Capella by Artal

CNES
CENTRE NATIONAL D'ÉTUDES SPATIALES

Successful MBSE landing on a CNES operational use-case

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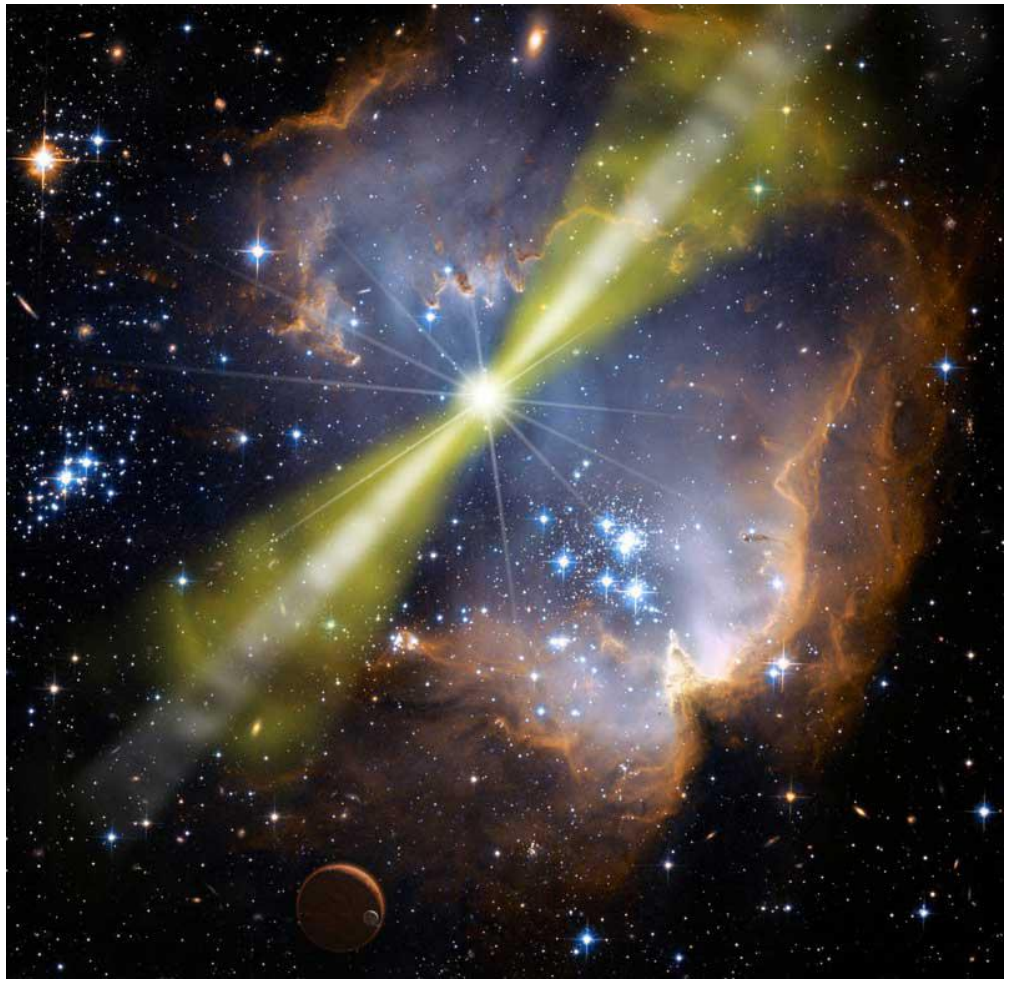
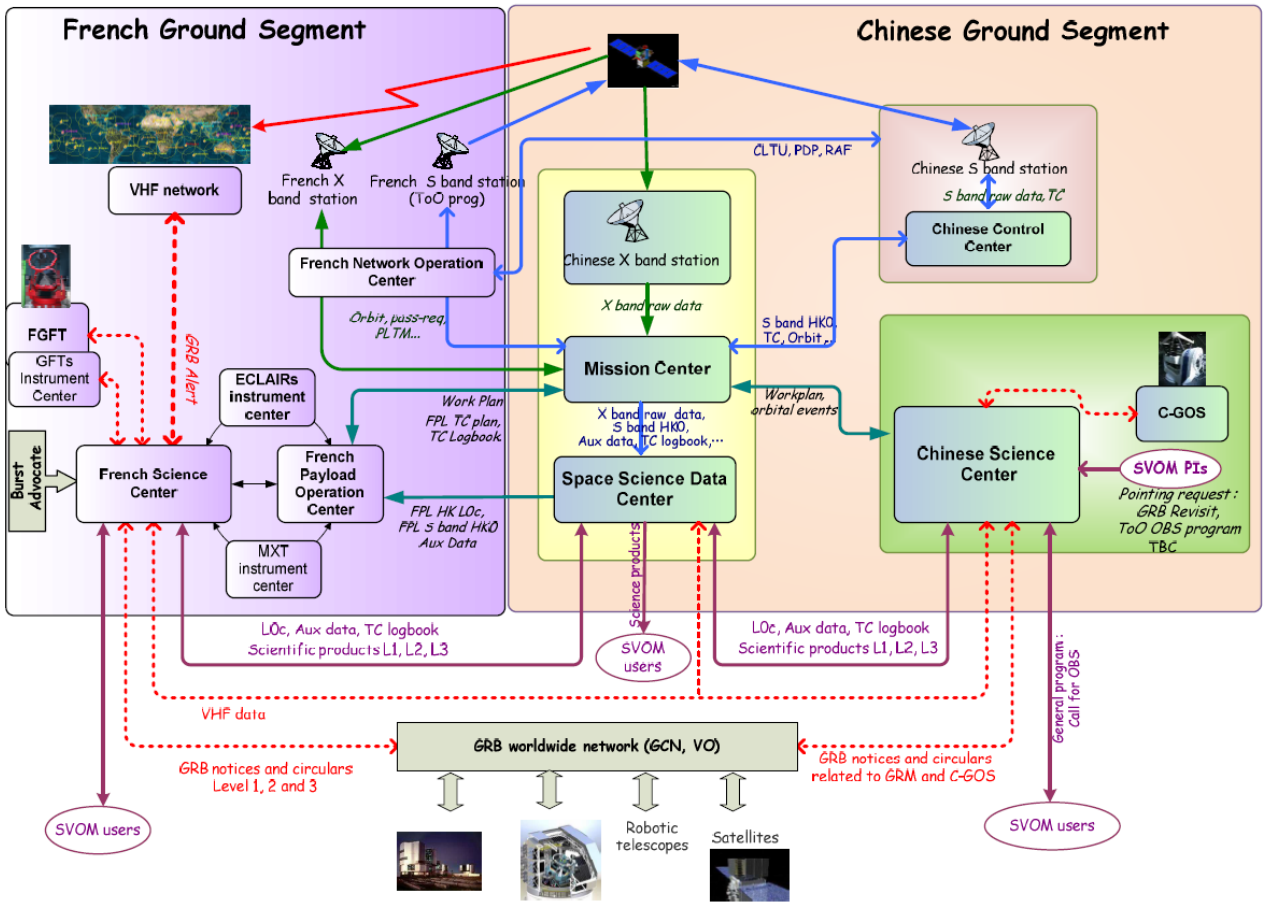
The SVOM Project

- Appears randomly in the sky
- Study of Gamma Ray Burst (GRB)
- Eruption of Gamma Photon
- Characteristics:
  - Appears randomly in the sky
  - Short time persistence
    - Short bursts: some seconds
    - Long bursts: some minutes
- Theories:
  - Short bursts : gravitational collapse of giant stars
  - Long bursts : merger of binary neutron star



The SVOM project

- Space segment
  - A satellite
  - Large angle detector
  - Narrow angle sensors for data measurements
  - Able to reorient autonomously
- Ground segment
  - Worldwide communication antenna network
  - Management centers
- France-China collaboration
- To be launched in 2021



Historical development process

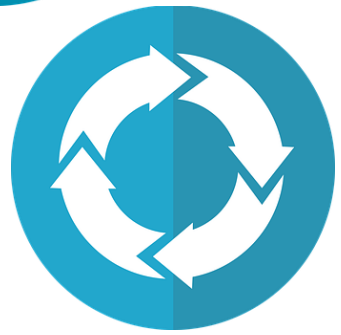
- (Digital) Textual document-based process
- Successive refinement of documents
- No structural consistency validation mechanism
- Validation based on human expertise

MBSE Experimentation

Why using models instead of regular documents to describe the system ?

Communicate: use of a rigorous and reader-friendly language to reduce ambiguities

Secure : validation of the specification using traceability and coverage mechanism to ensure consistency, completeness …



Generate: take advantage of the formal description to generate assets (and automate refinement steps)

CNES process vs Arcadia/Capella « way of life »

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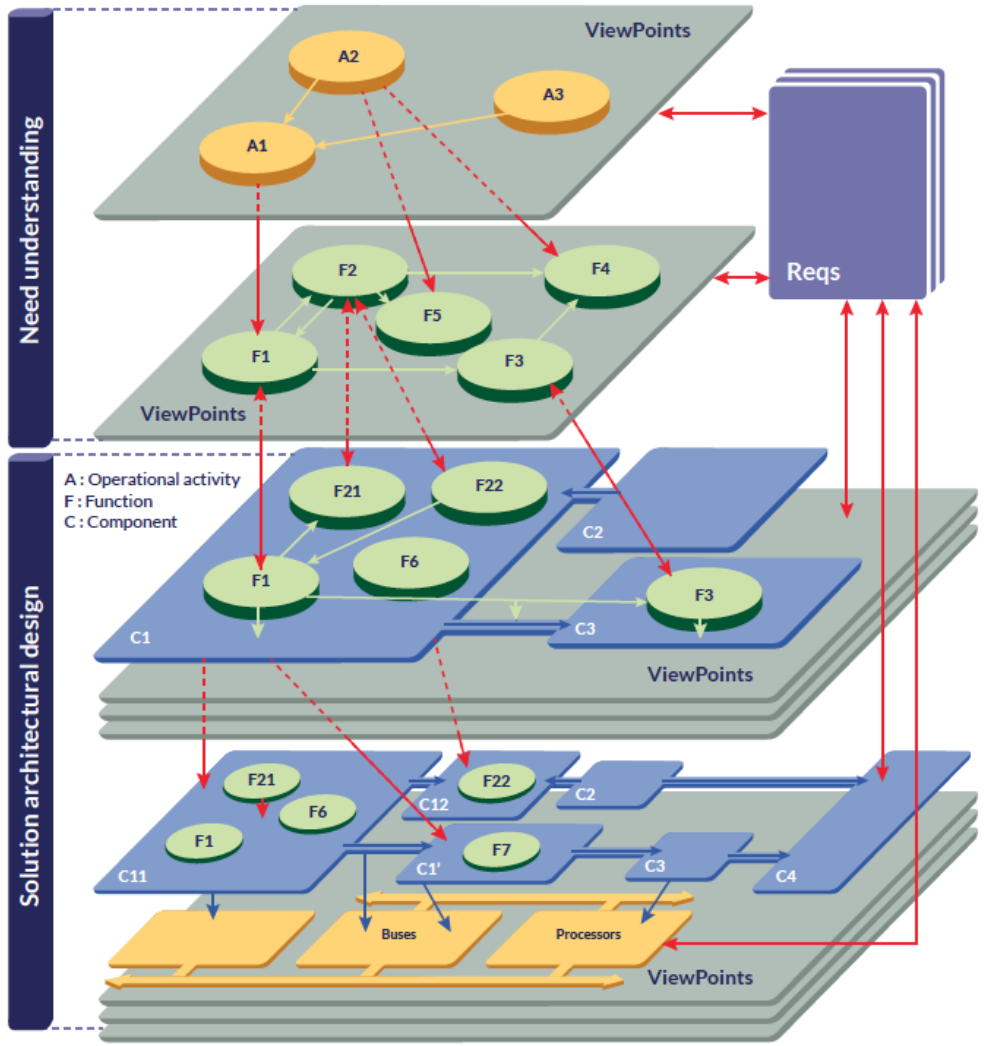


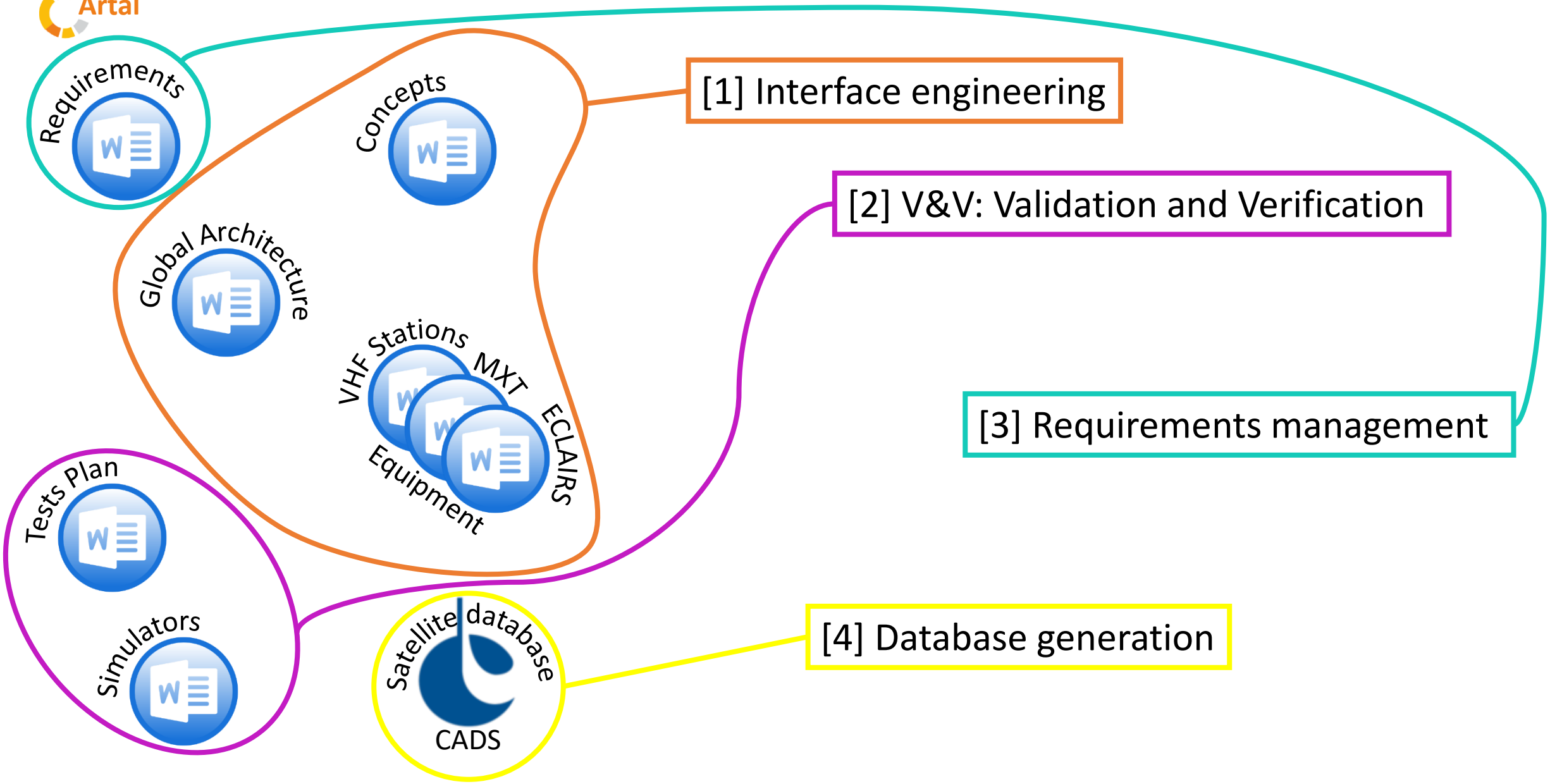
Operational Analysis
What the users of the system need to accomplish

Functional & Non Functional Need
What the system has to accomplish for the users

Logical Architecture
How the system will work to fulfill expectations

Physical Architecture
How the system will be developed and built

CNES process vs Capella/Arcadia « way of life »



[1] Interface engineering using Capella

Capella

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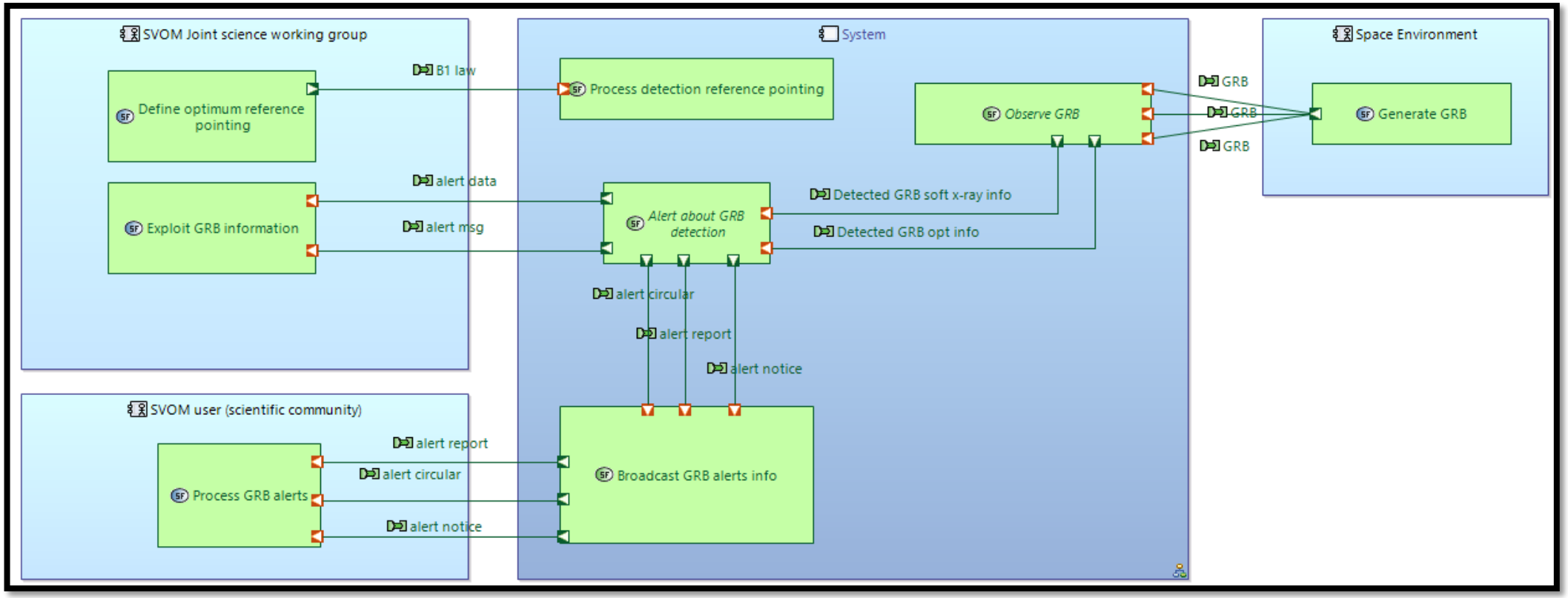
System Analysis Layer



[1] Interface engineering using Capella

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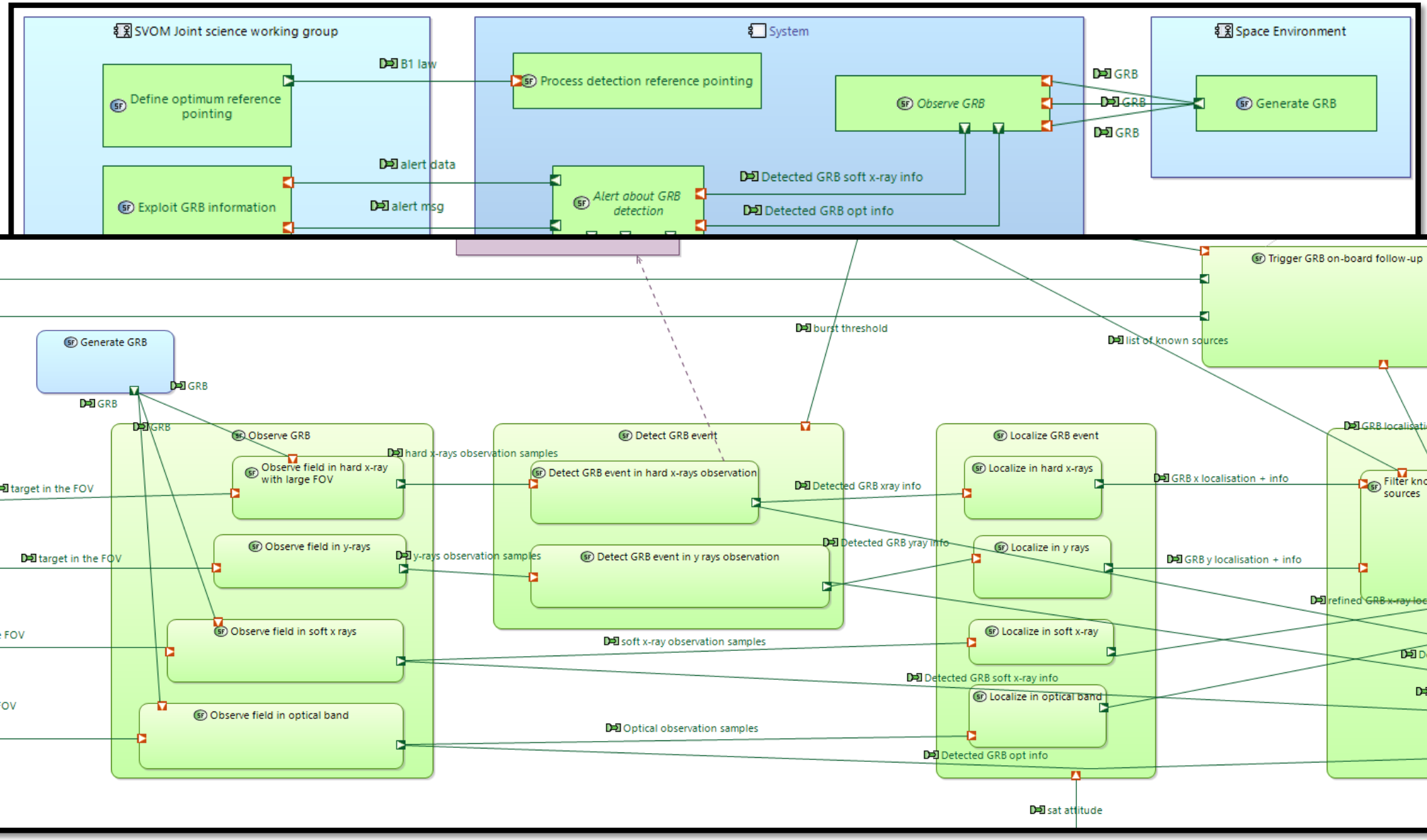
System Analysis Layer



Interface engineering using Capella

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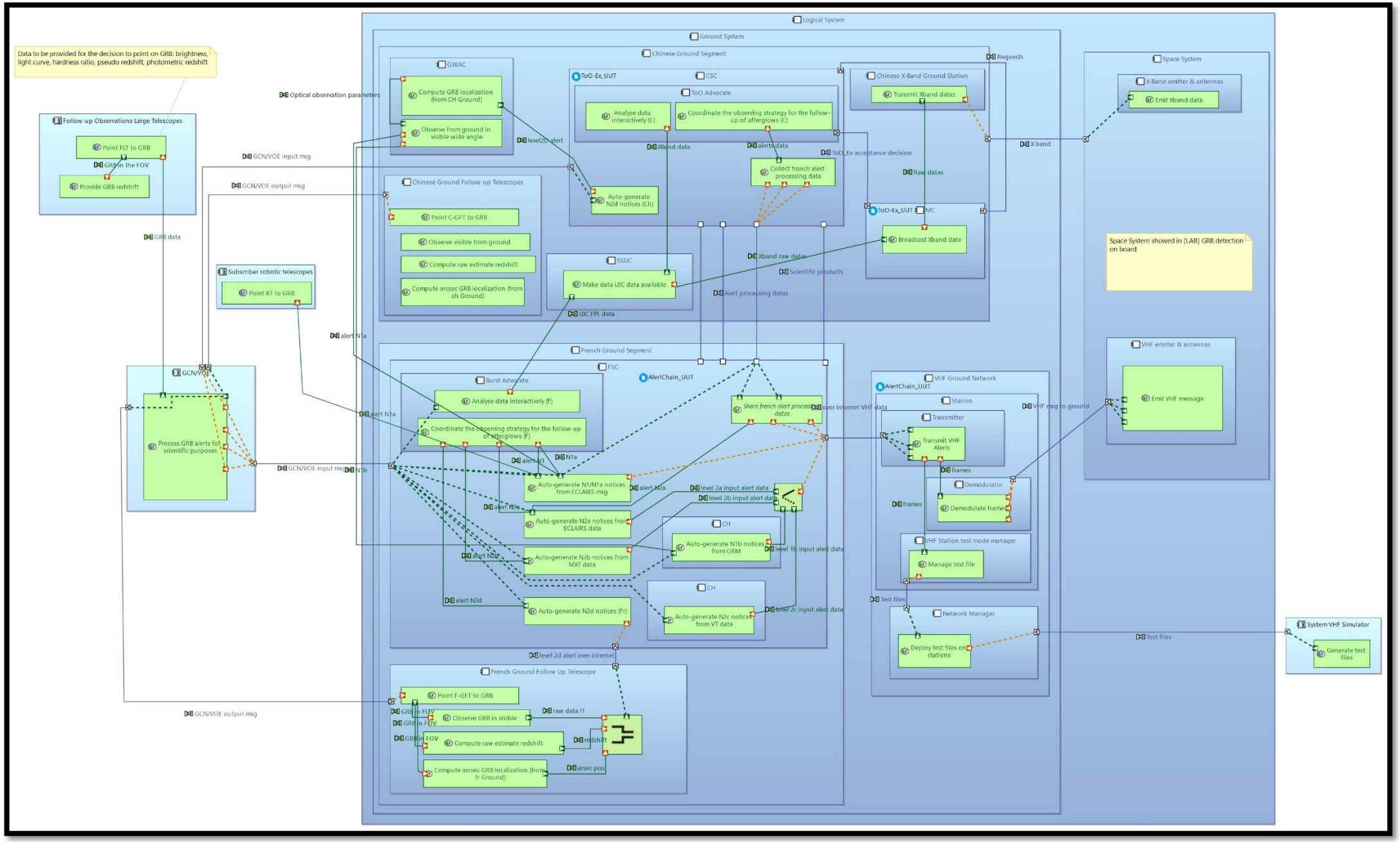
Logical Arch Layer



Interface engineering using Capella

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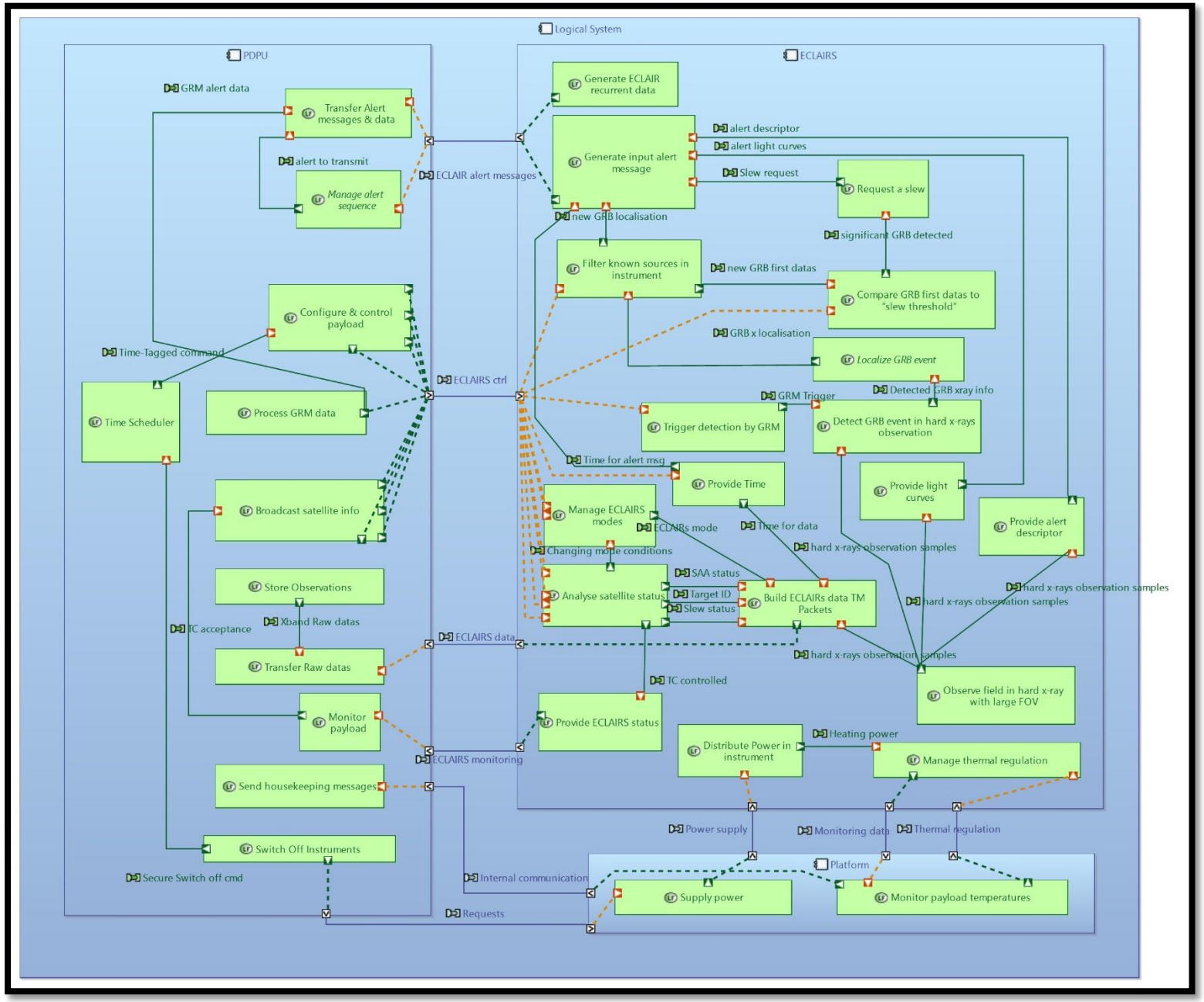

Interface engineering using Capella

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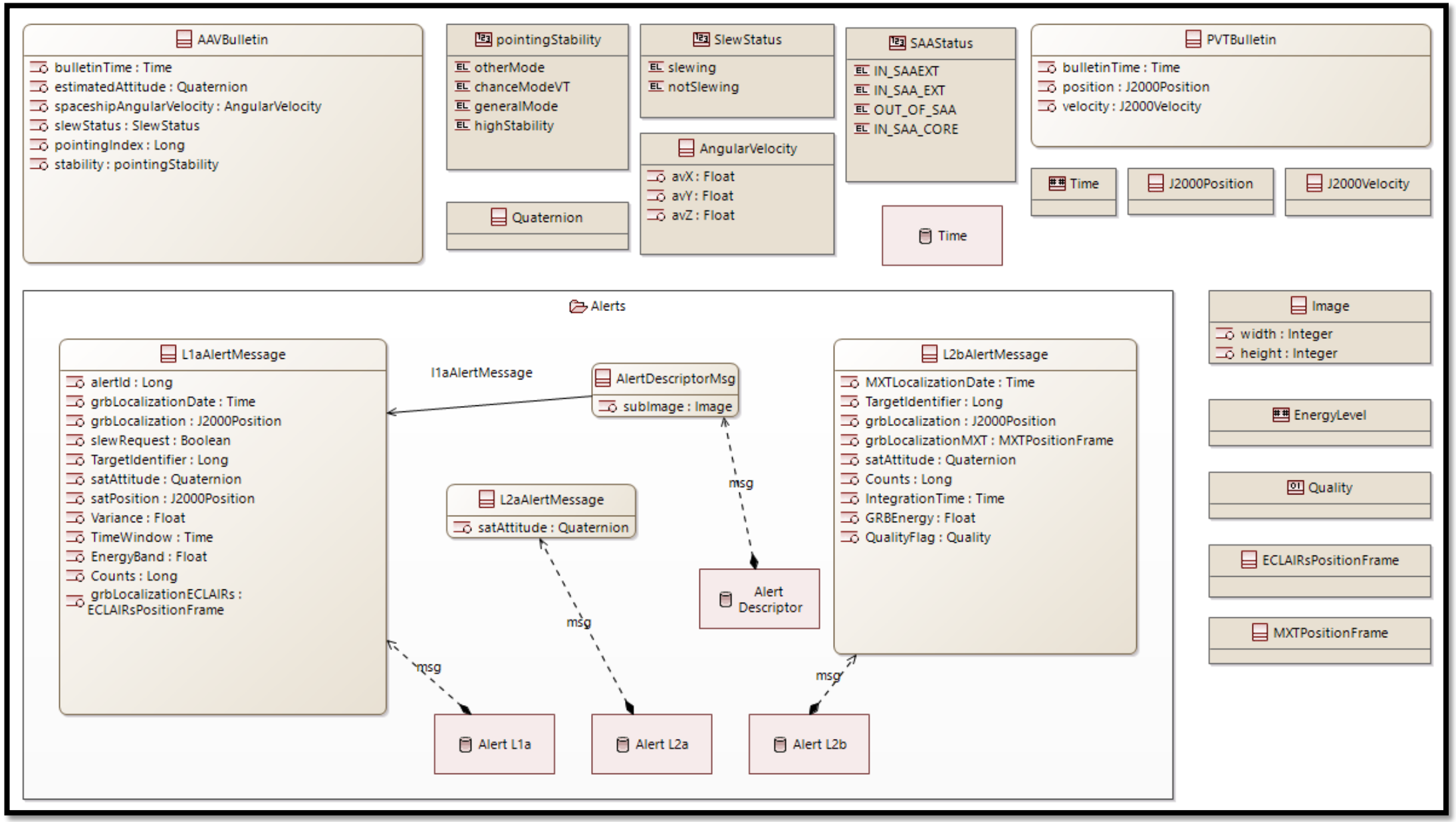
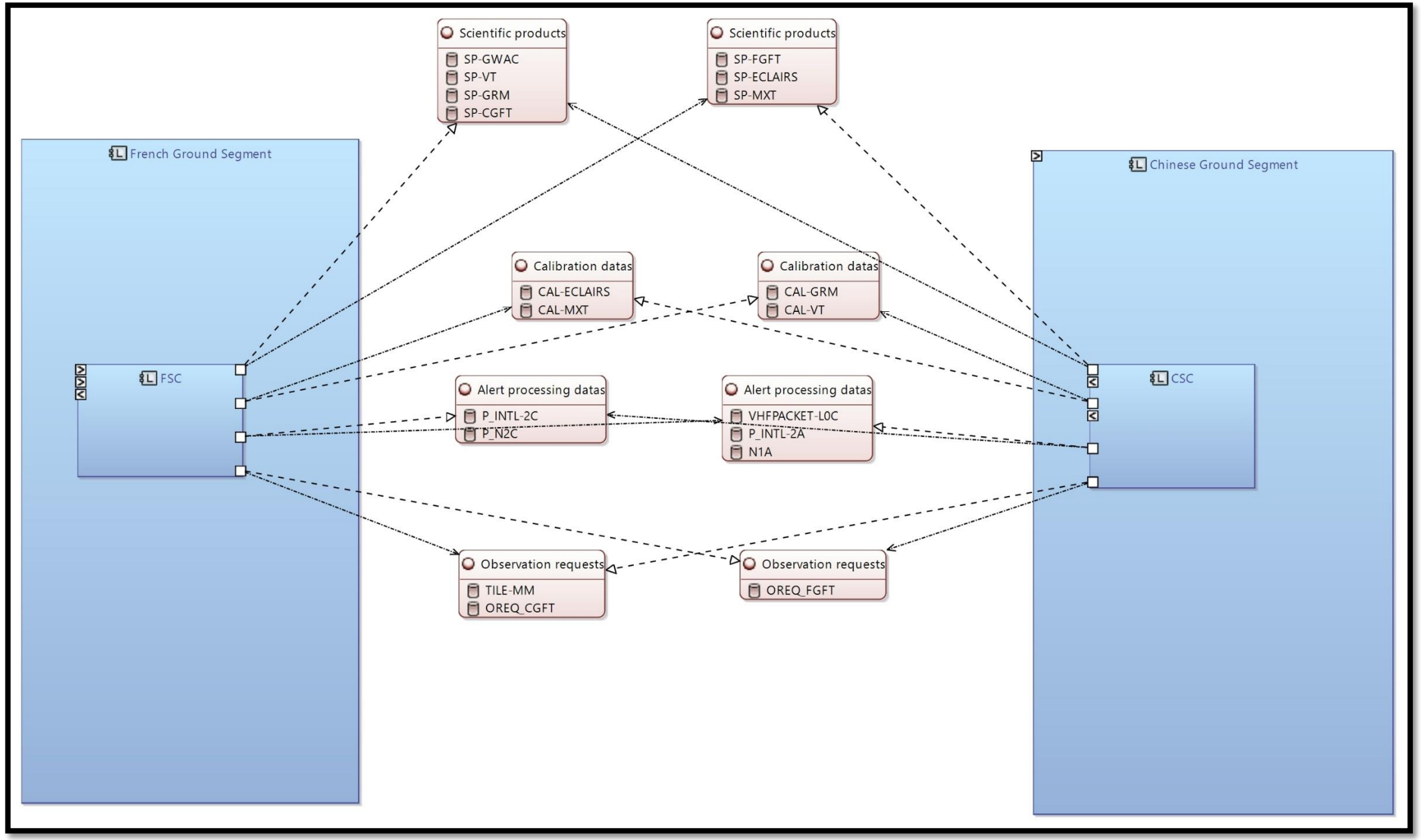
Logical Arch Layer

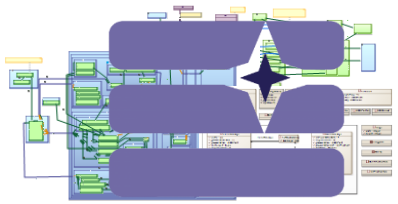


Interface engineering using Capella

Logical Arch Layer



Interface engineering: documentation generation



```
{ m:let allSrcFct = src.eAllContents()->filter(la::LogicalComponent)->including(src)->collect(comp | comp.ownedFunctionalAllocation)->collect(fa | fa.targetElement)}{ m:let allTgtFct = tgt.eAllContents()->filter(la::LogicalComponent)->including(tgt)->collect(comp | comp.ownedFunctionalAllocation)->collect(fa | fa.targetElement)}{m:let locEx = allFctEx->select(ex | (allSrcFct->includes(ex.source.eContainer()) and allTgtFct->includes(ex.target.eContainer())) or (allTgtFct->includes(ex.source.eContainer()) and allSrcFct->includes(ex.target.eContainer())))}{m:let diag1 = '[LAB] Interfaces '.concat(src.name).concat(' - ').concat(tgt.name)}{m:let diag2 = '[LAB] Interfaces '.concat(tgt.name).concat(' - ').concat(src.name)}{ m:if (not(locEx->isEmpty()) and (diag1.isRepresentationName() or diag2.isRepresentationName())) }
```

1.1 { m:src.name }/{ m:tgt.name }

```
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        {m:diag1.asImageByRepresentationName().fit(400,800)}
{m:else}
        {m:diag2.asImageByRepresentationName().fit(400,800)}
{m:endif}
```
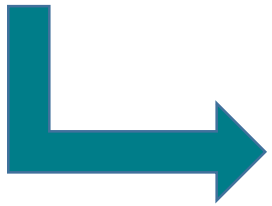
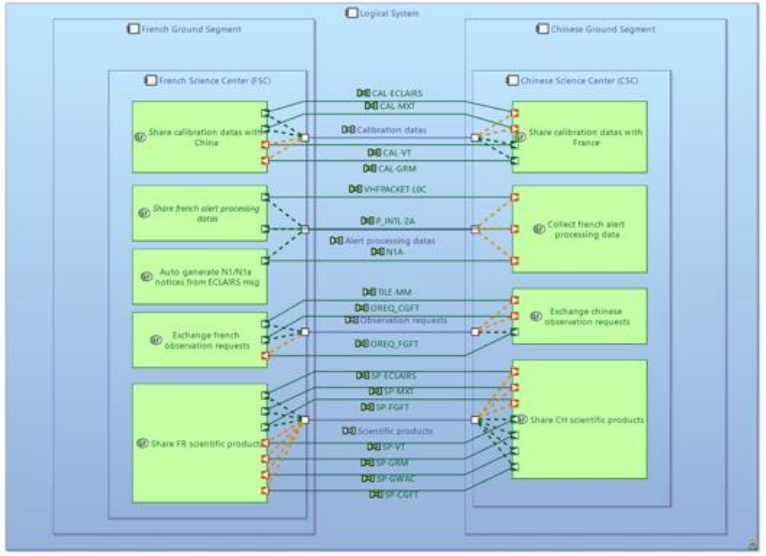



1.2 FSC/CSC



1.2.1 List of exchanges

CAL-ECLAIRS	Eclairs calibration data
CAL-MXT	MXT calibration data
SP-ECLAIRS	Eclairs Scientific Products
SP-MXT	MXT Scientific Products

Generated vs Original

1.2. FSC / CSC (IF 3)

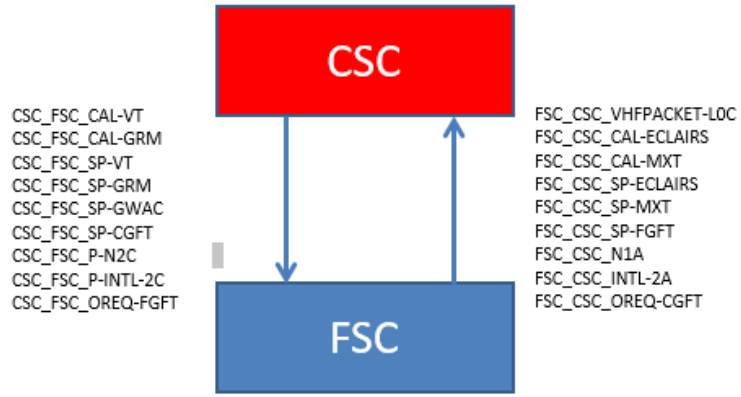


Figure 9 : FSC <> CSC Interfaces

1.2.1. List of exchanges

FSC_CSC_CAL-ECLAIRS	Eclairs calibration parameters
FSC_CSC_CAL-MXT	MXT calibration parameters
FSC_CSC_SP-ECLAIRS	Eclairs SP data product
FSC_CSC_SP-MXT	MXT SP data product

Interface engineering assessment

- (SVOM) Interface engineering
  - Crucial step in complex system development
  - The international context call for even more rigor
  - Late-update can be costly
- Capella is « ready » for interface engineering management
  - Vast expressivity
  - Traceability / continuity between specification layers
- MBSE objectives reached:


Formal specification available


Coverage of the needs / Completeness evaluation


Specification documents generation

⇒ Next step: operational capture of V&V data

Validation and Verification level 1: needs coverage

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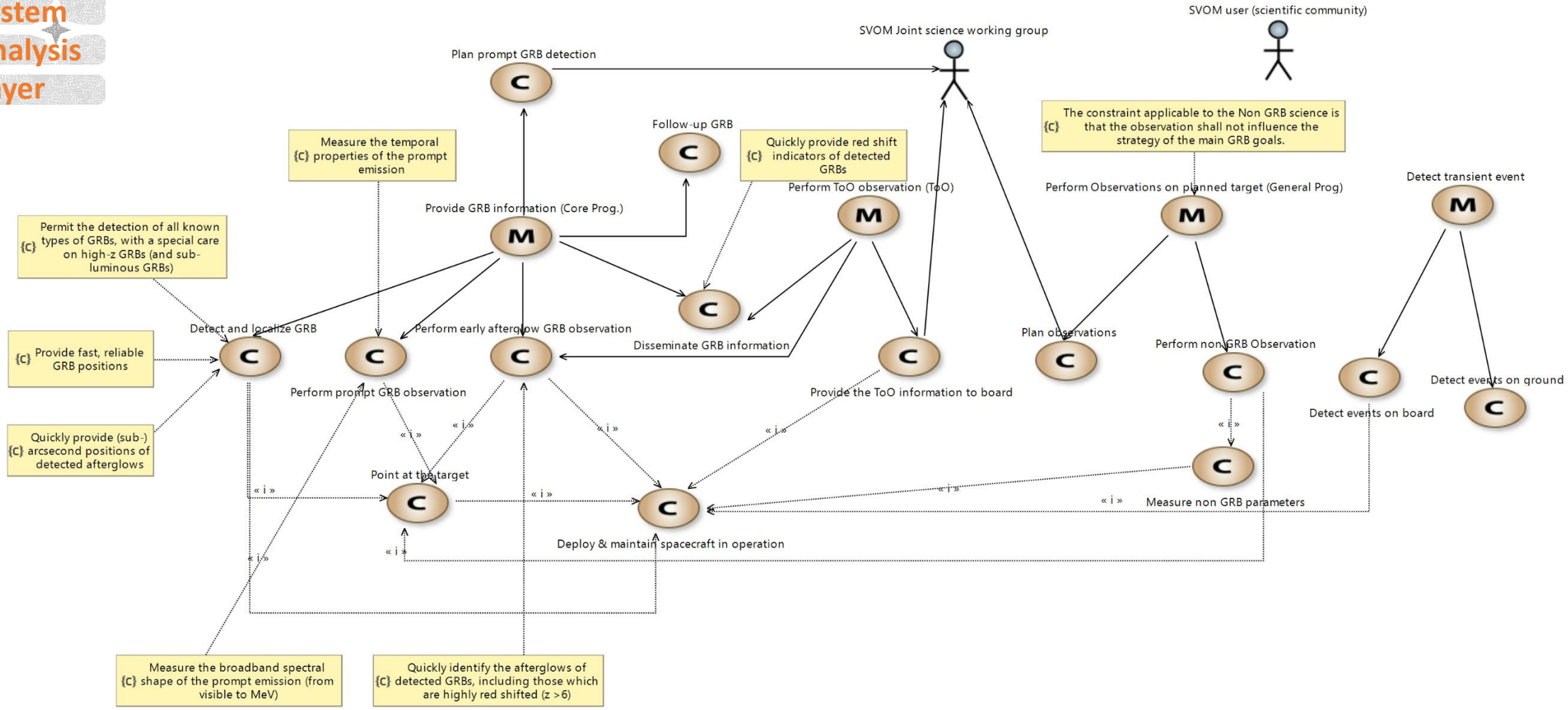
System Analysis Layer



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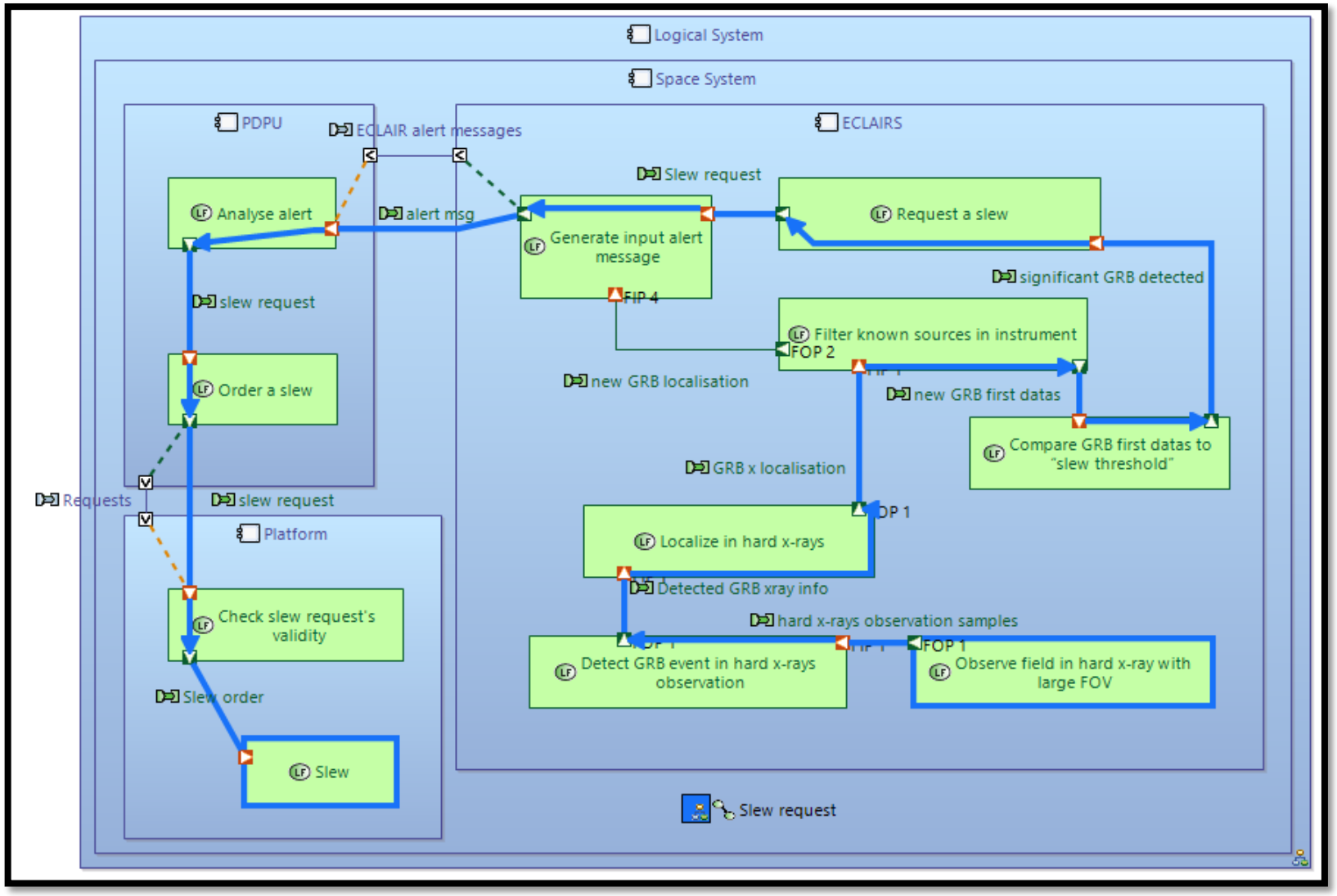
Logical Arch Layer

Validation and Verification level 2: functional chains



Validation and Verification level 2: functional chains

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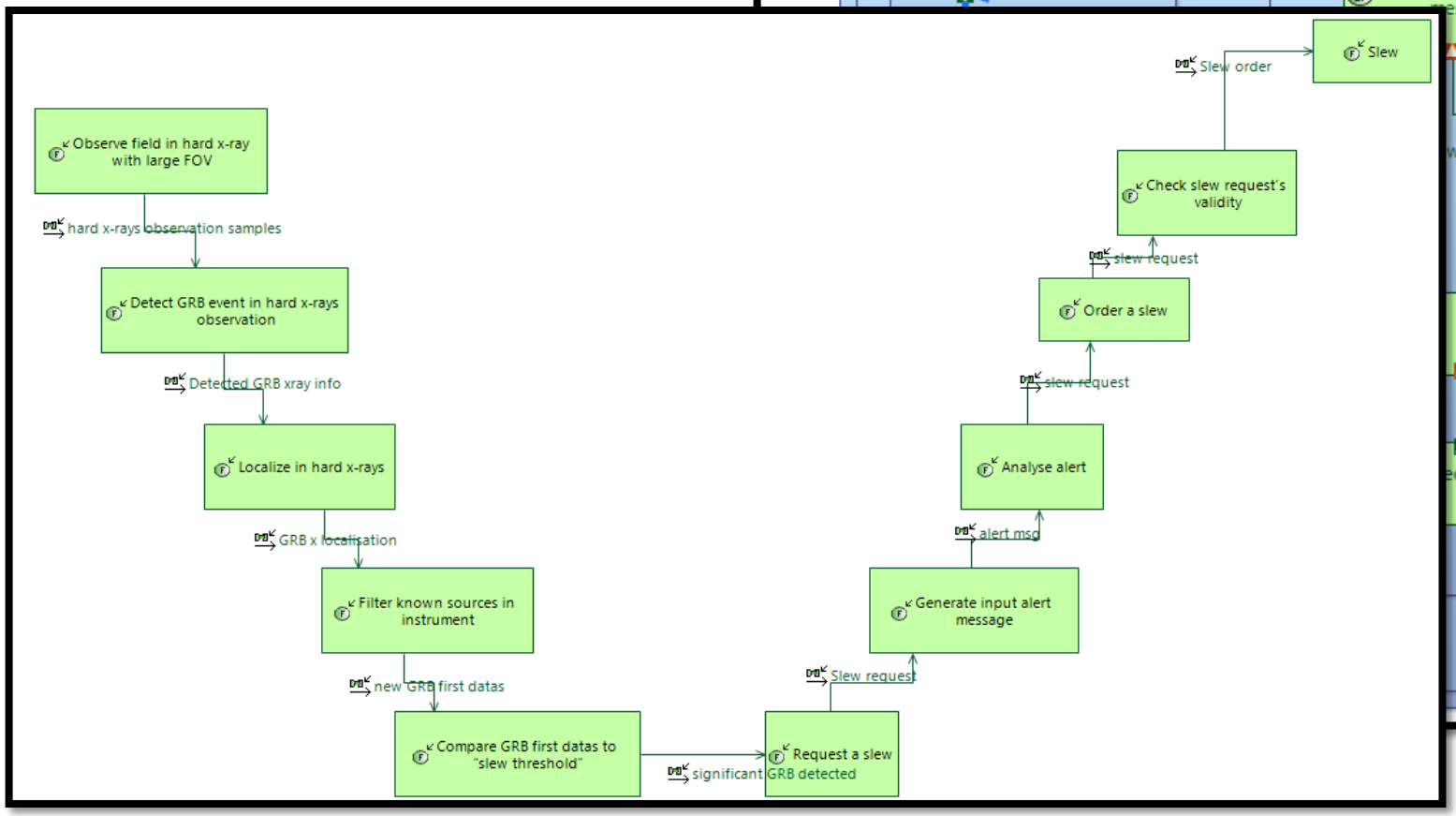
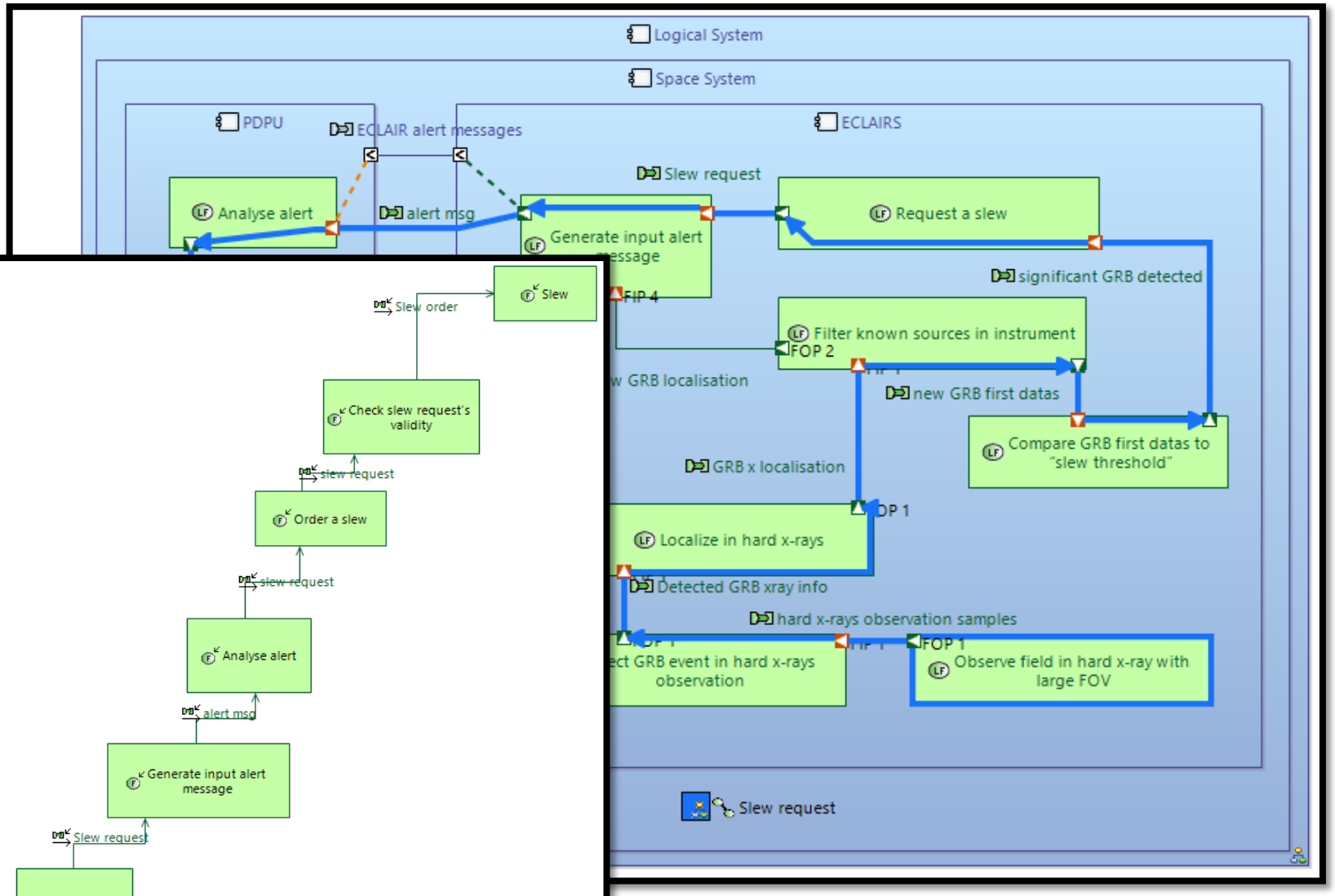
Logical Arch Layer





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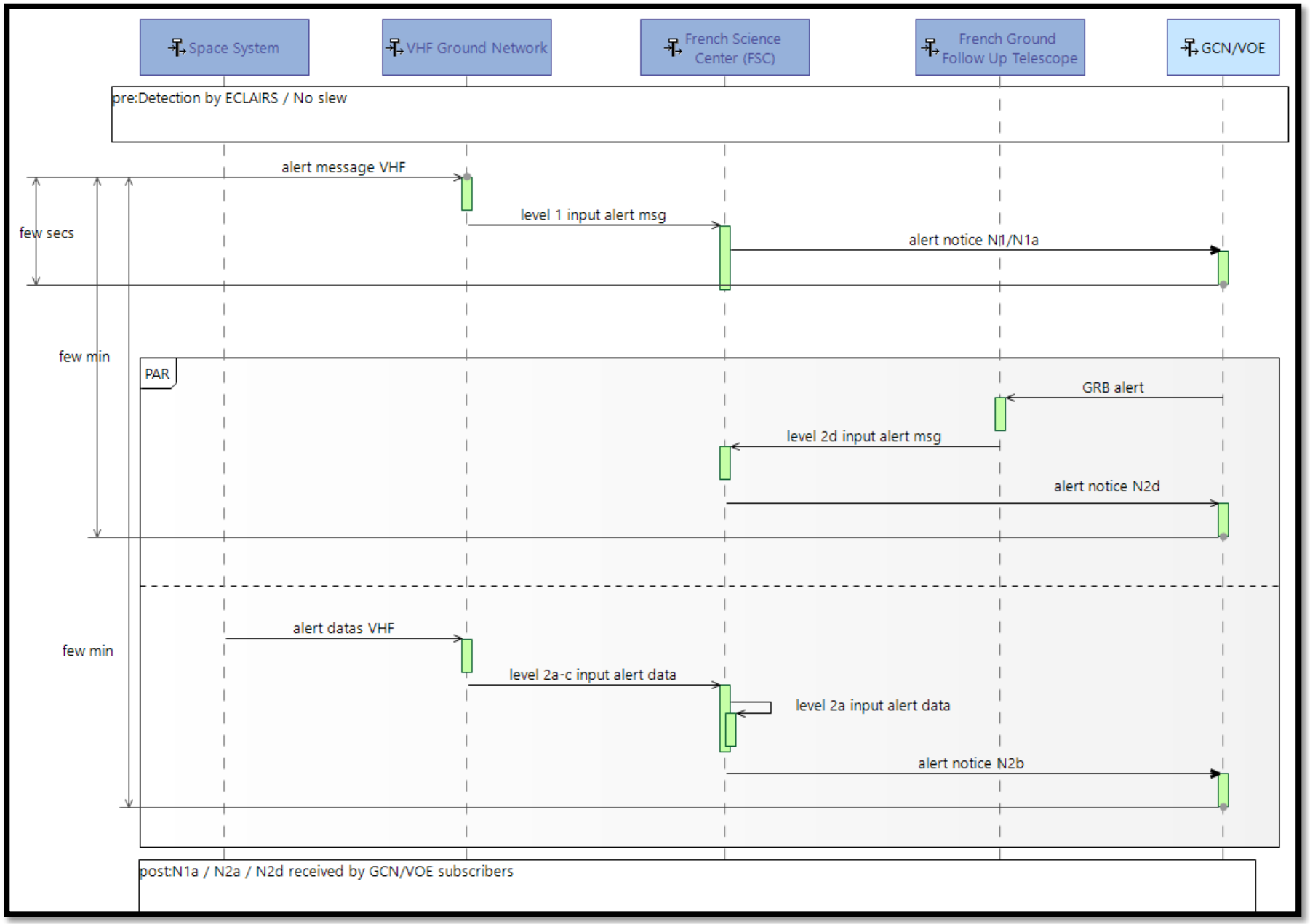
Logical Arch Layer

Validation and Verification level 2: scenarios



Validation and Verification level 3: a brand new Capella extension

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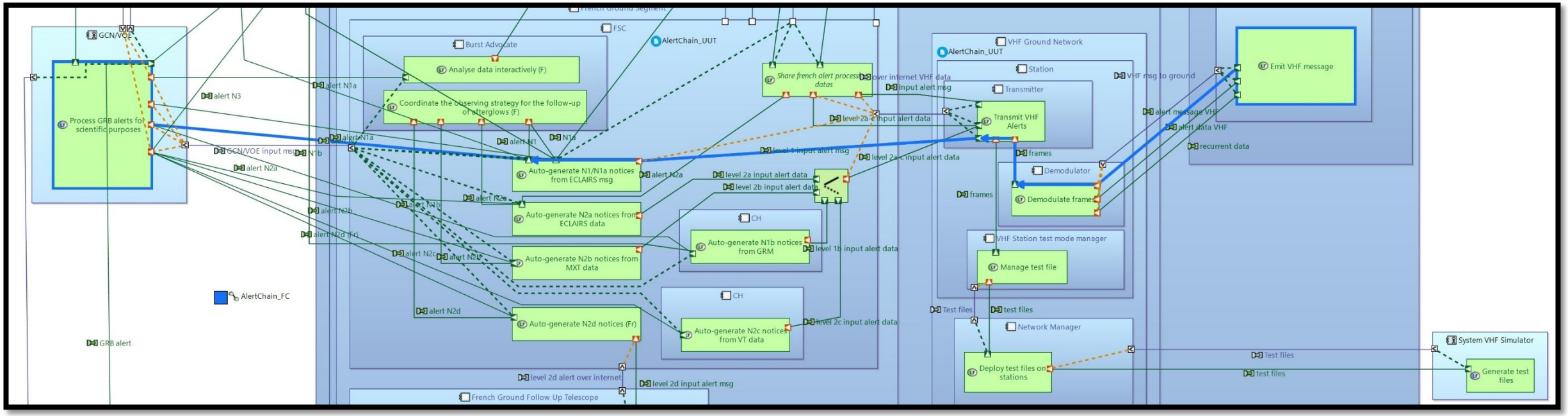
Logical Arch Layer



Validation and Verification level 3: a brand new Capella extension

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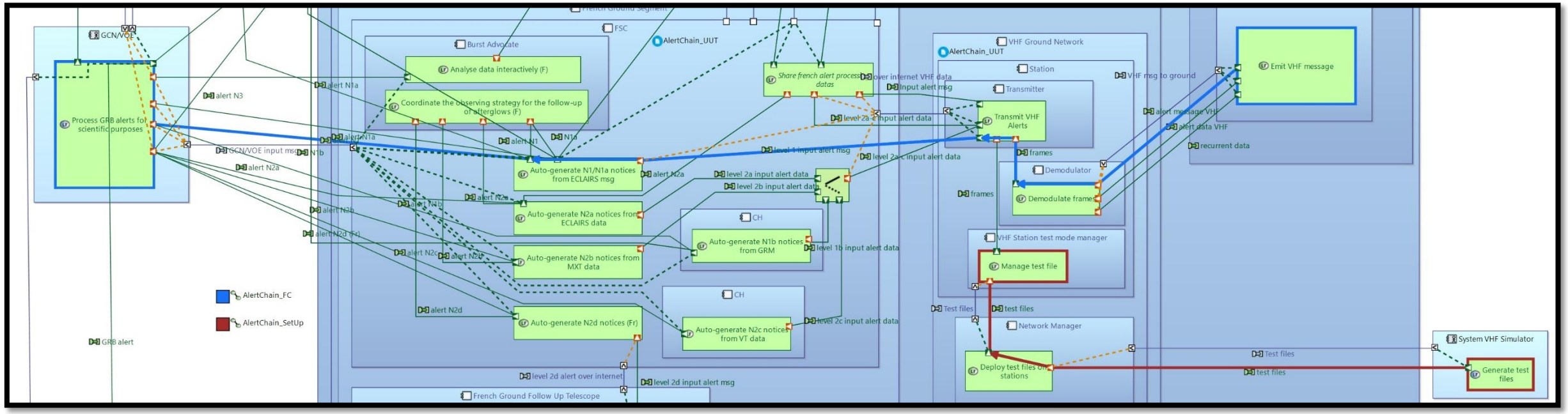
Logical Arch Layer



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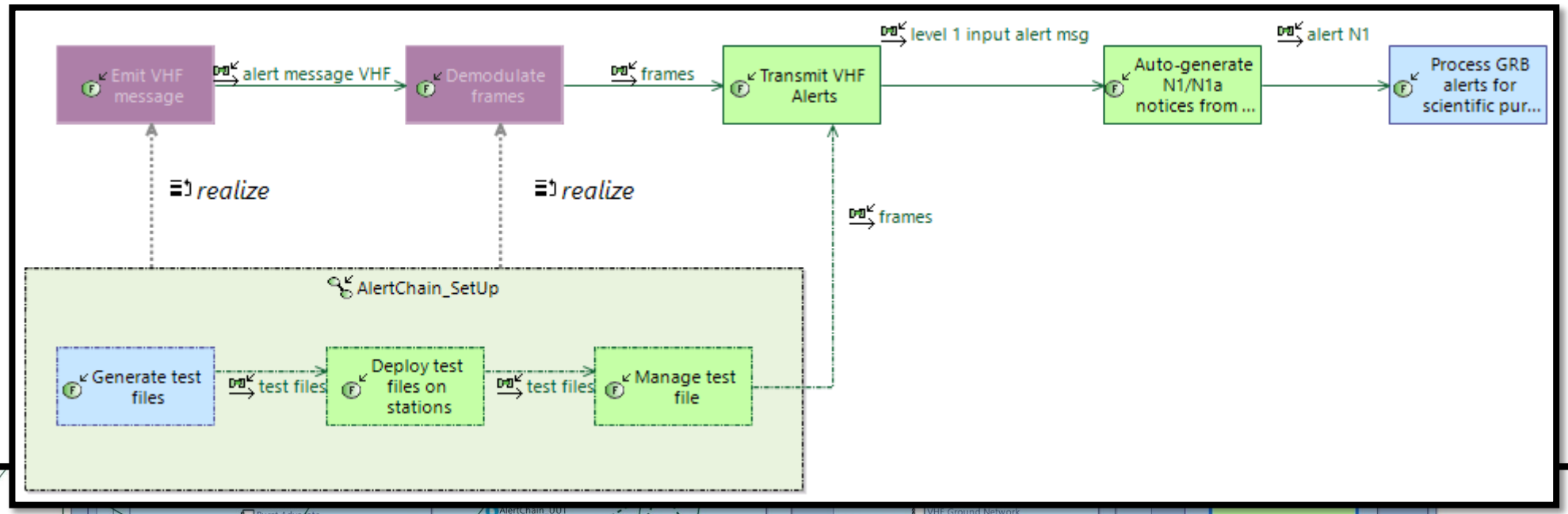

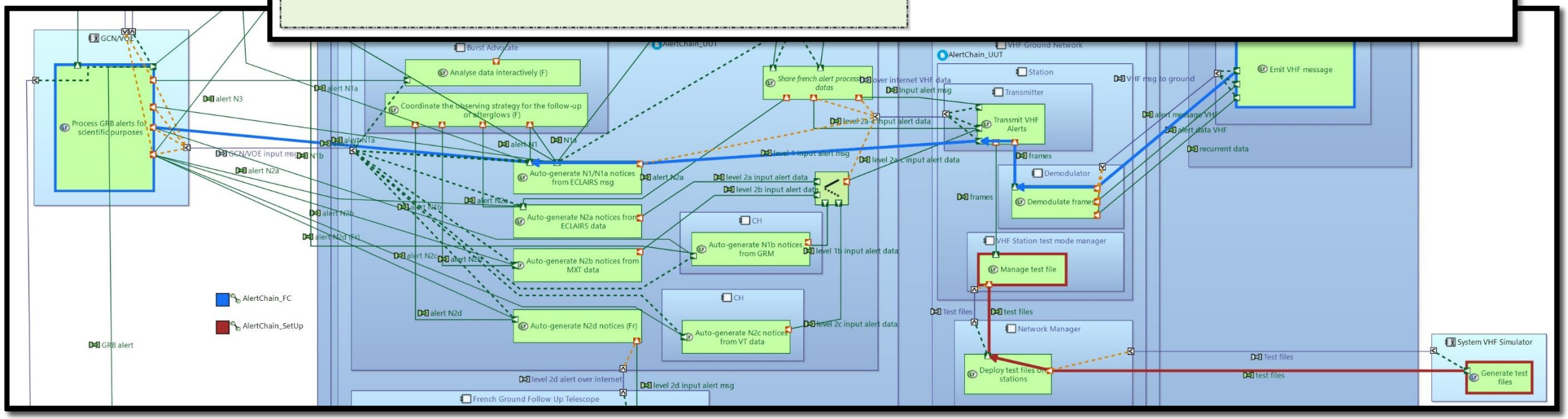

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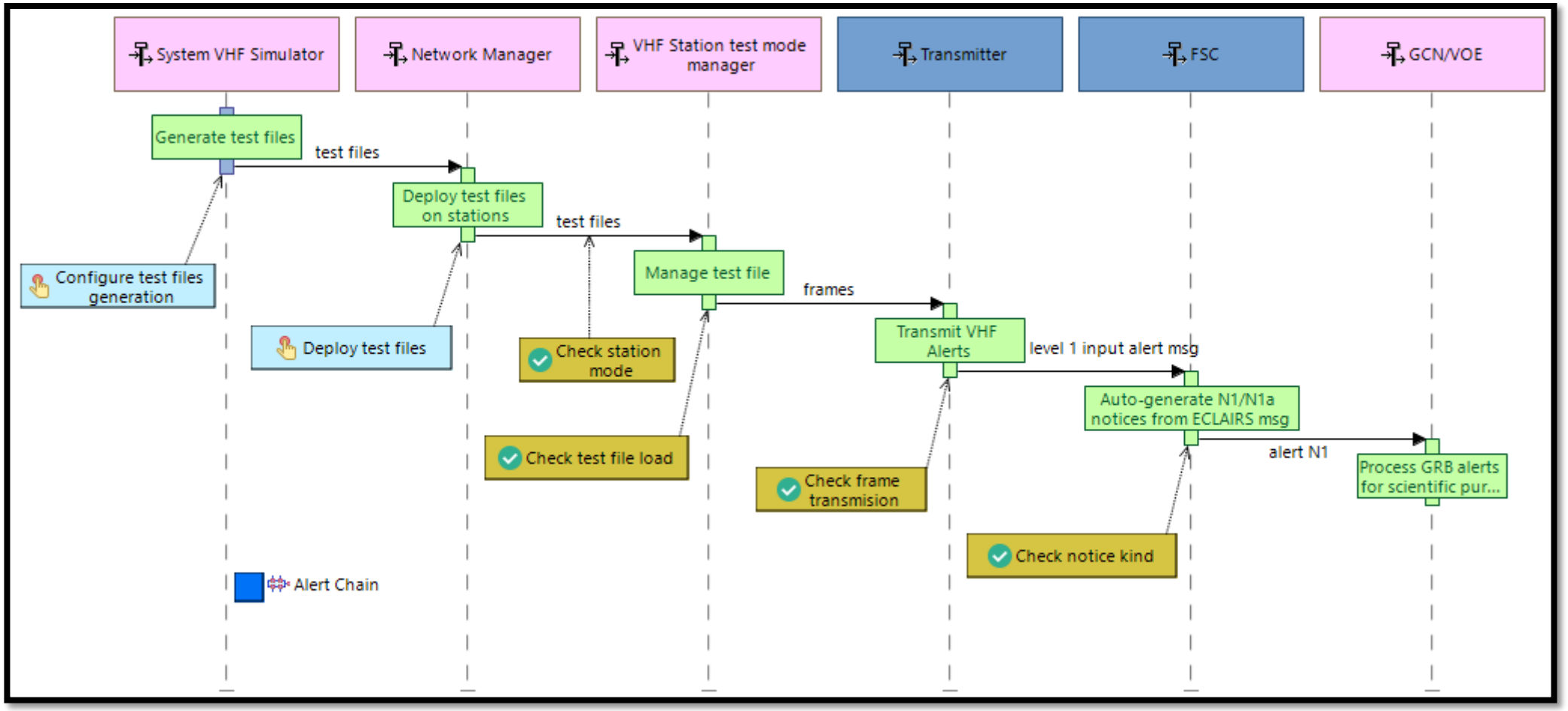
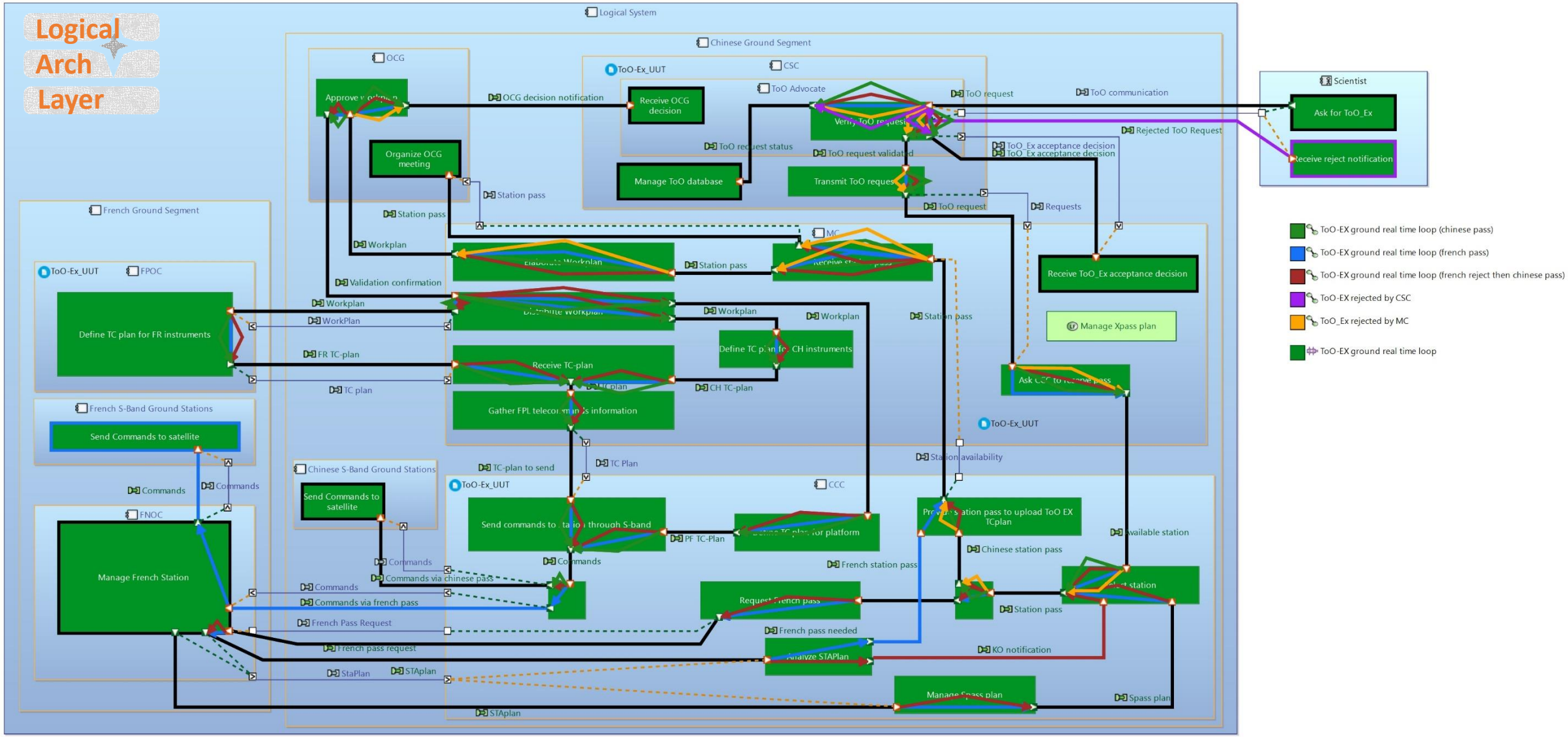


Validation and Verification level 3: propagation



Validation and Verification level 3: propagation

Capella

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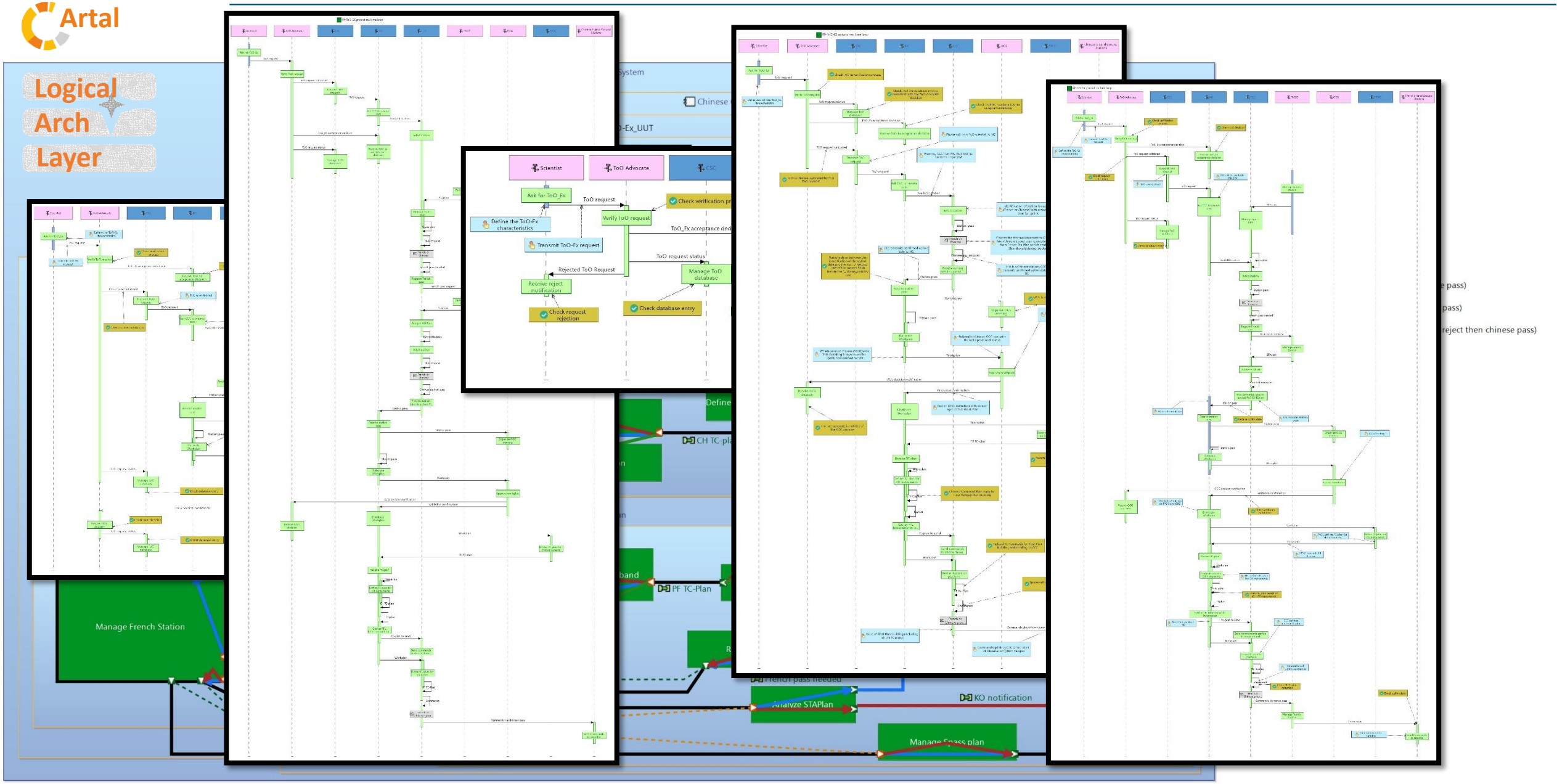
Logical Arch Layer



Validation and Verification assessment

- (SVOM) Validation and Verification process
  - Another crucial step in complex system development
  - Guarantee the coverage of the requirements and the system consistency
  - Potentially iterative
- Capella needs some extension
  - Validation campaign management (objectives, test sequences…)
  - But natively supports iterative processes
- MBSE objectives reached:


Model strongly used as working base to identify tests

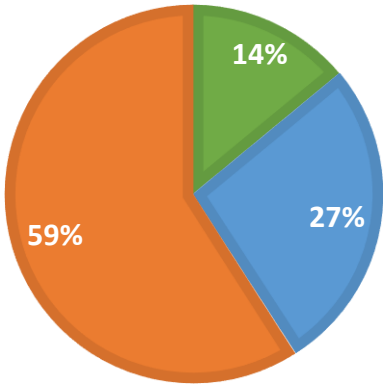

Evaluation of the coverage of the specification by the test


Specification documents generation (and simulation data generation?)

⇒ And what about the requirements themselves ?

Requirements analysis

- Challenges:
  - Organize requirements (allowing several reading paths)
  - Traceability between requirements and system specification (coverage)
  - Document generation including requirements and model items
- Analysis of the 579 textual requirements :
  - OK: can potentially be fully covered (replaced) by model elements
  - Partial: can be partially covered by the model
  - KO: cannot be covered by the model



⇒ Poor coverage: due to the heterogeneous level of the requirements

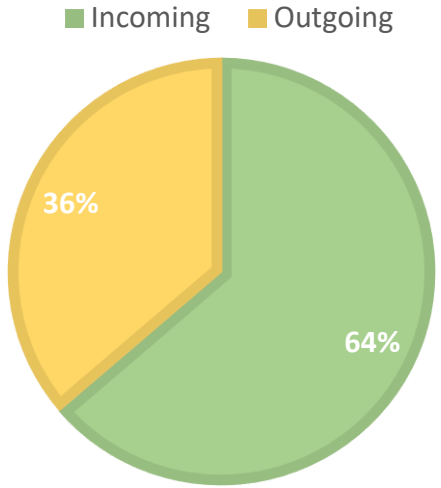
⇒ **Several requirements concerns the engineering process (and not the system itself)**

e.g. The verification phase shall not exceed 5 months.

⇒ Still need an autonomous requirement process… but need to be **structured** !

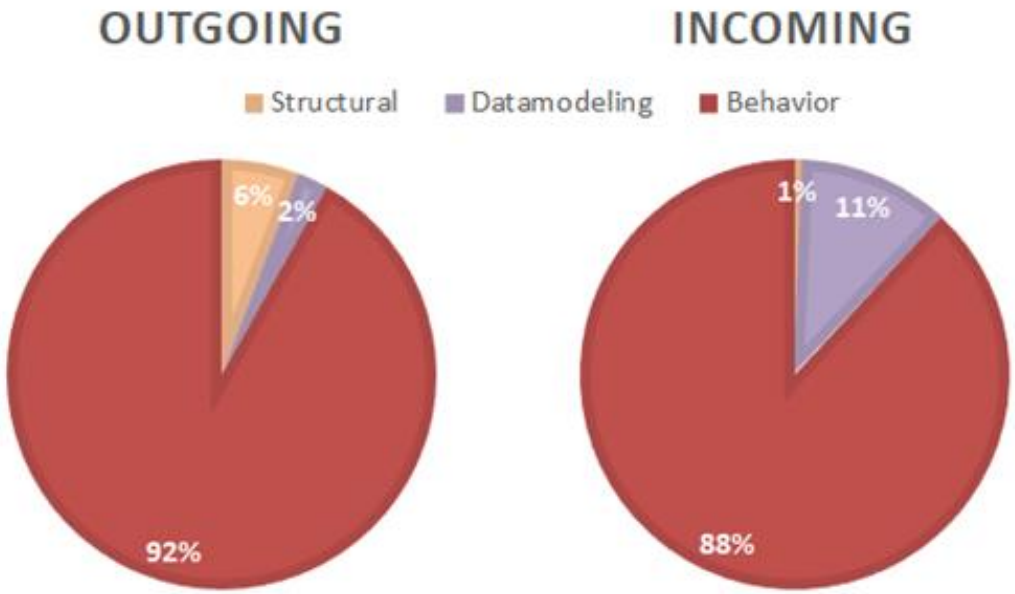
Requirements analysis

- Concerning the system specification requirements:
  - Incoming: upstream requirement: directly impacts the model
    e.g. *Mission Center shall merge both French and Chinese payload telecommand plan and send to CCC*
  - Outgoing: downstream requirement: complete the model
    e.g. The AAV bulletin shall be provided to the MXT each second



⇒ Mostly “incoming”: will allow to derive the specification from requirements

⇒ Mostly “behaviors”: will require other inputs to define the system structure (even if the behaviors to support will guide the system architecture)



Satellite database

- SVOM Satellite database
  - defined using a specific tool: CADS
  - define the resources of the satellite (components, data structures…)
  - part of the software implementation phase

  ⇒ Challenge: to generate (or initialize) it from the model
- Proof of concept:

Capella	CADS
State and Mode Machine	Application process
Mode	
State	

Capella	CADS
FunctionalExchange avec ExchangeItem SHARE_DATA	Instances TC/TM packet

PVT
AAV
GRM Trigger

PDPU_BP_AAV
PDPU_BP_PVT
PDPU_BP_GRMTRIGGER

Capella	CADS
TC/TM Primitive Class et property	Activity argument or Telemetric parameter

Class e

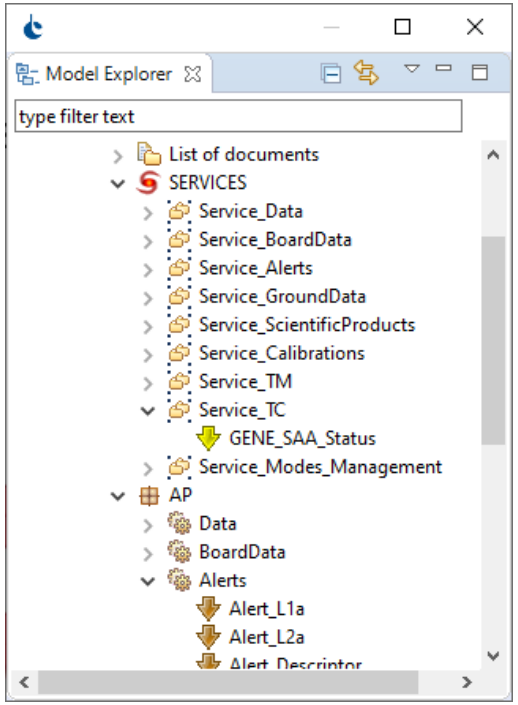
5.2

Functi

Telecommand properties :

Quaternion
AngularVelocity
avX : Float
avY : Float
avZ : Float

AAV-args
PDPU_AR_QATTSATQUAT
PDPU_AR_QATTSATQUAT0
PDPU_AR_QATTSATQUAT1
PDPU_AR_QATTSATQUAT2



The CNES feedback

Real guide / useful help: - Right questions at the right time - Structuration of work - Impose rigor
Non-ambiguous specification
Sharing communication platform
Full process coverage: from preliminary definition to project validation
Return on investment confirmed

Specification building: - Heterogeneous requirements - Still requires “classical engineering work”
Hard to identify the right modeling level
Not fully convinced by doc generation: - Hard template customization - Numerous iteration

Future according to the CNES:

- The team is resolute to apply MBSE on next projects
- The whole team will have to be trained before the beginning of the project
- Will require the integration of a Capella expert in the team (System engineers will not be autonomous in Capella use)

More information on
http://capella.artal-group.com