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A Framework for Innovation within Aerospace Segment

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Abstract

This work presents an innovation framework that was developed in AEL Sistemas to motivate and incentivize research groups inside the company. AEL Sistemas is a Brazilian company in the Aerospace and Defense sector that designs, develops, and manufactures products, providing maintenance and logistics support for its clients. Research groups were developing organically throughout the company and, as it is in AEL's interest to nourish and harvest this energy, the Innovation Framework was designed by observing those internal research movements in the company. This paper presents the research groups' main structures and how AEL Sistemas fomented them to then propose the AEL Sistemas Innovation Framework, where skills and interests meet enablers, such as people, technology, and tools.

Keywords: Innovation, Systems Engineering, STPA, MBSE

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 [12]. The Aerospace and Defense 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 and to encourage innovation in the company culture.

Innovation is part of AEL' strategy to keep the company position as a reference for its capacity to provide creative and high-quality solutions for its clients. From the improvement of a step in the production of an LRU (Line-replaceable unit) to the exploration of news methodologies inside the engineering process, AEL stimulates its employees to generate new ideas. Today, new ideas are mainly acquired through two methods: the "Right Idea" procedure, which rewards the top three innovative ideas of the semester; and the Inspect and Adapt (I&A) ceremony, which is a knowledge-share session that occurs 4 times a year and incentives engineers to share different knowledge or points of view learned in their respective projects and rewards 3 ideas selected by employees' votes.

Over time, the company noticed an increase in employees' interest in developing new proposals. This encourages AEL to promote a safe environment for employees to create, test, and consolidate solutions not only for its production line but also for the future of Systems Engineering. In AEL's Systems Engineering Research & Development (R&D) Area, a group of Systems Engineers founded and now manages a Community of Practice (COP) to discuss and share ideas around the system engineering concepts and development themes. Following the innovative atmosphere in the company's R&D, some employees formed a handful of research groups. This paper focuses on 2 of those research groups, the Model-Based Systems Engineering (MBSE) and the System Theoretic Process Analysis (STPA) groups. This research groups were formed organically, gathering people with similar interest in learning and sharing information over a topic.

The first research group focusses on the study of the MBSE concepts and the possibility to add this methodology to AEL's systems engineering process. The second research group focused on the study and a hands-on experience using the System Theoretic Process Analysis (STPA), a tool applied generally for safety and cybersecurity analysis. With this groups development and results, the company was able to capture emergent patterns of development and create a framework for innovation, fast-tracking others studying groups process and simplifying their learning curve for the company.

This paper presents the result of this study and proposes the AEL Sistemas Innovation Framework,

where skills and interests meet enablers, such as people, technology, and tools.

2. Research Groups

Intending to promote innovation and capture knowledge in the organization, AEL Sistemas is developing and implementing an Innovation Framework within the company's organizational structure. For the development of the Innovation Framework prototype, two research groups practices are observed, and presented in the following chapter.

2.1 MBSE Research Group

The MBSE Research Group [13] was created organically as a collective interest of AEL employees in Model-Based Systems Engineering (MBSE). MBSE is a collection of processes, methods and tools that supports the development lifecycle of requirements, designs, analysis, verification, and validation of complex systems. MBSE is an approach that supports Systems Engineers during the product development, by utilizing models to represent the systems' behavior and the interactions between their subsystems and the actors that interact with them [1].

The group was composed by 13 employees who worked as systems engineers on the company. Its intention was to extract the advantages of the MBSE methodology and to understand the applicability of the methodology in the company's Systems Engineering process. With this goal in mind, the group created a Minimal Viable Product (MVP) using MBSE for a feature that was being developed with the classic document-based systems engineering method. In this case, it was also possible to compare the artifacts obtained with MBSE and with the Document Based approach. The purpose of the MVP was to generate a solution as close to reality as possible, with low cost and low complexity, facilitating the user understanding to better evaluate the idea and asses if the company should invest on the study of MBSE. After the MVP execution, the results collected by the group were presented for the company's directors, which resulted on the formalization of the group and the approval to continue with its research.

Once formalized, the group studied not only the theoretical concepts of MBSE but also the frameworks, methodologies and languages that are commonly used when applying MBSE. The goal of the study was to understand MBSE and the advantages of each combination of frameworks, methodologies, and languages to apply MBSE on the systems engineering process. The results gathered on this phase were presented on the company's CoP, which lead to the conclusion that the group should follow its study by assessing if AEL should add this methodology in its R&D process.

2.2 STPA Research Group

The STPA study group was created within the context of innovation promoted by AEL's culture, mainly because of the common interest from a group of Systems Engineers that worked with safety analysis. The STPA is a hazard analysis technique based on an extended model of accident causation and systems theory. In addition to component failures, it assumes that accidents can also be caused by unsafe interactions of system components, none of which may have failed [9].

The group started with a brief study of the STPA methodology, then focused on a hands-on experience working with a AEL's Data Link System project. The project is a tactical communication system that interacts with ground/air command & control (C2) and aircraft pilots, focusing on the situation awareness enhancement. Aiming to prevent information leakage, the System Engineers deemed necessary to perform a security analysis and, as it is a complex system of systems, it is interesting to use methods based on a systems approach, such as STPA.

The group started working with two Systems Engineers to perform the security analysis for the Data Link System project. The development was conducted by a systems engineer without previous experience in the Data Link System or security systems under the supervision of an experienced systems engineer, as a STPA facilitator having applied the method before. It is worth highlighting that a systems engineer was chosen as the facilitator because of the experience dealing with complex systems and systems thinking principles. Each system enginner worked with 50% of their time allocation.

As the STPA method tries to portray the system as close to reality, the elaboration of the control structure capturing functional relationships between the subsystems of the Data Link system. For the elaboration of the control structure the participation of software, hardware and systems engineers and people with operational experience (such as pilots) was important to develop and validate each step. This allowed a refinement of this stage and the subsequent one, which the development of control

actions (actions between each subsystem) and causal scenarios (causal factors that can lead to the security hazards) based on the experience of the staff was performed.

The STPA group has involved software engineers, hardware engineers, systems engineers and people with operational experience, such as pilots, being a multidisciplinary group. The analysis took 3 months to be completed, and generated about 400 design recommendations (which create the security requirements) and more than 250 unsecure control actions (security vulnerabilities identified in the system). The result of the analysis was used to have a robust requirements basis and as input to create test cases to validate the system.

The STPA group presented their analysis on the company's CoP and on the 2021 STAMP Workshop. The workshop provided an opportunity for the member of the research group to share the application and experience using the STPA technique outside the company.

3. Innovation Framework Development

For the development of the Innovation Framework, a Soft Systems Methodology (SSM) approach was used. This methodology attempts to foster learning and appreciation of the problem situation rather than set out to solve a pre-defined problem [11]. The adaptable framework was designed in two steps. Firstly, by capturing the common practices that the research groups used to communicate their results, and how more experienced engineers used to mentorship this groups through their development. This became the prototype for the framework hierarchy and interactions. Secondly, by capturing common characteristics that were considered good practices for development fast-tracking throughout the groups' development. This became the prototype for the framework methods and tools.

3.1 Innovation Framework Hierarchies and Interactions

This section presents the Innovation Framework hierarchy and interactions. This was elaborated from observation of how the research groups organized themselves internally, who they communicated their results to and how their structure reorganized with each interaction and feedback.

The research groups performed studies and documented the results with a set of people, then, incrementally, the results were presented and evaluated by other set of people. This paper refers to the first set of people as the development team and the second set of people the validation team. The members of the research groups formed these teams organically, given individual preference, time availability, interest, and previous knowledge in the subject. When the research group agreed they reached a deliverable package, some members of each team presented the results to the rest of the company or even in events outside the company.

With the result of the observation, the Innovation Framework identified three hierarchical levels: the Community Level, the BrainTrust Level, and the Guild Level. The hierarchies were designed to become iterative processes to allow incremental deliveries and, by applying SSM, the structure evolves and adapts according to the development of the other levels and their interactions.

The Figure 1 presents the hierarchical levels, the levels components, and the interactions between the components. The components of each hierarchical level correspond to an element of one of the observed research groups and used here to exemplify how they fit into the framework.

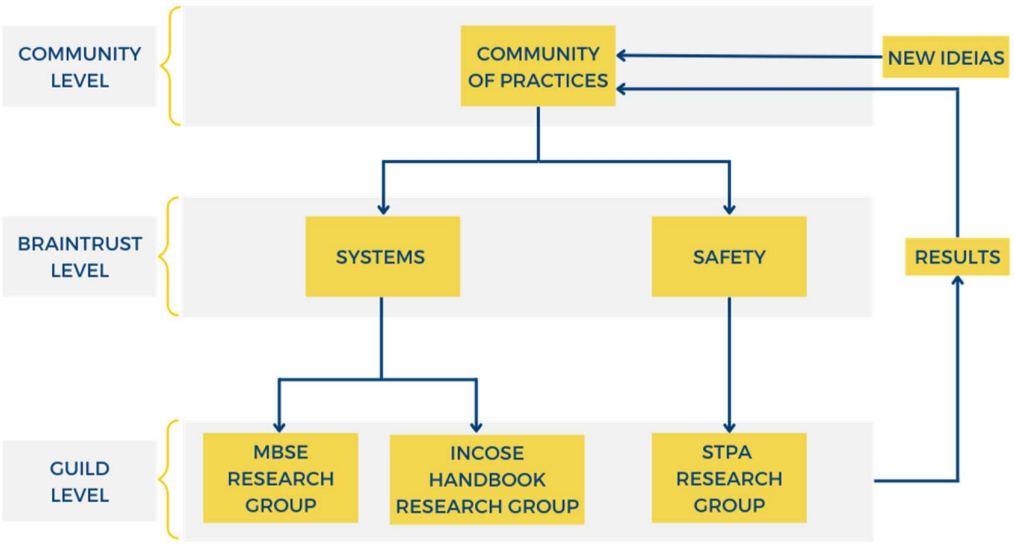

Figure 1: AEL Sistemas Innovation Framework

At the Community Level is the Research and Development Community of Practices (CoP). The CoP focus on the major problems and discussions. It is the space where people and groups can present their studies, research, and innovative ideas. The community promotes practical experiences to all the company, spreading knowledge into other areas and absorbing interested people.

At the Braintrust level are the Systems and Safety groups, composed of engineers with experience in diverse topics and who deeply understand the benefits of innovation and research of new technologies and methods of development. These engineers are responsible to orient and mentor research groups within the company, giving them space to explore hypotheses and possibilities while directing their energy to the company's main problems. This hierarchal level is based in the well-known BrainTrust group created at Pixar. The Co-Founder of Pixar Edwin Earl Catmull describes the BrainTrust group as “a small group of creative leaders who oversees the company’s development” and its premise as “put smart, passionate people in a room together, charge them with identifying and solving problems, and encourage them to be candid” [7].

The third hierarchal level is the Guilds Level. The idea was extracted from the Spotify Agile method [14]. The Guilds can be defined as an organic and wide-reaching community of interest and practice; a group of people who want to share knowledge, tools, and practices. The research groups are located in the Guilds Level. The research groups create hypotheses and research topics that are relevant for company and engineering field. They develop experiments and prototypes for testing and validating such hypotheses. After the Research Groups achieve a conclusion that they judge as valuable, the results are presented at the CoP for the engineering community. These presentations attract new people for the research group and encourage the formation of new research groups in topics that may have potential for innovation and growth.

Ideas that don’t have a research group in the company are also presented at the Community of Practices. These ideas are evaluated by the engineers at the Braintrust level, and if they are deemed as having potential, and there are people interested in studying them, a new research group will be formed at the Guilds Level.

3.2 Innovation Framework Methods and Tools

This section highlights the methods and tools used by the research groups to guide the development and to organize the work methodology. The conjuncture of these methods and tools became the prototype for the framework methods and tools.

The first methodology identified on both groups was the use of the Double Diamond principles on their development process. To create results fast and adjust the work during the development, this methodology, presented in Figure 2, applies the principles of diverging and converging iterations, respectively creating and making choices. The Double Diamond is an iterative and incremental methodology to support designers to use critical thinking and reflexive practices to reach a creative solution [2].

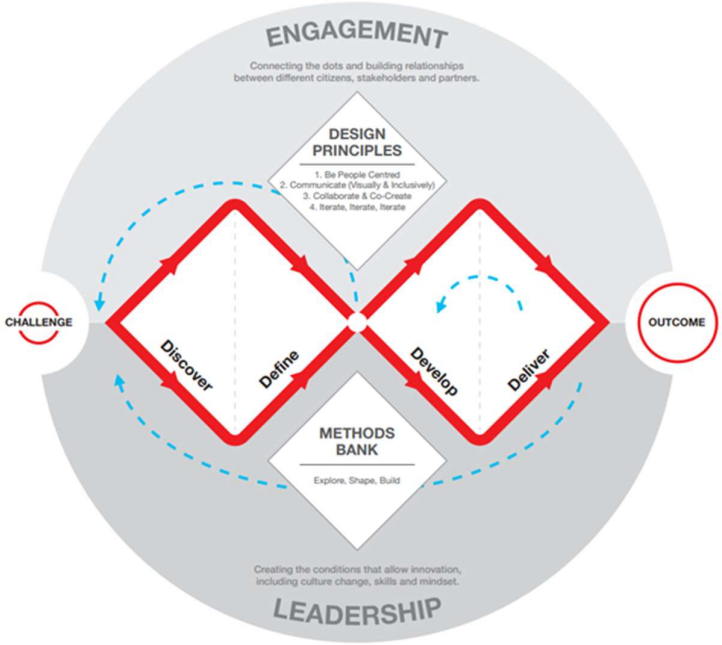

Figure 2: Double Diamond [2]

Both Research Groups adopted pillars to create an open space for all members' participation. The groups deemed as important to have an open space because it stimulates ideas and better evaluation of problems, generating insights and broad perspectives. These pillars were: Communication, Collaboration, Cooperation, Diversity, Confidence and Frankness.

Each research group was composed of two teams. One team was concerned with developing the activities and end-user needs, such as the MVP. This group of people are located in the Guilds Level. The other team assigned with the tasks to verify and validate the increments is composed of engineers at the BrainTrust Level. This creates engagement and interaction into the innovation framework, facilitating coordination and mentoring by BrainTrust and creating new hypothesis for the Research Group. Per example, the MBSE research group is composed by 13 participants. Four of them, who have less experience in system engineering than the others, are part of the core team that works on the modeling and development of the system's project. The other members, with more experience on Systems Engineering, work as consultants, providing feedbacks about the developed system and supporting the team with their knowledge on Systems Engineering.

To organize the work, both Research Groups worked, planned and executed their activities in incremental steps. This pattern is aligned with AEL Sistemas methodologies, as the company uses Scrum methodology in order to manage the development of its products aligned to agile principles. Through Program Increments (PI) and Sprints, the teams deliver incremental value in the form of work, tested software and systems. Inside each PI, there are four incremental iterations and one innovation and planning phase. Aligned with AEL Sistemas PI execution, the Research Groups used this framework to deliver value and gather lessons learned while executing the process. In each PI, the Research Groups had a Planning and a Retrospective meeting to allow the group members to realign the scope and optimize future task regarding the proposed schedule.

The Research Groups also adopted an agile technique to reduce the time to produce an MVP and present their ideas with the least amount of effort and time without compromising the quality. The MVP carried just enough characteristics to satisfy customers and to gather feedback for subsequent development following the incremental deliveries aspects of the previously mentioned agile methodology to organize the work load.

Based on the methods and structure used in the observed research groups, the framework suggests the following methodology for new research groups: Design Thinking approach for development, Agile Methodology to organize the incremental work packages and agile techniques to develop an MVP.

The Design Thinking approach main goal is solving complex problems collectively and collaboratively with a focus on people [3]. By placing people at the center of the product development, it is possible to extract maximum value for all stakeholders, including researchers and their personal

interests. Both groups used the Design Thinking approach to optimize the environment in which such groups can develop themselves and to obtain results faster in order to adjust the work during the development.

The use of an Agile Methodology the suggested way to manage a project by breaking it up into several phases and dividing the working load. The methodology shall involve constant collaboration with stakeholders and continuous improvement at every stage and the interaction between the hierarchies, and supports the incremental deliveries obtained using the Design Thinking approach during the development. Once the work begins, teams' cycle through a process of planning, executing, and evaluating. Continuous collaboration is vital, both with team members and with project stakeholders.

The elaboration of an MVP is a distinguished way to present the idea to the stakeholders as it provides enough information for a buy in without the sensation of selling/buying an incomplete product. Additionally, the dynamicity of the agile techniques allows the one to present their idea and collect feedback faster to realign the scope and intention of the research. The iterative development of functional product increments being shippable to potential customers at the end of a development phase helps the research groups to align the product to the internal customers' needs and to reduce the development time significantly. [4]

4. Results

The Innovation Framework proposed by AEL translates the process for creating and conducting the Research Groups. As already attested by the results obtained by the Research Groups, the framework increases the team engagement, creates a better planning and development process, and improves communication. As the framework introduces more and complex questions earlier on the project development, it creates team awareness within respect to the problem that is been researched.

This environment encourages BrainTrust's and Guilds to use the methods and tools that are provided by the framework, such as Design Thinking and Agile Method, but they can develop their own routines and adapt as much as necessary for the group reality. Instead of just strictly follow the Scrum framework, the company considers more important to focus on the agile engineering culture. In other words, the agile principles matter more than any specific practices. That allows a high level of autonomy inside each group, and all of them are aligned with the company´s culture, as seen by the differences of MBSE and STPA groups.

This framework is generating new outcomes for the company, for example the MBSE Case Study created a series of presentations about MBSE, which will prepare its employees for the future of Systems Engineering, ramp up new employees, and spread a researching mindset into the company.

5. Conclusion

The framework is already being excited through different innovation hypothesis, where all levels of the framework hierarchy levels are working as mentioned and planned. The positive externalities from the innovation groups are spreading into the company by courses, presentations, knowledge capture, people development, and solutions. One of these results is the creation of new research groups inside the company, since the framework started running a DevOps, a Safety and a Incose Handbook Research Groups were created.

It is noteworthy the influence of innovation approaches inside the mentioned groups of MBSE and STPA, for, respectively, Systems Engineering and Safety analysis. In the near future, these approaches could provide more reliability into a very robust Aeronautical process. Enabling the extraction of more information from the systems under development, equipping the engineering teams with more powerful tools to better develop their roles.

The Innovation Framework is a continuous improvement system itself, because, while the research groups explore their case studies, they can also explore new tools and methodologies, which can be captured for the Innovation Framework from the CoP or BrainTrust's and become enablers for next hypothesis testing. Besides that, the research groups show that, by applying the Framework, it is possible to learn and apply the method in a short period of time, for example he STPA MVP took 3 months to be completed.

Furthermore, the research groups show that the focus of the research group can produce outcomes that are strategic for a company, as the presentation of the MBSE MVP resulted on the AEL Sistemas sponsorship approval for the next year, seeking to introduce MBSE on the company's

development process. The goal is extended to choosing a composing a MBSE process compliant with the company's current process, followed by the training of other employees.

The research groups resulted in a great number of other engineers interested in learning the method, showing that it is possible to expand it organically inside the company. Nowadays, the experience dealing with the STPA methodology resulted on the consent of the company to apply it inside the same project, but now focusing on the Human Factors perspective. In order to achieve these results, the framework implemented within AEL Sistemas Innovation context was highly useful and is currently helping the groups, providing tools, best practices and experience for the Research groups thrive through Research activities complexity. Moreover, this framework enables other research topics to be created and explored, by spreading knowledge into AEL Sistemas and creating Awareness to Research utmost necessity into Innovative environments.

The Innovation Framework supports the environment where AEL Sistemas can ramp-up its current knowledge, becoming agile and prepared for the emerging future possibilities. Moreover, this framework approach for innovation can provide Methodologies and Tools for the company to systemically innovate for its clients, creating new products and solutions, while a self-iterating system is capturing knowledge from inside and outside the corporation.

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7. Copyright Statement

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