



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.

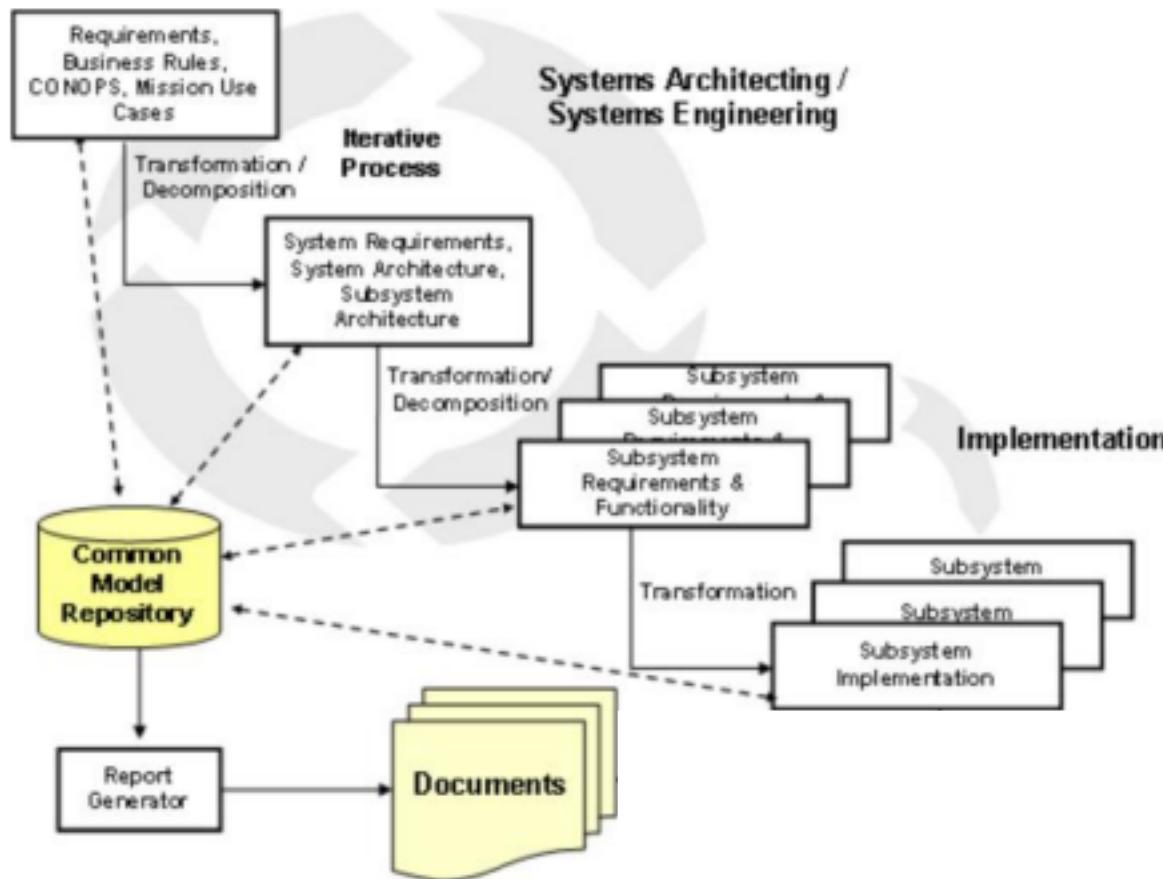
Outline

- 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**

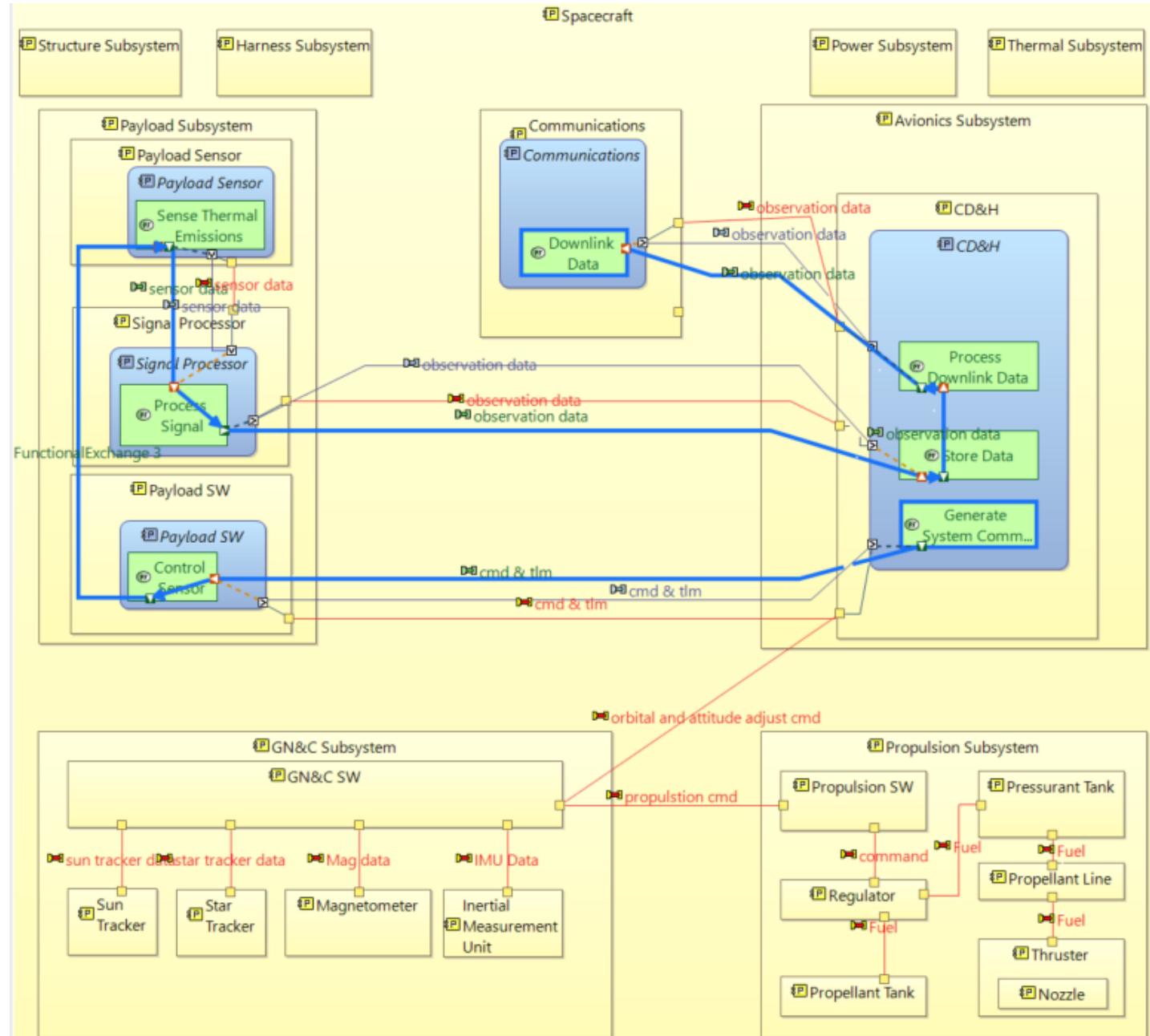
Definition (INCOSE)

“Model-based systems engineering (MBSE) is the *formalized application of modeling* to support system requirements, design, analysis, verification and validation activities beginning in the conceptual design phase and continuing throughout development and later life cycle phases.”

INCOSE SE Vision 2020 (INCOSE-TP-2004-004-02, Sep 2007)



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)
- ...

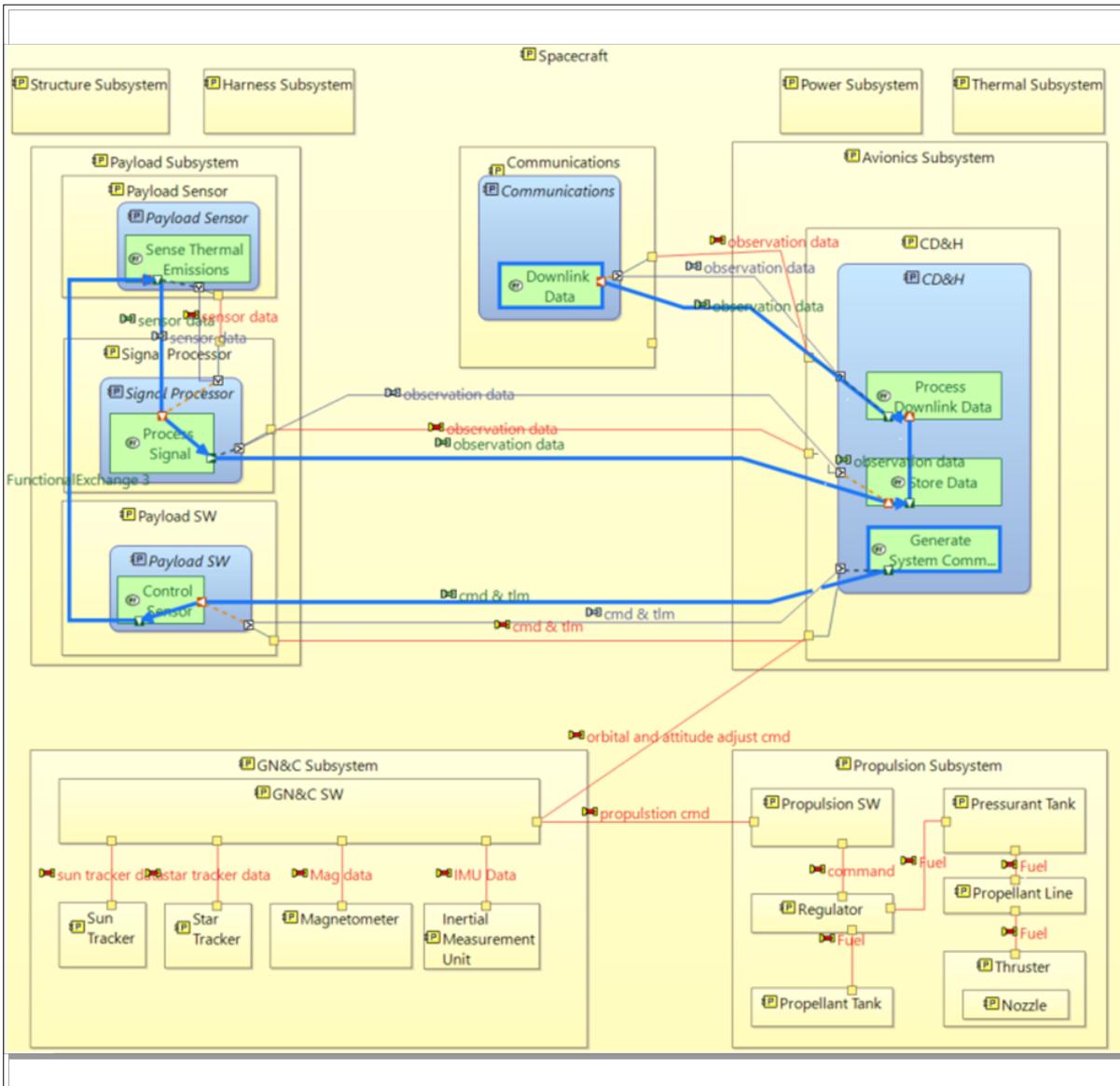
• Key functions and data exchanges identified

- 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

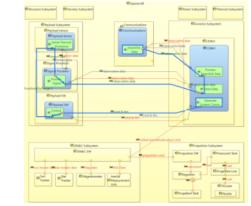
Physical Link: orbital and attitude adjust cmd

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

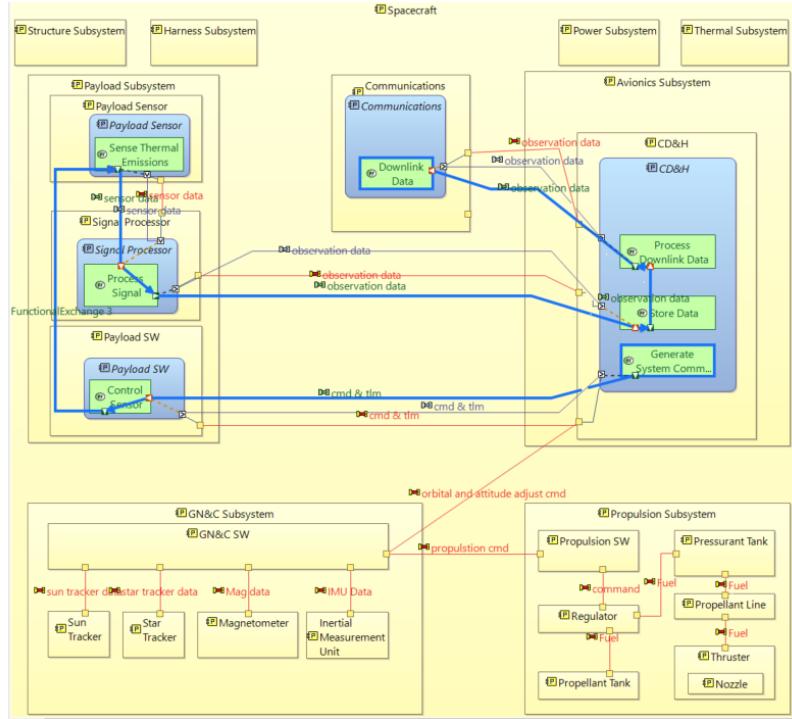
Port: cmd&tlm i/f

Interfacing components:

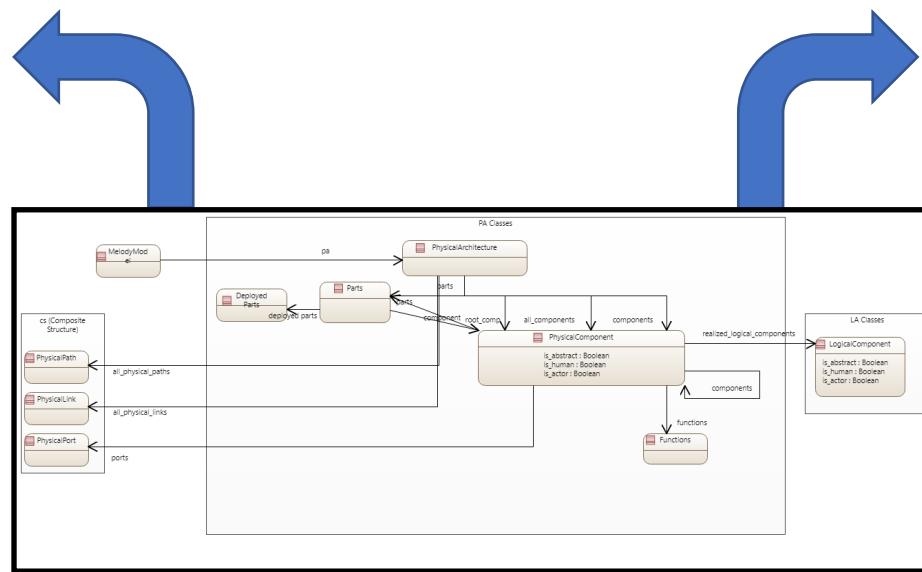
- Payload SW via the port: cmd&tlm i/f

MBSE for Interface Control

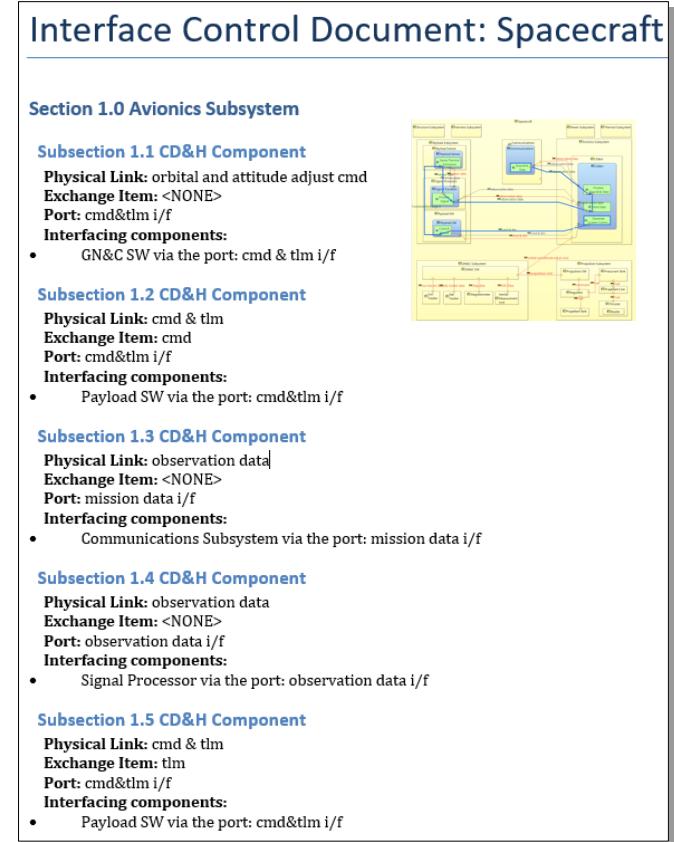
In the model-based approach, the diagrams are models captured by an underlying data model. **The data model is the master.** Documents and views are generated from the data model.



View



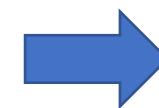
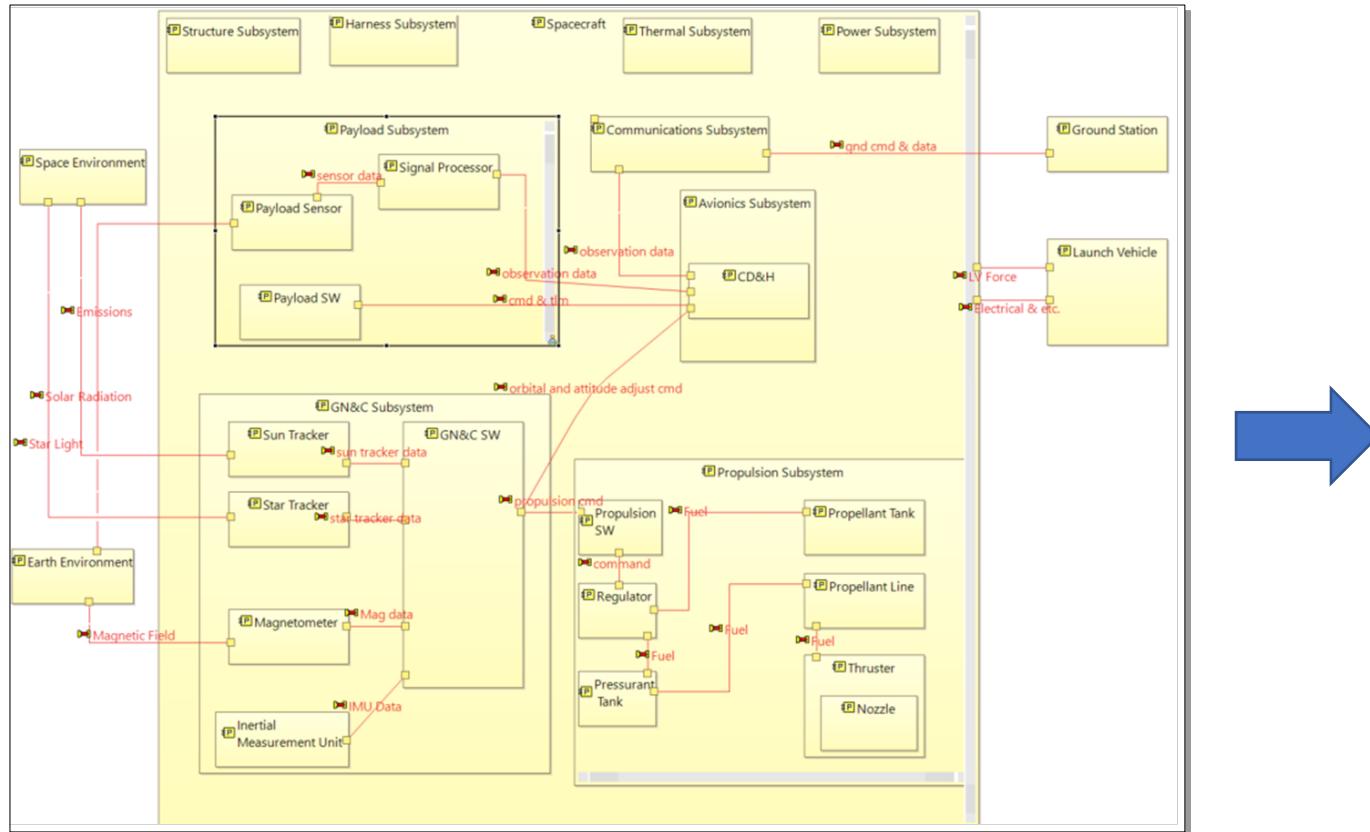
Data Model = Master



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
Section 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

Section 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

Section 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

Section 6.4 Earth Environment Component
 Physical Link: Magnetic Field
 Exchange Item: <NONE>
 Port: PP.1
 Interfacing components:

- Magnetometer via the port: PP.2

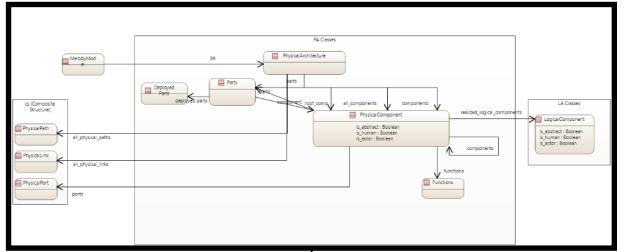
Section 6.5 Space Environment Component
 Physical Link: Star Light
 Exchange Item: <NONE>
 Port: PP.2
 Interfacing components:

- Star Tracker via the port: PP.2

Section 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

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:

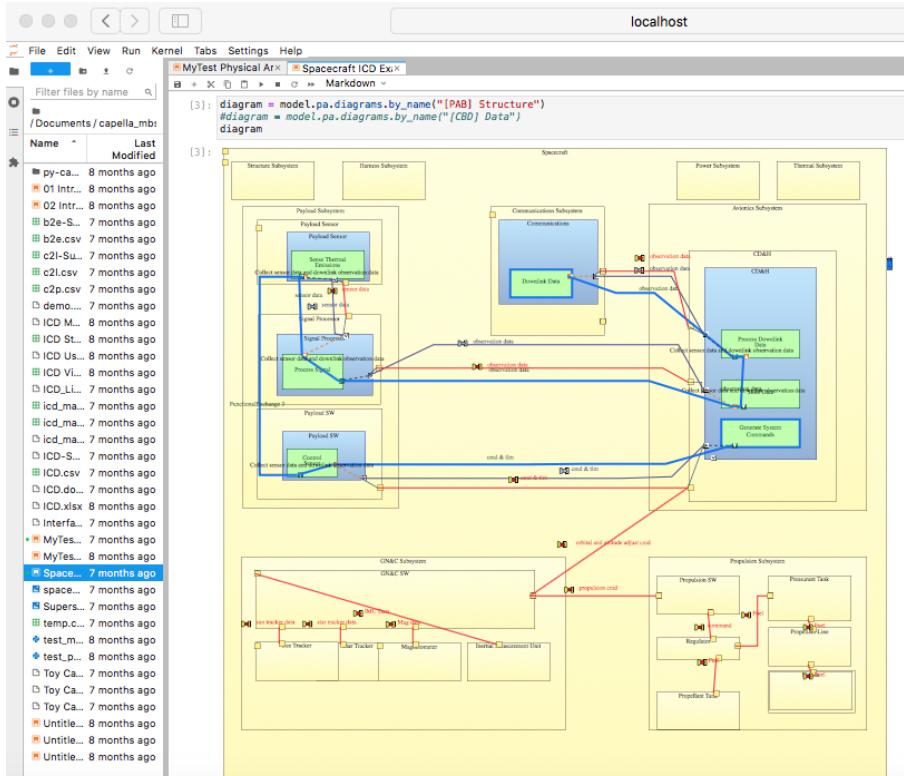
- parsing .aird files
- easy access to model elements and objects
- property-value access and manipulation
- diagram access and export as SVG

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_uuid	exchanges	exchange_items	physical_links	physical_links_uuid	exchanges_uuid
0	Avionics Subsystem	CD&H	NODE	cmd&tim i/f	62ba879f-5add-404c-a1c2-082788f0eef2			orbital and attitude adjust cmd	5e83d465-6e9a-4aaf-9554-587f5e337d8c	
1	Avionics Subsystem	CD&H	NODE	cmd&tim i/f	62ba879f-5add-404c-a1c2-082788f0eef2	cmd & tlm	cmd	cmd & tlm	fceb4170-a4d0-40e7-8c96-3c16207ae9	3392ff80-4a29-4912-a1e1-5f040b7e3a08
2	Avionics Subsystem	CD&H	NODE	mission data i/f	12d48384-4300-49f8-a1e5-f1d64b13e71f			observation data	bcb87c9d-9b29-4511-8ec2-efcc4fc127b7	
3	Avionics Subsystem	CD&H	NODE	observation data i/f	0a3271b6-5bd6-41a0-ad8e-e02cc557a3e9	observation data		observation data	4eacaafe-994d-4996-ba41-5e7f5af0ba3	e66bc4f5-eb73-4473-84f6-9ccc2bb1efd5
47	Avionics Subsystem	CD&H	NODE	cmd&tim i/f	62ba879f-5add-404c-a1c2-082788f0eef2	cmd & tlm	tlm	cmd & tlm	fceb4170-a4d0-40e7-8c96-3c16207ae9	3392ff80-4a29-4912-a1e1-5f040b7e3a08
16	GN&C Subsystem	GN&C SW	NODE	pp 4	15b7c0f9-34bf-469e-9c9a-028df0230a6d			Mag data	28124912-6d8-441e-aa42-100d62c6272f	
15	GN&C Subsystem	GN&C SW	NODE	pp 3	9fcacb89-4227-4a6b-830b-83374dc48f26			star tracker data	98387ffd-ec39-4417-83dc-0abbd6f15345	
14	GN&C Subsystem	GN&C SW	NODE	pp 2	2030be3c-ccc4-44af-aaef-ab8771c0bba2			sun tracker data	b02b7e6e-b9d3-4177-91dc-ceaad69c6c3d	
13	GN&C Subsystem	GN&C SW	NODE	cmd & tim i/f	9fd40cce-1ca6-4da1-9e1b-ccfdfe15135b			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			IMU Data	00302f69-5b41-498b-b5ab-d42ffdd3661c	
11	GN&C Subsystem	Sun Tracker	NODE	pp 2	d95e93fa-dd05-414b-be97-06c0ae041838			Solar Radiation	11512a16-5130-403f-a59e-2197c51e244	
9	GN&C Subsystem	Magnetometer	NODE	pp 2	6fe35bb6-2492-47aa-8875-a66e434abb9			Magnetic Field	51592b48-b056-4b38-9a1b-6b2a71c8b758	
8	GN&C Subsystem	Sun Tracker	NODE	pp 1	c64aa2b4-caf1-43cd-8069-ca8baab9598a			sun tracker data	b02b7e6e-b9d3-4177-91dc-ceaad69c6c3d	
7	GN&C Subsystem	GN&C SW	NODE	cmd & tim i/f	9fd40cce-1ca6-4da1-9e1b-ccfdfe15135b			propulsion cmd	7f784ba2-158e-43e4-a1a5-1abe31b0593b	
6	GN&C Subsystem	Inertial Measurement Unit	NODE	pp 1	5bb6f13e-c014-4aad-88a1-effff999dfbb			IMU Data	00302f69-5b41-498b-b5ab-d42ffdd3661c	
5	GN&C Subsystem	Star Tracker	NODE	pp 1	e2327f3c-da16-4523-a40a-c5c434c162ea			star tracker data	9a837ffd-ec39-4417-83dc-0abbd6f15345	

Generating ICDs from the Model

The screenshot shows a Jupyter Notebook interface with the following details:

- Title Bar:** localhost
- File Menu:** File, Edit, View, Run, Kernel, Tabs, Settings, Help
- Toolbar:** Back, Forward, Stop, Refresh, Python 3
- Left Sidebar:** Shows a file tree under "/Documents/capella_mbse/" with numerous files listed, including various CSV and JSON files.
- Current Tab:** Spacecraft ICD Example
- Content Area:**
 - Section:** Generate Interface Control Diagram from Capella Model
 - Note:** A note about using pandas is present.
 - Cell 1:** pip install pandas
pip install python-docx
 - Cell 2:** Python code for initializing a Capella model:

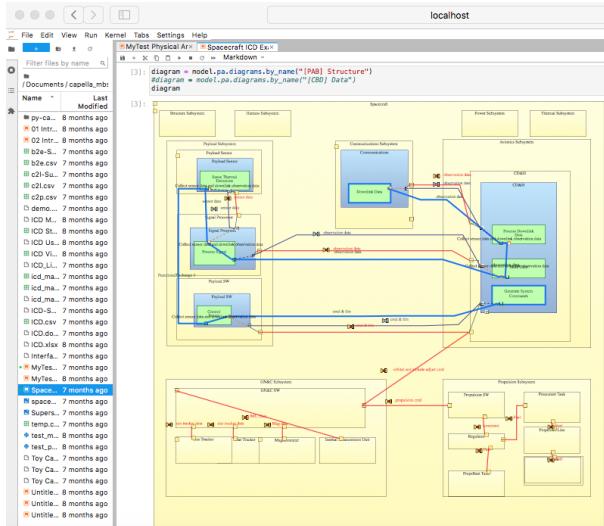
```
import capellambse
import logging
import pandas as pd
import math

logging.getLogger().setLevel(logging.CRITICAL)
path_to_model = "/Users/mikeali/Documents/capella_mbse/Toy Catapult.aird"
model = capellambse.MelodyModel(path_to_model)
```
 - Text:** A note about the PA metamodel.
 - Text:** A note about part re-use.
 - Text:** A note about the API supporting both cases.
 - Text:** A note about rendering PA diagrams outside of Capella.
 - Cell 3:** Python code for rendering a diagram:

```
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

parent	component	nature	physical_ports	physical_ports_uuid	exchanges	exchange_items	physical_links	physical_links_uuid	exchanges_uuid
0	Avionics Subsystem	CD&H NODE	cmd&tim i/f	62ba879f-5add-404c-a1c2-08278ff0feef2			NaN	5e83d465-6e9a-4aa1-9554-687f5e33708c	
1	Avionics Subsystem	CD&H NODE	cmd&tim i/f	62ba879f-5add-404c-a1c2-08278ff0feef2	cmd & tim	cmd	cmd & tim	fceb4170-4xd0-4047-8c96-32c2f6207eeb9	3392ff80-4a29-4912- a1e1-5f040b7e3a08
2	Avionics Subsystem	CD&H NODE	mission data i/f	12d49384-4300-49ff-a1e5-f1664b13a71f		observation data		bc897c9d-9029-4511- 8e2c-efcc4fc127b7	
3	Avionics Subsystem	CD&H NODE	observation data i/f	0a3271b6-5bd6-41b0-ad8e-e02cc57a3e9f		observation data		4eacaafe-994d-4996- b441-5e75af5ab0a3	e68c04ff-eb73-4473- 84ff-9cccbb1bfed5
47	Avionics Subsystem	CD&H NODE	cmd&tim i/f	62ba879f-5add-404c-a1c2-08278ff0feef2	cmd & tim	tim	cmd & tim	fceb4170-4xd0-4047-8c96-32c2f6207eeb9	3392ff80-4a29-4912- a1e1-5f040b7e3a08
16	GN&C Subsystem	GN&C SW NODE	pp 4	1b57cf0f-346f-459a-9c9a- 83374dc4d7f6			Mag data		281249f2-6d9f-447e- aa12-5e75a09727d7
15	GN&C Subsystem	GN&C SW NODE	pp 3	9fcact89-4277-428e-8020- 83374dc4d7f6			star tracker data		983d7f1e-4c39-4407- 83dc-0abbcd9f15345
14	GN&C Subsystem	GN&C SW NODE	pp 2	2030be3c-cccd-44af-aaf- a85777c0ba2			sun tracker data		b026/ed6-b9d3-1177- 91cc-ceaa0d9f0cc3d
13	GN&C Subsystem	GN&C SW NODE	cmd & tim i/f	9fd40cce-1ca6-4d41-9e1b- ccfd15135b			orbital and attitude adjust cmd	5e83d465-6e9a-4aa1-9554-687f5e33708c	
12	GN&C Subsystem	GN&C SW NODE	pp 5	7281133a-5f0c-4e99-9e29- 36c641e69eef			IMU Data	003026b9-5b41-498b- b5ab-042ffdf3361c	
11	GN&C Subsystem	Sun Tracker NODE	pp 2	d95e93fa-d053-414b-be97- a15212019398			Solar Radiation	11512a16-5130-403f- a59d-2191014444	
9	GN&C Subsystem	Magnetometer NODE	pp 2	6fe35bb6-2492-472a-887c- a6ff4354abae9			Magnetic Field	510294b4-b686-458b- 91fb-7e27b827b298	
8	GN&C Subsystem	Sun Tracker NODE	pp 1	c64aa2b4-caff-45c1-9e59- cb2aa30b399a			sun tracker data	b026/ed6-b9d3-1177- 91cc-ceaa0d9f0cc3d	
7	GN&C Subsystem	GN&C SW NODE	cmd & tim i/f	9fd40cce-1ca6-4d41-9e1b- ccfd15135b			propulsion cmd	778ab2-158e-434e- a1e5-1ab31b0593b	
6	GN&C Subsystem	Inertial Measurement Unit NODE	pp 1	5bb0f13e-c014-4aa1-88a1- effffff999fffb			IMU Data	003026b9-5b41-498b- b5ab-042ffdf3361c	
5	GN&C Subsystem	Star Tracker NODE	pp 1	e2327f3c-daf6-4523-a0a- c5c434c162ea			star tracker data	9a837ff4-ea39-4417- 83dc-0abbcd9f15345	

Output table in desired format

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

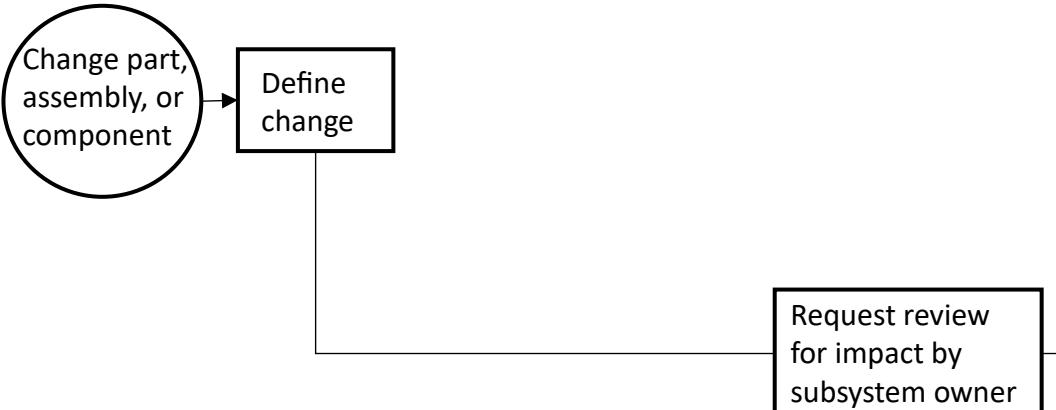
Subsection 1.5 GN&C SW Component

- 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

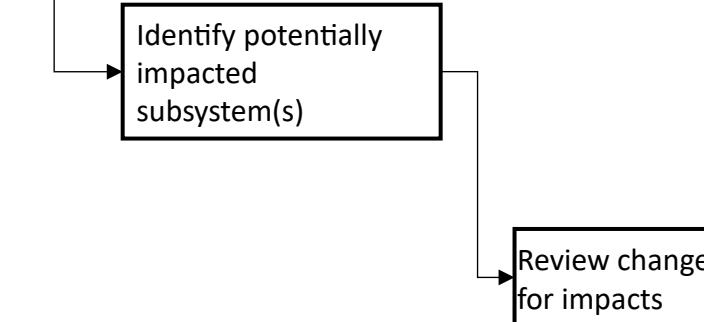
Design Engineer



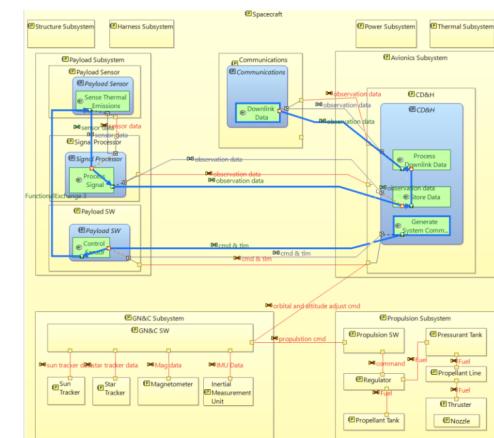
EBOM Tool (PLM)

GEN000242/A-3-Spacecraft - Latest Working - Date - "Now"		
BOM Line	Price /	Source of Material
GEN000242/A-3-Spacecraft		
GEN000242/A-3-OPC Subsystem		
GEN000242/A-3-OPC SW	\$14.36	Atmel
GEN000242/A-3-Sun Tracker	\$3.86	Maxim
GEN000250/A-3-Sun Tracker	\$6.73	Dallas Semi
GEN000251/A-3-Magnetometer	\$0.90	Maxim
GEN000252/A-3-Inertial Measurement Unit		
GEN000266/A-3-Ultimate Sensor Fusion Solution		
GEN000267/A-3-USB Cable	\$2.37	Atmel
GEN000244/A-3-Avionics Subsystem		
GEN000244/A-3-Clock Recovery		
GEN000247/A-3-MCU	\$3.75	Atmel
GEN000257/A-3-Supervisor Circuit	\$6.73	Maxim
GEN000258/A-3-Real Time Clock	\$0.90	Dallas Semi
GEN000259/A-3-RS-232 Level Converter	\$0.00	Maxim
GEN000253/A-3-Memory	\$0.00	Atmel
GEN000260/A-3-Memory	\$0.00	Atmel
GEN000261/A-3-Power MOSFET	\$0.00	International Rectifier
GEN000255/A-3-Analog-to-Digital	\$0.00	Texas Instruments
GEN000262/A-3-ADC	\$0.00	YSI
GEN000256/A-3-Sensors	\$0.00	Maxim
GEN000263/A-3-Thermistor	\$0.00	National Semi
GEN000264/A-3-Current Sensor	\$1.88	Atmel
GEN000265/A-3-IC Temperature Sensor	\$3.63	Atmel
GEN000240/A-3-Payload Subsystem		
GEN000268/A-3-Image Sensor		
GEN000276/A-3-Signal Processor		
GEN000277/A-3-Payload SW		
GEN000269/A-3-Propulsion Subsystem		
GEN000278/A-3-Propulsion SW		
GEN000279/A-3-Pressurant Tank		

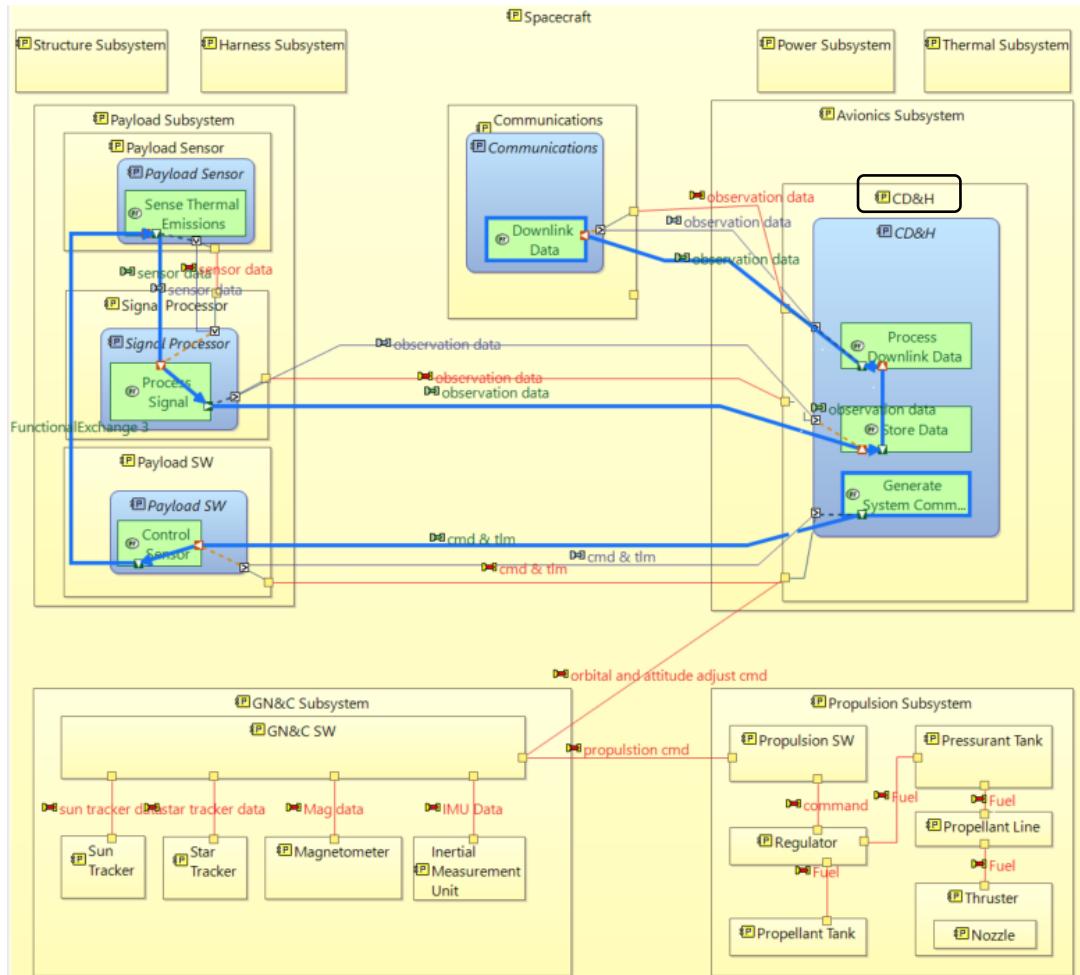
Systems Engineer (or ICD owner)



MBSE Tool

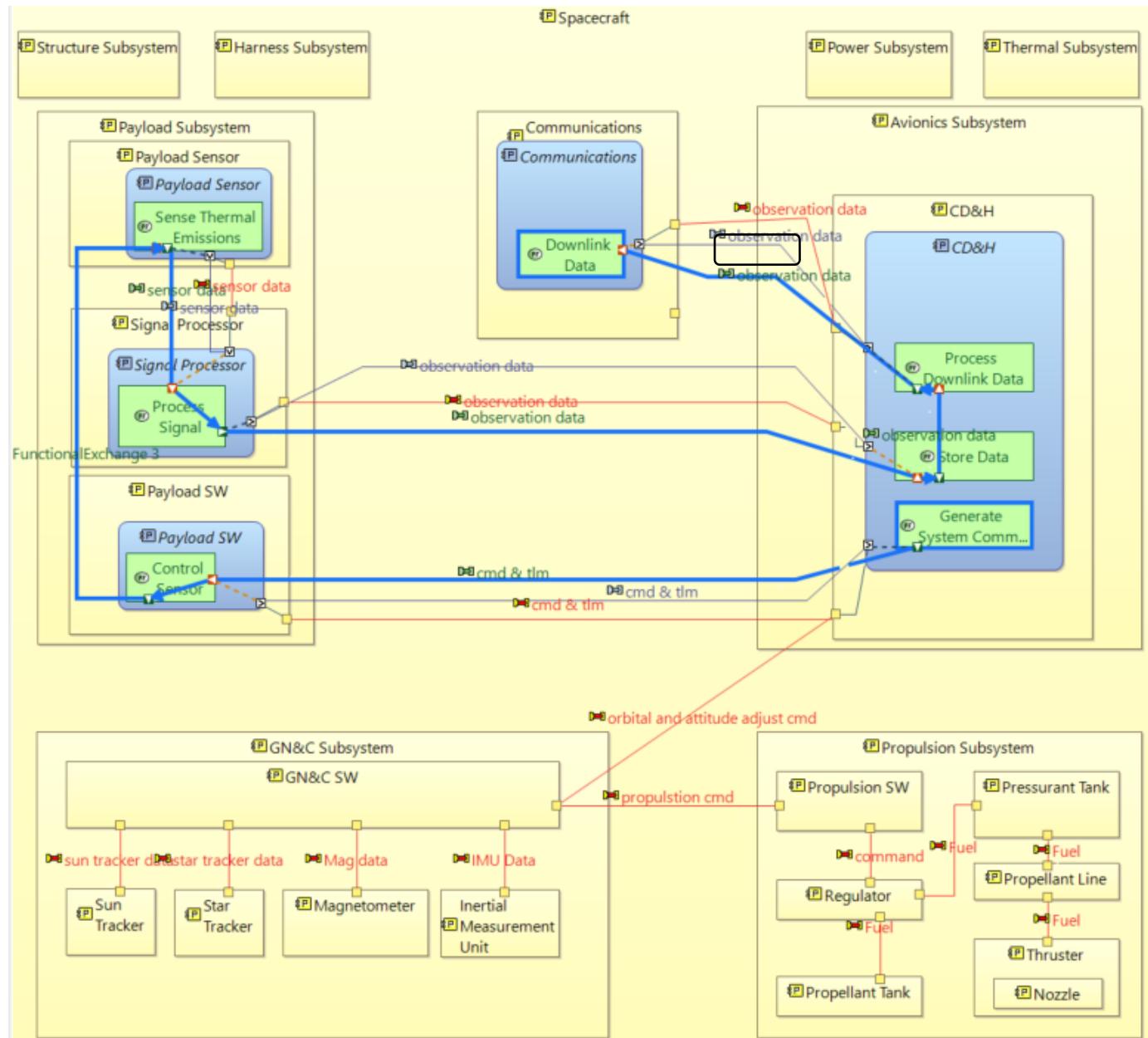


MBSE Model and EBOM



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	\$14.36	Atmel
GEN000249/A;2-Sun Tracker	\$3.86	Maxim
GEN000250/A;2-Star Tracker	\$6.73	Dallas Semi
GEN000251/A;2-Magnetometer	\$0.90	Maxim
GEN000252/A;2-Inertial Measurement Unit		
GEN000266/A;2-Ultimate Sensor Fusion Solution	\$2.37	Atmel
GEN000267/A;2-USB Cable	\$3.75	Internation Rectifier
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	\$2.37	Atmel
GEN000260/A;2-Memory	\$3.75	Internation Rectifier
GEN000254/A;2-Power	\$8.80	Texas Instruments
GEN000261/A;2-Power MOSFET	\$0.00	YSI
GEN000255/A;2-Analog-toDigital	\$1.88	Maxim
GEN000262/A;2-ADC	\$3.63	National Semi
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

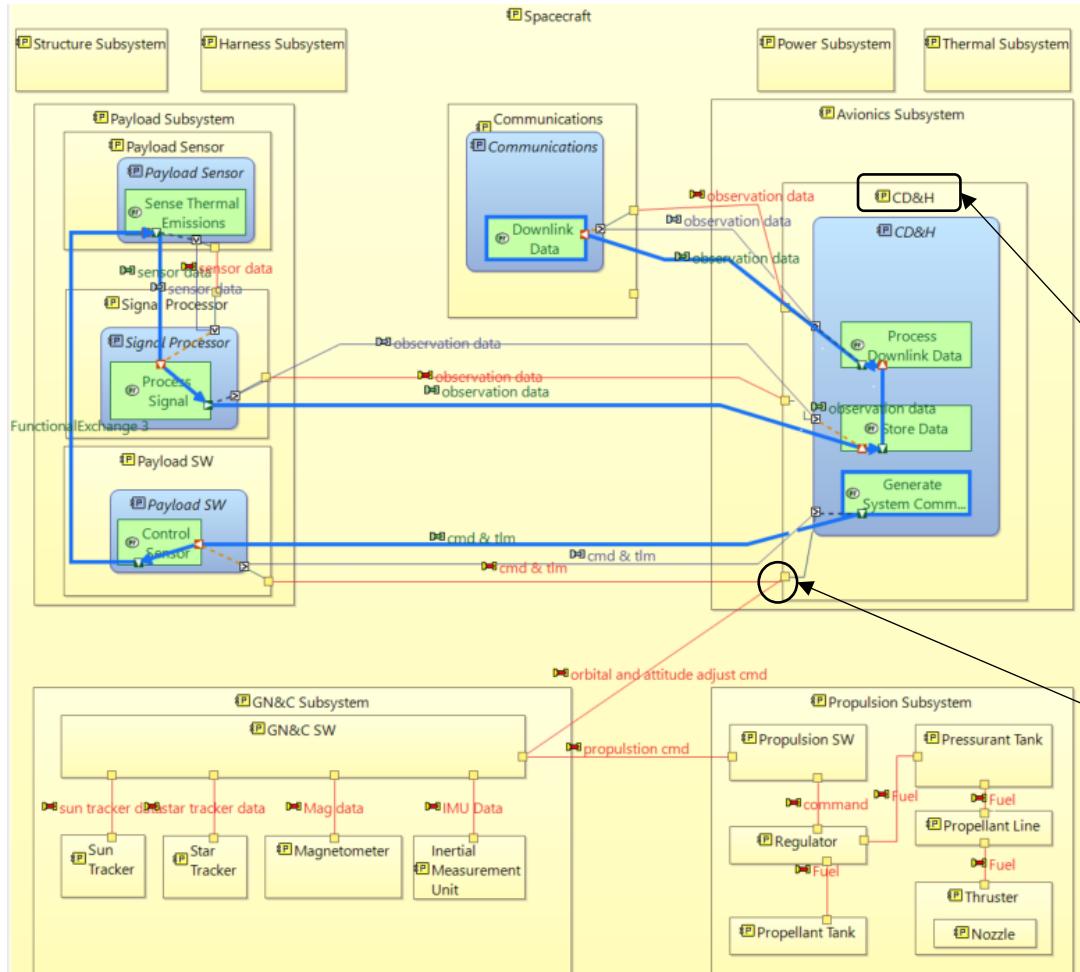
- **Saratech approach**

- 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)

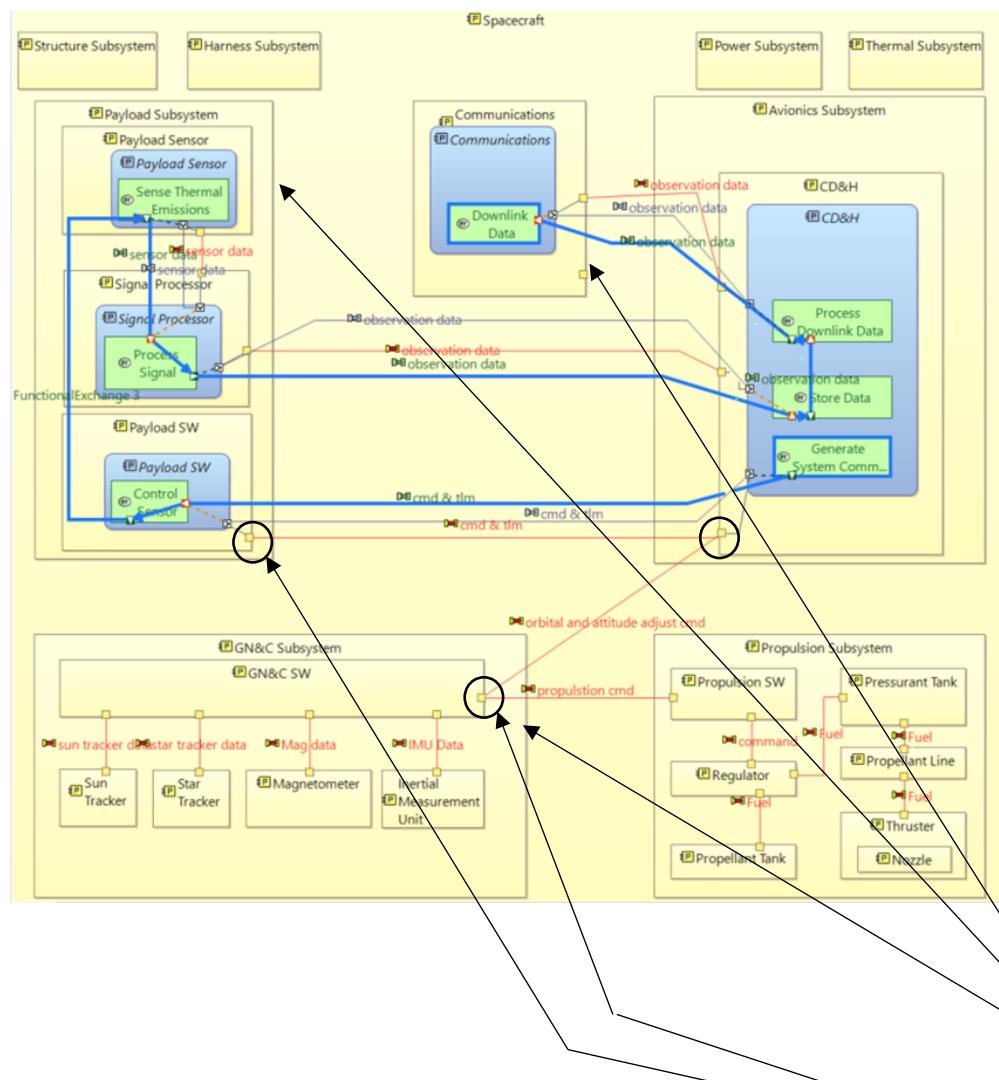


GEN000242/A;3-Spacecraft - Latest Working - Date - "Now"

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

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

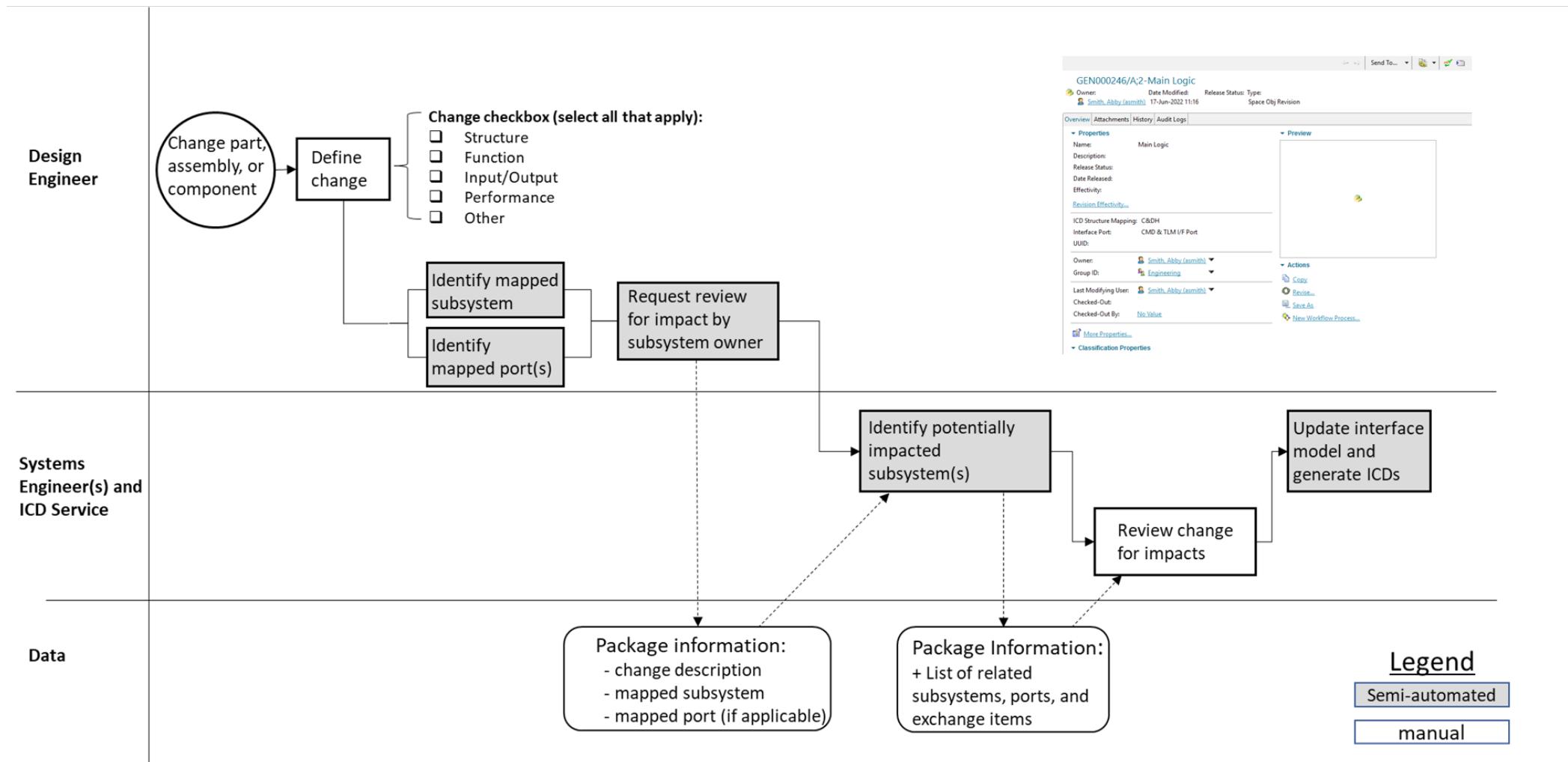
Example: EBOM in Teamcenter links to ICD model for change impact studies

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

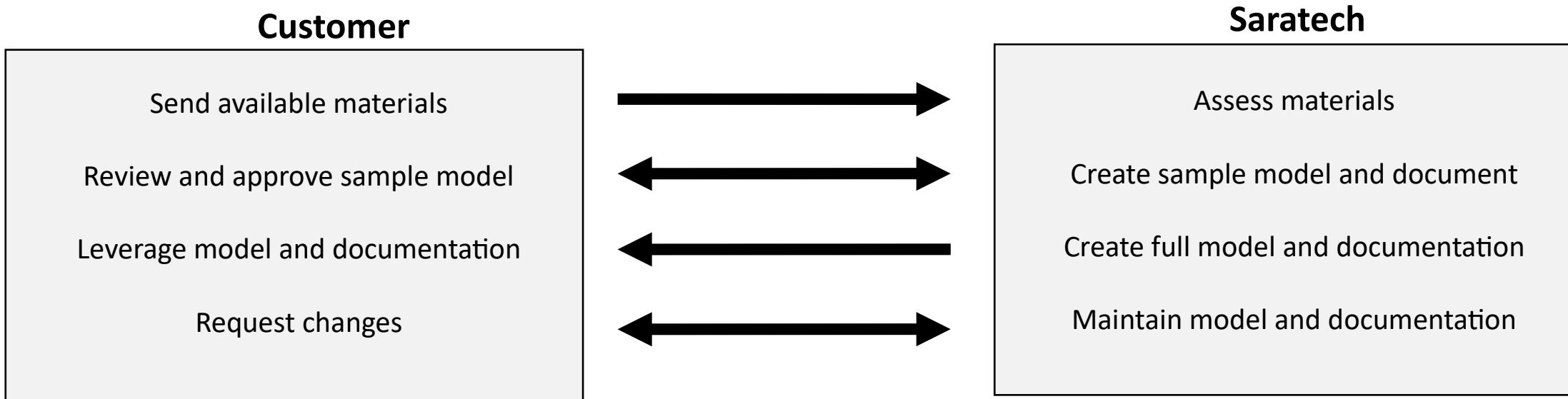
Next Steps

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