank you.  
Questions?**

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