Call for paper for MBSE 2021 conference

MBSE on MSR ERO: a use case

MSR ERO: the mission

Bringing samples from Mars is the next major challenge of Mars exploration with high scientific added value but with some technical challenges as well. ESA and NASA collaborated to put in place a demanding mission concept to achieve this goal. Several components of this mission concept were identified: three launches will be necessary to accomplish landing, collecting, storing and finding samples and delivering them to Earth.

- NASA's **Mars 2020** mission is currently exploring the surface and rigorously document and store a set of samples in canisters in strategic areas to be retrieved later for flight to Earth.
- A subsequent NASA launch will send the **Sample Return Lander – SRL** mission to land a platform near the Mars 2020 site. From here, a small ESA rover (the Sample Fetch Rover – SFR) will head out to retrieve the samples. Once it has collected them, it will return to the lander platform and load them into a single large canister on the Mars Ascent Vehicle (MAV). This vehicle will perform the first liftoff from Mars and carry the container into Mars orbit.
- ESA's **Earth Return Orbiter - ERO** will be the final mission, timed to capture the basketball-size sample container orbiting Mars. The samples will be sealed in a biocontainment system to prevent contaminating Earth with unsterilised material before being moved into an Earth entry capsule. The spacecraft will then return to Earth, where it will release the entry capsule for the samples to end up in a specialised handling facility.

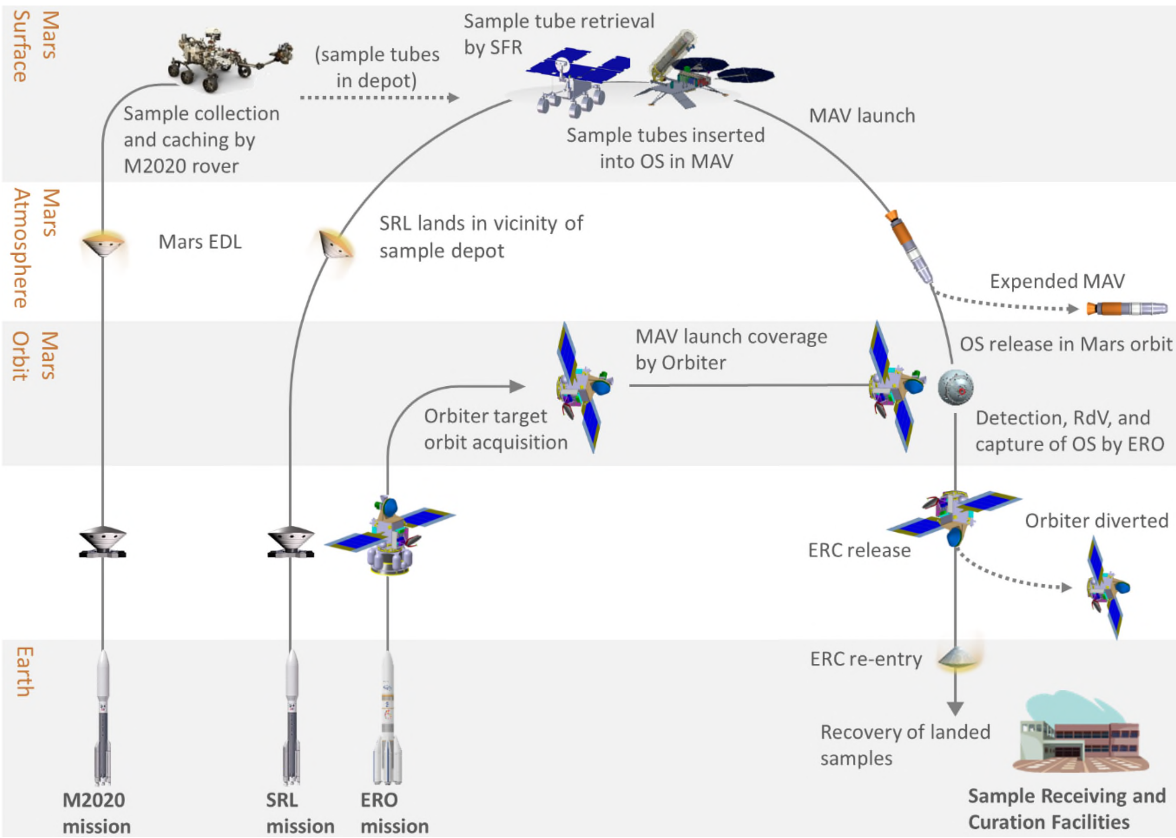

Figure 1 : Mars Sample Return mission concept

ESA selected Airbus Defence and Space for the implementation of B2-C-D phases of MSR ERO for which PDR has been successfully achieved in February 2021.

Why applying MBSE techniques on MSR-ERO?

Several reasons led to the decision to deploy MBSE framework on the project:

- Short study duration: MSR ERO is planned for launch in September 2026
- Project complexity from both technical and programmatic point of view: many stakeholders and interfaces, numerous mission phases with dedicated constraints
- Large project: requiring a huge engineering team with several iterations design loop at different levels
- Request of ESA to support exchange with NASA

Major motivation for implementing an MBSE environment is to facilitate a common understanding among people committed in the project of the mission needs, concept of operations as well as functional and logical architectures by a model centric information management rather than documents based one and by flowing down the system context into the disciplines. This model centric approach is also an easier way to ensure consistency and exhaustiveness of architectures.

MBSE on MSR ERO in practice: MOFLT approach

This general framework provides a modelling method, which is tool and language agnostic, compliant with ECSS and extensible with tailoring points. It relies on 5 layers of system engineering: Mission, Operational architecture, Functional architecture, Logical architecture, and technical/Physical architecture.

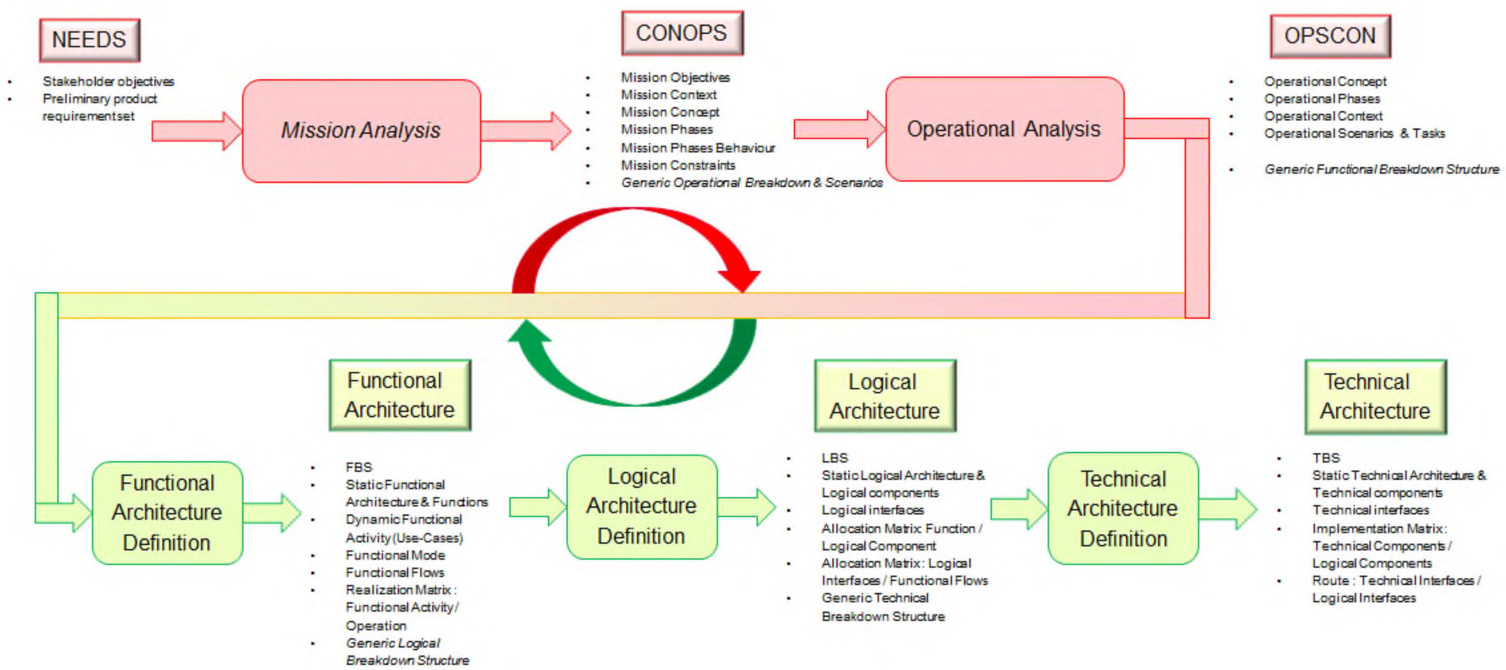

Figure 2: quick overview of the modelling layers supported by Airbus MBSE framework

The approach is summarized as follows:

- Mission analysis: what is the problem we need to solve and what are the potential ways of solving it?
  - Definition of the mission: objectives and effects
  - Determine potential ways of realizing a mission (mission concept)
- **Operational analysis: what the system of interest will do to contribute to the mission? What is the context of the system of interest?**
  - **Definition of operational concept on an entity: context, constraint, system of interest**
  - **Definition of operational scenarios consistent with mission concept**
- **Functional architecture: how the system of interest will work to meet the 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** and logical interfaces
    - **Allocation of function to logical components**
- Technical (physical) architecture: how the system of interest will be implemented?
    - Definition of technical (physical) components and technical (physical) interfaces
    - Realization of logical components
    - Realization of logical interfaces by technical components

The elements highlighted in bold are the one that have been modelled for MSR-ERO. These elements are detailed in the following paragraphs

Operational analysis

The different mission phases were identified and implemented as state machines, as shown below:

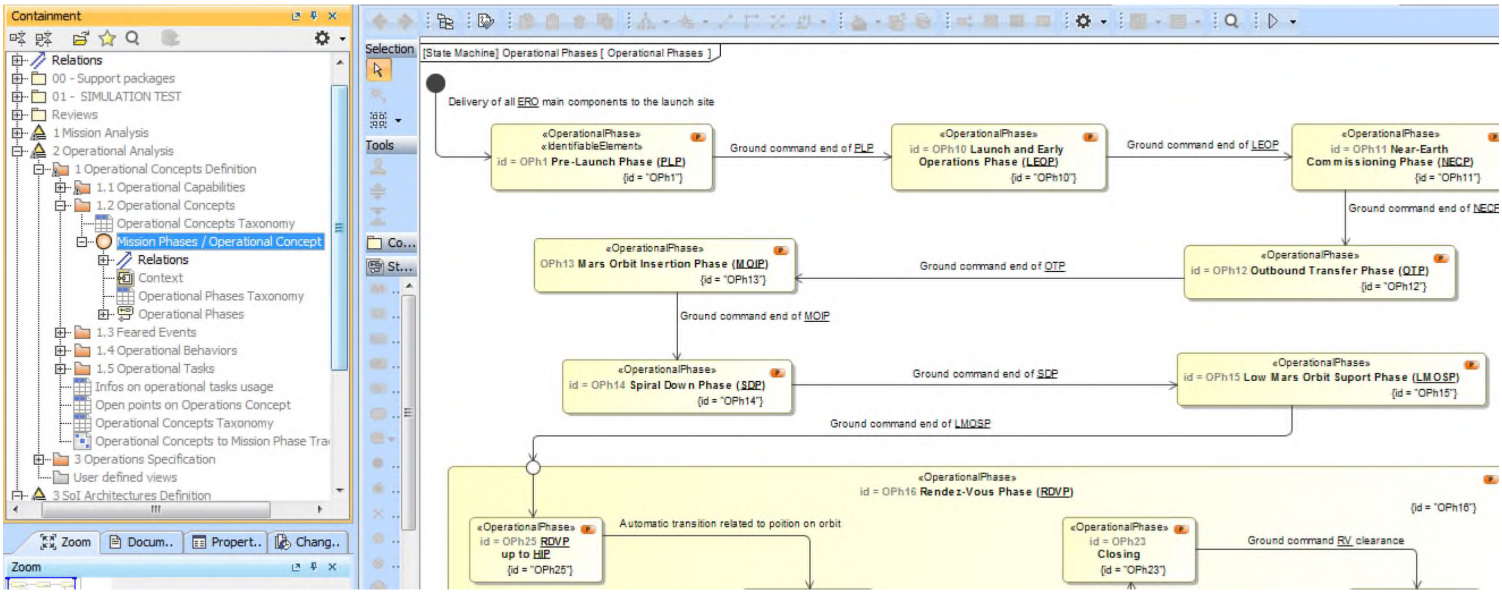

Figure 3: MSR-ERO operational concept implemented with Cameo

Operational phases have been associated to each Mission phase. The operational tasks describing the behavior of the ERO System of Interest together with the operational exchanges with external stakeholders, such as Mission Control Center or Mars assets on Mars surface, have been defined and presented in the form of SysML activity diagrams (see figure 4). The resulting set of ERO behaviors all along the mission builds the backbone of the OPSCON.

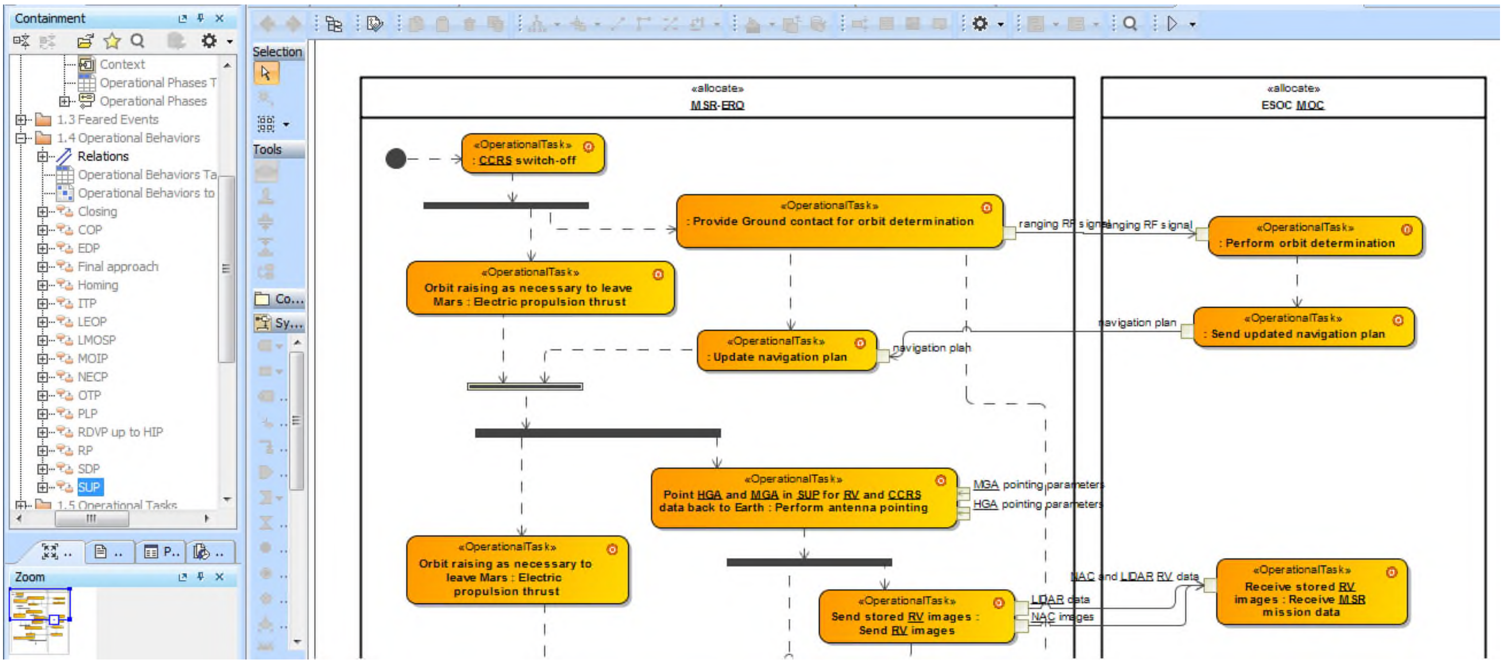

Figure 4: Example of operational tasks dedicated to Spiral Up Phase (SUP)

Functional architecture

The functional architecture package is located in the SoI Architectures Definition Packages and contains the functions structured in several level of composition. Each function is represented by a block diagram showing its sub-functions and a behavior showing the interaction (functional flow) between its sub-functions which is described through an activity diagram.

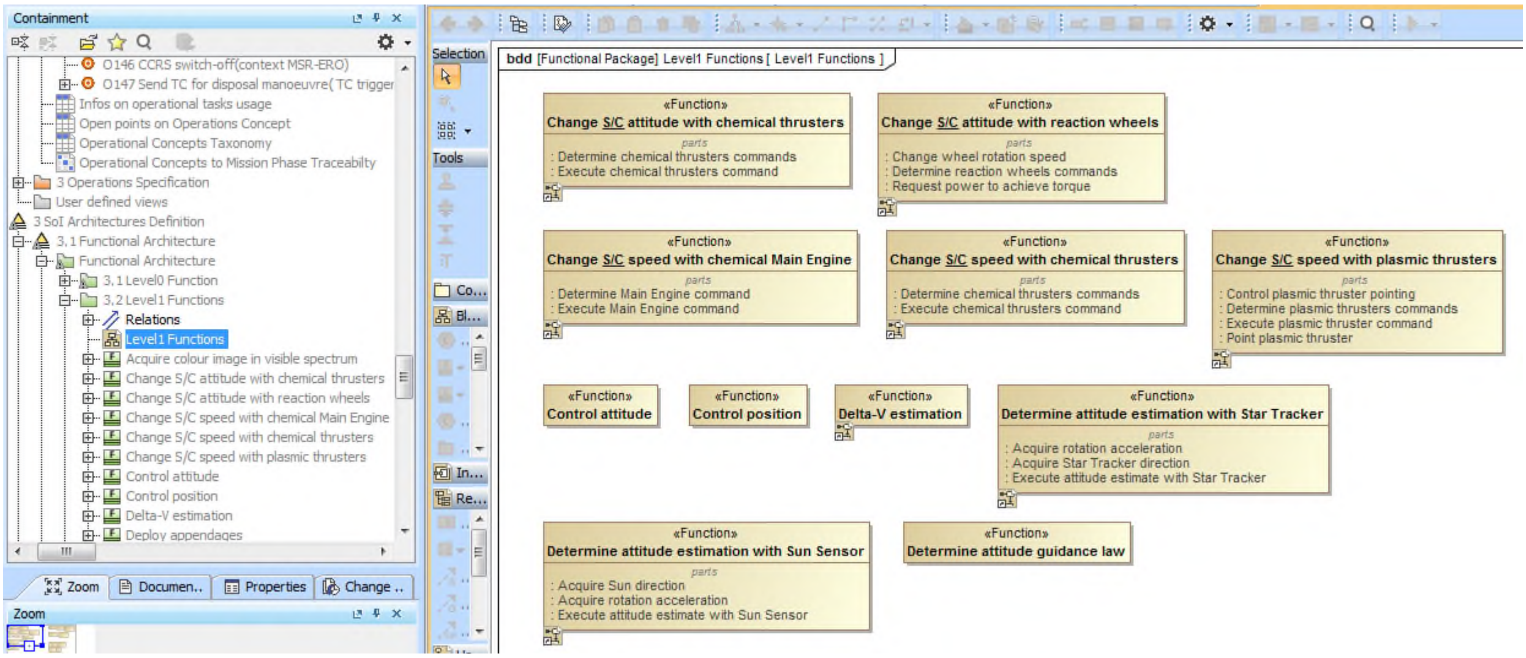

Figure 5: Some of the level 1 functions for MSR-ERO

Logical architecture

The logical architecture package is located in the SoI architecture definition package and contents:

- the logical components structured in several levels of composition
- the allocation of the leaf functions to the different logical components, as shown in the matrix below

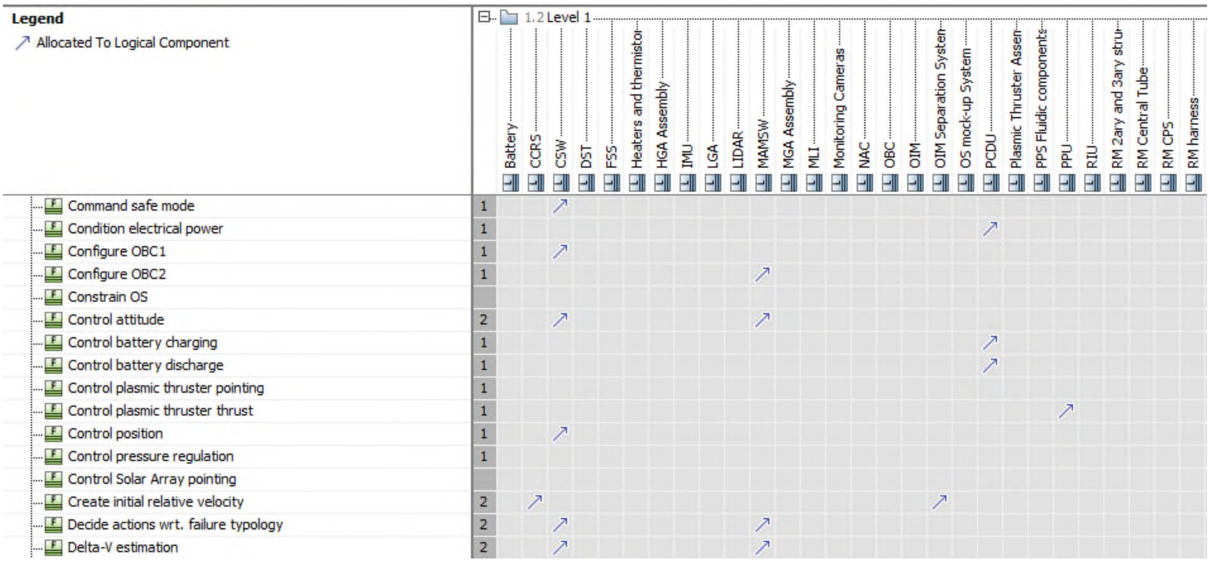

Figure 6: Leaf functions allocation to logical components

The impact of any function modification on logical components can easily be assessed with this matrix. Similarly, the impact assessment of a change of logical component on function architecture is straightforward.

Next steps: requirement mapping on the model

Another added value of MBSE approach is to have the ability to map specifications with the MOFLT model. This allows to manage consistently a set of requirements (identified by a type compatible with MOFLT object mapping) and to check that:

- all the requirements are satisfied
- no requirement is missing
- there is no useless requirement

Once this mapping is done, the assessment of the impact of any modification is easier, from both need (mission, operation) and solution domains (functional, logical).
The requirement mapping on MSR-ERO is planned for the weeks to come. It has been decided to map Airbus DS most critical specifications (traceability with ESA specifications being already done), as shown below:

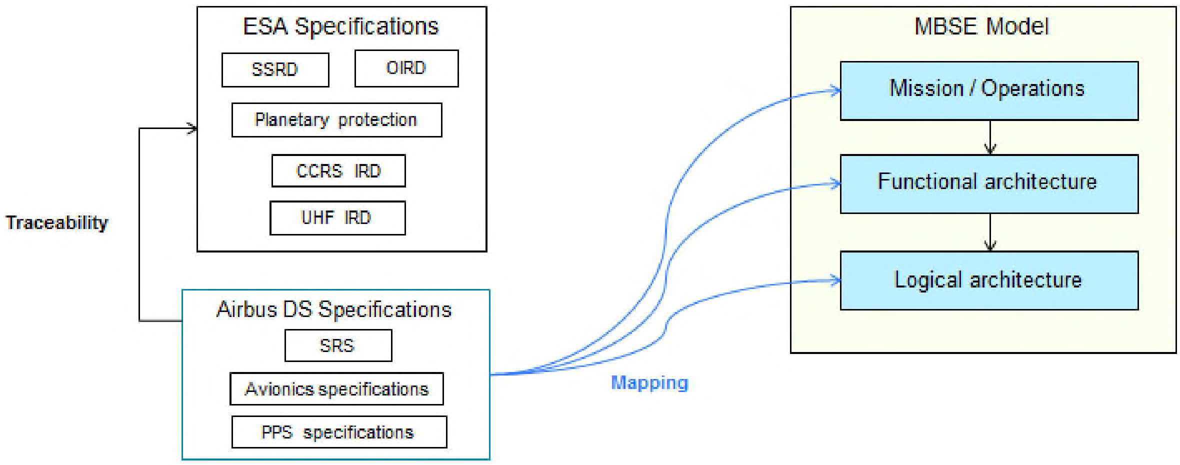

Figure 7: Principe of requirements mapping for MSR-ERO

A dedicated method is being defined to perform the mapping. At the time being, the associated checks described below are done by hand using traceability matrix, but a tooling is in development for automatization providing synthesis results.