Experience gained on applied MBSE at Spaceship FR.

Short-Paper Proposal for MBSE 2022 Conference (ID: O-1)

Author: *Marcos Eduardo Rojas Ramirez[2] on behalf of the Spaceship FR Team[1] in collaboration with ISAE SUPAERO.*

Collaborators: *Alexis Paillet[1], Jean-Charles Chaudemar[2], Stéphanie Lizy-Destrez[2].*

Organizations: *Centre national d'études spatiales (CNES), Toulouse, France. [1] Institut Supérieur de l'Aéronautique et de l'Espace (ISAE-SUPAERO), Toulouse France. [2]*

Abstract

The implementation of Model-based Systems Engineering (MBSE) approaches to support systems engineering activities for the design and analysis of space systems is one of the top priorities for many actors in the space sector, such as Space Agencies, Privates Companies, Research Entities, and Small and Medium-sized Enterprises (SMEs). As a result, various organizations have launched initiatives to support the development of knowledge and experience on MBSE practices in a collaborative framework to ensure coordination, even if each actor uses different tools and methods. The French Space Agency (CNES) supports such initiatives by collaboratively and internally working on multiple aspects of MBSE implementation, such as coordinating workshops and discussions around the subject and actively working on technical projects.

This short paper summarizes the results and lessons learned from using Capella and the Arcadia Method to perform the Operational Analysis of an Inflatable Lunar Habitat. The Spaceship FR Team at CNES performed this work to understand more about the benefits of MBSE in practice and evaluate its use when working on a collaborative project. In this case, the direct collaborator was a start-up that provided the topic and followed up on the progress of the MBSE activities.

Introduction

Spaceship FR is a team at the French Operations Center for Science and Exploration (FOCSE), which works on Lunar and Martian exploration projects. These projects are usually done collaboratively and concern new concepts of space technologies for exploration with a low Technology Readiness Level (TRL). Furthermore, since its projects are not associated with any particular mission, the team avoids the pressure of having strict deadlines. As a result, the team has enough time to assess digital tools and methods in-depth and provide valuable feedback. Such aspects allow Spaceship FR to support CNES by serving as a testbed for different MBSE applications.

For the work presented in this paper, the Spaceship FR Team worked with a start-up referred to as "the client", who proposed a project based on a concept for an inflatable lunar habitat which became the System of Interest (SoI). The work on this project was divided into three parts:

- Creating a documented basis on MBSE tools and methods to answer the questions and concerns of the client.
- Using Capella and Arcadia to perform the Operational Analysis based on the use case provided by the client.
- Evaluating the efficiency of both the tool and the method to respond to the needs of the Spaceship FR team and the client.

Introducing MBSE to the Client

Before being able to model, the Spaceship FR team had to answer the questions and concerns of the client concerning MBSE. This situation resulted from each partner's different levels of knowledge and experience. Since the Spaceship FR team already had some experience on MBSE, its benefits on the project and the optimal approach were evident to Spaceship FR but not to the client. The following table describes the actions taken to introduce the client to MBSE.

Table 1. Actions performed to introduce MBSE to the client

Actions	Description
Explaining the benefits of MBSE to the client.	The team explained the benefits of MBSE to the client, providing examples of other projects in the industry and focusing on the usefulness of the relationship between the MBSE and Product Line Engineering. This decision was based on the long-term goals of the client included in their development plan for multiple versions of their product.
Guiding the client in choosing an MBSE tool.	The team conducted a study on space projects that used MBSE and presented it to the client. The final decision was to use Capella and the Arcadia Method since the tool and method seemed to be widely used by many actors in the Space Sector, including those of interest to the client. [1-2]
Clarifying the relationship between MBSE and concurrent engineering.	The team explained to the client that the data from concurrent engineering tools such as the Open-Concurrent Design Tool or IDM-CIC could complement the information provided by the MBSE model. Ideally, both tools should be used to have a complete conceptual design. The MBSE model can be used to decompose the system and its functions, while the concurrent engineering tools can be used to manage all the different parameters required for budgeting and their traceability.

While the client's concerns were expected, the time and effort it took to convince them about the benefits of MBSE were more than expected. From this experience, the team learned the importance of having a well-documented source of references that can help guide anyone through what MBSE is and its benefits. Ideally, one should use MBSE based on a defined vision with clear objectives and expected added value from each modeling activity. However, when acting as a consultant or advisor, one may have to help the client build its vision before starting to model, as it was in this case.

Capella and the Arcadia Method

Capella is an Open-Source MBSE tool developed and distributed by the Eclipse Foundation. Compared to other MBSE tools, Capella seemed to be more intuitive and a better choice when introducing someone to MBSE, thanks to its methodology "Arcadia" and its formal modeling language based on SE concepts [1-2]. Capella's main advantage is that it is a customized tool where anyone can begin to model relatively quickly without requiring a strong background in MBSE. In addition, the methodology is described well enough to be learned simultaneously as the modeling language and the software, having fewer things to know beforehand and a faster learning rate. Previously, ESA and CNES had evaluated this tool, and both reached similar conclusions [1-2].

Operational Analysis of an Inflatable Lunar Habitat

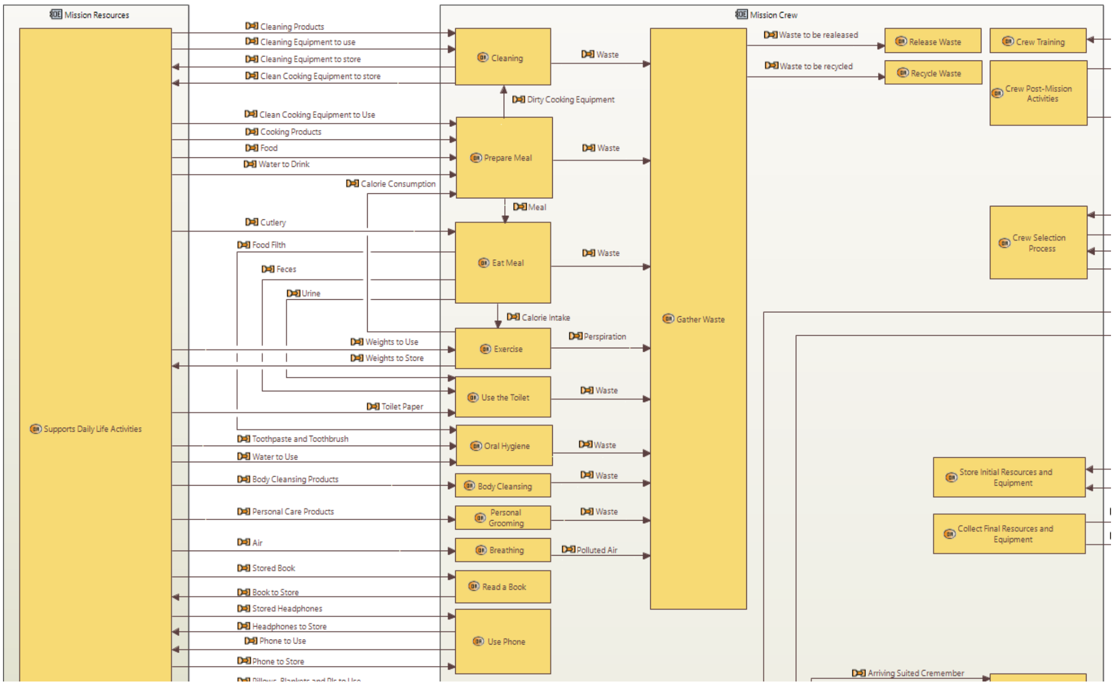

Figure 1. Operational Architecture Diagram. (Partial View)

The Operational Analysis (OA) is the first MBSE process performed within the Arcadia method [3]. This process consists of a series of tasks that allow the modeler to define operational entities, activities, and interactions around the system. In this layer, the SoI is absent since the objective is not to represent the SoI but to show what activities the user needs to perform. By the end, the modeler arrives at the Operational Architecture Diagram (see Figure 1). In this diagram, each box containing yellow boxes is an operational entity (the users or actors). In contrast, the yellow boxes are the operational activities, and the lines that connect them represent their respective interactions with one another.

While the Arcadia method contains three more processes (System Analysis, Logical Architecture, and Physical Architecture), the Spaceship FR team decided to focus on the OA since it answered many questions concerning the concept of operations. Also, it's important to mention that while the team only made a single operational architecture, it followed the recommended product line engineering approach based on Arcadia, conceiving three types of habitats derived from three different operational scenarios. This task involved identifying operational features such as weight, cost, durability, or crew capacity and defining multiple possibilities for them depending on the scenario. For example, if the SoI is used as a transitory habitat, it would only need to sustain the minimum number of astronauts required for an EVA, which is two. In contrast, if the SoI serves as an emergency habitat in case of a failure in the lunar base, then the crew capacity should be increased to four to meet the astronauts' needs in that scenario.

During the OA, the team described all the activities and interactions between the mission crew, the mission control team, the mission stakeholders, supporting mission elements (external systems and resources), and the external environment. Also, based on the diagrams offered by Capella, the team could show how the mission would be coordinated and performed, including a nominal day with a sequence of activities and interactions between the crew and the mission control team. Lastly, the team could also define states for the crew based on the arrival, stay, and departure sequence, accounting for the possibility of a contingency during each state.

Lessons Learned & Conclusion

This work allowed the Spaceship FR Team to separate the truths from the myths concerning applied MBSE and evaluate the benefits of using Capella and the Arcadia Method. These are presented below.

Table 2. MBSE Myths vs. Truths.

Myth	Truth
Open-Source Tools provide free access to MBSE.	Any MBSE tool will have a cost in deployment and maintenance.
Documents are not necessary.	From our point of view, formal written documents were still useful to share information with our client, especially our approach and decision rationales.
A methodology is enough to be able to perform MBSE properly.	While most MBSE methodologies explain each process well, sometimes they don't mention aspects that beginner modelers often aren't aware of. An example would be configuration management.

Table 3. Benefits of Capella and the Arcadia Method

Benefits of using Capella
• The time it takes to learn how to use the tool is relatively short. • The tool is easy to install. • A big community uses the software, and many people are willing to help new users learn how to use the tool properly. • There are many free webinars where people from the industry show their work on Capella. • Since it is open-source, many people are developing new add-ons that enhance this tool. • The tool has a JAVA interface that allows the creation of custom add-ons and plug-ins. • When identifying errors in the model, the tool describes the type of error and how to fix it.
Benefits of using Arcadia
• The method is straightforward, and its documentation is of good quality. • The operational analysis is quite helpful, particularly when there is not much information about how and where the SoI will operate. • Having multiple ways to describe the interactions between operational activities is helpful. • Multiple diagrams can be created displaying different levels of the same architecture. This aspect is helpful when presenting to diverse audiences.

In conclusion, this experience allowed the Spaceship FR team to gain experience in applied MBSE from the perspective of an advisor or consultant. In this case, the team acted as modelers, translating all the documentation and information from the client to the model. As a result, all the client's objectives were met, which were the definitions of the Concept of Operations and the establishment of the foundation of the product line of their system.

References

[1] Successful MBSE landing on a CNES operational use-case. *Jonathan Lasalle, ARTAL Technologies at MBSE 2020.*

[2] Modelling Avionics Interfaces and Generating ICDs for the Propulsion Subsystem of the MPCV-ESM. *Delia Cellarier, European Space Agency at MBSE 2020.*

[3] Voirin, J. (2017). Model-based System and Architecture Engineering with the Arcadia Method (Implementation of Model Based System Engineering) (1st ed.). ISTE Press - Elsevier.