Reverse Engineering of a CubeSat with MBSE

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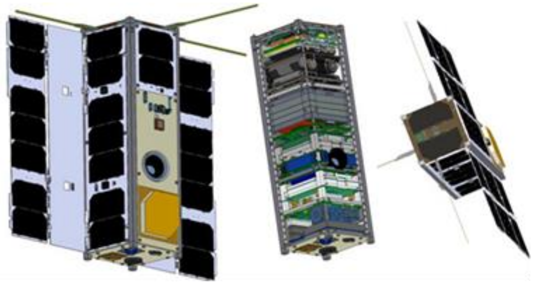
CESAM COMMUNITY

Agenda

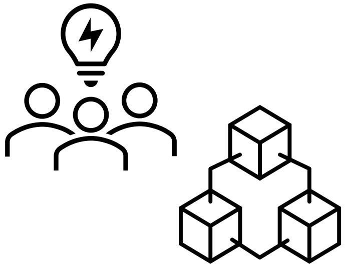
1. Introduction: activity background and objectives
2. Context of the reverse engineering activity
3. Initial approach to support reverse engineering with MBSE
4. Improvement proposal to reach digital continuity faster
5. Conclusion

1. Introduction



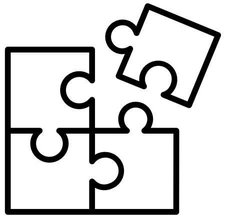
- In April 2021, ESA has launched a study on Reverse engineering with MBSE of an OPS-SAT mission and system
  - First CubeSat mission designed and operated by ESA since 2019
  - Low-cost, open, and flexible flying ‘laboratory’ powerful platform for in-orbit demonstration (IOD)
  - Large and diverse team mixing academic and industrial stakeholders

  ➔ some challenges and pain points…



- Goal #1: can MBSE approach with tool address those pain points ?
  - To which extent ?

Scope of this presentation



- Goal #2: can we provide a reference model for future IOD missions?

Not addressed today but presented at “ESA MBSE 2022” conference in Toulouse

2. Context of the reverse engineering activity

1st challenge – build a model from various documents

- svt-0 procedures
- DHSO-SYS-RS-1001-OPS-SAT System Requirements Document_v1_2.pdf
- ESA-ESC1-GST-DOC-0001 - ESOC-1 Network Configuration Document OPS-SAT.docx
- ESA-OSAT-MCS-DD-0001 - OPS-SAT OMCS Architectural Design Document - 2.0.docx
- ESA-OSAT-MCS-IF-0001 - OPS-SAT OMCS Experimenter Packet Level ICD - 1.0.docx
- ESA-OSAT-SW-TN-0001_1.0-OPS-SAT SPP bridge.docx
- ESA-OSAT-SW-TN-0002_1.0-OPS-SAT Nanosat MO Framework.docx
- ESA-SMILE-GST-ICD-0001 - SMILE Ground Station ICD i1r0(1).pdf
- OPS-SAT - Automation_Concept.docx
- OPS-SAT Flight Operations Procedures.pdf
- OPS-SAT Mission Operations Plan.docx
- OPS-SAT Pocket+ Design overview.docx
- OPS-SAT SOW_v2_3_1.pdf
- OPS-SAT Space Shell Design overview document.docx
- OPS-SAT SVT 2 Procedures and Test Report 1.0 signed.docx
- OPS-SAT SVT-2 Configuration.docx
- OPS-SAT System Summary for Experimenters - v1.pdf
- ops-sat_lessons_learnt_01_02_2021.xlsx
- opssat-samares.pdf
- OPSSAT-SYS-SDR_v4.4_Excerpt_v1.0.pdf
- OPSSAT-SYS-SGICD_v4.3.pdf
- Software integration process for experimenters.pdf

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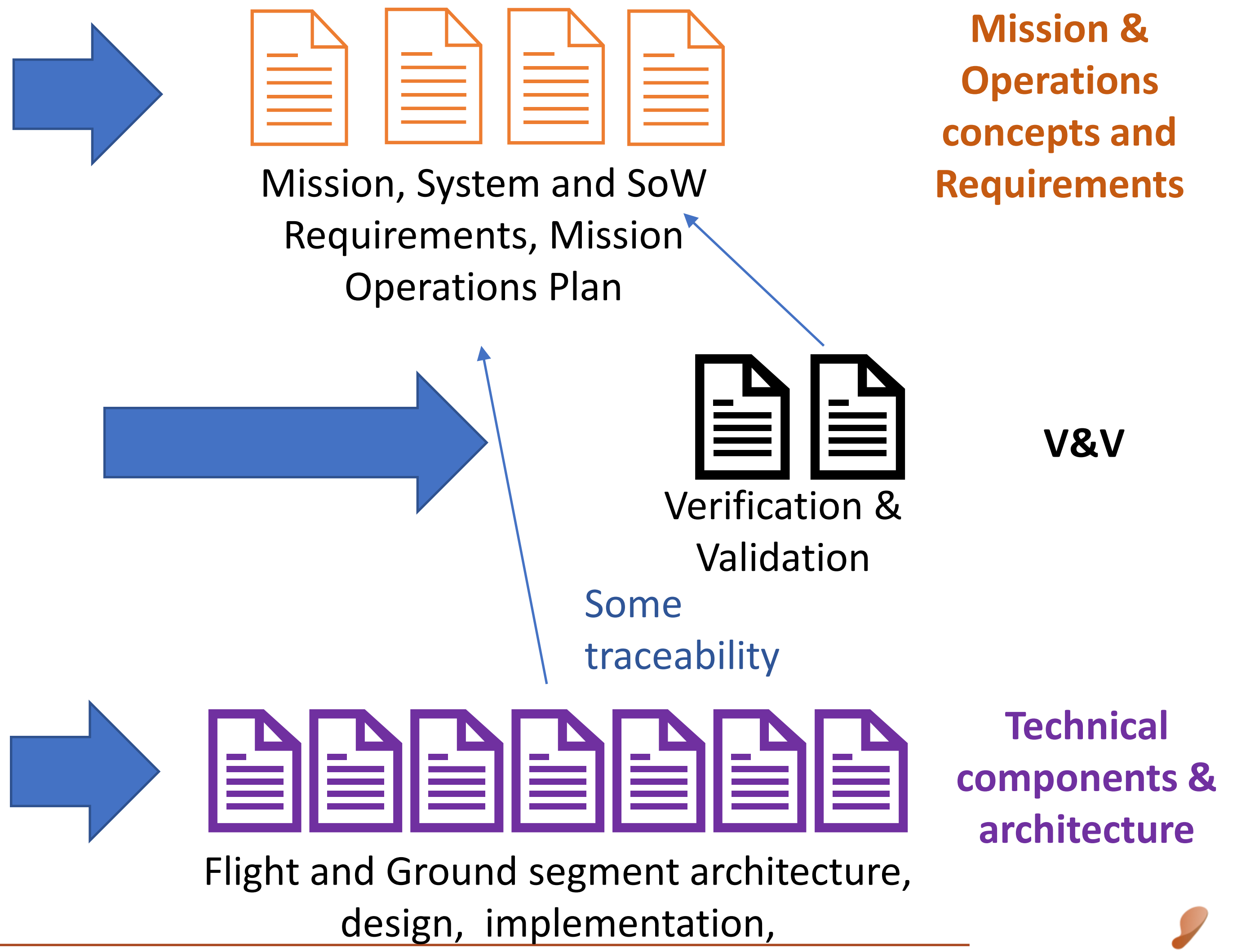


* TU Graz was the prime (ESA contractor in charge of the satellite)

2nd challenge – select an efficient MBSE framework

- A key decision: select the Airbus MBSE Framework (MOFLT)

Mission Analysis : WHAT is the problem that we need to solve, and WHAT are the potential ways of solving it?

- *Definition of SoS Mission : Objectives / Effects*
- *Determine and characterize potential ways of realizing a Mission (Mission Concept)*

***CONOPS** - Concept of Operation*

Operational Analysis: WHAT the System of Interest will do to contribute to the mission ? What is the context of the SOI ?

- *Definition of Operational Concept focusing on a Entity : Context / Constraint / SOI*
- *Definition of Operational Scenarios consistent with Mission Concept*

***OPSCON** - Operational Concepts*

Functional Architecture : HOW the System of Interest will work to meet expectations ?

- *Definition of execution sequence between functions to realize operations*
- *Definition of structural arrangement of functions & interfaces*

Logical Architecture : HOW the System of Interest is organized ? (Abstract Component)

- *Definition of logical components + logical interfaces*
- *Allocation of functions to logical components*

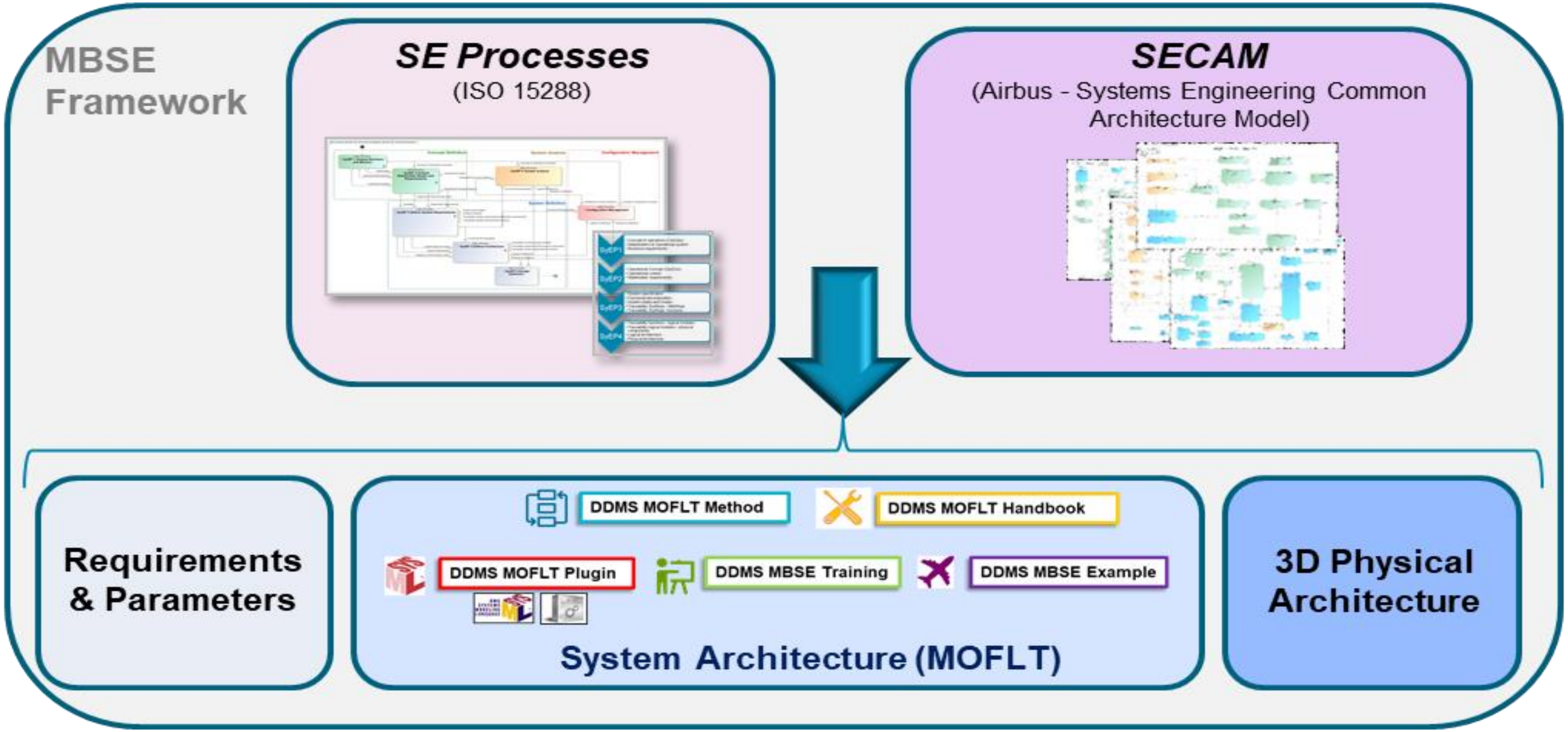
Technical Architecture : HOW the System of Interest will be implemented ?

- *Definition of technical components & interfaces*
- *Realization of logical Components / interfaces by technical Components / interfaces*

Architecture Dossier / System Interface Document

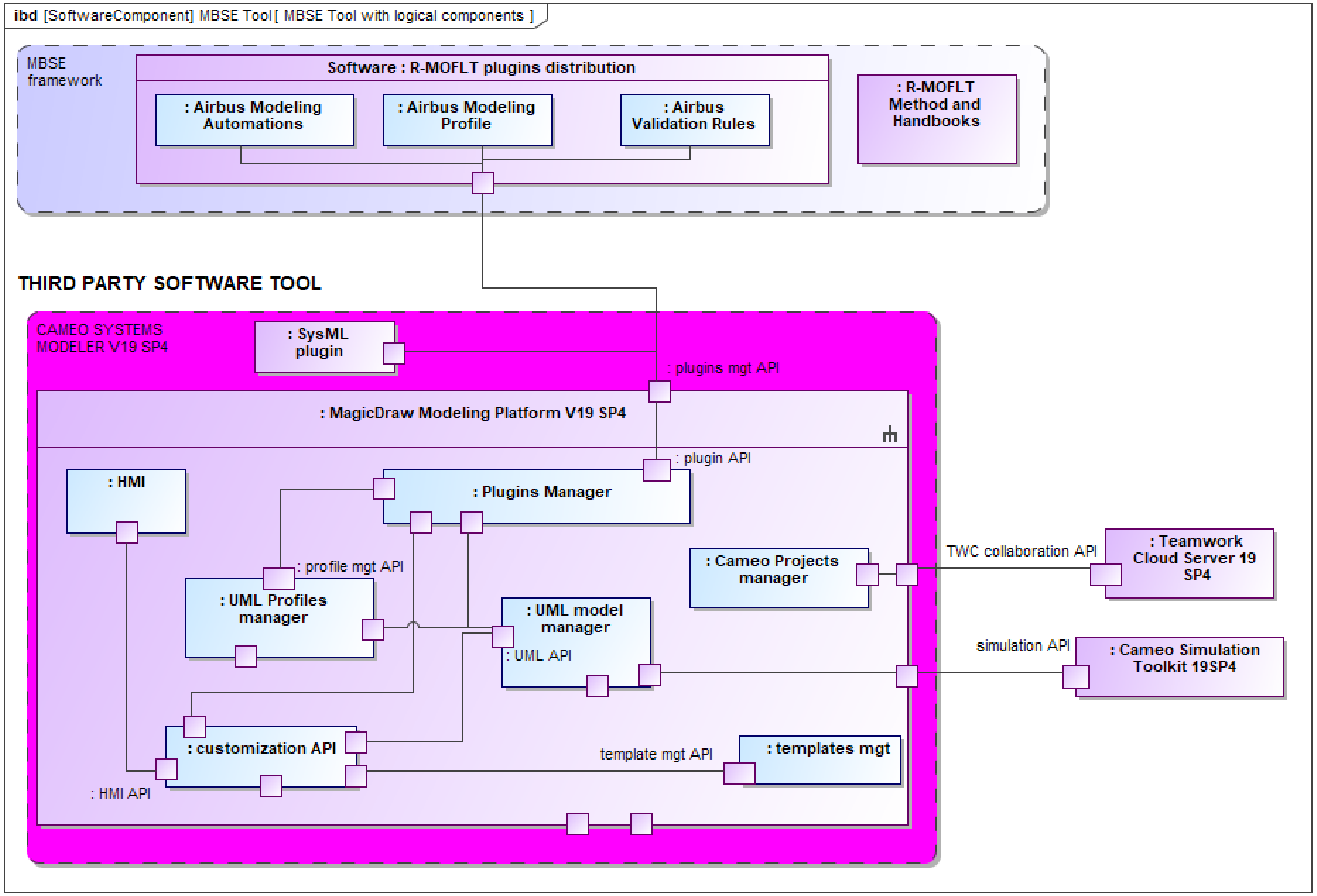
Foundations of Airbus MBSE framework

- MOFLT framework derived from strong foundations



SysML tool used to build the MBSE framework

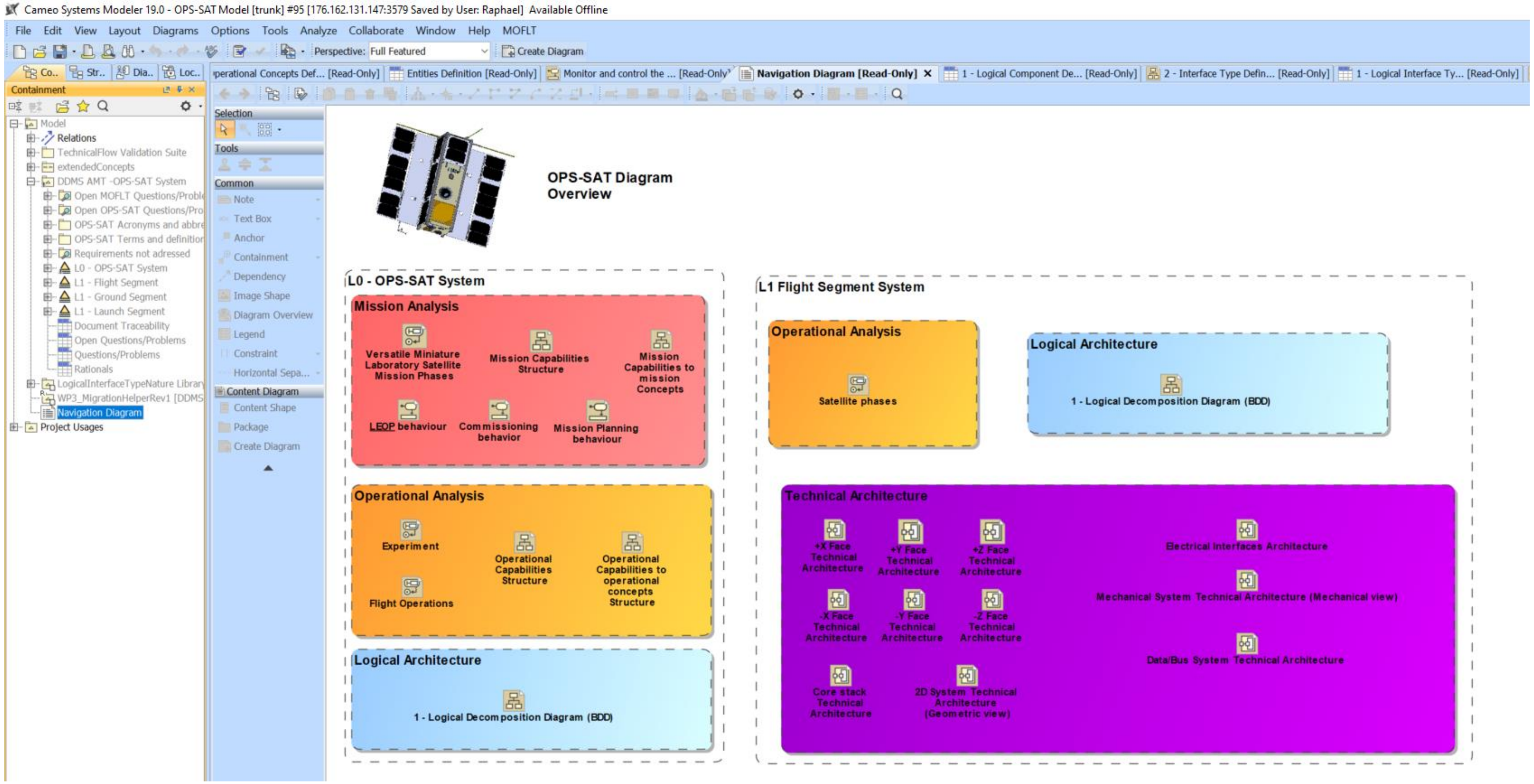
- MBSE framework implemented on top of Cameo Systems Modeler



3. Initial approach for reverse engineering

Model structure – 2 models to match 2 levels of systems

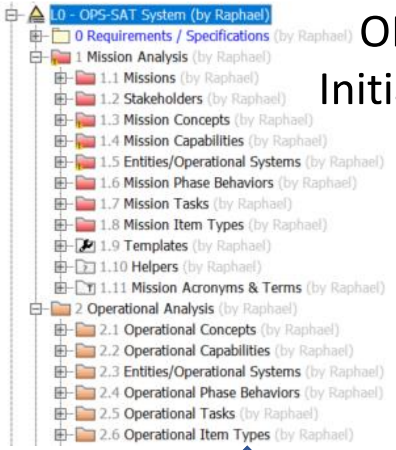
- 2 levels of systems:
  - OPS-SAT global system at Level 0 (L0) mainly focused on the mission and operations (needs)
  - OPS-SAT flight segment system at level 1 (L1), mainly focused on reflecting the satellite technical architecture



A strategy into 2 main steps: translate and complete

Mission, System and SoW Requirements, Mission Operations Plan

1.1 Translate with traceability



OPS-SAT GLOBAL SYSTEM (Level 0)
Initialized with mission and operations

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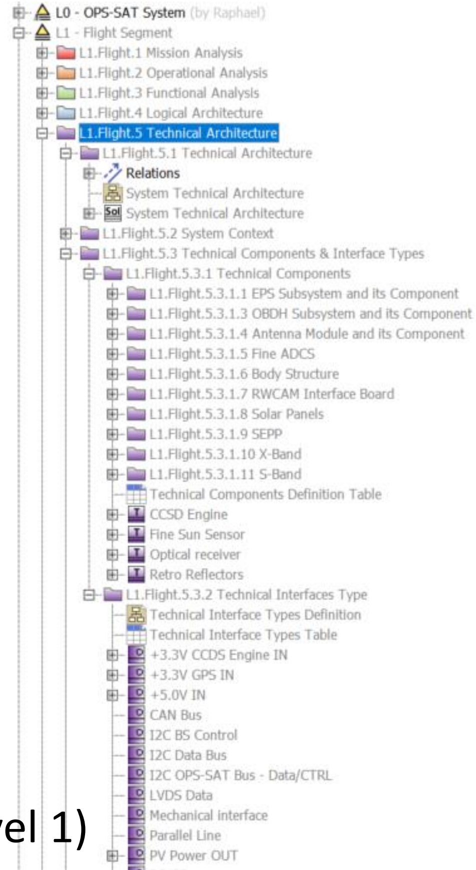
2. Ensure continuity between L0 and L1: use of functions and logical components at L0 and L1 to fill the gap (refinement and abstraction) and reach end to end traceability



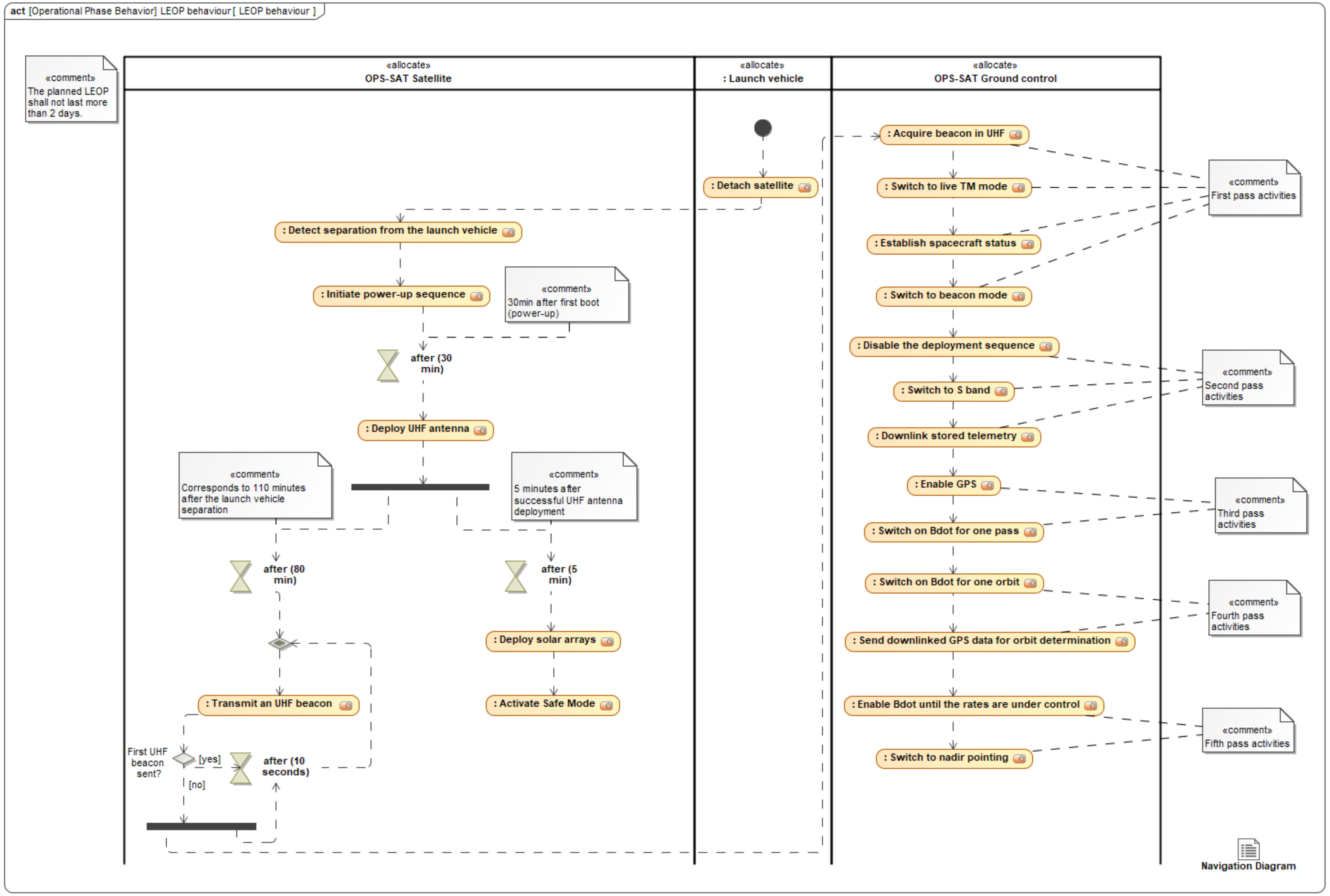
Flight and Ground segment architecture, design, implementation,

1.2 Translate with traceability

OPS-SAT FLIGHT SEGMENT (Level 1)
Initialized with data about equipments

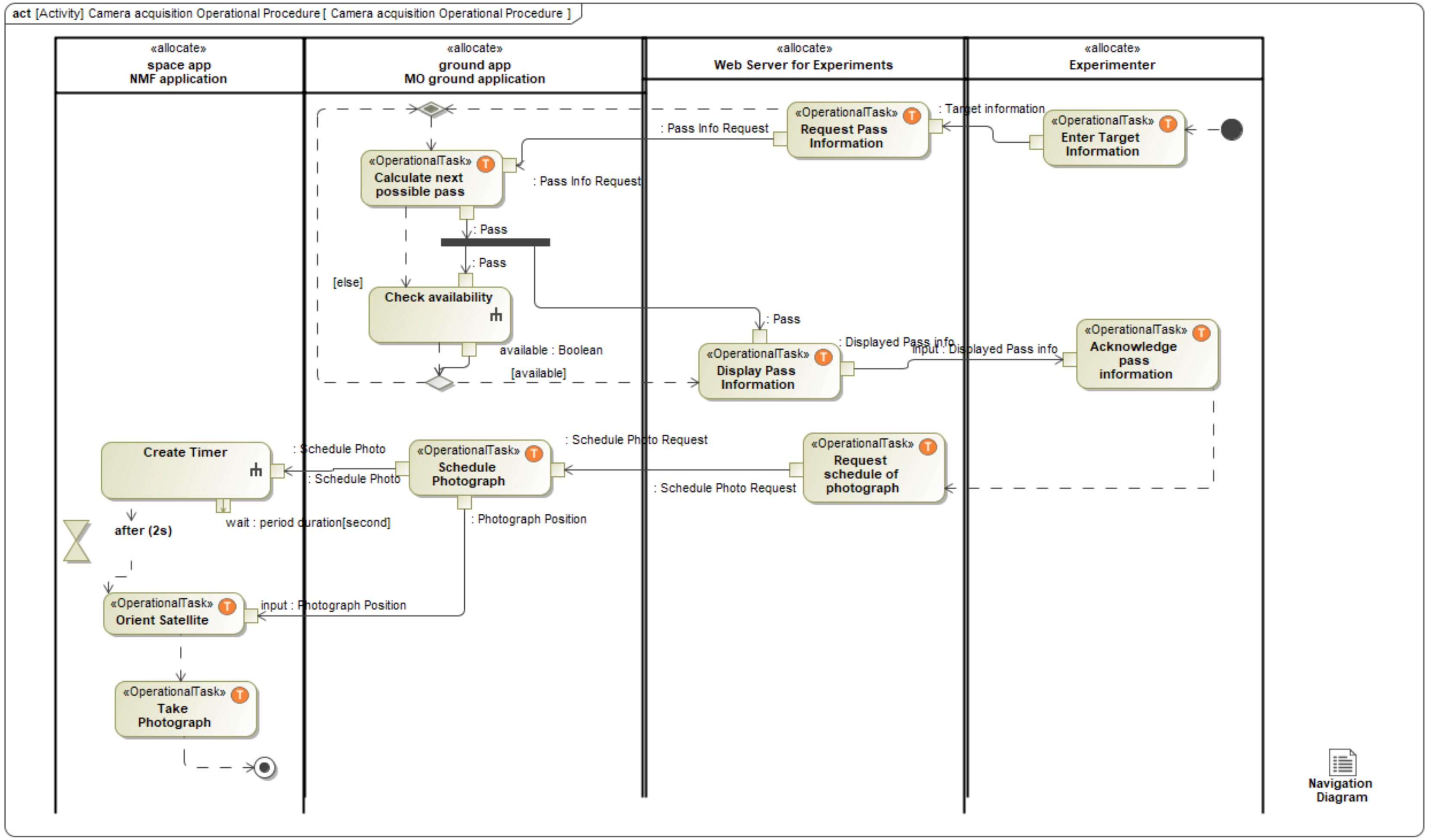
Step 1 – translate operational concept in operational tasks

- The operational concepts



Step 1 – translate experiment usage into operational tasks

- The operational procedure is made of an arrangement of operational tasks allocated to different parts



Step 1 – translate technical views of the satellite

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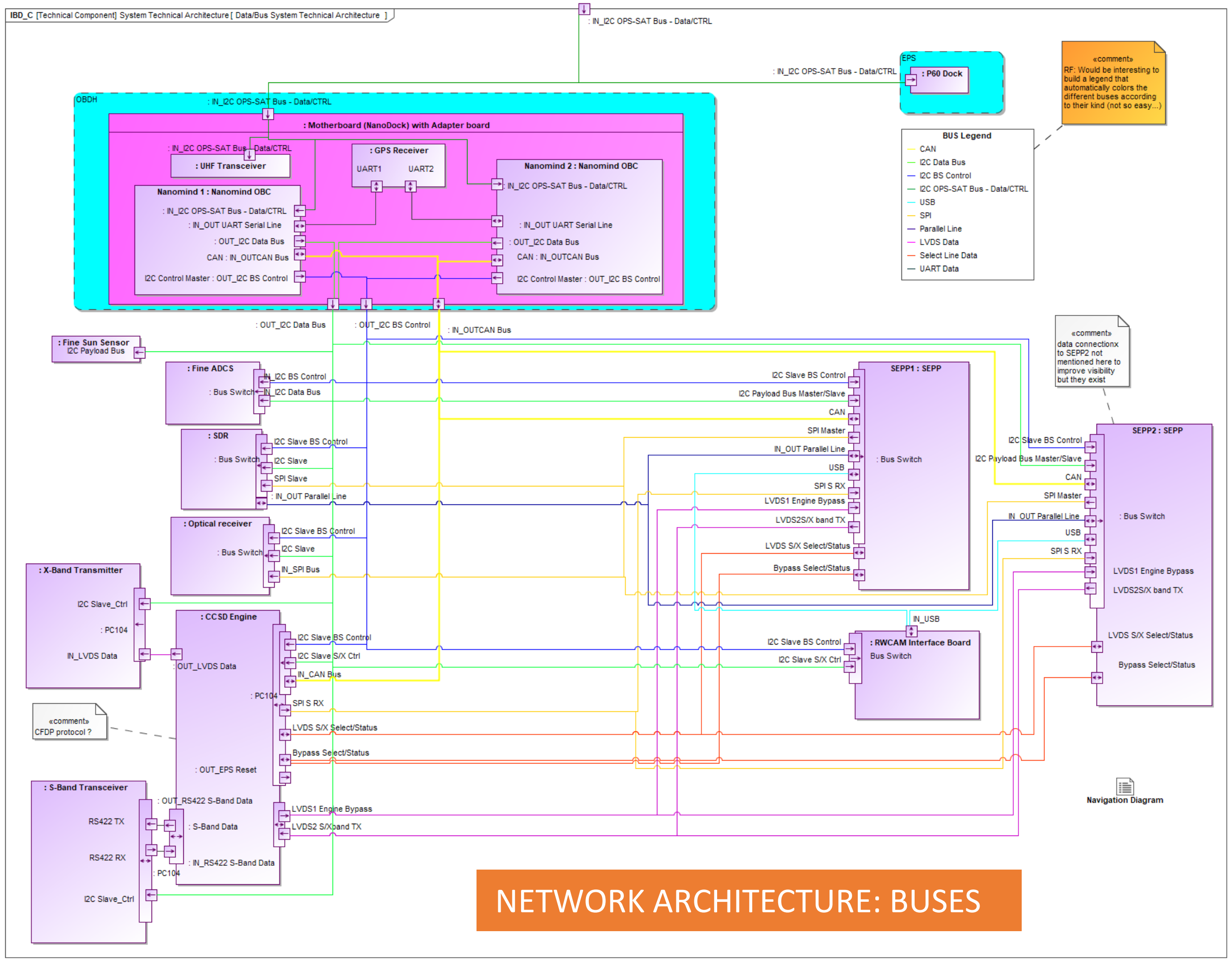
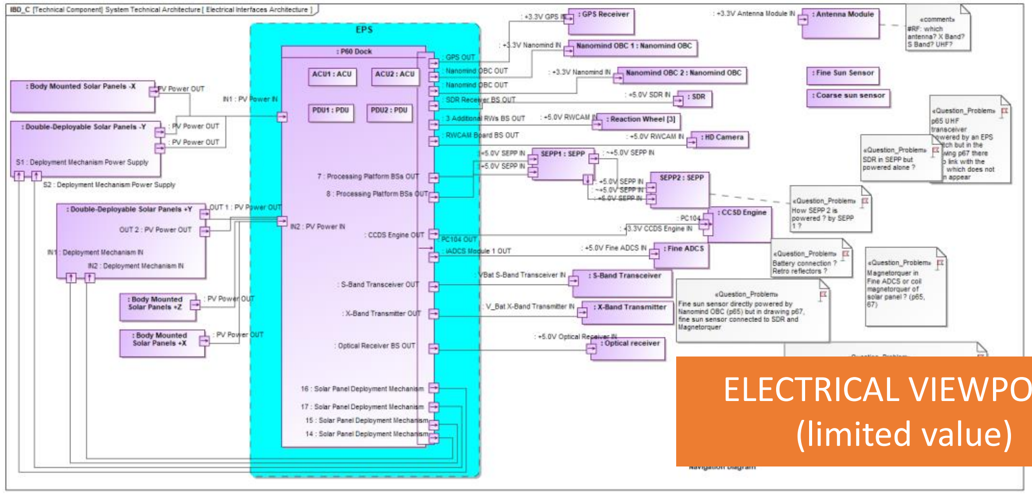
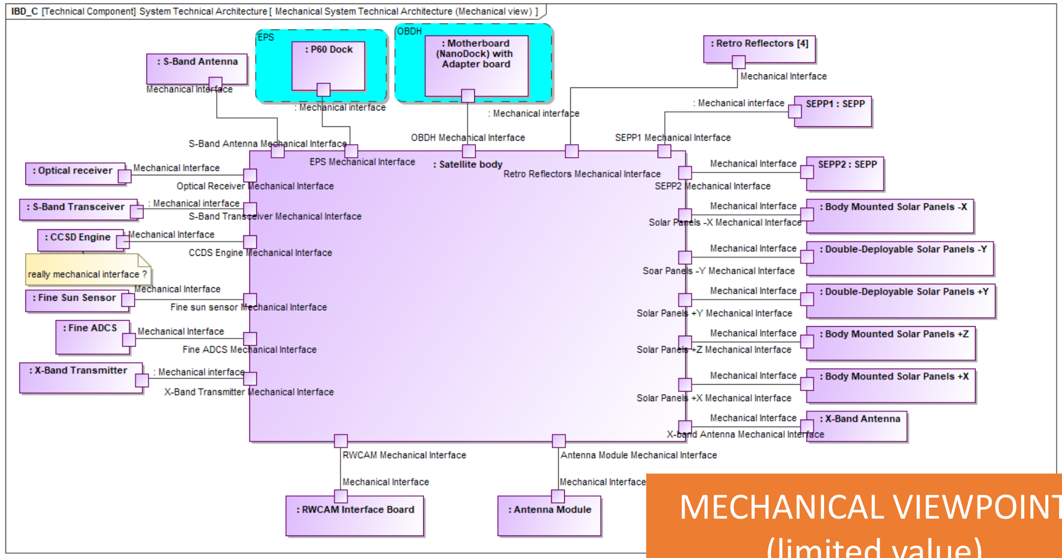
3 different views of the **same technical architecture => consistency**



NETWORK ARCHITECTURE: BUSES

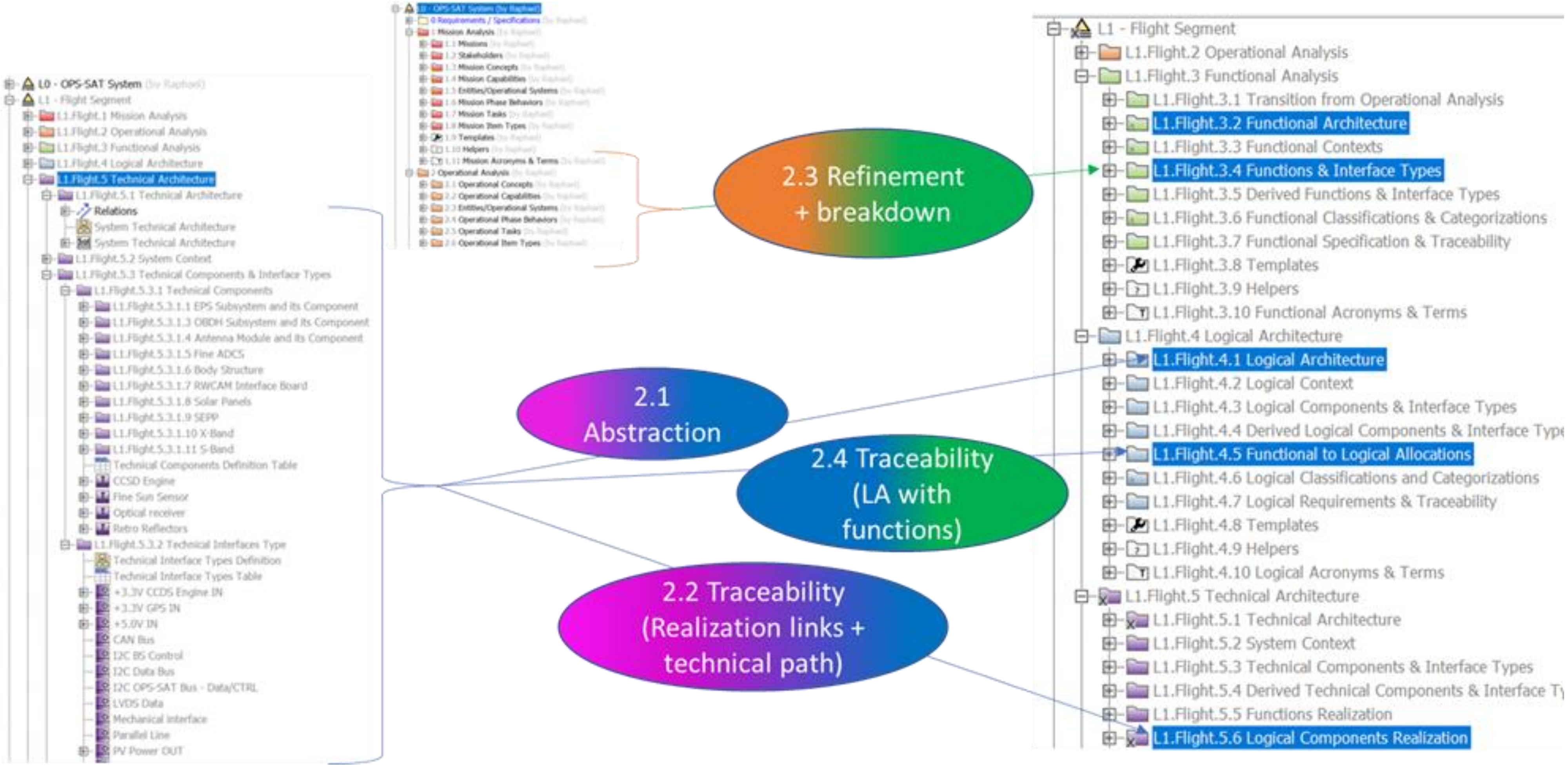


ELECTRICAL VIEWPOINT
(limited value)



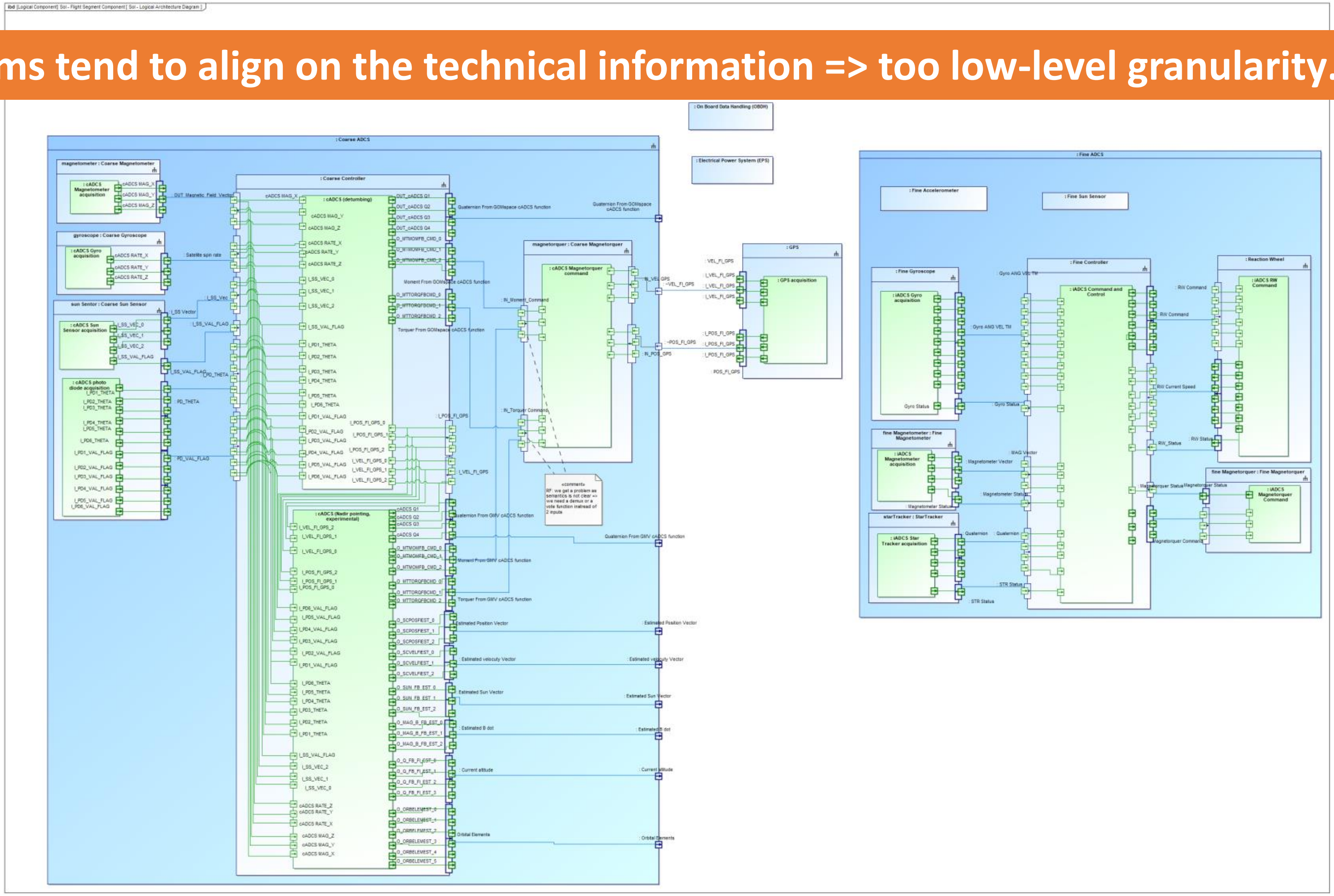
MECHANICAL VIEWPOINT
(limited value)

Step 2 – the strategy: refinement and abstraction



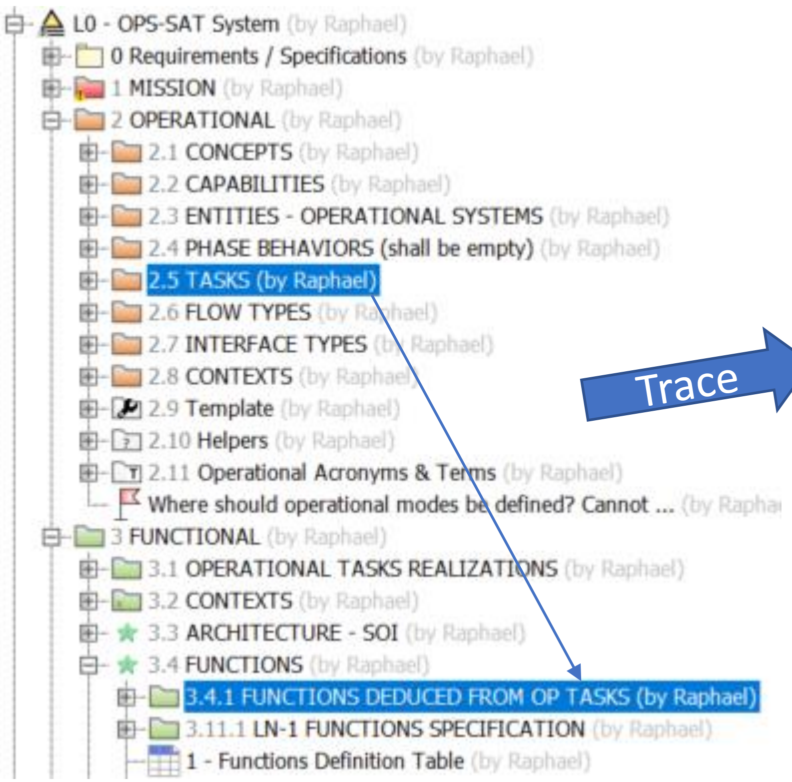
Step 2 – abstract logical components and functions from technical architecture

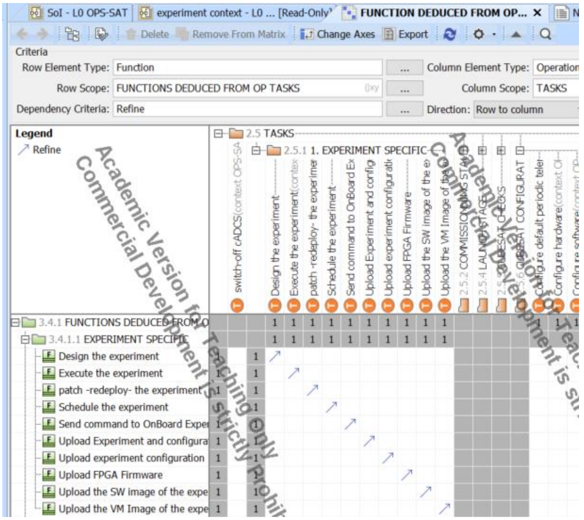
Very difficult exercise: logical items tend to align on the technical information => too low-level granularity…

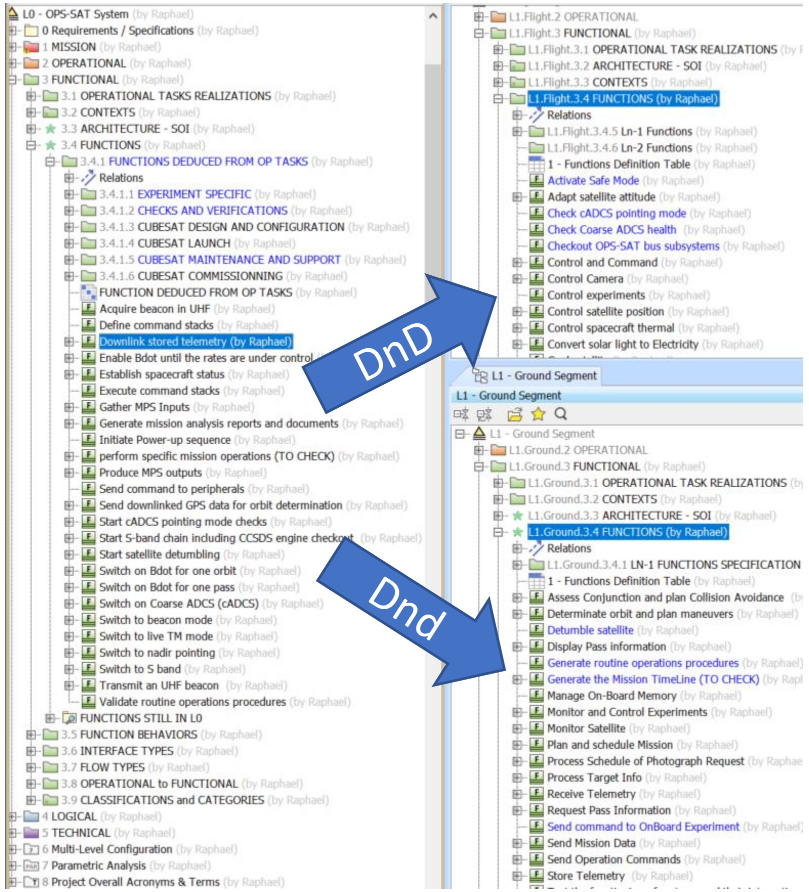


Step 2 - From Operational Tasks to functions

- Duplicate, refactor, trace functions







- Then move L0 functions to L1 Flight and L1 Ground

Functions remain close (semantics) to the operational concept => too specific...

Reverse engineering modeling approach – not easy !!!

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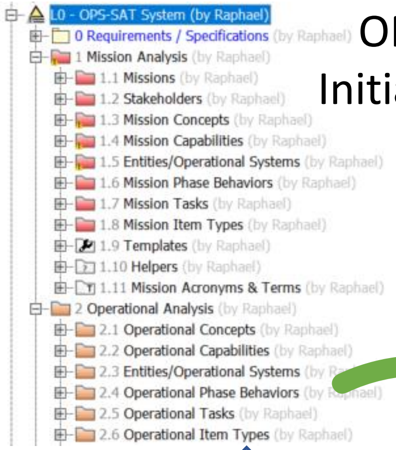
Mission, System and SoW Requirements, Mission Operations Plan

1.1 Translate with traceability



OPS-SAT GLOBAL SYSTEM (Level 0)
Initialized with mission and operations

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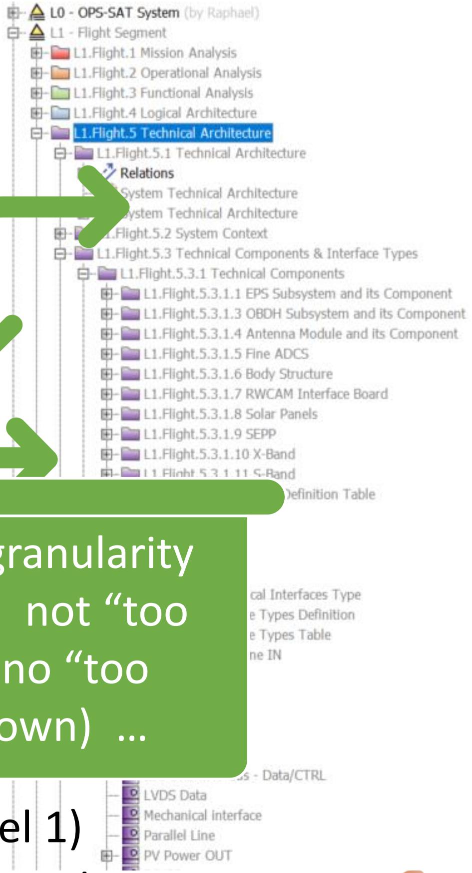


2. Ensure continuity between L0 and L1 use of functions and logical … to fill the gap (refine … reach end …

Hard to identify the right granularity level for system functions: not "too technical" (bottom-up), no "too mission-specific" (top-down) …

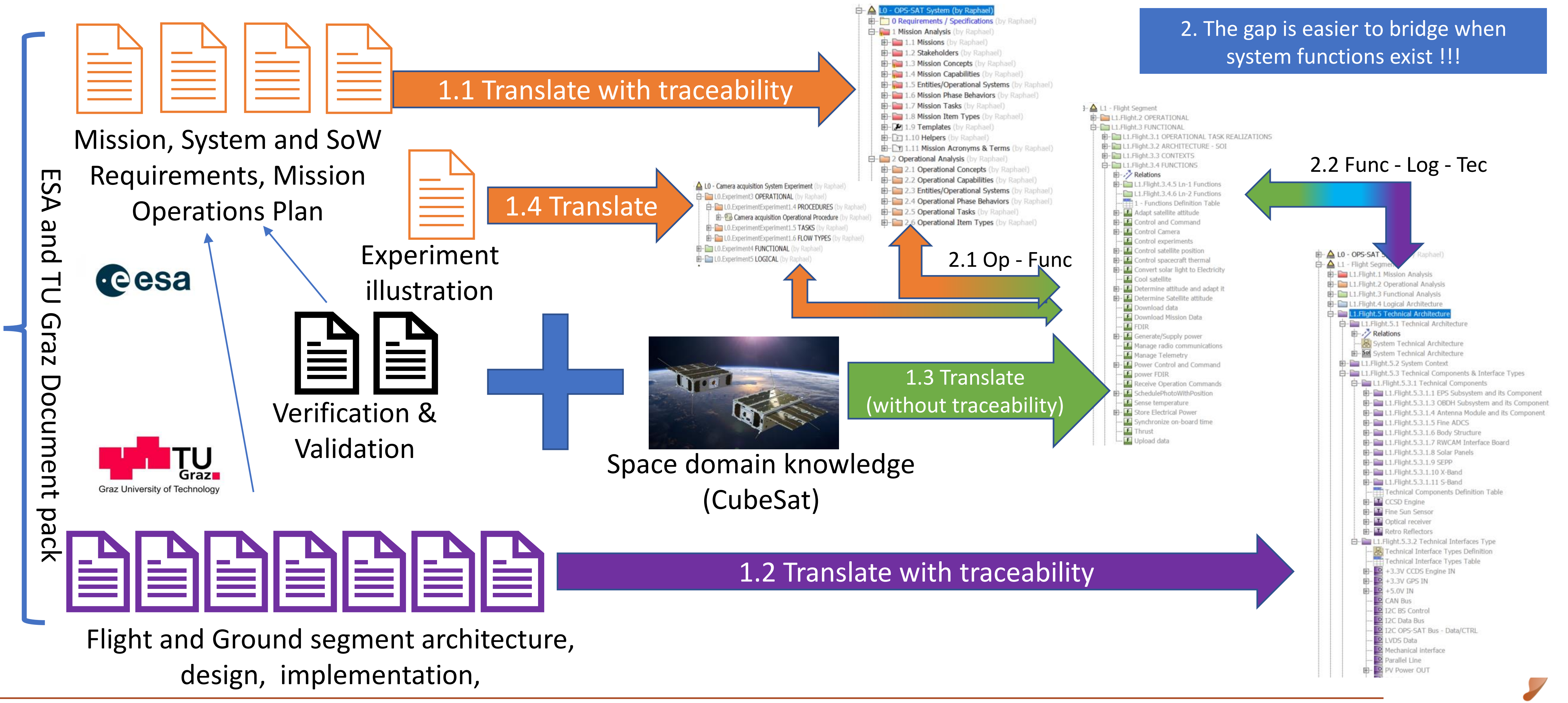
1.2 Translate with trac…

Flight and Ground segment architecture, design, implementation,

OPS-SAT FLIGHT SEGMENT (Level 1)
Initialized with data about equipments

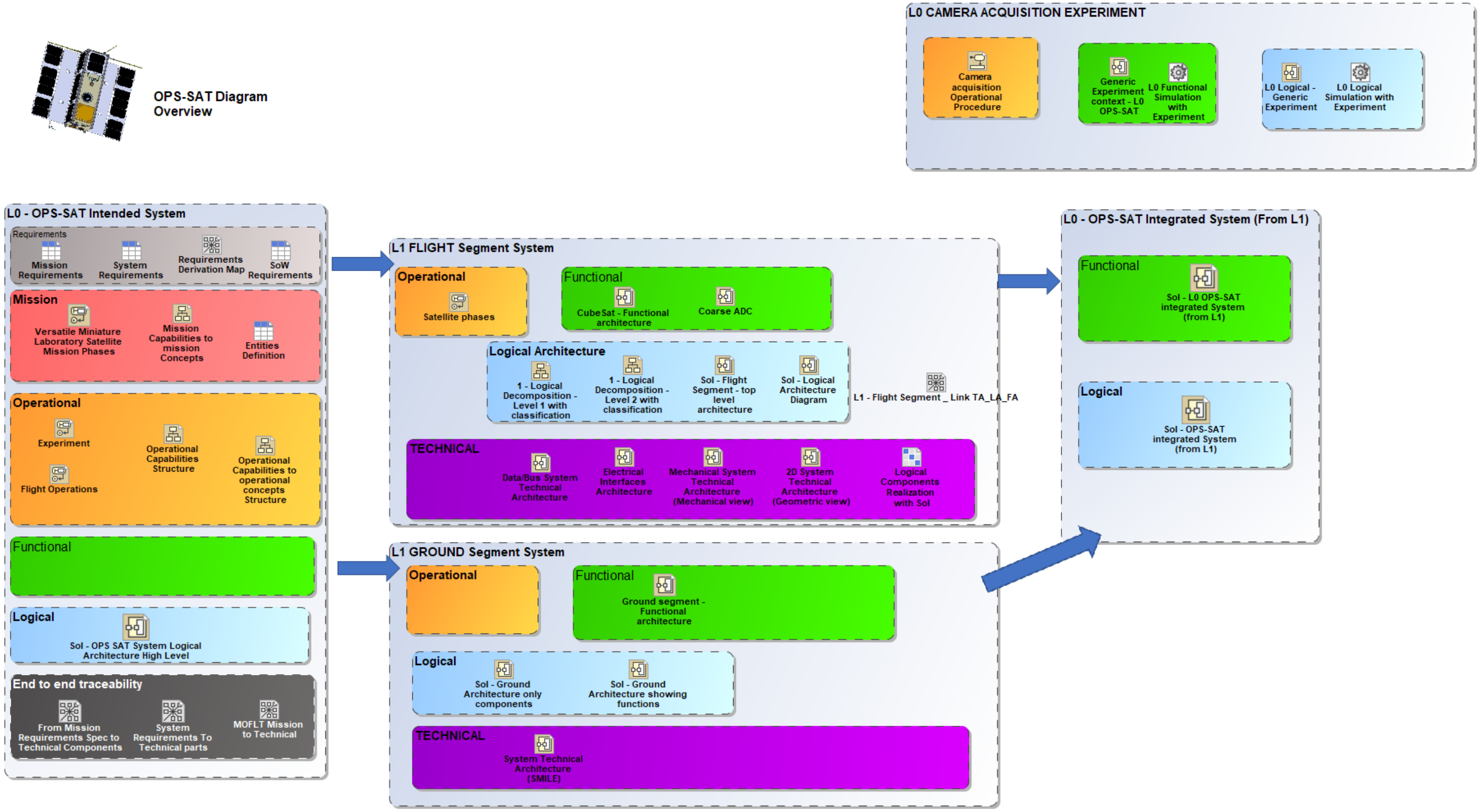
4. Improvement proposal to ease the digital continuity

Reverse engineering modeling approach – V2



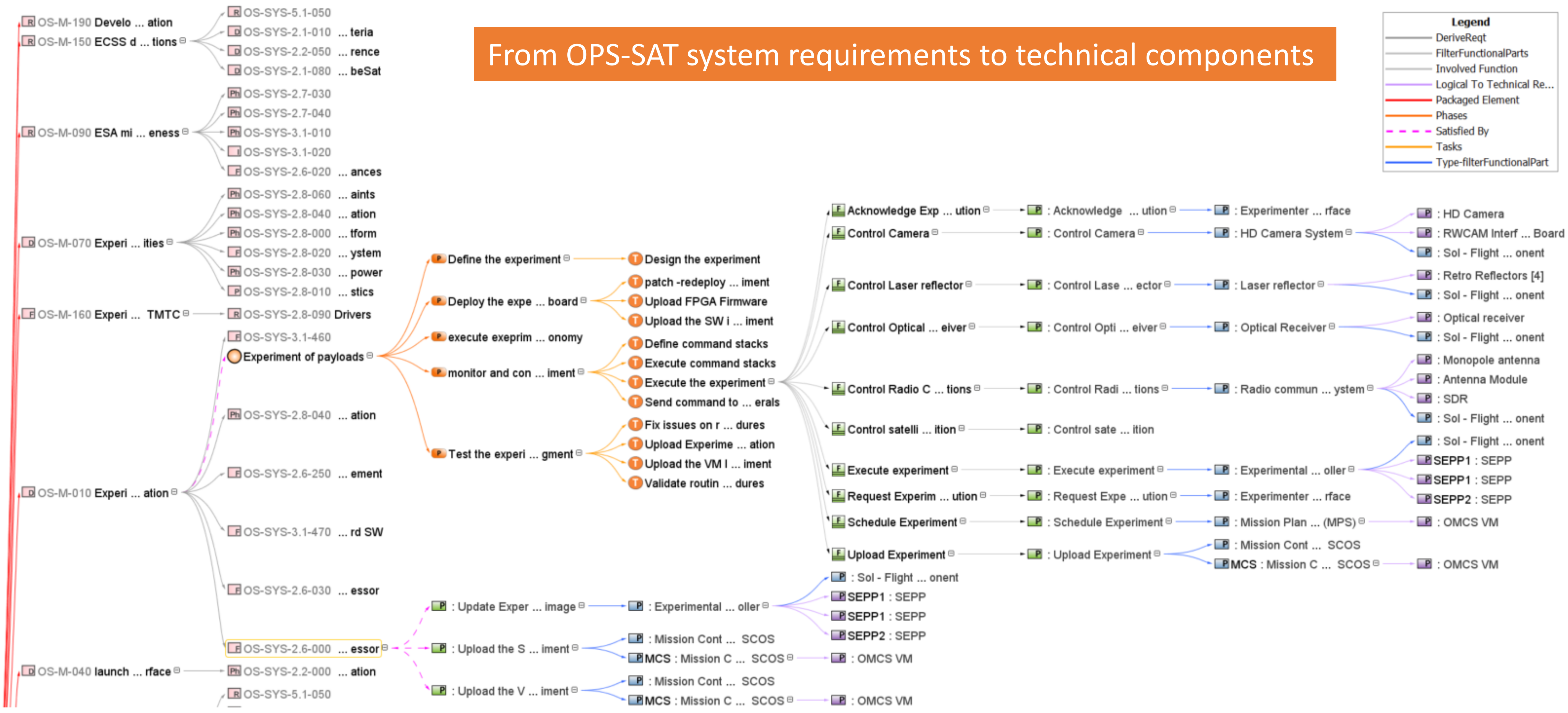
A larger set of models to better reflect all systems

- 5 related models:
  - One for the intended global system
  - One for each segment (flight and ground)
  - One for the integrated system
  - One for an experiment of the system (usage)



Functions can be introduced at the right abstraction level in any of those models

With the introduction of “domain” functions, digital continuity was easier to achieve…



5. Conclusion

Lessons learned about reverse engineering with MBSE

1. Choose the right level for the technical/physical architecture
   - The formalization of physical products from their datasheets is very time consuming and does not help in building the digital continuity ➔ not the 1st target
2. Mechanical and electrical views have low value if done in SysML or require a lot of efforts for useful concepts, not needed with dedicated tools
3. System functions are key to bridge the gap between mission and the technical architecture, but it is very hard to identify the “good” ones
   1. When refined from mission/operations (top-down), they are too “mission” specific
   2. When abstracted from equipments, they remain too “technical”
   3. **The best approach seems to use “space domain knowledge” as input for those functions and then adapt those functions to meet in the middle…**

Thank you for your attention!

Q&A

Contact

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