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

[1]Corresponding author: University of Beira Interior - UBI, Portugal, juliosantoswork@gmail.com
[2]University of Beira Interior - UBI, Portugal.
[3]University of Coimbra - UC, Portugal

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

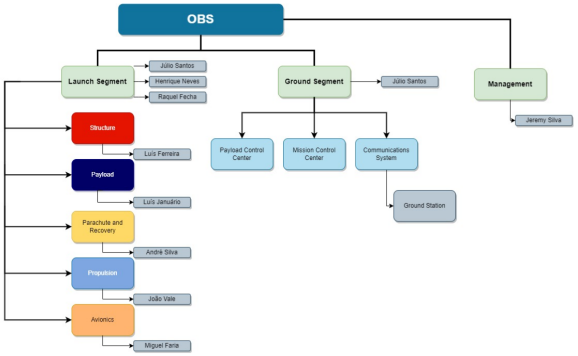


Figure 2. Organisational Breakdown Structure

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).

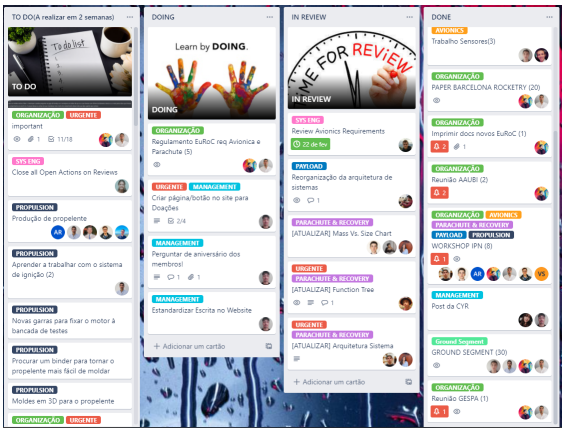


Figure 3. Trello Board in Use

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.

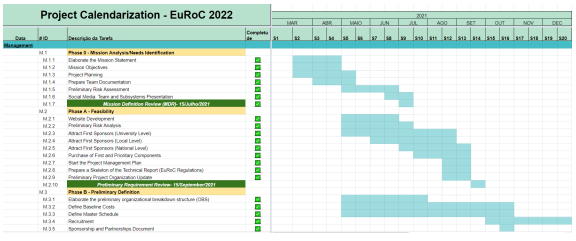


Figure 4. Management timeline of the project

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.

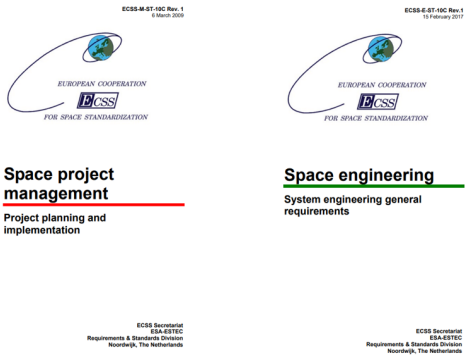


Figure 5. ECSS Standards [3] and [4]

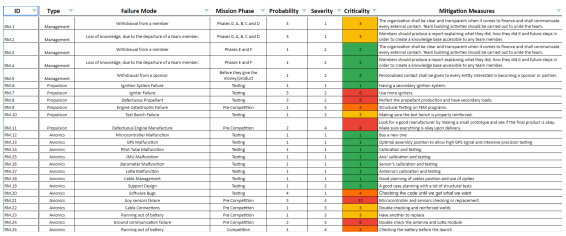
3.5. *Requirements*

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
Mit.1	Management	Withdrawal from a member	Phases D, A, B, C and D	3	1	3	The organisation 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.
Mit.2	Management	Loss of knowledge, due to the departure of a team member.	Phases D, A, B, C and D	3	1	3	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.
Mit.3	Management	Withdrawal from a member	Phases E and F	1	2	2	The organisation 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.
Mit.4	Management	Loss of knowledge, due to the departure of a team member.	Phases E and F	1	2	2	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.
Mit.5	Management	Withdrawal from a sponsor	Before they give the money/product	1	2	2	Personalized contact shall be given to every entity interested in becoming a sponsor or partner.
Mit.6	Propulsion	Ignition System Failure	Testing	1	1	1	Having a secondary ignition system.
Mit.7	Propulsion	Igniter Failure	Testing	1	2	2	Use more igniters.
Mit.8	Propulsion	Defficitous Propellant	Testing	3	2	6	Perfect the propellant production and have secondary loads.
Mit.9	Propulsion	Engine Catastrophic Failure	Pre-Competition	1	4	4	Structural Testing on HIFI programs.
Mit.10	Propulsion	Test Bench Failure	Testing	1	3	3	Making sure the test bench is properly reinforced.
Mit.11	Propulsion	Defficitous Engine Manufacture	Pre-Competition	2	4	8	Look for a good manufacturer by making a small prototype and see if the final product is okay. Make more testing & data upon delivery.
Mit.12	Avionics	Microcontroller Malfunction	Testing	1	1	1	Have a backup.
Mit.13	Avionics	GPS Malfunction	Testing	1	1	1	Optimal assembly position to allow high GPS signal and intensive precision testing
Mit.14	Avionics	Pitot Tube Malfunction	Testing	1	1	1	Calibration and testing
Mit.15	Avionics	IMU Malfunction	Testing	1	1	1	Axis' calibration and testing
Mit.16	Avionics	Barometer Malfunction	Testing	1	1	1	Sensor's calibration and testing
Mit.17	Avionics	Lora Malfunction	Testing	1	1	1	Antenna's calibration and testing
Mit.18	Avionics	Cable Management	Testing	1	1	1	Good planning of cables position and use of cables
Mit.19	Avionics	Support Design	Testing	1	2	2	A good case planning with a lot of structural tests
Mit.20	Avionics	Software Bugs	Testing	4	1	4	Checking the code until we get what we want
Mit.21	Avionics	Any sensors failure	Pre-Competition	5	4	20	Mini-accelerator and sensors checking or replacement
Mit.22	Avionics	Cable Connections	Pre-Competition	1	3	3	Double checking and reinforced welds
Mit.23	Avionics	Running out of battery	Pre-Competition	1	3	3	Have another to replace
Mit.24	Avionics	Ground communication failure	Pre-Competition	1	3	3	Double check the antenna and Lora module
Mit.25	Avionics	Running out of battery	Competition	1	4	4	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.

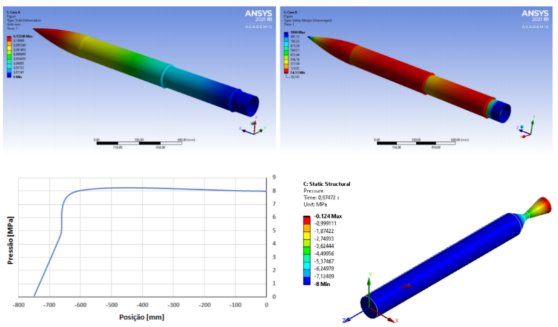


Figure 7. Structural Tests to the Shell of the Rocket

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

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