
# Interface Document Generation and Linkage to PLM BOM

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VP of Engineering Operations

# 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.*

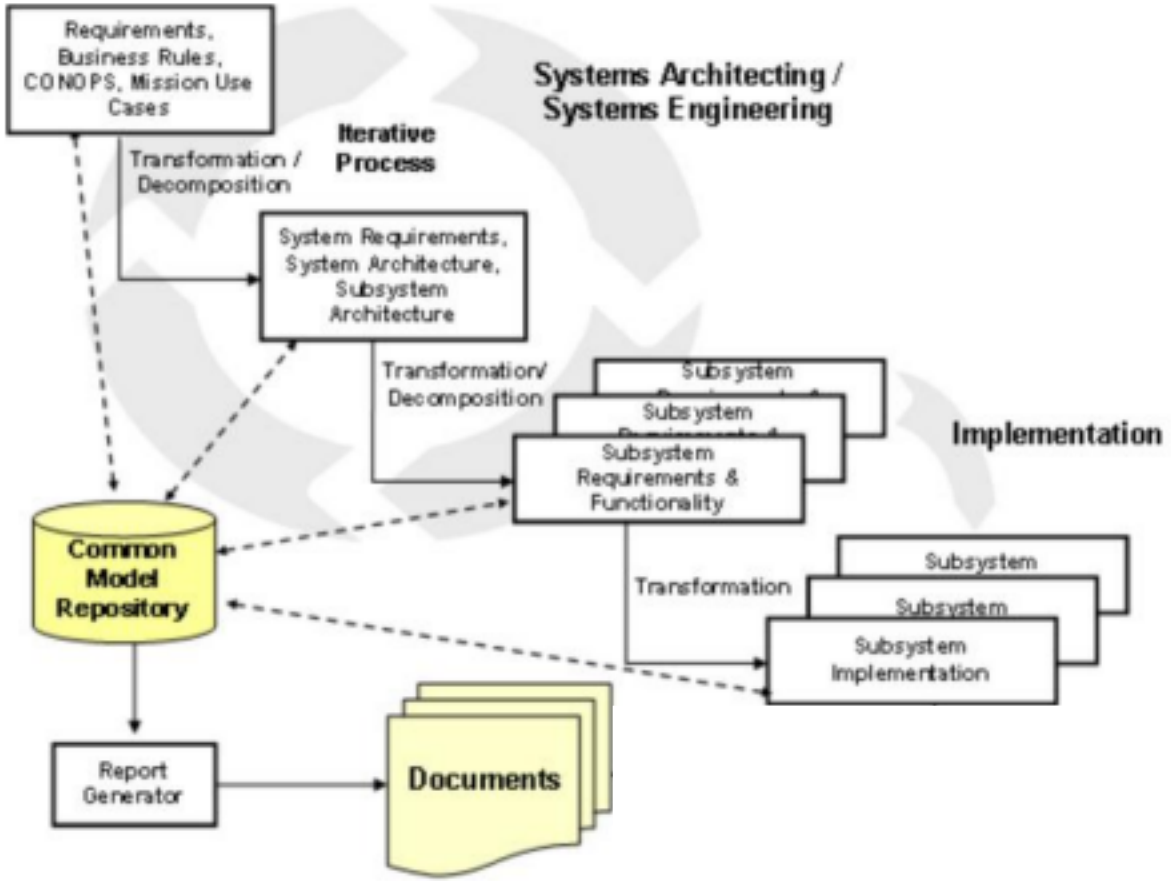
# Outline

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

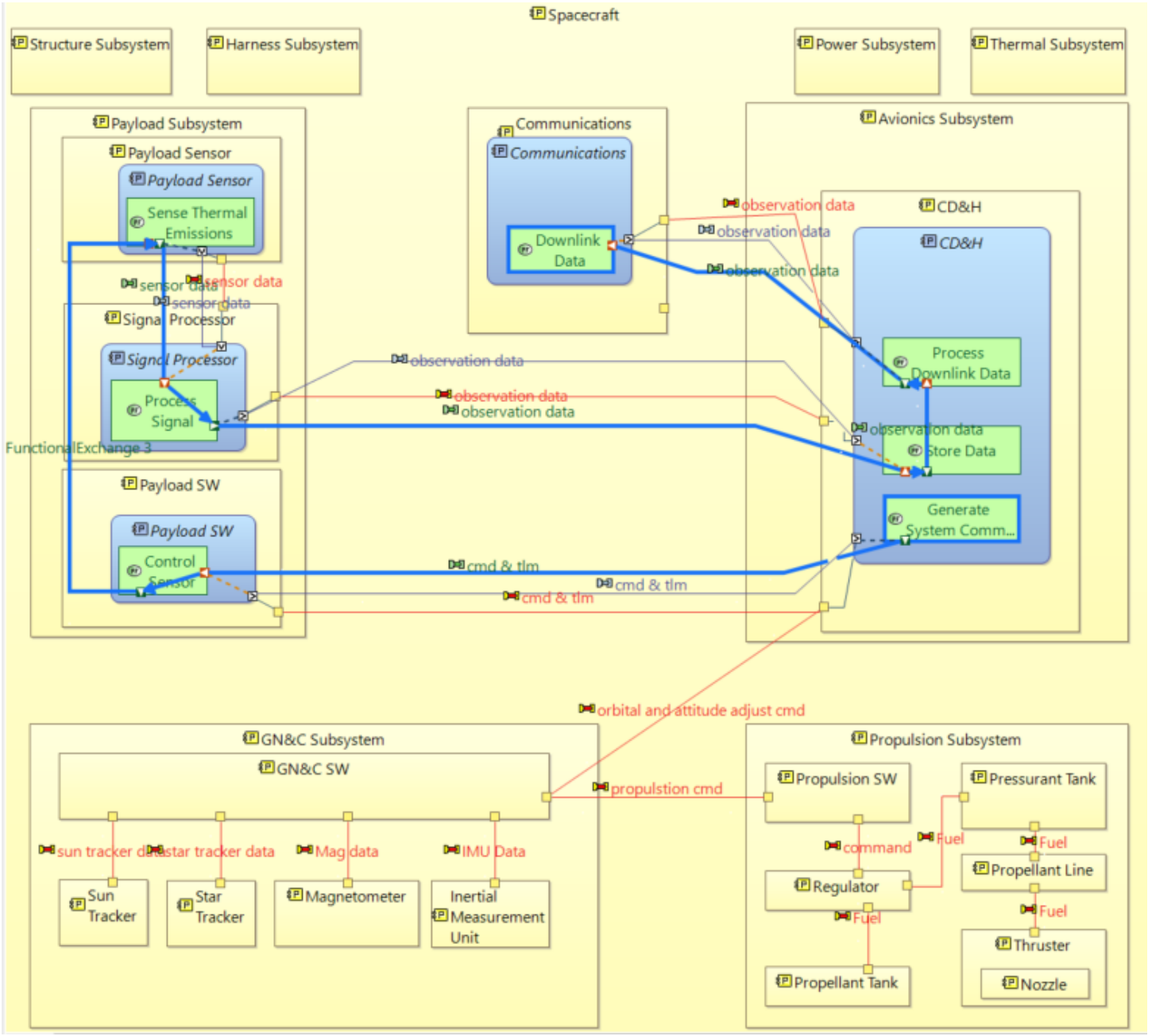
# Definition (INCOSE)

"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

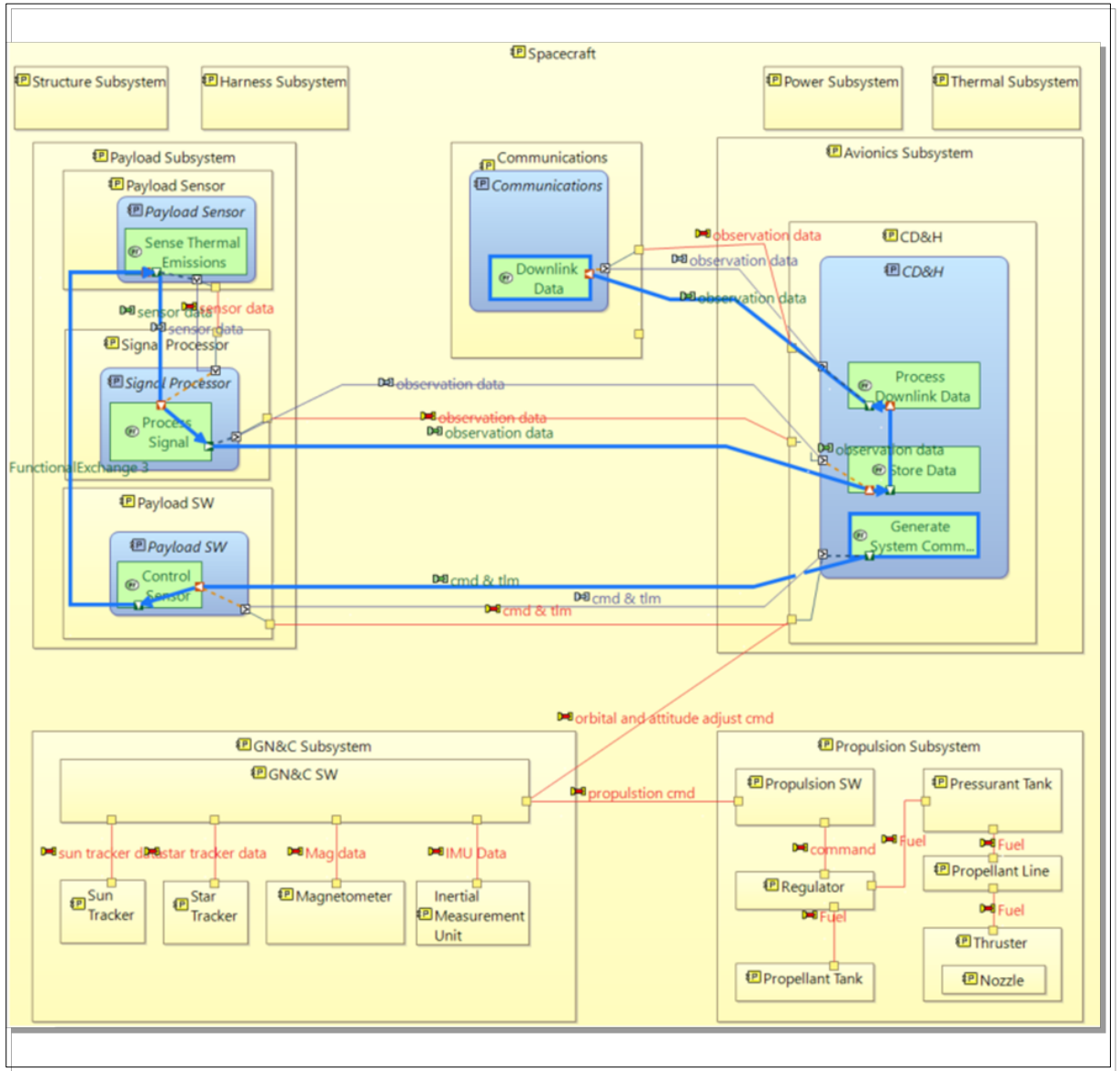



- **Subsystems and components shown**
  - Guidance, Navigation, & Control (GN&C)
  - Propulsion
  - Payload
  - Avionics with Command & Data Handling (C&DH)
  - …
- **Interfaces captured**
  - Command and telemetry (cmd & tlm) link
  - Fuel link
  - GN&C sensor links (ex: sun tracker)
  - …
- **Key functions 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)**

**Diagram created using data from the book: "Architecting Spacecraft with SysML" by Friedanthal and Oster**

# 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 Friedanthal 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

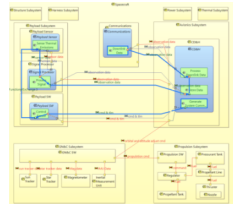
**Text ICDs are still needed for:**

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

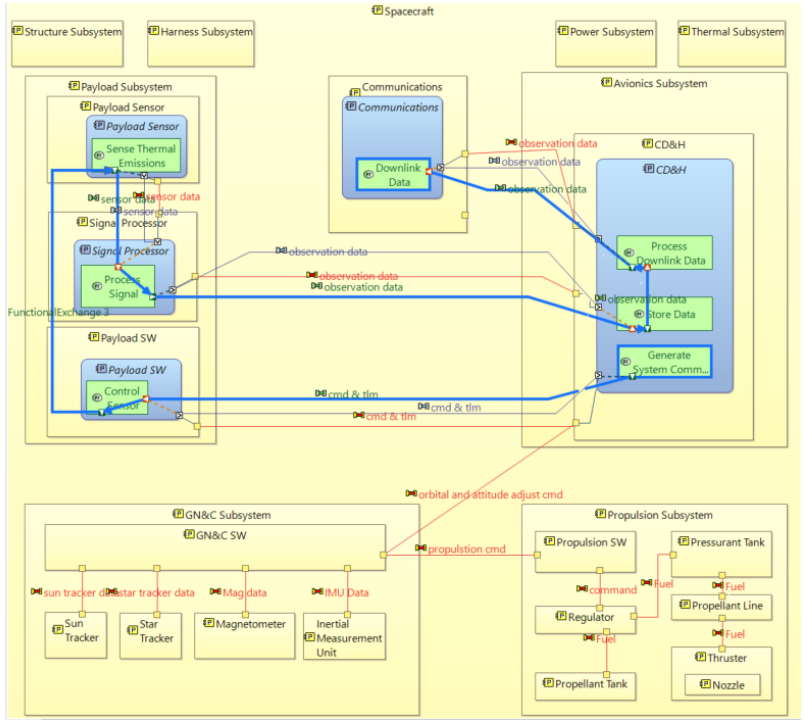
#### Subsection 1.5 CD&H Component

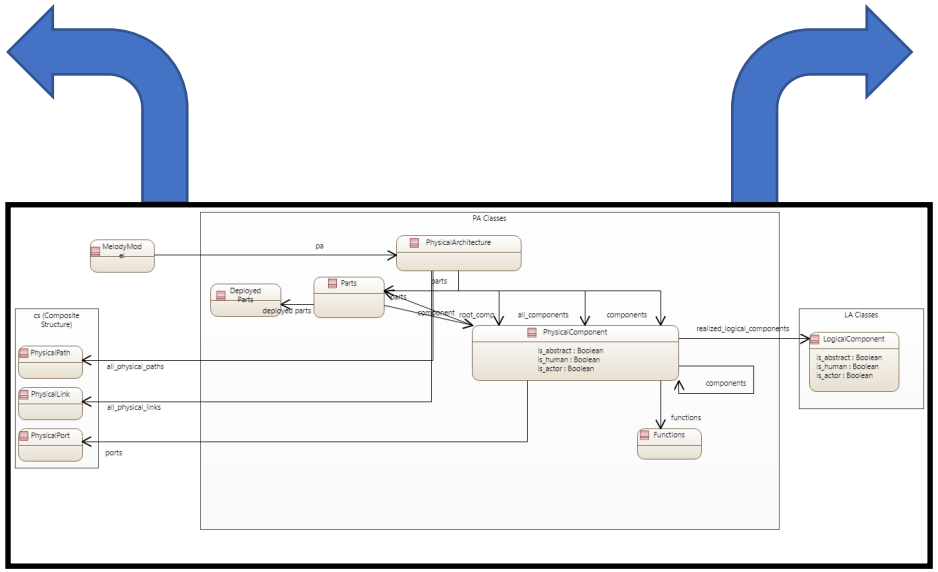
**Physical Link:** cmd & tlm
**Exchange Item:** tlm
**Port:** cmd&tlm i/f
**Interfacing components:**

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

# MBSE for Interface Control

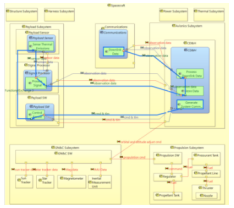
In the model-based approach, the diagrams are models captured by an underlying data model. **The data model is the master.** Documents and views are generated from the data model.




## 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

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**Physical Link:** observation data
**Exchange Item:** <NONE>
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**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

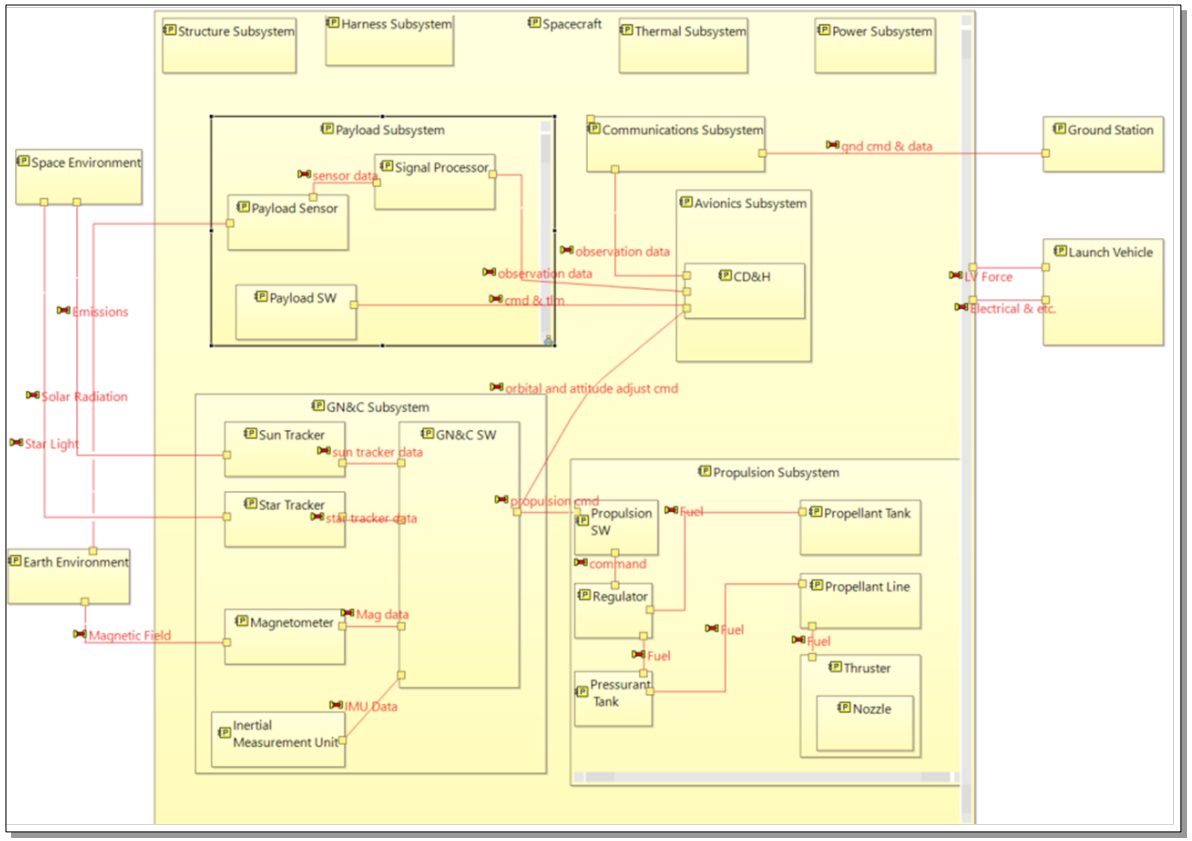
#### Subsection 1.5 CD&H Component

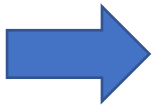
**Physical Link:** cmd & tlm
**Exchange Item:** tlm
**Port:** cmd&tlm i/f
**Interfacing components:**
- Payload SW via the port: cmd&tlm i/f

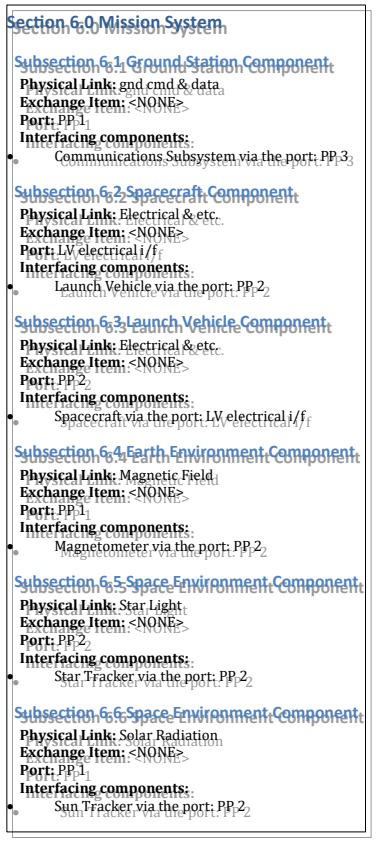
**View** | **Data Model = Master** | **Text Document**

# Benefits of MBSE for Interface Control

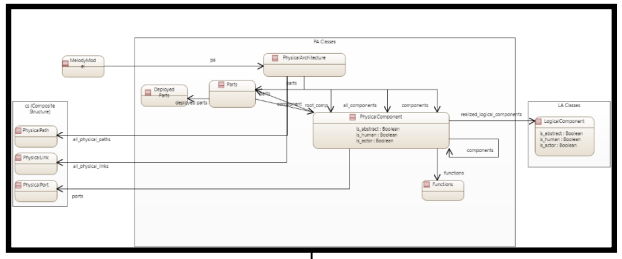
| Action/Check | How addressed |
|---|---|
| **Verifying completeness** | Visual check can be trusted, since the views are derived from the model, which is the master. Can also validate algorithmically for data not on the diagram (ex: specifications). |
| **Identifying mismatches** | Can validate algorithmically 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. |





# 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 | |
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| 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 |
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| 24 | Propulsion Subsystem | Regulator | PP 2 | Fuel | |
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| 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

M2Doc

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:

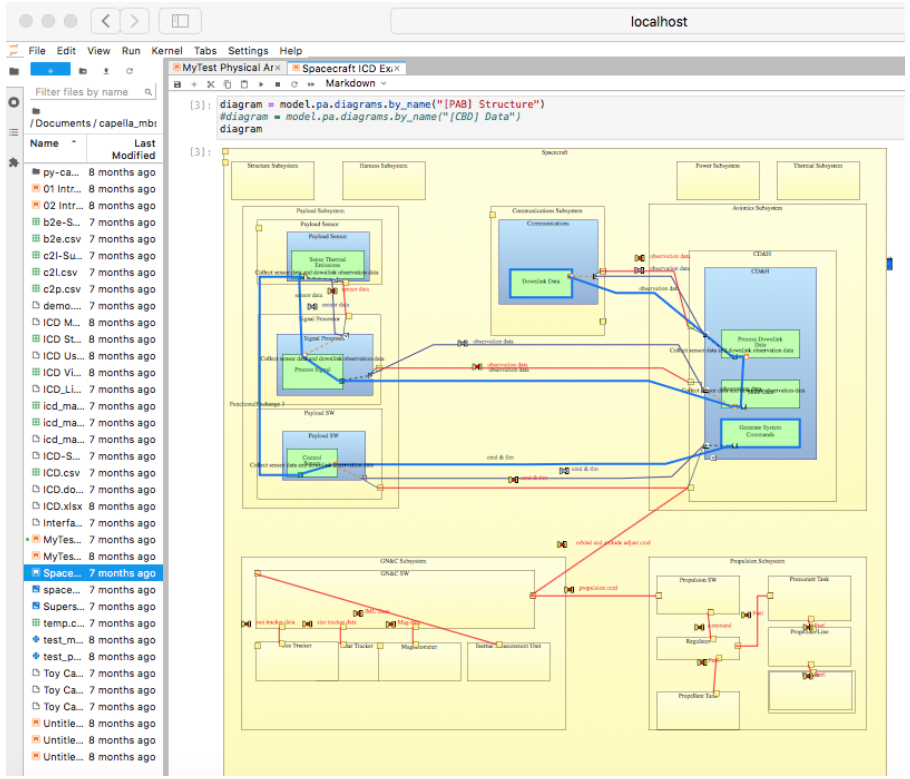
- parsing .aird files
- easy access to model elements and objects
- property-value access and manipulation
- diagram access and export as SVG

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.

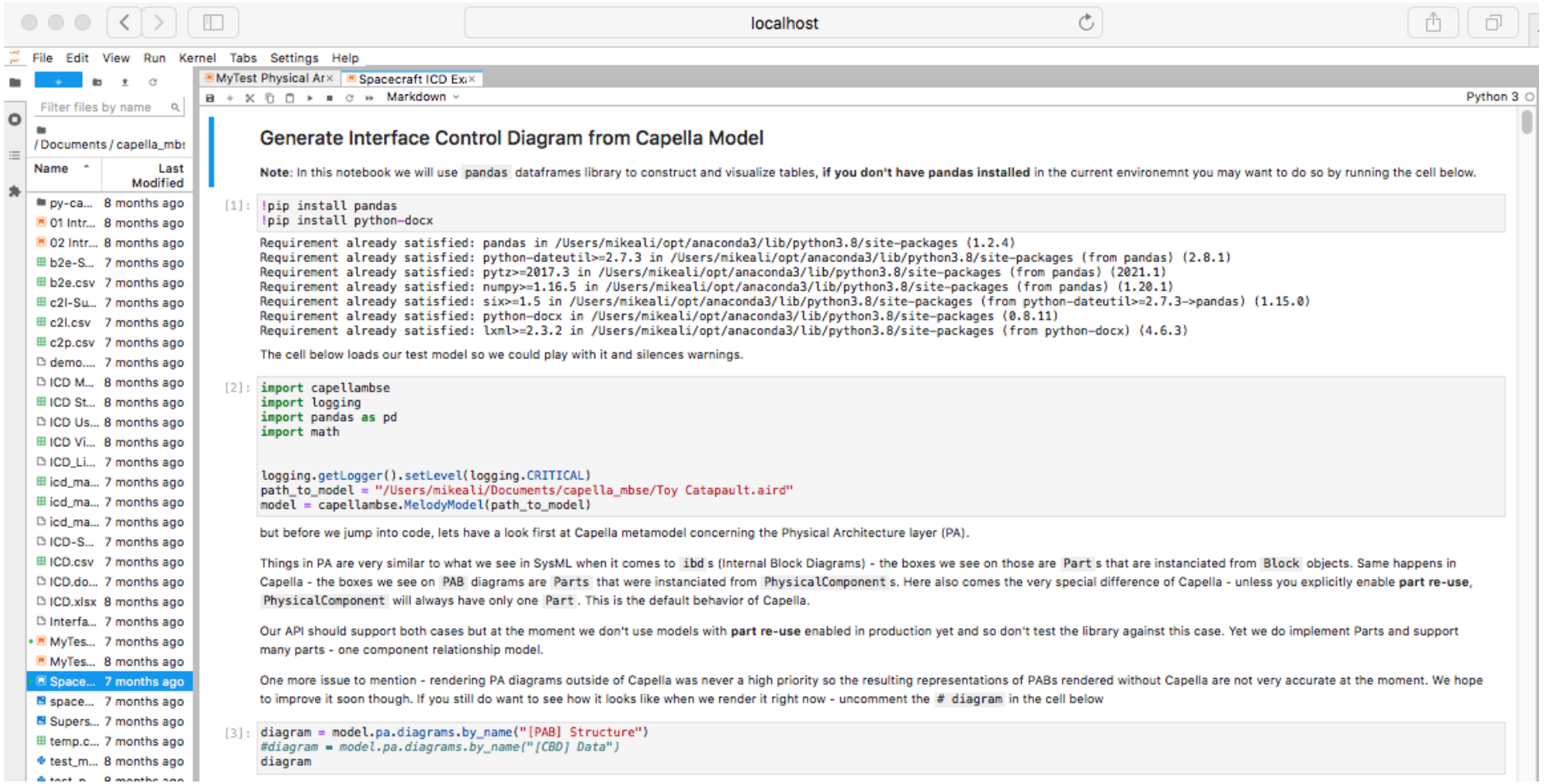
https://dsd-dbs.github.io/py-capellambse/

# Generating ICDs from the Model




| | parent | component | nature | physical_ports | physical_ports_uuid | exchanges | exchange_items | physical_links | physical_links_uuid | exchanges_uuid |
|---|---|---|---|---|---|---|---|---|---|---|
| 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 | fceb4170-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-e02cc557a3e9 | 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 | fceb4170-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-ceaad69c6c3d | |
| 13 | GN&C Subsystem | GN&C SW | NODE | cmd & tlm i/f | 9fd40cce-1ca6-4da1-9e1b-ccdfde15135b | | 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 | 11512a16-5130-403f-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-ca8baa9b598a | | NaN | sun tracker data | b02b7e6e-b9d3-4177-91dc-ceaad69c6c3d | |
| 7 | GN&C Subsystem | GN&C SW | NODE | cmd & tlm i/f | 9fd40cce-1ca6-4da1-9e1b-ccdfde15135b | | NaN | propulsion cmd | 7f784ba2-158e-43e4-a1a5-1abe31b0593b | |
| 6 | GN&C Subsystem | Inertial Measurement Unit | NODE | PP 1 | 5bb6f13e-c014-4aad-88a1-efff999dffb | | 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

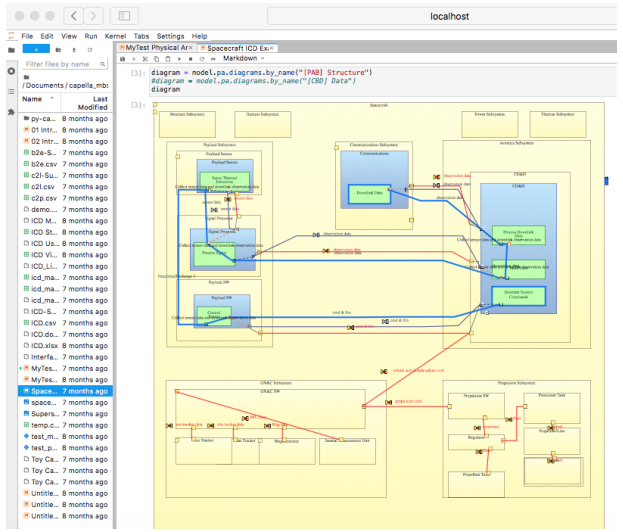


# Generating ICDs from the Model

Read diagram

Convert diagram to table

Output table in desired format




| | parent | component | nature | physical_ports | physical_ports_uuid | exchanges | exchange_items | physical_links | physical_links_uuid | exchanges_uuid |
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| 1 | Avionics Subsystem | CD&H | NODE | cmd&tlm i/f | 62ba879f-5add-404c-a1c2-082788f0eef2 | cmd & tlm | cmd | cmd & tlm | fceb4170-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-e02cc557a3e9 | 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 | fceb4170-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 | 9fcaeb89-4227-4a6b-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-ceaad69c6c3d | |
| 13 | GN&C Subsystem | GN&C SW | NODE | cmd & tlm i/f | 9fd40cce-1ca6-4da1-9e1b-ccdfde15135b | | NaN | orbital and attitude adjust cmd | 5e83d465-6e9a-4aaf-9554-587f5e337d8c | |
| 12 | GN&C Subsystem | GN&C SW | NODE | PP 5 | 7281133a-5fcc-4ea9-9e29-36c641e09ee7 | | 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 | 11512a16-5130-403f-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-ca8baa9b598a | | NaN | sun tracker data | b02b7e6e-b9d3-4177-91dc-ceaad69c6c3d | |
| 7 | GN&C Subsystem | GN&C SW | NODE | cmd & tlm i/f | 9fd40cce-1ca6-4da1-9e1b-ccdfde15135b | | NaN | propulsion cmd | 7f784ba2-158e-43e4-a1a5-1abe31b0593b | |
| 6 | GN&C Subsystem | Inertial Measurement Unit | NODE | PP 1 | 5bb6f13e-c014-4aad-88a1-efff999dffb | | 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 | |

## 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

# Linking BOM changes to interface impact

**Design Engineer**

Change part, assembly, or component

Define change

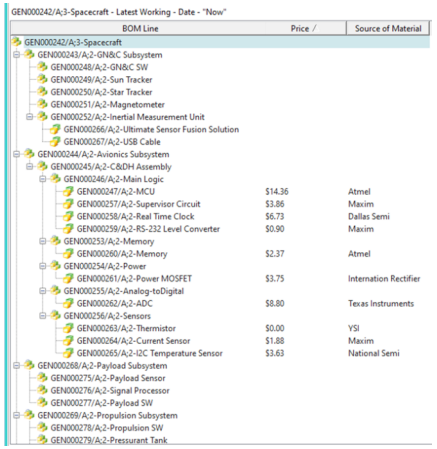
Request review for impact by subsystem owner

**Systems Engineer (or ICD owner)**

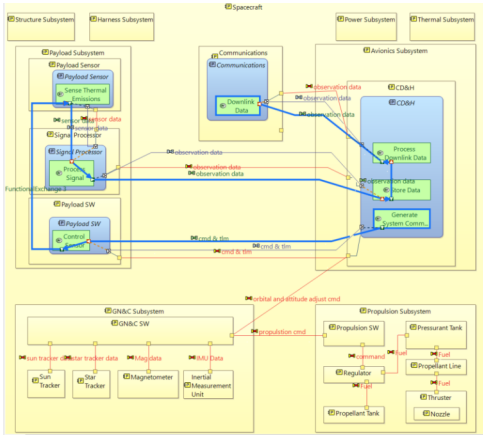
Identify potentially impacted subsystem(s)

Review change for impacts

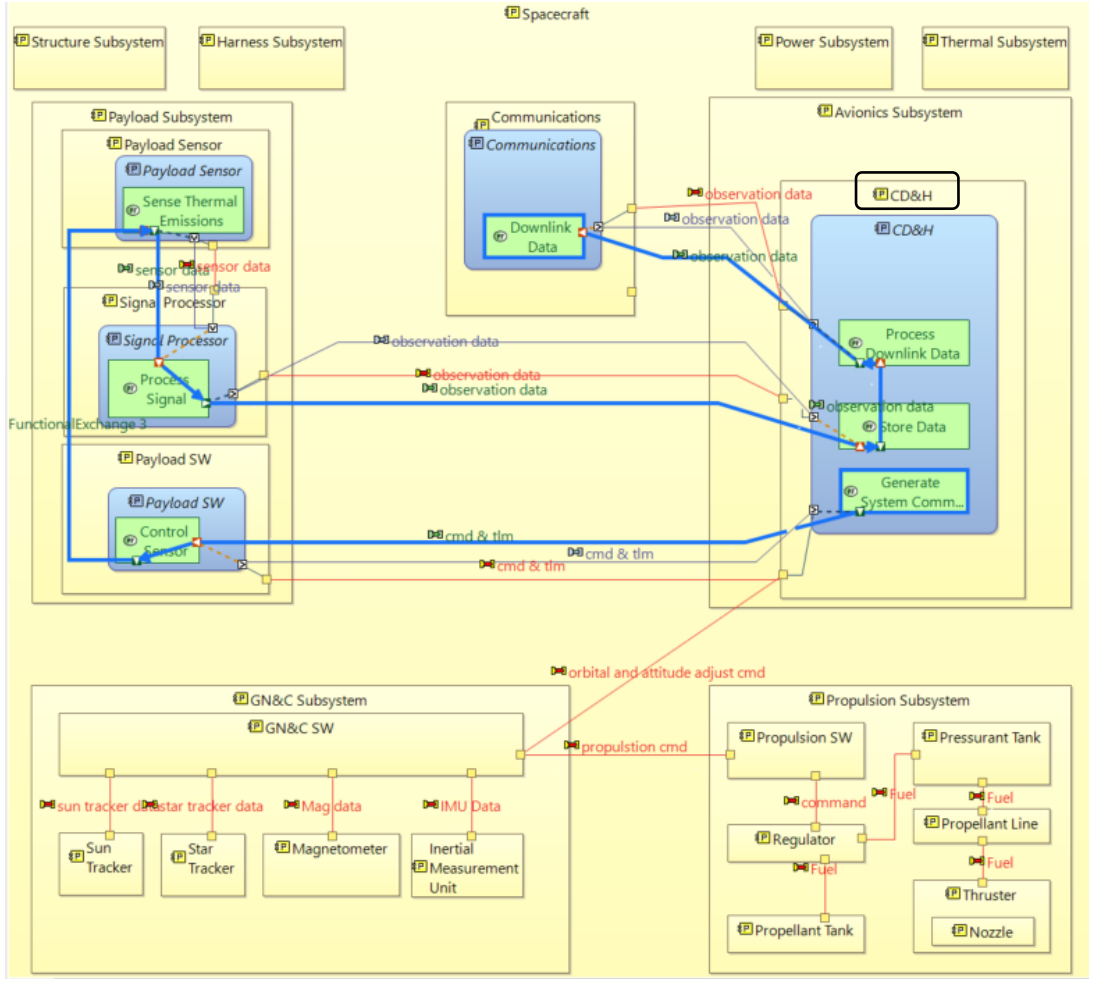
## EBOM Tool (PLM)




## MBSE Tool



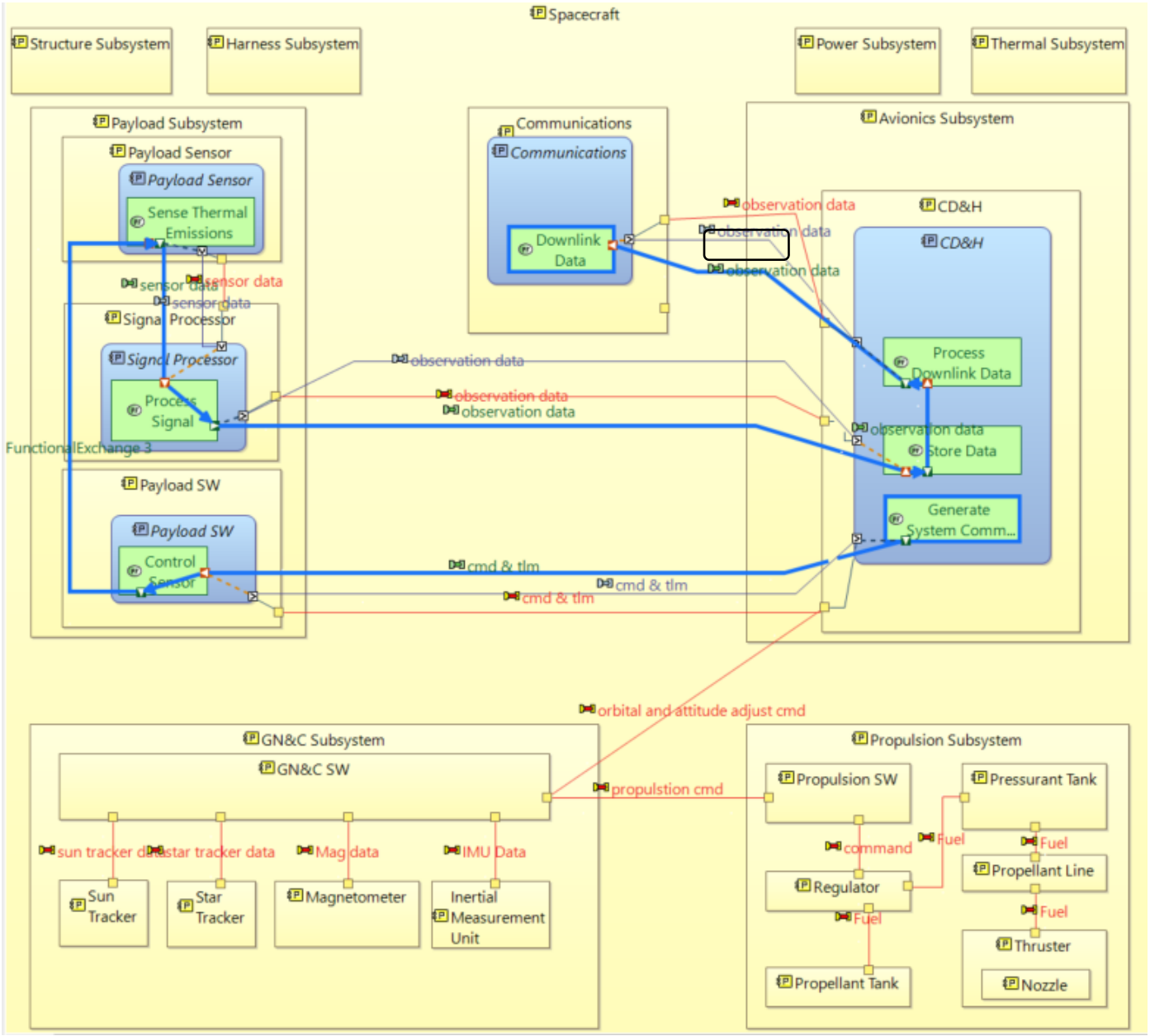
# MBSE Model and EBOM




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 | | |

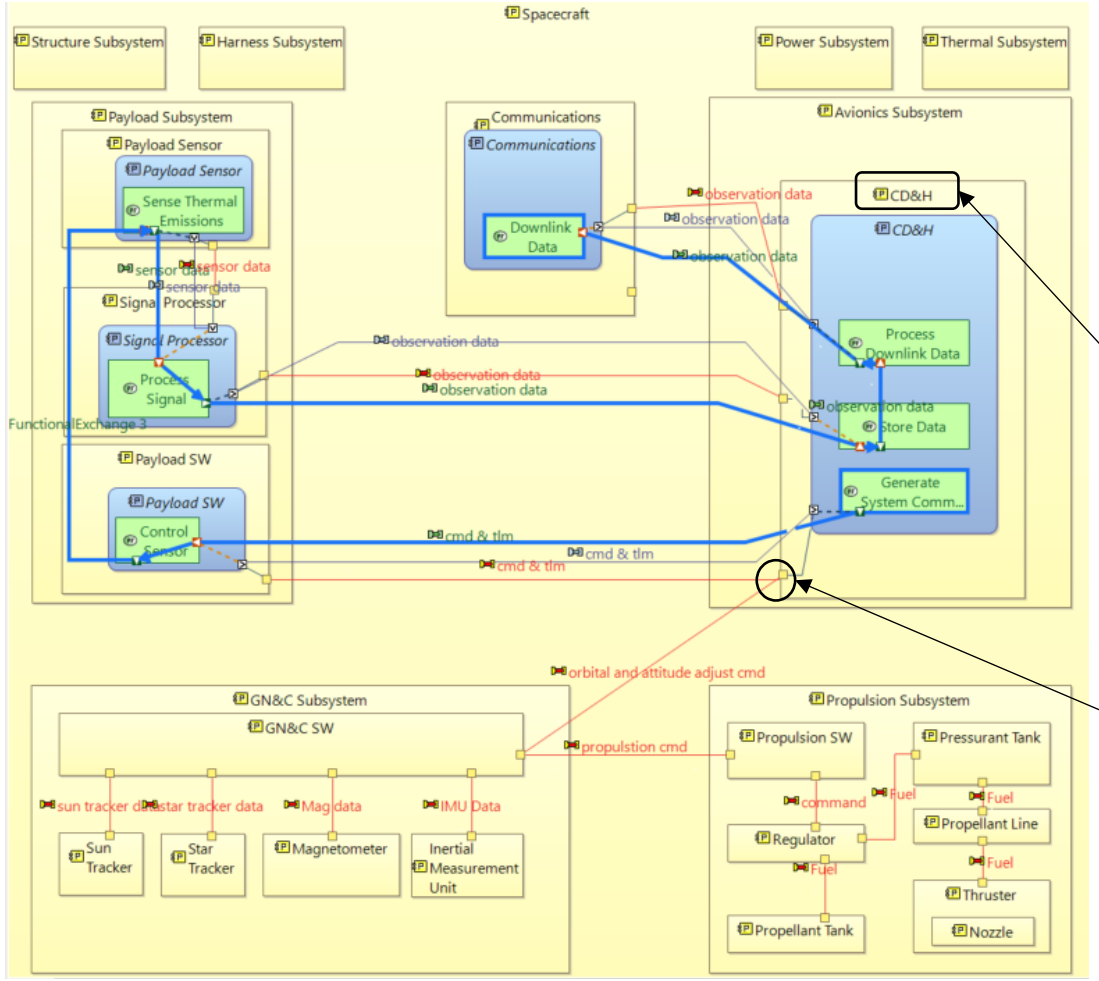
# Connecting the EBOM to the ICD Model

- **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)



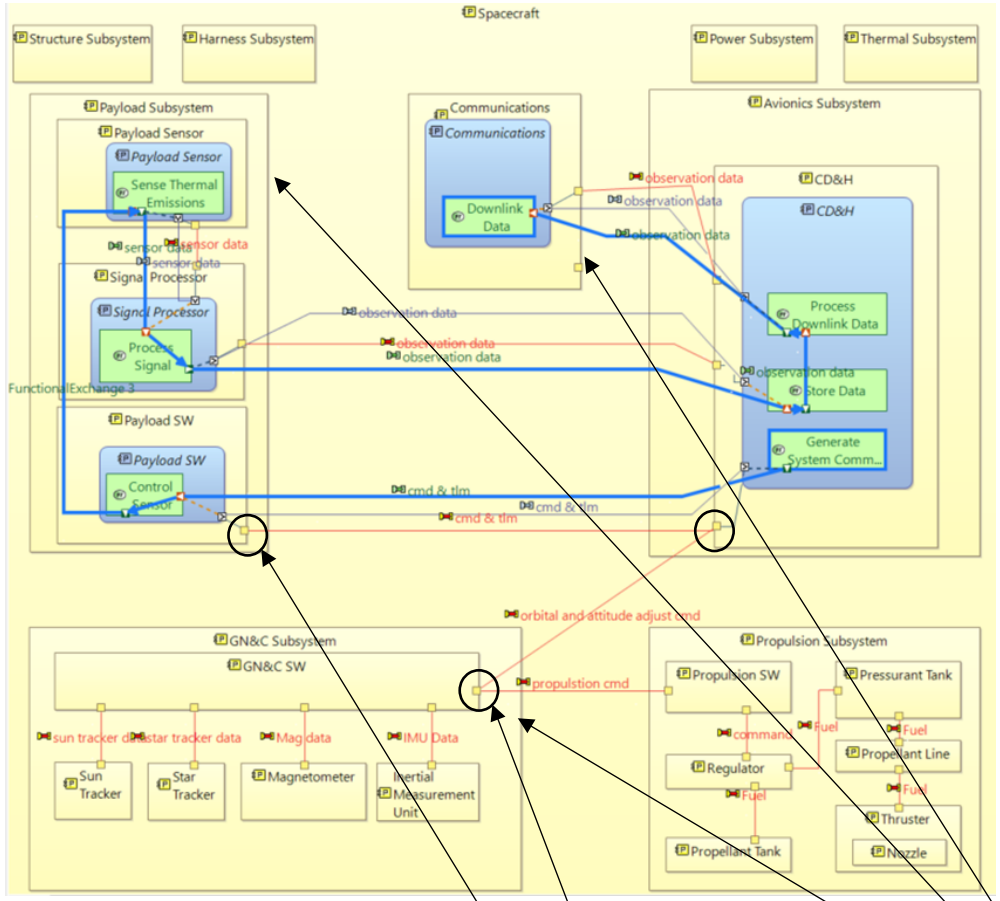

GEN000242/A;3-Spacecraft - Latest Working - Date - "Now"

| BOM Line | ICD Structure Mapping | Interface Port | Price | Source of Material |
|---|---|---|---|---|
| GEN000242/A;3-Spacecraft | | | | |
| GEN000243/A;2-GN&C Subsystem | | | | |
| 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-toDigital | 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 | | | | |

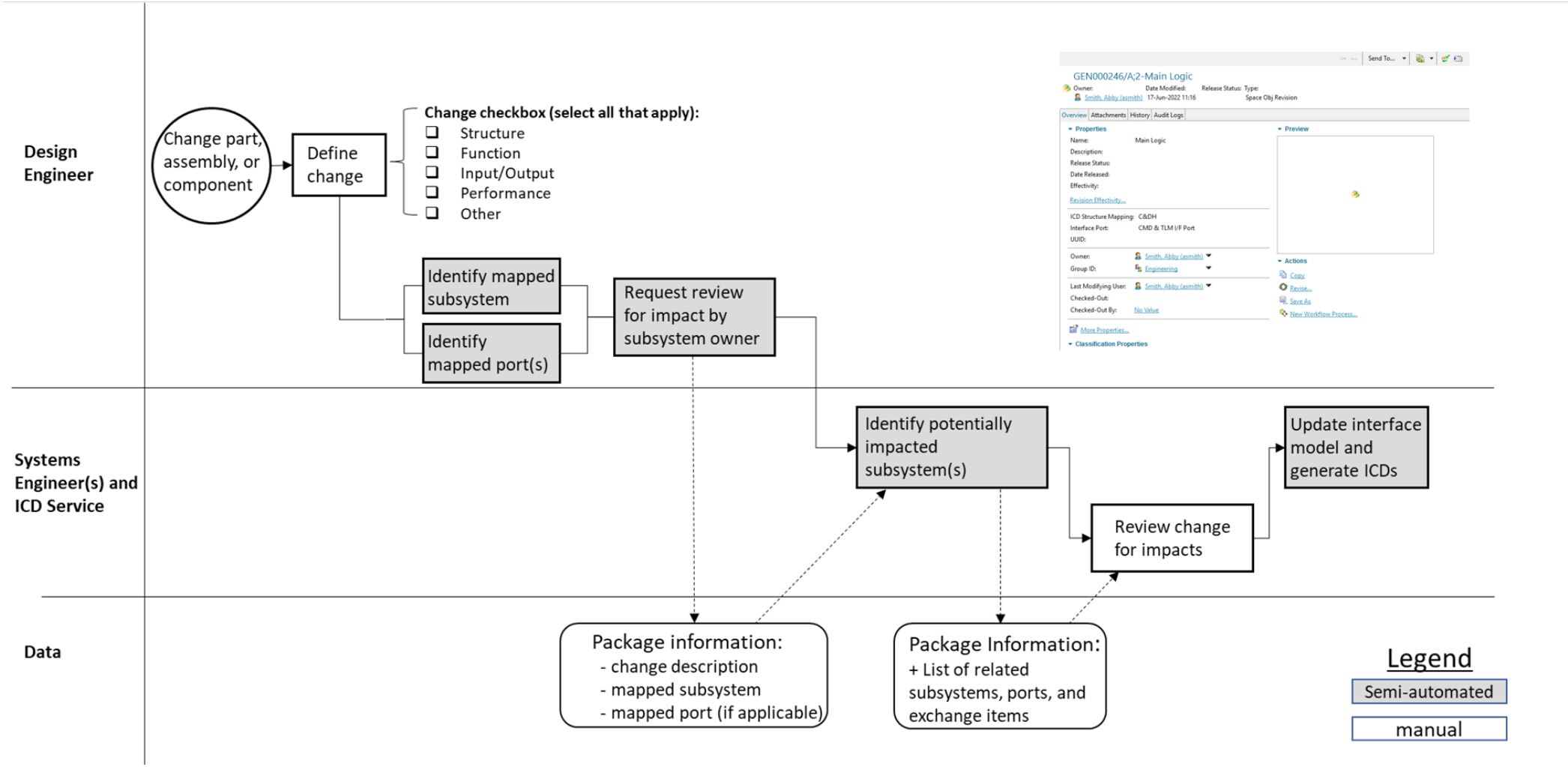
**Example: EBOM in Teamcenter links to ICD model for change impact studies**

**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 checked for impact against all interfaces to the cmd & tlm i/f port

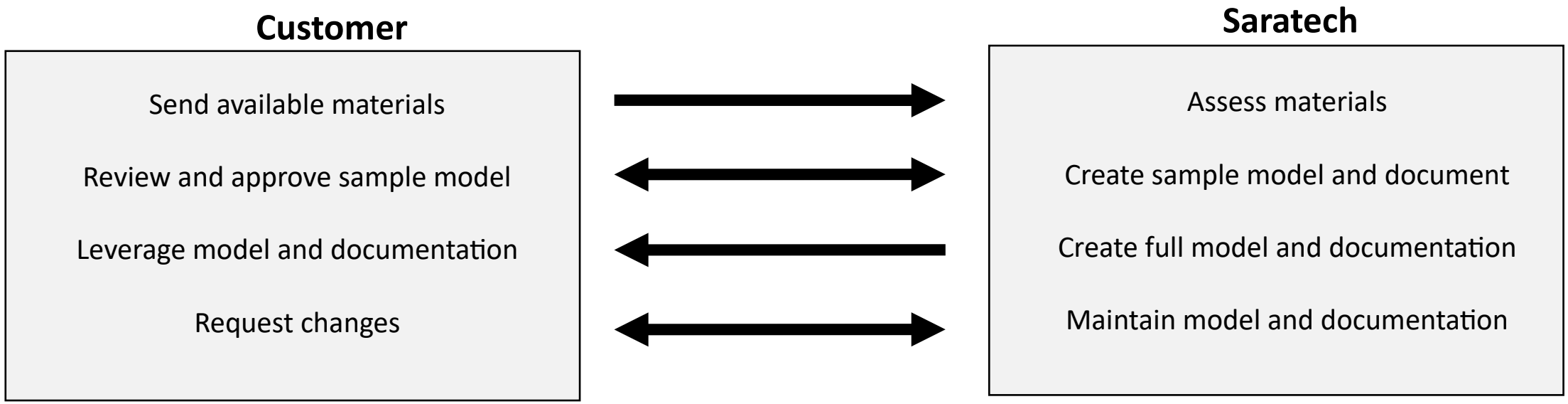
# Next Steps

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**