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EXTRACTING MODEL-BASED SYSTEMS ENGINEERING VALUE THROUGH A MINIMUM VIABLE PRODUCT CASE STUDY AT AEL SISTEMAS

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Abstract

This work presents the planning, preparation, and modeling phases of a Model-Based Systems Engineering (MBSE) Study Case. The study sought to extract MBSE's value through a Design Thinking approach applying the concepts of Minimum Viable Product (MVP) and Double Diamond methodology. The work was developed at AEL Sistemas, an Aerospace and Defense Brazilian company that designs, develops and manufactures products, providing maintenance and logistics supports for its clients. AEL Sistemas is developing a Flare Guidance Symbology for one of its products by classic Systems Engineering approach. The Flare Guidance feature provides additional information and guidance for the Pilot during the performance of the Flare Maneuver – the critical phase of the landing procedure of an aircraft. The presented work uses this feature as a Benchmark for the MBSE Case Study, gathering quantitative and qualitative results to be compared with the classic Systems Engineering approach. The use of an MVP approach and the choice of an already classically developed feature were vital to highlight the value of the MBSE approach. The applied methodology was highly effective on the extraction and understanding of MBSE's value, hence its results were presented to company's directors and time allocation and sponsorship were gained to continue MBSE studies.

Keywords: MBSE, MVP, Systems Engineering, Design Thinking

1. Introduction

AEL Sistemas is a Brazilian company that serves the Aerospace and Defense Market by designing, developing, manufacturing, and providing maintenance and logistics support for its clients [1]. This market is facing an exponential increase in complexity and innovation; therefore, it is important to use a Systems Engineering Approach in the development of products.

In a highly Volatile, Uncertain, Complex, and Ambiguous world, described as VUCA [3], it is notoriously important to innovate and adapt alongside such reality. With this notion, the Systems Engineering discipline is moving to a "model-driven" context, utilizing the Model-Based Systems Engineering (MBSE) methodology. The MBSE approach supports the Systems Engineering Approach during the product development using models to represent the system's behavior and the interactions between its subsystems and the actors that interact with them [8].

Another approach used to deal with complexity is the Design Thinking Approach. This approach's main goal is solving complex problems collectively and collaboratively with a focus on. Therefore, it adds professionals with different skills and a common objective: to understand and serve the potential client. In short, people are placed at the center of the product development and not just at the end consumer. Working in multidisciplinary teams is common in this approach. Through all the development phases, the Design Thinking approach maximizes the value of the solutions generated by the team.

One of the main tools used in Design Thinking is the Minimum Viable Product (MVP), which seeks to get a solution as close to reality as possible with low cost and complexity so that the user can better evaluate the idea, generating insights and broad perspectives [6].

This paper presents a project developed in R&D Systems Engineering. The project consists of the development of a Minimum Viable Product applying the MBSE methodology and some concepts of Design Thinking, such as the MVP approach and the Double Diamond tool. The end goal of this project was to extract the advantages of the MBSE methodology and to understand the applicability of the methodology in the company's Systems Engineering process.

2. Development

The planning and preparation of the MVP were architected through the Design Thinking approach. The "Double Diamond" methodology (Figure1) was used for controlling the MVP formulation, by diverging and converging iterations, respectively creating, and making choices [4].

The first phase of the methodology is the Discovery phase. In this phase, the scope of the problem was defined and the solution to be studied as well. Once the scope was defined, interviews and brainstorming sessions were conducted to understand the possibilities. After gathering the necessary information, the second phase started. This phase is the Definition phase, where the main objective, the tool to be used, and the reach of the MVP were defined. In the third phase, the Development phase, the group was trained on using the tool, the activities to be performed were defined and the model was developed. The last phase is the Delivery phase. In this phase, the MVP package developed during phase 3 was analyzed to extract the values raised in phase 1 and be presented to the sponsors.

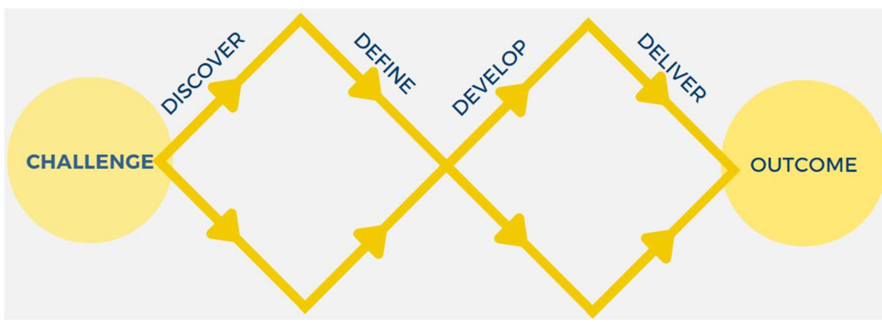

Figure 1 – Double Diamond Methodology

2.1 Discovery

In this phase, the scope of the problem and solution to be studied were defined. The development of systems in the aerospace industry is complex work. It requires numerous text documents to describe each part of such systems, from functions the system must perform to hardware and software components. Words and sentences must, by necessity, come only one at a time in linear, logical order. Systems happen all at once. They are connected not just in one direction but in many directions simultaneously [12]. In a complex system, these connections are exponential. Each function or component is related to a large number of other functions or components. This complexity creates gaps and reworks during the development, as well as miscommunications and misunderstandings between team members – which also causes gaps and rework. The study of new engineering methods that could help unify understanding was debated within AEL Sistemas, and the Model-Based Systems Engineering method shined most among other proposals. A team of systems engineers was formed to dive deeper into the solution for the problem - to understand how Model-Based Systems Engineering could assist in complexity management and unification of understanding.

The MBSE study team sought to develop and collect data by applying a Minimum Viable Product to understand if the use of Model-Based Systems Engineering (MBSE) was a satisfactory solution for the company. The team was composed of members with dissimilar experience levels who joined the team for different reasons. The engineers at the beginning of their careers believed this project would provide them with more experience and knowledge in Systems Engineering. More experienced members believed this methodology to be a trend for the future and wanted to contribute to its adoption by the company.

To extract the most value possible with the MVP, an interview was conducted with the company's stakeholder and sponsor for the project – the Systems Engineering manager. The interview was focused on answering three points:

- The main gaps in systems engineering within the company at present.
- What is innovation and what value does it create in the Research and Development department.
- Expectations for the MBSE Study team

To prepare for the interview a mind map with the objectives was created. The objectives were unfolded into open-ended questions. These open-ended questions allowed the stakeholder to express his concerns without being directed to an answer. The interview steered the team toward the points that would bring the most value to the company. Based on these points the team drafted a methodology for how the development would unfold and which path to take, leading to phase 2 of the Double Diamond – the Definition phase.

2.2 Definition

Phase 2 of the Double Diamond methodology is the Definition phase. Here the main objective was summarized – execute an MVP to evaluate MBSE value coordinated with the value points established in the Discovery phase. This objective combined what was desirable, feasible, and viable. With the objective defined, it was possible to establish the team structure and what features would be modeled. To prove the MBSE value over the classical Document-Based Systems Engineering (DBSE), the feature that was chosen was being developed at the same time by two team members using the DBSE method. The feature was the Flare Guidance symbology for an airplane Head-Up Display (HUD) System. This feature provides information and guidance to the pilot during the Flare Maneuver and has complex behavior. A presentation of the feature and its behavior was given for the team to create a uniform understanding. To complement the operational understanding and necessities, a pilot, who represents the End-User and stakeholder for the feature, was brought into the development and an interview was conducted to extract his needs (Figure 2)

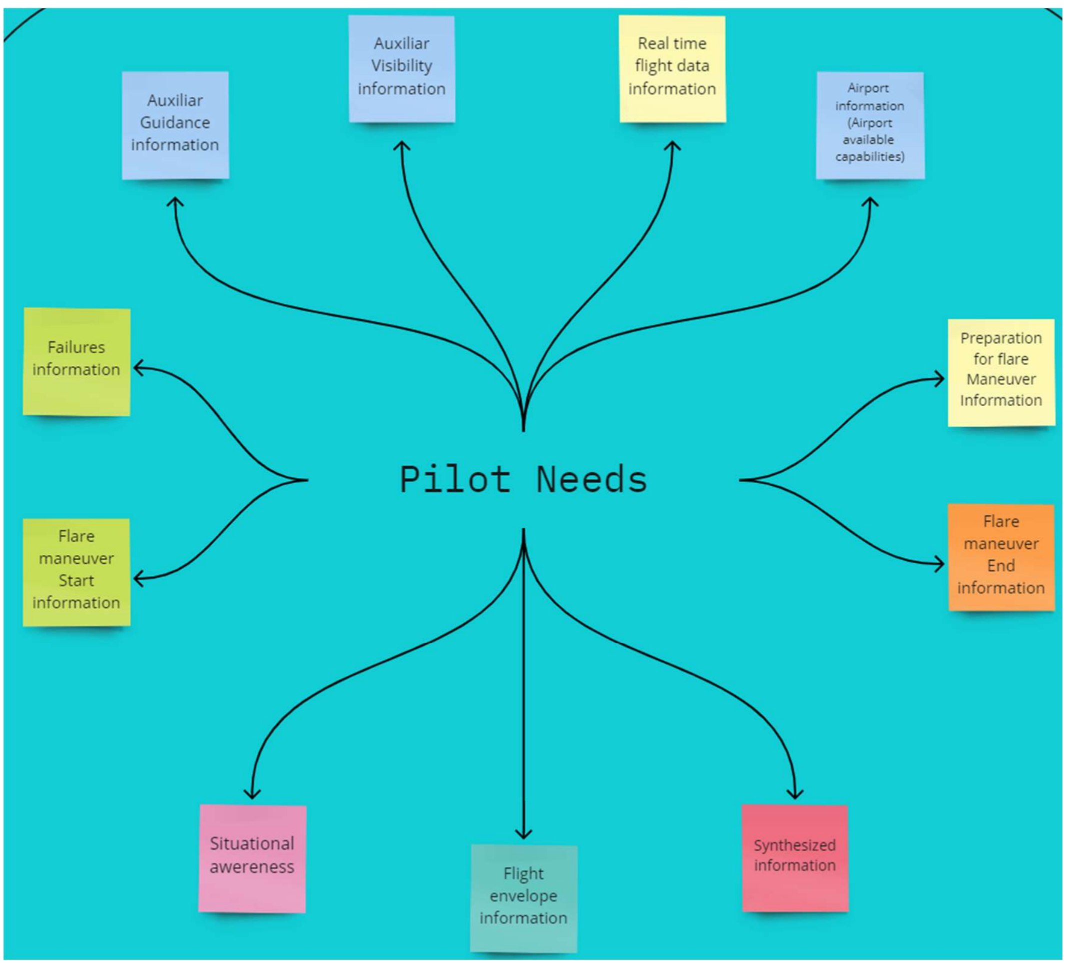

Figure 2 - Pilot Needs

Seeking soaring efficiency and velocity, it was defined that the team would be divided into two groups. One group would work with the modeling while the other would be concerned with the models' verification and validation activities. The modeling group would be leaner, composed of the developers involved in the feature, and experts on the formal development. At the end of each iteration, the validation group would be involved, with the objective of refining, verifying, and validating the developed models.

The next step was to define how the MBSE process would be conducted, therefore it was important to understand its bases. MBSE is an approach intrinsically linked to modeling activities, and modeling is based on three pillars: Tool, Language, and Method [9]. The Tool is the instrument that will be used; in this case, the software where the modeling would be done. The Language is the communication method between user and tool. The Method is the process that is embedded during the modeling practice. To implement the MVP, it was necessary to choose a tool, language, and methodology. Since the objective of the project was to analyze the MBSE value and not choose the best tool, language, or methodology, the Capella's Software was chosen. One team member already had experience with the software, which is Open-Source, used by large players in the industry, meets in one tool the before mentioned three pillars of MBSE, and has an embedded methodology, called Arcadia [10].

Arcadia's methodology divides the system modeling into four phases, as shown in Figure 3. The first one is the operational analysis. Here it is defined what the users of the system need to accomplish. The second one is the functional and non-functional need. What the system must accomplish (the users' needs) is defined in this phase. The third one is the logical architecture. It details how the system will work to fulfill its expectations. The last one is the physical architecture - where how the system will be developed and built is defined. Since no team member had allocated time to develop this project, it was necessary to extract the maximum value on the evaluations with the minimum effort due to time constraints. Therefore, team decided to implement only the operational analysis and functional and nonfunctional needs on this project.

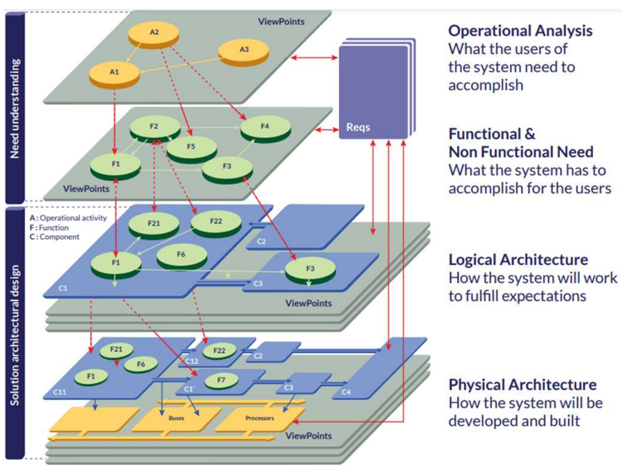

Figure 3 - Arcadia's Modelling Phases

With the full scope of what and how to develop to accomplish the defined goal, the team was ready to begin phase 3 – the Development Phase.

2.3 Development

After the definition of the MVPs (Minimum Viable Product) goal, the feature to be implemented, and how the development process would work, the development phase of the project started. Due to the inexperience of the modeling team using the Capella software, it was necessary to start the process by training its members. Besides the software documentation, Capella also has free tutorials, which contain all the steps necessary to develop all the project phases.

The tutorial used by the group was the Toy Catapult training [11]. This tutorial was chosen because it is well documented and combines the step by step to use the tool with the MBSE and arcadia methodology fundamentals, improving the knowledge the team could obtain with the training. Due to the choice to implement only the operational analysis and functional and non-functional needs, only these two phases of the tutorial were performed by the group. The time required for this training was 2 hours per person.

After the training, the proper modeling started. During this phase, there were two meetings every week. One was the modeling meeting, and the other was the model validation, verification, and refining meeting. At the start of all meetings, a five-minute recap was performed to engage all participants. If necessary, a re-planning was performed to keep track of the objectives. The end-user stakeholder was involved in the development through all cycles, giving important insights and perspectives during the modeling of the Operational Activities.

The embedded methodology in the Capella Software helped the modeling team. The fixed structure made possible to move forward quickly in the modeling. This embedded methodology helped the team keep its focus and achieve the goals set for every meeting.

The Operational Needs Analysis consisted of:

- Defining Operational Entities and Capabilities;
- Allocating Operational Activities to Operational Actors, Entities or Roles;
- Defining Operational Activities and Interactions.

Through Allocation of Operational Activities to Operational Actors and Entities, an iterative and recursive process was performed, where the following steps were used:

- Creating a new Operational Entity Scenario of a Capability;
- Creating the new Operational Scenario activities and allocating them to their Entities at the Operational Architecture Diagram;
- Refining the Operational Entity Scenario with the activities and create their interactions;
- Refining both diagrams until the capability under development is fully verified and validated.

After all the Capabilities were verified and validated, an automated process of Capella's software was used to transition from the Operational Analysis to the Systems Analysis phase. This process creates entities and missions for the Systems under development and transforms the previous activities into functions. Then, the same modeling process was used to perform the System Analysis. As planned, the first two phases of the Capella method were performed. With the implemented artifacts at hand, it was possible to move to the next phase – the Delivery phase.

2.4 Delivery

Once the development phase ended, the delivery phase started. This phase is where the objective defined in the Definition phase - execute an MVP to evaluate MBSE value coordinated with the value points established in the Discovery phase – was assessed. The results were summarized and compared with the expectations from the Discovery phase and the problems that inspirited the presented study. The team analyzed the implemented models and compared them against the results obtained on the implementation with the classic systems engineering development (DBSE). Beyond the technical implementation results, information about the time required for the training and the development of the models was gathered. The advantages and disadvantages of using the MBSE approach were listed by the team based on the obtained experience.

After the results were gathered, the assessed results were that it would be beneficial for the company to move forward with the MBSE studies. Hence a presentation was performed for the sponsors and stakeholders, to obtain sponsorship and time allocation for the group to continue with the studies to implement MBSE within the company's R&D process. This was the last phase of the Study Case project, and which results are presented in the next chapter.

3. Results

During the development of the project, results were gathered about the time required for the training on Capella's software and the development of the models, the advantages, and disadvantages of using MBSE when compared to DBSE, the advantages of involving the stakeholder in the development process and the feedback provided by the sponsor and stakeholder after the presentation of the results. These results are presented in the current chapter.

The team that worked on the MVP project was composed of 13 participants. Four of them, who had less experience in system engineering than the others, were part of the core team that worked on the modeling and development of the system's project. The other members, with more experience in Systems Engineering, worked as consultants, providing feedback about the developed system, and supporting the team with their knowledge of Systems Engineering. From the whole team, only two people already knew how the system and the modeled functionality worked. The whole project was developed with approximately 80 engineering hours for the modeling team and 164 engineering hours considering the whole group involved. The team developing the feature through the DBSE method was composed of two Systems Engineers, one with 3 years of experience in DBSE and the system, and one with 6 months. Through the classical DBSE, the development of the same feature with the same implementation depth consumed 480 engineering hours. This result doesn't prove that it is easier to develop a functionality through MBSE. Two team members were developing the feature through DBSE. The solutions to problems faced during the development were already at hand. However, it does prove that it is easier to pass on complex knowledge through MBSE. The team members who were not familiar with the system could understand the problems and suggest solutions. The process utilized during the MVP development resembled MBSE. Different knowledge levels were connected, and the connection was accessible conveniently, permitting knowledge to flow in all directions. The expertise of all team members was available to every team member. The network between more experienced and less experienced engineers made the process flow. In the DBSE development, these different experience levels are - usually - niched. The flow of knowledge doesn't occur with such fluidity, consuming more engineering hours to spread the necessary knowledge base. The MVP was profoundly fruitful in extracting and understanding the benefits of MBSE. Applying the methodology increased team engagement, improved communication, and induced more questions earlier in the project development. By presenting the information of the System of Interest (SOI) in models, the exposure to the system's shortfalls was more effortless. The use of MBSE also induced the need to perform an operational analysis. For most of the systems developed at AEL Sistemas, the operational analysis performance doesn't happen close to the system development. Moreover, the results of such analysis are not simple to understand. By bringing the Operational analysis closer to the development team and presenting it in models, the team members' awareness of the criticality of the system increased. The team went out to understand the needs of the pilot. The vital stakeholder (pilot) presence in the development process was fundamental to help the team understand its needs during each operational step. This analysis aided the team's comprehension and unified the system understanding between all its members.

Another advantage reported by some team members, who had less experience in Systems Engineering practices, was that this methodology deepened their knowledge in Systems Engineering. Aeronautical projects take many years to develop. Engineers at the beginning of their careers don't have the experience in the whole development cycle. Applying MBSE introduced some phases to the engineers with less experience that would take them a couple of years to contact. Some members' passion for Systems Engineering relit, while others found theirs. This methodology improved and unified the understanding of the system and the needs of its stakeholders.

For the members that were working with the formal development of this feature within the company, it provided a better overall understanding of the system's operational context, amplifying the development awareness and resulting in better-written requirement.

Another relevant result was the fast ramp-up in the use of the Capella software and methodology. It took two hours for each member of the modeling team to learn how to use the software through the training provided by Capella.

The previous results were presented to the company's sponsors and stakeholders, meeting the expectations gathered from them in the interviews executed during the first development phase. By meeting these expectations, the team gained sponsorship and time allocation to continue with its studies to implement this methodology within the company's R&D process. A year plan was drawn separated into quarters. The first dedicated to studying the MBSE concepts. The second quarter focused on the more in-depth study of solutions used worldwide. The third quarter was dedicated to developing a study case to test tools and frameworks. And the last quarter set to understand how to implement MBSE in the current Company Systems Engineering process.

4. Conclusion

With the planning, preparation, and modeling phases presented, it was possible to develop a Minimum Viable Product of Model-Based Systems Engineering with tremendous efficiency and agility. During this process, all the members observed that the system portrayal using models improved the system's overall understanding and the quality of the description of the system. Another important remark was the fast ramp-up in systems engineering provided using this methodology, which was observed by all the members of the modeling team. The MVP process and results were presented to sponsors inside the company, which led to the decision to form a group responsible to introduce this methodology within the company's R&D process. The members of the modeling team received formal allocation to lead this group and the next steps of this project were defined. Starting with the formal study of methodologies, languages, frameworks, and software tools for MBSE to choose the ones that are more compliant with the company's current process and followed by the test of tools and frameworks provided by AEL's partners. Following will be the training of other employees to multiply the obtained knowledge and assist with adopting this methodology within the company.

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6. Copyright Statement

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