



SARATECH

Interface Document Generation and Linkage to PLM BOM

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Abstract

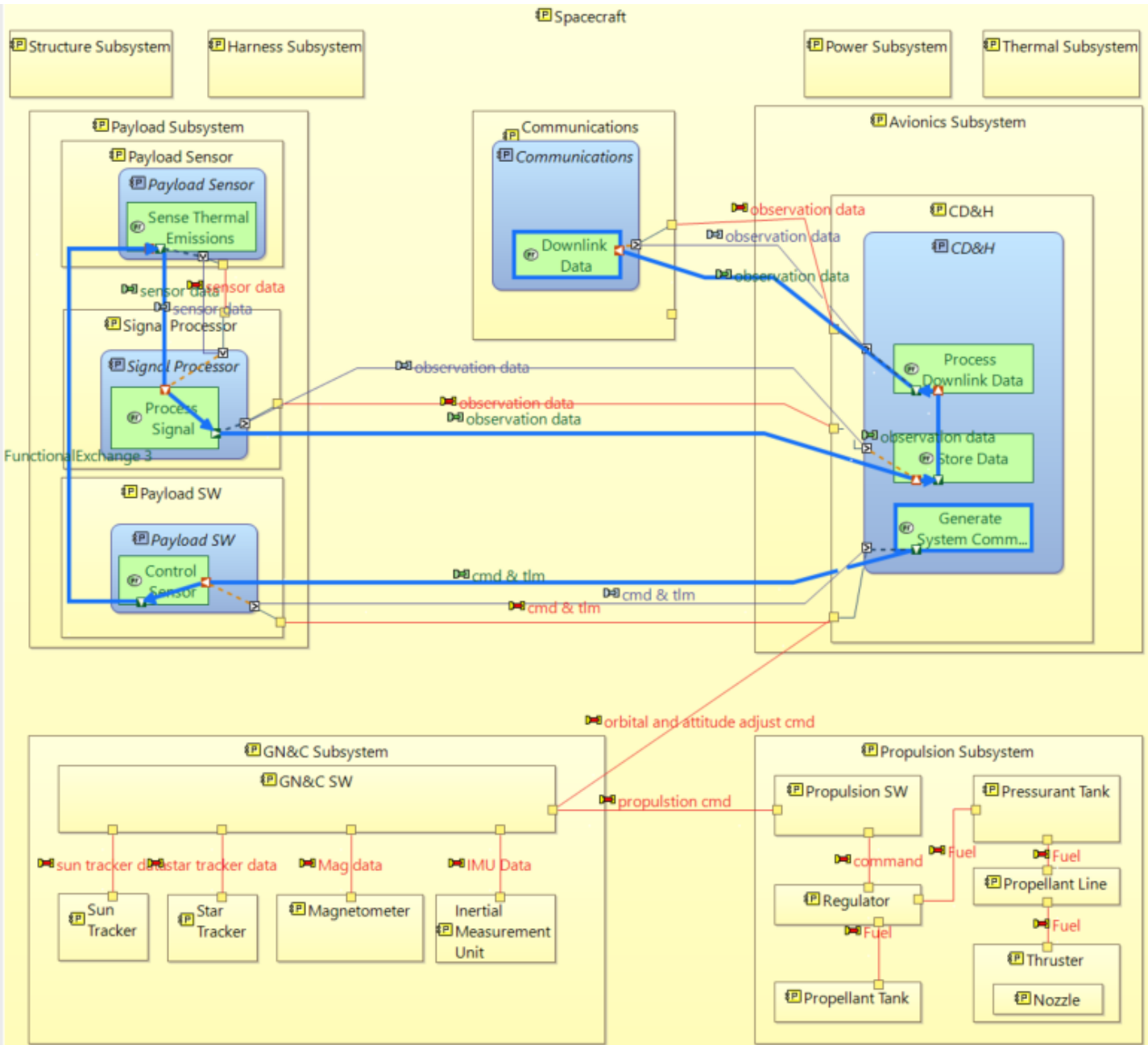
Interface Control Document Generation and Linkage to PLM EBOM

Generation of Interface Control Documents (ICDs) using a model-based method has a number of advantages over text-based approaches. This paper describes the Python-based software that was written to automatically generate different versions of an ICD from a structure model in Capella. One use case for this approach is checking parts changes captured in the Engineering Bill of Materials (EBOM) using a PLM tool. We demonstrate an automated workflow that links changes in the EBOM to a request to vet the change against the ICD. This presentation will discuss our rationale, approach, results, and lessons learned.

Outline

- I. MBSE Definition**
- II. MBSE and Interface Control Visualization**
- III. Generating Interface Control Documents from the model**
 - A. Selection of technologies**
 - A. M2Doc**
 - B. Py-capella**
 - B. Extracting interface information**
 - C. Solution Architecture**
- IV. Linking BOM changes with Interface Control**
 - A. Motivation: example workflow**
 - B. Linkage approaches**
 - C. Implementation**
- V. Status and Next Steps**
- VI. Lessons Learned**

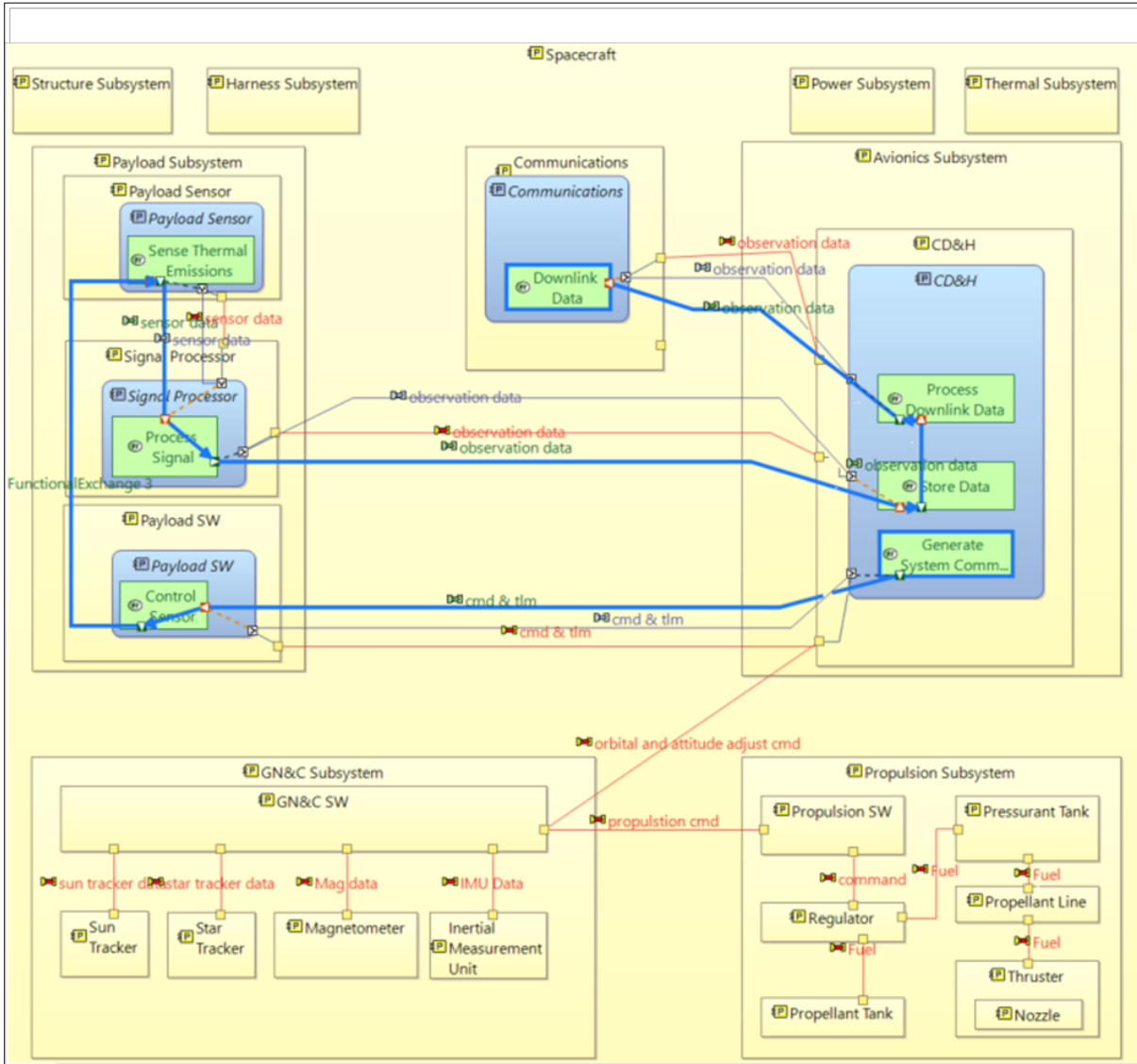
Models: Engineers already create diagrams with useful information for systems engineering



- **Subsystems and components shown**
 - Guidance, Navigation, & Control (GN&C)
 - Propulsion
 - Payload
 - Avionics with Command & Data Handling (C&DH)
 - ...
- **Interfaces captured**
 - Command and telemetry (cmd & tlm) link
 - Fuel link
 - GN&C sensor links (ex: sun tracker)
 - ...
- **Key functions and data exchanges identified**
 - Sense thermal emissions and sensor data
 - Process signal and observation data
 - Control sensor and cmd & tlm data
 - Generate system commands with orbital adjust cmd
 - ...
- **Scenarios captured (collect payload sensor data)**

Interfaces

Generally best *visualized* using diagrams and tables...



	parent	component	physical_ports	physical_links	exchanges
0	Avionics Subsystem	CD&H	cmd&tlm, i/f	orbital and attitude adjust cmd	
1	Avionics Subsystem	CD&H	observation data	observation data	observation data
2	Avionics Subsystem	CD&H	mission data, i/f	observation data	
3	Avionics Subsystem	CD&H	cmd&tlm, i/f	cmd & tlm	cmd & tlm
4	GN&C Subsystem	GN&C SW	cmd & tlm, i/f	propulsion cmd	
5	GN&C Subsystem	GN&C SW	cmd & tlm, i/f	orbital and attitude adjust cmd	
6	GN&C Subsystem	GN&C SW	PP_2	sun tracker data	
7	GN&C Subsystem	GN&C SW	PP_3	star tracker data	
8	GN&C Subsystem	GN&C SW	PP_4	Mag data	
9	GN&C Subsystem	GN&C SW	PP_5	IMU Data	
10	GN&C Subsystem	Magnetometer	PP_1	Mag data	
11	GN&C Subsystem	Sun Tracker	PP_1	sun tracker data	
12	GN&C Subsystem	Star Tracker	PP_1	star tracker data	
13	GN&C Subsystem	Inertial Measurement	PP_1	IMU Data	
14	Payload Subsystem	Payload Sensor	PP_1	sensor data	sensor data
15	Payload Subsystem	Signal Processor	observation data	observation data	observation data
16	Payload Subsystem	Payload SW	cmd&tlm, i/f	cmd & tlm	cmd & tlm
17	Payload Subsystem	Signal Processor	PP_1	sensor data	sensor data
18	Propulsion Subsystem	Pressurant Tank	PP_1	Fuel	
19	Propulsion Subsystem	Pressurant Tank	PP_2	Fuel	
20	Propulsion Subsystem	Propulsion SW	PP_1	command	
21	Propulsion Subsystem	Propellant Line	PP_2	Fuel	
22	Propulsion Subsystem	Thruster	PP_2	Fuel	
23	Propulsion Subsystem	Regulator	PP_3	command	
24	Propulsion Subsystem	Regulator	PP_2	Fuel	
25	Propulsion Subsystem	Regulator	PP_1	Fuel	
26	Propulsion Subsystem	Propulsion SW	cmd & tlm, i/f	propulsion cmd	
27	Propulsion Subsystem	Propellant Tank	PP_1	Fuel	
28	Propulsion Subsystem	Propellant Line	PP_1	Fuel	

Diagram created using data from: "Architecting Spacecraft with SysML" by Friedenthal and Oster

Interfaces

...but are usually *controlled* using Interface Control Documents (ICDs)

Actions that require less effort in diagrams and tables vs text ICDs:

1. Verifying completeness
2. Checking for mismatches
3. Capturing additions/modifications

Text ICDs are still needed for:

4. Viewing detailed specifications (power, dimensions, forces, etc.)
5. Combining text, diagrams, and tables
6. Common format (pdf) for version-controlled transmission to all stakeholders

Need: Visualization & analysis with detail & control

Interface Control Document: Spacecraft

Section 1.0 Avionics Subsystem

Subsection 1.1 CD&H Component

Physical Link: orbital and attitude adjust cmd

Exchange Item: <NONE>

Port: cmd&tlm i/f

Interfacing components:

- GN&C SW via the port: cmd & tlm i/f

Subsection 1.2 CD&H Component

Physical Link: cmd & tlm

Exchange Item: cmd

Port: cmd&tlm i/f

Interfacing components:

- Payload SW via the port: cmd&tlm i/f

Subsection 1.3 CD&H Component

Physical Link: observation data

Exchange Item: <NONE>

Port: mission data i/f

Interfacing components:

- Communications Subsystem via the port: mission data i/f

Subsection 1.4 CD&H Component

Physical Link: observation data

Exchange Item: <NONE>

Port: observation data i/f

Interfacing components:

- Signal Processor via the port: observation data i/f

Subsection 1.5 CD&H Component

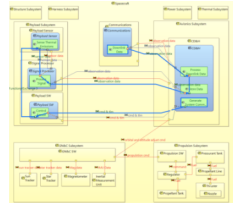
Physical Link: cmd & tlm

Exchange Item: tlm

Port: cmd&tlm i/f

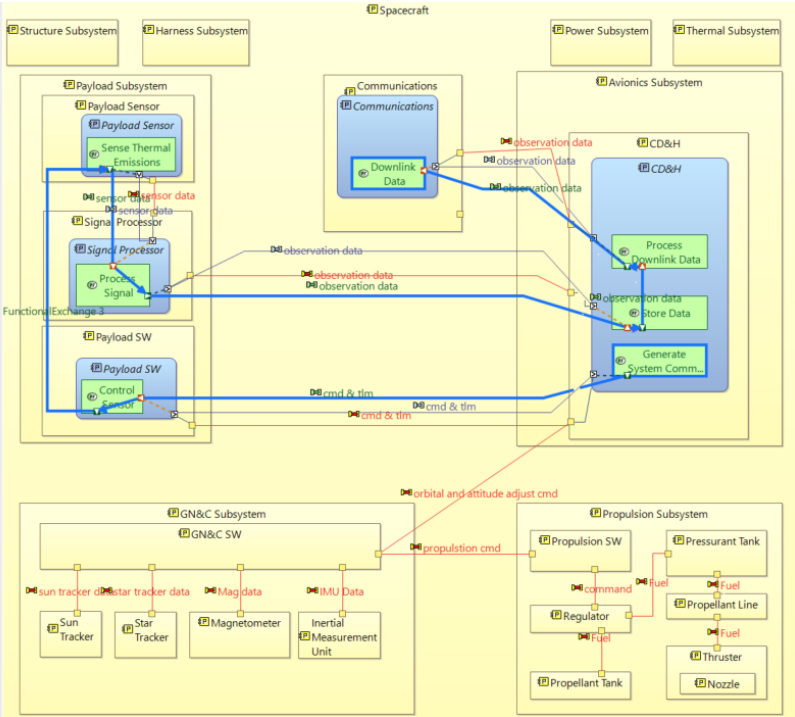
Interfacing components:

- Payload SW via the port: cmd&tlm i/f

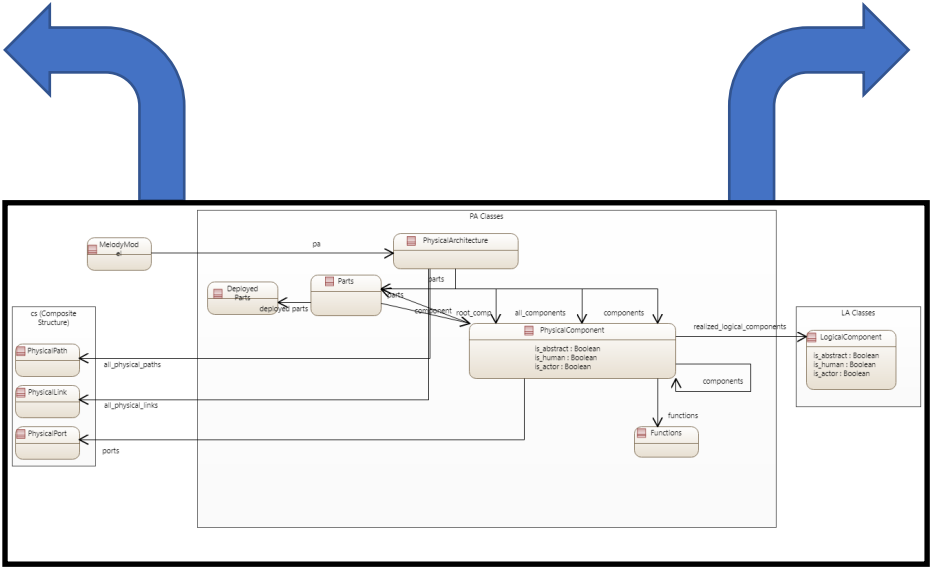


MBSE for Interface Control

In the model-based approach, the diagrams are models captured by an underlying data model. **The data model is the master.** Documents and views are generated from the data model.



View



Data Model = Master

Interface Control Document: Spacecraft

Section 1.0 Avionics Subsystem

Subsection 1.1 CD&H Component
Physical Link: orbital and attitude adjust cmd
Exchange Item: <NONE>
Port: cmd&tlm i/f
Interfacing components:

- GN&C SW via the port: cmd & tlm i/f

Subsection 1.2 CD&H Component
Physical Link: cmd & tlm
Exchange Item: cmd
Port: cmd&tlm i/f
Interfacing components:

- Payload SW via the port: cmd&tlm i/f

Subsection 1.3 CD&H Component
Physical Link: observation data
Exchange Item: <NONE>
Port: mission data i/f
Interfacing components:

- Communications Subsystem via the port: mission data i/f

Subsection 1.4 CD&H Component
Physical Link: observation data
Exchange Item: <NONE>
Port: observation data i/f
Interfacing components:

- Signal Processor via the port: observation data i/f

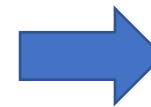
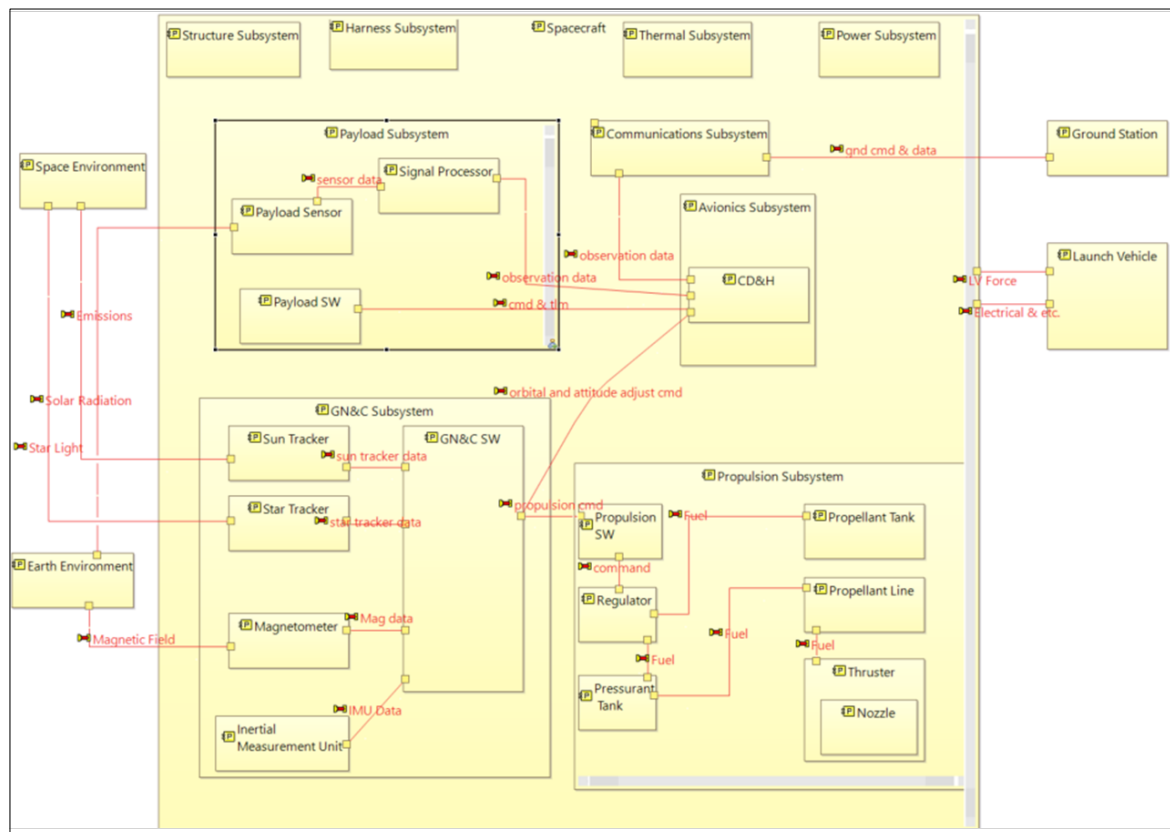
Subsection 1.5 CD&H Component
Physical Link: cmd & tlm
Exchange Item: tlm
Port: cmd&tlm i/f
Interfacing components:

- Payload SW via the port: cmd&tlm i/f

Text Document

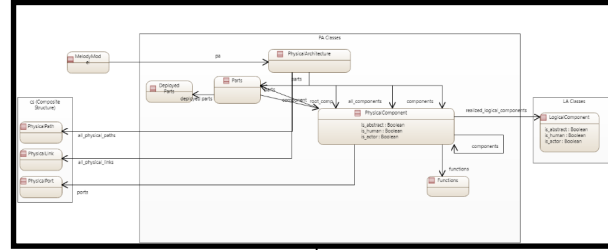
Benefits of MBSE for Interface Control

Action/Check	How addressed
Verifying completeness	Visual check can be trusted, since the views are derived from the model, which is the master. Can also validate algorithmically for data not on the diagram (ex: specifications).
Identifying mismatches	Can validate algorithmically vs manual text comparison
Capturing additions/modifications	See addition of external interfaces example below. Subsystem and interface updates in the model are automatically generated in the ICD, no manual updating required.



Section 6.0 Mission System	
Subsection 6.1 Ground Station Component	Physical Link: gnd cmd & data Exchange Item: <NONE> Port: PP,1 Interfacing components: Communications Subsystem via the port: PP,3;
Subsection 6.2 Spacecraft Component	Physical Link: Electrical & etc. Exchange Item: <NONE> Port: LV electrical i/f Interfacing components: Launch Vehicle via the port: PP,2
Subsection 6.3 Launch Vehicle Component	Physical Link: Electrical & etc. Exchange Item: <NONE> Port: PP,2 Interfacing components: Spacecraft via the port: LV electrical i/f
Subsection 6.4 Earth Environment Component	Physical Link: Magnetic Field Exchange Item: <NONE> Port: PP,1 Interfacing components: Magnetometer via the port: PP,2
Subsection 6.5 Space Environment Component	Physical Link: Star Light Exchange Item: <NONE> Port: PP,2 Interfacing components: Star Tracker via the port: PP,2
Subsection 6.6 Space Environment Component	Physical Link: Solar Radiation Exchange Item: <NONE> Port: PP,1 Interfacing components: Sun Tracker via the port: PP,2

Example benefit: generating multiple consistent ICD variations from one data model (requires code!)



By subsystem

Section 1.0 Avionics Subsystem

Subsection 1.1 CD&H Component

Physical Link: observation data

Exchange Item: <NONE>

Port: observation data i/f

Interfacing components:

- Signal Processor via the port: observation data i/f

Subsection 1.2 CD&H Component

Physical Link: observation data

Exchange Item: <NONE>

Port: mission data i/f

Interfacing components:

- Communications Subsystem via the port: mission data i/f

Subsection 1.3 CD&H Component

Physical Link: cmd & tlm

Exchange Item: cmd

Port: cmd&tlm i/f

Interfacing components:

- Payload SW via the port: cmd&tlm i/f

Subsection 1.4 CD&H Component

Physical Link: cmd & tlm

Exchange Item: tlm

Port: cmd&tlm i/f

Interfacing components:

- Payload SW via the port: cmd&tlm i/f

Subsection 1.5 GN&C SW Component

Physical Link: propulsion cmd

Exchange Item: <NONE>

Port: cmd & tlm i/f

Interfacing components:

- Propulsion SW via the port: cmd & tlm i/f

By interface

Section 1.0 IMU Data

- GN&C SW Component exchanging item: <NONE>
- Inertial Measurement Unit Component exchanging item: <NONE>

Section 2.0 sensor data

- Payload Sensor Component exchanging item: <NONE>
- Signal Processor Component exchanging item: <NONE>

Section 3.0 Fuel

- Thruster Component exchanging item: <NONE>
- Propellant Line Component exchanging item: <NONE>

Section 4.0 Mag data

- Magnetometer Component exchanging item: <NONE>
- GN&C SW Component exchanging item: <NONE>

Section 5.0 Fuel

- Pressurant Tank Component exchanging item: <NONE>
- Regulator Component exchanging item: <NONE>

Table

	parent	component	physical_ports	physical_links	exchanges
0	Avionics Subsystem	CD&H	cmd&tlm i/f	orbital and attitude adjust cmd	
1	Avionics Subsystem	CD&H	observation data	observation data	observation data
2	Avionics Subsystem	CD&H	mission data i/f	observation data	
3	Avionics Subsystem	CD&H	cmd&tlm i/f	cmd & tlm	cmd & tlm
4	GN&C Subsystem	GN&C SW	cmd & tlm i/f	propulsion cmd	
5	GN&C Subsystem	GN&C SW	cmd & tlm i/f	orbital and attitude adjust cmd	
6	GN&C Subsystem	GN&C SW	PP 2	sun tracker data	
7	GN&C Subsystem	GN&C SW	PP 3	star tracker data	
8	GN&C Subsystem	GN&C SW	PP 4	Mag data	
9	GN&C Subsystem	GN&C SW	PP 5	IMU Data	
10	GN&C Subsystem	Magnetometer	PP 1	Mag data	
11	GN&C Subsystem	Sun Tracker	PP 1	sun tracker data	
12	GN&C Subsystem	Star Tracker	PP 1	star tracker data	
13	GN&C Subsystem	Inertial Measurement	PP 1	IMU Data	
14	Payload Subsystem	Payload Sensor	PP 1	sensor data	sensor data
15	Payload Subsystem	Signal Processor	observation data	observation data	observation data
16	Payload Subsystem	Payload SW	cmd&tlm i/f	cmd & tlm	cmd & tlm
17	Payload Subsystem	Signal Processor	PP 1	sensor data	sensor data
18	Propulsion Subsystem	Pressurant Tank	PP 1	Fuel	
19	Propulsion Subsystem	Pressurant Tank	PP 2	Fuel	
20	Propulsion Subsystem	Propulsion SW	PP 1	command	
21	Propulsion Subsystem	Propellant Line	PP 2	Fuel	
22	Propulsion Subsystem	Thruster	PP 2	Fuel	
23	Propulsion Subsystem	Regulator	PP 3	command	
24	Propulsion Subsystem	Regulator	PP 2	Fuel	
25	Propulsion Subsystem	Regulator	PP 1	Fuel	
26	Propulsion Subsystem	Propulsion SW	cmd & tlm i/f	propulsion cmd	
27	Propulsion Subsystem	Propellant Tank	PP 1	Fuel	
28	Propulsion Subsystem	Propellant Line	PP 1	Fuel	

Generating ICDs from the Model



OVERVIEW DOWNLOAD GET STARTED GET INVOLVED DOCUMENTATION SUPPORT FAQ

OVERVIEW

The M2Doc project provides Word document (.docx files) generation based on a document template and EMF models.

The overall approach consists in creating templates in the OOXML format where static text authoring benefits from the WYSIWYG capabilities of Microsoft Word. Dynamic parts are inserted using a dedicated vocabulary of OOXML fields code. Fields are mainly used to insert page numbers, references, etc. M2Doc makes use of them to describe documentation generation directives. This allows a total separation between the document and the M2Doc directives.



<https://www.m2doc.org/>

Python Capella MBSE Tools

code style: black

Date: Nov 01, 2022 **Version:** 0.5.4.dev8

Description

This library was designed to enable and support Model Based System Engineering using Polarsys' [Capella](#) with Python. Common usage for this API:

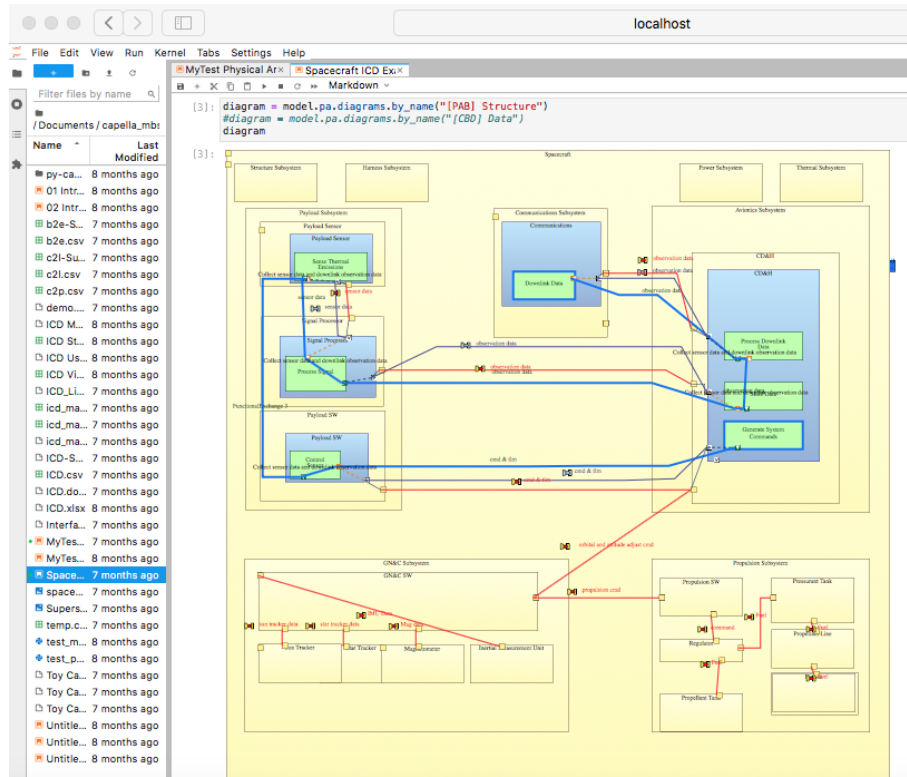
- parsing .aird files
- easy access to model elements and objects
- property-value access and manipulation
- diagram access and export as SVG

Additionally and as a core idea it provides an interface for the underlying database of the Capella model.

Since v0.5, it also supports a simple, but powerful [declarative modelling language](#), which is based on the API for the semantic model.

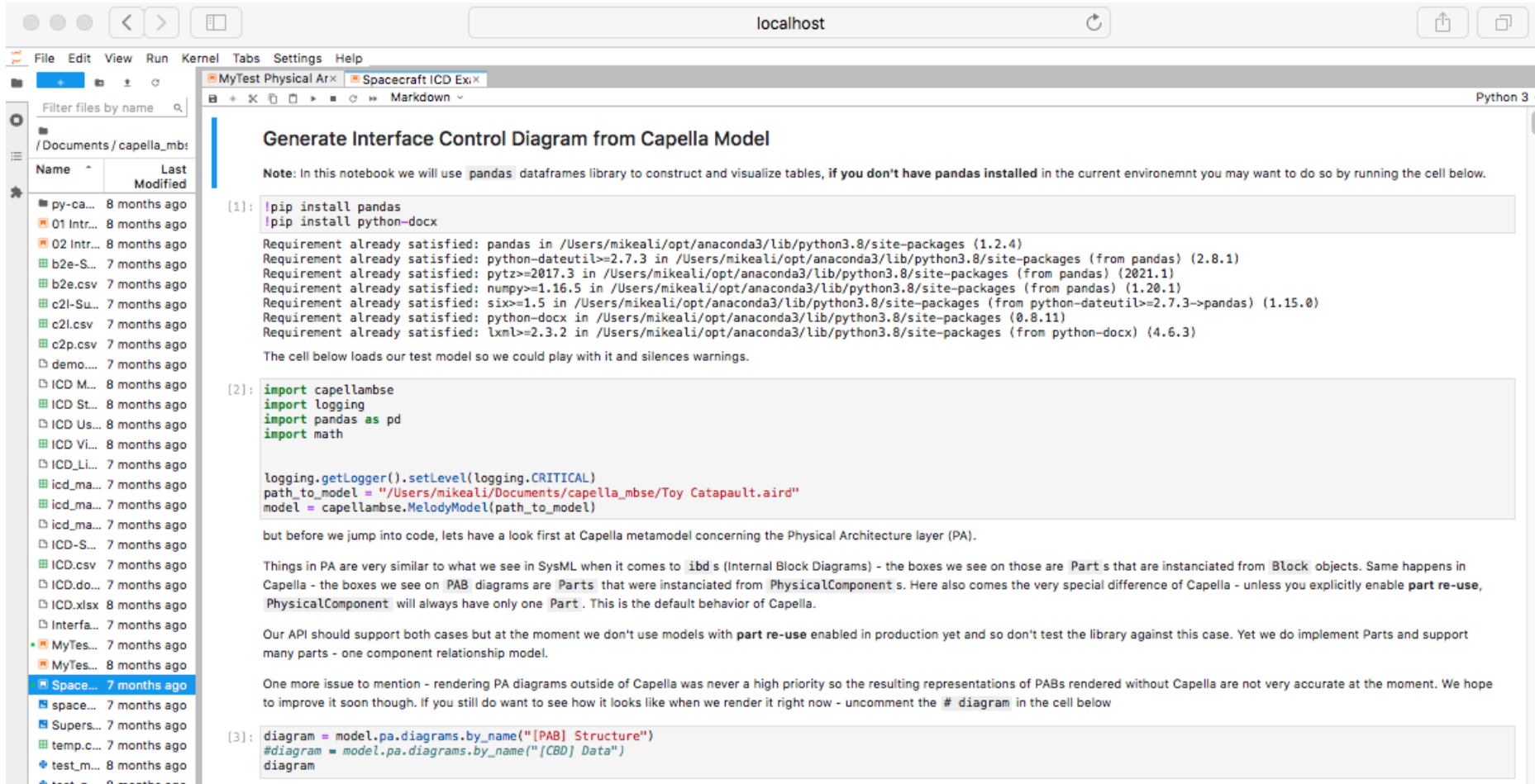
<https://dsd-dbs.github.io/py-capellambse/>

Generating ICDs from the Model



	parent	component	nature	physical_ports	physical_ports_uid	exchanges	exchange_items	physical_links	physical_links_uid	exchanges_uid
0	Avionics Subsystem	CD&H	NODE	cmd&tlm i/f	62ba879f-5add-404c-a1c2-082788f0eef2		NaN	orbital and attitude adjust cmd	5e83d465-6e9a-4aaf-9554-587f5e337d8c	
1	Avionics Subsystem	CD&H	NODE	cmd&tlm i/f	62ba879f-5add-404c-a1c2-082788f0eef2	cmd & tlm	cmd	cmd & tlm	feb4170-a4d0-40e7-8c96-3c216207aeb9	3392ff80-4a29-4912-a1e1-5f040b7e3a08
2	Avionics Subsystem	CD&H	NODE	mission data i/f	12d48384-4300-49f8-a1e5-f1d64b13e71f		NaN	observation data	bc887c9d-9b29-4511-8ec2-efcc4fc127b7	
3	Avionics Subsystem	CD&H	NODE	observation data i/f	0a3271b6-5bd6-41a0-ad8e-e02cc657a3e9	observation data	NaN	observation data	4eacaafe-994d-4996-ba41-5e7f5afd0ba3	e66bc4f5-eb73-4473-84f6-9ccc2bb1efd5
47	Avionics Subsystem	CD&H	NODE	cmd&tlm i/f	62ba879f-5add-404c-a1c2-082788f0eef2	cmd & tlm	tlm	cmd & tlm	feb4170-a4d0-40e7-8c96-3c216207aeb9	3392ff80-4a29-4912-a1e1-5f040b7e3a08
16	GN&C Subsystem	GN&C SW	NODE	pp 4	15b7c0f9-34bf-469e-9c9a-028df0230a6d		NaN	Mag data	28124912-6df8-441e-aa42-100d62c6272f	
15	GN&C Subsystem	GN&C SW	NODE	pp 3	9fcacb89-4227-4a6b-830b-83374dc48f26		NaN	star tracker data	9a837ffd-ec39-4417-83dc-0abbd6f15345	
14	GN&C Subsystem	GN&C SW	NODE	pp 2	2030be3c-ccc4-44af-aaef-ab8771c0bba2		NaN	sun tracker data	b02b7e6e-b9d3-4177-91dc-ccaa69c6c3d	
13	GN&C Subsystem	GN&C SW	NODE	cmd & tlm i/f	9fd40cce-1ca6-4da1-9e1b-ccdfe15135b		NaN	orbital and attitude adjust cmd	5e83d465-6e9a-4aaf-9554-587f5e337d8c	
12	GN&C Subsystem	GN&C SW	NODE	pp 5	7281133a-5fcc-4ea9-9e29-36c641e69ee7		NaN	IMU Data	00302f69-5b41-498b-b5ab-d42ffdd3661c	
11	GN&C Subsystem	Sun Tracker	NODE	pp 2	d95e93fa-dd05-414b-be97-06c0ae041838		NaN	Solar Radiation	11521a16-5130-403f-a59e-2197cc51e244	
9	GN&C Subsystem	Magnetometer	NODE	pp 2	6fe35bb6-2492-47aa-8875-a66e434abbe9		NaN	Magnetic Field	51592b48-b056-4b38-9a1b-6b2a71c8b758	
8	GN&C Subsystem	Sun Tracker	NODE	pp 1	c64aa2b4-caf1-43cd-8069-c8baa9b6c98a		NaN	sun tracker data	b02b7e6e-b9d3-4177-91dc-ccaa69c6c3d	
7	GN&C Subsystem	GN&C SW	NODE	cmd & tlm i/f	9fd40cce-1ca6-4da1-9e1b-ccdfe15135b		NaN	propulsion cmd	7f784ba2-158e-43e4-a1a5-1abe31b0593b	
6	GN&C Subsystem	Inertial Measurement Unit	NODE	pp 1	5bb6f13e-c014-4aad-88a1-effff99dfdb		NaN	IMU Data	00302f69-5b41-498b-b5ab-d42ffdd3661c	
5	GN&C Subsystem	Star Tracker	NODE	pp 1	e2327f3c-da16-4523-a40a-c5c434c162ea		NaN	star tracker data	9a837ffd-ec39-4417-83dc-0abbd6f15345	

Generating ICDs from the Model



The screenshot shows a Jupyter Notebook interface with a file browser on the left and a code editor on the right. The notebook is titled "Generate Interface Control Diagram from Capella Model".

Note: In this notebook we will use `pandas` dataframes library to construct and visualize tables, if you don't have `pandas` installed in the current environment you may want to do so by running the cell below.

```
[1]: !pip install pandas
     !pip install python-docx
```

Requirement already satisfied: pandas in /Users/mikeali/opt/anaconda3/lib/python3.8/site-packages (1.2.4)
Requirement already satisfied: python-dateutil>=2.7.3 in /Users/mikeali/opt/anaconda3/lib/python3.8/site-packages (from pandas) (2.8.1)
Requirement already satisfied: pytz>=2017.3 in /Users/mikeali/opt/anaconda3/lib/python3.8/site-packages (from pandas) (2021.1)
Requirement already satisfied: numpy>=1.16.5 in /Users/mikeali/opt/anaconda3/lib/python3.8/site-packages (from pandas) (1.20.1)
Requirement already satisfied: six>=1.5 in /Users/mikeali/opt/anaconda3/lib/python3.8/site-packages (from python-dateutil>=2.7.3->pandas) (1.15.0)
Requirement already satisfied: python-docx in /Users/mikeali/opt/anaconda3/lib/python3.8/site-packages (0.8.11)
Requirement already satisfied: lxml>=2.3.2 in /Users/mikeali/opt/anaconda3/lib/python3.8/site-packages (from python-docx) (4.6.3)

The cell below loads our test model so we could play with it and silences warnings.

```
[2]: import capellambse
     import logging
     import pandas as pd
     import math

     logging.getLogger().setLevel(logging.CRITICAL)
     path_to_model = "/Users/mikeali/Documents/capella_mbse/Toy Catapult.aird"
     model = capellambse.MeLOdyModel(path_to_model)
```

but before we jump into code, lets have a look first at Capella metamodel concerning the Physical Architecture layer (PA).

Things in PA are very similar to what we see in SysML when it comes to `ibds` (Internal Block Diagrams) - the boxes we see on those are `Part`s that are instantiated from `Block` objects. Same happens in Capella - the boxes we see on `PAB` diagrams are `Parts` that were instantiated from `PhysicalComponent`s. Here also comes the very special difference of Capella - unless you explicitly enable `part re-use`, `PhysicalComponent` will always have only one `Part`. This is the default behavior of Capella.

Our API should support both cases but at the moment we don't use models with `part re-use` enabled in production yet and so don't test the library against this case. Yet we do implement `Parts` and support many parts - one component relationship model.

One more issue to mention - rendering PA diagrams outside of Capella was never a high priority so the resulting representations of PABs rendered without Capella are not very accurate at the moment. We hope to improve it soon though. If you still do want to see how it looks like when we render it right now - uncomment the `# diagram` in the cell below

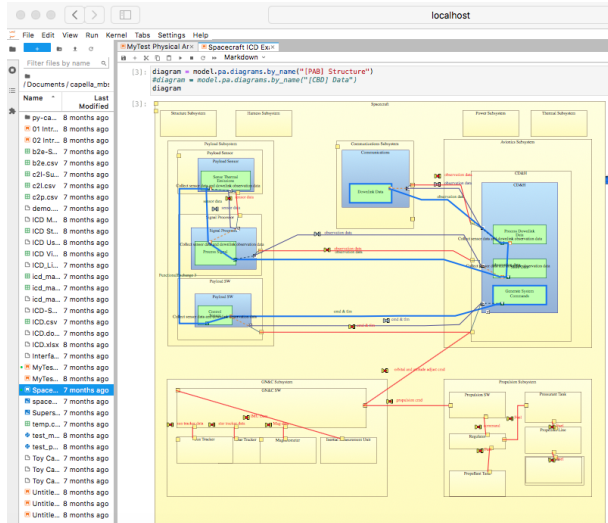
```
[3]: diagram = model.pa.diagrams.by_name("[PAB] Structure")
     #diagram = model.pa.diagrams.by_name("[CBD] Data")
     diagram
```

Generating ICDs from the Model

Read diagram

Convert diagram to table

Output table in desired format



parent	component	nature	physical_ports	physical_ports_uid	exchanges	exchange_items	physical_links	physical_links_uid	exchanges_uid
0	Avionics Subsystem	CD&H	NODE	cmd&tim i/f	62ba879f-5add-404c-a1c2-082789f0eef2		NaN	orbital and attitude adjust cmd	e6834465-6e9a-4aa1-9554-587f9a33708c
1	Avionics Subsystem	CD&H	NODE	cmd&tim i/f	62ba879f-5add-404c-a1c2-082789f0eef2	cmd & tim	cmd	cmd & tim	f0eb4170-a4d0-40e7-8c96-3c216207aeb9
2	Avionics Subsystem	CD&H	NODE	mission data i/f	12048384-4300-49f8-a1e5-f16c4b13e71f		NaN	observation data	bc887c9d-9b29-4511-8ec2-efcc4fc127b7
3	Avionics Subsystem	CD&H	NODE	observation data i/f	0a3271b6-0b08-41a0-a28e-4202c557a3a9	observation data	NaN	observation data	4eacacfe-994d-4996-8a41-5e1f68f02a3
47	Avionics Subsystem	CD&H	NODE	cmd&tim i/f	62ba879f-5add-404c-a1c2-082789f0eef2	cmd & tim	tim	cmd & tim	f0eb4170-a4d0-40e7-8c96-3c216207aeb9
16	GN&C Subsystem	GN&C SW	NODE	pp 4	10b7c0f9-346f-489a-0c9a-0289f0230a6d		NaN	Mag data	28124912-6d98-441e-aa42-100d62c8272f
15	GN&C Subsystem	GN&C SW	NODE	pp 3	9f0ccb89-4227-4a8b-830b-823746d48f5b		NaN	star tracker data	9a837f0c-ac39-4477-836c-9abbd6f16345
14	GN&C Subsystem	GN&C SW	NODE	pp 2	2030b3c-ccc4-44af-aaef-ab8771c0bba2		NaN	sun tracker data	b02b76e6-b9d3-4177-91dc-ccaa999c6c3d
13	GN&C Subsystem	GN&C SW	NODE	cmd & tim i/f	9f640cce-1ca6-4da1-9e1b-ccd9e10135b		NaN	orbital and attitude adjust cmd	e6834465-6e9a-4aa1-9554-587f9a33708c
12	GN&C Subsystem	GN&C SW	NODE	pp 5	7281133a-5fcc-4ea9-9e29-36c041e69ee7		NaN	IMU Data	00302f69-5b41-498b-b5ab-042f0d33661c
11	GN&C Subsystem	Sun Tracker	NODE	pp 2	d95e93fa-d905-414b-ba97-06c3a016358		NaN	Solar Radiation	11012a16-5130-403f-a59e-210cc016344
9	GN&C Subsystem	Magnetometer	NODE	pp 1	61e330b6-2492-47aa-8875-406443abb8e9		NaN	Magnetic Field	51562048-b056-4c38-9a1b-0a2a718bb708
8	GN&C Subsystem	Sun Tracker	NODE	pp 1	0644a2b4-caf1-43cd-8089-ca8ba965998a		NaN	sun tracker data	b02b76e6-b9d3-4177-91dc-ccaa999c6c3d
7	GN&C Subsystem	GN&C SW	NODE	cmd & tim i/f	9f640cce-1ca6-4da1-9e1b-ccd9e10135b		NaN	propulsion cmd	7f784ba2-198e-43e4-81a6-14b61616593b
6	GN&C Subsystem	Inertial Measurement Unit	NODE	pp 1	5bb6f13e-c014-4aad-98a1-efff99d9ff1b		NaN	IMU Data	00302f69-5b41-498b-b5ab-042f0d33661c
5	GN&C Subsystem	Star Tracker	NODE	pp 1	e2327f3c-da16-4523-a40a-c5c44c162ea		NaN	star tracker data	9a837f0c-ac39-4477-836c-9abbd6f16345

Section 1.0 Avionics Subsystem

Subsection 1.1 CD&H Component

Physical Link: observation data

Exchange Item: <NONE>

Port: observation data i/f

Interfacing components:

- Signal Processor via the port: observation data i/f

Subsection 1.2 CD&H Component

Physical Link: observation data

Exchange Item: <NONE>

Port: mission data i/f

Interfacing components:

- Communications Subsystem via the port: mission data i/f

Subsection 1.3 CD&H Component

Physical Link: cmd & tim

Exchange Item: cmd

Port: cmd&tim i/f

Interfacing components:

- Payload SW via the port: cmd&tim i/f

Subsection 1.4 CD&H Component

Physical Link: cmd & tim

Exchange Item: tim

Port: cmd&tim i/f

Interfacing components:

- Payload SW via the port: cmd&tim i/f

Subsection 1.5 GN&C SW Component

Physical Link: propulsion cmd

Exchange Item: <NONE>

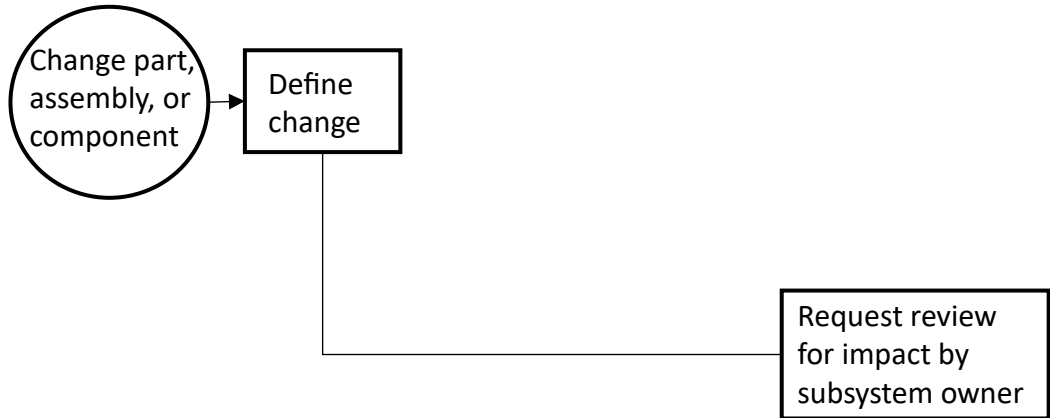
Port: cmd & tim i/f

Interfacing components:

- Propulsion SW via the port: cmd & tim i/f

Linking BOM changes to interface impact

Design Engineer

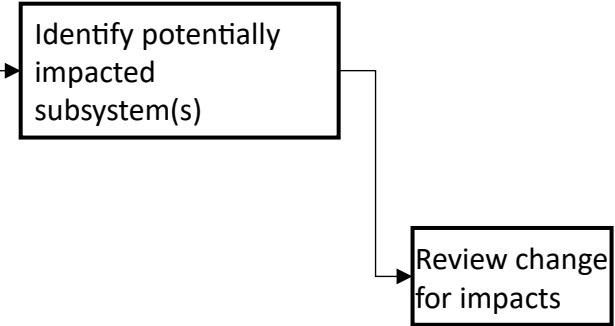


EBOM Tool (PLM)

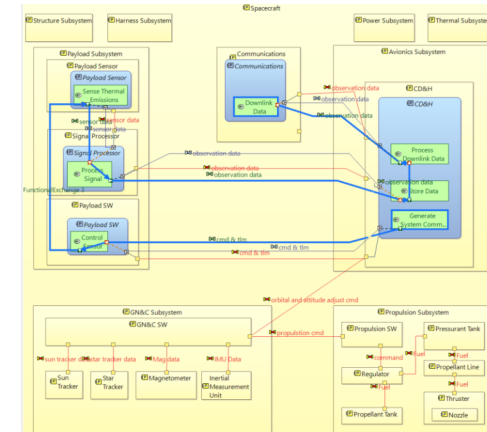
GEN000242/A/3-Spacecraft - Latest Working - Date = "Now"

BOM Line	Price /	Source of Material
GEN000242/A/3-Spacecraft		
GEN000243/A/2-GN&C Subsystem		
GEN000248/A/2-GN&C SW		
GEN000249/A/2-Sun Tracker		
GEN000250/A/2-Star Tracker		
GEN000251/A/2-Magnetometer		
GEN000252/A/2-Inertial Measurement Unit		
GEN000266/A/2-Ultimate Sensor Fusion Solution		
GEN000267/A/2-USB Cable		
GEN000244/A/2-Avionics Subsystem		
GEN000245/A/2-C&DH Assembly		
GEN000246/A/2-Main Logic		
GEN000247/A/2-MCU	\$14.36	Armel
GEN000257/A/2-Supervisor Circuit	\$3.86	Maxim
GEN000258/A/2-Real Time Clock	\$6.73	Dallas Semi
GEN000259/A/2-RS-232 Level Converter	\$0.90	Maxim
GEN000253/A/2-Memory	\$2.37	Armel
GEN000260/A/2-Memory	\$2.37	Armel
GEN000254/A/2-Power		
GEN000261/A/2-Power MOSFET	\$3.75	International Rectifier
GEN000255/A/2-Analog-to-Digital		
GEN000262/A/2-ADC	\$8.80	Texas Instruments
GEN000256/A/2-Sensors		
GEN000263/A/2-Thermistor	\$0.00	YSI
GEN000264/A/2-Current Sensor	\$1.88	Maxim
GEN000265/A/2-IDC Temperature Sensor	\$3.63	National Semi
GEN000268/A/2-Payload Subsystem		
GEN000274/A/2-Payload Sensor		
GEN000276/A/2-Signal Processor		
GEN000277/A/2-Payload SW		
GEN000269/A/2-Propulsion Subsystem		
GEN000278/A/2-Propulsion SW		
GEN000279/A/2-Pressurant Tank		

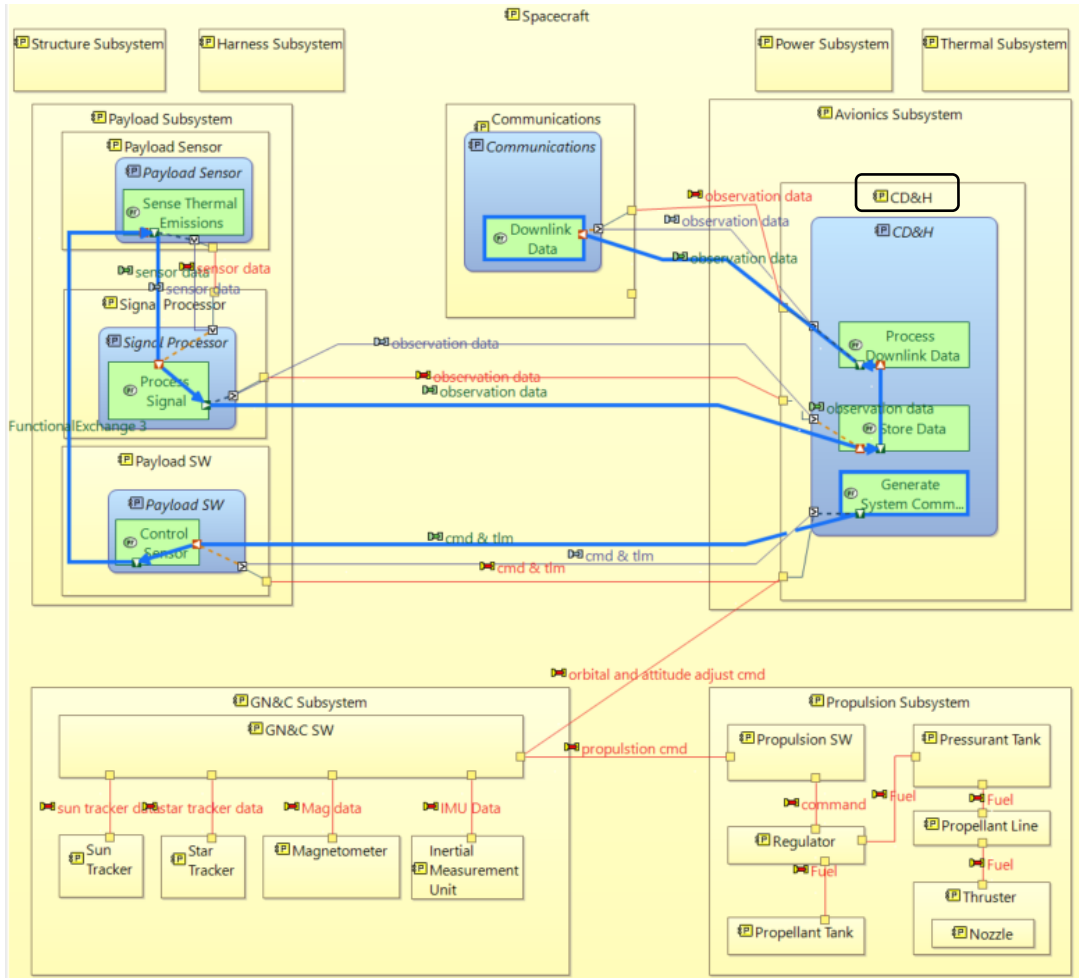
Systems Engineer (or ICD owner)



MBSE Tool



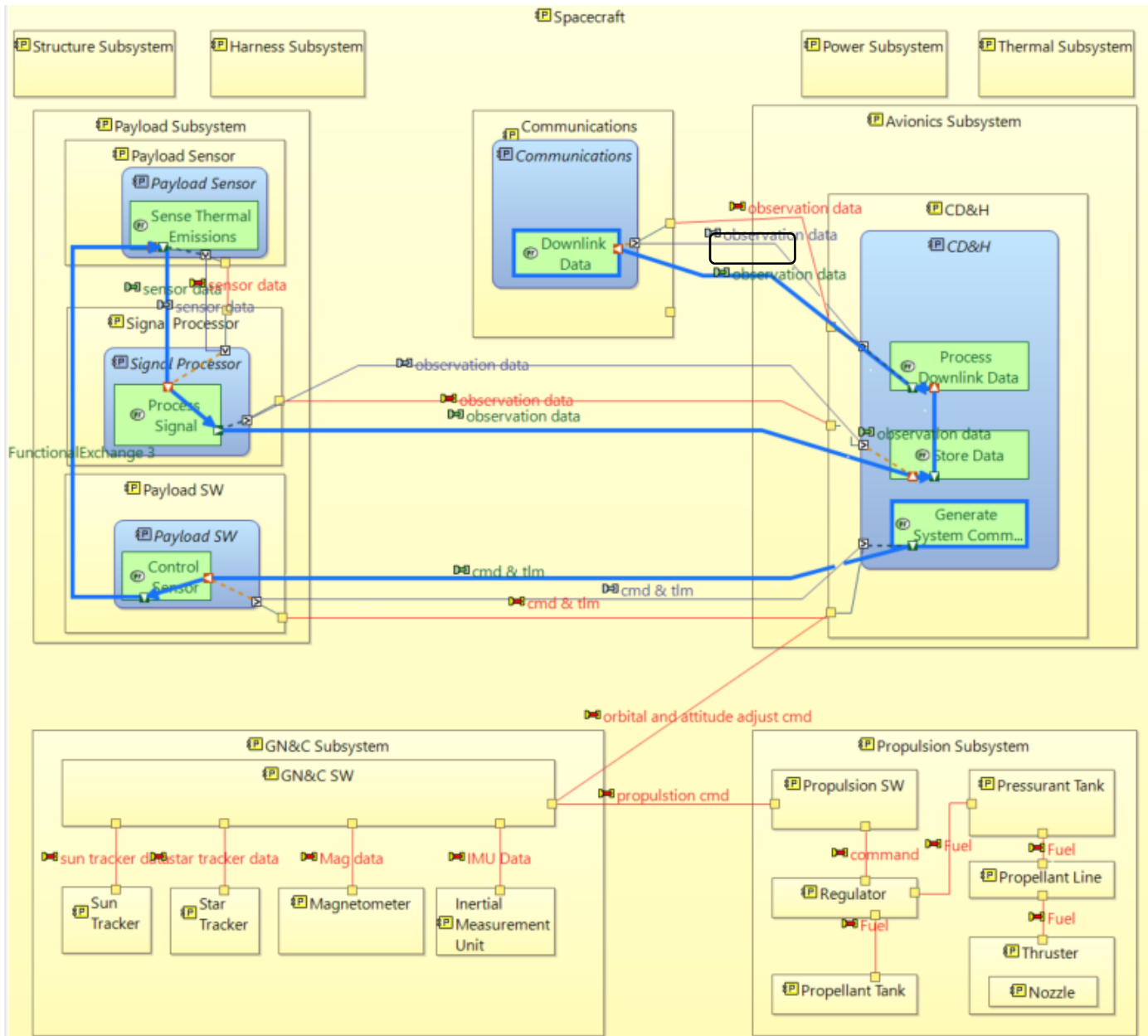
MBSE Model and EBOM



GEN000242/A;3-Spacecraft - Latest Working - Date - "Now"

BOM Line	Price /	Source of Material
GEN000242/A;3-Spacecraft		
GEN000243/A;2-GN&C Subsystem		
GEN000248/A;2-GN&C SW		
GEN000249/A;2-Sun Tracker		
GEN000250/A;2-Star Tracker		
GEN000251/A;2-Magnetometer		
GEN000252/A;2-Inertial Measurement Unit		
GEN000266/A;2-Ultimate Sensor Fusion Solution		
GEN000267/A;2-USB Cable		
GEN000244/A;2-Avionics Subsystem		
GEN000245/A;2-C&DH Assembly		
GEN000246/A;2-Main Logic		
GEN000247/A;2-MCU	\$14.36	Atmel
GEN000257/A;2-Supervisor Circuit	\$3.86	Maxim
GEN000258/A;2-Real Time Clock	\$6.73	Dallas Semi
GEN000259/A;2-RS-232 Level Converter	\$0.90	Maxim
GEN000253/A;2-Memory		
GEN000260/A;2-Memory	\$2.37	Atmel
GEN000254/A;2-Power		
GEN000261/A;2-Power MOSFET	\$3.75	Internation Rectifier
GEN000255/A;2-Analog-toDigital		
GEN000262/A;2-ADC	\$8.80	Texas Instruments
GEN000256/A;2-Sensors		
GEN000263/A;2-Thermistor	\$0.00	YSI
GEN000264/A;2-Current Sensor	\$1.88	Maxim
GEN000265/A;2-I2C Temperature Sensor	\$3.63	National Semi
GEN000268/A;2-Payload Subsystem		
GEN000275/A;2-Payload Sensor		
GEN000276/A;2-Signal Processor		
GEN000277/A;2-Payload SW		
GEN000269/A;2-Propulsion Subsystem		
GEN000278/A;2-Propulsion SW		
GEN000279/A;2-Pressurant Tank		

MBSE Model and EBOM



MBSE Model and EBOM

GEN000242/A;3-Spacecraft - Latest Working - Date - "Now"

BOM Line	Price /	Source of Material
GEN000242/A;3-Spacecraft		
GEN000243/A;2-GN&C Subsystem		
GEN000248/A;2-GN&C SW		
GEN000249/A;2-Sun Tracker		
GEN000250/A;2-Star Tracker		
GEN000251/A;2-Magnetometer		
GEN000252/A;2-Inertial Measurement Unit		
GEN000266/A;2-Ultimate Sensor Fusion Solution		
GEN000267/A;2-USB Cable		
GEN000244/A;2-Avionics Subsystem		
GEN000245/A;2-C&DH Assembly		
GEN000246/A;2-Main Logic		
GEN000247/A;2-MCU	\$14.36	Atmel
GEN000257/A;2-Supervisor Circuit	\$3.86	Maxim
GEN000258/A;2-Real Time Clock	\$6.73	Dallas Semi
GEN000259/A;2-RS-232 Level Converter	\$0.90	Maxim
GEN000253/A;2-Memory		
GEN000260/A;2-Memory	\$2.37	Atmel
GEN000254/A;2-Power		
GEN000261/A;2-Power MOSFET	\$3.75	Internation Rectifier
GEN000255/A;2-Analog-toDigital		
GEN000262/A;2-ADC	\$8.80	Texas Instruments
GEN000256/A;2-Sensors		
GEN000263/A;2-Thermistor	\$0.00	YSI
GEN000264/A;2-Current Sensor	\$1.88	Maxim
GEN000265/A;2-I2C Temperature Sensor	\$3.63	National Semi
GEN000268/A;2-Payload Subsystem		
GEN000275/A;2-Payload Sensor		
GEN000276/A;2-Signal Processor		
GEN000277/A;2-Payload SW		
GEN000269/A;2-Propulsion Subsystem		
GEN000278/A;2-Propulsion SW		
GEN000279/A;2-Pressurant Tank		

Connecting the EBOM to the ICD Model

- **Siemens approach (*tracelink*)**

- Siemens System Workbench tool-centric, tool only used by systems engineers
- High effort: systems engineer must create links between BOM and system model, one-by-one
- Tight coupling: requires the integrated Teamcenter/System Modeling Workbench setup

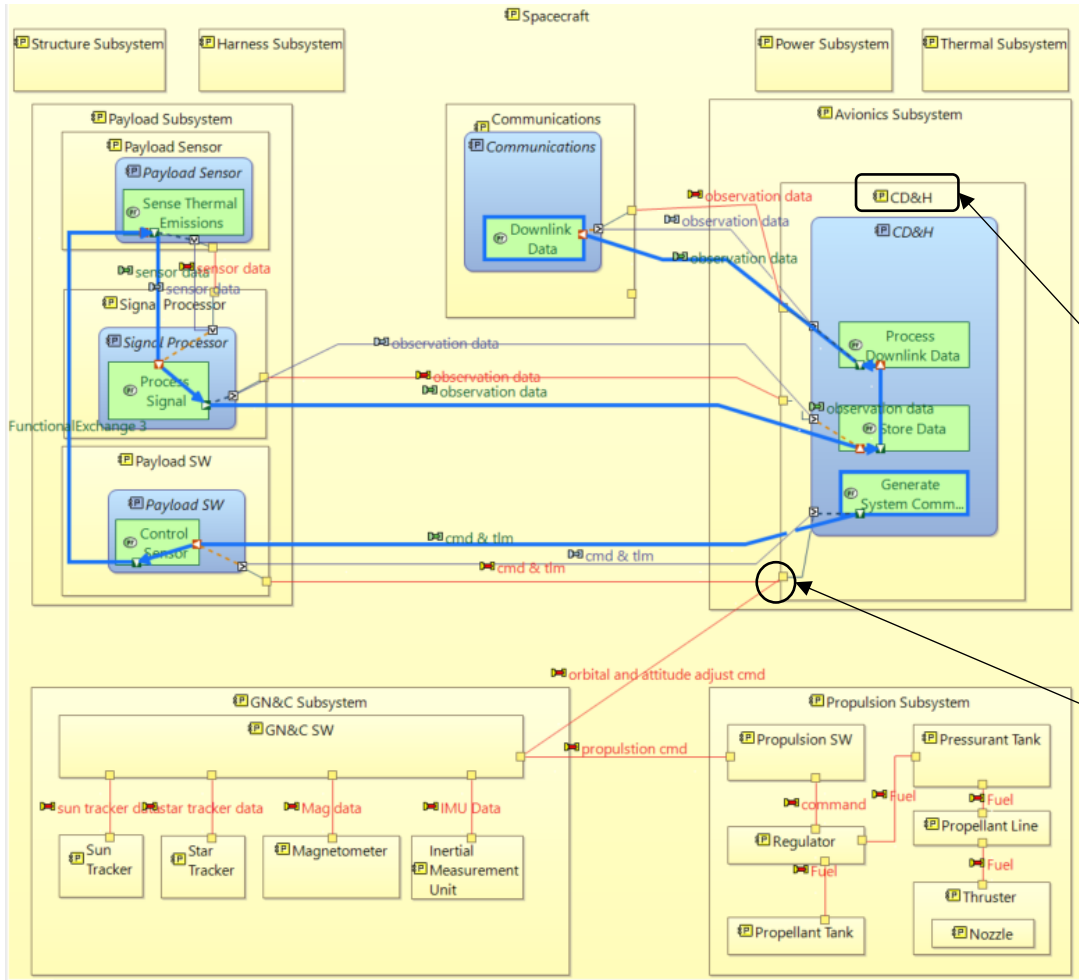
- **Saratech approach**

- Teamcenter-centric, tool used by most of the engineering team
- Low effort: filling attributes in a table, mostly cut and paste
- Leverages Teamcenter workflow capabilities
- Loose coupling between Teamcenter and System Modeling Workbench, compatible with service offering

Connecting the EBOM

Link EBOM to structure model with two custom attributes:

- mapping EBOM parts to subsystems (every item in BOM)
- mapping parts to I/O ports (where needed)



GEN000242/A;3-Spacecraft - Latest Working - Date - "Now"

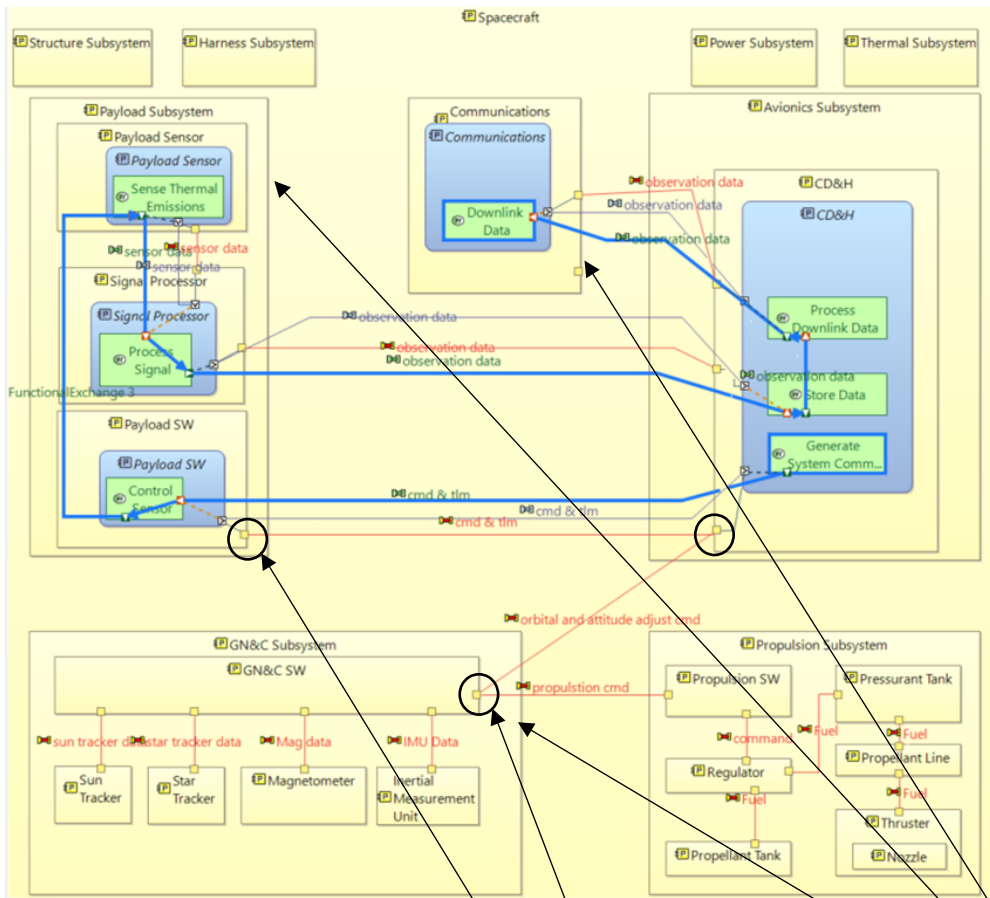
BOM Line	ICD Structure Mapping	Interface Port	Price /	Source of Material
GEN000242/A;3-Spacecraft				
GEN000243/A;2-GN&C Subsystem	GN&C SW			
GEN000248/A;2-GN&C SW	GN&C SW			
GEN000249/A;2-Sun Tracker	Sun Tracker			
GEN000250/A;2-Star Tracker	Star Tracker			
GEN000251/A;2-Magnetometer	Magnetometer			
GEN000252/A;2-Inertial Measurement Unit	IMU			
GEN000266/A;2-Ultimate Sensor Fusion Solution	IMU	IMU Data Port		
GEN000267/A;2-USB Cable	IMU	IMU Data Port		
GEN000244/A;2-Avionics Subsystem				
GEN000245/A;2-C&DH Assembly	C&DH			
GEN000246/A;2-Main Logic	C&DH	CMD & TLM I/F Port		
GEN000247/A;2-MCU	C&DH		\$14.36	Atmel
GEN000257/A;2-Supervisor Circuit	C&DH		\$3.86	Maxim
GEN000258/A;2-Real Time Clock	C&DH		\$6.73	Dallas Semi
GEN000259/A;2-RS-232 Level Converter	C&DH		\$0.90	Maxim
GEN000253/A;2-Memory	C&DH			
GEN000260/A;2-Memory	C&DH		\$2.37	Atmel
GEN000254/A;2-Power	C&DH			
GEN000261/A;2-Power MOSFET	C&DH		\$3.75	Internation Rectifier
GEN000255/A;2-Analog-toDigital	C&DH			
GEN000262/A;2-ADC	C&DH		\$8.80	Texas Instruments
GEN000256/A;2-Sensors	C&DH			
GEN000263/A;2-Thermistor	C&DH		\$0.00	YSI
GEN000264/A;2-Current Sensor	C&DH		\$1.88	Maxim
GEN000265/A;2-I2C Temperature Sensor	C&DH		\$3.63	National Semi
GEN000268/A;2-Payload Subsystem				
GEN000275/A;2-Payload Sensor	Payload Sensor			
GEN000276/A;2-Signal Processor	Signal Processor			
GEN000277/A;2-Payload SW	Payload SW			
GEN000269/A;2-Propulsion Subsystem				
GEN000278/A;2-Propulsion SW	Propulsion SW			
GEN000279/A;2-Pressurant Tank	Pressurant Tank			

Main Logic Board is linked to the C&DH component and the cmd & tlm i/f port

Connecting Models (MBSE to EBOM)

Link EBOM to structure model with two custom attributes:

- mapping EBOM parts to subsystems (every item in BOM)
- mapping parts to I/O ports (where needed)



GEN000242/A;2-Spacecraft - Latest Working - Date - "Now"

BOM Line	ICD Structure Mapping	Interface Port	UUID	Source of Material	Price
GEN000242/A;2-Spacecraft					
GEN000243/A;1-GN&C Subsystem					
GEN000248/A;1-GN&C SW	GN&C				
GEN000249/A;1-Sun Tracker	GN&C				
GEN000250/A;1-Star Tracker	GN&C				
GEN000251/A;1-Magnetometer	GN&C				
GEN000252/A;1-Inertial Measurement Unit	GN&C				
GEN000266/A;1-Ultimate Sensor Fusion Soluti...	IMU	IMU Data Port			
GEN000267/A;1-USB Cable	IMU	IMU Data Port			
GEN000244/A;1-Avionics Subsystem					
GEN000245/A;1-C&DH Assembly	C&DH				
GEN000246/A;1-Main Logic	C&DH	CMD & TLM I/F Port			
GEN000247/A;1-MCU	C&DH			Atmel	\$14.36
GEN000257/A;1-Supervisor Circuit	C&DH			Maxim	\$3.86
GEN000258/A;1-Real Time Clock	C&DH			Dallas Semi	\$6.73
GEN000259/A;1-RS-232 Level Converter	C&DH			Maxim	\$0.90
GEN000253/A;1-Memory	C&DH				
GEN000260/A;1-Memory	C&DH			Atmel	\$2.37
GEN000254/A;1-Power	C&DH				
GEN000261/A;1-Power MOSFET	C&DH			Internation Rectifier	\$3.75
GEN000255/A;1-Analog-to-Digital	C&DH				
GEN000262/A;1-ADC	C&DH			Texas Instruments	\$8.80
GEN000256/A;1-Sensors	C&DH				
GEN000263/A;1-Thermistor	C&DH			YSI	\$0.00
GEN000264/A;1-Current Sensor	C&DH			Maxim	\$1.88
GEN000265/A;1-I2C Temperature Sensor	C&DH			National Semi	\$3.63
GEN000268/A;1-Payload Subsystem					
GEN000275/A;1-Payload Sensor	Payload				
GEN000276/A;1-Signal Processor	Payload				
GEN000277/A;1-Payload SW	Payload				
GEN000269/A;1-Propulsion Subsystem					
GEN000278/A;1-Propulsion SW	Propulsion				
GEN000279/A;1-Pressurant Tank	Propulsion				

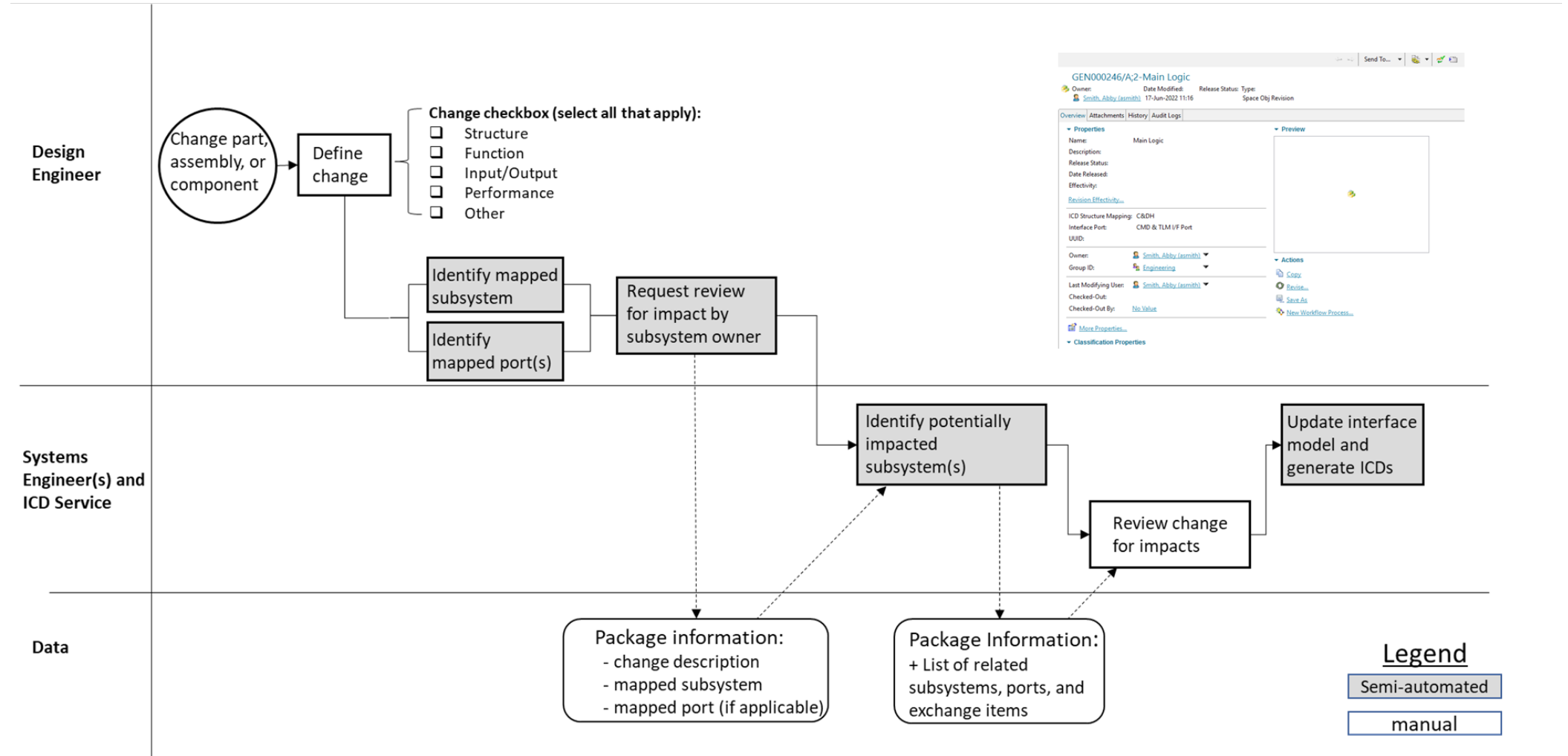
Example: EBOM in Teamcenter links to ICD model for change impact studies

Main Logic Board is linked to the C&DH component and the cmd & tlm i/f port

1. A change to the Main Logic Board can now be checked for impact against subsystems/components interfacing with the C&DH component
2. A change to the Main Logic Board can now be checked for impact against all interfaces to the cmd & tlm i/f port

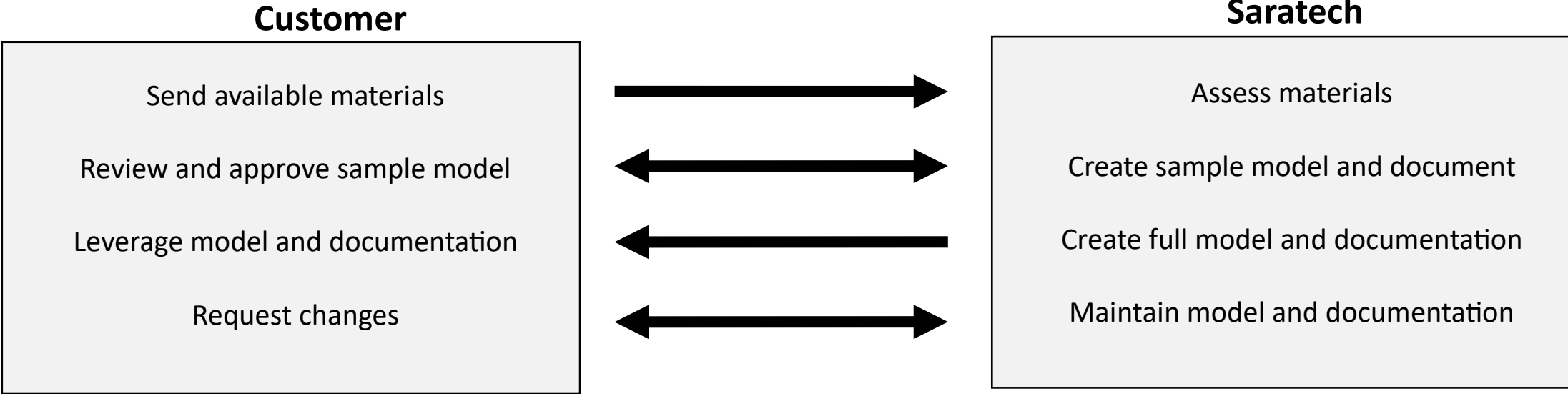
Next Steps

If the customer uses a PLM system, we can use a semiautomated workflow to identify potential interface impacts from parts changes



Next Steps

ICD Service Workflow



Lessons Learned

- Extracting the diagrammatic information into a table takes trial-and-error (learning the data model). Opportunity for Capella developers to provide Python-friendly interfaces to provide this data.
- Using Jupyter Lab with py-capellambse allows for rapid prototyping and documenting the process as you go
- Powerful demonstration of the benefits of the model-based approach vs text-based

Saratech is an Ideal Partner

- Experienced leadership team
- Experienced engineers with a long track record of program success
- Program management & industry best practices for project control
- We help solve complex problems

Thank you for your interest in Saratech