EUROPEAN PROJECT SEMESTER 2023

STRATEGIC & INTERFACE DESIGN FOR CLASS-M ROCKET LAUCH SAFETY

FINAL REPORT

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09/05/2023

Content

Acknowledgement

We would like to thank Andrew Paliwoda for providing us with the project and giving guidance and support with the technical elements of this project

We would also like to thank Patricia Muñoz de Escalona for her continued support and guidance through the project and the ideas that have been provided to further help our research

Finally, we would like to thank Andrew Quinn for providing us with his expertise in team projects as well as supporting us with projects needs and requirements

Personal introduction

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Abstract

In recent times, humanity is looking to explore the furthest outreaches of our universe by using the newest technologies and by improving current launch techniques, we have been able to launch rockets higher and faster than ever before, allowing us to understand more about the universe we live in as well as our own planet.
However, these industry developments are not possible without the continued stream of students and talented individuals who strive to improve the field of rocketry with their own knowledge and skills. These talented individuals use their passion to develop and launch rockets in order to test their own ideas and theories on how to improve the rockets they have.

Students and amateur rocket launch teams all across the world develop and launch rockets regularly. However, the safety measures that are in place are often vague, open to interpretation, and difficult to locate.
With this project, the aim was to improve these safety standards within the United Kingdom and create an environment where rocket launches could be done safely, while also making it more accessible to increase rocket launch engagement.
Before tackling the issue of rocket safety, a basic understanding of rockets and their potential hazards had to be researched to ensure that the safety measures put in place were relevant and stringent enough to keep everyone safe. The research covered a broad range of information such as how rockets worked and their construction. This was essential as this allowed for the understanding of which areas of the rocket were hazardous when working with or launching the rocket and where issues could arise if procedures were not followed correctly. Extensive in-depth research was also conducted to investigate current safety measures in place so that relevant recommendations could be provided.

The project's main objectives, increasing the safety of rocket launch events and making these events more accessible to a wider audience, were accomplished by creating an application which can be used for multiple functions. Some of these include pre/post-launch checklists, seeing networking with other rocket teams globally, and directly accessing the most recognised rocket launch safety standard (UKRA safety code).
The application's aim is to make information easily digestible to ensure that all safety measures are being upheld and to make the rocketry environment easier to get involved in and understand.
Alongside this application, a list of recommendations is developed to further improve the safety of the launch sites and a set of accessible posters was created to improve the clarity of onsite rules and ensure all attendees at these events are aware of what they can and cannot do.

Introduction

"Internationally students are increasingly becoming involved within sounding rocket projects, with students all over the world developing rockets in small university workshops, building upon existing amateur rocketry communities. TU Delft in the Netherlands currently holds the altitude record for a student team.

Student teams are seeking for their rockets to fly higher and utilise unique methods of propulsion. Increasingly the teams are seeking for their rockets to fly past the Karman line.

This project aims to understand how Spaceport 1 (SP1) can provide a safe and standardised way to launch the rockets and for open published operational standards could be used to support these student teams.

Ground support equipment can play a significant role in the design and flight of sounding rockets, and SP1 seeks to understand how open documentation can support teams in this area." (cf. Appendix 1)

There are two big parts in the process from the beginning to the end of these types of ticket projects: building and launching. In the building part there is a designing process, add the electronic components and the proper building up of the rocket. The launching phase involves the transportation of the rocket, the preparation of the rail, the ignition moment and the recovery of the rocket.

Even though building the rocket is a much longer process the risks are minimal and not often when compared to the hazards and risk which are associated with the launching of the rocket. In the launching process there are lots of risks that need to be considered, even after the rocket is launched. In the event of an accident people involved in the launching process and spectator could be at risk. That's why the team decided to focus on the risks and safety precautions in the launching process.

This project focuses mainly on the Spaceport 1 site. Spaceport 1 is a project led by a public/private sector consortium which seeks to provide affordable, reliable and safe access to polar and sun synchronous orbits through commercial vertical launch situated at Scolpaig North Uist. [1]

Figure 1: Launching site Spaceport 1

The purpose of the project is to provide permanent infrastructure for the launch of Suborbital sounding or research launch rockets. These represent a class of launch vehicles which are capable of operating above the stratosphere but will not enter orbit. [2]

Spaceport 1 has a large launch area. It is bounded by the EEZ (Exclusive Economic Zone) of Scotland boundaries near the launching pad.

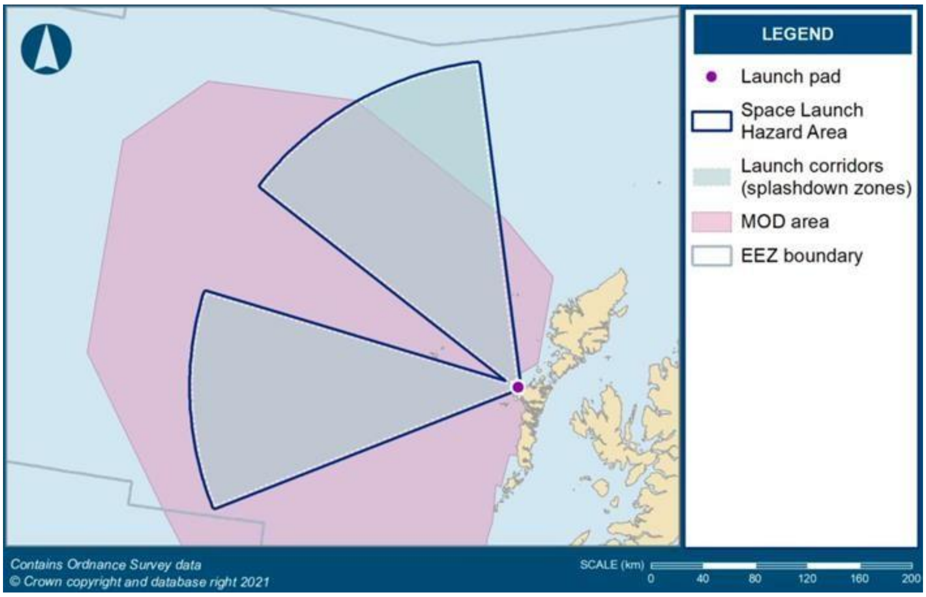


Figure 2: Airspace for Spaceport 1

1. Methodology

1.1. Meetings

During the whole project, several meetings have been organised with the tutors and the team members.
It has been decided that the team members will meet the tutors at least once a week to discuss what has been done and what should be done next. The students presented their work and the research done so far. The tutor helped and gave advice to keep going or redirecting the students towards different tasks to meet deadlines established in the Gantt chart.

The team members also decided to meet every Tuesday and Thursday of each week. Those meetings allowed the members to discuss the information gathered related to the project. If the tasks were finished, another was programmed, if not then the students kept going on their work.
Having these meetings allowed the students to move forward on the project. They all responded to problems or questions they had over the week or the weekend.
This particularly kept a good atmosphere within the team. Indeed, all the problems were solved together, and the team members developed a real team spirit over the weeks.

The meetings are most of the time in person. But the team also used virtual conferences at some point such as Microsoft Teams. This has particularly been helpful with the industrial supervisor who could not come to meet the students because of distance.

By the end of the meeting, the students have been taking notes on the job to do. The notes were shared with the team members, so everyone knows what tasks need to be done for the next meeting.

1.2. Organisation

After the meetings, the students usually spread the workload. Each student decided to fulfil one of the tasks identified during the meeting. The tasks can be linked to the students' expertise, but most of the time, the project needed general research.
The work has been divided equally between all the members. Each student had to do its work until the next meeting and share the work.

The team has been using WhatsApp and created a group to communicate over the project. This was really helpful because a lot of work, information, questions and responses have been shared through this device.
WhatsApp helped the team move forward, share the research and complete the information within the team.

To keep all the work done by the members, a Google Drive has been created. This file contains all the information provided by the team.
This tool helped the team put all the information in the report which was written on a Google Document. Doing so the student could comment every paragraph and eventually change things that were not in line with the project.
The planning was posted on the drive allowing all the students to know what must be done by each member. The notes taken during the meetings have also been shared on this file.

1.3. Planning

Over the past few weeks, the EPS students have been introduced to project management and the use of Microsoft Projects.

The project team found it would be valuable to utilise these skills in the project.
The Gantt chart (cf. Appendix 3) is really useful because it helps the team plan and organise the work. All the meetings are put in this table. The tasks are clearly defined. Each member knows what they must do, how long it should take and when the deadlines are. This is also a great tool because everyone can know if the work is done on time, late, or early.

For this project, several distinct stages are organised. The first part is before midterms followed by the midterm's presentation. The second part is before the finals followed by the final's presentation.

The part before midterms is focused on the research and all the information that can be useful to the project. The research has been spread between the four members of the team.

The writing of the report and the presentation are made by everyone. There is a period before the midterms presentation that allows the team to share the research and write a summary of what it has done so far.

The second part of the project is after midterms and before finals. This phase of the project is focussed on the solution provided by the team. It is during this period that the team will meet the student's team and spectate a launch.
The writing of the final report, the preparation of a video and the presentation will be done by everyone in the team. There will be a period of almost 2 weeks where the team will be able to gather and produce the final response to the problem. m/s

1.4. Timeline

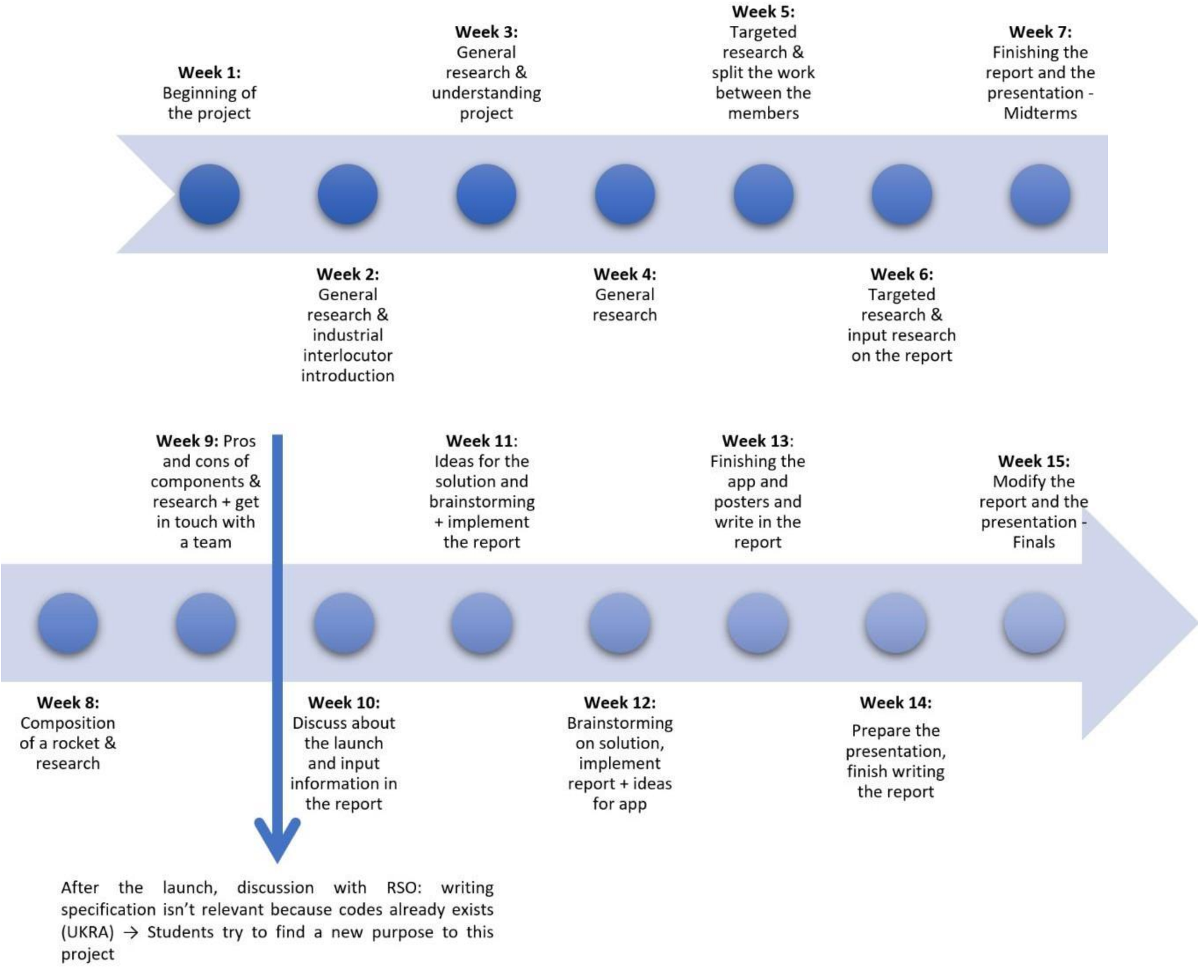


Figure 3: Timeline of the work done over the project

2. Literature Review & Research

2.1. The Rocket

2.1.1. Definition of a rocket

A rocket is a moving object, such as a missile or an aircraft, that is propelled by an engine that develops thrust through the rapid discharge of a fluid, such as hot gases or burning fuel. Spacecraft, missiles, and vehicles for both military and recreational purposes are propelled by rockets. [3]

The term “rocket” only defines the rocket engine. The motor is decomposed into three parts which are the combustion chamber full of very high-pressure gas, a throat which pressurises the gas even more to create a thrust while getting out through the nozzle.
Most of the rocket’s thrust force is generated by pushing the action area.

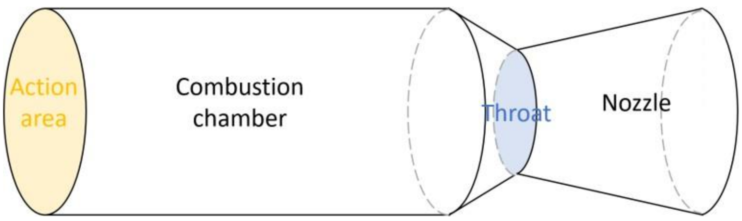


Figure 4: Schematic of a rocket engine [4]

The third law of Newton says: when two objects interact, they apply forces to each other of equal magnitude and opposite direction. Saying so, it is possible to say what is following. [3]

The internal pressure is pushing equally all over the inner walls of the combustion chamber. The pressure against the lower and the upper part cancel out because the same force pushes into two different sides. The pressure is equally spread on both these walls. The pressure against the forward part is not cancelled out because the air is getting out through the back side. There is not equal pressure on these opposite sides. Thus, the pressure on the forward wall hoists the engine in the air. [4]

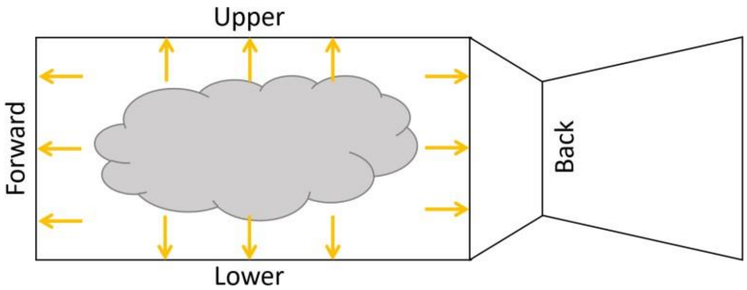


Figure 5: Schematic of the inner forces in the rocket engine [4]

To improve the rocket, it is necessary to reduce the leakage of gas. This should be done without affecting the thrust. Indeed, the thrust allows the rocket to have more energy while launching and getting high. But the thrust forces are equal to the quotient of the internal gas pressure by the action area. [4]
So, the improvement can be done by heating the gas in choosing a propellant that will burn like fuel and oxidizer. However, heating the gas does not increase the thrust, it is the density that drops and less atoms are able to get out.

There are a lot of rules for rockets. The most important ones are:

- Certification flights can only use certified high-power engines
- The high-power rocket engines only can fly from high-power launch sites
- Where possible, detonators should be removed, and all ignition sources switched off before a missile is lowered from the launch position.
- Smoking or vaping within 25 feet of any material used for the launch is not allowed.
- The area around each launch pad must be cleared of flammable materials, few examples are:
    - Solids that form embers (wood, paper, cardboard, fabric, PVC, …)
    - Liquids or liquefiable solids (petrol, diesel, oil, paraffin, polyethylene, polystyrene, …)
    - Gas (butane, propane, methane, dihydrogen, …)
    - Metals (iron, aluminium, sodium, magnesium, …)

Rockets are built in different ways depending on the user or designer, but most of them have lots of parts in common. Rockets of the class can be divided into 3 parts:

- The bottom of the rocket which contains the motor pack, which has the motor on the inside and the fins attached to the outside.
- The body tube which holds and covers the electronics like accelerometer or GPS and where the parachute is usually found
- The top part called the nose cone contains ballast weight for stability and where the second parachute if there is one.

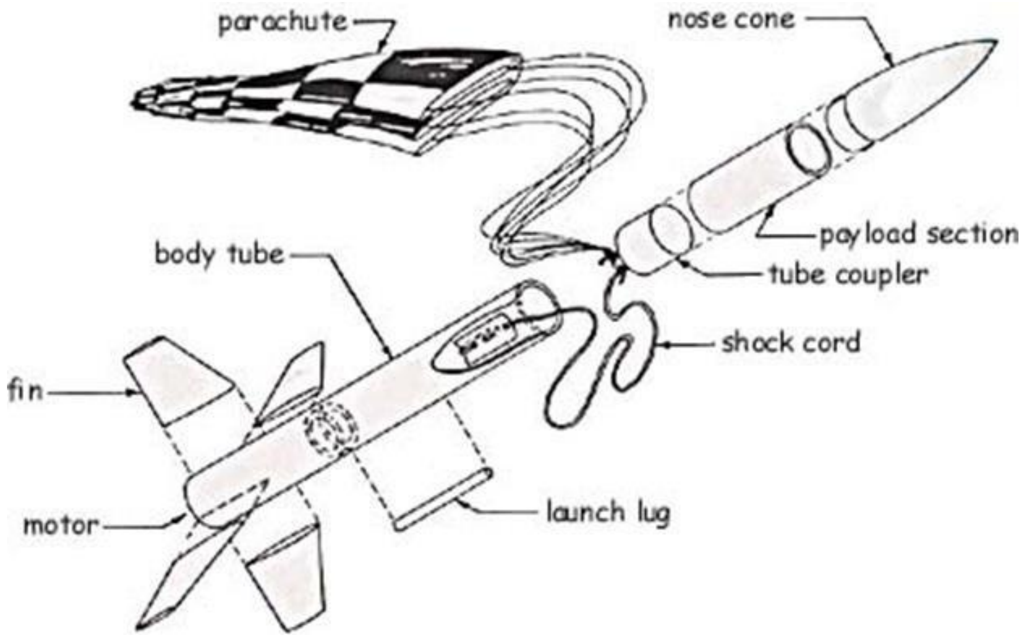


Figure 6: Rocket construction

When building a rocket, resistant and light materials have big advantages, so materials like aluminium and fibreglass are used, and maybe steel and other metals for the electronics and rods. To assure that everything stays in place anything moves when the rocket launches, epoxy and other types of glue are used, and when manufacturing these components builders should wear PPE (Personal Protective Equipment), especially. when cutting the fibreglass tubes, as micro pieces can get inside the lungs. Most rocket builders use simulation programs like 'Rasero' and 3D design programs for the design. [5]

2.1.2. Hybrid engines rocket

Hybrid rocket engines are a type of rocket engine that includes elements of both liquid and solid rocket engines. A hybrid rocket engine uses a solid fuel grain in conjunction with a liquid or gaseous oxidizer.

The solid fuel grain is commonly constructed of polyethene or hydroxyl-terminated polybutadiene (HTPB) and is cast into a cylindrical shape. The oxidizer, which is commonly a liquid or gaseous form of oxygen, is fed into the combustion chamber and combines with the solid fuel grain, creating hot gases that are released via the nozzle.

In contrast to a solid rocket engine, in which the fuel and oxidizer are mixed and burned simultaneously, the oxidizer in a hybrid engine is delivered separately and burns on the surface of the solid fuel grain. This provides better control over the combustion process, which may be changed by adjusting the oxidizer flow rate.

One advantage of hybrid rocket engines is that they are generally safer and more reliable than traditional solid rocket engines, which can be difficult to throttle or shut down once they have been ignited. Furthermore, hybrid engines can be made reusable, with wasted fuel grains simply replenished between flights. [6]

Although hybrid engines are the engines that are most commonly used when creating high power rockets some teams opt for the other engine types to do the different bonuses and drawbacks each engine type use. A list of advantages and disadvantages of each rocket type or rocket is available in the appendices (cf. Appendix 6). [7]

2.1.3. Composition of a rocket

Most of the rockets are built with a maximum of solid and light materials in the meantime. As the second law of Newton says, the acceleration depends on the forces and the weight. [3]

$$a = \frac{F}{m} \tag{1}$$

Where:

- a: acceleration (m/s^2)
- F: force (N)
- m: mass(kg)

If the weight decreases and the force increases, then the acceleration increases. So, the rocket needs to be as light as possible to maximise the acceleration and have the highest energy at take-off.

The elements that compose a rocket are spread into 2 categories which are the metals and the composites.

The aluminium and titanium are two of the most commonly used metals in rockets. It is indeed light, easy to be machined and quite cheap.
The composites are mainly made of carbon or boron fibres mixed with non-metallic matrices such as aluminium and magnesium.
It is also possible to find honeycomb cores especially for panels.

The table in appendix 4 summarises all the components available for rockets, their application and their advantages and disadvantages.

2.1.4. Rocket categories

There are different categories of rockets which depend on the type of motor they use. They are classified in alphabetical order depending on the total impulse executed, measured in N.s. Impulse is Force times the difference in time, which means it is measuring the force acted in the propulsion time. For amateur rockets the classes go from letters A to S, which can reach a height of 43 km [7] and an impulse of 655,360 N.s. Achieved by a University in California which holds the actual record. Rockets with a higher impulse are then classified as professional propulsion systems. [8]
Furthermore, for rockets with motors which can reach at least 160 N.s of impulse, it is necessary to have a certification. There are four levels of certification, Level 1 for rockets from 160.01 to 640 N.s, class H and I. Level 2 rockets go from 640.01 to 5,120 N.s and level 3 have an impulse range from 5,120.01 to 40,960 N.s, class M to O. The last level of certification

needed is a class 3 waiver from the UK's Civil Aviation Administration (CAA), which goes from 40,960.01N.s to 655,360 N.s. (cf. Table 1)

Class	Total impulse (N.s)	Requirements
A-G	<160.0	
H	160.01 - 320.0	Level 1 Certification
I	320.01 - 640.0	
J	640.01 - 1280.0	Level 2 Certification
K	1,280.01 - 2,560.0	
L	2,560.01 - 5,120.0	
M	5,120.01 - 10,240.0	Level 3 Certification
N	10,240.01 - 20,480.0	
O	20,480.01 - 40,960.0	
P	40,960 - 81,920.0	CAA Class 3 waiver
Q	81,920 - 163,840.0	
R	163,840 - 327,680.0	
S	327,680 - 655,360	

Table 1: Rocket classification [7]

2.1.5. Level 3 certification

To build and launch rockets from class M to class O, the level 3 certification is needed. To get this certification it is needed to contact a rocketry association. In this case a good example will be the United Kingdom Rocketry Association (UKRA). It is needed to fulfil a series of requirements, also UKRA provides their insurance. First of all, it is necessary to have the Level 2 certification after obtaining the Level 3.[9] Also, it is compulsory to send a detailed report of the rocket the candidate wants to launch. UKRA recommends sending this written report before the starting of the construction because maybe the rocket does not accomplish the requirements and so will not be allowed to launch. They also will provide a project advisor and supervisor.[10]

2.2. Explosions

2.2.1. Common Fuel Used

The fuels used for rocket launches is vital to understand as different fuels will result in different safety problems and potentially different with regards to rocket launches and problems. Solid rocket propellant, which can include a combination of chemicals like ammonium perchlorate, aluminium powder, and a binding agent is typically the fuel utilised by students to launch M-class motor rockets. Solid rocket propellant is a popular option for amateur rocketry since it is relatively simple to handle and has a high energy density, enabling rockets to reach great heights and velocities. Nonetheless, it is crucial to remember that using solid rocket propellant can be dangerous and should only be done under suitable safety protocols and advice. [11]

2.2.2. Calculating Clearance Area

Several variables, including the rocket's trajectory, velocity, and altitude as well as the launch site's range safety standards, must be considered when calculating the clearance area for a rocket launch. These are the standard procedures for determining the clearance area for a rocket launch:

1. Determine the rocket's highest height for the duration of the flight. Based on the design of the rocket, the engine parameters, and the flight plan.
2. Find the distance that the rocket will travel to horizontally from the launch site.
3. Estimate the hazard area surrounding the rocket's course of flight. This will cover the areas that would be impacted by any debris or a rocket malfunction in flight.
4. Check the launch site's range safety standard, which is the minimum separation required between the rocket's flight path and any inhabited regions or sensitive facilities often specified in the specific site guidelines.
5. Combine the hazard area with the required safety distance to determine the total clearance area for the rocket launch.

It is important to keep in mind that determining the clearance area is a difficult process that calls for deep knowledge and understanding of rocket design, trajectory analysis, and range safety. To guarantee a safe and successful rocket launch, it is advised to seek advice from experienced specialists and respect set protocols and criteria. [12]

For an M-class motor-powered rocket the necessary safety clearance is dependent on a variety of variables, including the kind of engine, the rocket's weight, the projected height it would reach, and the particular restrictions of the launch site being employed as previously stated.

Typically, rocket launches must adhere to a particular set of safety standards determined by the launch location. Among these regulations may be the absolute minimum distances required for launch pads, spectators, and other launch site infrastructure. The authorities at the launch site or the body in charge of rocket launches there will normally specify the necessary Areas of safety.

A good example of this is the National Association of Rocketry (NAR). this organisation has developed a set of basic safety standards that serve as a good guideline for secure rocket launches. For us, the most relevant Rocket engine that we are looking at is the M-class engine-powered rocket and the NAR advises maintaining a minimum separation of 1000 feet between the launch pad and any occupied facilities or viewing areas. (cf. Appendix 2)

However, it is vital to remember that these suggestions only serve as a minimum; depending on the individual launch location and the launch's specific conditions, extra safety measures may be required. To protect everyone's safety, it is essential to check with expert rocketry specialists and launch site authorities to determine the proper safety clearance for your rocket launch.[13]

2.2.3. Calculating Explosion Radius

The formula for determining the fuel explosion radius depends on a number of variables, including the kind of fuel, the amount of fuel, and the circumstances surrounding the explosion.

The TNT equivalency calculation, however, offers a more straightforward method for calculating the fuel explosion radius. According to the following equation, the amount of explosive energy released by a fuel is expressed in terms of the quantity of TNT that would produce the same amount of energy:

$$Explosive\ energy = Fuel\ mass \times TNT\ equivalent\ factor \quad (2)$$

The relative explosive strength of the fuel compared to TNT is measured by the TNT equivalent factor, which varies based on the kind of fuel. For instance, the TNT equivalent factor for gasoline is roughly 0.7, whereas the value for diesel fuel is about 0.8.[14]

To calculate the explosive radius, we also need to know the air blast coefficient
The formula for the air blast coefficient is given:

$$k = \frac{P_d}{P_0} \quad (3)$$

Where:

- K is the air blast coefficient
- P_d is the dynamic pressure of the blast wave (Pa)
- P_0 is the static pressure of the ambient air (Pa)

The dynamic pressure P_d is calculated as:

$$P_d = 0.5 \times \rho \times V^2 \quad (4)$$

Where:

- ρ is the density of the air
- V is the velocity of the blast wave (m)
- P_0 (the statistic pressure) is the air pressure in the area where the blast wave is being measured (Pa)

The air blast coefficient has no units since it is a dimensionless quantity. whereas the static pressure P_0 is measured in psi or kPa, the dynamic pressure P_d is normally measured psi or kPa. [15]

Once these values have be calculated the formula below may be used to predict the explosion radius once the explosive energy has been determined:

$$\text{Explosion radius} = \sqrt[3]{\frac{\text{explosive energy}}{\text{air blast coefficient}}} \tag{5}$$

The air blast coefficient is a constant that relies on the characteristics of the explosion, such as the height and the form of the explosion. Typically, it falls between 1 and 10ith higher numbers denoting more powerful explosions.

It is essential to keep in mind that these formulae are simply approximations and shouldn't be used to determine explosion radii with precision in real-world settings. Accurate evaluations of explosive threats and safety precautions require professional skills and sophisticated equipment. [11]

2.2.4. Calculating Fragmentation from Explosion

The fragmentation of an exploding rocket engine can be calculated using the following steps:

1. Calculate the explosive force by utilising the type and quantity of propellant in the engine.
2. Establish the engine's structural strength, taking into account aspects like engine's design and casing strength.
3. Determine the energy needed to break up the engine. This may be done by utilising equations that take into account the mass of the engine as well as the energy needed to break up the materials.
4. Evaluate the energy needed vs the explosive force. If the engine needs more energy to fracture than the power of the explosion, the engine will not fragment.
5. Calculate the size and form of the shrapnel. This will rely on the engine's layout and the explosion's force parameters.

It is important to keep in mind that figuring out how a rocket engine would fracture when it explodes is a difficult procedure with potentially many unknown altering factors. So, it is crucial to exercise caution and implement the necessary safety precautions when handling rocket engines. [16]

2.2.5. Formula for Explosive Fragment Distance

The distance of explosive fragments can be calculated using the following formula:

$$d = \frac{W}{2} \times \frac{V^2}{g} \times \sin(2 \times \theta) \tag{6}$$

Where:

- d is the distance of the fragments from the point of detonation (m)
- W is the weight of the explosive charge (kg)
- V is the velocity of the explosive wave (m/s)
- g is the acceleration due to gravity (9.81 m/s^2)
- θ is the angle between the line of sight and the horizontal direction (rad)

This calculation assumes that the fragments are distributed uniformly around the explosion's point of detonation and that the explosion occurs in an open area without any obstructions that could impact the fragments' trajectory. [16]

2.3. Existing safety protocols

Many different safety protocols can already be found on the internet. Among others from NASA, UKRA, TRIPOLI, and many more. Yet all these safety protocols are like each other. There are important elements that will be mentioned below.

2.3.1. General Rules

Below there are some general rules written for the student teams.

- All participants must be properly trained in rocketry safety and adhere to all applicable laws and regulations such as the UKRA safety code. [8].
- All participants must wear appropriate safety clothing and equipment, including eye protection.
- All participants must be familiar with the launch site and observe any posted regulations.
- All launch vehicles must be inspected prior to flight for airworthiness and safety.
- No launch vehicle should exceed the launch site’s altitude limitations.
- All launches must be conducted in accordance with the manufacturer’s instructions.
- All engines must adhere to the safety rules for appropriate engine classes.
- All flights must be monitored by an experienced adult or launch director.
- All launch personnel must be familiar with the launch site's emergency procedures.
- All participants must be aware of their surroundings and be prepared to take appropriate safety measures in the event of an emergency. [17]

2.3.2. Operation

When operating a student rocket launch team, the team must ensure that they are in compliance with all applicable state, local and federal laws, regulations, and safety protocols. This includes having the necessary permits, insurance, and safety equipment. Additionally, the rocket launch team must ensure that the rocket is designed and constructed according to best practices and that all launches are closely monitored and supervised by trained personnel. Finally, the team should take special care to ensure that the launch site is free from

any hazards and that the rocket is launched in an area with sufficient space for the rocket to safely reach its maximum altitude. [11]
Radio-Control Boost Rocket Glider Rules Radio control is very important while launching a high-power rocket. That is why there are some rules drawn up to follow for radio control.

- All participants must abide by all safety regulations and guidelines established by the event organiser.
- All participants must have a valid insurance policy and proof of coverage prior to participate in the event.
- All participants must provide their own radio-control boost rocket glider, batteries, and fuel.
- All participants must use appropriate safety gear such as helmets, gloves, eye protection, and closed-toe shoes.
- All participants must be at least 18 years of age.
- All participants must adhere to all local laws and regulations regarding the use of radio-control boost rocket gliders.
- All participants must adhere to the rules set forth by the event organiser.
- All participants must respect the rights of all other participants and act in a manner that is conducive to the event.
- Any participant found to be in violation of the rules or regulations may be disqualified from the event at the discretion of the event organiser. [18]

2.3.3. The Launching site

The launch site is an important part of the safety regulations when launching rockets. Launching rockets can involve many dangers, which is why it is important to know well what requirements the launch site must meet. For example, the distance from the rocket to the spectators and the operators' is very important. The desired distance differs per rocket. That is why there are several tables indicating the desired distance (cf. Appendix 2). This can also differ per launch site.
There are also some standard rules for launching the rocket. These rules are obvious but very important. First, of all, fly your rocket in an open field. There should not be any obstacles on the field. This means you can not fly near trees, never fly near houses, and do not fly near highways because this can be dangerous for the people driving the highway. [19]

2.3.4. Legal requirements to flying a rocket

It is not illegal to fly a rocket without a certification. A lot of rocket motors can be purchased or flown and stored. But minors cannot purchase most of the rocket motors. You have a responsibility under the law to avoid putting other persons, property, or aircraft in danger when you are flying, and it is against the law to fly any aircraft, including model rockets and aeroplanes, into controlled airspace. The Civil Aviation Authority (CAA) regulates this activity through the Air Navigation Order (ANO). [11]

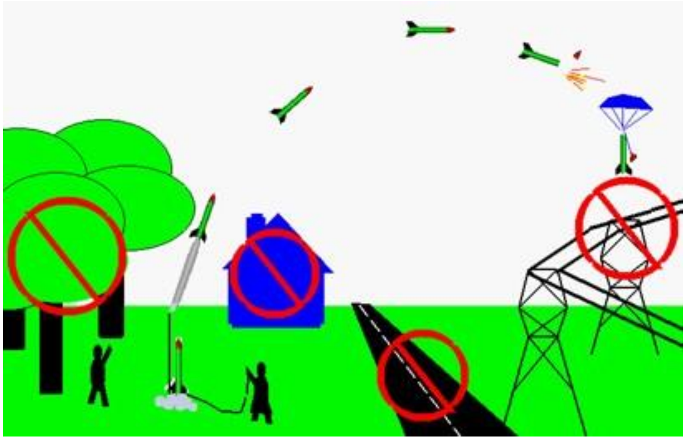


Figure 7: Safety rules for rocket [17]

2.4. Reviews on past reports on problems that happened

Over the last century, a lot of student teams and companies tried to launch rockets. But some of the projects do not end well. Sometimes it can even be tragic. This part of the report is focusing on why problems happen and especially if it is linked to safety guidelines.

The research has shown that in most of the student rocket accidents, no report is written. Indeed, students tend to focus on the technical aspects of the rocket before the launch. Their aim is to launch the rocket as fast as possible and as high as possible.

However, big projects such as the space shuttle always write a report after an incident. The reports present the issues linked to safety and what are the recommendations for the company to avoid this kind of event. If big companies must follow these guidelines to prevent accidents, then students should follow them as well.

2.4.1. Space shuttle Challenger disaster

NASA launched the space shuttle Challenger on the 28th of January 1986. This is one of the most devastating explosions. The launch was performed at 26°F (-3°C) which is a pretty low temperature. The shuttle's launch has been delayed many times. NASA did not want any more delay.

All 7 crew members died during this explosion.

The Rogers Commission determined causes and faults of the disaster.

For this mission, the Commission raised several issues in Safety, Reliability & Quality Assurance (SR&QA). As it is said in the report, "NASA has reduced or reassigned to other program areas inhouse SR&QA such as testing, analyses and instrumentation". [20]

The report concluded saying that the "existing contract incentives used by NASA do not adequately address or promote safety and quality concerns most emphasis is placed on meeting cost and schedule requirements". [20]

To avoid this kind of accident, the commission asked NASA to establish an appropriate office of SR&QA and define "the organization, goals, implementation strategies and resource requirements". [21]

2.4.2. Space shuttle Columbia disaster (mission STS-107)

On the 1st of February 2003, space shuttle Columbia disintegrated as it re-entered the atmosphere, killing all seven astronauts on board.

This disaster is also one of NASA's programs. Following this incident, the Rogers Commission wrote a report once again. They said that this accident was caused "during the lift-off by the breaking off of a piece of foam that was intended to absorb and insulate the fuel tank". [22]

In this report, the commission evaluated the best safety practices that exist in other programs to give an example to NASA. They used three specific independent safety programs which are the U.S. Navy Submarine Flooding Prevention and Recovery (SUBSAFE), the Naval Nuclear Propulsion (Naval Reactors) and the Aerospace Corporation's Launch Verification Process.

Using those examples, the commission highly recommend NASA to follow the rules listed below:

- <u>Communication and Action:</u> People from different levels should be informed of technical decisions and actions that affect their area of responsibility.
- <u>Recurring Training and Learning From Mistakes:</u> The company should learn lessons from both inside and outside programs and keep it in memory. They should understand and learn from their past failures in order to implement extensive safety training.
- <u>Encouraging Minority Opinions:</u> Asking for everyone's opinion is a good way to have multiple perspectives and critical questions to move on.
- <u>Retaining Knowledge:</u> The aim of this rule is to keep the key personnel in headquarters informed. They are put into field positions to remain familiar with aspects of operations, training, maintenance, development and the workforce.
- <u>Worst-Case Event Failure:</u> The company should evaluate and be prepared for potential damage and worst-case scenarios.
- <u>Clear Documentation:</u> Requirements should be achievable and not easily waived.
- <u>Separate Verification Organization:</u> An independent highly capable organisation should be able to assess program management and monitor the program for compliance.
- <u>Dissociate Safety and Technique:</u> The company should not have to joggle costs between safety and schedule. To do so they should try to get immune to budget pressures. However, it is difficult to put in place in NASA's case because of political and administrative pressure.

The Rogers Commission also noted some issues in NASA's organisation. Indeed, it is said that "Headquarters dictates what must be done, not how it should be done. The operational premise that logically follows is that safety is the responsibility of program and project managers".[23]

2.4.3. VLS-1 Rocket accident

The Brazilian Space Agency's third attempt to launch the VLS-1 rocket on the 22nd of August 2003 did not go as planned. Indeed, this launch is remembered as the saddest Brazilian space program because of the tragic accident that resulted.

The accident happened after the ignition of a first stage engine. This was probably due to electrostatic induction in the detonator.

But the report mentioned that this accident was also due to a “disinvestment in the programme, downsizing, overwork and lack of procedures” that have “seriously compromised the safety of the operation”. [24]

2.4.4. Summary of accidents

These research and these accidents show us that most of the accidents that happened are for sure linked to technical issues, but those technical issues appear because of a lack of safety guidelines.
Despite safety guidelines, other factors can interfere in an accident like the ones presented above such as overwork, requirements waived and costs issues.
But for the students' rockets, these factors are not as important because the resources involved are less significant.
However, since the reports give a lot of safety guideline advice, especially for NASA, it can be interesting to put them in place in a student's rocket team. Indeed, if such a program as NASA can avoid accidents thanks to those measures, then students should put them in practice for their projects.
Finally, the issue brought by this project is more than necessary to be solved since no guideline existed to frame the students' projects.

2.5. International Rocketing teams

2.5.1. United Kingdom

Sheffield

A UK altitude record for powerful rockets was established in 2019 by Team SunrIde from the University of Sheffield, which is composed of engineering and science students from throughout the University. The UK Rocketry Association has subsequently officially certified the record (UKRA).
The Sheffield students broke the UK record, which had stood for 19 years, by reaching 36,274 feet while competing in the Spaceport America Cup on behalf of the University of Sheffield and the UK. They were up against students from more than 120 of the world's top scientific and technology universities.
As part of the University of Sheffield Space Initiative, the students spent the whole academic year planning and building their rocket before travelling to New Mexico in the US to compete (SSI). In honour of Dr. Helen Sharman OBE, a science graduate of the University of Sheffield and the first British to travel to space, the record-breaking rocket was given the name Helen. [25]

Edinburgh

At a competition in Portugal in October 2022, a group of Edinburgh students captured a successful and innovative rocket launch. The University of Edinburgh team Endeavour

travelled to Ponte de Sor to compete in the European Rocketry Competition, where their Darwin III rocket ascended to a height of 7000 metres.
The rocket was also moving at 1.7 times the speed of sound and carrying a complete set of PCBs for data collecting, telemetry, power distribution, and GPS tracking that were built and coded by students. According to Endeavour, although experiencing a recovery anomaly, the data that was recovered verifies the highest height achieved was 6935 m. Also, based on barometric data, Darwin III outperformed in terms of velocity, going faster than the maximum speed that was predicted. [26]

Strathclyde

On July 12, 2022, a student team from Strathclyde University launched a rocket successfully and took first place in a contest to develop and construct a launch vehicle in space. Powered by UK Launch Services, UKSEDS, and Explore Space UK,
The Stratosphere 1 rocket was intended to fly to a height of 1,000 metres before releasing the two CanSats and a parachute. Following a successful launch, the crew demonstrated the rocket to local kids and explained how it operated.
In order to determine the team scores, three design evaluations that were conducted during the year were taken into consideration, along with flight performance. Strathclyde defeated University College London to win the 1000m Combination Category. [27]

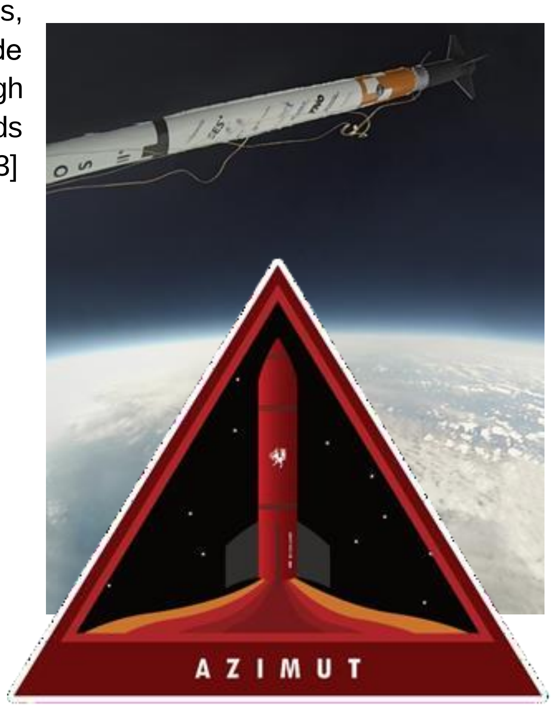
Every University student who is interested in space or space exploration can participate in the SSI programme of extracurricular activities. The project, which is open to undergraduate and graduate students in any faculty, was started to get students interested in the engineering and science problems associated with space travel. [26]

2.5.2. The Netherlands

Delft aerospace rocket engineering

Delft Aerospace Rocket Engineering (DARE) is a student organisation at the Delft University of Technology in the Netherlands. Founded in 2006, DARE is a student [18] organisation that aims to provide a platform for students to gain experience in rocket design, build, and launch. The organisation is 100% run by students and provides students with the opportunity to design, build, and launch a rocket of their own. [29]
DARE's primary mission is to design, build, and launch a student-built rocket that can reach an altitude of at least 32,800 feet (10 km). The organisation

has successfully achieved this goal, launching the student built “Stratos” rocket in 2015, which reached an altitude of 37,700 feet (11.5 km). [30]
The organisation has also launched several other rockets, including the “Eurydice” in 2017, which reached an altitude of 111,500 feet (34 km). In addition to reaching high altitudes, DARE's rockets are designed to carry payloads such as scientific experiments and imaging equipment. [33]



Space Society Twente

Space Society Twente is a student association from the University of Twente. The association covers space exploration, astronomy, space engineering, and space policy. They have several projects. The most ambitious project is AzinUT. [28]
AzinUT started in 2021. SST is currently still developing and working on building and launching rockets. The team is working on introducing rocketry to the University of Twente. They are planning to build rockets that will make them participate in national and international challenges. [31]

2.5.3. France

PERSEUS (Student European Project of Space and Scientific Research) is a project organised by CNES (Nation Centre of Space Studies) [32]. Their aim is to promote spatial activities to students in their school/campus/college through spatial projects. The industrial and pedagogic aspects are important. Students can develop their skills and look for technical and innovative solutions that can be put in place on space transport.
Starting in 2005, the project is made of 3 main points which are:
- Promote the professions of the pace sector
- Promote innovation and the development of technology
- CNES & PERSEUS at the service of students

Since 2005, about twenty experimental rockets (ARES) have been launched. [34]

2.5.4. Spain

Student association ‘Cosmic Research’, from Universidad Politecnica de Cataluña, Spain, built and launched the supersonic suborbital most powerful in Spain built by students. 30 November. 8km high, 1900 km/h. 16 students. Supersonic means it passes the speed of sound. (1234.8 km/h). This rocket only was propelled six seconds and got a height of 2.4km the rest of the altitude was just by inertia, till 8km. Cosmic Research also developed their own flight simulator so they could make their own flying predictions. [35]

3. Launch of a Rocket (site visit)

3.1. Rocket launch lead by the Leeds University (LURA)

The team has been given the opportunity to attend a rocket launch on 02/04/2023. The team was invited by their industrial supervisor Andrew Paliwoda to attend the launch of a rocket made by the student association LURA of Leeds University at the SARA Fairlie Moor launching site.
For the students of LURA, it was the second day testing the rocket they designed and made during their master project.

LURA
LEEDS UNIVERSITY ROCKETRY ASSOCIATION

Figure 8: LURA's logo

The LURA project “Project Aptos” is a project where the team is developing an aerodynamically active stabilisation system. This technology should ensure that rockets fly perfectly vertically, which means they fly higher.

During this project, a new rocket was built, The Pathfinder. This rocket functions as a prototype to test active control flights. This rocket was launched on Sunday 02/04/2023.

3.2. The launching site

The launching site where the launch took place is the SARA Fairlie Moor Launch site. This is located on the Fairlie Moor Road, which runs east-west between Dalry and the Ayrshire coast. Figure 9 and Figure 10 show an image of the launch site on 02/04/2023.

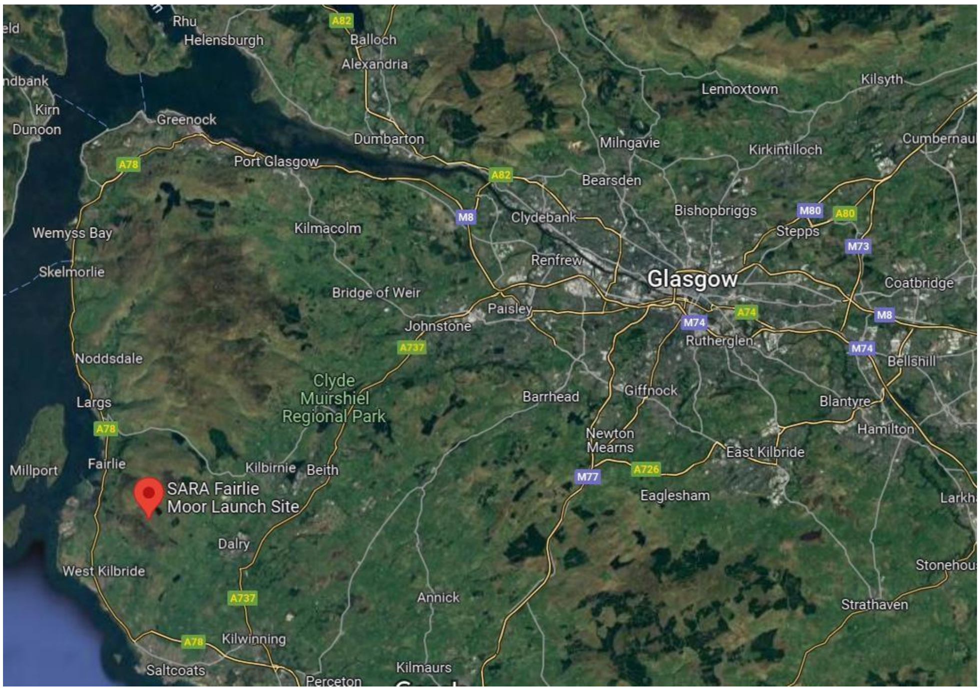


Figure 9: Location of the launching site

Figure 10: The launching site SARA

3.3. Elements for the launch

First of all, it is the RSO (Range Safety Officer) job to determine whether the weather conditions were suitable for launching or not. In this case, the RSO was M. John Bonsor, a member of the UKRA. His mission was to make sure the launching was safe and made in good conditions. After his approval, the rails were set up. All parts were carefully assembled and hoisted up.

Figure 11: The rail (first photo), the rail support (second photo), the tripod (third photo)

In the figure above, we can see three different elements that compose the launchpad. The rail shown on the first photo is spread into three parts of 2 metres each. They are fixed together and to the rail support shown on the second photo. The rocket is mounted on this rail. At launch, the rocket slides up the rail.

The rail support is spread into four parts of 1,5 metres each and fixed together.

Finally, the tripod shown on the third photo ensures that the rail and the rail support remain firmly in place. Each leg of the rail is 2 metres long and the whole structure is heavy, so the risk of the construction falling over is lower. The tripod is also levelled so that the construction is straight.

When all parts have been assembled and properly checked by the team, the launchpad is complete. The construction is 6 metres high. Once the construction is complete, it's time for the team to prepare the rocket for launch.

Figure 12: The launching rail fully assembled

3.4. Preparing and checking the rocket before launching

After the rails had been put together, the rocket was removed from the car and the preparation of the rocket could begin. The rocket was transported by the team in a duvet, which reduced the risk of damage. They then placed the rocket on a table they had taken to the launching site. First, all parts were checked thanks to a checklist they had written. They verified if all the parts looked good and had no damage. The rocket was then assembled and prepared for launch. In Figure 13 it is possible to see the pins that go into the rail. This is what allows the rocket to be guided by the rail during launch.

Figure 13: The rocket (left photo) and the red fixations for the rail (right photo)

While much of the team members were busy preparing the rocket, another team member was preparing the equipment for the launch. The LURA team had made the 2 boxes themselves. One was close to the rocket and the other had the launch button and it was at a safe distance from the rocket.

These two boxes are working together. The one near the rocket relates to a wire to the rocket. It sends an electrical signal to the system to allow the landing. The box is equipped with two switch buttons (ON/OFF). The first one is for the power and the second one for the isolation. If both the buttons are not on the position ON, then the rocket will not land. This provides security to the launch. Those buttons are activated once the whole team is at a safe distance. The second box is at a safe distance from the rocket and still connected to the first one with a cable. This box has a counter. It can be launched only if a key has entered and unlocked the lock. This helps launch the rocket in a safe and controlled environment. The red button is pressed to land the rocket.
The person switching the buttons ON is the same unlocking the lock and pressing the red button to launch the rocket.

Figure 14: The boxes near the rocket (left photo) and at the safe distance (right photo)

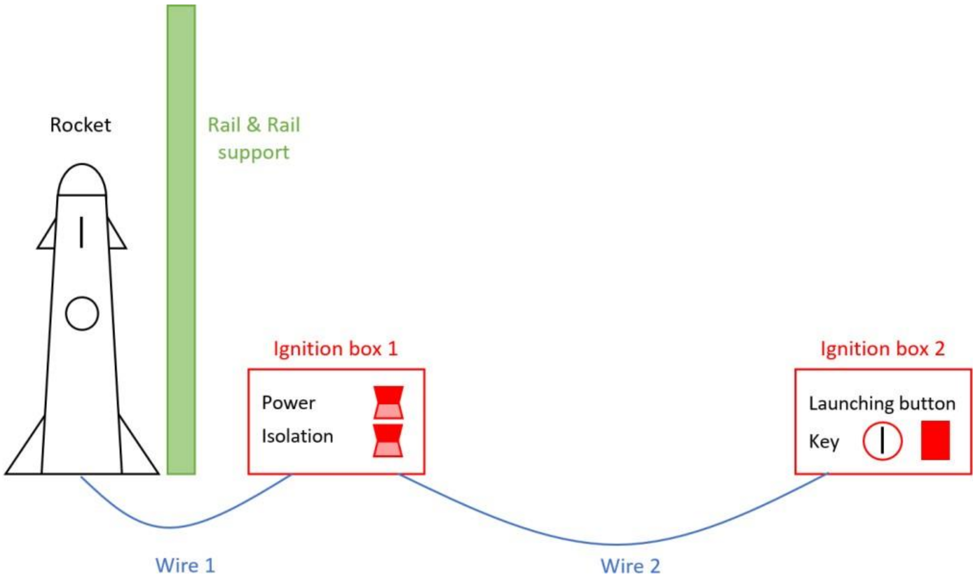


Figure 15: Functioning of the tow boxes

The team puts the cone all together on top of the rocket. It is then time to slide the rocket into the rail. This must be done with some precision as the fixations on the rocket are very fragile. If the team let the rocket hang down too much, it can break off. This is why the Figure 16 shows how the team lowered the rocket into the rails together with full concentration and good teamwork.

Figure 16: The rocket fully assembled

Figure 17: Placing the rocket into the rail

3.5. The launch

When the whole team had sufficiently distanced itself from the rocket at more than 45m (148ft) everyone gave permission for the launch, once permission was given by all involved one of the team members pressed the launch button, and the rocket was launched. This is important to note as this relates to the incident that occurred the launch went very smoothly according to the team. At his highest point, the parachute opened, and the rocket slowly fell. The team kept a close eye on the direction in which the missile fell so that it was easier to find.

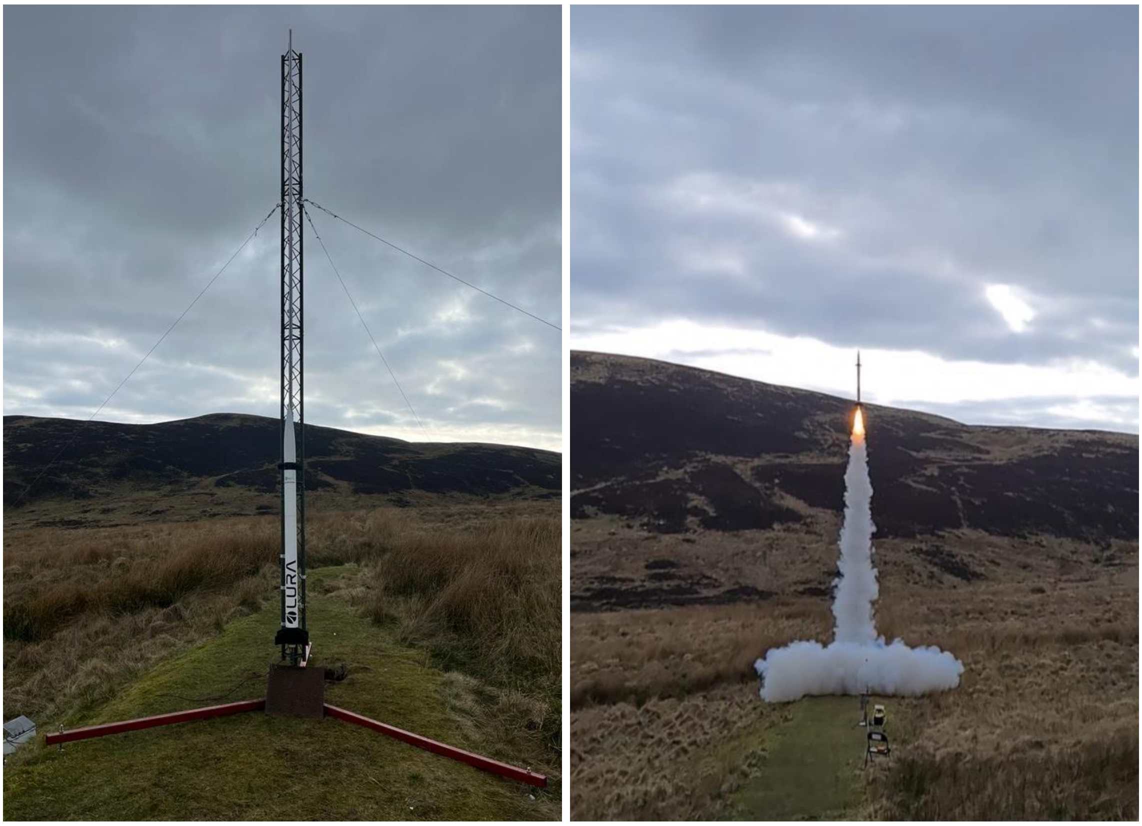


Figure 18: The rocket before (left photo) and during (right photo) launching

Figure 19: The landing of the rocket slowed down with the parachute

The team went looking for the rocket and when they found it, they first recorded everything before taking the rocket with them. The team members took pictures and discussed some points on the checklist before taking the rocket back to the launching site. Once back, the entire team reviewed the rocket and the launch data. They discussed what went well and what could have gone wrong.

Figure 20: Landing site

Figure 21: Pick up the rocket and storing the parachute

Figure 22: The rocket after the launch

3.6. Conclusion on the rocket launch

After visiting the launch, the team members came to a few conclusions. Here are some of the positives and negatives aspects noticed during that exercise.

3.6.1. Positive aspects

After assisting with the launch, the project team found out that checklists are already being used which was created by experts within this field, ensuring the quality of these checks were

of a high degree. In fact, the LURA team had its own checklist which was very comprehensive, and the team members felt that the whole launch went reasonably safely and structured.
People seemed to be a good distance since the RSO was here to prevent risks before and during the launch.
The team members were equipped with walkie talkies which facilitated the communication between each of them.
Finally, the launch seemed to be secured with the two boxes providing switch buttons and a lock to make sure nobody was near the rocket during the launch.

3.6.2. Negative aspects

On the other hand, the team observed some negative aspects about this launch. First of all, there was not any first aid kit visible or indicated on the site. This means that the visitors could not reach the kit without asking the student's team. The vehicles were parked near the launchpad, near the road. On the road there were no signs warning people they were entering a launching site and debris could fall from the sky. This is also very dangerous as people are driving as nothing is happening. However, marking the area could help the vehicle adapt their driving style and maintain a constant attention passing through this area.
The rocket was transported in a car in a duvet which did not seem to be good transportation. Indeed, the members assisting the launch wondered if the rocket could explode during such transportation.
Finally, as visitors, there were not any warning signs, or barriers to stay away from the rocket. Actually, as visitors, the members of the team were able to be near the rocket when it was hoisted on the launching pad which can be really dangerous for people that do not know anything about rockets and how dangerous it can be.

4. Solution

4.1. Brainstorming and ideas for a solution

At the beginning of the project, the team focussed their research on rocket in general. The aim was to produce a list of specifications for the team launching a rocket. To do so every team member had to get some knowledge about the rocket.
It was particularly found out that there were some safety issues on the rocket launching.

The team was proposed to assist with a rocket launch on week 10. It was mainly necessary to get knowledge on rockets and interview a team on the security and safety put in place for this launch.
However, the students launching their rocket already had a checklist that must be fully covered before the rocket can be launched. The particularity is that each rocket needs to have their own checklist because of all the design possible. Indeed, every design and conception do not have the same elements and the checking is thus not the same.
After research, it turns out that teams usually do have good information and checklists, but they are all written on paper.
A discussion with the RSO brought up to the team that safety specifications already exist. This is the UKRA code.

After this the team had to question the subject and find a new solution. It was proposed to use the code already in place and create a simple device to use it. As the team had long weeks of research to find everything about the rocket, they wanted to produce a tool that allowed the student's team to get all the information they needed in one go.
The team, therefore, came up with a solution to keep track of this in a safer and more efficient way. Namely, creating an application where everything can be kept in one place. All the information in the code will be available and it will be simple to use for the students.

During the launch the team also noticed that a lot of information was given by the RSO. As visitors, the team was not able to recognise all the safety measures put in place. The RSO was the only one able to indicate the first distance.
Then the team decided to come up with recommendations for the team launching and for the visitors.
To make sure everyone is aware of the recommendations and the danger they are putting themselves in, the team will design posters and signposts for different purposes.

4.2. The Survey

4.2.1. Results of the survey

To make sure an application is ideal for achieving the goal, a short survey was conducted. The survey includes questions to find out how often a smartphone is used and whether users like having a digital list.
The survey received 43 answers. With this, a few conclusions can be drawn.

The first questions focus on personal data of the responders. This makes it clear what the target group is of the people who completed the survey. This is what the picture below is presenting.
Here it can be seen that 90% of the target group is aged between 18-30 years old.

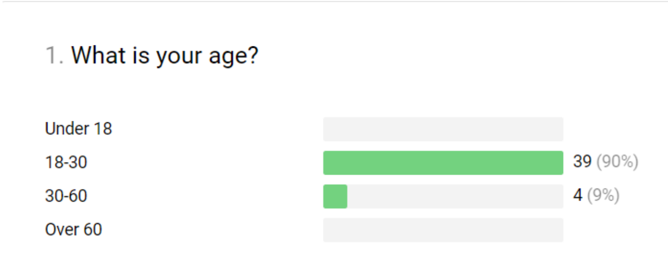


Figure 23: Results to question 1 of the survey

Of the responses, 60% are female and the rest are male as it is shown below.

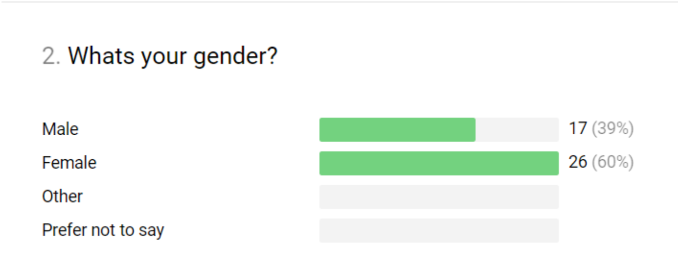


Figure 24: Results to question 2 of the survey

The responses had different nationalities, 16 French, 12 Dutch, 7 Spanish, 5 Scottish, 1 Egyptian, 1 American, and 1 Nigerian.

Figure 25: Results to question 3 of the survey

The last question on personal information is asking about the responders' occupation. Most of the responders are full time students, apart from that there are a few full times working, part time working, part time student and a small part unemployed. None of the people who completed the survey are retired.

Figure 26: Results to question 4 of the survey

The next question was asking the responders how many hours per day they use their phones. Here the answers were more scattered. Most of the responders used their phones between 4 and 5 hours a day. The rest of the group use their phones 0 to 3 hours or 6 to 8 hours a day. 1 responder uses his phone more than 8 hours a day.

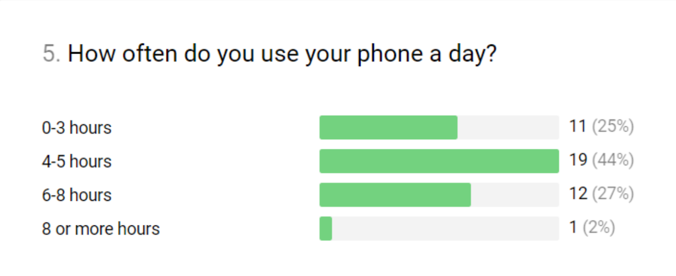


Figure 27: Results to question 5 of the survey

The question following clarified the reason why responders use their phones. The survey shows that the phone is most commonly used for entertainment, communication and social media. A small proportion use their phone for work and 1 person said he also use his phone as a GPS.

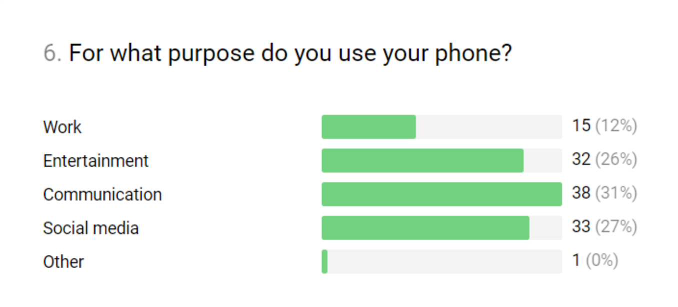


Figure 28: Results to question 6 of the survey

Responders were also asked how many applications they have on their phones related to work or studies. In this part of the study, just over half of the responders had 1 or 2 such applications on their phone. The rest had more than 3 such applications on their phones. None of them had no work or studies-related applications on their phone.

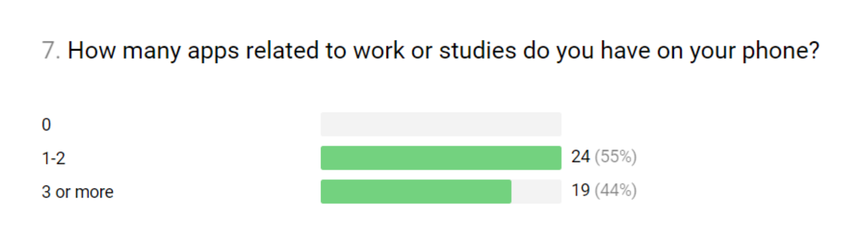


Figure 29: Results to question 7 of the survey

The question following provides information on whether responders prefer paper and electronic checklists (e.g., a shopping list). 72% would like to have their checklist electronically, 27% would rather have it on paper

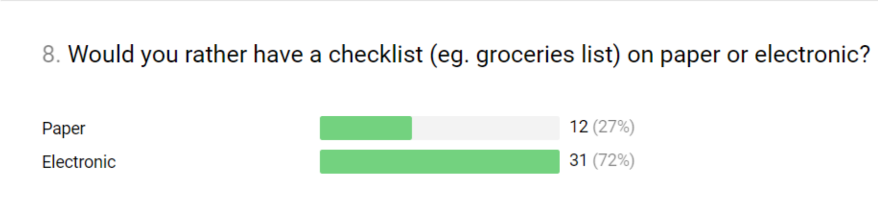


Figure 30: Results to question 8 of the survey

To better understand why responders prefer paper or electronic checklists, they were asked to explain their preferences for one or the other. Different types of answers came from this question.

Those who indicated that they preferred paper gave the reason that paper is more reliable, paper does not have any glitches or problems. Someone mentioned that paper can easily be put on the kitchen table, so that everyone can add whatever they want to the list. Another responder indicated that they do not like use their phone when they are shopping. It was also said that it is nice to have something physical to take with you and not forget.

The people who indicated they prefer an electronic list gave the reason that they almost always have their phone in their pocket, and the list in it as well. Many people also indicated that they do not like wasting paper. The fact that electronic lists can be adjusted was also mentioned. Things can be removed or added. Changing the list on paper creates more chaos, which is exactly why the responders do not want with a paper checklist.

9. Why do you prefer either paper or electronic?

Response #43 - I prefer paper because I'm more used to it, I find it practical and I don't have to use my phone in the mall.

Response #42 - Le papier est plus concret

Response #41 - Always have my phone with me

Response #40 - Electronic uses no paper

Response #39 - Can be put on kitchen table and complete by everyone

Answered by 43 of 43 respondents

Figure 31: Results to question 9 of the survey

4.2.2. Conclusion on the survey

Based on the survey, it appears that creating an application is a relevant solution for Spaceport1. This conclusion was drawn based on the following results from the survey:

- Phones are mostly used for entertainment, social media and communication. It can still be used for work.
- Almost everyone has work or studies-related applications on their phone.
- The majority of people prefer to use an electronic checklist.
- The most common reason is that an electronic list is more reliable and always easily accessible for the users.

4.3. The application

4.3.1. The application operation

The application is the first tool the team decided to create. It will be available for the team launching mainly as well as other rocket enthusiasts and will provide several information sources.
To use this application, every user must create a profile. This profile shows your personal details, your certificates, your team and other information. This application will provide the students with the general UKRA safety protocol. This application will also be equipped with a free place where teams can create and then use their own checklist and digitally record what has or has not been ticked off.
By doing this in an application, the risk of losing data is significantly smaller. Besides these main features, the application can also provide the weather forecasts and find important contacts for booking a launch site or getting help from professionals by allowing people to chat with one another.

4.3.2. Content of the application

After several brainstorming, it was decided which elements should be in the application. The list below presents all the elements the application should contains:

- A possibility to create a profile where all important personal data can be stored such as name, age, gender, profession and possibly specialty, certifications, experience and so on.
- A place where registration cards for launches can be filled in and stored digitally. This will help reduce printing and make sure the team get access to those documents in seconds.
- Creating a checklist: as described earlier, teams often have their own checklist, but these are usually on paper. The application has a place where the team can fill in their own checklist, making it digital. This way the whole team has access to the checklist and can modify it whenever it is needed. When someone checks off something on the checklist, the whole team receives a notification and it is digitally recorded where, when

and by whom this task was checked off. This allows the team to prevent problems and better analyse any issue

- Weather forecast: the application also includes a weather forecast with wind, air pressure, rain, humidity and so on. The weather is very important because bad conditions can lead to a cancellation of the launch.
- Safety specifications: URKA has a very clear and good safety code in the UK. It is important that all the team can access this document quickly and easily. Therefore, a shortcut would be created in the application to allow users to get direct access to the document as easily as possible.
- Location: the application will display a map showing all the different launch sites. Information about each launch site and how to reach it can also be found there.
- Countdown: there is also a countdown to keep track of how much time the team has until their launch. The team will then be aware of the number of days remaining until the launch and take care of everything that need to be done before to respect the deadlines.
- A feature that keeps track of the progress in percentage of each task until there are completed. The team will know what need to be done and if they are early, late or on time.

4.3.3. Design research

For creating the application, the team followed the basic structure for any product design. The first phase is market research. The team wanted to search some functional mobile applications which had similar function, like “Noysi” [36], “Google drive” or “Asana” [37], and other popular applications that worked directly with the user’s needs, like “Spotify” [38] and “McDonalds”.

The result of these research helps identifying the important elements that can be added to this application to be successful and satisfy the user’s needs. It also provides some ideas of layouts and essential features. The photos following are summing up the research.

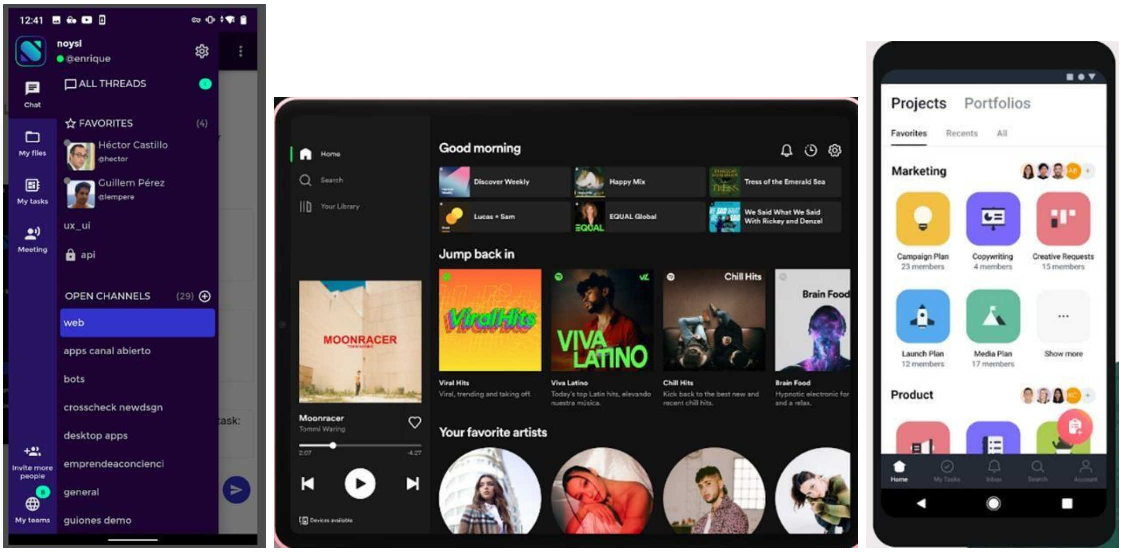


Figure 32: Noysi menu page [36], Spotify’s home page [38], Asana’s home pag e[37]

The team then defined the style of the application. The style board is a set of different images and inspirations to define a style that will draw the user's attention. In this case the target users are rocketry teams.
The image below presents the style board just mentioned. This style board was created to gather ideas on the potential style of the application. It is also important for the designers, so they do not lose track during the creation phase.

Figure 33: Style board for the application

Afterwards, the team identified which parts of the phone were easily accessible and which ones are not easy to reach. The figure following (cf. Figure 34) shows the different parts of a smartphone screen that can be reached. [39]
This helped the team decide how to organise the layout and to find the ideal place for each button. The most used buttons are best placed in the easiest area to reach (cf. Figure 34, the dark green parts), slightly less important buttons can be placed in the light green parts and the least used buttons can be placed in the yellow or hard to reach area.

Figure 34: Ergonomics for UX design (User eXperience design)

The figure bellow (cf. Figure 35) shows how the easy or hard-to-reach areas are moving on the screen depending on the hand position. Nevertheless, single handed is the most used and common way to hold a smartphone.

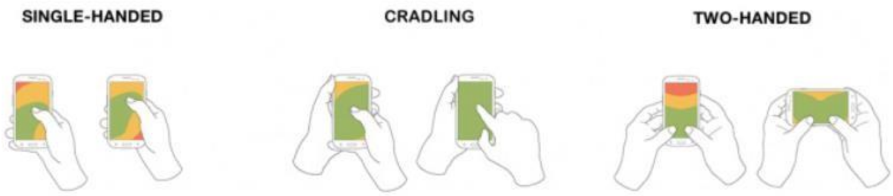


Figure 35: Different ergonomics for different hand position

4.3.4. Ideation phase

To create this application, the design must be clear and attractive to use. The ideation phase is a phase where the designers are creating ideas, brainstorming and portraying those ideas into sketches. A lot of different sketches were made such as different layouts, loading pages and other features of the application. The picture below shows the quick sketches made by the team members. These sketches can help test a lot of different things and figure out which idea suits the best.

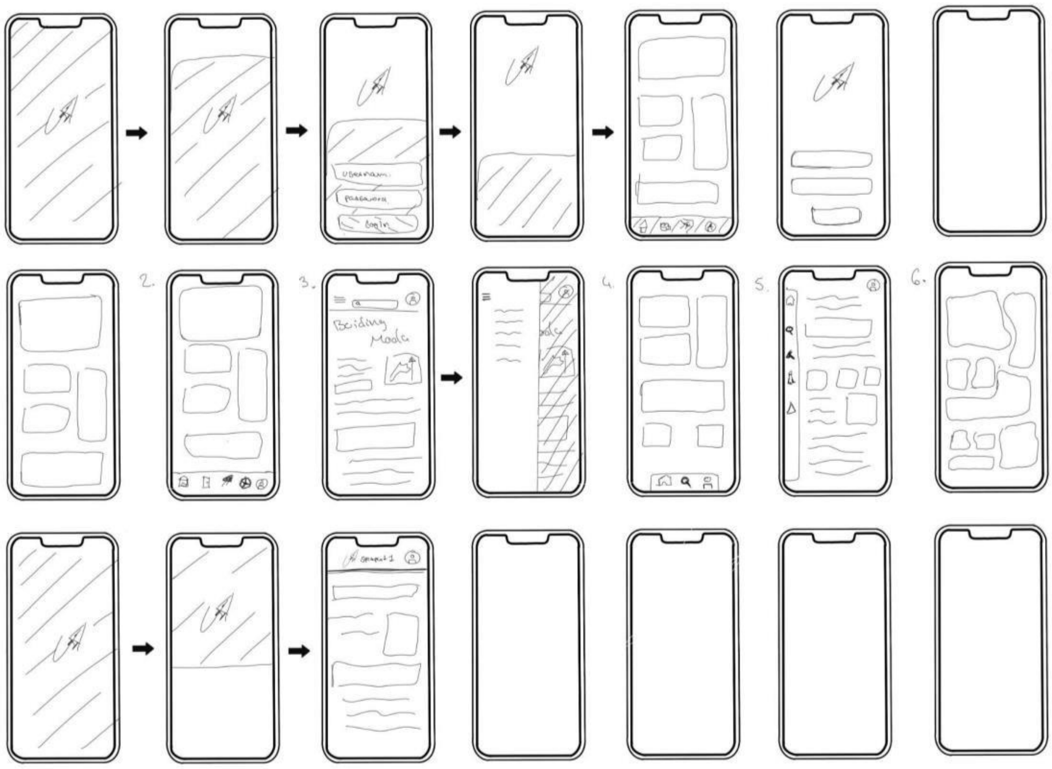


Figure 36: Sketches for the application

The home page will show all the features included in the application on the screen. This way, the users will save time, they will not have to scrolling or open a menu. The layout of the will help the user navigate and recognise easily the elements of the application.

A map is created to describe and show how the application is working and what is hiding behind each icon.
The sketches below show the functioning of the application.

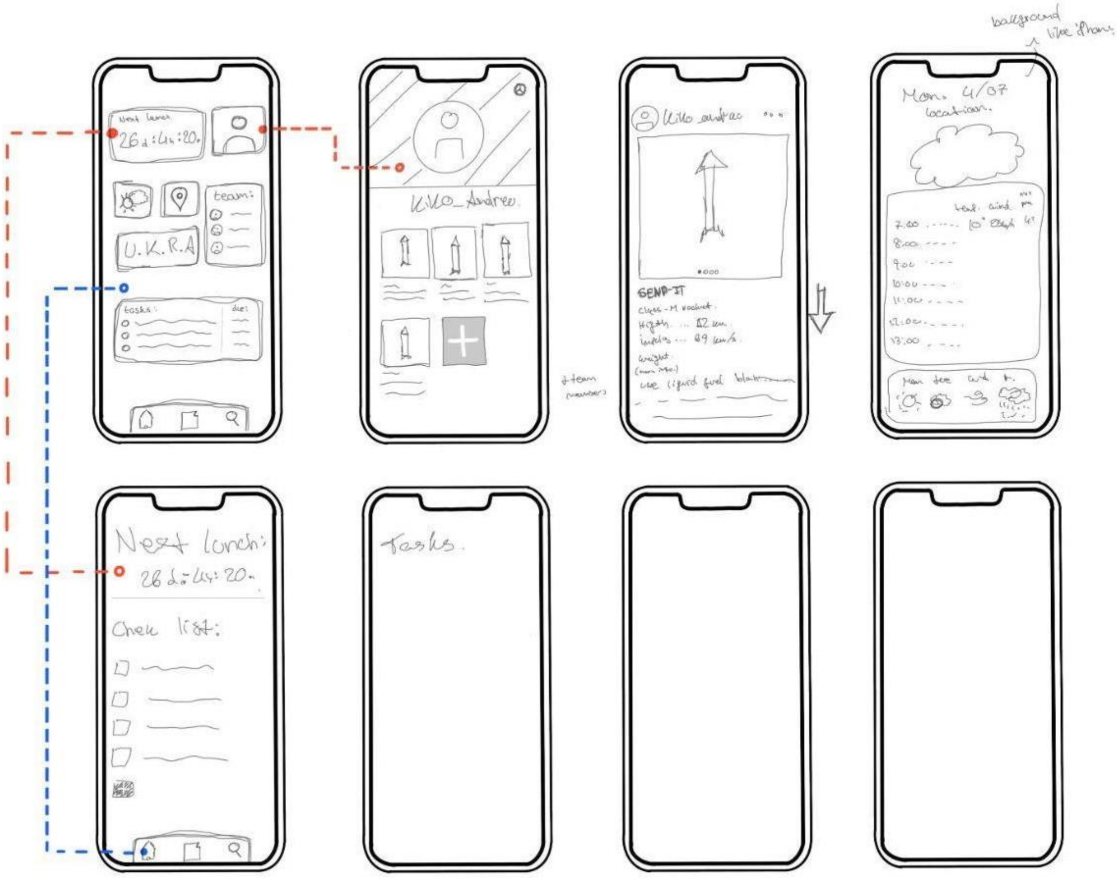


Figure 37: Sketches for functioning of the application

4.3.5. Conceptualisation phase

With all the elements from the research, the team decided to think a logo. Most of the applications need to have a logo. Therefore, the team came up with a logo they decided to create themselves.
The application allows rocketry teams to ensure safety in launching missiles. The logo is based on a warning signpost placed on the road. The rocket inside is added in the triangle so that it looks like an exclamation mark.

The name of the application is currently SafeSpace.

Figure 38: The logo of the application

Next step was to study and discuss which of the sketches drawn in the ideation phase adjusted better to the style already defined and which one had a more attractive design according to the user. The team decided to choose a simple and clear layout.
The sketches kept going clearer and more defined. The team then moved on to create concepts of the application. The concepts are more realistic and close the final layout. It is still in progress, but it is getting clearer.

The four designs that are following are made for the loading screen. From these designs it has been decided to keep going with the first one. However, the team wanted to add a little bit of yellow which is the colour used for warning signpost.

Figure 39: Layout for the loading screen

The four designs following are presenting concepts for the log in page. This page will allow the user to get access to his account and his personal information. From these designs it has been decided to keep the colours chosen for the loading screen. It is however close to the second design with a black logo instead of a yellow one.

Figure 40: Layout for the log in page

The four following designs are different options for making the home page. The home page will provide access to all the different functions of the application.
The clearest and easiest one chosen by the team is the second one. The colours however are more likely to be the one on the fourth design.

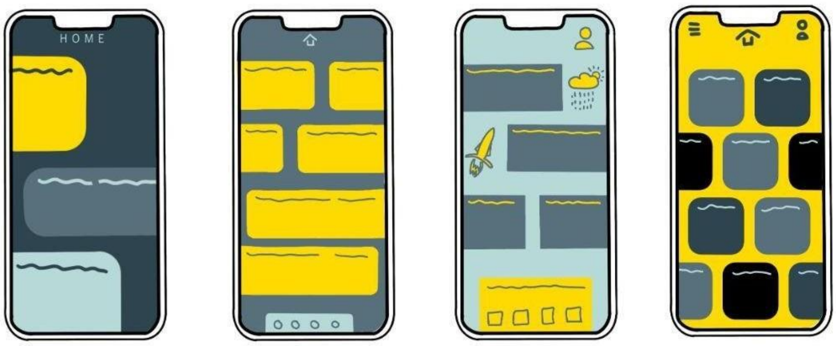


Figure 41: Layout for the home page

The pictures below (cf. Figure 42) are a first overview of what the homepage could look like. The boxes have rounded corners for a more friendly and calm look. The boxes also have different sizes to make the design playful.
Besides the layout, the final colour palette can also be seen. The blue represents reliability and clarity. The yellow/green provides a refreshing and cheerful touch. This shows the importance of the colours among other things.

The team has decided to keep going with the first layout as the differences in the dimensions of the rectangles seem to bring more dynamism to the homepage.

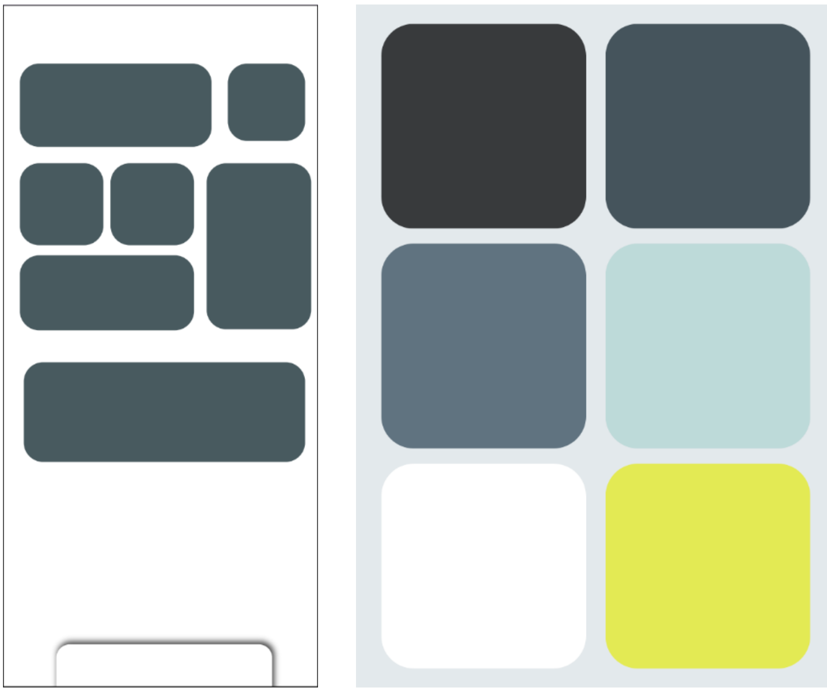


Figure 42: Layout of the homepage with different atmosphere

For the layout of the boxes, accessibility plays a big role. After a brief ergonomic study, the boxes were imagined as following.

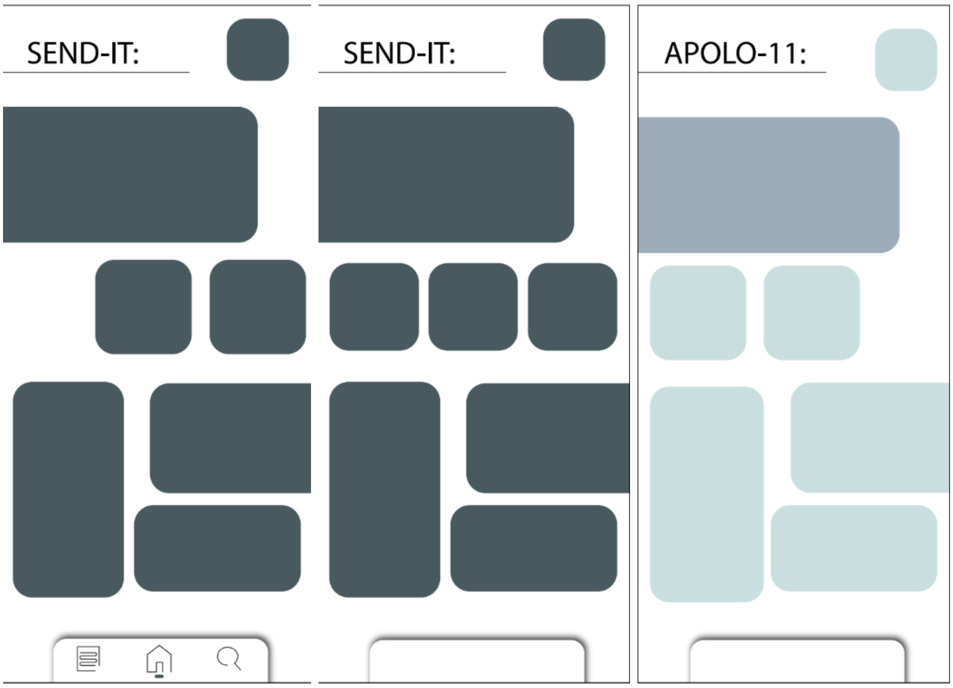


Figure 43: Layout of the boutons at the boxes of the home page

The details are then designed, and everything is gathered to have finalised concept. Layout is finally decided, gaps are standardised, functions are defined, and colours and backgrounds are added.

The picture below is presenting the final concept. The team wanted to add a background with more colours to add vivacity and some shapes to make it dynamic.

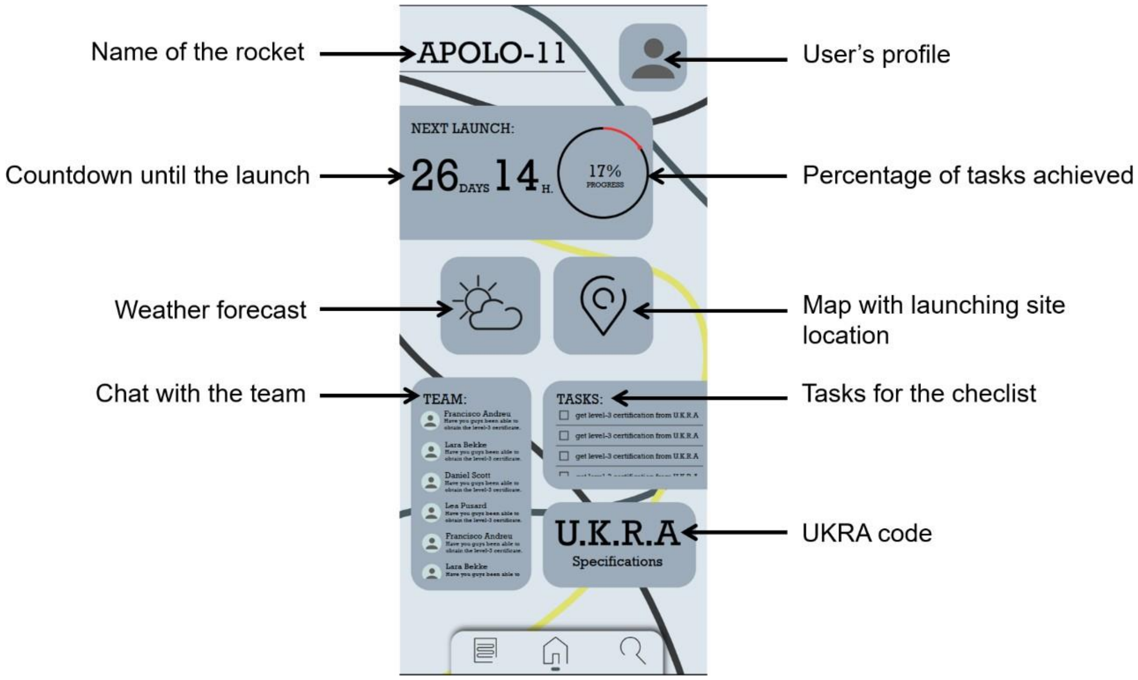


Figure 44: Finished layout of the homepage

Even if this concept seems to be finished, there are upgrades and changes that still need to be made to have a real prototype. After reflexion, the team found that the background was disturbing and could lead to bad user's experience. The team also decided to give more importance to the box called "Tasks" because this will be the common button to use.
Changes like, adding a shadow to the boxes, creating depth, improve visibility will also add a more realistic experience for the user.

4.3.6. Final design

Finally, after all the improvements the team came up the final design. The design is very intuitive and uses clear icons to make it easier to recognise features. The application includes a log-in page, a home page, weather forecasting, check list for launch day and launch countdown, tasks and progress monitoring, a map with launching sites and contacts, rocket social networking, U.K.R.A specifications and a team chat.

The left photo of the Figure 45 is the log-in page. The user will have to create an account and establish a password. Once that first process is done the user will have a quick access and will have an option if the password is forgotten. As it is shown on the right photo of the Figure

45, the home page includes all the features of the application. Without scrolling or displaying a menu the user can access to all the buttons.
At the bottom of the smartphone there will be a menu with three icons which will be always visible. This menu will give the user the possibility to go back to the home page (icon in the middle)), search other users profile (icon on the right), and select in what project they want to work (icon on the left).
The rest of the page covers all the features. From the top part where the name of the project is shown, until the last button which shows the tasks the users still need to fulfil. This layout is designed so that the most used buttons are the easiest to access with the thumb.

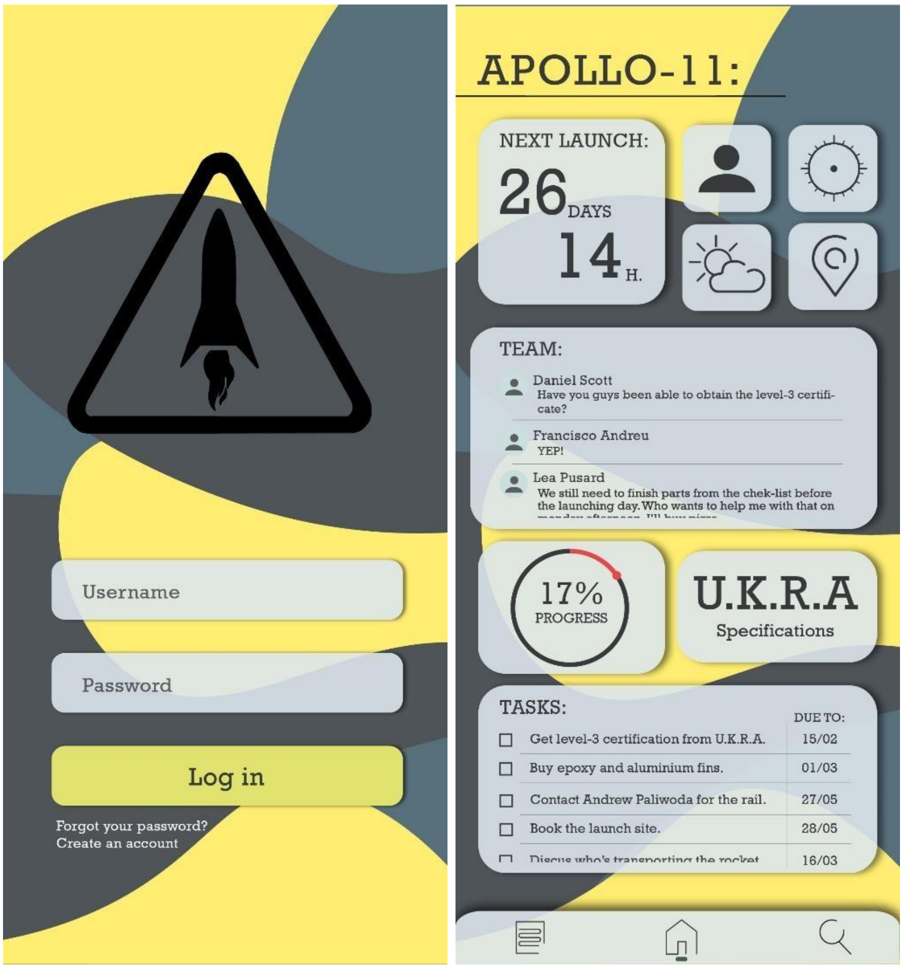


Figure 45: Final designs of the log in page (left photo) and home page (right photo)

To continue, the Figure 46 shows a countdown for the next launch and gives the user the opportunity to create the check list for that day. This list is shared between every member of the project and can be edited any time. The users will check the steps as they prepare for the ignition, this ensures everyone knows what is done and what needs to be done, increasing the safety precautions.

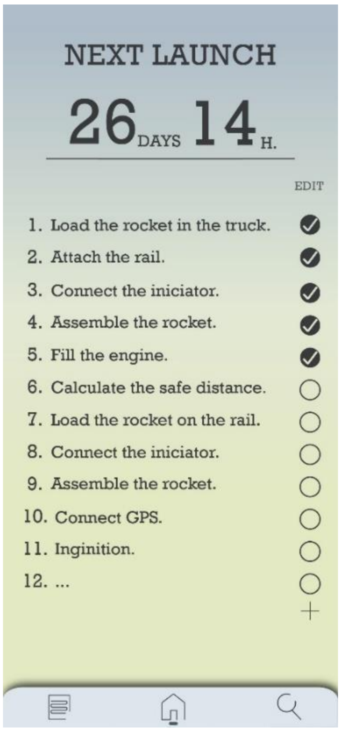


Figure 46: Final design of the launch page

The tasks page (cf. Figure 47) is going to be the most used element by the users. It is meant to be used during all phases of the project, designing, construction and launching. There is also an option that allow the user to add a deadline for each task. The user will be able to check the tasks that are already completed. This progress will be shown using a simple graph and a percentage in the home page.

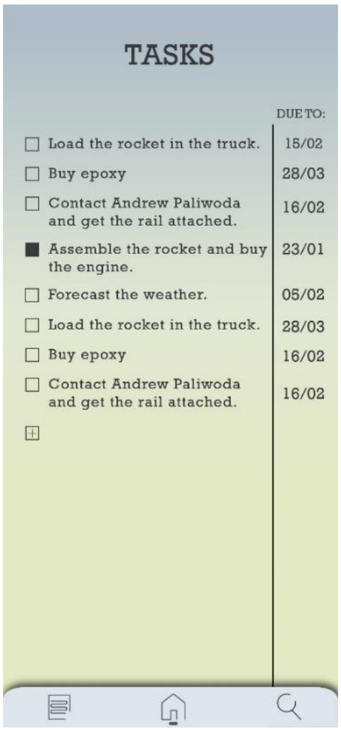


Figure 47: Final design of the tasks page

One of the most important features of the application for the team is the United Kingdom Rocketry Association code (cf. Figure 48). The code will be available on the application and the users will have an easy way to access it anytime. The team also added a research option to look for a specific thing quickly.

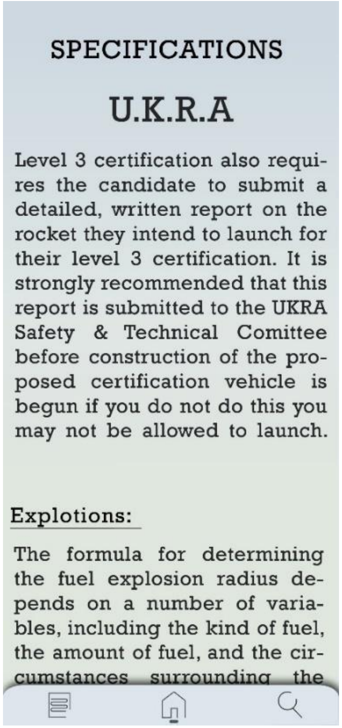


Figure 48: Final design of the UKRA code page

One of the features the team was looking forward to is the rocket social networking. This is an innovative space where users can post pictures and information about the past rocket projects. This not only helps to keep track of the projects and progress, but it is also a good option for other users to contact former members and create their team. The user will be able to post several photos in the same publication and write information about the rocket such as the altitude reached, the weight of the rocket, and so on.
The figures below show the two different pages presented above: a recompilation on all the projects posted (cf. Figure 49) and the publication with more information about that rocket. (cf. Figure 49)

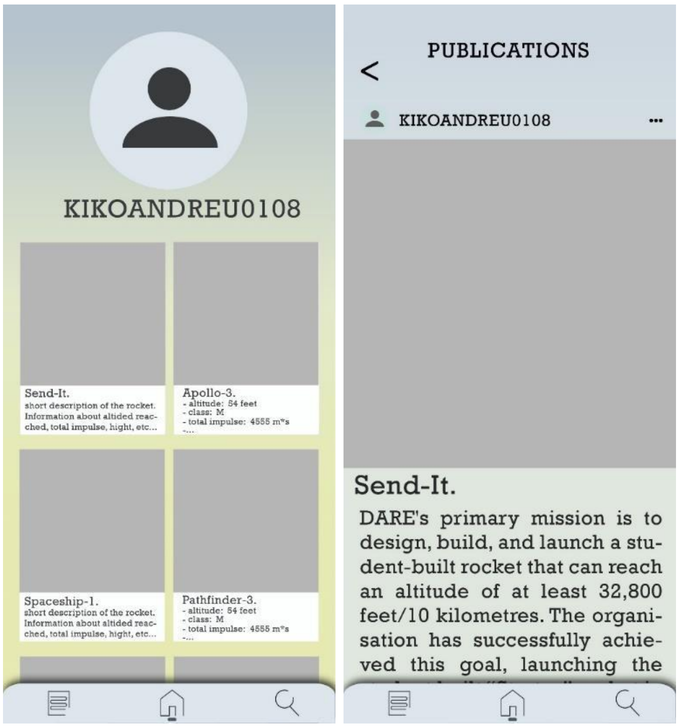


Figure 49: Final designs of the profile networking page (left photo) and the publication page (right photo)

The two pictures following were thought to help the user to contact and find the launching location (cf. Figure 50) and to forecast the weather (cf. Figure 50). The weather page also comes with other predictions such as the wind speed, percentage of humidity, rainfall and so on. The user can select a day from the top button and the predictions for that specific day and time will appear on the page.

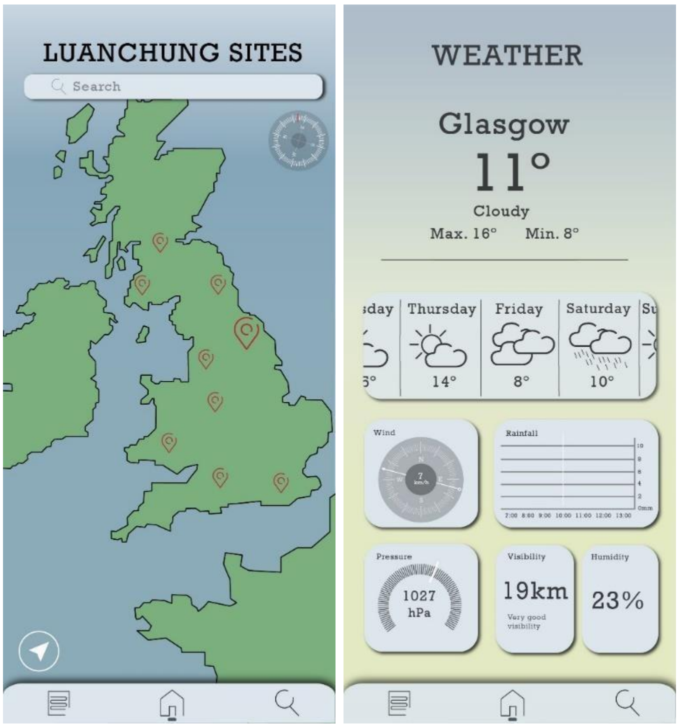


Figure 50: Final designs of the map page (left photo) and the forecast (right photo)

4.4. The posters

The main purpose of the posters is to make all the rules visible and easy to understand for everyone coming to the launching site. It is mostly targeted at the visitors which are not all the time aware of the danger when coming to watch the launch. The poster will be fixed everywhere to make sure people see everything.

The posters can be printed and stuck on a metallic board or laminated. This way it can be reused several times.

There are four different types of posters:
- Emergencies
- Safety & Security
- Distances markers
- Signpost

Each of them is going to be developed bellow.

4.4.1. Emergencies

In case of emergency, several tools can be used such as the first aid kit or the extinguisher.
As it is said in the UKRA code, the team has to be equipped with a first aid kit. The first aid kit is primordial if something happens to anyone on the site. It can save a person's life waiting for emergencies.
As everyone can be injured, even the students launching, it is important the visitors know where the first aid kit is in order to perform first aid procedures.
Next to this kit will be provided a list of all the nearby doctors and hospital and the phone numbers. This list can be found on internet by the students like it is for a risk assessment.

Figure 51: First aid kit poster

The team suggested that the students should also carry an extinguisher. There exist several kinds of extinguisher but the most adapted to the situation should be a powder extinguisher. Indeed, this fire extinguisher covers most types of fire (cf. Figure 52). As there can be electrical components, gases when launching and flammable materials and liquids (propellant), this model is the one with most advantages.

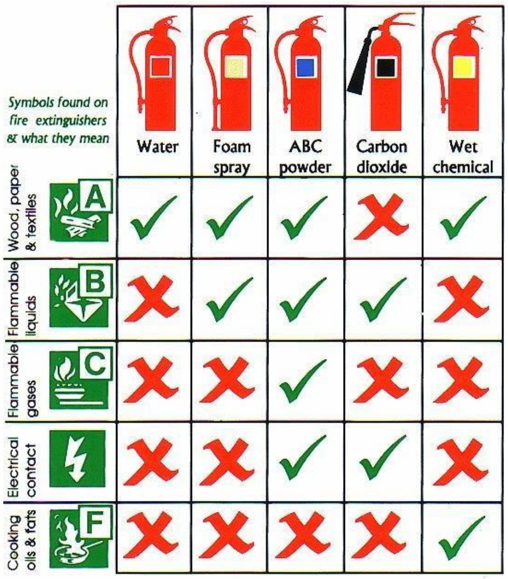


Figure 52: Types of fire extinguisher and their use

Figure 53: Fire extinguisher poster

In case of a fire or any other problem, everybody can gather at the meeting point. This point should be far enough from the launching pad to make sure everyone assisting is protected.

Figure 54: Meeting point poster

4.4.2. Safety and Security

To provide security and safety to the students launching and the people assisting, the following posters show the basic rules to respect.

There are 3 types of posters for different purposes.

The first one is called “Safety rules” (cf. Figure 55). It is mainly intended for the students launching the rocket. The aim is to always remind the students of the basic rules. It also shows them what they need to do to protect the visitors that came to assist the launching such as the range safety officer wearing the RSO armband.

Under each little logo, some words are added to be even more explicit.
This poster gathers all the important information about PPE because the students are exposed to dangerous materials and tools and can get hurt easily. This is why there should were protections for their head, eyes, ears, hands and body. They should also carry their walkie talkie with them to facilitate the necessary communication which is necessary to ensure everyone is remaining safe. They should not forget about their certification which can be retrieved from the UKRA and Uploaded on to the application. Finally, it is important to remind them a launch comes with dangers. It is very important to stay concentrated, focused and pay attention to everything that happen on the site or with the rocket.

Figure 55: Safety rules for the students

The last 2 posters (cf. Figure 56 and Figure 57) are targeted visitors.
There is a poster about “Security rules”. This poster looks like the previous one except it is for the visitors. This is why there are more prohibited signs on it. Similar to the poster above, words are added under the logs to make sure everyone understands the meaning.
This poster gives advice to the visitors saying they should wear part of the PPE. Indeed, they should protect their ear and eyes as a rocket is loud and small projectiles such as dust or dirt can get in the eyes of the visitors. The poster also reminds the visitors they are in a dangerous site, at their own risks. And in the event of a rocket failure Debris can fall from the sky and can land near or on them. Finally, it is important to warn the visitors that they should not run or scream as they can disturb the team and They should not smoke near the rocket since it is possible to cause damages to it.

Figure 56: Security rules posters

Finally, the last poster for the visitors is about all the prohibited items. This last poster is really important because all these items can cause problems to the student's team, other visitors or the launching itself.

As with the two other posters, every logo has some words underneath to make sure everything is clear.

This poster lists the items following because:

- Sharp objects, weapons, glass, aerosols, flammable liquids, needle and fireworks can cause damages to the rocket
- Alcohol and needle may cause visitors to be out of sorts (drunk and drugged) and they can be dangerous on the site
- Pets and children are the types of visitors that can disturb the launch and can be scared by it. It is not responsible to bring them during the launch

Figure 57: Prohibited items poster

4.4.3. Distances markers

To delimitate the safe distance for the visitors and the team, it is possible to add a security line like the one bellow.

Figure 58: Security line

The visitors will not be able to cross this line. This will leave space for the team to put their tools on the site without anybody touching it. This will also preserve the visitors from getting hurt by anything related to the rocket. To make sure the visitors respect this rule, the following poster will be installed on the boundary.

Figure 59: Poster "Do not cross this line"

To know the safe distance that needs to be put in place, it is important to know the impulse of the rocket and its class. Depending on that the distance can change. The UKRA code provides a table that summarise all the safe distances (cf. Appendix 5).

To make sure the visitors are in a safe space and free the student's zone from everyone not involved in the launch, the "free zone" is 1,5 times the distance for the team launching.
The schematic below shows the safe zones.

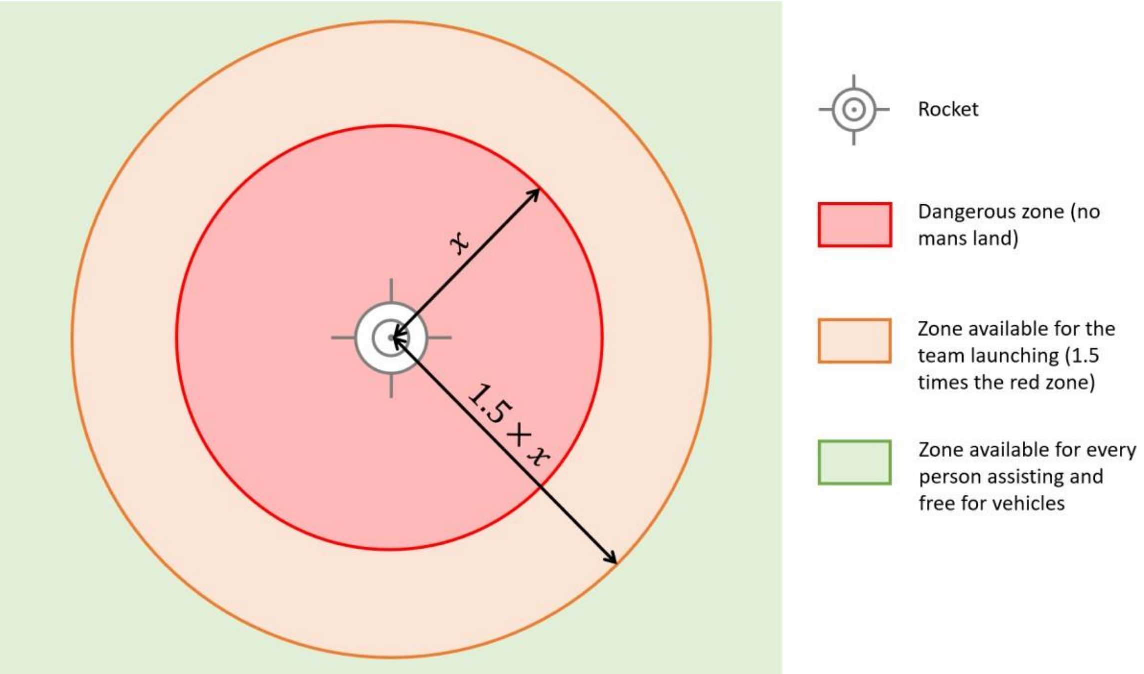


Figure 60: Safe distances for the team and visitors

4.4.4. Signpost

During the launch the team assisted on week 10, the member noticed they were near a road. The SARA Fairlie Moor Launch site (cf. Figure 9 and Figure 10) is easily accessible for every person including the ones who are not involved in the project.
The team also noticed that several cars keep trespassing on this road during the preparation of the launch and the launch itself.
The team came up with the idea to put signposts on the road to warn users of the road that a launch is being prepared.
The signpost will be a yellow triangle to show drivers this is a warning. The mention “Launch in progress” should be added underneath to be even more specific. The photo below is a representation of the signpost.

Figure 61: Signposts on the road to warn drivers

These signposts should be put 150 m away from the launching site on both sides. This way drivers will be aware of the danger, and they know they are entering a dangerous zone where debris can fall.

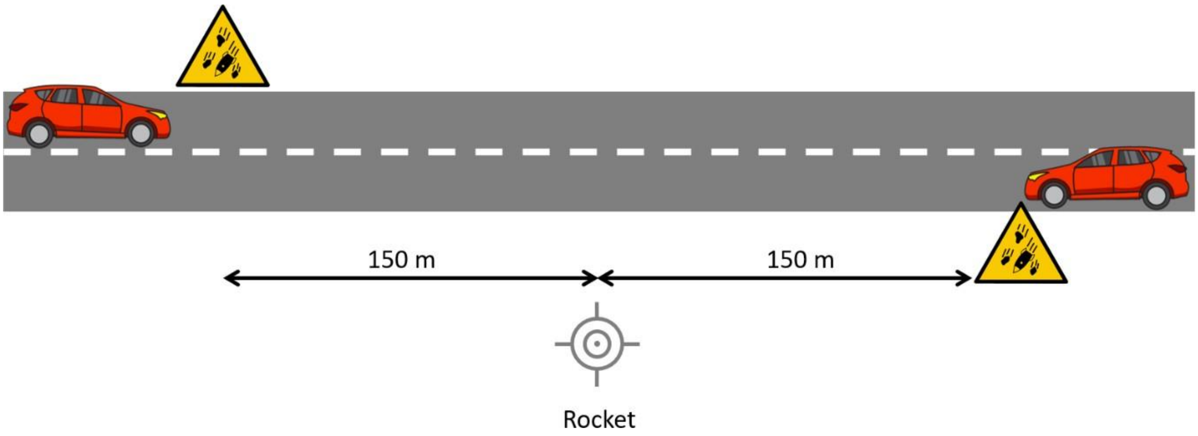


Figure 62: Placement of signposts on the road

4.5. Recommendations for safety code

While assisting the launch, the team noticed some elements missing in terms of safety. The team decided then to build a table and put all the recommendations which would improve the current safety operations in place
These recommendations are spread into several domains.

Domain	Recommendation
Rules for visitors or people not directly involved in the launch	- Obey the rules and the RSO for your own good - Do not try to speak to the team launching - Do not scream during the preparation of the launch - Do not try to go get the rocket once it has landed - Do not try to touch the rocket at any time - Do not run - No children under the age of 16 (unless supervised by their parents or tutors) - Animals can be terrified by the rocket launch. No pets on site - Do not enter the launching zone or cross any barrier or line - Goggles and ear plug for visitors who are sensitives (children, old people) - Put all your rubbish in the bins provided
Emergency	- Check doctors and emergencies on poster - Clearly indicate fire exits and evacuation meeting points in case of a fire - Have a designated first aider(s). They should have reliable regular contact with the person in charge of the event. On a larger event, radios make this process much quicker and save time in an emergency. - Use fire extinguisher in case of fire
Rocket rules	- Ensure suitable place to store the rocket - Make sure you get the engine from a reputable supplier - Ensure rocket has no loose pieces and all element of the rocket are secured properly

	- Never attempt to relight faulty rocket without guidance from site marshal - If you have several rockets, launch only one rocket at a time and maintain safe distance while launching
Vehicle	- Park all vehicle in zone designated and delimited
Check & protect dangerous materials on site or brought to the site	- Ensure gas are handled with care and sufficient storage areas are provided for canisters containing such - Electrical components are out of reach of children and loose wiring is secured within the rocket - Minimise the use of hazardous materials such as acetone, paints, flammable liquids or other potentially hazardous substances - Not near flammable materials
Leaving the site	- After launch: clear the site, make sure everything is taken away & nothing stays - Make sure that the fire is out, and surroundings are made safe before leaving.
Protection for visitors provided by the team launching	- The RSO should wear a high visibility vest and a fluorescent armband with the "RSO" label - Appropriate clothing, ear plug, goggles, gloves should be worn by team members - Cary a walkie talkie for all team members to facilitate the communication - Put in place bins and/or bags for the waste and rubbish - Plan & mark areas for spectators. Use a rope or a safe line (red and white) to delimitate the safe zone - Provide the right extinguisher (ABC powder) - Make sure noise levels do not exceed 120 dB and that all personnel are not exposed to sounds louder than 70db for prolonged periods of time

Table 2: Recommendations

Conclusion

To conclude, with the use of the research that had been done in the earlier stages of the project, the project was able to be completed to improve the safety of not only the rocket teams but also the officials and the visitors at the site.

By creating a mobile application to make safety specification more accessible for all users wither that be the rocket teams them self's or just someone interested in rockets all application users will be able to find the safety specification without having to scour the internet to find the correct one. Alongside this, it also allows for rocket enthusiast to have all their rocketry needs all in one place.

To further improve on site safety set of posters can also be utilised which along with the safety specification will ensure all attendees will understand the basic site rules and will alleviate any confusion that maybe caused from the specification its self

Finally, a list of recommendations has been developed to help with the clarity of the rules and make environment easer to navigate without accidently ending up somewhere you should not. If these recommendations are implemented correctly alongside the safety measures mentioned prior this will ensure a safe and welcoming environment for all.

Future work

If further time was allocated to continue working on this project the aim would be to continue developing and improving the application by creating proto-types and doing beta testing allowing users to give feedback and further improve the practicality and the usefulness of the application.

Due to the nature of the application, it could be continuously updated to include new safety regulations, new safety features and add additional features such as a rocket launch simulation software. It can even provide a platform for uploading rocket schematics for teams to work on together within the application. As it can be seen this application has the possibility to be the singular point of reference for any rocket team for any purpose if provided with the time and resources to become such.

Reflexion on the project

Team reflexion

As a team, we would like to say that this project helped a lot develop teamwork skills. We managed to solve problems even if we all have different opinions. The differences in our cultures and points of view were quite challenging as we do not work the same way. With good cooperation and consultation, we managed to work it out, and came up with ideas that we are all satisfied with.

The project was interesting as the subject was bred new for all of us. It was challenging since we needed to learn a lot before starting to think of a solution. We were feeling lost plenty of times, but we managed to get through it. Thanks to our tutors we also found new motivations and inspiration when we were out of ideas.
The team spirit and atmosphere between the members was really good. We managed to surpass the bad events as the good ones.

However, we were a little bit disappointed to change the vision we had of the subject after visiting the launch. We felt like what we did before was pointless as we did not write specifications. But we have bounced back to create a solution that pleases the industrial interlocutor and us.

Finally, we would like to say that we are happy with what we have done. We wanted to finish the application and make it available for the students before finishing the project. We hope the project will go on and hope another team will create the application.

Personal reflexion

Daniel Scott

EPS was an enjoyable and challenging experience that forced me to work outside my comfort zone on a project that that is outside the usual scope of my course. By participating in EPS, I was able to develop my project management skills and work on my communications skills, team working and a plethora of other soft skills whilst also developing my reporting skills. This will all be useful to me for working towards my dissertation in year 4. Overall, I felt this program was very enjoyable and made even better with the team I had to work with. The most difficult part of the project arose from the discovery of the already in place and good quality safety specification which made the team have to re-evaluate the project and alter the solution we had previously planned.

Francisco Andreu Capó

I was introduced for the first time to EPS at my home university, I thought it was a great opportunity to not only work with an international team but also experience, by doing a real-life project, how really life works. Even though at first the project topic wasn't what I expected due to that it's not really my topic area or similar to projects I've done before, it helped me readjust my skills and dappling my knowledge in other areas. EPS made me grow out of my comfort zone and also taught me other skills which definitely will be useful in the working world. Which I found quite an advantage, by doing this project I feel more prepared to approach and succeed in my first job.
To summarise, I generally think it was a great full and rewarding experience, which made me learn things I've wouldn't in other educational projects.

Lara Bekke

I learned a lot of new things during this project. First, this project was different from previous projects I have done. This meant I had to step out of my comfort zone and adapt to a new type of project. Although the project was not a design project as I am normally used to, I was still able to find a way to add my design skills to this project, yet I would have liked to use my industrial product design skills even more in this project, but unfortunately this was not necessary and therefore possible
Furthermore, I have improved my collaboration skills by learning to work with students of different nationalities. Halfway through my project, there was a moment where we as a project team were a bit lost and did not really know what to do anymore. Later on, all this worked out well and we found good solutions. I learned how to deal with setbacks and how to get over them.
Overall this project was really interesting and educational. I had a good experience.

Léa Pusard

This EPS was a real good experience for me. I learnt how to work and cope with people coming from all around the world on a project that does not have anything to do with my skills. Working on this project abroad helped me develop a team spirit and social skills. The project was full of challenges over the weeks, and I liked the fact that we needed to find solutions as a group. On the other hand, I am disappointed that I was not able to use and put in service my skills as a future mechanical engineer. I was hoping to create and build a rocket on our own to implement my skills while developing a team spirit.

Table of tables

Table of illustrations

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Appendices

Appendix 1: EPS Brief given by the industrial tutor

EPS Project Proposal Form
Semester B 2022/23

GCU Supervisor (completed by GCU)	Patricia Munoz-Escalona
Project title	Common Operational Standards for Student Sounding Rocket Launch
Project brief (aims)	Internationally students are increasingly becoming involved within sounding rocket projects, with students all over the world developing rockets in small university workshops, building upon existing amateur rocketry communities. TU Delft in the Netherlands currently holds the altitude record for a student team. Student teams are seeking to fly higher and utilise unique methods of propulsion. Increasingly student teams are seeking to fly past the Karman line. This project seeks to understand how Spaceport 1 can accommodate student teams in a safe and standardised way and if open published operational standard could be used to support these student teams. Ground support equipment can play a significant role in the design and flight of sounding rockets, and SP1 seeks to understand how open documentation can support teams in this area.
Preferred skills of the EPS team (desired areas of expertise)	Requirements Engineering Mechanical Engineering Electrical Engineering Safety Engineering Operations Management
Company	Spaceport 1
Company contact	Andrew Paliwoda
Other Comments, if required	It may be possible for the students to witness a launch at the SARA launch site in Ayrshire over the course of the project and to visit the GU Rocketry workshop at the University of Glasgow.

Appendix 2: Clearance distances for rockets

Minimum Distance Table

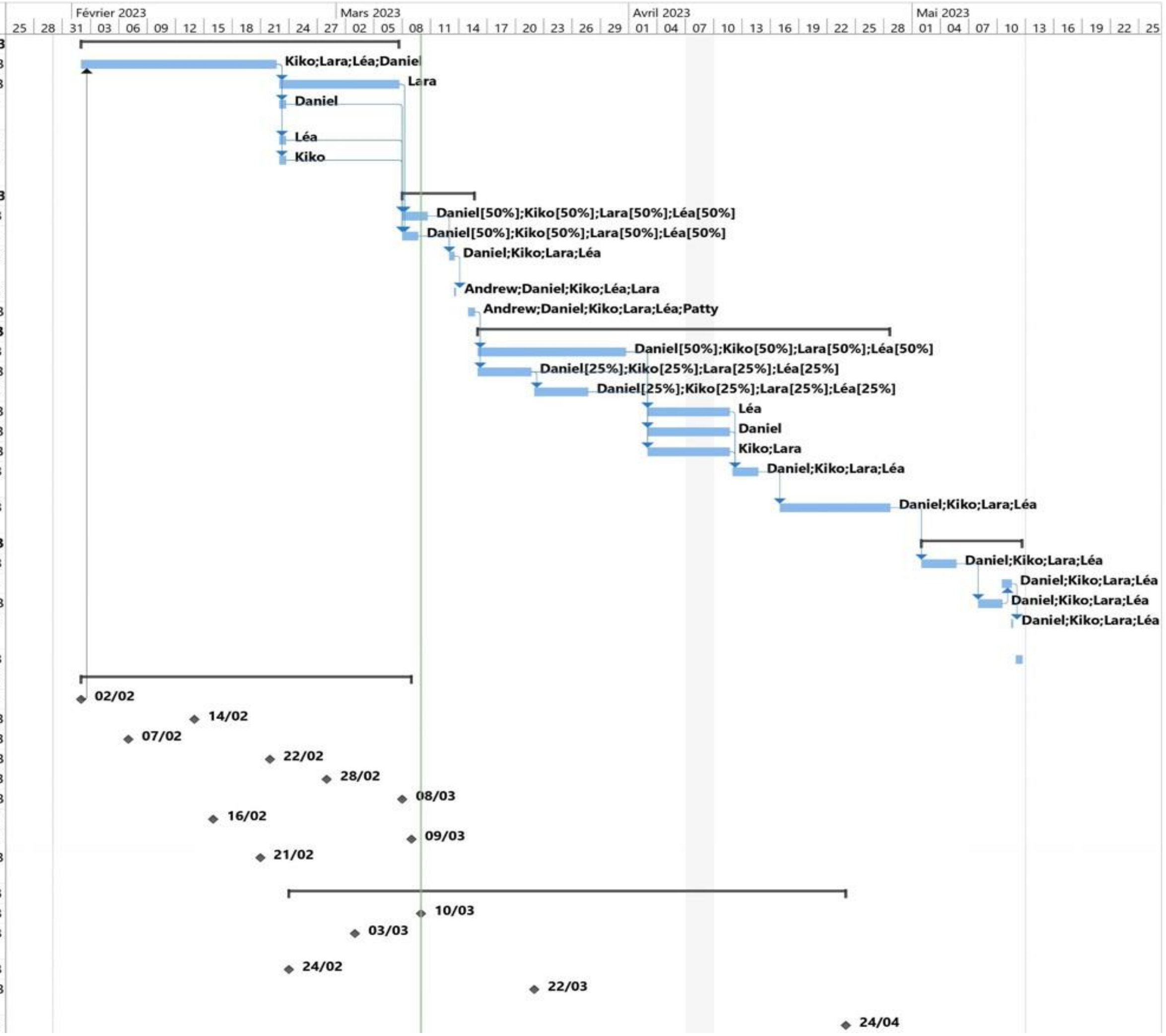
Installed Total Impulse (Newton-Seconds)	Equivalent High Power Motor Type	Minimum Diameter of Cleared Area (ft.)	Minimum Personnel Distance (ft.)	Minimum Personnel Distance (Complex Rocket) (ft.)
0–320.00	H or smaller	50	100	200
320.01–640.00	I	50	100	200
640.01–1,280.00	J	50	100	200
1,280.01–2,560.00	K	75	200	300
2,560.01–5,120.00	L	100	300	500
5,120.01–10,240.00	M	125	500	1,000
10,240.01–20,480.00	N	125	1,000	1,500
20,480.01–40,960.00	O	125	1,500	2,000

Note: A Complex rocket is one that is multi-staged or that is propelled by two or more rocket motors

Revision of August 2012

Appendix 3: Project Gantt chart

WBS	Nom de la tâche	Durée	Début	Fin
A	**Before midterms**	**24 jours?**	**Jeu 02/02/23**	**Mar 07/03/23**
A.1	General research	15 jours?	Jeu 02/02/23	Mer 22/02/23
A.2	Looking at curent safety	9 jours?	Jeu 23/02/23	Mar 07/03/23
A.3	Risks associated to fuel explosion	1 jour?	Jeu 23/02/23	Jeu 23/02/23
A.4	Reviews on past report	1 jour?	Jeu 23/02/23	Jeu 23/02/23
A.5	Process of journey of launch site	1 jour?	Jeu 23/02/23	Jeu 23/02/23
B	**Midterms report & presenta**	**6 jours?**	**Mer 08/03/23**	**Mer 15/03/23**
B.1	Writing of the report	3 jours?	Mer 08/03/23	Ven 10/03/23
B.2	Prepare the presentation	2 jours?	Mer 08/03/23	Jeu 09/03/23
B.3	Practice between the members	0,5 jour?	Lun 13/03/23	Lun 13/03/23
B.4	Blank presentation	0,5 jour?	Lun 13/03/23	Lun 13/03/23
B.5	Midterms presentation	1 jour	Mer 15/03/23	Mer 15/03/23
C	**Between midterms and final**	**30 jours?**	**Jeu 16/03/23**	**Ven 28/04/23**
C.1	Deepen the research	12 jours?	Jeu 16/03/23	Ven 31/03/23
C.2	Meet students team	4 jours?	Jeu 16/03/23	Mar 21/03/23
C.3	Spectate a launch	4 jours?	Mer 22/03/23	Lun 27/03/23
C.4	Mechanical safety	5 jours?	Lun 03/04/23	Mar 11/04/23
C.5	Electrical safety	5 jours?	Lun 03/04/23	Mar 11/04/23
C.6	Design sefety	5 jours?	Lun 03/04/23	Mar 11/04/23
C.7	Summarize and organise ideas	3 jours?	Mer 12/04/23	Ven 14/04/23
C.8	Starting the creation of a safety guideline	10 jours?	Lun 17/04/23	Ven 28/04/23
D	**Finals report & presentation**	**9 jours?**	**Mar 02/05/23**	**Ven 12/05/23**
D.1	Writing of the report	4 jours?	Mar 02/05/23	Ven 05/05/23
D.2	Creating the video	1 jour?	Mer 10/05/23	Jeu 11/05/23
D.3	Prepare the presentation	2,5 jours?	Lun 08/05/23	Mer 10/05/23
D.4	Practice between the members	0,5 jour?	Jeu 11/05/23	Jeu 11/05/23
D.5	Finals presentation	1 jour	Ven 12/05/23	Ven 12/05/23
E	**Meetings**	**25 jours**	**Jeu 02/02/23**	**Jeu 09/03/23**
E.1	Launching the project	0 jour	Jeu 02/02/23	Jeu 02/02/23
E.2	Meeting 1 with Rocketmar	0 jour	Mar 14/02/23	Mar 14/02/23
E.3	Meeting 1 with Andrew	0 jour	Mar 07/02/23	Mar 07/02/23
E.4	Meeting 2 with Andrew	0 jour	Mer 22/02/23	Mer 22/02/23
E.5	Meeting 3 with Andrew	0 jour	Mar 28/02/23	Mar 28/02/23
E.6	Meeting 4 with Andrew	0 jour	Mer 08/03/23	Mer 08/03/23
E.7	Meeting 1 with Patty	0 jour	Jeu 16/02/23	Jeu 16/02/23
E.8	Meeting 2 with Patty	0 jour	Jeu 09/03/23	Jeu 09/03/23
E.9	Meeting 1 between team members	0 jour	Mar 21/02/23	Mar 21/02/23
F	**Assessments**	**39 jours**	**Ven 24/02/23**	**Lun 24/04/23**
F.1	Coursework EOM	0 jour	Ven 10/03/23	Ven 10/03/23
F.2	Project Management assessment	0 jour	Ven 03/03/23	Ven 03/03/23
F.3	Design thinking assessmen	0 jour	Ven 24/02/23	Ven 24/02/23
F.4	Finance & Marketing assessment	0 jour	Mer 22/03/23	Mer 22/03/23
F.5	Communication - poster	0 jour	Lun 24/04/23	Lun 24/04/23



Appendix 4: Table summarising the components of rockets

Class of component	Type of component	Application	Component	Used for	Advantages	Disadvantages
Metallic	Aluminium	• Cryogenic applications • Fuel tanks • Primary structures (<200°C) • Struts • Sandwich construction facesheets and cores	A7075, A2024	Wide application		• Sensitive for moisture
			A7075-T7351, A7075-T7352, A7075-T6	Machined elements		
			A2024-T6, A2024-T36			
			A6061-T6		• No high strengh required	
	Aluminium-lithium alloys			External tank (superlight tank)	• 10% or more weight savings • Friction stir welding (no inert shielding gas, filler materials, reduce nb of weld defects, higher weld joint strength)	
	Aluminium alloys	• Havealy loeaded structures				
	Stainless steel		300 series (CRES)			• Should not be used above 370°C
			A286CRES, 302CRES, 305CRES	Small mechanical elements		
			Austenitic stainless steel		• Resistant to stress corossion cracking	
	Steel	• Pressure stabilised cryogenic fuel tanks • Solid rocket booster casings • Fuel lines • Sandwich facesheets in heavy loaded structures • Hot structures	RH1050, D6AC, AMS-6434		• Structural material for heavily loaded structures in, for example, aggressive environments (chemically active gases and fluids)	
	Titanium alloys	• Homogenuous lightweight structures with a complex shape • Truss and nodes in truss frames • Struts under compression • Pressure tanks • Cryogenic applications (tanks) • Fuel lines • Hot structures (<500°C) • Bolts	Ti-6Al-4V	Small mechanical elements	• Resistant to stress corossion cracking (>450-500°C) • High mechanical strength	• Poor ductile properties • Sensitivity to cracking in a weld state
	Magnesium alloys	• Lightweight structures with many material involved • Truss frames • Low level loaded structural parts	AZ31B, AZ31B-H24		• Low density • Good vibrations • Damping properties • High specific strength • Easy to weld	• Sensitive to corrosion • Low toughness
	Beryllium	• Stiff lightweight structures in compression (<530°C) • Construction under thermal shock • Increasing the natural frequency of structures • Low coefficient of thermal expansion	Lockalloy		• High rigidity • Reach high temperatures	• Toxic • Brittle • Expensive
			Glass (E-glass, S-glass, E-glass in epoxy, S-glass in epoxy)		• Low specific weight • High strength • Low thermal conductivity • High resistance to thermal • Chemical and biological effects	

Composites	Fibers		Organic (Aramids, Aramids in epoxy)		• High strength • High elasticity modulus • Minor creep properties • Low specific weight • High specific strength	
			Carbon (Graphite HM, Graphite HT, Graphite HM in epoxy, Graphite HT in epoxy, AS or T-300, AS or T-300 in epoxy)		• **Generally used** • Very good mechanical and physicochemical properties • Good thermal stability • Small expension coefficient • High resistance to ambieny effects • High strength and elasticity modulus	• Complicated thermochemimcal processing
			Boron (filaments, in epoxy)		• **Generally used** • An-isotropic	
			Organic			
			Carbon			
			Sicilian carbide		• Suitable for use at very high temperatures	
			Metal threads			
			Beryllium		• **Generally used**	
	Metallic matrices	• Used where high toughness is needed	Bron-Aluminium		• **Generally used**	
			Bron-Magnesium		• **Generally used**	
			Carbon-Aluminium		• **Generally used** • Most promising composite • Excellent machanical properties	
			Steel-Aluminium		• **Generally used**	
			Boron-Titanium		• **Generally used**	
	Non metallic matrices		Polyetherether ketone (PEEK)			
			Polyether imide (PEI)			
			Polyethersulfone (PES)			
			Polyamide imide (Torlon)			
			Polyamylene Sulphide (PAS)			
			Phenolic			
	Thermo sets		Epoxy		• Good adhesion properties • Processing requires low pressure	• Little amount of gas is producted as side-effect when it polymerises
			Phenolic			
			Polyimide			
			Bismaleimide			
			Polysulfone			
Sandwich honeycomb Core			Al-alloy 5056		• Excellent stiffness	

Appendix 5: Extract of UKRA code - Launch area safe distance

The next largest distance in the table must be used where any of the following conditions are met:

- The flight involves a boosted glider or winged recovery.
- The flight is considered Research or Experimental.

At the RSO's discretion the minimum safe distance may be reduced for those required to facilitate the launch of the rocket providing that:

- Safety of the flier, spectators and the public can be assured.
- The distance between the launch rail and anyone not directly involved in the launch is greater than or equal to the distances in the table below.

Safe distance table

Total Impulse (equivalent Impulse Class)	**Safe Distance from launch rail**	
	Single Motor metres (feet)	**Multiple Motors metres (feet)**
Up to 2.5 Ns (A)	2 (7)	3 (10)
2.5 - 10 Ns (B, C)	3 (10)	6 (20)
10 - 20 Ns (D)	5 (16)	10 (33)
20 - 40 Ns (E)	7 (23)	15 (50)
40 - 160 Ns (F, G)	10 (33)	20 (66)
160 - 320 Ns (H)	15 (49)	30 (98)
320 - 1,280 Ns (I, J)	45 (148)	60 (197)
1,280 - 2,560 Ns (K)	60 (197)	90 (295)
2,560 - 10,240 Ns (L, M)	90 (295)	150 (492)
10,240 - 40,960 Ns (N, O)	150 (492)	300 (984)

Appendix 6: Advantages and disadvantages of different types of rockets

Type of engine	Advantages	Disadvantages
Solid rocket engine	- They are relatively simple to manufacture and operate. - They have high thrust-to-weight ratios, which makes them ideal for use in the initial stages of a rocket launch. - They are very reliable and can be stored for long periods of time.	- They cannot be turned off once ignited. - They have limited throttle capability, which makes them less suitable for use in the later stages of a rocket launch. - They produce a lot of vibration and noise.
Hybrid Rocket Engines	- They combine the simplicity of solid rocket engines with the throttling capability of liquid rocket engines. - They can be turned off and restarted. - They have a high degree of safety because they do not use a liquid oxidizer.	- They are less efficient than liquid rocket engines. - They have lower thrust-to-weight ratios than solid rocket engines. - They can be difficult to control due to their hybrid nature.
Electric Rocket Engines	- They are highly efficient, with specific impulses much higher than traditional rocket engines. - They can be throttled and turned off and on with ease. - They are relatively quiet and produce less vibration.	- They are currently limited in their thrust capabilities and are best suited for use in small satellites and spacecraft. - They require a large amount of electrical power to operate, which can be a challenge in space. - They require a large amount of propellant for their operation