Feasibility implementation of agile project management in a Rocketry University Project

(Versão corrigida após defesa)

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Dissertação para obtenção do Grau de Mestre em

Engenharia Aeronáutica

(Mestrado integrado)

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junho de 2023

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ANEXO

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Universidade da Beira Interior, Covilhã, 16/06/2023

Jeremy Da Silva

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Acknowledgements

I am forever grateful to the talented and dedicated students who poured their hearts and souls into this project, making it possible. I am truly honoured to have been their project manager and to have had the privilege of working alongside such brilliant minds.

I am also deeply indebted to Professor José Manuel Mota Lourenço da Saúde for his guidance and support which were invaluable and to all the professors who have shared their knowledge and expertise with me throughout my academic journey.

To my family and friends, thank you for your unconditional love, unwavering support, and endless encouragement. I am forever grateful for the sacrifices you have made to help me achieve my goals.

I would also like to express my sincere gratitude to the sponsors of Fénix and all those who contributed directly or indirectly to the project's success. Their support and generosity enabled us to turn our dreams into reality and for that, I am forever grateful.

Finally, I would like to express my heartfelt thanks to the city and people of Covilhã and the University of Beira Interior for welcoming me with open arms and providing me with an unforgettable experience across all these years.

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Resumo

A necessidade de práticas eficazes de gestão de projetos é particularmente importante no contexto de projetos espaciais, onde os riscos são elevados, os prazos são apertados e os orçamentos são limitados.

Atualmente, não existem grandes estudos acerca da aplicação de metodologias de gestão de projetos no contexto do sector espacial a nível universitário e esta dissertação procura colmatar esta lacuna apresentando um caso de estudo de um projeto de foguete liderado por estudantes. A investigação baseia-se nos requisitos do European Rocketry Challenge e a equipa utilizou metodologias ágeis como Scrum e Kanban para gerir o seu trabalho.

Ao apresentar as diferentes fases do projeto, ferramentas e técnicas utilizadas no planeamento, monitorização, requisitos e gestão de riscos, a dissertação fornece um guia prático para projetos de nível universitário, onde os recursos são limitados e as equipas são frequentemente compostas por estudantes com experiência limitada no setor.

Globalmente, este trabalho destaca os desafios e oportunidades da gestão de um projeto espacial a nível universitário e fornece conhecimentos que podem ser aplicados a futuros projetos neste campo. Além disso, visa inspirar e orientar futuras gerações de estudantes a prosseguir a sua paixão pela exploração espacial e gestão de projetos.

Palavras-chave

Gestão de projetos espaciais; fases do projeto; Scrum; European Rocketry Challenge.

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Abstract

The need for effective project management practices is particularly important in the context of space projects, where the stakes are high, timelines are tight and budgets are constrained.

Currently, there are limited studies that examine the application of project management methodologies in the context of the space sector, especially at the university level, and this dissertation seeks to address this gap by presenting a case study of a student-led rocket project. Its research framework is based on the European Rocketry Challenge requirements and the team used agile methodologies such as Scrum and Kanban to manage their work.

By presenting the different phases of the project, tools and techniques used for planning, monitoring, requirement and risk management, the dissertation provides a practical guide for university-level projects, where resources are limited and teams are often composed of students with limited experience in the sector.

Overall, this work highlights the challenges and opportunities of managing a space project at a university level and provides insights that can be applied to future projects in this field. Furthermore, it can inspire and guide future generations of students to pursue their passion for space exploration and project management.

Keywords

Space project management; project phases; Scrum; European Rocketry Challenge.

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List of Acronyms

CPM	Critical Path Method
ECSS	European Cooperation for Space Standardisation
ESA	European Space Agency
EuRoC	European Rocketry Challenge
GPS	Global Positioning System
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
ISO	International Organization for Standardization
MDR	Mission Definition Review
NASA	National Aeronautics and Space Administration
PM	Project Management
PMBOK	Project Management Body of Knowledge
PMI	Project Management Institute
PDR	Preliminary Design Review
PRR	Preliminary Requirements Review
NASA	National Aeronautics and Space Administration
SAC	Astronomy Section of Coimbra
SRAD	Student Researched and Developed
UBI	University of Beira Interior
UC	University of Coimbra

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Chapter 1 – Introduction

1.1 - Motivation

In an increasingly competitive job market, it is essential that engineering university students have new experiences outside their curricular subjects. One of the main opportunities that exist is the participation in extracurricular projects, which is facilitated when they occur within the universities themselves. In addition to adding value to the curriculum, they provide an increase in knowledge in various areas.

Taking advantage of the visible growth of the space sector in Portugal, in October 2020 Professor Anna Guerman, her PhD student Jorge Monteiro and a team of students founded Spacelab, the first laboratory exclusively focused on space engineering at the University of Beira Interior (UBI).

Her students started researching the availability of several space projects. One of them was in the rocketry field, with the possibility of building a rocket that fulfilled the requirements to participate in the European Rocketry Challenge[1], displaying high engineering quality and innovation.

At the same time, at the University of Coimbra (UC), students from the astronomy section of Coimbra (SAC) were also examining the possibility of entering the rocketry world on their own.

While working on a space start-up, two Spacelab and SAC students met each other and realised they were doing the same thing. And, in March 2021, the opportunity came to join forces, making the most out of UC's strong background in electronics and UBI's knowledge and experience in structural and propulsive systems.

In that month, the Fénix[2] project was born, with the goal of building an unguided student researched and developed (SRAD) solid propulsion rocket. The project was also created with the aim of providing students with a space for creativity and self-development, thus facilitating the acquisition of not only the technical skills needed to work in this field but also interpersonal skills such as adaptability, communication, leadership and teamwork.

In this context, most engineering university projects involving students do not follow a strict management approach, either due to lack of time or human resources or simply due to the anxiety of "getting hands into work", making it easier to skip the planning phase. This common situation leads projects to go over the budget and over schedule, demotivating its participants and causing a lot of stress.

That could be avoided with the use of basic agile project management tools. The goal in this dissertation is then to assess the possibility to apply agile management methodologies (more specifically the ones

[1] The European Rocketry Challenge is a student competition for European university teams organized annually by the Portuguese Space Agency that brings together students to design, build and launch their rockets.
[2] Fénix is a project created with the aim of building a rocket to participate in the European Rocketry Challenge, the first of its kind at the universities of Beira Interior and Coimbra.

used in large space projects), namely to the Fénix project and prove that they can make a difference in saving time and money, while also improving the probability of success.

1.2 - Objective

The objective of this research work was to study the possibility of implementing management methodologies related to space projects in a work environment that is composed only by students, thus boosting results in terms of productivity and efficiency.

1.3 - Requirements

This section contains the terms under which the Fénix project is to be managed. These were defined in accordance with the European Rocketry Challenge's rules and are divided in six categories, which are:

- **Duration:** The project has a total duration of nineteen months;
- **Structure:** the project is to be organised in accordance with the European Cooperation for Space Standardisation (ECSS)[3];
- **Costs:** The project has a total cost of 15.750 €;
- **Human Resources:** Only students currently enrolled in a bachelor's or master's degree can participate in the project;
- **Venue:** The rocket is to be totally assembled in Covilhã. The rocket's payload is to be manufactured and tested in Coimbra and then sent to Covilhã to integrate the vehicle's structure. All the necessary tests before the launch are to occur in Covilhã. Then, the rocket will be transported to Ponte de Sor, where the European Rocketry Challenge takes place;
- **Documentation:** The project is to comply as possible as with ECSS standards, such as Project Planning Implementation and System Engineering General Requirements.

1.4 – Dissertation methodology

This dissertation covers the current state of project management in space projects by analysing bibliography adequate to the work in study. This includes space guidelines (like the ECSS Standards) and project management books (like the PMBOK® Guide[4]).

[3] The standards of the European Cooperation for Space Standardisation (ECSS) were established in 1993 by several national space agencies to "develop a coherent, single set of user-friendly standards for use in all European space activities" (European Cooperation for Space Standardization, 2021) improving project cost efficiency and product quality and safety in Europe's space sector.

[4] The Project Management Body of Knowledge (PMBOK® Guide) is a set of standard terminology and guidelines for project management. This body of knowledge has been evolving over time, with its last edition released in 2021.

Then, this knowledge is to be applied to Fénix to lead it to its success, organising the project in accordance with the European Cooperation for Space Standardisation and implementing Agile project management methodologies on the team of students working in the project.

Finally, the validation process is conducted under an enquiry to the students who were part of Fénix. The results of this enquiry will show how each member's experience was improved or not by the implementation of these methodologies, demonstrating the feasibility of the procedures defined by the project manager, as well as validating the management tools (also defined by the project manager) for planning, communication and control of the project.

1.5 – Work limits

The focus of the research is specifically on the management aspects of a rocket launch and does not extend to the broader realm of space technology and operations.

Likewise, the use of the results of the present research work cannot be anticipated to be applied/of use in future competitions, thus acting an additional validation element.

1.6 – Structure of dissertation

This dissertation is divided into five chapters. Each one is briefly described as follows.

Table 1- Structure of work

Chapter	Description
Chapter 1 - Introduction	It starts the dissertation describing its motivations, objective, requirements and work methodology. It also refers its limits and how the document is structured.
Chapter 2 –Research framework	It addresses the space projects where University of Beira Interior has been involved.
Chapter 3 – State of the art of space project management methodologies	It provides an overview of the existent methodologies worldwide enabling the management of space projects.
Chapter 4 – Project management approach	It presents and discusses the envisaged solution that the research proposes with respect to the management of the space projects according to the methodology and work limits defined. It also addresses the way the solution has been validated.

Chapter 5 – Conclusions, recommendations and future work	It ends the dissertation detailing the conclusions taken from this study and suggests work to be implemented in the future.

Chapter 2 - Research framework

2.1 - Spacelab

Spacelab is a laboratory located in the Department of Aerospace Sciences of the University of Beira Interior.

It was founded in 2020 and is currently focused on the research and development across five thematic lines: astrodynamics, space-earth applications, cybersecurity in space, propulsion (where the Fénix project is included) and space systems.

Spacelab was born from the joint vision of key members like the Center for Mechanical and Aerospace Science and Technologies (C-MAST) and Spaceway to boost the development of the Portuguese Space Sector at the University of Beira Interior and intends to train university students for the development of cutting-edge research in space systems engineering, thus contributing to the development of their technological skills and promoting an innovative culture among those who will be the future professionals of the growing space sector in Portugal.

2.1.1 – Projects

Currently, Spacelab has on-going projects in each of its thematic lines, going from launchers and spacecraft to ground segments.

One of those projects is the ANTAEUS satellite that was chosen to participate in the Fly Your Satellite [5]-Design Booster programme, under the European Space Agency (ESA). It is a 2U Cubesat that aims to monitor the soft gamma-ray domain of the electromagnetic spectrum, where it will make not only spectroscopy measurements but also photon linear polarization measurements of the strongest gamma-ray emitters in the universe, such as the Crab-Nebula.

Another project was presented, in May 2022, at the 4th Symposium on Space Educational Activities (SSEA) in Barcelona, through a scientific article entitled "Development of a Low-Cost Ground Segment Capable of Receiving Data from Nanosatellites: A Partnership between Brazil and Portugal" (Santos, J. et al., 2022, pp. 683-688), that received the “Best Oral Presentation” award in a scientific congress dedicated to the space area.

The project aimed at receiving data from Cubesat and PocketQube type nanosatellites, developing two ground stations capable of working together to receive telemetry data and decode information. The work opened doors for other students at the university, not only in the field of space telecommunications, but also in signal processing and graphical interface development.

[5] Fly Your Satellite (FYS) is an educational programme from the European Space Agency for university student teams from an eligible state that are developing a one, two or three-unit CubeSat, with mainly educational purposes.

The authors also presented another scientific paper at the congress entitled "How to Manage a Rocketry Student Project while Mitigating COVID-19" (Santos, J. et al., 2022, pp. 617-622), which addresses the Fénix project.

2.2 - European Rocketry Challenge

Experimental rocketry[6] has been around for more than sixty years (Stine, 1997). In all that time, it has proven to be challenging as well as educational. It is a challenging field because it requires a combination of technical skills, such as mechanical and electrical engineering, as well as a deep understanding of aerodynamics and propulsion systems. The educational aspect of experimental rocketry comes from hands-on learning experiences, as well as the opportunity to test and refine knowledge in real-world scenarios.

Figure 1 displays the anatomy of a common model rocket. All models consist of the same basic components:

- The nose cone (1) that allows the air to flow more smoothly over the rocket's body;
- The recovery system (2-6) that slows the rocket descent and returns it safely to the ground;
- A body tube (7) as the airframe of the model rocket;
- The engine (8 and 9) which powers the rocket into the air;
- A set of fins (10) to provide aerodynamic stability;
- The launch lugs (11) that allow the model rocket to slide along the launch rail or rod.

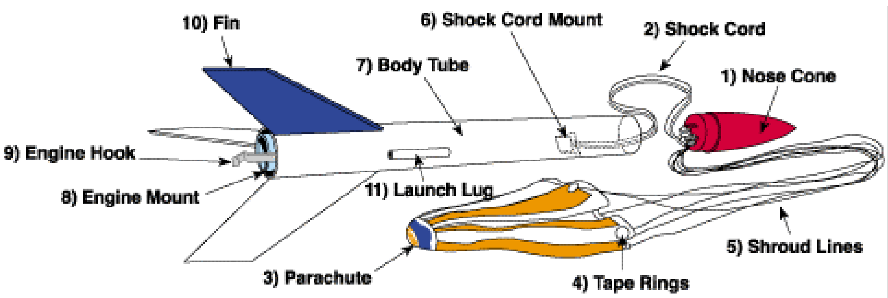

Figure 1 - Anatomy of a model rocket.
Source: (Pepperdine, 2020)

The Portuguese Space Agency took the initiative to organize the European Rocketry Challenge (EuRoC), a competition in the field of aerospace engineering and in the component of experimental launchers that takes place during the annual aeronautical summit at the Portuguese town of Ponte de Sor (in the centre of Portugal).

[6] Experimental rocketry is characterized as the design, construction, and testing of amateur or privately developed rockets.

In every edition EuRoC contributes to the development of technological skills among university students and to the promotion of a scientific and innovative culture, expanding the base of future professionals and reinforcing the means that ensure the sustainability of the aerospace sector in Portugal.

The Fénix team was selected to participate in the European Rocketry Challenge. Its mission objectives for the event are shown in the table below.

Table 2- Mission objectives.
(Fénix Rocket Team, 2022, p.1)

ID	Description
MO.1	Reach an apogee altitude of 3000 meters.
MO.2	Successfully design and build a SRAD solid motor.
MO.3	Successfully design, assemble and operate in-house electronics.
MO.4	Successfully recover the rocket.
MO.5	Successfully recover a functional payload, along with the rocket.

Chapter 3 - State of the art of space project management methodologies

3.1 –Project management overview

Before getting into project management, we must first understand what is, in fact, a project.

A project is a temporary effort undertaken to create a unique product, service or result. Projects are undertaken to fulfil objectives by producing deliverables, that can be tangible or intangible (Project Management Institute, 2017, p. 4).

It is intended to move an organisation from one state to another, to achieve a specific goal. Before the project begins, the organisation is commonly referred to as being in the current state, while the desired outcome of the change driven by the project is called the future state. Successful completion of a project results in the organisation moving to the future state and achieving the specific achievement of the specific goal, as presented in the figure below (Project Management Institute, 2017, p. 6).

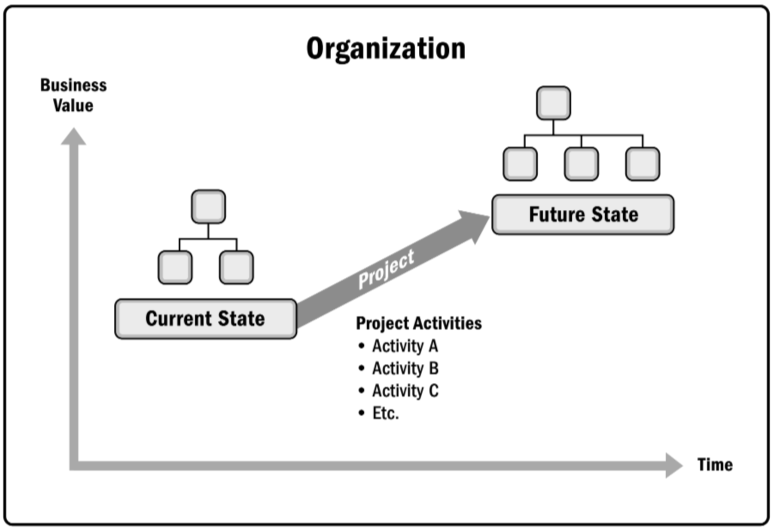

Figure 2 - Organizational state transition via a project.
Source: (Project Management Institute, 2017, p. 6)

Project management is the process of planning, organizing, and overseeing the completion of specific goals and objectives for a project. It includes the coordination and collaboration of resources, including people, time, and budget, to achieve the project's objectives.

It enables organizations to execute projects effectively and efficiently, helping individuals, groups and public and private organizations to:

- Meet business objectives;
- Respond to risks in a timely manner;
- Manage constraints (e.g., scope, quality, schedule, costs, resources).

The project manager plays a critical role in the leadership of a project team to achieve the project's objectives, fulfilling numerous roles within their sphere of influence, as shown in Figure 3. These roles reflect the project manager capabilities and are representative of the value and contributions of the project management profession (Project Management Institute, 2017, p. 52).

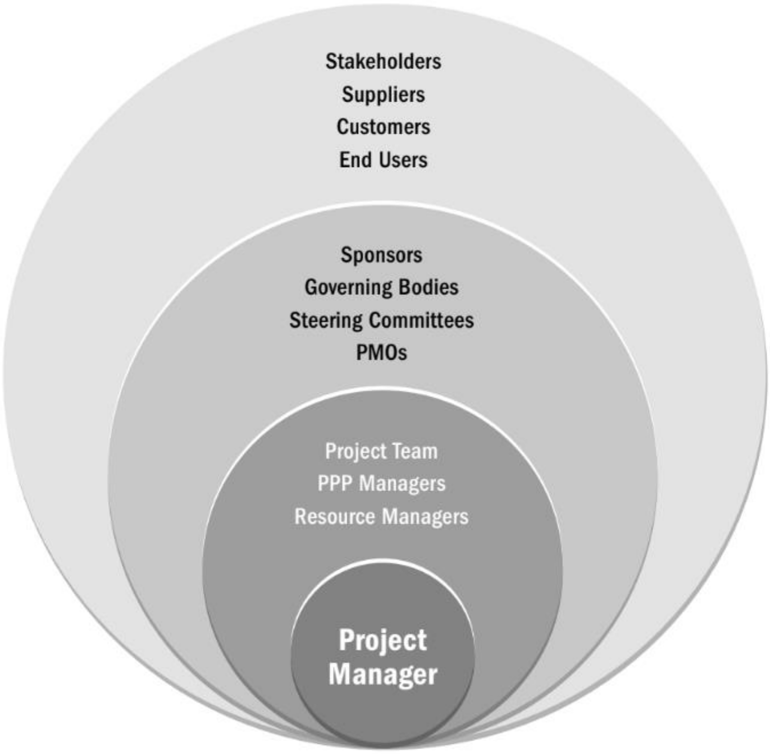

Figure 3 - Example of a project manager's sphere of influence.
Source: (Project Management Institute, 2017, p. 53)

The project manager performs communication between the project sponsor[7], team members and other stakeholders[8]. This includes providing direction and presenting the vision of success for the project, using soft skills (e.g., interpersonal skills and the ability to manage people) to balance the conflicting and competing goals of the project stakeholders to achieve consensus.

The project manager is becoming increasingly important - it is estimated that by 2027, businesses will need 87.7 million professionals in project management roles.

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[7] The project sponsor is a person or a group of people at the senior management level, who is responsible for the success of a project and provide necessary guidance and resources to the project team and manager (Asana, 2022).
[8] A project stakeholder is anyone who is affected by the execution or outcome of a project. It can be single individuals or entire organizations (Asana, 2022).

3.2 - Project management vs Systems Engineering

Due to the nature of their job, systems engineers have a different focus than project managers. However, as presented below, these are complementary functions, with great benefit from leveraging each other's strengths in a team environment.

Figure 4 provides a detailed visual example of how the two disciplines complement each other and their roles and responsibilities on different aspects of a NASA project.

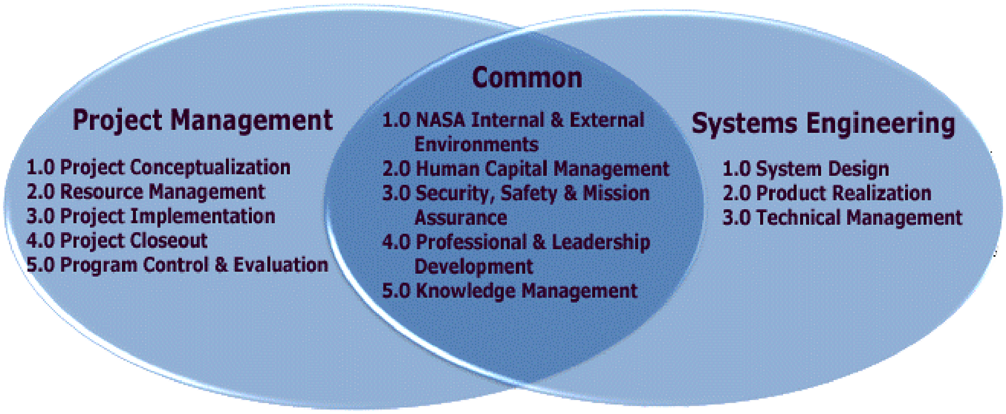

Figure 4 - NASA's Project Management/Systems Engineering Competency Model. Source: (NASA, 2010)

While the project manager is responsible for project outcomes as well as the time, cost and resources required to meet the requirements of both the product development and entire project, the systems engineer is primarily focused on ensuring that the identified product requirements are documented and written in such a manner that they can be verified ("built the product right") and validated ("built the right product").

Verification ensures the product requirements are met as documented, whereas validation is the equally important aspect of meeting the end user's original intent.

Working together, the project manager and the systems engineer ensure the customer is satisfied with the project product by focusing on the business case, the funding and the technical product aspects of the project, ensuring that the business case and product architecture solutions are adequate, achievable and verifiable (Project Management Institute, 2013).

3.3 – Project management methodologies

Project management methodologies are different ways to approach and implement the strategy, planning, organization and control of a project. Each one has a unique process and workflow and selecting the one is an essential part of getting a project done is such a manner it produces the desired output effectively and efficiently.

Most project management methodologies are concentrated onto two great families: the family of the traditional/sequential methodologies and the Agile family.

There are other categories of project management methodologies in addition to Agile and traditional. For example, hybrid methodologies, which combine elements of both agile and traditional approaches, have become increasingly popular in recent years (The Project Group, 2020).

Additionally, there are industry-specific methodologies, such as construction project management and IT project management, that have been tailored to the unique needs and constraints of those industries.

However, in this work, only two of this type of methodologies (traditional and Agile) will be focused on, as they are the most widely used and accepted by organizations (Sennett, 2022).

3.3.1 – Traditional/sequential methodologies

Traditional project management methodologies refer to the more structured and rigid approaches to project management that are characterized by sequential and well-defined phases. There are several different methodologies that fall under this type of methodologies, with the most well-established traditional project management models being Waterfall and the Critical Path Method (CPM) – which are defined below (Reaiche & Papavasiliou, 2022).

Waterfall

The Waterfall model is a sequential approach that involves distinct stages of planning, design, development, testing, and implementation.

The power of this methodology is that every step is planned and laid out in the proper sequence, as shown in Figure 5.

While this may be the simplest method to implement initially, any changes in stakeholders' needs or priorities will disrupt the series of tasks, making it very difficult to manage (Wrike, 2006).

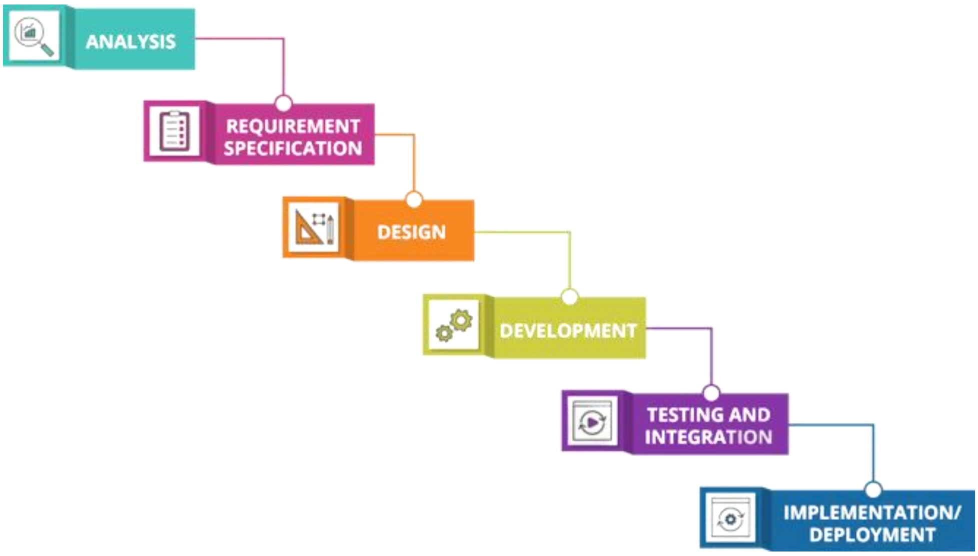

Figure 5 - Waterfall Model.
Source: (Jones, 2019)

For example, a software development project where the team has a clear idea of the requirements upfront would likely use a Waterfall approach, following a linear process that progresses through clearly defined phases.

Critical path method (CPM)

The critical path method was developed in the 1950s. A critical path is determined by identifying the longest path of dependent activities and measuring the time required to complete them from start to finish.

Identifying and focusing on this critical path allows project managers to prioritize and allocate resources to get the most important work done and reschedule any lower priority tasks that may be clogging up the team's attention. This way, if needed, changes can be made to the project schedule to optimize the team's work process without delaying the results (Wrike, 2006).

This method could be applied, for example, on a construction project, where there are many interdependent tasks that need to be completed in a specific order.

3.3.2 – Agile methodologies

The Agile project management methodologies were developed as a response to the traditional structure, being a much more fluid form of project management (Watts, 2022).

Rather than a fixed timeline, the schedule adapts itself as the project progresses. The team works on phases of the project concurrently[9], often with short-term deadlines, which welcomes incorporating

[9] Working on different project phases concurrently refers to the process of simultaneously executing multiple phases of a project, rather than completing one phase before moving on to the next.

changes of direction even later in the process, as well as accounting for stakeholders' feedback throughout the process.

Agile methodologies are growing in popularity, thanks to a highly competitive business environment and increased innovation. In general, Agile methodologies prioritize shorter, iterative cycles and flexibility (Wrike, 2006). Figure 6 shows the cycle of an Agile based project.

For the purposes of this work, we will focus specifically on two of the most widely used Agile methodologies: Scrum and Kanban. Both methodologies have been widely adopted in the software development industry and have proven to be effective in managing projects with rapidly changing requirements and tight deadlines.

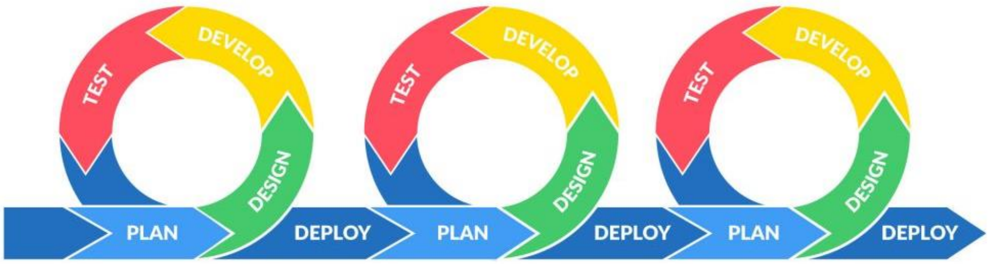

Figure 6 - Agile Cycle.
Source: (EOIIN, 2020)

Scrum

Scrum is the most popular Agile framework. In Scrum, a small team is led by a Scrum master whose main job is to clear away all obstacles to working efficiently. The team works in short cycles of two weeks called "sprints", although the team members meet daily to discuss their work and any roadblocks that need clearing. This methodology allows for rapid development and testing, especially within small teams (Wrike, 2006).

Scrum is suitable, for instance, for software development projects where requirements are not fully defined upfront and the team needs to be able to respond to changing requirements throughout the project.

Kanban

Kanban is a framework for implementing Agile methodologies based on a team capacity. It originated in Toyota's factories during the 1940s, when the departments used a visual system of cards to signal that their team was ready for more raw materials and had more capacity to produce.

Today, this visual approach to managing a project is well-suited to work that requires steady output, like marketing campaigns. Teams create visual representations of their tasks, often using sticky notes and whiteboards (or online Kanban boards, like the one shown in Figure 7), moving the notes or tasks through predetermined stages to see progress as it happens and identify where roadblocks could occur (Wrike, 2006).

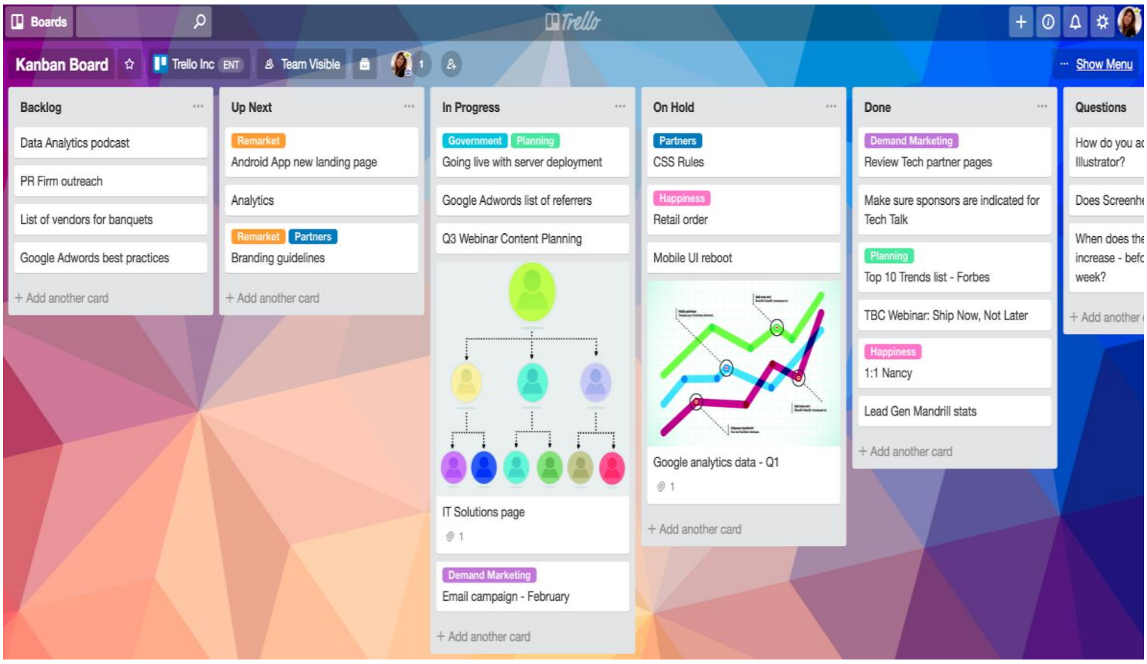

Figure 7 - Example of a Kanban digital board.
Source: (Atlassian, 2022)

3.3.3 – Traditional methodologies vs Agile methodologies

The table below summarizes the differences between traditional and Agile methodologies. These differences must be considered when choosing the methodology that will guide a project to its success.

Table 3- Main differences between the traditional and Agile methodologies
Source: (Silva, 2023)

Characteristic	Traditional	Agile
Approach	Goals and outcome established from the beginning	Team initiative and short-term deadlines
Project plan	Linear	Complex and iterative
Requirements	Clear initial requirements and low change rate	Adaptable as the project progresses
Flexibility	Low	High
Stakeholder interaction	Less interaction with stakeholders	Frequent stakeholder interaction
Results	Delivered at the end of the project	Delivered continuously

In short, traditional methodologies are best suited when a project must meet strict regulations as it requires deliverables for each phase before proceeding to the next one.

Alternatively, Agile methodologies are better for teams that plan on moving fast and experiment with direction. These are now used in a variety of industries, such as construction, software development, telecommunications and aerospace.

3.4 - Project management in the aerospace sector

The space age ushered in a series of projects of such scope and magnitude with challenges that no human had ever faced. An example of those projects was the International Space Station - a multi-nation construction project that is the largest single structure humans ever put into space.

A proposal to initiate a space project can be raised by a government (or in co-operation between several governments), national or international space agencies, scientific communities or operators of commercial space systems (ECSS, 2008, p. 12). Figure 8 shows the major stakeholders in the decision-making process for a space exploration programme, giving an overview of these groups. Each of these stakeholders can be further decomposed into stakeholder sub-groups.

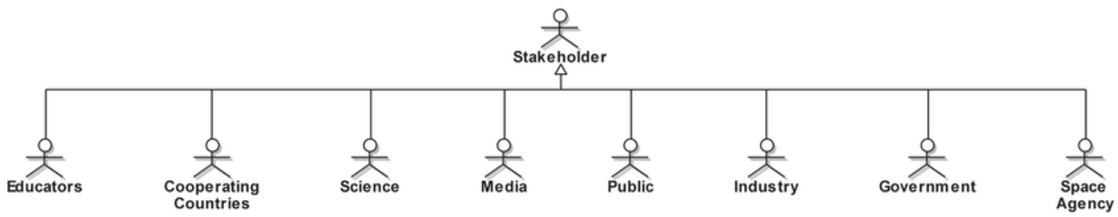

Figure 8 - Overview of major stakeholders on space programs.
Source: (Hein, 2011, p. 4)

Space projects are commonly structured in several stages or phases, reflecting the different types of activities carried on within a project. The overall process is called the “life cycle" of a space system.

This life cycle is defined by ISO/IEC/IEEE 15288:2015 - a standard that provides a framework for managing the entire life cycle of a system from conception to retirement. This standard is applicable to all types of systems, including those in the space sector. In the space sector, this standard is particularly useful for managing the development and deployment of complex space systems, such as satellites and spacecraft, which have a long life cycle and require a high level of coordination and management (ISO/IEC/IEEE, 2015).

Figure 9 illustrates the phase models used in different institutions to structure the life cycle. The numbering and naming of those phases is slightly different among these institutions. However, they denote the same types of activities that are needed to conceive, design, build and operate a space system.

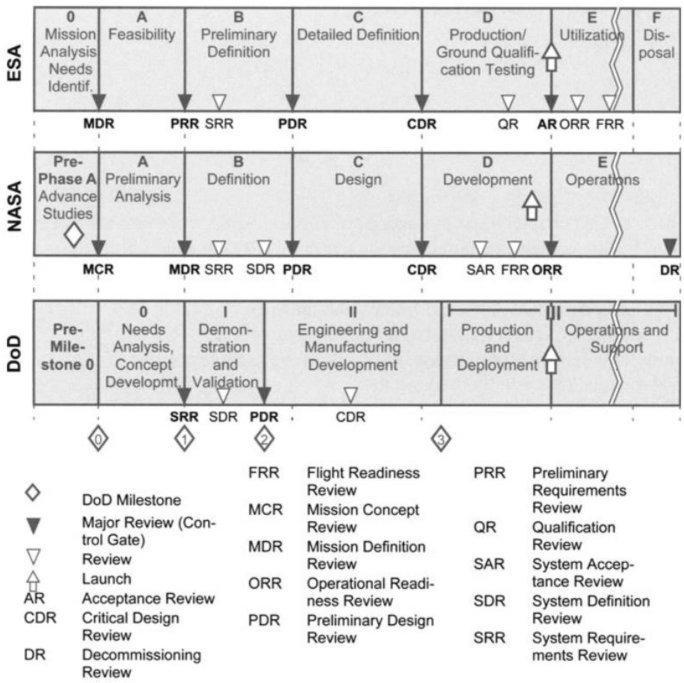

Figure 9 - Life cycle of a space system.
Source: (Messerschmid, 1999, p. 330)

Both NASA and ESA use these phases as a framework to guide the development process, ensure efficient use of resources and mitigate risk. However, the specific activities and milestones within each phase may vary depending on the scope and complexity of the project.

As seen in the figure above, in Europe the labels 0 and A-F denominate the life cycle phases. An overview of the typical major tasks associated review milestones and review objectives for each of the phases in a European space project life cycle is presented below.

Phase 0 - Mission Analysis

The project begins with the identification of the requirements by the team responsible for initiating the project and the end user (European Cooperation for Space Standardization, 2009, p. 21).

This phase allows:

- The identification and characterisation of the intended mission;
- Its expression in terms of needs, expected performance and safety goals, assessment of operating constraints regarding the physical and operational environment;
- Identification of possible system concepts, with emphasis on the degree of innovation and any critical aspect.

These studies are consolidated in a document equivalent to the project's opening statement - the Mission Statement - and this phase concludes with the Mission Definition Review (MDR), which verifies the adequacy of the preliminary specifications and the evaluation of aspects related to the project's organization.

Phase A – Mission Feasibility

In this phase the feasibility analysis of the possible concepts continues through the further identification of constraints that concern the implementation of the project, such as: costs, schedules, organisation, operation, maintenance, production and disposal (European Cooperation for Space Standardization, 2009, p. 22).

The feasibility phase should result in the proposition of solutions that meet the needs perceived in phase 0 by quantifying and characterising their critical elements (for technical and economic suitability).

The main outcomes of this phase are:

- The proposition of a first concept for system configurations and operations;
- Establishment of technical specifications at system level;
- Definition of preliminary management, development and quality plans;
- Definition of the Function Tree.

The Phase A is concluded with the Preliminary Requirements Review (PRR), which aims at the acceptance of the plans and confirms the technical feasibility of the system concepts. It leads to a system concept selection and the establishment of the controlled baseline of the Functional Specification associated to it (European Cooperation for Space Standardization, 2009, p. 23).

Phase B – Preliminary Definition

On Phase B a concept proposal for the system configurations and operations is presented.

The associated preliminary design is then developed, emphasizing the chosen technical solutions. The fabrication of the Engineering Models of the selected equipment and subsystems begins while the product tree, analytical design structure and specification tree are established.

Also, this phase includes:

- The assessment of techniques, technologies and means to implement (logistics and maintenance);
- The assessment of manufacturing, production and operating costs;
- The analysis of the logistics necessary for fulfilling the mission.

This phase ends with the Preliminary Design Review (PDR), which has the main objective of evaluating the preliminary design of the system concept (European Cooperation for Space Standardization, 2009, p. 24).

Phase C – Detailed Definition

This phase allows a detailed study of the solution retained during the previous phase, leading to a detailed definition of the system and its components. It allows:

- The confirmation of the set-up, test and qualification conditions and the initialising of the methods and means of production and verification;
- The start-up of technology assessments and qualification, as well as the starting of procurement[10];

At the end of this phase, the Critical Design Review (CDR) is conducted. This review assesses the qualification and validation status of the critical processes and their readiness for deployment for phase D, confirm compatibility with external interfaces (European Cooperation for Space Standardization, 2009, p. 25).

Phase D - Production and Qualification

The phase D is the end of the system development. In this phase, the engineering model of the selected equipment and subsystems is subjected to tests that demonstrate the feasibility of the design solutions adopted.

It enables the confirmation and qualification of methods, procedures and the production means, allowing manufacture, assembly, integration and verification tasks to be performed.

This phase allows the preparation of the Operations phase and the series production (if there is any). It ends with the Acceptance Review (AR), which confirms that the product is ready for operational use (European Cooperation for Space Standardization, 2009, p. 26).

Phase E - Operations

This phase comprises the launch campaign (which involves preparation of the launcher stages, their inspection, encapsulation of the payloads, transfer between the various buildings and the final countdown), launch and in-flight acceptance of space elements (if needed).

It is the phase in which the spacecraft or other space-related systems are actively being operated and maintained in their intended environment.

This phase includes the ongoing monitoring of the systems and their performance, as well as any necessary adjustments or repairs to ensure continued functionality. It also includes the collection and analysis of data generated by the systems, which is used to improve their performance and achieve the

[10] Procurement refers to the process of acquiring goods, services, or works from an external source. This process typically involves identifying a need, specifying requirements, soliciting bids or proposals, evaluating and selecting a supplier, negotiating terms and conditions, and finalizing a contract (Beroe Inc., 2023).

goals of the project. The duration of this phase can vary greatly depending on the specific project and its objectives, but it typically lasts for the entirety of the systems' operational lifetime.

This phase is often divided into two sub-phases:

- **E1: overall test and commissioning[11] phase of the system -** It comprises launch activities and in-flight qualification and acceptance testing of the system (which allows assessment and measurement of performance);
- **E2: the utilisation phase itself -** This shall consider the technical events of operation and feedback obtained regarding the state of the system in operation.

Phase F - Disposal

Phase F comprises all activities to be performed to safely dispose all products launched into space as well as the ground segment (European Cooperation for Space Standardization, 2009, p. 20).

3.5 - ECSS Standards

Space is a risky business where technology is stretched to its absolute limit and the expense required investment is high. In addition, the space environment often does not offer the option of correcting problems that were not identified before launch. All this imposes a very strict approach to the engineering of the space segment - the mission element operating in space - and the ground segment (Cendral, 2005, p. 73).

For these reasons, industry and space agencies have engaged in engineering standardization to cut costs associated with development and operations while also lowering the risk of failure. Additionally, standardization frequently promotes interoperability, which implies that if the standards are correctly implemented, many space agencies' testing and operations facilities can be utilized, further reducing investment and maintenance costs.

Engineering standards, however, have only developed in the last forty years (Jean-Leon Cendral, 2005, p. 73). Before it, the many space agencies either used internal standards or they developed their own internal or proprietary systems using no standards.

The Consultative Committee for Space Data Systems (CCSDS), an international standardization body created in 1982 by ESA, NASA and CNES (France's Centre National d'Etudes Spatiales), addresses communications and data-handling techniques for data system interoperability and standardization of space-related information technologies.

[11] The commissioning phase of space systems takes place after launch and orbit insertion, to verify the systems in their intended space environment, determine all systems have survived the harsh launch conditions, deploy all components and fine-tune instruments as the spacecraft gets ready for the operational portion of the mission (Turner, 2022).

In order to create a unified, coherent collection of standards for use in all European space design and development operations, the European Cooperation for Space Standardization (ECSS) was founded in 1993.

It is currently supported by the following entites: Agenzia Spaziale Italiana (ASI), UK Space Agency, Centre National d'Etudes Spatiales (CNES), Deutsches Zentrum für Luft- und Raumfahrt (DLR), European Space Agency (ESA), Netherlands Space Office (NSO) and the Norwegian Space Centre. The European industry is represented by Eurospace[12] (ECSS, 2023).

The primary areas of standardization now covered by the ECSS are depicted in the figure 10. These standards apply to any party participating in the definition, development, manufacturing, verification and operation of any assembly, equipment, subsystem, system or service used for any space mission.

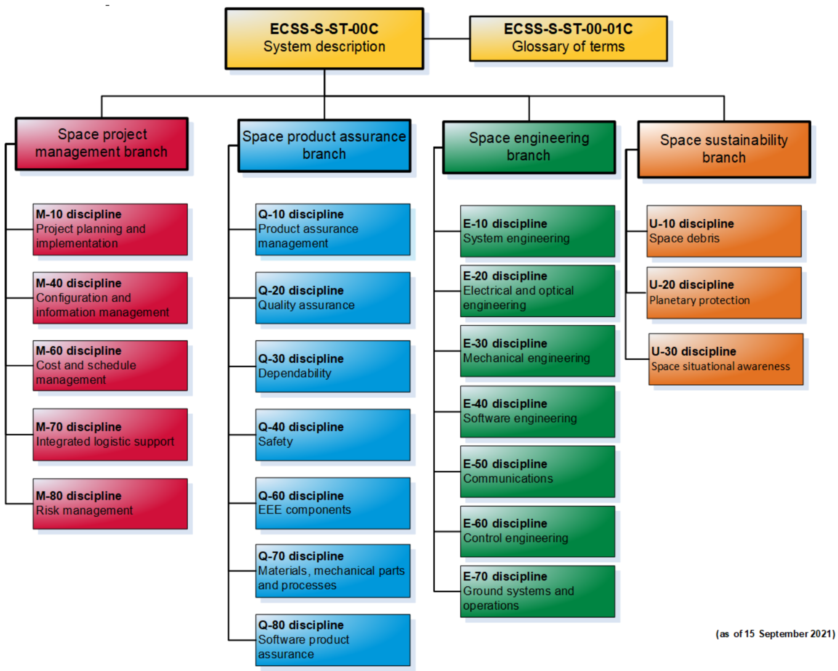

Figure 10 - ECSS Disciplines as of September 2021.
Source: (European Cooperation for Space Standardization, 2021)

Over 300 space missions have used the CCSDS and ECSS established standards as of now and all ESA missions currently in production likewise rely on them.

3.6 - Synthesis

This chapter provided an overview of the existent methodologies worldwide enabling the management of space projects. The implementation procedure established for the Fénix project, which will be discussed in the following pages, is supported by this chapter.

[12] Eurospace is the trade association of the European Space Industry. It is a non-profit European organisation created in 1961 and today represents 90% of the total turnover of the European Space Industry (Eurospace, 2018).

Chapter 4 – Fénix project – case study

4.1 – Concept of operations

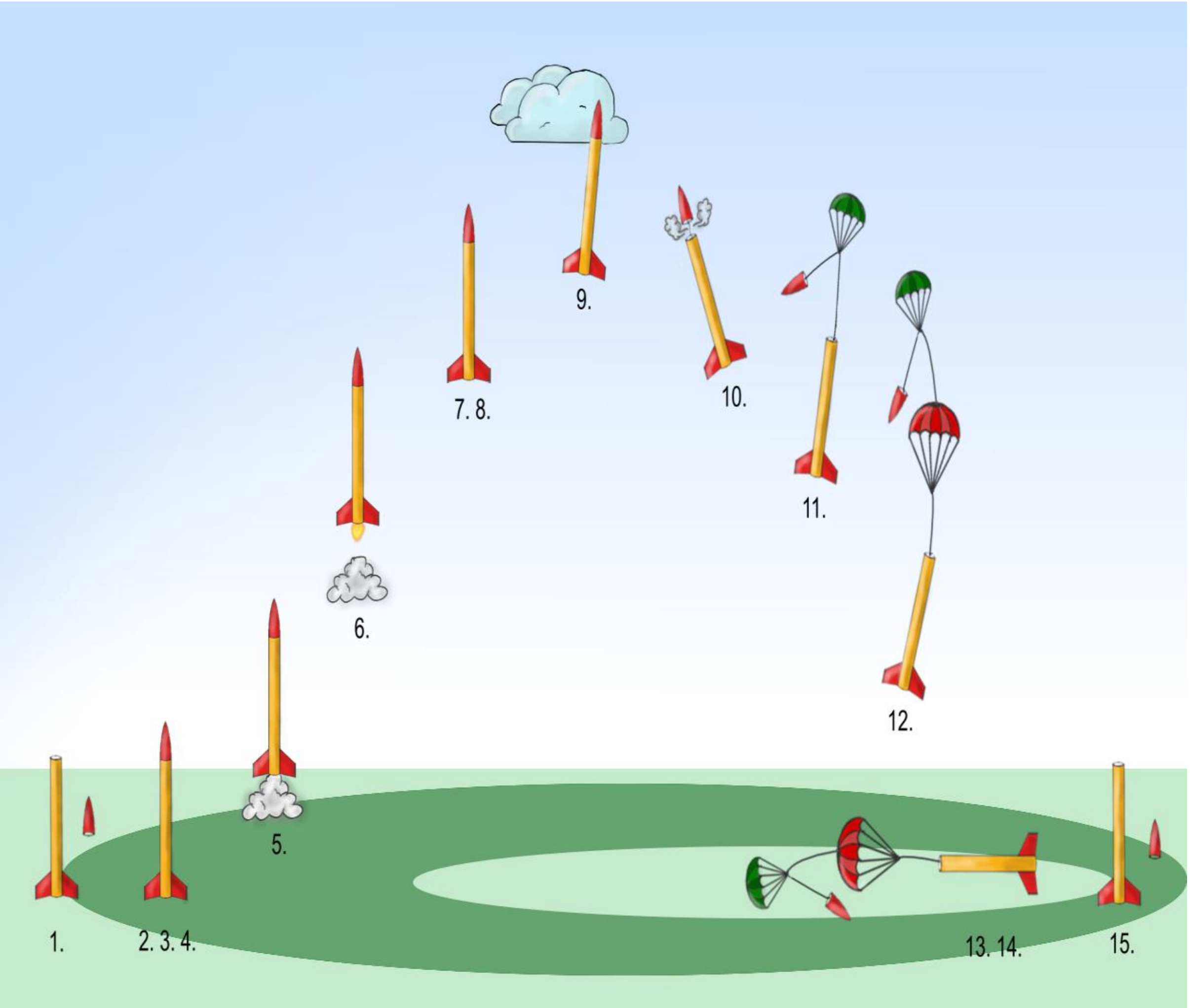

Figure 11 - Fénix operations (with phases from 1 to 15).
Source: (Fénix Rocket Team, 2022, p. 38)

Figure 11 shows a representation of the operations that will be performed by Fénix. The rocket system shall be launched from the launch rail (phase 5) and raise its altitude to apogee (phase 9), where a first phase small parachute shall be ejected for the rocket to begin its controlled descent (phase 10). At a lower altitude, a second phase larger parachute shall be ejected for final approximation to ground (phase 12) and, finally, touchdown (phases 13 and 14). Throughout its operations, the rocket shall send telemetry and tracking data to the ground control station.

These phases can be seen in more detail on the table 4 below:

Table 4- Operations description
Source: (Fénix Rocket Team, 2022, p. 38)

Phase	Description
1, 2, 3, 4	Arming of the rocket and nosecone insertion.
5	Rocket ignition.
6	Controlled ascent.
7, 8	Transition from vertical ascent to the end of propellant burning.
9, 10	Apogee reached and nose cone ejected through a signal sent in negative velocity.
11	Drogue parachute deployed at apogee.
12	Main parachute deployed at 300 meters altitude.
13, 14	Landing of the rocket.
15	Disassembly of the nose cone and transportation of the rocket.

4.1.1 – System architecture

The rocket is divided into three sections: the lower body (which contains the engine), the upper body (where the recovery systems are stored) and the nose cone (which holds the payload and avionics systems).

This division is expressed in the figure below.

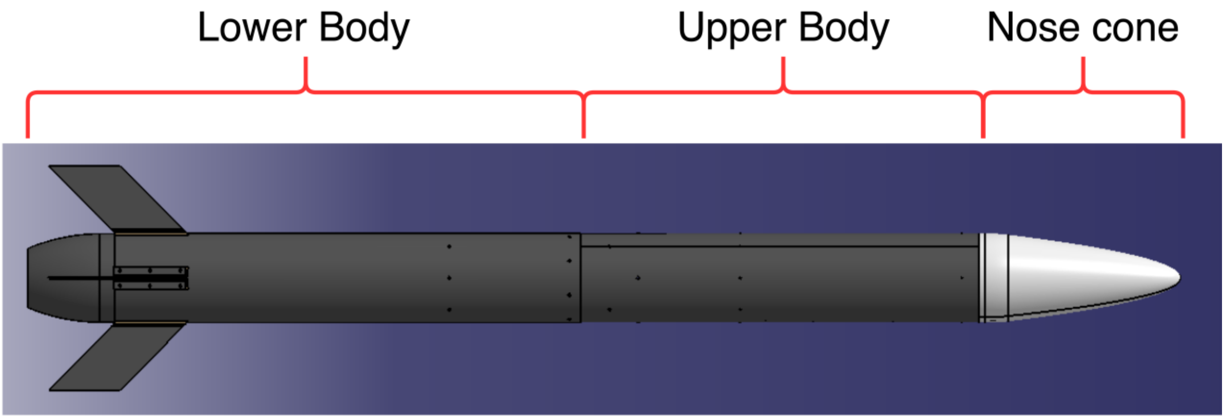

Figure 12 - Functional segments of the rocket.
Source: (Fénix Rocket Team, 2022, p. 7)

Table 5 shows the length and predicted[13] mass for each of the rocket segments.

[13] This estimation was done considering the weight of each component (as well as all the structural frame of the rocket) and factors such as material properties, design specifications and manufacturing processes.

Table 5- Dimensions and masses of the different segments of the rocket.
Source: (Fénix Rocket Team, 2022, p.8)

Segment	Length [mm]	Predicted mass [kg]
Lower body	955	14.4
Upper body	695	5.2
Nose cone	350	5.5
Total	**2000**	**25.1**

4.2 – Team organisation

The development of rocket systems and technologies requires careful planning and execution as they are complex projects, which in turn require effective project management practices.

The Fénix project required the coordinated effort of a large team of students from multiple disciplines including engineering, management and operations. These were divided into several working groups, as illustrated in the organisational breakdown structure below.

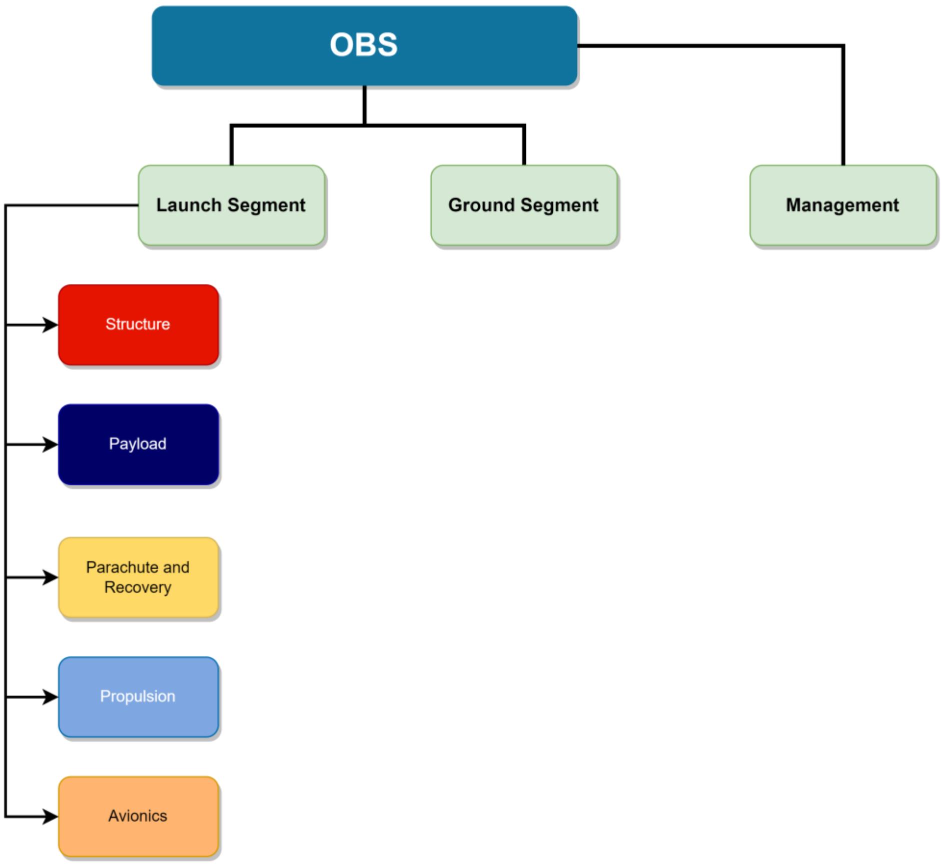

Figure 13 - Organisational breakdown structure of Fénix.
Source: (Fénix Rocket Team, 2021, p. 5)

Each group's job description is detailed in the table below.

Table 6- Formal job description of each group.
Source: (Fénix Rocket Team, 2021, p. 1)

Segment	Team	Responsibility
Launch Segment	Structure	In charge of ensuring that the rocket maintains its structural integrity throughout the flight and responsible for the internal organization of all the subsystems.
	Payload	Accountable for the design and building of a payload that performs an experiment during the flight time of the rocket.
	Parachute and recovery	Responsible for the rocket's dual-stage recovery system.
	Propulsion	Responsible for developing the engine, test bench and manufacturing the propellant, as well as the ignition system.
	Avionics	Responsible for all electronic systems used in the rocket, namely all the telemetry, navigation and sensor data acquisition.
Ground Segment	Ground Segment	Accountable for the reception of all the data generated by the rocket, being fundamental in the mission control and support of all operations.
Management	Management	Responsible for managing human resources and for all the documentation, communication with companies and promotion of the project. Their range of responsibilities also include travel logistics for testing and launch, as well as monitoring the financial aspects.

4.3 – Project management approach

Since its beginning, Fénix was based on Agile methodologies, with the Scrum and Kanban methods being applied.

The Scrum approach, which is a popular Agile project management methodology, is characterized by short, iterative development cycles, known as sprints, during which the team works on a set of prioritized tasks and objectives.

At Fénix, the team works in sprints of fifteen days where after each one there is a meeting to review every task, causing there to be a constant concern in complying with the initially defined timeline. Scrum helps teams to learn through experience, reflecting on their own achievements and difficulties, making retrospectives and reviews, thus providing structure to the team and schedule.

This adaptable and effective framework was implemented using three informational tools:

- Google Drive, where important documents, excel sheets and budgets are stored;
- Discord[14], used for communication, containing individual voice and text channels for all the teams;
- Trello[15] (displayed in the figure below), where the Kanban method is deployed on five columns:
    - "Backlog" – tasks to be performed in the next sprints;
    - "To Do" - tasks that needs to be performed in fifteen days;
    - "Doing" - tasks that are being done during the current sprint;
    - "In Review" – tasks that need to be reviewed;
    - "Done" - tasks that are finished.

Figure 14 - Trello board in use[16].
Source: (Silva et al., 2022)

4.4 – Project schedule

The project schedule is defined using a graphical representation (Gantt chart) to illustrate a detailed overview of the planned timeline and key milestones for the Fénix project, detailed in figures 15 and 16.

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[14] Discord is a communication platform designed for communities and groups to connect, share information and collaborate in real-time.

[15] Trello is a web-based project management application that enables users to create and organize tasks and projects using boards, lists, and cards.

[16] This image featured in a scientific paper presented in May 2022 at the 4th Symposium on Space Educational Activities (SSEA) in Barcelona entitled "How to Manage a Rocketry Student Project while Mitigating Covid-19", referring to the management of the first months of the project, where every meeting was online and new teleworking solutions had to be found.

As previously stated, the project is divided into a series of smaller and more manageable two-week sprints, during which the team focuses on completing specific tasks and delivering incremental results.

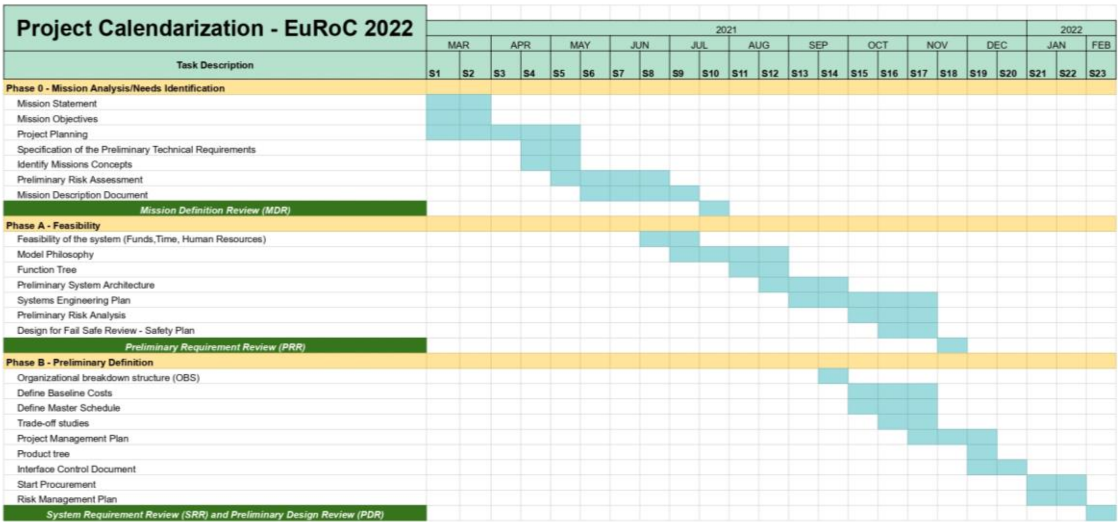

Figure 15 - Fénix Gantt chart (phases 0, A and B).
Source: (Fénix Rocket Team, 2021, p. 6)

Figure 16 - Fénix Gantt chart (phases C, D, E and F).
Source: (Fénix Rocket Team, 2021, p. 6)

Once the overall schedule is set, the project manager is responsible for monitoring the progress of the project and revising the schedule, if needed.

4.5 – Cost estimates

Cost estimates are a critical component of project management, as they help to ensure that the project is completed within budget and that resources are allocated effectively.

Table 7 displays Fénix's cost estimates, which predict the expenses associated with each project segment and team. These estimates are obtained by summing up the price of each individual component at the time of the research.

Table 7- Cost estimates for the project.
Source: (Fénix Rocket Team, 2021)

Segment	Team	Estimated cost (€)
Launch Segment	Structure	1 330
	Payload	200
	Parachute and recovery	2 080
	Propulsion	5 590
	Avionics	1 070
Ground Segment	Ground Segment	0
Management	Management	5 480
	Total	15 750

Propulsion turns out to be the most expensive subsystem, mainly due to the machining of the engine and the quantities of propellant needed for every test and launch.

The cost estimate for the ground segment is zero as the team plans to utilize existing materials, such as antennas, already present in Spacelab, making the purchase of additional equipment unnecessary. The management costs are explained due to the inclusion of registration fees (100€ per person) that are mandatory to be in the EuRoC competition (Portuguese Space Agency, 2021, p. 11).

4.6 – Risk Management

Risk management refers to the practice of identifying, evaluating and preventing or mitigating risks of a project that have the potential to negatively impact the desired outcomes.

As such the risk management process is designed to help to ensure that any potential threats to the project are identified and addressed in a timely manner.

As the team cannot predict the future with certainty, it was essential that everyone brainstormed about what failure modes their subsystem could have and in which phases of the project they would tend to happen.

To put it in a more concise way, the likelihood of a failure mode occurrence and the severity of the occurrence are assigned values according to the following tables 8 and 9 (Portuguese Space Agency, 2021,

p. 45). Then, these values are multiplied according to the following equation (where P and S represent failure probability and severity, respectively) and the criticality (C) of the failure is obtained - table 10.

$$C = P * S$$

Table 8 - Likelihood of failure
Source: (Portuguese Space Agency, 2021, p. 45)

Failure probability (P)	Value	Assessment of risk
Remote	1	This is unlikely to happen
Occasional	2	This might happen
Probable or likely	3	This is likely to happen

Table 9- Severity of occurrence
Source: (Portuguese Space Agency, 2021, p. 46)

Mishap severity (S)	Value	Effect of failure mode
Minor or negligible	1	Minor impact on mission
Critical	2	Deterioration of performance and mission
Catastrophic	3	Safety hazard and/or likely loss of mission

Table 10- Criticality ranking.
Source: (Portuguese Space Agency, 2021, p. 46)

Criticality ranking (C)	Overall impact	Severity of need for attention/mitigation
1	Minor	This failure mode is not a concern
2	Minor	This failure mode is of very minor concern
3	Medium	Review needed before launch
4	High	Technical approval needed before launch
6	Critical	Action required to reduce ranking before launch
9	Critical	Action required to reduce ranking before launch

Once the risks were identified by every team, they are analysed by the systems engineers to identify the qualitative and quantitative impact of the risk on Fénix, so that appropriate steps can be taken to mitigate them. To do that, the probability and severity of each occurrence are pointed out and the criticality is calculated by multiplying the two, as described by the above equation. Finally, a mitigation measure was defined for every failure mode. Table 11 displays Fénix's risk assessment.

Table 11- Risk Assessment at Fénix
Source: (Fénix Rocket Team, 2022, p. 57)

Type	Failure Mode	P	S	C	Mitigation Measures
Avionics	GPS Malfunction	1	1	1	Optimal assembly position to allow high GPS signal and intensive precision testing.
Avionics	Electronic Explosion/Fire	1	3	3	Appropriate ventilation and a good choice of battery.
Parachute	Igniter Misfire (Late Deployment)	2	3	6	Use of Teensy 4.1 - a microcontroller - allowing for redundancy and help prevent a late deployment.
Parachute	Parachutes cords intertwine	2	3	6	In case of wind or any other perturbation in the parachutes, these might intertwine their cords - to prevent this one shall use **swivel links**.
Parachute	Wrong Readings of Sensors	1	3	3	The deployment will depend on sensors; these might have the wrong readings of air pressure and ignite the match too early. In order to prevent this, tests will be made to make sure the barometers are presenting the right values by comparison to the ones already simulated and check their error propagation.
Payload	Card memory Fail	1	3	3	Use a second card and isolate the card from radiation.
Payload	Sensor Malfunction	2	2	4	Proper installation of the sensor to avoid malfunction (e.g., short circuit). For this, it is necessary to isolate the most sensitive parts of the sensor using a Kapton tape.
Payload	Dumping structure break.	2	2	4	Running structural simulations to design the best dumping for the mission and test the structure in different scenarios.
Propulsion	Test Bench Failure	1	3	3	Making sure the test bench is properly reinforced.
Propulsion	Igniter Failure	2	2	4	Try several amounts of black powder in the igniters, to make sure they never fail. Besides that, there shall be more than one igniter, to ensure redundancy and a better ignition.
Propulsion	Flawed Propellant	2	2	4	Improve the propellant production by testing different combinations of sorbitol and potassium nitrate, in order to always have ignition.
Structure	Person injuries during fabrication	1	3	3	Having and ensure safety regulations to prevent handling.
Structure	Instability due to mass distribution	2	2	4	Design an interchangeable fin system so the stability margin can be tailored late in the rocket construction. Check stability through simulation.
Structure	Bad Physical Interface between Subsystems and Structure	1	3	3	Structures shall promote an Interface Document with requirements and technical drawings of the physical interface.

4.7 – Formal reviews

Formal reviews are an important component of project management, as they provide a structured approach to evaluate the progress of the project. This sub-chapter describes the key reviews that will be conducted throughout Fénix.

As stated in sub-chapter 3.4, space projects are divided into several phases (each with its own set of tasks and objectives) and at the end of each one a comprehensive review is conducted to assess the progress made and compare it with the expectations.

Project leadership has the duty of performing these reviews, that will be used as milestones, allowing the team to have “snapshots” of the various phases of the project. Identifying and mitigating problems early in the design phases is the key goal, as it prevents mistakes from propagating throughout the project.

The reviews that need to be performed are (European Cooperation for Space Standardization, 2009, p. 19):

- Mission Definition Review (MDR);
- Preliminary Requirement Review (PRR);
- System Requirement Review (SRR);
- Preliminary Design Review (PDR);
- Critical Design Review (CDR);
- Acceptance Review (AR).

4.8 – List of deliverables

Based on the applicable ECSS standards to this project and in the purpose of this dissertation, Fénix has several documentation outputs to be delivered, which are described in table 12.

Table 12- List of ECSS deliverables applicable to Fénix
Source: (European Cooperation for Space Standardization, 2017, pp. 53-55)

Deliverable	ECSS document	Deliver final version at the end of:
Mission description document	ECSS-E-ST-10, Annex B	Phase A
Technical requirements specification	ECSS-E-ST-10, Annex A	Phase A
Project management plan	ECSS-M-ST-10, Annex A	Phase B
Work breakdown structure	ECSS-M-ST-10, Annex C	Phase B
Cost estimate	ECSS-M-ST-60, Annex G	Phase B
Schedule	ECSS-M-ST-60, Annex B	Phase B
Risk assessment	ECSS-M-ST-80, Annex C	Phase B
Function tree	ECSS-E-ST-10, Annex H	Phase B
Product tree	ECSS-M-ST-10, Annex B	Phase D
Systems engineering plan	ECSS-E-ST-10, Annex D	Phase D
Verification plan	ECSS-E-ST-10-02, Annex A	Phase D
Interface control document	ECSS-E-ST-10-24, Annex B	Phase D

Furthermore, the organisation of the European Rocketry Challenge demands certain documents and deliverables to be performed before the event, which if not approved lead to the elimination of the respective team. Table 13 provides an analysis of the key technical outputs that are required in order to participate in EuRoC.

Table 13- List of technical deliverables needed to participate in the European Rocketry Challenge. Source: (Portuguese Space Agency, 2021, pp. 22-26)

Phase	Deliverable	Deadline	Description
Design process	Technical Questionnaire	T- 6 months	Online questionnaire that the team shall fill with technical information regarding the project.
	Concept report	T- 5 months	Short report describing the project's concept, containing main system description, performance parameters and the planned mission concept of operations.
	Design report	T- 3 months	Report focusing on the project's special design features.
Launch preparation	Technical report	T- 1 month	Report describing the team's project, to be evaluated by the judges and competition officials. Main source of information in what regards to the project.
	Flight simulation	T- 1 month	OpenRocket project file containing a highly detailed model of the team's rocket.
Recovery	Post-flight Record	T+ 1 day	Record to be filled out by the teams with flight information and delivered to the officials at the Postflight Debriefing.

4.9 – Internal feedback analysis

Internal feedback fosters a culture of open communication, collaboration and continuous learning, which are key components of agile project management practices.

Obtaining regular feedback from team members at Fénix is key to help the project leadership to make informed decisions, implement necessary changes and drive continuous improvement, leading to a more successful project outcome.

For this dissertation, a specific inquiry was made to the team to provide valuable insights into their perceptions and experiences with the Agile methodologies being applied.

The inquiry was launched using Google Forms and it was distributed to the project team to gather their insights and opinions on the use of agile methodologies and the associated tools. It consists of seventeen questions, which were selected to cover key aspects of the project, including task management, communication, teamwork, technical skills development, and overall satisfaction.

The questions were structured in a logical order, beginning with general questions about the participant's role in the project and their level of involvement and progressing to more specific questions about their experience with project management tools and techniques. The full inquiry is represented in Annex A.

4.10 – Results

Although the team faced numerous challenges and obstacles along the nineteen months, perseverance and commitment to the project never faltered. As a result, students were able to create a rocket that was showcased at the European Rocketry Challenge (Figure 17).

Figure 17 - Fénix team's stand at the European Rocketry Challenge. Source: (Fénix Rocket Team, 2022)

As previously discussed in the Internal Feedback sub-chapter, an inquiry to evaluate the team's experience with agile methodologies and the associated tools was conducted.

Out of the 35 current members of the project, 18 transited from the original team and were eligible for taking the inquiry. Of those, 16 answered. The following paragraphs presenting the key findings from the survey, highlighting the main themes that emerged from the responses.

When asked about their previous background with space sector projects, the wide majority of the team members (15 out of 16) reported having no prior experience. In terms of agile methodologies, 4 team members (25%) reported having worked with them, while the remaining 12 (75%) declared having no previous contact with these methodologies.

When asked to rate the effectiveness of the two-week sprint cycle, most respondents (9) answered with a score of 4 out of 5, indicating that it worked well for the team. However, in response to the inquiry question regarding the clarity and achievability of sprint goals and timelines, 50% of students rated it with a score of 3 out of 5.

A vast majority of the participants in the inquiry provided a positive evaluation on the effectiveness of Discord as a communication tool, with 13 respondents giving it the highest rating of 5, and 3 people giving it a rating of 4. Additionally, the inquiry showed that the use of different channels for different topics, such as “#rocket-design”, “#euroc-deliverables” and “#outreach”, was perceived as helpful by the team.

When asked "Did you find Trello helpful for managing tasks?", 75% of the individuals answered 4 or 5. However, opinions were more varied when asked "Did you feel like you had a good understanding of what tasks were assigned to you and what tasks others were working on, based on the Trello board?" with the mean of the answers being 3.78, calculated on a 0-5 scale. It is notable that while Trello was not as unanimously well-received as Discord, it still received positive feedback from most of the team.

Overall, the team also found Google Drive to be a useful tool for document sharing, with a majority of respondents (81%) indicating a high level of satisfaction with its performance.

Most of the participants reported a high degree of improvement in their technical skills during the project, with a large proportion of them (56%) rating their development as 5.

4.11 – Synthesis

Overall, this chapter provided an overview of the case study and its context and a foundation for the analysis and evaluation of the feasibility of implementing agile project management methodologies in the project.

Chapter 5 - Conclusions, recommendations and future work

5.1 – Conclusions

This dissertation aimed to investigate the implementation of different project management methodologies related to space projects in a student-based work environment, with the aim of improving productivity and efficiency.

To establish a comprehensive foundation for this study, the current state on various project management methodologies was examined. Each of these was analysed in detail, highlighting the advantages and limitations of each approach, which enabled the understanding of the core principles and practices of each method, as well as the circumstances under which they are best suited.

To gather data for the study, a survey was conducted among students who participated in the project. It focused on understanding the perception of the students and the effectiveness of the project management methodologies applied and the impact on their personal and professional development.

The results of the inquiry indicated that the majority of the team members found the two-week sprint cycle to be effective, with a considerable proportion of them reporting positive feedback on the clarity of sprint goals and timelines, as well as the general meetings held at the end of each sprint. The communication tools implemented in the project, namely Discord and Trello, were also positively evaluated by the team. Similarly, the use of different channels in Discord and different lists in Trello was seen as helpful in facilitating communication and task management within the team.

Overall, the implementation of Agile methodologies in this student-led rocketry project was positively evaluated by the team, suggesting that these methodologies can be effective in enhancing team communication and task management, as well as promoting the development of technical skills, demonstrating the feasibility of the procedures defined by the project manager and validating the management tools for planning, communication and control of the project.

The contribution of this work lies in providing insights into the use of these methodologies in a non-professional context, namely among students in a space project, showing that they are not only applicable in a professional setting but can also be effective in a student-led project.

5.2 – Recommendations and future work

Based on the findings of this project, some recommendations and areas for future work can be suggested. Firstly, it is recommended to provide more clarity and guidance in defining sprint goals and timelines, as 50% of participants responded with a rating of 3 or below on this topic thus to improve the lack of communication from project leaders or an inadequate task breakdown, which can lead to confusion and misunderstanding among team members.

To address this, project leaders shall schedule more frequent meetings to discuss sprint goals and timelines, provide detailed task breakdowns and ensure that everyone has a clear understanding of their roles and responsibilities. By doing so, the team can benefit from increased productivity, improved task completion rates and a more effective use of resources.

Secondly, it may be beneficial to incorporate more training sessions or workshops to address the technical skills development of the team. Although most participants reported significant improvement in their technical knowledge (with a mean response of 4.5 out of 5), providing more opportunities for learning and skill-building on topics such as space system architecture and design, this proposal could further enhance the quality of work produced by the team.

Finally, one potential area for future improvement identified in this study is the development of a platform that integrates multiple tools into a centralized hub for team members to communicate, collaborate and manage tasks. Such a platform could include features such as progress tracking and task assignments to increase productivity and efficiency, or a knowledge base that would allow team members to easily access information related to the project and share their expertise with others. Its development could lead to significant improvements in project management and team collaboration.

This would create the opportunity to take advantage of this work by converting it into a practical solution.

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Annexes

Annex A – Fénix Agile Methodologies Feedback Inquiry

Fénix Agile Methodologies Feedback

Agile methodologies are iterative and flexible ways of managing projects, with a focus on collaboration, continuous improvement, and responsiveness to change.

The goal of this inquiry is to evaluate the use of agile methodologies, such as Scrum and Kanban, in our rocket project, gathering feedback from the team on how these methodologies were applied in the project and their effectiveness in achieving our objectives.

1. Did you have any previous experience working on space projects before joining the team?

   Mark only one oval.

   - Yes
   - No

2. Did you ever work on a project that used agile methodologies before joining the team?

   Mark only one oval.

   - Yes
   - No

3. Scrum is a framework that emphasises teamwork, frequent inspection and adaptation to rapidly deliver results. In Fénix this was visible, for example, with the implementation of two-week sprints and a monthly retrospective self-evaluation meeting.

   To what extent did the two-week sprint cycle work well for the team?

   Mark only one oval.

   Not at all

   1 ⬭

   2 ⬭

   3 ⬭

   4 ⬭

   5 ⬭

   Extremely

4. Were the sprint goals and timelines clearly defined and achievable within the two-week period?

   Mark only one oval.

   Not at all

   1 ⬭

   2 ⬭

   3 ⬭

   4 ⬭

   5 ⬭

   Extremely

5. To what extent did the general meetings at the end of each sprint help to provide a clear understanding of the progress made and the next steps to be taken?

Mark only one oval.

	Not at all
1	⬭
2	⬭
3	⬭
4	⬭
5	⬭
	Extremely

6. Did you feel that the monthly retrospective self-evaluations (with the columns "What well", "To Improve" and "Action Items") provided valuable insights that helped the team?

Mark only one oval.

	Not at all
1	⬭
2	⬭
3	⬭
4	⬭
5	⬭
	Extremely

7. Were you satisfied with the frequency and structure of sprint reviews and self-evaluation retrospectives?

Mark only one oval.

	Not at all
1	⬭
2	⬭
3	⬭
4	⬭
5	⬭
	Extremely

8. On a scale of 0-5, how much did Discord contribute to the team's communication?

Mark only one oval.

1	⬭
2	⬭
3	⬭
4	⬭
5	⬭

9. Was it helpful to have different channels for different topics (e.g. rocket-design, euroc-deliverables, outreach)?

Mark only one oval.

Not at all

1 ⬭

2 ⬭

3 ⬭

4 ⬭

5 ⬭

Extremely

10. Kanban is a visual system used to manage and keep track of work as it moves through a process. In Fénix, it was applied using Trello with columns for "Backlog", "to Do", "Doing", "In Review", "Done", etc.

Did you find Trello helpful for managing tasks?

Mark only one oval.

Not at all

1 ⬭

2 ⬭

3 ⬭

4 ⬭

5 ⬭

Extremely

11. Did you feel like you had a good understanding of what tasks were assigned to you and what tasks others were working on, based on the Trello board?

Mark only one oval.

Not at all

1 ⬭

2 ⬭

3 ⬭

4 ⬭

5 ⬭

Extremely

12. Did Trello help you visualise project progress?

Mark only one oval.

Not at all

1 ⬭

2 ⬭

3 ⬭

4 ⬭

5 ⬭

Extremely

13. Did you find Google Drive to be an effective tool for document sharing?

Mark only one oval.

Not at all

1 ◯

2 ◯

3 ◯

4 ◯

5 ◯

Extremely

14. In sum, do you feel that the methodologies applied helped improving the overall project performance?

Mark only one oval.

Not at all

1 ◯

2 ◯

3 ◯

4 ◯

5 ◯

Extremely

15. Would you recommend the use of this kind of methodologies on future projects?

Mark only one oval.

	Not at all
1	⬭
2	⬭
3	⬭
4	⬭
5	⬭
	Extremely

16. To what extent do you feel that you developed your technical skills in the project?

Mark only one oval.

	Not at all
1	⬭
2	⬭
3	⬭
4	⬭
5	⬭
	Extremely

17. To what extent did this project made you want to work in the space sector in the future?

Mark only one oval.

Not at all

1 ◯

2 ◯

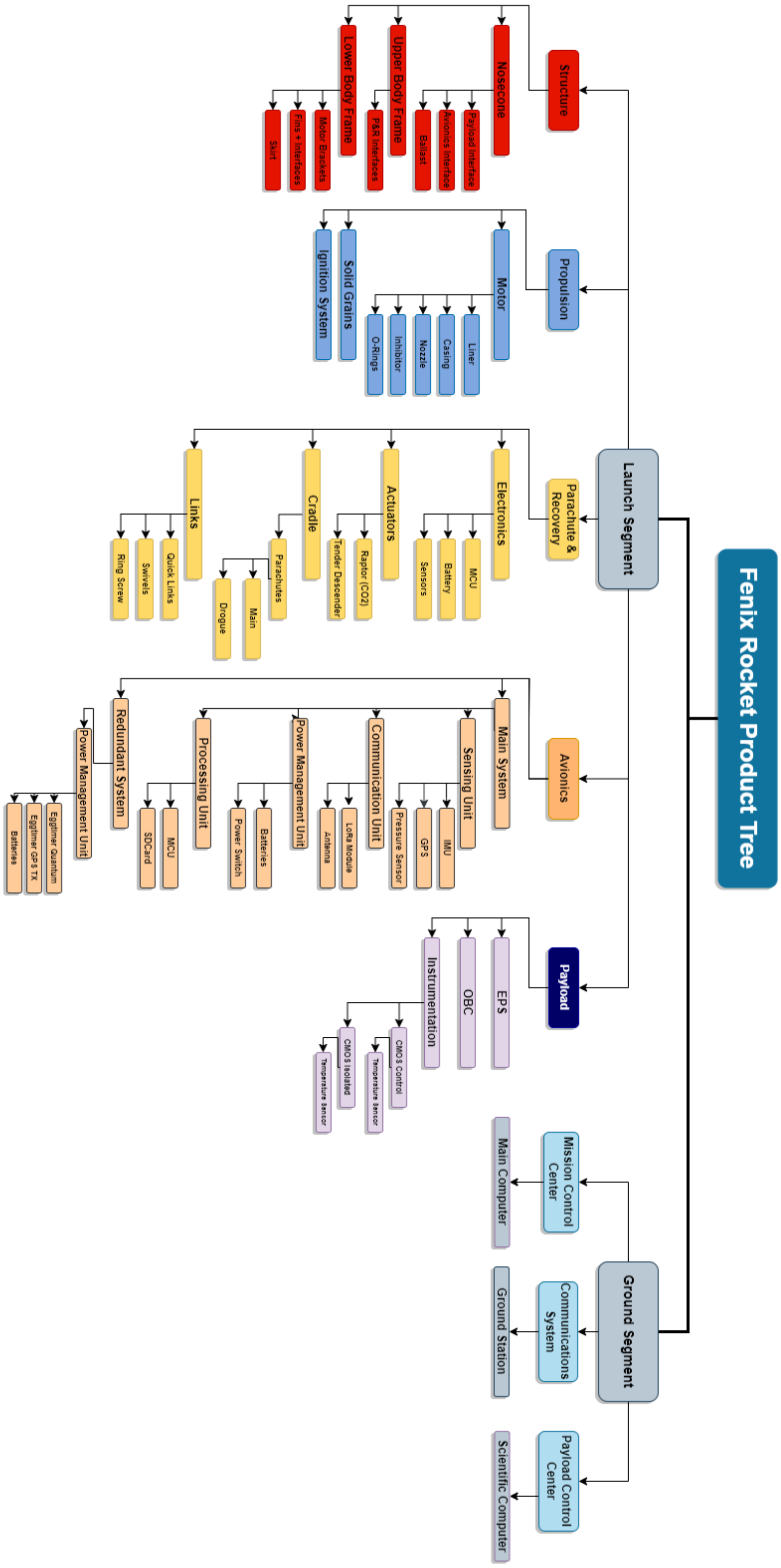
3 ◯

4 ◯

5 ◯

Extremely

Annex B – Product tree



Annex C – Review template

<REVIEW NAME>

Date:

Review Team Members:

1 Review Objectives

2 Review Actions

ID	Subsystem	Description
<R.#>	<Subsystem name>	<Description of the review action.>

3 Review Results

4 Signatures

Annex D – Management during Covid-19

How to Manage a Rocketry student project in full quarantine

Júlio Santos[1], *Jeremy Silva*[2], *Henrique Neves*[3]

Abstract

The Fénix Project was created by a multidisciplinary team of forty students that aims to design and build a rocket totally Student Researched and Developed (SRAD), capable of reaching three thousand metres of altitude to participate in universitary rocket launch competitions in Europe. It was born from the will of students at the University of Beira Interior(UBI) and the University of Coimbra (UC) who in 2022 have the goal to participate in the European Rocketry Challenge (EuRoC), organised by the Portuguese Space Agency, and to present a high powered solid rocket. In the desired category, students have to develop a motor from scratch and produce its solid fuel.

Due to the current pandemic situation it was impossible, on the one hand, to hold face-to-face meetings regarding teamwork and, on the other hand, to organise fundraising events. In this way, the team was forced to develop teleworking solutions and look for other ways to get some monetary sponsorship. For this, tools such as Discord, Trello, Google Drive and Google Meets were used.

The hardest thing to control on a team of so many people in a full quarantine is precisely the pace. For that, this project was based on an Agile methodology - Scrum approach - which encourages teams to learn through experience, reflecting on their own achievements and difficulties during work sprints of fifteen days, promoting continuous improvement and causing there to be a constant concern in complying with the initially defined timeline. To reward the effort allocated by students on the project, points were given to the several teams.Being compliant with the applicable standards of the European Cooperation for Space Standardisation (ECSS) also gave students a great sense of responsibility and endeavour, due to the proximity of the tasks that are performed in huge space agencies, such as the European Space Agency (ESA).

With the right approach, COVID-19 effects can be mitigated without ever losing the main focus, which is facilitating the acquisition of soft-skills and hard-skills by students who want to participate and be a part of this fascinating sector.

Keywords

Agile Methodologies, Education, Project Management, Remote, Rocket

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Acronyms/Abbreviations

All used acronyms and abbreviations should be listed in alphabetical order, as follows:

AR *Acceptance Review*

CAD *Computer Aided Design*

CDR *Critical Design Review*

MDR *Mission Definition Review*

PDR *Preliminary Design Review*

PRR *Preliminary Requirements Review*

SSEA *Symposium on Space Educational Activities*

SRAD *Student Researched and Developed*

SRR *System Requirements Review*

UBI *University of Beira Interior*

UC *University of Coimbra*

1. Introduction

COVID-19 has been severely affecting the entire space sector and this long-lasting pandemic will have consequences for years to come. It is threatening the economic viability of companies, jobs and working conditions [1]. But in plain lockdown there was a project rising from the ashes.

Created in March 2021, Fénix is a partnership between the University of Beira Interior (UBI) and the University of Coimbra (UC) that aims to develop a rocket capable of participating in university rocket launch competitions in Europe and other events that encourage university students to design, build and launch their own vehicles. At a time when the importance of diversity is increasingly recognized in the world, Fénix is proud to present a group formed by a mix of experience with youth, with forty students from the University of Beira Interior and University of Coimbra, some without any connection to the space area, and others with major projects such as Stratospolca participating in Balloon Experiment for University Students (BEXUS) - collaboration with the European Space Agency (ESA) - in their curriculum. This project's ultimate goal is to prove that learning Rocket Science/Engineering is for anyone, opening up horizons for space lovers and future professionals in this fascinating area.

2. Objectives

2.1. Technical Objectives

Fénix's mission consists in the building of an unguided Student Researched and Developed (SRAD) Solid Propulsion Rocket capable of reaching an apogee of 3,000 metres. Additionally, it shall employ internal electrical and software subsystems and must have a dual-stage parachute as a mandatory condition to ensure the rocket is successfully recovered, and can be reusable. The functionality of the payload is also a key detail in this project, as well as the portability of its Launch System and Ground Segment.

2.2. Non-Technical Objectives

One of the major objectives with this initiative is to provide students a space for creativity and self-development, thus facilitating the acquisition of soft-skills and hard-skills. Every member should individually acquire knowledge of the respective subsystem in which they are working, as well as an overview of how a space project is managed and planned.

The project is intended to reach a wide audience, being mentioned in national and international newspapers and media. As the space sector is booming in Portugal [2] and more and more students from Faculties of Engineering want to participate and be part of this fascinating sector, we hope that this project will promote UBI and UC as being at the forefront of the Portuguese Space Sector, and that it is maintained for many years, with the foundations being created for new patents to be developed and for this to become a profitable business, if the next generations of students/professors wishes to do so.

Figure 1. Mission Patch

3. Project Management Approach

There are several constraints to this project on a management level. Firstly, since it is composed only by students, it requires from them the ability to excel in discipline and time management in order to conciliate their work with the ever so important academic career, as well as other extracurricular activities they may have and their free time. Also, the two hundred kilometres that separate the two universities participating in this project complicate the possibility of face-to-face work and regular meetings/team-buildings. However, and as this paper will try to prove, teams can develop exceptional communication and relationships by bringing their work cultures to the virtual space.

3.1. Organisation

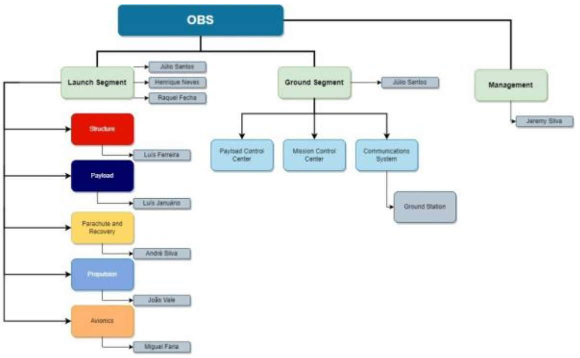

Figure 2. Organisational Breakdown Structure

The leadership of the project is in charge of the Team Leader. Together with the Project Manager, they supervise all the work and guarantee that every member knows their job description and what authority they have.

The rest of the team is divided into several working groups (subsystems), inside two segments: Ground and Flight. The latter is divided into Avionics, Propulsion, Structure, Parachute & Recovery and Payload, as seen in the Figure above.

Each working group has a coordinator, who is responsible for managing and motivating every group member, reporting the information to the Team Leader and Project Manager, who also has the task of leading the Management team, ensuring all the communication with stakeholders, documentation and promotion of the project. Their range of responsibilities also includes travel logistics for testing, as well as monitoring the financial aspects. This organisation offers the framework for the project's execution.

The team has also three System Engineers who assess every system and ensure that all the parts function as a whole, determining problems, providing solutions to issues that arise, designing, upgrading and maintaining systems, while also brainstorming possible improvements that can be made to a system in the future. They assume the functions of an "Operations Director", tracking and reviewing every team's work. Finally, they are in charge of the validation and verification tests necessary until the final decision to launch.

3.2. Agile Methodology

On a team of so many people, the pace is hard to control. That is why this project was based on an Agile methodology (Scrum approach) which encourages teams to learn through experience, reflecting on their own achievements and difficulties, making retrospectives and reviews. The team works in sprints of fifteen days where after each one there is a meeting to review every task, causing there to be a constant concern in complying with the initially defined timeline.

This adaptable and effective framework was implemented using three main softwares: Google Drive, where important documents, excel sheets and budgets are stored; Discord, used for communication, containing individual voice and text channels for all the teams; and Trello, where the Scrum approach is deployed on three columns ("To Do" - tasks that needs to be performed in fifteen days; "Doing" - tasks that are being done during the current sprint, and "Done" - tasks that are finished).

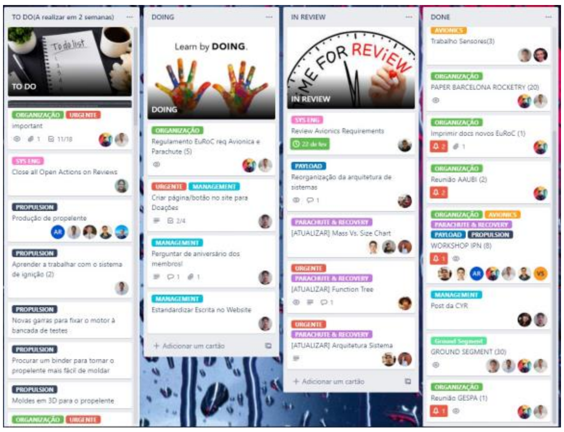

Figure 3. Trello Board in Use

3.3. Cost Management

Cost is usually one of the first aspects that come up in any project, but when it comes to a universitary project, it can be challenging to forecast and manage costs effectively. In fact, there is news every day about projects going over budget and time, yet this is avoidable with strong cost management.

For the project to have its desired success, it was necessary to resort to the support of entities willing to dispense some type of collaboration, mainly national and international companies to which the project was aligned with their strategic plan and activities, many of them offering materials that the company had, rather than money. Funding was also acquired through other sources, such as raffle tickets.

The cost estimate for this project started out as a rough figure and got more refined, as the project work and materials were defined in one Google Sheets document, where every team has a particular budget associated with their monetary expenses.

Registration fees of the competitions are also important to take into consideration, as they round up to 100€ per person.

3.4. Schedule

Project scheduling is just as important as cost budgeting, as it determines the timeline, resources needed, and reality of the delivery of the project. Once an overall schedule is set, using a consensus-driven estimation method the project manager is responsible for monitoring the progress of the project and revising the schedule if needed. This must be done in consultation with project team members who are doing the work. It is essential for the project manager to keep all participants informed as to current schedule status.

Figure 4. Management timeline of the project

As well as the cost budget, the schedule estimate for this project started out as a rough figure and got more refined, as the project deadlines were defined in a Gantt Chart.

3.4.1. Deliverables

The desire was to be as compliant as possible with the applicable standards of the European Cooperation for Space Standardisation (ECSS). Making regular technical meetings and elaborating system engineering reviews gives students a great sense of responsibility and endeavour. The reviews that need to be performed are:

- Mission Definition Review (MDR);
- Preliminary Requirement Review (PRR);
- System Requirement Review (SRR);
- Preliminary Design Review (PDR);
- Critical Design Review (CDR);
- Acceptance Review (AR).

The usage of Reviews as Milestones serves the very useful function of allowing users to have "snapshots" of the various phases of the project and providing a formal approval for the start of the next phase. This has allowed the team to identify and mitigate problems early on in the design phases and not allows for the mistakes to propagate throughout the project, such as the usage of materials or components not acceptable for the performance requirement of the system.

Two major ECSS Standards that are being followed in this project are Project Planning Implementation [3], and System Engineering General Requirements [4]. These guides provide important rules for space projects.

Figure 5. ECSS Standards [3] and [4]

3.5. Requirements

The first activity in a space project is, obviously, to define its requirements. In Fénix this is not an exception. High-level requirements were first defined, and then subsystem requirements were also defined. Collaborative documents were used to host all the requirements, making use of an ID to identify the requirement itself and adding a third column to explain the rationale behind it. Also, a Change Log was created to store the major changes in the project, and register the affected subsystems.

3.6. Risk Management

Risk management is the practice of identifying, evaluating, and preventing or mitigating risks to a project that have the potential to impact the desired outcomes.

As the team cannot predict the future with certainty, it was essential that everyone brainstormed about what failure modes their subsystem could have and in which phases of the project they would tend to happen. Once the risks were identified by every team, they were analysed by the Systems Engineers to identify the qualitative and quantitative impact of the risk on Fénix so that appropriate steps can be taken to mitigate them. To do that, the probability and severity of each occurrence were pointed and the criticality was calculated by multiplying the two. Finally, a mitigation measure was defined for every failure mode.

ID	Type	Failure Mode	Mission Phase	Probability	Severity	Criticality	Mitigation Measures
RM.1	Management	Withdrawal from a member	Phases 0, A, B, C and D	3	1	[illegible]	The organization shall be clear and transparent when it comes to finance and shall communicate every external contact. Team building activities should be carried out to unite the team.
RM.2	Management	Loss of knowledge, due to the departure of a team member.	Phases 0, A, B, C and D	3	1	[illegible]	Members should produce a report explaining what they did, how they did it and future steps in order to create a knowledge base accessible to any team member.
RM.3	Management	Withdrawal from a member	Phases E and F	1	2	[illegible]	The organization shall be clear and transparent when it comes to finance and shall communicate every external contact. Team building activities should be carried out to unite the team.
RM.4	Management	Loss of knowledge, due to the departure of a team member.	Phases E and F	1	2	[illegible]	Members should produce a report explaining what they did, how they did it and future steps in order to create a knowledge base accessible to any team member.
RM.5	Management	Withdrawal from a sponsor	Before they give the money/product	1	2	[illegible]	Personalized contact shall be given to every entity interested in becoming a sponsor or partner.
RM.6	Propulsion	Ignition System Failure	Testing	1	1	[illegible]	Having a secondary ignition system.
RM.7	Propulsion	Igniter Failure	Testing	3	2	[illegible]	Use more igniters.
RM.8	Propulsion	Defectuous Propellant	Testing	3	2	[illegible]	Perfect the propellant production and have secondary loads.
RM.9	Propulsion	Engine Catastrophic Failure	Pre Competition	1	4	[illegible]	Structural Testing on FEM programs.
RM.10	Propulsion	Test Bench Failure	Testing	1	3	[illegible]	Making sure the test bench is properly reinforced.
RM.11	Propulsion	Defectuous Engine Manufacture	Pre Competition	2	4	[illegible]	Look for a good manufacturer by making a small prototype and see if the final product is okay. Make sure everything is okay upon delivery.
RM.12	Avionics	Microcontroller Malfunction	Testing	1	1	[illegible]	Buy a new one
RM.13	Avionics	GPS Malfunction	Testing	1	1	[illegible]	Optimal assembly position to allow high GPS signal and intensive precision testing
RM.14	Avionics	Pitot Tube Malfunction	Testing	1	1	[illegible]	Calibration and testing
RM.15	Avionics	IMU Malfunction	Testing	1	1	[illegible]	Axis' calibration and testing
RM.16	Avionics	Barometer Malfunction	Testing	1	1	[illegible]	Sensor's calibration and testing
RM.17	Avionics	LoRa Malfunction	Testing	1	1	[illegible]	Antenna's calibration and testing
RM.18	Avionics	Cable Management	Testing	1	1	[illegible]	Good planning of cables position and use of zipties
RM.19	Avionics	Support Design	Testing	1	2	[illegible]	A good case planning with a lot of structural tests
RM.20	Avionics	Software Bugs	Testing	4	1	[illegible]	Checking the code until we get what we want
RM.21	Avionics	Any sensors failure	Pre Competition	3	4	12	Microcontroller and sensors checking or replacement
RM.22	Avionics	Cable Connections	Pre competition	1	3	[illegible]	Double checking and reinforced welds
RM.23	Avionics	Running out of battery	Pre Competition	1	3	[illegible]	Have another to replace
RM.24	Avionics	Ground communication failure	Pre Competition	2	3	[illegible]	Double check the antenna and LoRa module
RM.25	Avionics	Running out of battery	Competition	1	4	[illegible]	Checking the battery before the launch

Figure 6. Risk Matrix of the project

3.7. Promotion

The advertising of this project is done through the Fénix website - http://fenixrocket.pt/, where it is possible to find information about the rocket, including reports on its development and future announcements - and in social networks. There is currently a Facebook and LinkedIn page, and an Instagram account (@fenixrocket) - where news about the project is being published and the experience is presented to the general public. This is the way of attracting sponsors and partners to finance Fénix.

4. COVID-19 and its Mitigation

Fénix's project started officially in March 2021, during a full quarantine situation in Portugal, at a time where on average the number of new infections was decreasing every day and about 3% to 4% of the population was vaccinated [5].

However, with still more than one thousand cases of COVID-19 diagnosed daily in the country, new risk-mitigation strategies needed to be implemented.

During the first months, every meeting was online and new teleworking solutions were found, such as AnyDesk, a powerful Remote Support Software that enabled students to use the university's supercomputers processing power from any physical location, thus facilitating every structural and thermal test, as well as the Computer Aided Design (CAD) drawings.

In fact, the first two-thousand hours of work were all done at distance, which demonstrates the perseverance of the group. To reward the effort allocated by the students on the project, points and prizes were given to the several teams according to the number of hours spent on a given task, thus creating a healthy competition between different working areas.

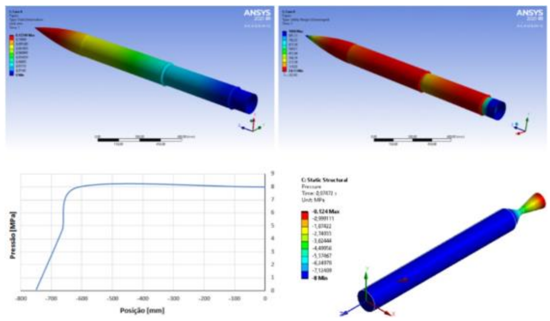

Figure 7. Structural Tests to the Shell of the Rocket

The Management team also organised a raffle draw, sending every raffle book via post to each students' home and collecting the money via a service of instantaneous banking transfers, with the sortition being done online. To keep everyone motivated, prizes such as hotel vouchers were given to the students who could sell the most raffles. Team building was also a concern, especially among students from two different universities who had never seen each other, as this could lead to feelings of loneliness and alienation from other coworkers, lowering productivity. Therefore, virtual activities were arranged to dynamize the team and make sure everyone felt comfortable and capable of communicating openly, solving difficulties, and collaborating effectively.

When restrictions were lifted and face-to-face work started, it was required to implement new physical distancing measures, as well as increased hygiene (with mandatory masks and the use of disinfectant), and other safeguards to prepare students for a safe return to the university.

5. Lessons Learned

Several lessons from the one-year duration of this project were taken, such as:

Requirements are a responsibility of everyone - Never accept requirements without discussing them. It is dangerous when the requirements come from a so-called intelligent student, because no one questions them. They shall be discussed by everyone in the team. There are no stupid opinions.

Requirement Identification is a fingerprint - To avoid confusion, never change the ID of a requirement. Most of the time, if an ID is changed, the requirements will be confused in other documents. Instead, write "Deleted" in the requirement text.

Holidays are to rest - Never plan a review on holidays. Students need the appropriate schedule to perform a final review, and this takes time. Plan in advance and look at the student's exams calendar.

Unforeseen events really happen - Account on delays in the delivery of pieces from companies, because most of the time they have their machines in use and university projects are not their priority.

6. Conclusions

Despite the distance that separated the team members, one of the most powerful ways to unite people is to make everyone work with a common goal. The outcome of the learning experience of managing a project within the special context of Fénix is that, with work ethics a logical organisation of the work, thorough coordination, and bespoke motivation, teams can overcome the hardships. Future work to be done comprises the need to move from a totally web-based team to a hands-on team, cooperating from different sites, but building a system that interfaces correctly between each of its subsystems.

COVID-19 has taught us to expect the unexpected. But hopefully, this project proves that even in the worst situations, no student should stand still or fail to chase his/her dream.

Acknowledgements

We would like to thank the Portuguese Space Agency for organising EuRoC (a competition available to every european student), to Dr. Abílio Silva, Dr. Anna Guerman, Dr. Francisco Brójo and Dr. Pedro Gamboa for the availability and full cooperation. We would also like to express our very great appreciation to our sponsors Spaceway, Fundaço, Penedo da Saudade and M. Xavier da Costa, Lda, and our partners Frezite High Performance, Instituto de Soldadura e Qualidade, Comércio Ibérico de Rolamentos Lda - CYR, RatRig, Nova Forma and the Portuguese Army, whose collaboration is essential to the success of the project.

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