Personal Project [years x-x]

What Challenges are Faced When Sending a Rocket to Space?

xxx

xxx School

3493 words

Personal Project Report

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Investigating

My Idea (Why Rockets?)

The inspiration for my topic has come from years of fascination. Since I was of a very young age I've had an increasing curiosity for the universe and what lies outside our atmosphere. Pursuing that curiosity, I have read many different books and watched numerous documentaries, enhancing my knowledge of our universe as well as creating more of this urge to discover and inquire. Back then, my dream was to become an astronaut and travel to space myself, but more recently, I have been gaining an interest in what happens behind the scenes at companies such as NASA, the ESA, and SpaceX, and have been fascinated by what the aerospace engineers do.

Whilst pondering for a good idea, I began veering towards a topic with relations to the subject of space. Many different ideas came into light, but I ultimately decided to investigate the challenges that aerospace engineers face when they build rockets, and this would be done through the creation of my own model rocket. I knew I would encounter a wide variety of difficulties in my rocket, so it would help me imagine how much more difficult it is to construct rockets that have to escape the atmosphere and survive the unforgiving environment of space.

The construction of a model rocket was not the only product that I pondered about, as numerous other ideas came to my head. The strongest competitor was the construction of a Dobsonian telescope, which I could have perhaps used to observe our moon. Although this idea was of a strong interest to me, it is an extremely expensive product to build, with the designs I wanted costing anywhere from £265 to the outrageous price of £1120.[1] This is because telescopes require specially made and shaped glass, which costs a very large amount to purchase, and an even larger amount to create by hand. Furthermore, I am more strongly captivated by rockets than telescopes, which is why I made the decision to build a model rocket.

The Global Context

Another decision I had to make regarding my topic was which Global Context I needed to revolve my project around. Out of the six options, the one most suitable was "Scientific and Technical Innovation." My plan was to research the basics of the science behind how rockets work—combined with the foundation of prior knowledge that I had on the subject—and then innovate technically through the creation of my own cheap, functioning, large model rocket, which would be built from scratch.

Preliminary Research and Gathering of Information

When investigating the different topic ideas for this project, I needed to conduct some simple, preliminary research to ensure that I understood certain aspects of the creation of different products (in particular, the rocket and the telescope).

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[1] Fox, Karen C. "How To Build a Dobsonian Telescope: DIY Astronomy Project."*Popular Mechanics*. Popular Mechanics, 9 Oct. 2008. Web. 22 Jan. 2015. <http://www.popularmechanics.com/science/space/telescopes/4286700>.

"Homemade 12.5 Inch Dobsonian Telescope." *Instructables.com*. Instructables.com, n.d. Web. 22 Jan. 2015. <http://www.instructables.com/id/Homemade-125-inch-Dobsonian-Telescope/?ALLSTEPS>.

To start off with, I looked at a variety of DIY websites, to see what kind of steps would need to be taken in order to build the different products. I discovered that *Instructables* (http://www.instructables.com) is a fantastic website for the homemade creation of anything. Through this website, as well as others, I discovered that model rockets are much, much cheaper to build than telescopes, for reasons mentioned previously—such as the cost of the specially made glass. Furthermore, Dobsonian telescopes are much larger than model rockets, and therefore require a larger quantity of materials such as wood, essentially increasing the price. The total price of the parts for the average Dobsonian telescope appeared to cost between £250 and £400 in total.[2] The prices of model rocket parts vary between vendors, but all of my parts were purchased for about £30, and only the parts of very large, high-powered rockets would cost much more than that. It was easy to find the different prices online, seeing as there is a very large range of companies that sell their parts through the Internet (such as *Estes* and *Apogee*).

The other important piece of information was to get a general idea of the difficulty of building these products. Unfortunately, I struggled to find this information online, but my father has some good friends of his who used to participate in model rocketry, so I spoke to them in depth, and gained some valuable insight.

This information aided me in the decision of what to create as a product. Speaking to the experienced rocketeers further increased my curiosity in that field, so I decided to pursue rocket-building rather than telescope-building. Furthermore, it is considerably cheaper to build a model rocket, which played a large role in my final decision on the product.

2 Fox, Karen C. "How To Build a Dobsonian Telescope: DIY Astronomy Project."*Popular Mechanics*. Popular Mechanics, 9 Oct. 2008. Web. 22 Jan. 2015. <http://www.popularmechanics.com/science/space/telescopes/4286700>.

Planning

The Goal

The goal that I formulated for this project was to learn more about how rockets work and basic rocket science, through the means of designing and building my own model rocket by December. A picture of the final rocket can be seen in Appendix A. Although this was the original goal, this project brought me so much more, especially since I now have a newfound interest in model rocketry.

The first part of my plan to achieve this goal was to conduct a solid amount of research into the basics of rocket science, as well as model rockets. The basic rocket science would help me understand how rockets work, as the topic is of great interest to me. Furthermore, it is useful to have a nice foundation of knowledge whenever completing a difficult task, so this research would help me understand how model rockets may apply this science. The research into model rockets, however, was essential for my project. I needed to understand certain aspects about model rocketry that are crucial for the construction of such a product.

The next part of my plan was to design the rocket and plan its creation. I needed to create more detailed specifications, draw sketches, and even predict the flight statistics through the use of simulating computer software. All of this would eventually put me in the correct position to actually construct the rocket from scratch. Arguably the most difficult stage, this would put all my newfound knowledge to the test, as rockets need to be constructed quite precisely to work properly. Finally, I planned to launch my creation to see how it performed. All of this would gift me with some valuable experience and tons of new knowledge, essentially fulfilling my original goal.

The Global Context's Effect

As mentioned previously, the selected global context for this project was "Scientific and Technical Innovation." Although it is difficult to innovate with model rockets (as the hobby has been a popular one for decades, resulting in current designs being very efficient and reliable), there are still minor ways in which a person can innovate, specifically in the construction of the rocket. Due to my lack of experience, I planned on encountering numerous issues, some being quite difficult to overcome. The innovation that would need to be completed would mainly be through the use of "out-of-the-box" solutions to the problems that arose, as opposed to conventional ones.

The Original Product Criteria

As part of the early stages of the project, I also needed to set out criteria with which I could assess the final product. Although simple, these were important criteria that I needed to adhere with. The first criterion was that the size (height) of the rocket had to be between one and two metres tall, classifying my model rocket as a large model rocket. The second was that the rocket had to be re-usable, essentially meaning that the rocket needed to have a mechanism that would deploy either a parachute or streamer. The third original criterion was that the rocket would have to be able to launch to a minimum apogee of 1000 feet, as I was quite ambitious at the start (I later realised that this criteria was practically unachievable with the resources and experience I had). The next criterion was that everything required for the construction of the rocket had to cost less than £100 pounds, and the final criterion was that the rocket had to use homemade rocket fuel (but later research showed me that this is illegal where I live, and rocket motors must be bought through authorised companies). Despite being the original criteria, these were expanded upon further in the project, and the improved criteria were the ones used in the final evaluation.

Additional Research

The large amount of additional research that I completed during the investigation stage of my project was crucial to the overall success. For the majority of the time, the research remained on the Internet, through a variety of useful websites and articles. To start with, I studied the introductory material of rocket science, particularly looking at the four different aerodynamic forces (lift, weight, drag, and thrust). NASA's website (http://www.nasa.gov) was a popular one for me, as it was very useful, explaining all of this information in an understandable manner. It described the topics without the use of more complicated, subject-specific vocabulary that only a certain number of people would know, which was extremely helpful. I also came to the realisation that certain sources can also be misleading and unreliable, such as forums or articles written by those without credentials on the topic. I learned through this research process to stick with better-known, more reliable articles from renowned organisations (such as NASA). I began studying bits of information about the authors of the articles I read (if provided) so that I could better understand what kind of person was writing the information. Further information on what specifically was studied can be found in Appendices B and C.

After learning about rockets in general, I conducted research into different, important aspects of model rocketry. The first example of this was how I could create my own homemade rocket fuel. Although I did find a way, further research brought me to the important discovery that it is actually illegal in England to create homemade rocket fuel due to safety concerns. As a result, I then did some research into pre-made model rocket motors, just so I could understand how they work and how they are classified. Another piece of important information I required was the different materials that model rockets can be built out of, which I got through numerous forums and articles written by rocket enthusiasts that were found online. Contrary to my original belief, model rockets aren't actually made out of strong materials (like metal), but rather out of materials with a very good strength-to-weight ratio, like balsa wood and certain plastics.

Although this was the extent of the research I did during the investigation stage of my project, I learned more valuable information in the subsequent stages, especially tips and tricks that help during construction. Some of these tips were obtained through means other than the Internet, such as books, conversations with other people, and personal experience.

Taking Action

Modifications to the Plan

As the project progressed, there were numerous modifications to the plan based on unexpected events, ideas, and a handful of other reasons. One of the largest and most helpful modifications took place during my designing stage, in which I made the decision to attend a local Rocketry Society monthly launch day. This experience gave me some incredibly useful information, as I spoke with a large number of rocket enthusiasts, asking questions in all aspects of enquiry. I had the opportunity to personally view a very large number of rockets, which gave me a much clearer idea of what to expect. Furthermore, this experience allowed me to form numerous relationships, such as with rocket part sellers, who aided me in the future.

Another major alteration that occurred in the middle of the project was the updating of the original criteria. This new set of criteria was more extensive, detailed, and realistic, as a result of the research conducted in the investigation stage of the project. Some new specifications that were added include the maximum width and weight of the rocket, the classification of engine that would be used, and the aesthetics of the product. The full table of specifications can be found in Appendix D.

The other major alterations in my plan occurred during the construction stage of the problem, and all of them were a result of problems that arose during my original plans. One large example of this was during the process of building and placing the fins. I encountered issues with the alignment and fixation of the fins, as well as the precision of their shape. My original plan was valuably modified to benefit the product, and details of the entire modification process can be found in Appendix E.

Similar problems were encountered with the bulkhead, which is another key component of the rocket. There were issues with sizing, fixation, shape, and stiffness, all of which were overcome through multiple attempts. The final solution was quite ingenious, and examples the use of my imagination to modify the plan in a way that suited my needs. Further details on the modification of the bulkhead can be found in Appendix F.

Personal Insights on Research/Process Used in Product Completion

In hindsight, I am quite pleased with the effectiveness of my research, plan, and process used in the completion of my product. The research successfully set me up with a strong base of knowledge, which allowed me to continue with the project, as I understood the necessary information. As expected, there were gaps within the research that I identified further on in the project, but those gaps were filled as time progressed, so the issue didn't escalate.

The creation of a plan was also a very helpful action that eased the process of project completion. It allowed me to set goals, which in turn gave me the required motivation to finish the rocket and process journal before the deadline. It also allowed me to ensure that there was "cushion time" towards the end of the project, to make sure that any problems that would inevitably arise didn't result in a disaster that would create an inability to hand the project in on time. I believe that the improvement of my goal and deadline setting will be extremely helpful in the future, as I now understand my boundaries and limits, so it will be easier for me to set attainable goals and deadlines in the future.

The other undertaking that I truly believe to be one of the most beneficial things completed throughout the process was the attending of the rocket society monthly launch in November. I have mentioned it numerously on previous occasions, but I simply cannot properly describe how worthwhile the experience was. In all honesty, I believe that the project would have resulted very differently (in a negative fashion) had this event not been attended, so I am extremely glad that I grasped the opportunity.

Reflecting

Evaluation of Product Against Criteria

After some thought, I had deemed it more suitable to evaluate the product against the developed criteria that were formulated later in the project (as opposed to the original ones). I was very pleased to notice that my rocket fulfilled almost all the criteria and specifications that were created. For further information on the exact criteria, see Appendix D. For starters, my rocket took off successfully, and landed (in part) safely, hence completing the first criterion. The second criterion, however, cannot fully be analysed, seeing as the altimeter in the rocket failed to work, and therefore no flight data (specifically the apogee of the flight) was recorded. I believe, however, through my own guesses, that the rocket did reach a minimum apogee of 500ft. For a comprehensive report of the launch day, see Appendix G.

The next three criteria—which place focus on the dimensions of the rocket—were all fully completed. The rocket's height was approximately 120cm (between 100cm and 175cm), width was about 12cm (putting it well under the maximum size of 20cm), and the rocket weighed much less than 1kg. The rocket used a D-class motor and an ogive nose cone for the flight, which fulfils the subsequent two criteria. The next criterion (which stated that the amount of money spent on the rocket couldn't exceed £100) was definitely achieved, with all the parts costing about £30, and the altimeter costing a further £40. The rocket was made only using materials specified in the research section of the project, and it also had a parachute system built-in, making it recoverable and successful in the 9^{th} and 10^{th} criteria. Finally, the rocket was painted (red, white, and black), vastly improving the aesthetics, but the opinions of others were not obtained, so this opinion is solely a personal one.

New Insights on the Topic

As predicted at the beginning of the project, this experience has offered a huge amount of new insight into the topics of rocket science and model rocketry as a whole. The additional research completed was quite extensive for an MYP project, and the basics of rocket science (particularly the aerodynamic forces) quickly grasped my attention. Surprisingly, though, a very large portion of this insight wasn't gained through the research stage, but rather through the planning and creation stages. When I was the individual who had to figure everything out when planning and building, a whole new layer of knowledge and understanding was obtained. The experience of applying my newly acquired knowledge allowed me to identify what I didn't truly understand, and what required further research. Some examples included the understanding of the parachute deployment mechanism, the interior structure of a model rocket, and techniques used in the construction of such rockets. Furthermore, the new insight has only further expanded my curiosity into the topics, so I believe this project was a gateway for me to begin exploring the complex realm of rocket science and how it's applied on a smaller scale.

New Insights on the Global Context

Similarly to the topics, I also gained some valuable insight into my chosen Global Context, which was "Scientific and Technical Innovation." The experience has demonstrated to me the difficulty and degree of imagination required to innovate, specifically in the scientific and technological categories. My research led me to the realisation that unfortunately, in model rocketry, most innovation has already been made, seeing as the modern version of the hobby has existed since the early 1950's.[3] Despite this, I was still forced to create ingenious solutions to the numerous problems that arose throughout the project. The largest example of this was my decision to use a second engine mount tube with a piece of balsa wood plugging the hole as a makeshift bulkhead. Details of this decision can be located in Appendix F.

Development of the IB Learner Profile

There were three IB Learner Profile traits that I believe developed the most throughout the project. The first of these traits was to be knowledgeable. Although I had a minuscule base of knowledge on rocket science, it was nowhere near sufficient enough to carry out this project, and hence, a great deal of research was required in both basic rocket science and model rocketry. Furthermore, it wasn't only the textbook knowledge that grew, but also valuable designing and constructing techniques, which can be utilised in other fields besides model rocketry.

The second Learner Profile trait that developed quite largely was to be a thinker. I encountered numerous complex and serious issues throughout the project, particularly during the construction section, as have been specified previously in the report. In order to obtain solutions for such problems, I was often forced to step back and analyse the situation in detail, in search for a reasonable solution that would benefit the product as a whole. Although I struggled with such actions at the beginning of the project, my ability rapidly improved, and I am now confident with my decision-making in complex situations.

The final Learner Profile trait that developed by a considerable amount was risk-taking. Prior to the beginning of this project, I felt more comfortable taking the "safe" option in most situations, as opposed to attempting something slightly risky. This was mainly due to my fear of failure, and was a largely problematic characteristic of mine. Throughout the project, I was forced to take numerous risks; most of which ended successfully, but others didn't exactly result in the same fashion. I was not disappointed by the "failures" (for lack of a better word), but rather viewed in a different light, spotting areas for improvement that could be developed on in the future. I believe that this is an extremely important improvement of a characteristic of mine, as risk-taking is quite essential for success in the future.

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[3] Stine, G. Harry, and Bill Stine. *Handbook of Model Rocketry*. Hoboken, NJ: J. Wiley, 2004. Print.

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Appendix A

Evidence of my product, which is a photo depicting me and my rocket on the day of its launch:

Appendix B

A section of my process journal that gives an example of some of the research conducted:

INVESTIGATE

7th August

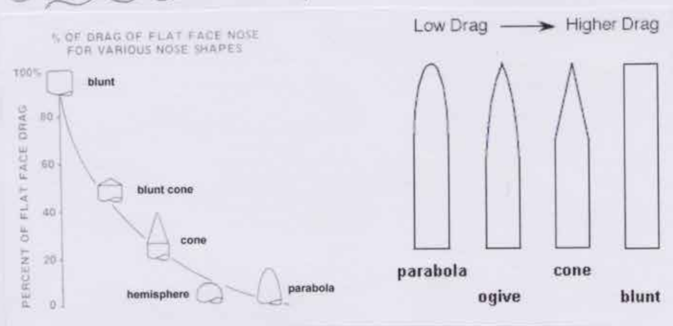
Research

Drag

* Drag is like "aerodynamic friction" or "resistance"
* One source of drag is skin friction
  ↳ Between air and the solid surface of the rocket
* A smooth, waxed surface produces less skin friction than a rough surface
* Another source of drag is form drag
  ↳ Aerodynamic resistance on the rocket
* Depends on the shape of the rocket

Reducing Drag:

① Nose cone: The shape of the nose cone is important for drag



- Rounded nose cones are better for subsonic speeds
  - Hemisphere
  - Parabola
- Pointed nose cones are better for supersonic speeds
  - Cone
  - Ogive
- For a model rocket, the ogive's nose cone is best (they go very fast)

INVESTIGATE

7th August

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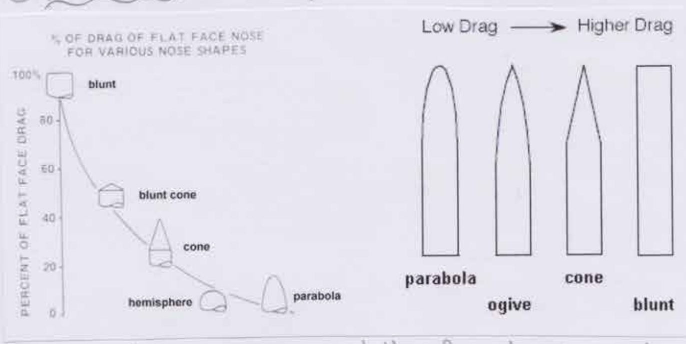

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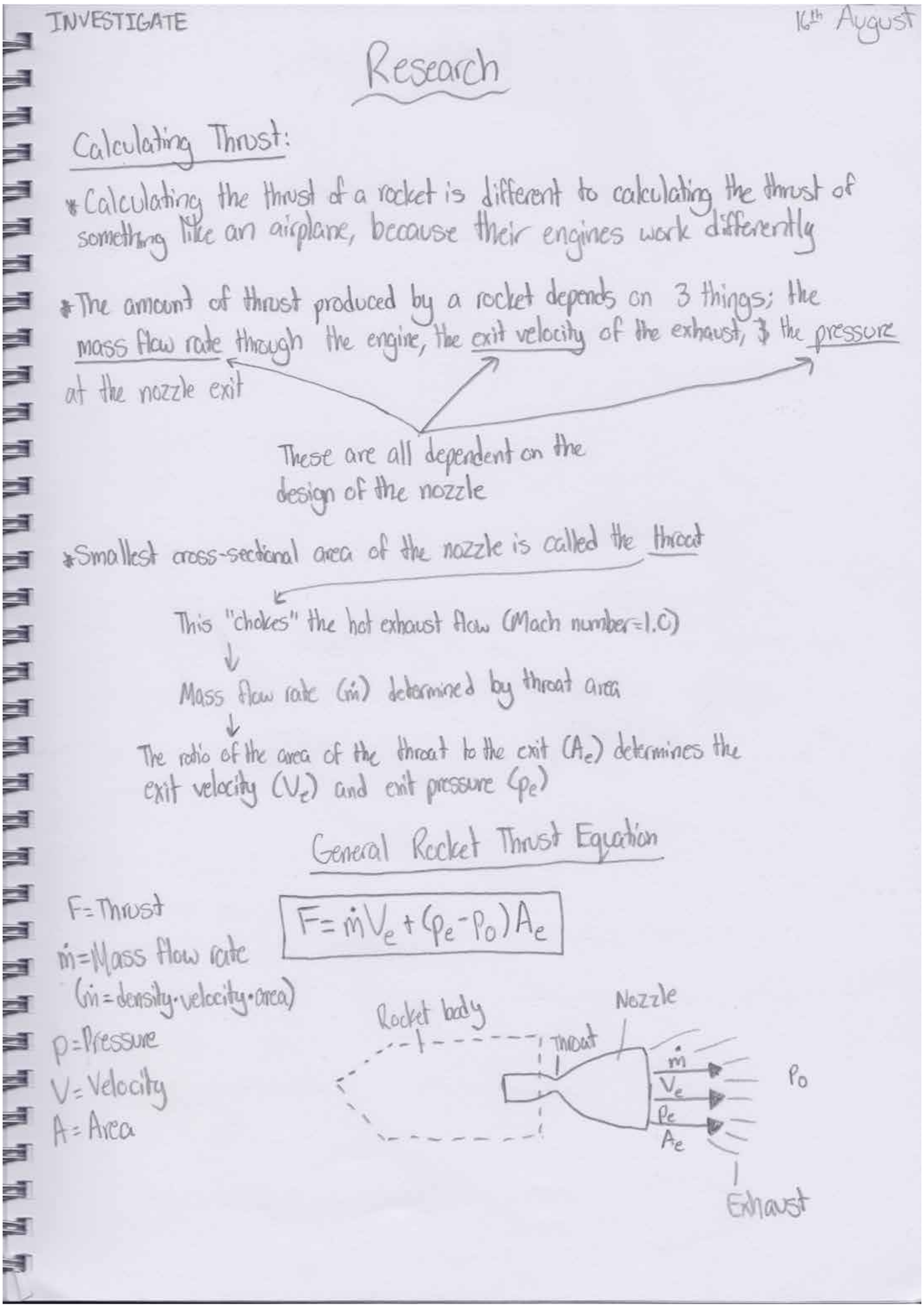
Appendix C

Another section of my process journal that gives an example of some research that was conducted:



INVESTIGATE

16th August

Research

Calculating Thrust:

* Calculating the thrust of a rocket is different to calculating the thrust of something like an airplane, because their engines work differently

* The amount of thrust produced by a rocket depends on 3 things; the mass flow rate through the engine, the exit velocity of the exhaust, & the pressure at the nozzle exit

These are all dependent on the design of the nozzle

* Smallest cross-sectional area of the nozzle is called the throat

This "chokes" the hot exhaust flow (Mach number = 1.0)

↓

Mass flow rate ($\dot{m}$) determined by throat area

↓

The ratio of the area of the throat to the exit (A_e) determines the exit velocity (V_e) and exit pressure (p_e)

General Rocket Thrust Equation

F = Thrust

$\dot{m}$ = Mass flow rate

($\dot{m}$ = density · velocity · area)

p = Pressure

V = Velocity

A = Area

$$F = \dot{m}V_e + (p_e - p_0)A_e$$

Appendix D

A section of my process journal that gives a detailed view of the updated and improved specifications/criteria:

DESIGN/PLAN

19th September

Initial Specifications

* The first step in the design stage is to create a simple list of initial specifications about the rocket
* Below is a table of the specifications:

Category	Target Description	Test
What should it do?	Take off and land safely	Launch the rocket and see if it performs correctly
How high should it fly?	Minimum of 500ft to about a maximum of 1500ft	Place an altimeter on the rocket
Size? (Height)	Minimum size should be 100 cm and maximum size should be my height (175cm)	Measure how tall the rocket is
Maximum width?	The diameter of the rocket's body should be no longer than 20cm	Measure the diameter of the rocket's body
Maximum weight?	Maximum weight is 1kg	Weigh the rocket
What type of engine should it use?	D, E, or F class motor	Cannot test
Type of nose cone?	Uses ogive nose cone	Cannot test
Maximum amount of money spent on the rocket?	No more than £100 should be spent on the rocket	Check total amount spent at end of project
Materials used?	Only materials listed in the research section	Cannot test
How will it be recovered?	The rocket will have a parachute attached to it	Make sure the parachute is on and works correctly
Aesthetics?	Paint the exterior of the rocket to make it look nicer	Ask friends about the looks of the rocket

Analysis of changes: (from basic criteria at beginning)

* Change in predicted height of flight
  - Minimum height reduced from 1000ft → 500ft
  - After research was completed, this was a much more reasonable objective
  - The rocket will be quite large, and to launch it to higher heights requires much more complex multi-stage motors which are too advanced for my level
* Change in the motor as mentioned earlier
  - Change from the use of homemade rocket fuel to a store-bought motor
  - This is due to legal issues with the construction of dangerous rocket fuel
  - Also, it is a lot more complex and time consuming, and won't perform nearly as well as an assembled motor

Appendix E

A section of my process journal that describes the modifications made to the fins of the rocket after problems were encountered:

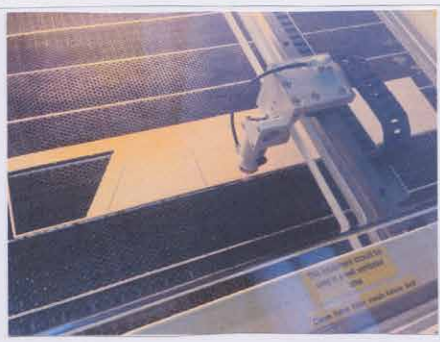
CREATION

Construction of Fins (31st October–8th November) 9th November

★ Due to time constraints, it was more effective to type this section ★

Description of First Attempt:

My first attempt at the fins started with me drawing the trapezoidal fin shapes onto the sheet of balsa wood I had purchased. These trapezoids had a base that was 120mm long, a height of 80mm, and a sweep length (length of smaller base) of 5cm. After the designs were drawn, I cut them out by hand with the modelling knife and used a ruler so I could get the cut as clean and straight as possible. I then sanded all of the fins, and started to glue them on without any guidance, as accurately as I could. For some unfortunate reason, the fins wouldn't align very nicely, and the fins were constantly shifting after they had been stuck down. Furthermore, the adhesive wasn't working as the bond was very weak and the first two fins I was putting on fell off after 30 minutes. At this point I knew I had a problem, because the launch date was two days away and I still needed to somehow cram the creation of the rest of the rocket in one day. Realising that it was practically impossible to achieve this task, I did some research and it turned out that another rocketry club—[redacted]—had a scheduled launch date the week after (9th November). Having set this as my new aim, I relaxed a bit and retried the creation of the fins, but this time, much differently and in a much better fashion.



Description of Second Attempt:

For the second attempt, I realised that I had the opportunity to complete this stage much more accurately. The first thing that needed improving was the positioning of the fins, so I purchased a guillotine jig online from the United States so it could be shipped here. This jig locks the body tube in place, and has lockable metal railings that line up the fins perfectly and hold them in place whilst the glue dries. Whilst waiting for the arrival of this jig, I looked at

CREATION

9th November

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alternatives for the cutting of the fins. I remembered that the school owns a laser cutter, so I spoke to my Design teacher and he agreed to let me use the equipment with his supervision. I designed the fins in a slightly different manner, creating a trapezoidal fin that had a right angle on one of its sides, but still had the same major dimensions, and put the design into the software for the laser cutter. The machine then got to work, and cut extremely precise fins for my disposal. I also realised that the sheet of balsa wood that I had used to cut the first fins was bent slightly, so I cut the new fins out of the sheet of basswood that I had also brought with me. I sanded the edges as well to ensure that each edge was flat, and rounded the leading edge of the each fin to reduce the drag produced by the fins. Once the guillotine jig finally arrived, it was time to glue the fins on. For added precision this time around, I used a sheet of paper to design a placement guide for the fins, which meant that they would be evenly spaced out around the tube. The final improvement during the gluing process was the use of a different gluing technique, which I had read about in a book, called the double joint glue bond. Basically, I applied a layer of glue to both the body tube and the fin, let it dry for 15 minutes, and then applied another layer to each and pressed it together. This bond makes sure that the glue bonds to other glue, creating a much stronger and firmer hold.

Evaluation:

The creation of the fins was definitely much for difficult and time consuming than the creation of the motor mount tube. I encountered numerous problems along the way that forced me to make improvements, and I believe that this only benefitted me. The decision to postpone the launch date was crucial, because I honestly do not think that I would've been able to finish the rest of the rocket in the remaining day, and even then, I still had quite a challenge to finish the rocket by the 9th November. The extra time allowed me to sit back and rethink how I was creating the fins, and this improved the result phenomenally. Had the original fins been used, the lack of accuracy and quality might have had a very large impact on the stability and outcome of the flight, so the new, precisely made fins were a major upgrade. I believe that the creation of the fins helped improve my problem-solving skills, because there were numerous improvements that I had to make, and they all required me to think differently. Problem-solving hasn't always been my strongest aspect, so I am pleased that I managed to fix what went wrong and end up with a final product that was done as accurately as I possibly could've done it.

Appendix F

Another section of my process journal that describes the modifications made to the bulkhead of the rocket after problems were encountered:

CREATION

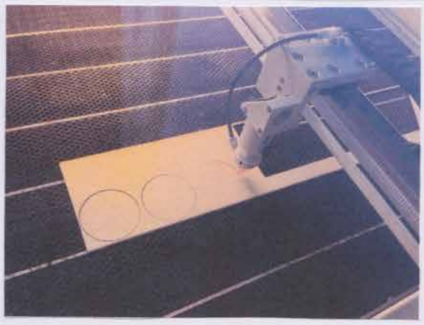
17th November

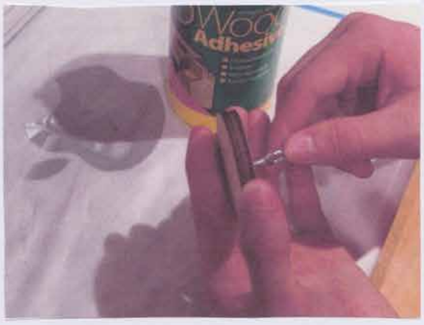
Construction of Bulkhead (31st October - 14th November)

☆ Due to time constraints, it was more effective to type this section ☆

Description of First Attempt:

My first attempt at the creation of a bulkhead started with the simple use of the bulkhead purchased from . The bulkhead I was using needed to both help the ejection of the parachute and hold the parachute as well. Despite being shaped so that it should fit perfectly inside a BT-70 body tube, it simply wouldn't fit, so I resorted to sanding the edges to create a smaller circle. Not only does this take a very, very long time, it also distorts the perfect circular shape, making it more difficult to fit into a circular design. Nonetheless, I still attempted to make this work, and managed to reduce the size of the circle significantly. One other problem encountered was the fact that the screw eye had barely anything to be screwed into, so I cut up small pieces of wood and glued on top of the other to create something for the screw to grasp on to. Once this was all finished, I tried to fit the bulkhead into the tube, but its distorted design meant that it didn't stick very well, even when accompanied with glue. Unfortunately, bulkheads need to be placed very tightly, because when the parachute deploys, the sudden change in speed means that a lot of force will be placed on the bulkhead, and it needs to remain in place. Realising that this simply wouldn't do, I had to look at other options.





Description of Second Attempt:

In an attempt to improve things, I decided to create my own bulkheads that would be the correct size. Along with the final set of fins I used on the rocket, I went to the Design lab in school and used the laser cutter to design and create perfect circles out of tough plywood that would fit exactly into the tube. I cut multiple ones, and this time around, I

CREATION

17th November

Construction of Bulkhead (31st October- 14th November)

glued multiple bulkheads together. The first reason this was done was so that the screw eye could have more wood to dig into, and secondly, this creates a larger surface area over which glue could be applied, meaning that it would stick even more solidly into the tube. Furthermore, glue isn't actually required for this bulkhead, because its extremely tight fit means that a friction bond will be substantial to withstand the forces. Using this idea, I jammed the bulkhead into the tube, and it fit perfectly (and very tightly). I put it through some tests to make sure that it could withstand some forces, by knocking it and pulling on the screw to see that nothing broke off. Once satisfied, I placed the upper tube into the lower tube, and that's where I noticed a problem. The bulkhead made that part of the tube very stiff, and the upper body tube didn't fit very well into the lower body tube. Unfortunately, this is a major problem in model rocketry, because it is crucial that the two halves can separate easily, so that the parachute can be deployed with ease. Realising that I had yet another problem on my hands, it was back to the beginning and I needed another solution.

Description of Third Attempt:

At this point in time, I was in quite a desperate position, because I needed to think of a solution very quickly, as the launch date was in two days. My dad was checking the website to confirm the location of the launch site when the club released an announcement that due to very bad weather conditions that were predicted for the entire weekend, the launch date would be postponed by a week to the 16th November. This news couldn't have come at a better time, because now I could afford to think about a solution for a while. Just when I had thought I was out of ideas, a great one popped into my mind. I had previously built a second motor mount for back up, and it fit perfectly into the body tube. By gluing this into the upper body tube, all I needed to do was plug the hole of the tube and it created a makeshift "bulkhead." I decided to use a balsa wood adapter originally designed for the Comet Chaser (the first of the two practice rockets I built) and glued it into the hole using 5 minute epoxy adhesive (which is very powerful). Now, I had a piece of wood into which I could put the screw eye, and I had something that the ejection charge could push off of to separate the two halves of the rocket during flight.

CREATION

17th November

Construction of Bulkhead (31st October – 14th November)

Evaluation:

Similarly to the creation of the fins, the creation of a bulkhead was a lot harder than expected. I faced numerous problems, and it took three attempts to find something that worked. Yet again, the postponing of the launch date by the club gave me some much-needed time, and allowed me to ponder solutions to the different problems that kept arising. However, I do feel like the final "bulkhead" that was used in the rocket perhaps wasn't the best solution in terms of efficiency (the second idea did the job perfectly with a tougher plywood), but despite this, the final solution was the only one that solved all the problems. It is a slightly risky solution as well, but I believe it was a risk worth taking. Again, I believe that this section improved my problem-solving skills, and required me to think out-of-the-box quite a bit, formulating a solution that I previously would have never thought of. This section also made me realise that I should've done more extensive research into bulkheads, because surely there is a much simpler and efficient solution for larger model rockets.

Appendix G

A section of my process journal that gives a comprehensive report of the launch day as a whole:

CREATION

19th November

Description of Launch Day (16th November)

☆Due to time constraints, it was more effective to type this section☆

The day started out with quite some terrible weather, as it was raining and windy in the morning. I checked the Rocketry website, and it seemed as if the launch would go on despite the rain, because the weather was predicted to clear up at around noon. My family and I packed the car with the rocket as well as all the tools and equipment just in case they were needed. After a 2 and half hour car drive, we finally arrived at the launch site in , which is northeast of . It had stopped raining, but was still overcast with low visibility, which meant that nobody was allowed to launch a rocket above 1000ft. This wasn't a problem for me, as my rocket was predicted to fly no higher than 500ft, and the terrible weather conditions of the day meant that it probably wouldn't even reach that height.

Once I had the trunk of my car set up with the rocket, I went and purchased the last thing I needed, which was a D12-5 motor (D12-3s were not available, and this will be expanded upon later). I set up the motor inside the motor mount, secured it, and prepared the rocket for flight. This included attaching the parachute, stuffing the rocket with recovery wadding (which protects the parachute from the heat produced by the motor), and storing the parachute inside the body tube for flight. I also set up the altimeter, and now, I was completely ready for launch.

Just as I had finished preparing the rocket, the weather worsened once more, as the wind picked up and it started to rain again. Knowing I needed to launch the rocket as soon as I could, the launch range officer helped me set the rocket up on the launch pad, and connected the electrical wires to the motor of the rocket. We moved back 20ft, switched on the launch controller, and I pressed the button, but the rocket didn't take off. After standing down the launch, the range officer checked that the wires were hooked up correctly, and we tried once more, but yet again, the rocket failed to launch. This time around, we checked the igniting plug, and realised that it had burnt itself out and that was why the rocket wouldn't launch. After quickly replacing the igniting plug, I tried for a third time, and this time, I had a launch.

The rocket shot off of the launch pad quite well, but a gust of wind tilted its course by a bit instead of straight up. Despite this, the rocket continued into the air, coasted, reached its apogee, and then began falling back down to the ground as the parachute didn't deploy at apogee like it was supposed to. It began accelerating quite quickly towards the ground, and finally, once the rocket was about 15m from impact (and travelling quite fast) the parachute finally deployed. Unfortunately, the sudden change in speed meant that the two halves of the rocket were ripped apart and both hit the ground pretty hard, as they were only slowed down a bit. After analysing the damage, I noticed that the top half of the rocket landed nose first into the ground, and remained perfectly intact, as the plastic nose cone is quite tough. The bottom half, however, had one of its fins broken off, as that specific fin took the brunt of the force. I also realised that it was the screw eye that was ripped out of the balsa wood, and that was why the two halves didn't remain together. Furthermore, the altimeter didn't record any data, which was very confusing for me as I was sure I had set it up properly and that it was ready for flight.

CREATION

19th November

Description of Launch Day (16th November)

Although it may appear as if this flight was a failure, I was actually quite pleased with the fact that the rocket even made it up a couple hundred feet into the air. The damage to the rocket is very easily fixable with strong glue, and fin breaks are very common in model rocketry, even when parachutes deploy properly. Furthermore, everything that went wrong was all tied back to two things, which were the weather and ejection time of the motor. For starters, wind and rain are the two conditions in which it is best not to fly a model rocket. They can easily turn rockets off-course, and have a high chance of causing problems during the flight. Nonetheless, I made the decision to go through with the launch, because I had a strong urge to see the rocket I spent so long designing and building in action. As a result of launching it in these conditions, the rocket's flight path was distorted and perhaps that could have had an effect on the outcome of the flight and why the parachute deployed so late. Perhaps, had the conditions been nicer, the apogee of the flight would have been higher in the sky, and the rocket's flight time would have been longer. As a result, the parachute would have deployed earlier.

The other (larger) issue that resulted in the damage was the ejection time of the motor. The simulating software showed me that the optimum delay time was 3.45 seconds, meaning that a D12-3 motor would have been best suited for the flight of this rocket. Unfortunately, come the day of the launch, those motors were not available, so I settled on a D12-5, hoping that it would still work fine. Contrary to my belief, the 5-second delay charge did not work very well during my flight, and is the exact reason why the parachute deployed so late into the flight. Had a D12-3 motor been used, the parachute would have deployed at apogee, and the rocket would have floated down gently and return undamaged.

The largest thing that this launch has taught me is the importance of ejection timing. The launch of my own rocket has showed me how much of a difference two seconds can make. Despite this problem technically being out of my control (the motor I needed wasn't available), it may be a better idea in the future to order the motors online prior to the day of the launch. I have also learned about the importance of weather conditions, and perhaps some people may think it would've been a better idea to call off the launch and wait for better weather. Unfortunately, this was my last opportunity to launch the rocket, and I really wanted to see it go up, so I made the decision to launch it in the rain and wind, and still stand by that decision. The damage caused is very easily fixable, so I believe that the flight was a success overall.