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PEOPLE

Lessons learned on the use of MBSE in the preliminary design of space systems at CT Paris,

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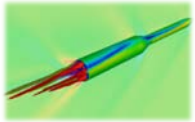
Introduction

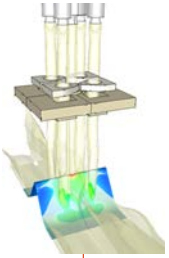
CT Paris : Bringing innovation over the whole space system life cycle

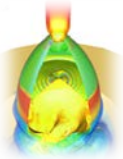
- Innovative solutions

- Microlauncher design

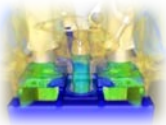


- External Aerothermodynamics





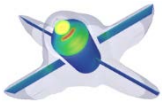
- Numerical & physical rocket engine test bench



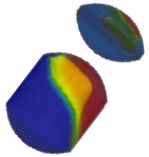
- Risk assessment

Needs identification	Feasibility studies	Preliminary Design	Detailed Design	Qualification production	Utilization
Phase 0	Phase A	Phase B	Phase C	Phase D	Phase E

- System, sub-system and components design



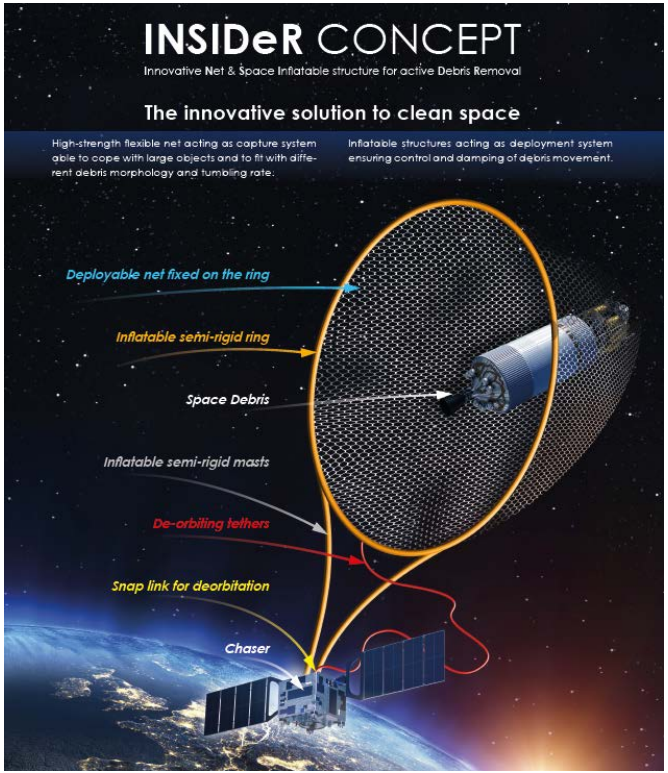
- System performances & detailed component analysis
  - Rocket engines
  - Tanks
  - Launcher stages

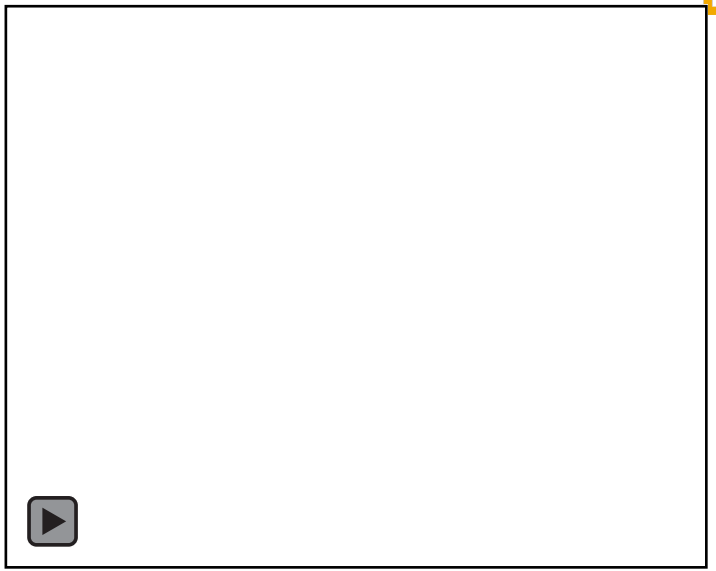


- Development and operation of a sounding rocket

- Support to operational decision making process

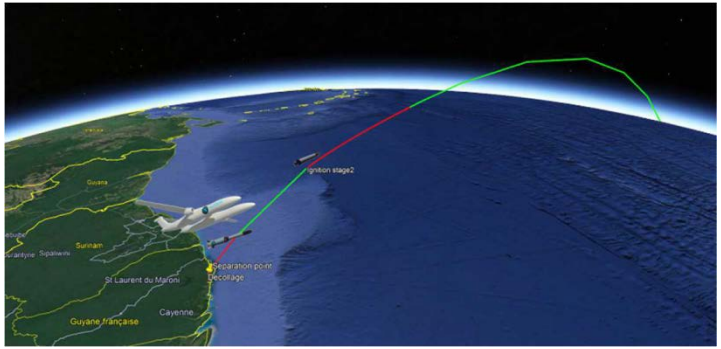
INSIDeR Concept (CT Patent)

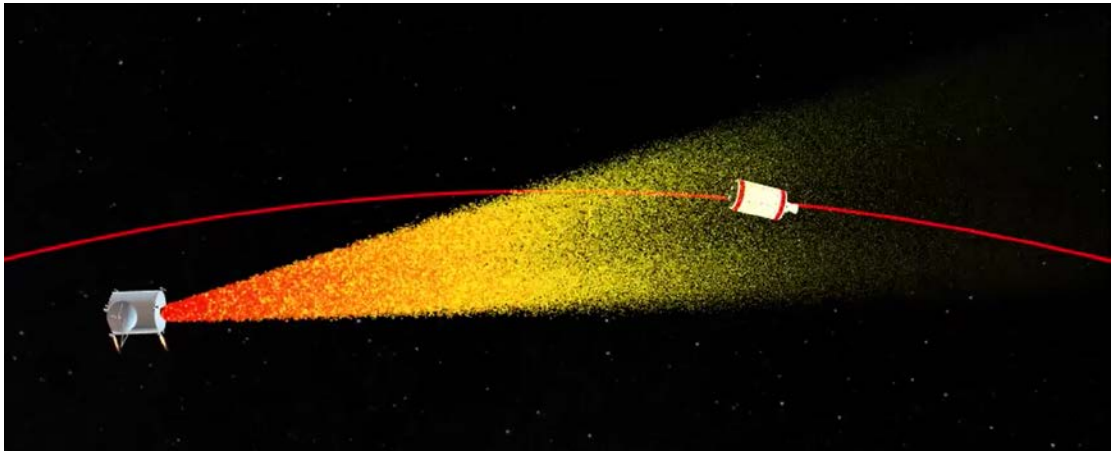




- Insider: Net deployed with inflatable structure for space debris deorbitation.

The Blow Rocket Project





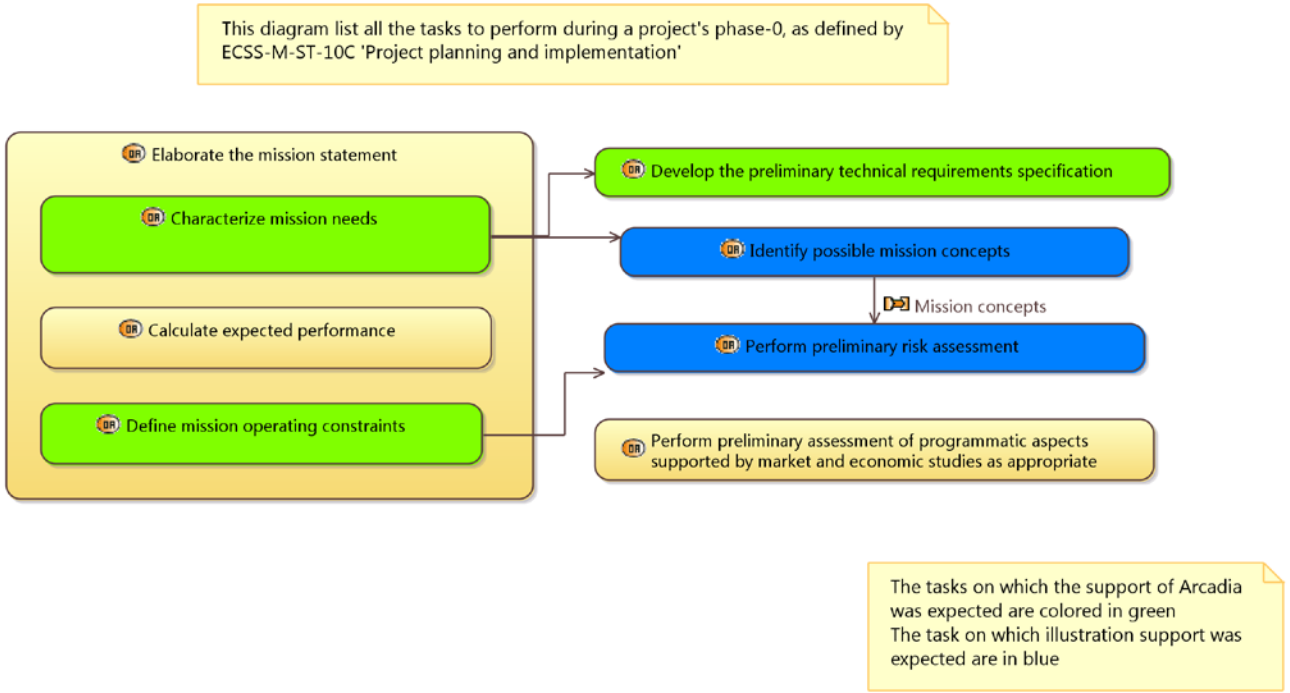
- Particles ejector that can brake a space debris for Just-in-time collision avoidance
- Whole system and concept of operation definition (reactivity regarding the detection time of the collision)

Why introducing MBSE in thoses activities?

- To **capitalize** from one study to another.
  - Insider concept started in 2011, JCA system in 2016.
  - Time consuming to integrate new engineers on the project.
- To avoid the **proliferation** of heterogenous data & documentation
  - Silo effect
- To have a formal way to **communicate** on the system concept and architecture

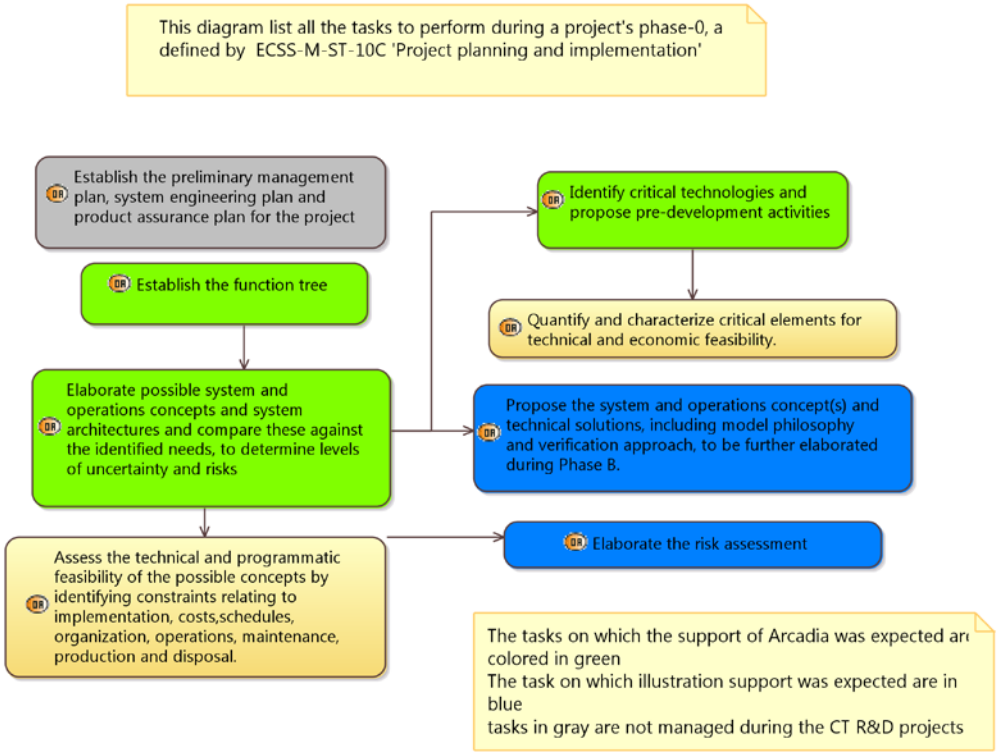
What we expected from MBSE (in phase 0)

- Not only the tool and language, but also methodology



What we expected from MBSE (in phase A)

- MBSE impact expected for concept definition, but not for quantitative assessment.



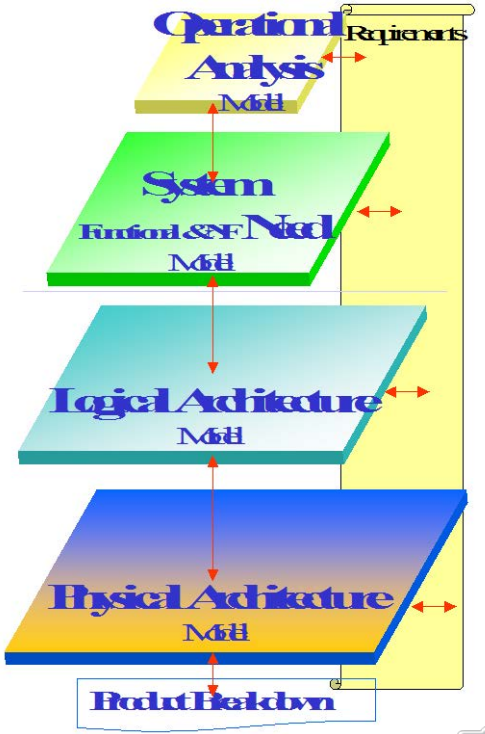
Choice of Arcadia and Capella as a MBSE support

▷ Main Arcadia difference:

5 perspectives that are interconnected by that uses their own concepts and that follows their own logic. Traceability is kept between elements defined in those layers.

▷ Driver for our choice:

The Operational Analysis layer and its focus on **customer's needs.**



02

Conception of our models

Comparison with Value Analysis method

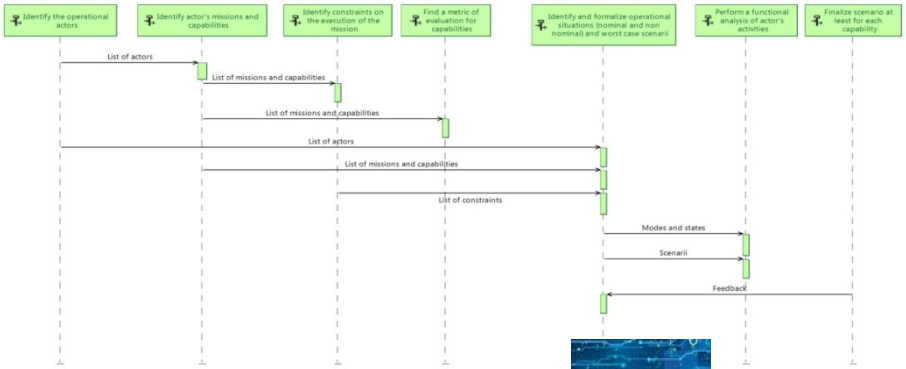
System requirements

System design

Strategy to build Arcadia model

1. **Identification of the main steps of the method.**

   On Capella scenarii format (do not try to read it, it will be detailled in a few slides ☺)

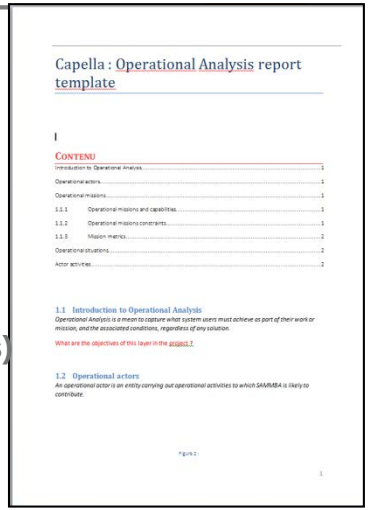


(Thanks to Jean-Luc Voirin method 

)

2. **Creation of an output template**

   (thanks to Obeo Open-source tools)

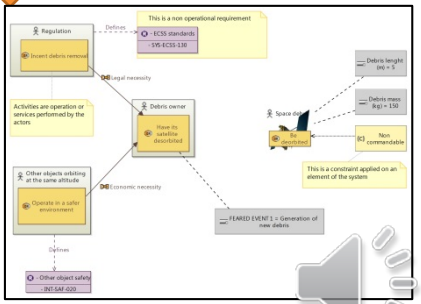

Capella : Operational Analysis report template

CONTENU

1.1 Introduction to Operational Analysis

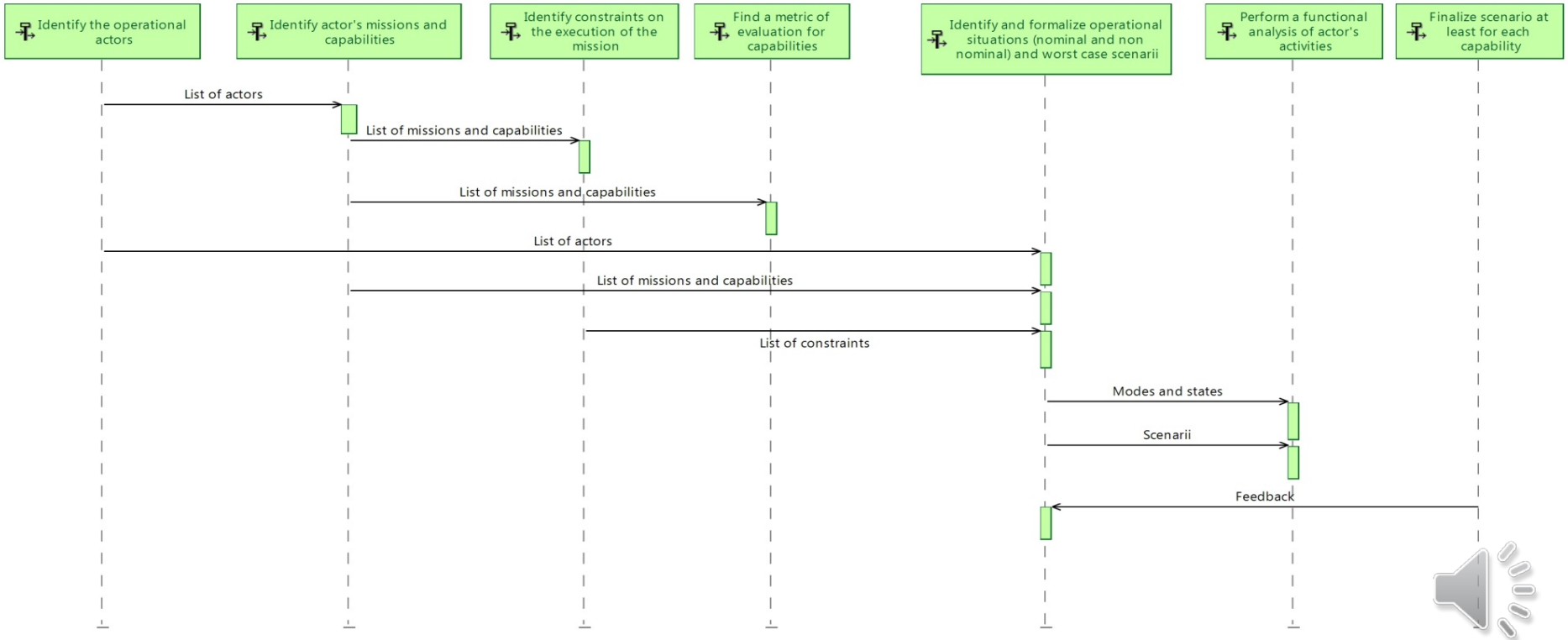
1.2 Operational actors

3. **Creation of the model**



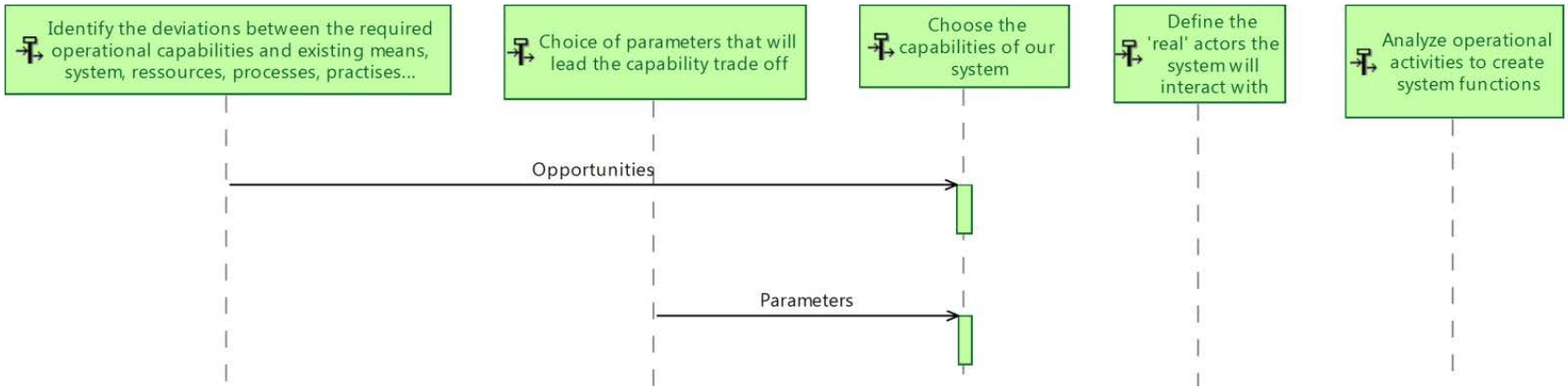
Operational Analysis process

Illustration of the Operational analysis workflow with a Capella Scenario

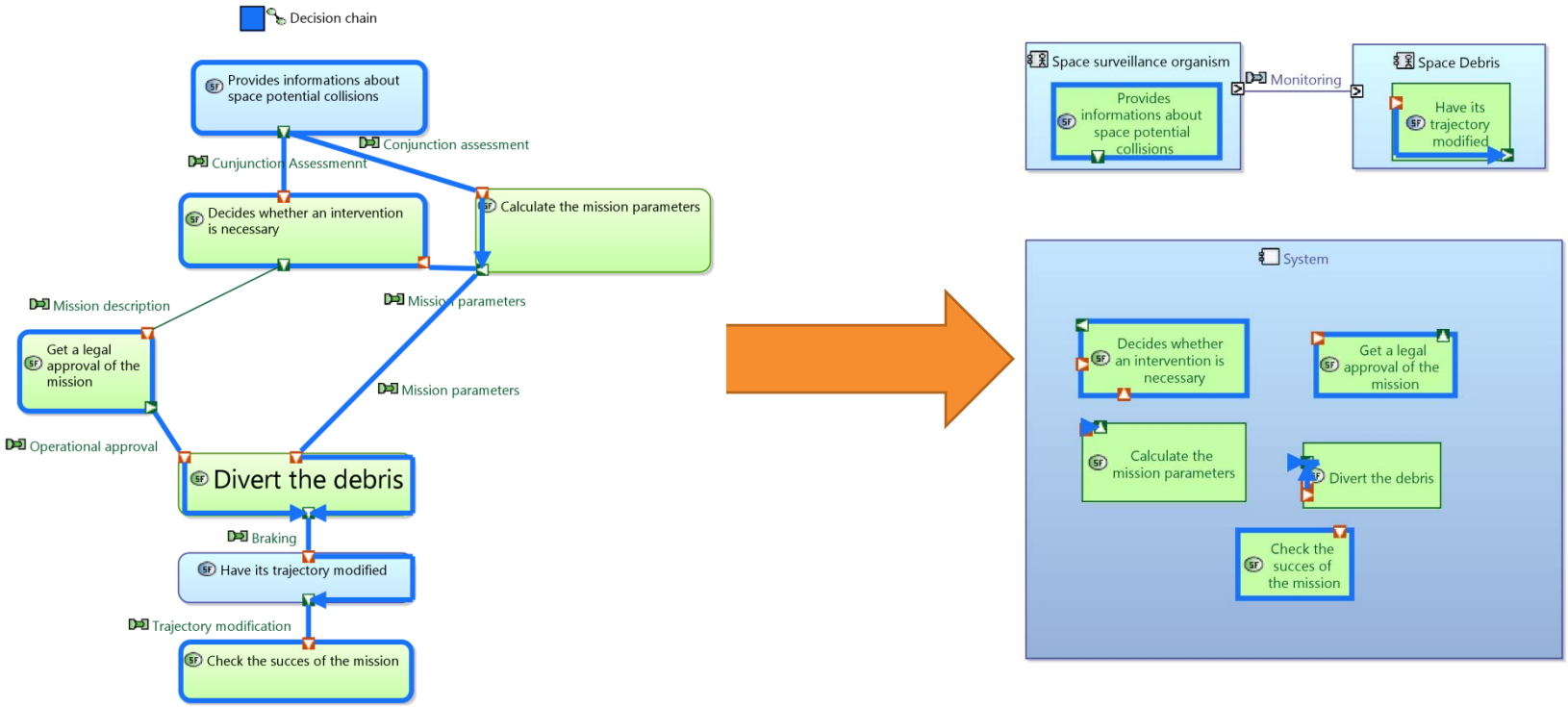


System analysis process

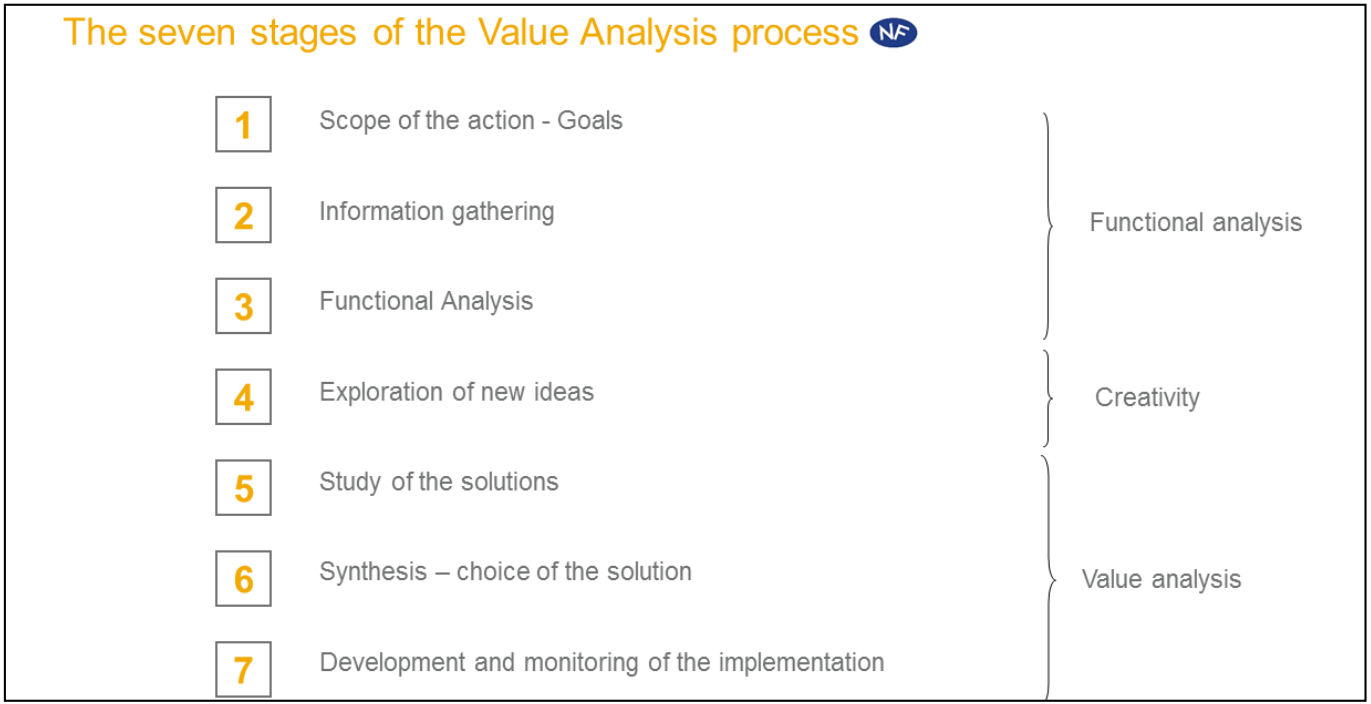
Illustration of the System Need analysis workflow with a Capella Scenario



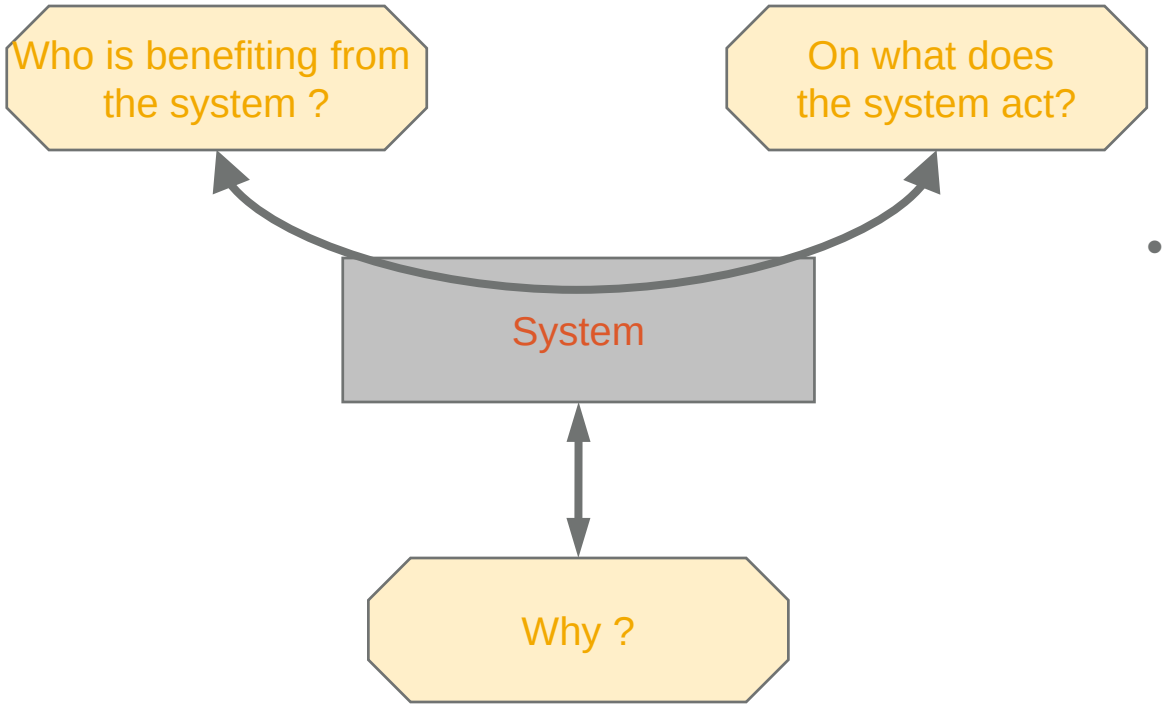
Construction of System Need analysis for JCA system



Comparison of Arcadia to Value Analysis process:

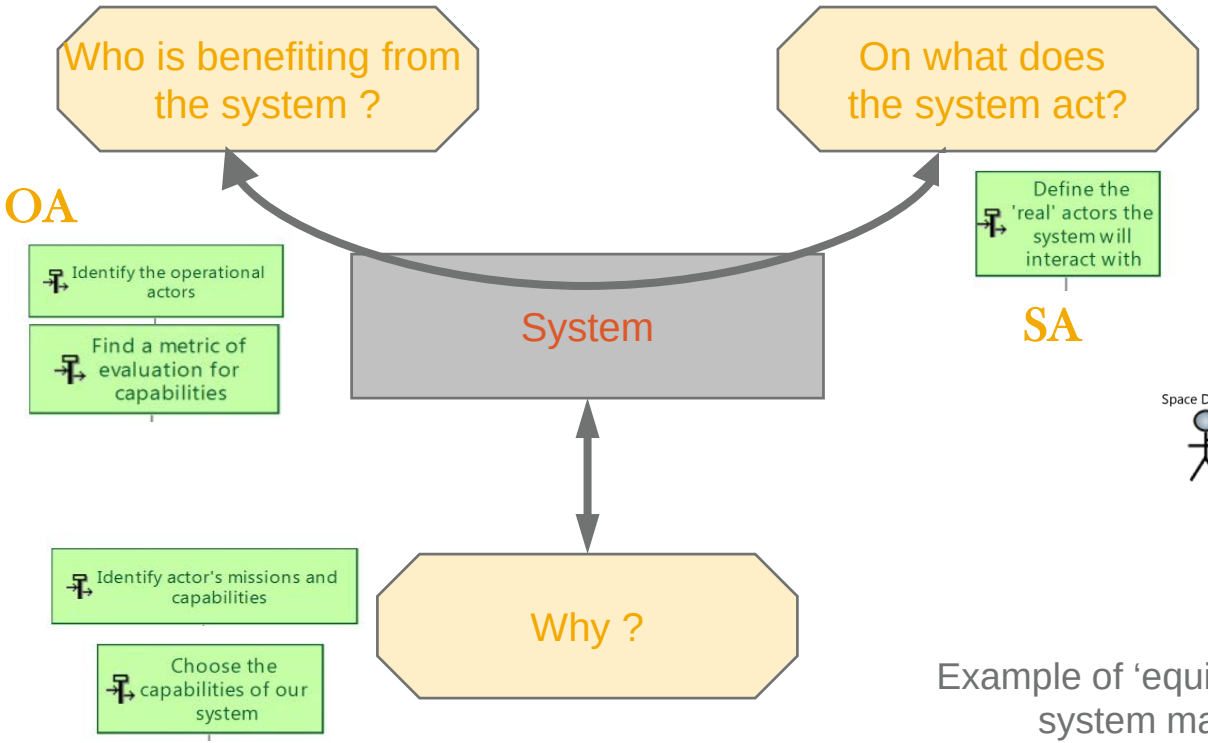


Value analysis tool: bulkhead

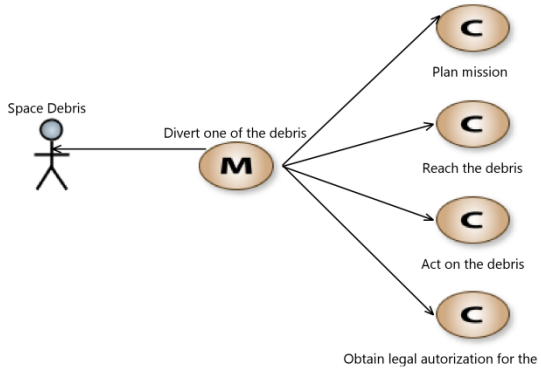


- Main tool to represent the system's scope and the involved actors

Value analysis comparison: bulkhead



- Bulkhead tool equivalent to Missions and Capabilities in OA and SA



Example of 'equivalent' Capella diagram representing the system main mission and the actors involved

Value analysis tool: Life cycle identification

- Identification of the life-cycle of the system in order to identify non-nominal constraints

Value analysis comparison: Life cycle identification

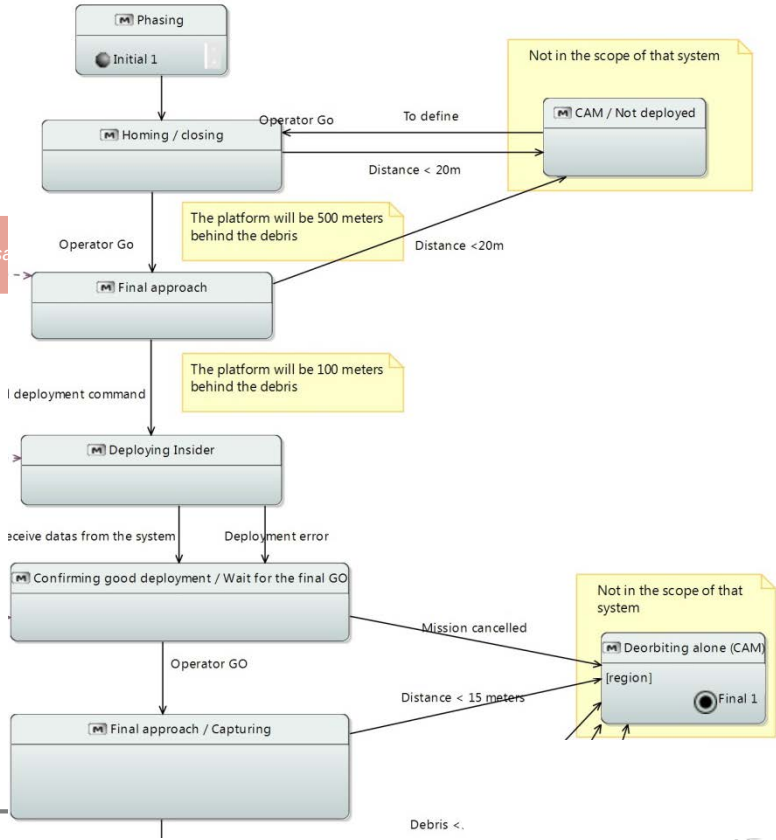
OA

Identify constraints on the execution of the mission

OA

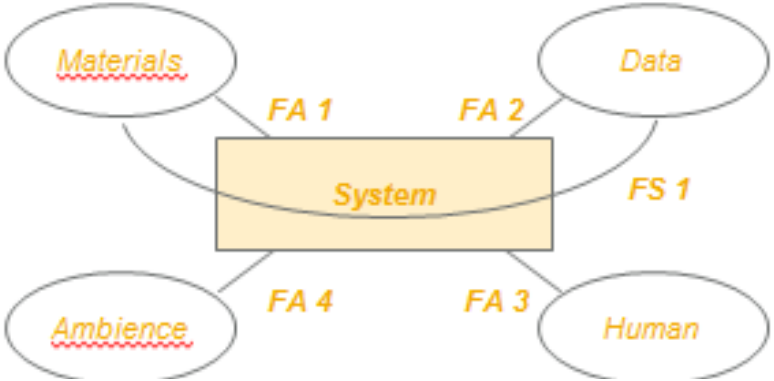
Identify and formalize operational situations (nominal and non nominal) and worst case scenarii

Transport | Stocking | Use case 1 | Use case 2 | Maintenance | Disposa



- Use of **Modes and States machines** in Capella can be used for the same purpose
- Advantage: enable to **filter** all model elements linked to any mode or state.

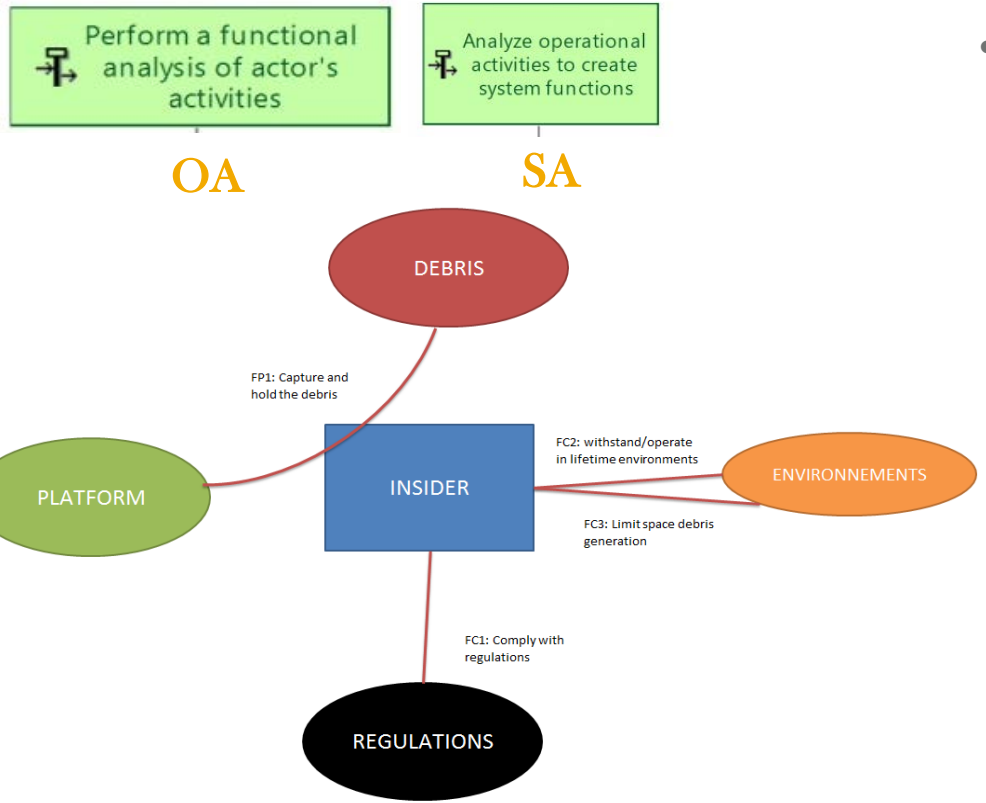
Identification and characterization of service functions



- Realisation of a **transversal** functional analysis

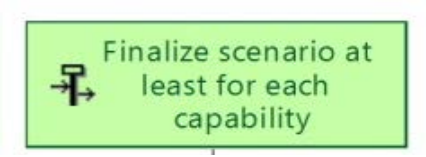
n°	Label	Criteria	Levels	Flexibility / Priority
F_{ij}	One verb, one or two complement to express the expected service or the constraints to satisfy	Parameter mesurable allowing the quantification or the qualification of the verb of the function, or the description of the parameters of the environment.	Mesurable value (given in the adapted scale for the criteria of the function)	Indications on the possible modulations on a criteria's desired level

Identification of service functions

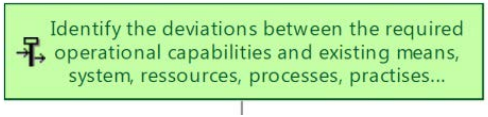


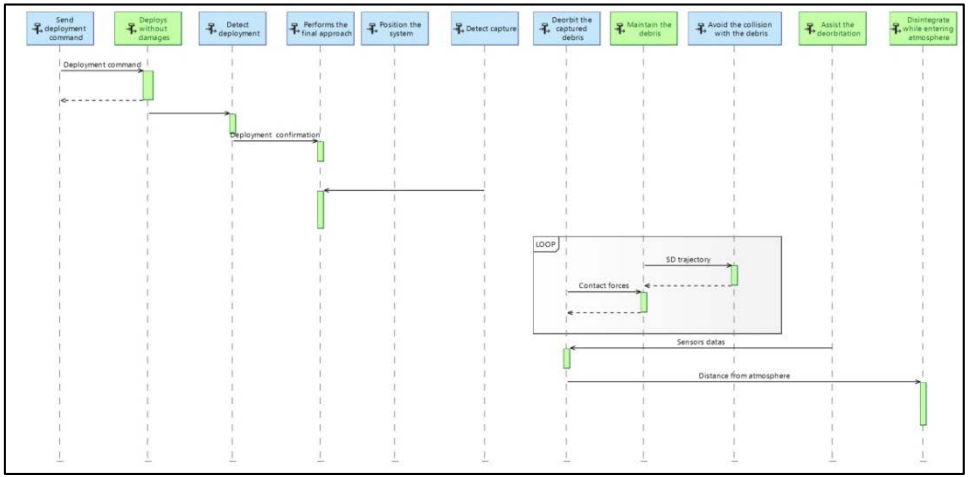
- Differences with functions found with Arcadia (functions **added**):
  - => Need for emergency release
  - => Need for information gathering during deorbitation
  - => Need for communication with the platform for decision-making processes

What are the elements missing in the value analysis process?



- Consideration of real uses cases and **dynamic processes** is extoled with Arcadia





- The scoping of the system's influence is determined considering the **operational analysis** results

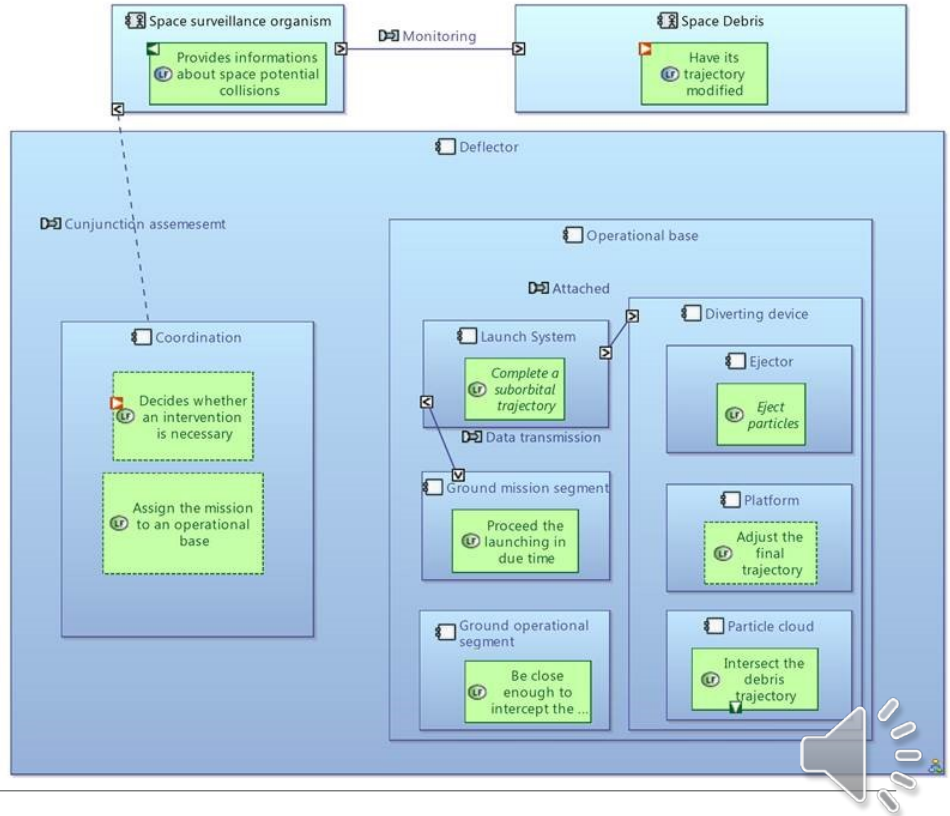
Conclusion : Arcadia method enable to perform a deeper analysis on System requirements

=> ! Need for evaluation on time spend on model construction (no data for old analysis made with Value Analysis)

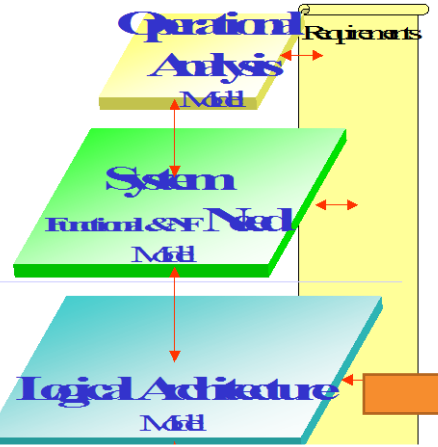
Preliminary system design for JCA system

Construction of Logical Architecture

- Definition of principles underlying system behavior
- Transition of system functions from System need analysis perspective to Logical Architecture perspective
- Refinement through allocations of functions to model elements



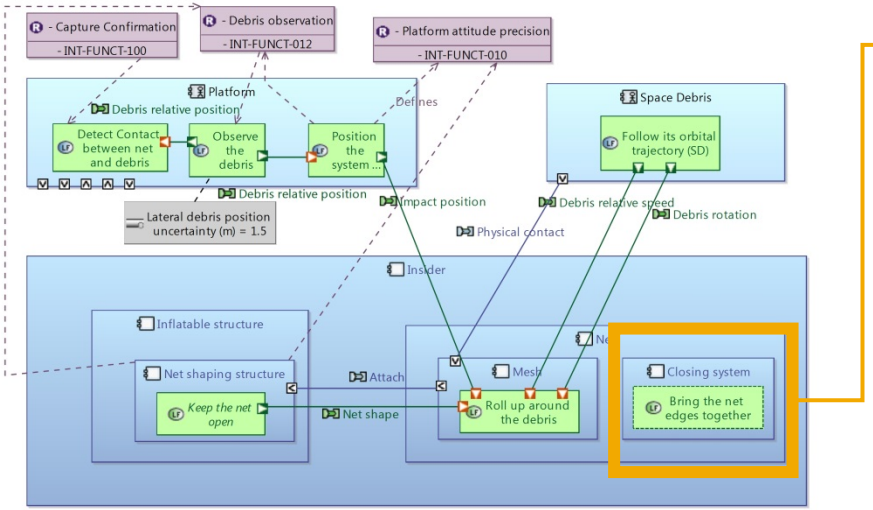
Construction of a model: Logical and physical architecture



The seven stages of the Value Analysis process

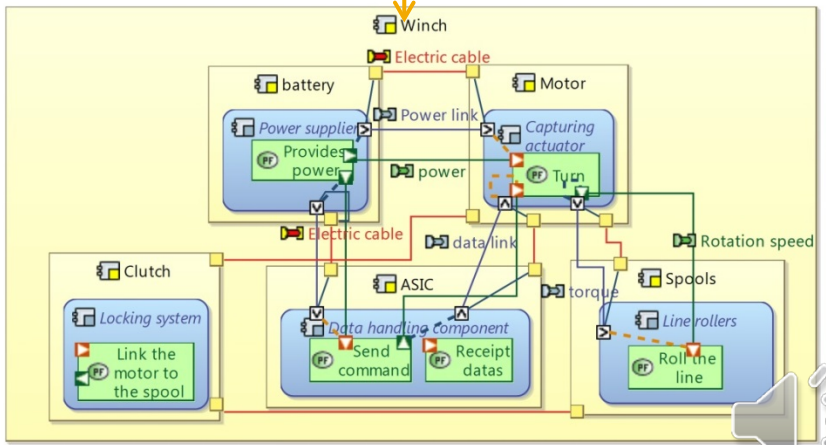
1	Scope of the action - Goals	Functional analysis
2	Information gathering	
3	Functional Analysis	
4	Exploration of new ideas	Creativity
5	Study of the solutions	Value analysis
6	Synthesis – choice of the solution	
7	Development and monitoring of the implementation	

From Logical to Physical architecture



Logical Architecture enables to identify **critical** components that have to be designed

Brainstorming sessions are organised in order to find solution that can be implemented in Physical Architecture

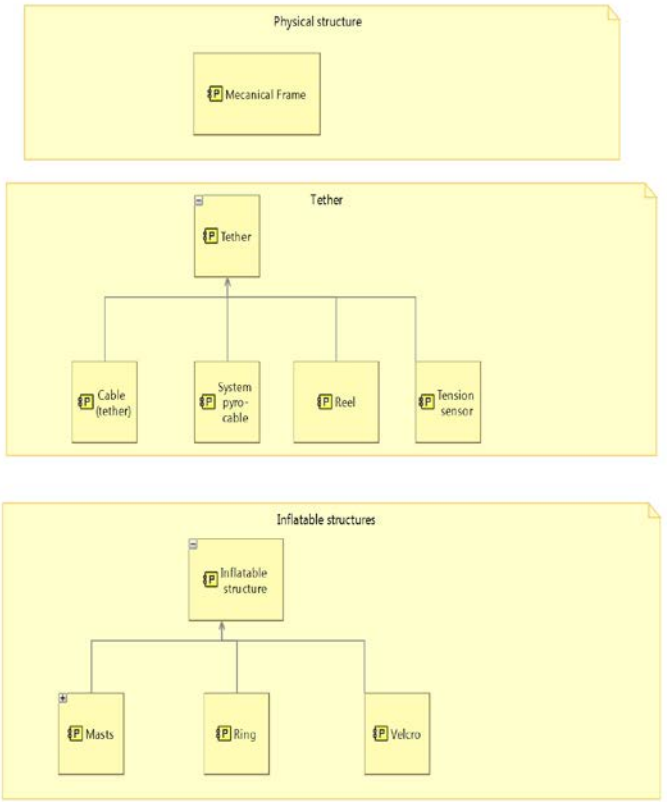


03

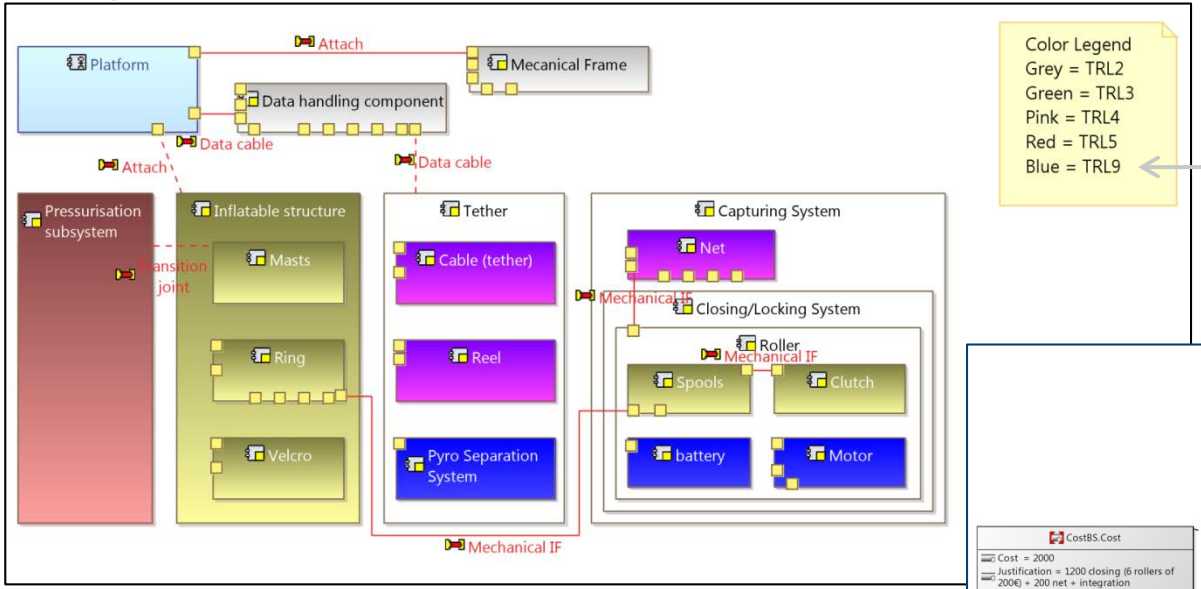
Use of the models

Uses of the model

- Use of the models are the points on which the Capella ecosystem is the most active
  - Traceability of requirements among them and with model elements
    - Thanks to Thales Open Source requirements add-on
  - Simples Budgets (since the Product Breakdown structure is defined in the model)
    - Thanks to Thales Open Source Property Management add-on
  - Verification of consistency between the Arcadia perspective
    - Thanks to the features embedded in Capella



Multiple uses of PBS: TRL and cost

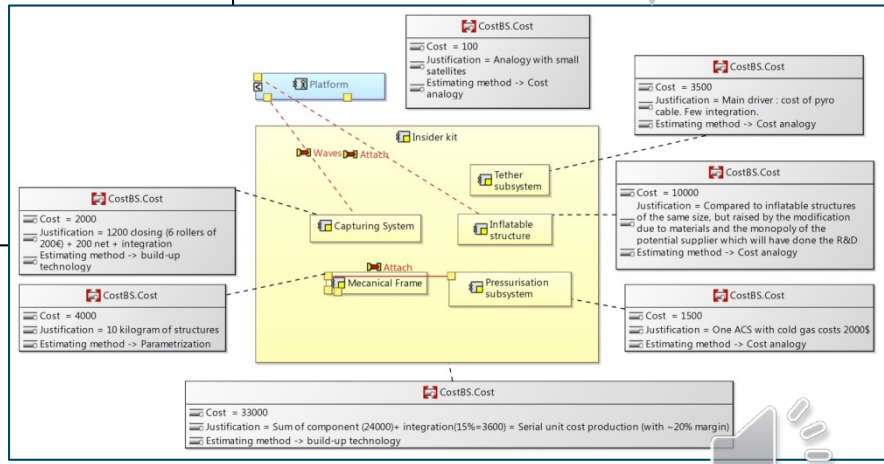


Color Legend
Grey = TRL2
Green = TRL3
Pink = TRL4
Red = TRL5
Blue = TRL9

Allocation of values for all system compo

TRL

and Costs



Lessons learned: consistency with our prime objectives

- **Capitalisation?**

Inside the project => Reference documented model, that will be reused for next phases. However, the time saved to understand the system concept may be ‘spoilt’ in explainations about the Arcadia language/logic.

  - Future work: evaluation of the gain of time when further developments of those projects.

Globally => Use of **librairies** that can be used in other projects (with some training for the ones who will use it)

- **Centralization?**

Usefull for PBS in previous slide, and for system behavior desciption.
Issue : how to warn the involved stakeholders when a value is updated ?
An embedded Git allows the comparison of models, but not of diagrams.

- **Communication?**

Main interest, both inside the team and for external actors (diagrams have been putted in articles and conference presentations)
Hard to maintain Layout.
Scenarios & dynamic processes are difficult to read for Capella non-users.

- **Customer vision?**

The Top-down analysis extoled by the method does not always fit with our requirements. Arcadia will extol to stay as generic as possible when there are no constraints, and to detail only in situations where a clear choice have to be made. A **bottom-up transition** is missing to simplify this process.

04

Future of Capella utilization in CT Paris

Future expectatives

Three main topics on which we are working:

- Exploration of dynamical processes through Capella (CONOPS, **AIT** processes).

- Internal and external interfaces management (**ENVOL** project: https://cordis.europa.eu/project/id/870385/fr)

- Improvement of High-level and System requirement management (communication, update with numerous external partners in **SAMMBA** project: https://cordis.europa.eu/project/id/870451/fr)