Prototyping the Power of Compressed air

Systems Engineering Portfolio

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Adjusted Assessment Criteria

Note: Indicators for each Criteria are hyperlinked to the first relevant slide that addresses the indicator, however, naturally there may be other slides that have a relevance to that indicator.

The Systems Engineering 2020 Assessment Criteria have been adjusted, in response to the coronavirus pandemic and the obstructing, unexpected events throughout the school year of 2020.

Assessment Criteria 1

Criteria:

Investigation of a problem/situation/opportunity/need and develop a design brief for an integrated controlled system including evaluation criteria

Indicators:

Identifies problem / situation / opportunity / need	Design brief for an integrated controlled system, explains its context, constraints and considerations	Develops evaluation criteria and justifies how the evaluation criteria relate to the requirements of the design brief	Responds to design Brief - proposed project with very clear statement of what was intended to be built.	References factors that influence the creation and use of the system – include relevant electrical and mechanical concepts

Assessment Criteria 2

Criteria:

Researching, devising, designing and modelling design options

Indicators:

Conducts research including modelling of components, subsystems, systems	Generates design ideas	Produces feasible design options, using annotated diagrams and technical data to justify feasible options	Selects and justifies preferred option, with consideration of the likely outputs and performance, with the feasibility of production

Assessment Criteria 3

Criteria:

Planning the creation of the system

Indicators:

Devises workplan (timeline, sequence of steps and associated equipment, components, (materials, and processes) that applies the Systems Engineering Process	Analysing how materials, components, processes and tools will be used for the successful creation of the preferred option	Describes safety and risk assessment for materials, components and processes

Assessment Criteria 4

Criteria:

Use of tools, equipment and machines to make an integrated controlled aspect of the mechanical and electrotechnological ~~the~~ system

Indicators:

Implements the relevant steps of a work plan independently using production processes, and tools, equipment, components and materials with precision and technical skills to produce an integrated controlled aspect of the mechanical and electrotechnological ~~the~~ preferred option	Compliant with OH&S requirements

Assessment Criteria 5

Criteria:

Realisation of an aspect of the integrated controlled system

Indicators:

Independently produces an operational aspect of an integrated, controlled system that addresses the performance of the aspect, relevant context, considerations and constraints of the design brief and as described in the work plan with documented modifications.

Assessment Criteria 6

Criteria:

Use of diagnostic test procedures and interpreting test data

Indicators:

Identifies and provides reasons for diagnostic tests, then explains how to set up diagnostic tests	Conducts these tests, accurately following the procedure, to generate data. Presents accurate, relevant and quantified test data	Uses extensive technical information and comprehensive understanding of the test data to interpret the data and draw conclusions	Takes appropriate action, such as modifications or repairs, based off conclusions of the data to optimise the performance of the system

Assessment Criteria 7

Criteria:

Project management to realise an integrated controlled aspect of the preferred option

Indicators:

Independently demonstrates skills in time management, the Systems Engineering Process and organisation to produce an integrated controlled aspect of the preferred option, while addressing factors that influence the project	Describes evidence of progress for production work and diagnostic testing	Describes evidence of risk assessments for production work and diagnostic testing	Justifies decision-making, which supports that choices were appropriate, and modifications where required

Assessment Criteria 8

Criteria:

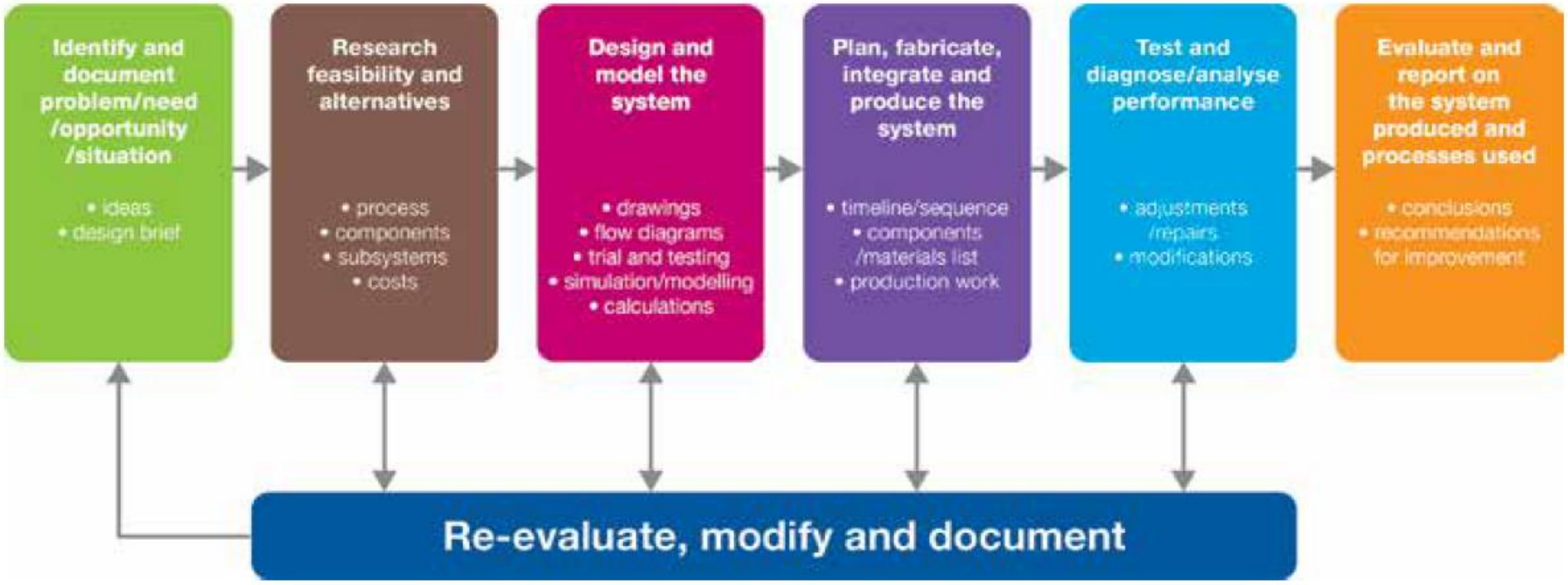
Evaluating the use of the systems engineering process~~, including finished, integrated controlled system~~

Indicators:

Discusses the difficulties and deviations from the work plan during the production stage, with a reflection on the actions taken in response.	Comprehensively evaluates and reflects on the use of the Systems Engineering Process and the effectiveness of the planning stage to the performance of production, making references to the work plan, progress reports, difficulties, materials, tools and processes. Justifies any suggested improvements to the production of the aspect of the system.	Uses the systems engineering process including diagnostic testing and the pre-determined criteria to evaluate the performance of the integrated controlled aspect of the system	Evaluates the design and provides thorough recommendations to the design, with consideration of factors that influenced the design, planning, production and evaluation criteria.

System Engineering Process

The systems engineering process, illustrated below, represents the stages in creating a system. The process is iterative. Students must continuously re-evaluate their progress and make necessary modifications after having revisited an earlier stage or activity. The goal of the application of the systems engineering process is to achieve an efficient, optimised, quality system.



The Opportunity.

Data collected from the prototype developed will indicate the capabilities of compressed air. From this, predictions and considerations can be made into the designs of cars and other applications with compressed air. There have been many attempts to apply compressed air in the transportation industry, such as to transport vehicles. These designs typically operate by releasing air from a container to drive an engine's turbines or pistons.

Another perspective is to expel highly pressurized cold air to provide the vehicle with an additional boost in acceleration. The concept is to store a substantial amount of pressurized air in a very small space within the vehicle then, as boosters, help propel and stop the vehicle. Such an application can support turning at high speeds or tight corners by releasing the air from the sides of the car, front or back. As the traction limit of the tires constraints the power output of an engine, thrusters can overcome this barrier and improve cornering and braking. Similarly, the vehicle's 0 to 100km/h time record quickens by 20% (4.16s to 3.31s) with the addition of thrusters.

This is just one of the many potential uses of air compression. I intend to demonstrate and evaluate the performance of air compression through utilising a compressed air rocket launcher and the rocket's flight data.

Design Brief

This project is a protype and proof of concept, demonstrating the power of compressing air to explosively launch a rocket. To improve the use of the product, called Air Pro, the design must be portable. Consequently, considerations of the design must ensure the weight and size are reasonable and physically possible to transport, particularly through doorways and corridors.

Within Scope

Pressurize a PVC tank with air through a compressor, utilising a pressure transducer to measure the pressure.

Check the pressure in the system and once complete, ready to launch. Can set the limit of PSI in a set range. Pressure relief valve ensures the system does not compress above the set limit.

Release compressed air to accelerate the rocket upwards to a high altitude and record flight data with a 9-axis sensor along with camera feed. Raspberry Pi in rocket connects in real time with the Raspberry Pi at the launch site.

Recover the rocket through the recovery system, utilising a parachute.

Relay the data through an access point to the server raspberry pi to feed to the screen and display the data to the user in an understandable and informative manner.

Not in Scope

Determine what makes a rocket aerodynamic.

To investigate the relationship between the volume of air and performance of rocket.

To investigate the relationship between temperature of compressed air and the performance of the rocket.

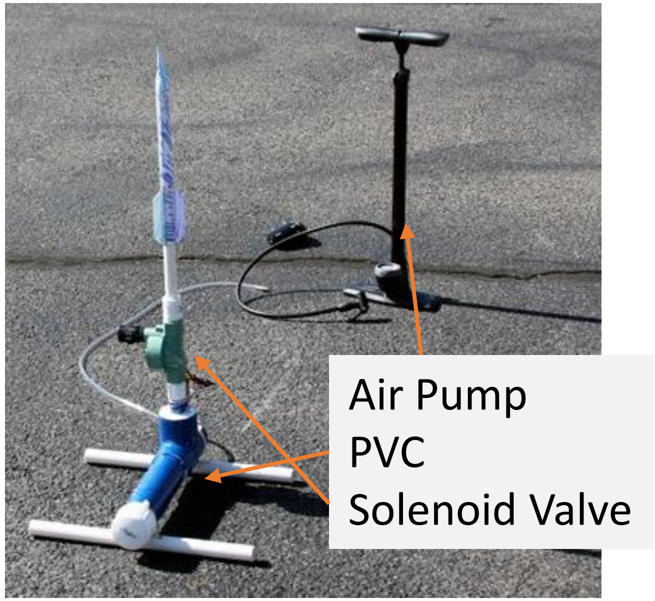
Evaluation of my project

The launch system can launch the rocket to a height of 15m. The height of the flight indicates the effectiveness compressed air has been used to project the rocket into the air. As such, the performance of the launch system can be assessed by the flight height of the rocket, with the target being 15m high.
The pressure transducer can measure the air pressure accurately (±1.5% of the actual pressure) and communicate to the system in a timely manner (within 2ms). Essential for accurate calculations leading to wise analysis and deduction.
To timely validate the performance of the launch system, synchronous communication between the rocket and the launcher is vital. Consequently, it is necessary for the data to be wirelessly received with accuracy. As such, the time taken to send and receive data can be assessed with the expectation of 10ms. Furthermore, there is an expectation that no errors occur during data communication, which can be assessed by monitoring the system for such errors.
The rocket land momentum must be reasonable for recovery, to ensure the collision between the ground and the rocket is minimal. Hence improves the cost-efficiency and minimises production time, as the rocket and its parts are reused, appealing to potential experimenters. Considering this, the momentum of the rocket as it lands must be no more than 5 m/s kg. The flight data can be utilised to assess to what extent the rocket's landing meets this target.
Rocket CEP (Circular Error Probable) is the radius of the circle in which 50% of the fired rockets land. The flight of the rocket regarding its horizontal travel during the flight can be analysed to assess the effectiveness of the fins to keep the rocket stable in flight and on course. As such, the rocket's CEP is expected to be within a 10m radius. Flight data can be used to calculate the horizontal distance and evaluate the performance of the flight regarding the target. This is of serious concern due to the threat to people and infrastructure should the rocket horizontally travel and collie.
With all these measures of success, trials can be performed to evaluate whether the results indicate the performance of the system is consistently within the targets.

My Project

The project is to build a PVC pressurised system to store compressed air, while using a pressure transducer to monitor the air pressure. The pressure relief valve ensures and prevents over-pressurization of the system, to eliminate the risk of components being damaged and experimenters endangered. The solenoid valve opens to release compressed air, accelerating the rocket while the payload containing an electrical system records and sends flight data to the user interface. Prior to this, the gantry aids the rocket with balance support but retracts to prevent any collision with the rocket during takeoff.

Example Rocket Tutorial



https://makezine.com/2010/07/11/how-to-building-the-compressed-air/

The project design is similar to the design of the launch system for tutorials regarding building a compressed air rocket launcher, but with a key difference that a electrical compressor pressurises the system to a higher degree than a hand pump and more air is stored.

The project will use flight data to support the concept that air compression can be used to launch a rocket. Ultimately, the desire is that the uses and limitations of air compression are evaluated through the performance of the flight.

Meanwhile, the screen interface will support the user in launching the trial and understanding the flight data that will highlight key statistics.

Factors to Consider

Ultimately, the project is constrained by a competition date of the week before the September holidays (11th September). As time is of the essence, the designs must be realistic in that they can be produced and operational within the timeframe, with an allowance for unexpected mistakes or errors. Another time consideration is to constantly review the production progress. While this may take valuable time, being organized will improve efficiency and may prevent errors by revising design ideas prior to production.

The budget of $220 benefits the product, since even if impressive results are made, industries will be less keen if the product is not profitable and cost effective. Essentially the components must be purchased and selected wisely to minimize costs, which stems from realistic designs and strategic sourcing of components. Not only cost, but the ease of use, weight and location impacts the component used. Similarly, performance of selected components must be analyzed, as a compressor rated for 150PSI cannot operate safely beyond this limit, although PVC Piping class 12 has a maximum pressure rating of 174PSI. Considering each component and its technical information produces a lasting, functional and safe system. However, when working with compressed air, the components, experimenters and nearby people are at a risk of accidental over-pressurization, so an incorporated pressure relief valve is a fail safe to prevent such accidents.

The following, from AC 101-02 regarding rockets, primarily impacts the conditions of the location for rocket launching. However, 101.425 highlights an important consideration in the rocket design. Particularly that it cannot weigh more than 1500 grams and not to be made of metal for structural parts, potentially for safety precautions to people at a risk of the projected rocket.

From AC 101-02 regarding rockets:

101.055

A person must not operate an unmanned aircraft in a way that creates a hazard to another aircraft, another person, or property. A person must not launch a rocket that is not an aircraft in a way that creates a hazard to an aircraft. A person must not launch a rocket that is not an aircraft in a way that creates a hazard to another person or to property.

101.455

A person must not launch a rocket (including a model rocket) to higher than 400 feet AGL in controlled airspace

101.470

A person must not launch a model rocket into cloud. A person must not launch a model rocket to higher than 400 feet AGL within 5 nautical miles of an aerodrome.

7.2.1

When considering a launch site for flying small model rockets several factors need addressing. The launch site should;

(a) be in a cleared area;

(b) be free of tall trees;

(c) be free of overhead power lines;

(d) be free of buildings;

(e) be free of dry brush and grass;

101.425

model rocket means a rocket that:

(a) weighs no more than 1 500 grams; and

(b) carries no more than 125 grams of propellant; and

(c) produces no more than 320 newton-seconds of impulse; and

(d) is made of balsa, wood, paper or plastics or a combination of those materials, but contains no metal as structural parts.

https://www.casa.gov.au/standard-page/casr-part-101-unmanned-aircraft-and-rocket-operations

How do I plan to make it?

1. Build launch system
2. Make balance support
3. Integrate Subsystems from 1 and 2 on an appropriate base
4. Program screen and integrate user interface with electronics
5. Fabricate rocket body and fins
6. Construct rocket interior electronics
7. Create rocket parachute recovery subsystem

Furthermore these subsystems are considered in depth when designing to explore a variety of alternatives. For instance, the design of the PVC pipes have many alternatives, where some specialize in compactness and ease of transport of the product.

Additionally, each design idea and the related component(s) can be evaluated at a micro basis. Each component and design idea has relevant mechanical and electronical principles and uses related to it. Hence, the purpose of these designs are interpreted, so consequently, the design idea is fundamentally understood and possibly questioned for its suitability. As later revealed, the gantry subsystem has design alternatives. Each design alternative has different principles associated and considering the nature and function of the subsystem, the most suitable option can be carefully selected. The less appropriate design idea for the gantry system could eventually reveal the fundamental flaw of the design, such as that the gantry system failures to provide balance to the rocket, due to the required shape of the claw or the stress on gears and the servo in suddenly stopping the rotating crane of the gantry.

In addition, design ideas that are realistically doable at home, such as programming, are easily identified while the cutting of the wood and other mechanical aspects are allocated to class time.

Continue to Components

Components and Materials

At the beginning of research and designing, the lack of understanding regarding PVC pipes, fittings, solenoid valves and so on obstructed realistic and usable design ideas. Hence, I realised how essential it is to understand the components and materials before diving into designs.

Launch System	Gantry	Screen & Programming	Rocket	General
Pressure Transducer	Limit Switch	Display	Fins	Printing Filament
Relief Valve	Stepper Motor	Microcontrollers	Power Supply	Glue
Solenoid Valves	Actuators	Router	Voltage Regulator	Wood
PVC Pipes	Steel Angle Brackets		Parachute	Jumper Cables
Primer and Cement			Parachute Ejection	Power Lead
Teflon Tape			Camera	
Compressor			Electricity Storage	
Relay			The Batteries	
Power Supply			Sensors	

Spreadsheet for Budget and Sourcing Components is here.

Pressure Transducer

Purpose

An instrument for measuring the condition of a fluid (liquid or gas) that is specified by the force that the fluid would exert, when at rest, on a unit area

P (Pressure) = F (Force) / A (Area)

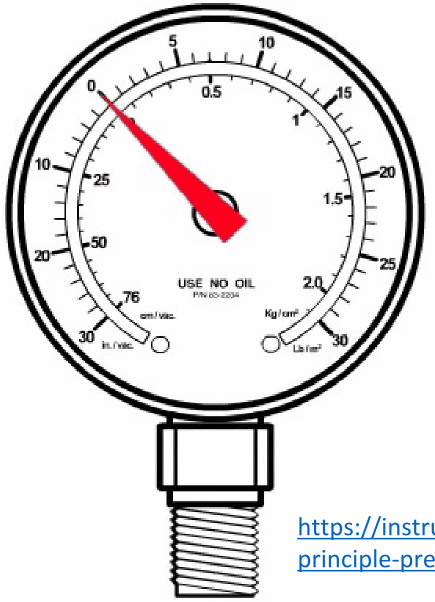
Data Sheet of Pressure Transducer

https://www.variohm.com/news-media/technical-blog-archive/working-principle-of-a-pressure-sensor

Operation

Digital pressure transducers involve the sensing element with a constant area that respond to the force applied on this area by the fluid’s pressure. The force applied deflects the diaphragm within the pressure transducer. The deflection is measured and converted into an electrical output, allowing the pressure to be monitored by microprocessors.

On the other hand, Bourdon pressure gauges use the principle that a flattened tube tries to straighten or regain its cross-sectional form when pressurised. Consequently, as the pressure heightens in the demonstration on the right, the closed end of the tube moves in an arc, and this movement is converted into rotation of the pressure gauge to indicate the pressure status. Since there is no electrical signal involved, these gauges are applicable for people rather than microcontrollers.



https://instrumentationtools.com/working-principle-pressure-gauge/

Relief Valve

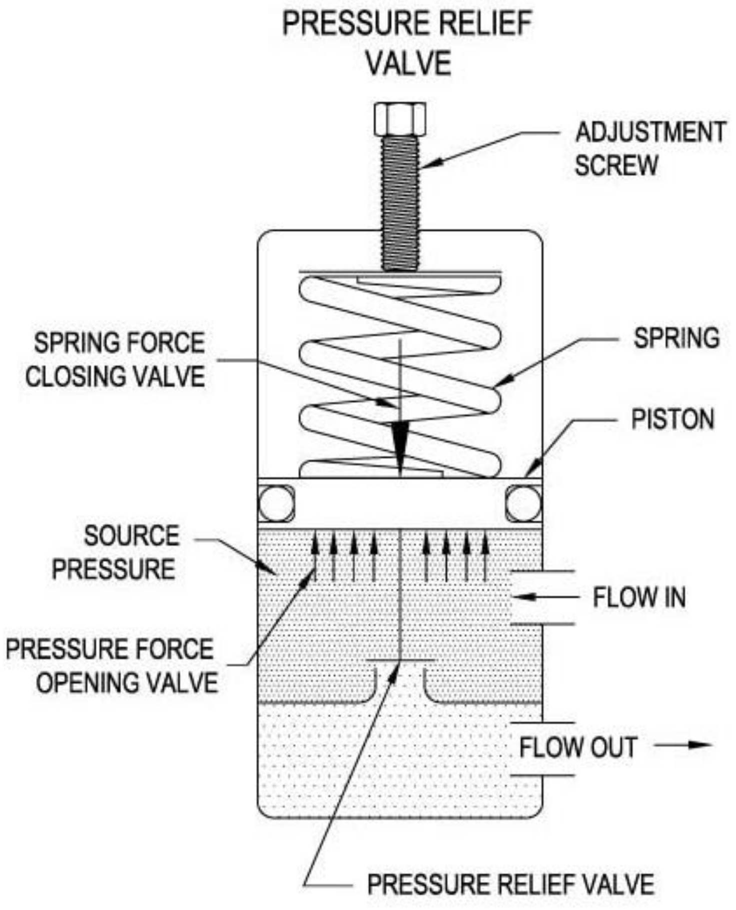
Purpose

To protect a pressurized vessel or system during an overpressure event. An overpressure event refers to any condition which would cause pressure in a vessel or system to increase beyond the specified design pressure or maximum allowable working pressure (MAWP)

Function

The pressure relief valve remains normally closed until pressures upstream (in the system) reaches the selected set pressure. The valve opens when the set pressure is reached, and remains open until the upstream pressure falls below the set pressure.

The spring exerts a force on the sensing element, so closes the valve. However, when the upstream pressure exerts a greater force than the spring force, the relief valve opens and allows the fluid to exit through the outlet. Hence, pressure relief valves can protect the system, since fluid releases, lowering the pressure in the system, at a certain pressure limit.



https://www.beswick.com/resources/the-basics-of-pressure-relief-valves/

Part 1: Solenoid Valves

A solenoid refers to a coil of wire used to make an electromagnet. In doing so electricity can transform to mechanical energy, as the electromagnet with flowing electrons induce a magnetic field around an iron core. The magnetic attraction with the plunger applies a force on the plunger to overcome the spring force. A normally closed valve means that the plunger is lifted, so the seal (F in the diagram) opens the aperture, allowing the flow of the fluid through the valve. Opposite to this, normally open, is when the plunger is down so that the seal (F) blocks the aperture, preventing the flow of fluid.

Direct-acting Solenoid Valves

Direct-acting solenoid valves use electric current to active the coils in the solenoid to generate an electric field that attracts the plunger towards the midpoint of the coil. As the plunger is normally blocking the air of fluid flow, the plunger's movement will stop blocking the flow and so the solenoid valve is opened. They require a constant flow of electricity to remain open as once the current is stopped the electromagnetic field stops and so the valve will return to its original closed position due to the restoring force of the spring.
As a high amount of current is constantly flowing to keep the valve opened, these valves are less efficient and waste electricity from the generation of heat and sound.

Solenoid Valve Diagram

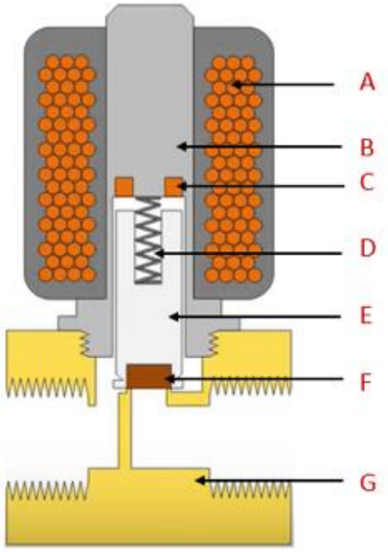


Figure 2: Components of a solenoid valve; coil (A); armature (B); shading ring (C); spring (D); plunger (E); seal (F); valve body (G)

https://tameson.com/solenoid-valve-types.html

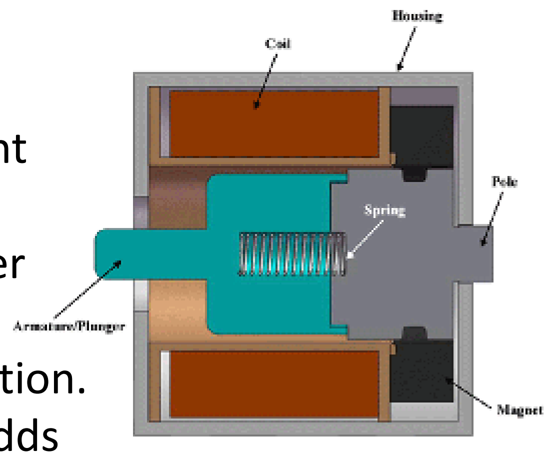
Continue to Part Two (Latching) of Solenoid Valves

Part 2: Solenoid Valves: Latching

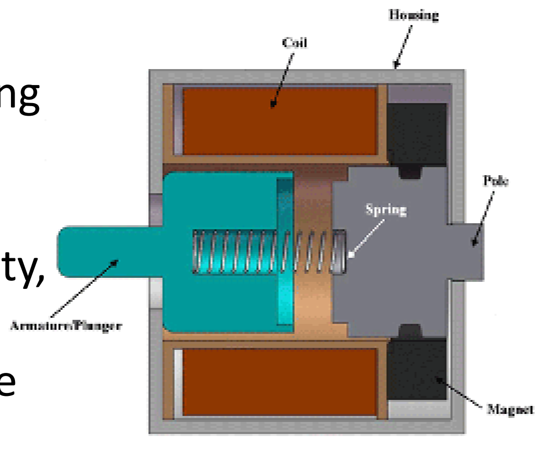
On the other hand, latching solenoids use an electrical current pulse and internal permanent magnet to maintain a set position without requiring the constant flow of electricity. They operate similar to typical linear solenoids, but have two stable positions giving them another name 'bistable solenoid'.

Latching solenoids use electrical polarity to apply a force on the armature in a specific direction. When the current flows in one direction energizing the magnetic field, the magnetic field adds to the pull of the permanent magnet making the armature be attracted to the stationary pole. When the armature reaches the magnet, after switching off the supply of electricity the armature will remain in position. The armature is released from this latched position by turning on the current in the opposite direction as the magnetic field produced cancels the magnet's attraction allowing the spring to return the armature to the de-latched position.

As latching solenoids can remain in the latched position without the constant flow of electricity, they are more energy efficient in the regard that they remain in the latched position without using electricity. Coupled with this, they produce less heat and sound so are less noisy and are unlikely to heat up potentially benefiting heat-sensitive applications where the heat from solenoid valves could cause lead to consequences. As they are turned on for a short pulse, higher currents can be used to producing a faster operating speed and pulling force without the excessive power consumption and heat production normal solenoids would lead to. They are also suited to battery operated applications due to their low power usage.



Latched Position



De-Latched Position

https://www.tlxtech.com/uploads/pdf/Understanding-Latching-Solenoid-Presentation.pdf

Part 1: PVC

Purpose: Stores the compressed air from the compressor for the rocket launch.
In addition, fittings can provide additional features to the system, such as connections for valves or pressure transducers.

Units and Understanding Importance of Specifications

PVC is pressure rated in terms of bars, with 1 bar equivalent to 14.5PSI and 100 kPa. Pipes are categorised by their nominal pressure rating or class (PN) at 20°C. For a specific pipe diameter, the wall thickness increases with increasing pressure rating. So for products labelled PN18, this indicates a maximum of (18*14.5) = 261PSI.
The **safety factor** is a ratio between the strength of the system over the maximum stress that the system will encounter. Considering the safety factor of the system during design can reduce the likelihood of part failure. When the safety factor is less than 1 as the stress the system is expected to endure is beyond what the system is rated for then it indicates that the system is highly likely to break down.
Dangerous to over-work components as their failure can put lives as risk. For instance, PVC exploding from over pressurisation can severely injure people. This article stresses that extended use of PVC and use in abnormally high temperatures reduces the maximum pressure the PVC can tolerate. The specifications of PVC pipes must be considered to produce a safe, operational product.

Specifications Documents	PVC Class to PSI Rating	PVC Dimensions and Specifications

Continue to Part Two of PVC

Part 2: PVC

PVC, a synthetic plastic made of polyvinyl chloride, has a wide range of applications from plumbing systems to small projects and DIY racks. PVC pipe is connected to a pipe fitting using primer then cement, forming an airtight and leak-proof bond. The versatile properties, such as lightweight, durable and low cost allow this product to be useful in a wide range of applications. The composition is typically 57% chlorine and 43% carbon.

Forms of PVC

Plasticized or Flexible PVC: PVC-P: Formed by addition of suitable plasticizers to PVC which lower the crystallinity and these plasticizers act like lubricants allowing clearer and flexible plastic.

Un-plasticized or Rigid PVC: PVC-U: Stiff and cost-effective with a high resistance to impact, water, weather, chemicals and corrosive conditions.

Chlorinated Polyvinyl Chloride: CPCV: Prepared by chlorination of PVC resin. High chlorine Criteria results in high durability, chemical stability, flame retardancy and wider range of temperatures.

Molecular Oriented PVC: PVC-O: Reorganized amorphous structure of PVC-U into a layered structure. Bi-axially oriented PVC imparts enhanced physical properties.

Modified PVC: PVC-M: Alloy of PVC formed by addition of modifying agents, enhancing the toughness and impact properties.

Continue to Part Three of PVC

Part 3: PVC Common Parts

Sockets

Slip refers to the fact that there are no threads or barbs. To secure a slip fitting, glue or some other adhesive must be used. PVC pipes fit into PVC fittings, as PVC fittings have a larger circular radius to allow PVC pipes to fit snug.

PVC Tee

PVC Cap

PVC 90° Elbow

PVC Pipe

PVC Valve Socket

PVC Reducing Coupling

Images from http://www.bunnings.com.au/

Continue to Part Four of PVC

Part 4: PVC Threads

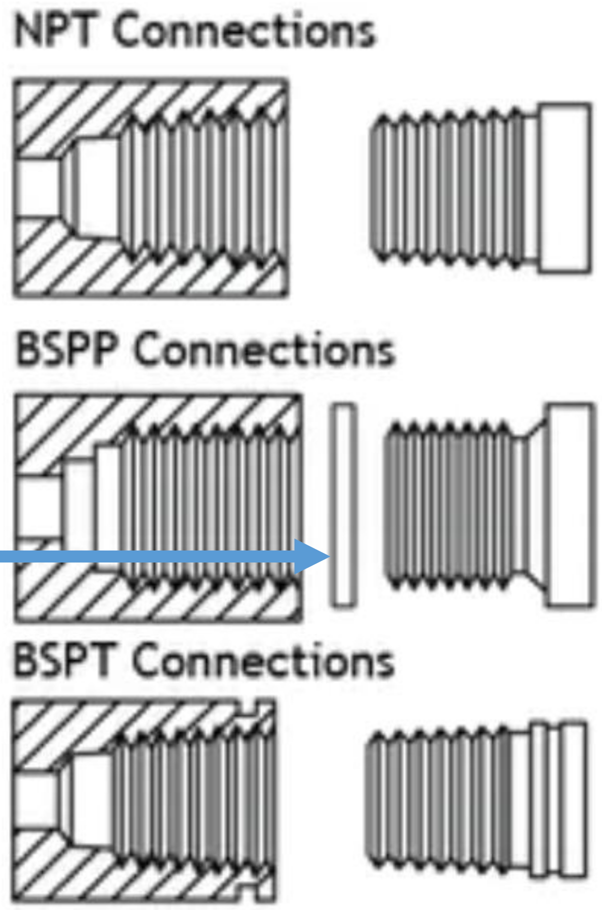
NPT (National Pipe Thread)

Similar to BSPT, but slightly different as peaks and valleys are flat while the angle of thread is 60 degrees.
BSP is not compatible with NPT so requires an adaptor
MPT , MNPT or **NPT** (M) for male external threads and FPT, FNPT or **NPT**(F) for female internal threads

BSP (British Standard Pipe)

BSPT stands for British Standard Pipe Thread.
These connections have rounded peaks and valleys while the angle of the thread is 55 degrees, indicating they are not compatable with NPT threads.

BSPP stands for British Standard Parallel Pipe, sometimes referred to as G. This parallel thread fitting requires a bonded **seal ring** to seal the connection, due to the parallel connection.
BSPT (tapered) male **will** mate with a **BSPT** (tapered) female, or a **BSPP** (parallel) female



Images from https://www.ralstoninst.com/news/story/the-difference-between-npt-bspp-and-bspt-seals

Continue to Part Five of PVC

Part 5: PVC: Properties

Key properties of PVC polymer are summarised below.

Property	Description
Electrical	Has good dielectric strength, so is an insulator.
Durability	Resistant to weathering, chemical rotting, shock and corrosion. Hence, a suitable material in long-term and outdoor applications.
Flame Retardancy	The high chlorine composition allows PVC products to be self-extinguishing. PVC has a high fire performance.
Cost to Performance	Long life span and low maintenance with durable physical properties suggests that the material has remarkable cost to performance advantages.
Mechanical	Abrasion resistant (ability to withstand friction and not to wear away) and is both lightweight while tough.
Chemical Resistance	Resistant to all inorganic chemicals and high resistance to diluted acids, diluted alkalis and aliphatic hydrocarbons. However, is damaged by ketones and some grades are not resistant to chlorinated and aromatic hydrocarbons, esters and nitro compounds.
Safety and Heath Impacts	Polyvinyl Chloride (PVC) commonly enters the body from ingestion, such as contaminated food or water. Inhalation is possible by breathing in emissions from the manufacture or incarnation of PVC. Lastly, skin contact is another possibility. A main component of PVC, chlorine, can impact the health of the person from exposure. Short term exposure to low levels may lead to nose, eye and throat irritation. However, high chlorine levels in the air cause more severe consequences such as coughing and difficulty breathing, blurred vision, nausea and vomiting. Breathing in high amounts may even be life threatening unlike skin contact that can only lead to irritation and blisters. Meanwhile, long term exposure can lead to respiratory problems, memory loss, impaired balance, slow reaction time and hearing loss.

Continue to Part Six of PVC

Part 6: PVC: Recycling

PVC is **100% recyclable** and is identified by recycling code #3.

A balance is necessary between the economic benefits and environmental impacts in the process of recycling PVC. One of the key financial implications in recycling plastics is that the sorting plastic waste is labour intensive while yielding little revenue, so proves difficult to be profitable.

Mechanical recycling of PVC is a process where PVC is shredded and grinded. The quality of the recycled product is dependent on its original composition and can vary significantly. After mechanical separation, PVC is grinded, washed and treated to eliminate impurities then reprocessed and reused. The incineration of PVC releases dioxins and other toxic chemicals.

Chemical recycling breaks down the polymer into monomers or other substances. The chlorine component is extracted in the form of Hydrogen Chloride then re-used or neutralised so that new products can be made. Stabilizers with a high composition of heavy metals tend to end up in landfill. The separation process of different additives and compounds forming the plastic has lead to difficulty in the recycling process.

Feedstock recycling typically uses thermal treatment of the PVC while extracting the hydrogen chlorine which can be used to produce recycled PVC or for other products.

Thermoplastics can be remelted then reused, although the quality of the material typically reduces after each reuse. Meanwhile, **landfill of PVC** impacts the environment and society. As **PVC is not biodegradable**, it will remain in landfill forever and can potentially pollute the soil and water with dangerous chemicals.

The Society of the Plastics Industry (PSI) made a classification system to identify the type of plastic for sorting during disposal. The coding system has a SPI code with an arrow symbol that is required to be moulded or imprinted to the bottom of plastic products.

Continue to Part Seven of PVC

Part 7: PVC: Recycling

Australian Standards have a safety factor included and varies depending on one of three different standards. Checking the pipe specifications indicates whether it meets a certain standard.

Many factors which must be considered when determining the severity of service and the appropriate pipe used.

Factors include:

Operating pressure characteristics:

a) Maximum steady state or static pressures.

b) Dynamic conditions, frequency and magnitude of pressure variations due to system operation or demand variation

Temperature: PVC stress capability is temperature dependent.

Other load conditions: Earth loads, traffic loads, bending stresses, installation loads, expansion and contraction stresses and other mechanical loads.

Service life required: As the PVC subsystem is unregularly used during 6 months, the service life is very brief.

Safety Factor:

Safety factor generally influenced by the risk assessment and financial implications of the components failing and the possible risks associated with the components.

Default factors of safety are built into Australian Standards for PVC pipes with the expected design point of 50 years. For PVC-U to AS/NZS 1477 the standard safety factor is 2.145, PVC-O and PVC-M has 1.6 and 1.4 respectively. Hence purchased PVC for the project can be evaluated with the associated Australian Standard to evaluate the safety factor built into the product.

Part 1: Glues

Glue bonds the two materials together but the suitable glue for these two materials and strength required varies.

White Craft Glue

Most common craft glue suitable for porous lightweight materials including paper, cardboard, cloth and small crafts. As it is water-based, the glue has low to no toxicity. Takes a few minutes to an hour to set.
Dries clear and is to some degree flexible.

Yellow Wood Glue

Any type of adhesive specifically designed to bond together wood and wooden surfaces. As such, applications include furniture and wood crafting. Various range of wood glues available, each suitable for specific needs for the application. In general, any wood glue has a high strength, resistance to humid or wet environments and fills any gaps between the wood surfaces when it sets. Takes a couple of hours to a day to completely set with clamps needed to keep the materials firmly pressed together.

Super Glue

Super glue has superlative properties, allowing it to bond a variety of materials such as metal, ceramics, wood and plastic. Cyanoacrylate adhesives, what super glue is, is well-known to set quickly with a strong bond and a clear finish. Cyanoacrylate adhesives are efficient in forming strong bonds with plastic and wood materials, allowing the 3D printed plastic spikes to be strongly fastened to the wooden base.

Applying

Sand surfaces to develop a good surface contact area to maximise the strength of the bond Sets within 60 seconds and cures hard within two hours.
Once cured, residue visible can be cleaned with acetone.

Continue to Part Two of Glues

Part 2: Glues

Hot Glue

Hot glue refers to the melting and cooling of polymers that can act as an adhesive. The hot glue from a glue gun is typically melted between 120°C to 190°C, with the properties of the adhesive dependent on the type of polymer melted. Hot glue is applicable for a range of applications, including porous and non-porous surfaces. The high viscosity can bond uneven surfaces and fills in gaps. Furthermore, while the glue forms a high strength bond, the bond weakens in elevated temperatures.

Hot glue sets very quickly while being easy to use and is applicable to any material besides metals.

While the hot glue will not develop as strong a bond between plastic and wood, it has potential benefits. If the materials were uneven or inconsistent, hot glue could potentially bond the surfaces better than super glue. However, as these surfaces are flat super glue will result in a better bond.

Epoxy

Epoxy is a type of glue made from epoxy, a chemical compound. The composition of these adhesives varies, allowing for a range of glues with different properties suitable for specific applications. Their bonds have high strength, as these adhesives can fill microscopic holes on the surface of materials being bonded together. Meanwhile, these adhesives can offer a range of flexibility and fast cure speed.

Epoxy glues come with the bottle applied first, the resin, and the second bottle, the hardener. Some epoxies are multi-purpose while others are formulated for certain uses.

Epoxy can be useful in joining plastic with wood. The adhesive dries fast, works in a range of environments and temperature and fills gaps in uneven porous surfaces. However, considering useful super glue with bonding strength on par with epoxy is readily available for use, super glue is more favourable. If epoxy were to be used, it'd likely take longer to apply as there are two bottles requiring more steps unlike superglue, that is already on hand.

Part 1: Plywood

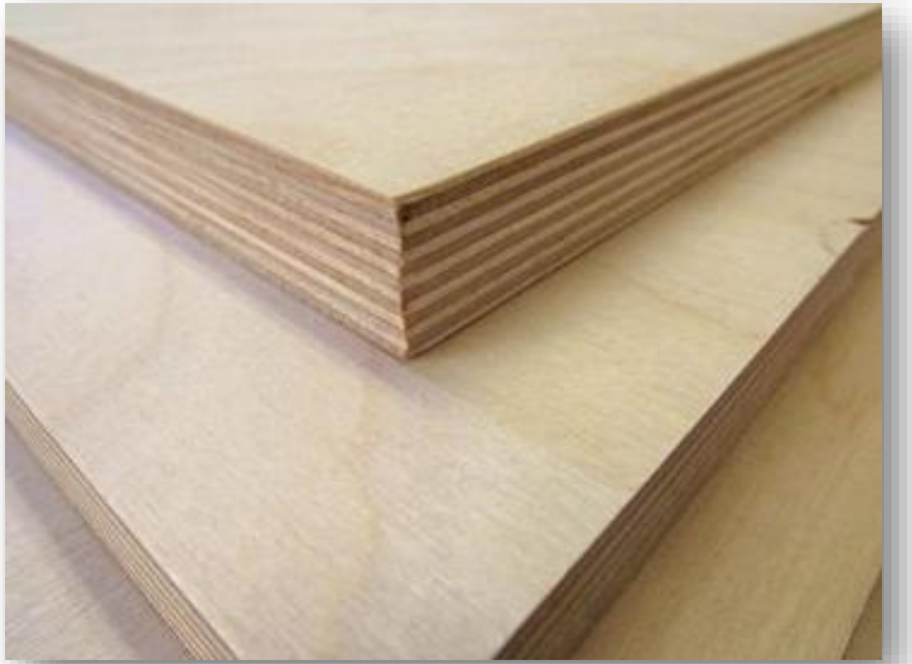
Plywood is an engineering panel produced from slicers of thin veneers and alternating the grain direction each successive layer, then gluing these together.
Plywood is also a renewable resource, indicating the use of plywood does not harm the environment.

There are four different types of plywood, being structural plywood, interior plywood, exterior plywood and marine plywood.
Both structural and marine plywood are suitable for the project as they have a high strength and stiffness to weight ratio, dimensional stability, damage resistant and chemically resistant. Marine plywood is both paintable and water resistant, increasing how useful the material can be to the project. Although the rocket is not intended to be launched on water nor is it necessary to paint the base as the natural wood looks appealing, these properties have potential use in the future if the project were further developed or modified.
On hand is marine plywood and considering the suitability it will be used as the base and support for the gantry. MDF is also readily available, however, the coming slides explain why marine plywood is the better choice.

Continue to Part Two of Plywood: Marine Plywood

Part 2: Marine Plywood

Marine plywood has waterproof glue used. Gaps weaken the strength of the plywood and allow for water to enter the material. Marine plywood has no core gaps, indicating that the plywood is stronger than ordinary plywood, better water resistance and naturally looks attractive. Lastly, the material of the face and veneers are high quality producing a high performing product while exposed to harsh elements. Marine plywood has high weathering properties so is suitable for exterior applications. Furthermore, the good structural properties such as excellent stability, durability, physical an mechanical resistance allows the material to be suitable for a wide range of applications. This plywood is scratch proof and impact resistant, as it has extremely hard outer layers and can withstand daily wear and tear in commercial uses.
With this, the surface finish forms an incredible material that, as the base of the project, will be stable and strong while giving a stunning appearance of the natural wood.



https://www.indiamart.com/proddetail/marine-plywood-19624005791.html

Continue to Part Three of Plywood: MDF and Selection

Part 3: MDF and Selection

MDF saves trees as the material is made of compressed wood fibres and adhesives. As it is typically made using wood scraps and waste, it is less expensive than plywood. MDF is weaker than plywood and can split or crack under high loads. Furthermore MDF absorbs water quicker than wood so can easily swell from exposure to water and moisture. As water damage is likely, its use is limited to furniture construction where it is sheltered from the weather.

It is difficult to screw and nail into MDF, adding reason to why MDF is not suitable to be used as the base for the project. While it may be a cheaper alternative than plywood, the material is comparatively weak and poses much greater risk in being damaged from exposure to the weather and water while flights are conducted.

Hence the better material choice is the marine plywood for the strength, ease of use, already available and professional look.

https://www.addicted2decorating.com/mdf-vs-plywood-differences-pros-and-cons-and-when-to-use-what.html

Primer and Cement

Different kinds of cements and primers are formulated for various types of plastic piping. Ensure the type used is suitable for the piping.
PVC pipes and fittings are fused together through chemical reactions known as solvent welding, making two separate pieces of plastic one piece.

Primer

Primer is made of around 20% to 40% acetone.
Primer begins the chemical reaction that softens PVC and provides a prepared surface for the solvent cement. As primer contains acetone, applying primer softens the outer layer of PVC resulting in maximum joint strength.
The Data Sheet of the Primer is here.

Cement

Solvents dissolve, soften and melt plastics allowing them to meld the pipe and fitting into one piece. As PVC cement is a solvent, applying cement softens the PVC and the molecules bond together to form a single piece of plastic.
Cement selected is compatible with the PVC selected and will form a strong bond for pressurized systems.
The Data Sheet of the Cement is here.

Teflon Tape

Teflon tape creates a tight-fitting seal around the threads of many joints in piping and ductwork. The layers help to prevent leaks, however, due to the very low surface friction using Teflon tape provides lubrication to mate connections tightly and smoothly. Furthermore later uncoupling joints are easier and less prone to damage and wear.
Teflon tape is recommended for threaded connections without a built-in rubber seal. As it is water-repellent, the product is applicable for a wide range of plumbing and ductwork.

The selected Teflon is suitable up to 2,000 kPa, equivalent to 290PSI.
The Data Sheet for the Teflon Tape selected is here.

Part 1: 3D Printing Filament

ABS is a terpolymer, a combination of styrene, acrylonitrile and polybutadiene, while PLA is a polyester produced by fermentation under controlled environments of a carbohydrate source such as corn starch or sugarcane. Thermoplastics are liquid when they enter a glass transition at a certain temperature, so they can be heated to this temperature then cooled in certain shapes to rapidly fabricate protypes and parts.

Density Comparison

ABS is 1.04g/cm^3 PLA is 1.24g/cm^3 (1.24-1.04)/1.04*100=19.2308%

These calculations indicate the density of ABS is 19% less than PLA

Biodegradability

PLA is stable in typical atmospheric conditions. Takes 50 days to biodegrade in industrial composters and 48 months in water.

ABS is not biodegradable but recyclable.

Strength

In some applications such as on the base rather than the rocket, the strength of the component is more important than how much it weighs. While ABS is less dense, this study supports that PLA is stronger than ABS. Using PLA rather than ABS in structural situations can improve the strength of the component as it can withstand greater loads before breaking.

Comparison of PLA and ABS for Printing

Temperature	PLA	ABS
Print bed temperature	20-60°C (optional)	80-110°C (mandatory)
Glass transition temperature	57°C	104°C
Melting temperature	150-160°C	N/A*
Printing temperature	180-230°C	210-250°C
Enclosure	Optional	Recommended
Clogs/Jams Nozzle	Occasionally	Never
First Layer Adhesion	Minor problems	Minor problems
Fumes	Little to none	Bad and intense
Absorbs Moisture	Yes	Yes

https://all3dp.com/1/pla-vs-abs-filament-3d-printing/

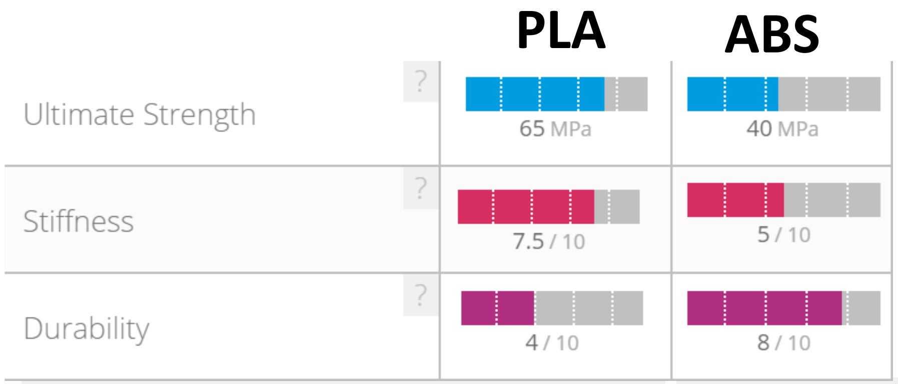
Continue to Part Two of 3D Printing Filament

Part 2: 3D Printing Filament

PLA (Polylactic Acid)

PLA is a user-friendly thermoplastic with a higher strength and stiffness than both ABS and nylon. With a low melting temperature and minimal warping, PLA is one of the easiest materials to 3D print successfully. Unfortunately, its low melting point also causes it to lose virtually all stiffness and strength at temperatures above 50 degrees Celsius. In addition, PLA is brittle, leading to parts with poor durability and impact resistance.

Although PLA is the strongest of these three plastics, its poor chemical and heat resistance force it into almost exclusively hobbyist applications.



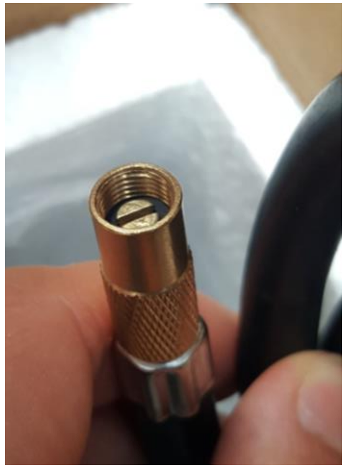
https://www.simplify3d.com/support/materials-guide/properties-table/?filas=abs,pla

https://markforged.com/resources/blog/pla-abs-nylon

ABS (Acrylonitrile butadiene styrene)

ABS, while weaker and less rigid than PLA, is a tougher, lighter filament more suitable for some applications beyond purely hobbyist. ABS is a bit more durable and has four times higher impact resistance. ABS does require more effort to print than PLA because it's more heat resistant and prone to warping. This calls for a heated bed and an extruder that is 40-50 degrees Celsius hotter. ABS, while by no means a heat resistant plastic, has superior heat deflection temperature compared to PLA. The improved durability over PLA lends ABS to some more practical applications, such as prototyping and low-stress end-use parts.

Compressor



23-Feb-2020

Air compressors operate by forcing air into a chamber and pressurising it, by pumping air in to build up the pressure. The electrical energy transforms into kinetic energy of the air particles. The power supply provides up to 15A at 12V; a sufficient amount of current to operate the compressor according to the user manual's specifications. Furthermore, the power supply unit displays a gauge of the current being drawn to verify and analyse current draw over time and the corresponding PSI. The Data Sheet for Ozito 12V 150PSI Air Compressor is here.

Schrader and Presta Valves

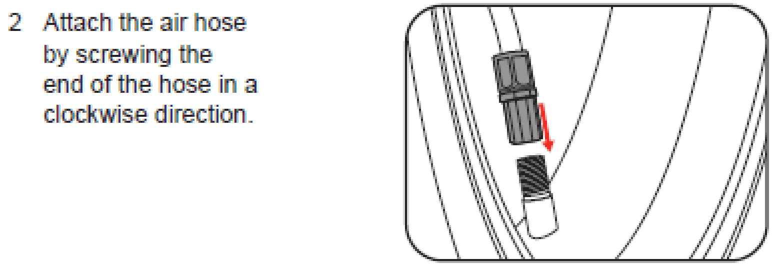
Presta valves are primarily used on bicycle inner tubes and due to their slender shape are popular on thin tires of sports and racing bicycles. Their diameter is 6mm while Schrader valves have an 8mm diameter. Furthermore, their connection is different to Schrader valves so cannot be so easily integrated with the connection of the compressor's hose.

The particular benefit of the Schrader valve is the ease of use and functionality as the hose can be screwed onto the Schrader valve for reliable pumping of air.

The Data Sheet for the Schrader Valve is here.

https://bicycles.stackexchange.com/questions/8157/why-are-both-schrader-and-presta-valves-still-used-on-tubes/8162

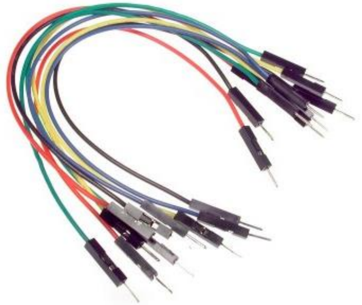
As emphasised by the user manual, the Ozito Air Compressor hose screws onto a Schrader valve (identified by the image of the valve.)



Snippet of Ozito Air Compressor Manual

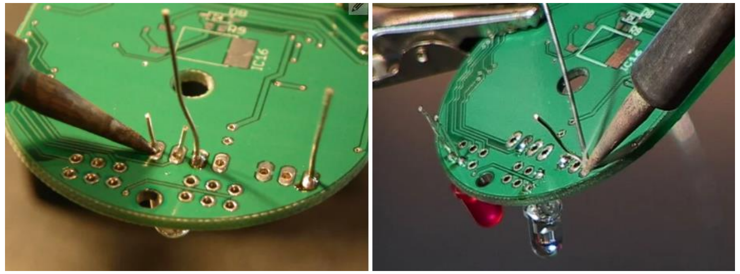
Power and Jumper Cables

From Bunnings, this Extensions Lead is 20m length and runs at 240V, 10amp and 2400 watt. The compressor runs at 12V max 14amp, so 168 watt is well within the 2400 watt capability of the power lead.
Hence overheating and risk in overloading the extension lead is negligible.
The power lead is essential since the rocket is launched away from infrastructure, so a moderate distance is necessary. While a battery is a mobile power source, it is an unnecessary hassle to charge and a significant cost factor to the product. Consequently, customers are less attracted to such a product.
The electricity in the wires runs through the MP3800, Data Sheet here, an AC to DC **variable power supply**. 12V DC can be easily configured using knobs to alter the output voltage. The power supply unit reduces the voltage using a step-down transformer to the required voltage. The AC voltage is rectified typically using a set of diodes, converting the sine waves into a series of positive peaks.



https://www.exploringarduino.com/parts/jumper-wires/

Jumper cables connects components, as the cables allow electricity to flow since the wire is metallic and is a good conductor. While a Printed Circuit Board (PCB) properly secures the connections and forms a neat system, due to time constraints of the prototype, jumper cables are favoured. Similarly, jumper cables used during construction and testing supports rapid prototyping and testing to efficiently identify issues with a subsystem. *Note that electrical components are wired in parallel, to provide sufficient voltage and allows for individual control of the component*.



https://www.instructables.com/id/How-to-solder/

Relay

The relay offers two different types of electrical connections. The normally open (NO) terminal is normally open, indicating that only when the relay is switched on will the loop be closed and current will flow. Opposite to this is the normally closed (NC) terminal, which as the name suggests, the loop is normally closed and current normally flows through. As Diagram 1 demonstrates, the signal from the microcontroller opens the Normally Closed circuit indicating current ceases to flow.

The relay is like a Single Pole Double Throw, however, a microcontroller operates the switch by sending a HIGH signal at the signal pin. The relay switches using an electromagnet, where the induced magnetic field pushes the contacts of the switch open or closed.

Hence, relays protect circuits by isolating them from high currents and voltages. For instance, the microcontroller cannot directly operate the compressor as the high currents and voltage would damage the microcontroller, so a relay is essential.

Relay Diagram

Diagram 1

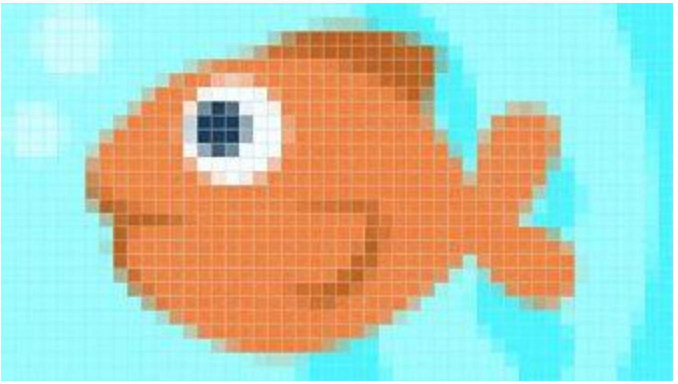
https://mounishkokkula.wordpress.com/how-the-5v-relay-works/

Diagram 2

https://mounishkokkula.wordpress.com/how-the-5v-relay-works/

Raspberry Pi Display

3.5" Display for Raspberry Pi
Data Sheet here.
Features 320×480 resolution and resistive touch control
The display is formed of tiny blocks called pixels.
The LCD display operates by using the liquid crystals embedded into the display screen. The backlight behind the screen illuminates each pixel individually to form the image.
Images are formed as the display is made of several layers, including electrodes and a polarised filter. When the backlight is turned on, light is somewhat obstructed by the liquid crystals. Consequently, the pixels illuminate as a certain colour and form an image. This concept is emphasised by the fish diagram, where the pixels are largened to demonstrate how they work together to form an image.



https://www.bbc.co.uk/bitesize/topics/zf2f9j6/articles/z2tgr82

http://www.lcdwiki.com/images/3/36/MPI3501-002.jpg

Microcontrollers

Components Criteria 2 Criteria

Arduino Leonardo vs Arduino Uno *(from https://www.arduino.cc/)*

Name	Processor	Operating/Input Voltage	CPU Speed	Analog In/Out	Digital IO/PWM	EEPROM [kB]	SRAM [kB]	Flash [kB]	USB	UART
Leonardo	ATmega32U4	5 V / 7-12 V	16 MHz	12/0	20/7	1	2.5	32	Micro	1
Uno	ATmega328P	5 V / 7-12 V	16 MHz	6/0	14/6	1	2	32	Regular	1

Microcontrollers have a CPU, Central Processing Unit, which allows the program to run. Meanwhile, RAM, Random-Access Memory, is where the microcontroller stores information. They are like computers in that regard but are programmed to perform a specific task whereas computers run a variety of programs. Arduino is an "open-source electronics platform", allowing users to program specific tasks. Arduino is a single-board computer, meaning it is a combination of microprocesses, ports and memory. On the other hand, Raspberry Pi is a cheap and small computer with models including built in Wi-Fi and Bluetooth functionality.

The table above compares the Uno to the Leonardo. They both have the same CPU speed, Voltage, EEPROM, Flash, UART, but the Leonardo offers a USB-Micro connection and more Analog and Digital Pins. The length and width of the Leonardo is 68.6mm and 53.3mm respectively, while that of the Uno is 68.6mm by 53.4mm. Hence, these microcontrollers are fairly identical excluding additional pins and a micro USB connection for the Arduino.

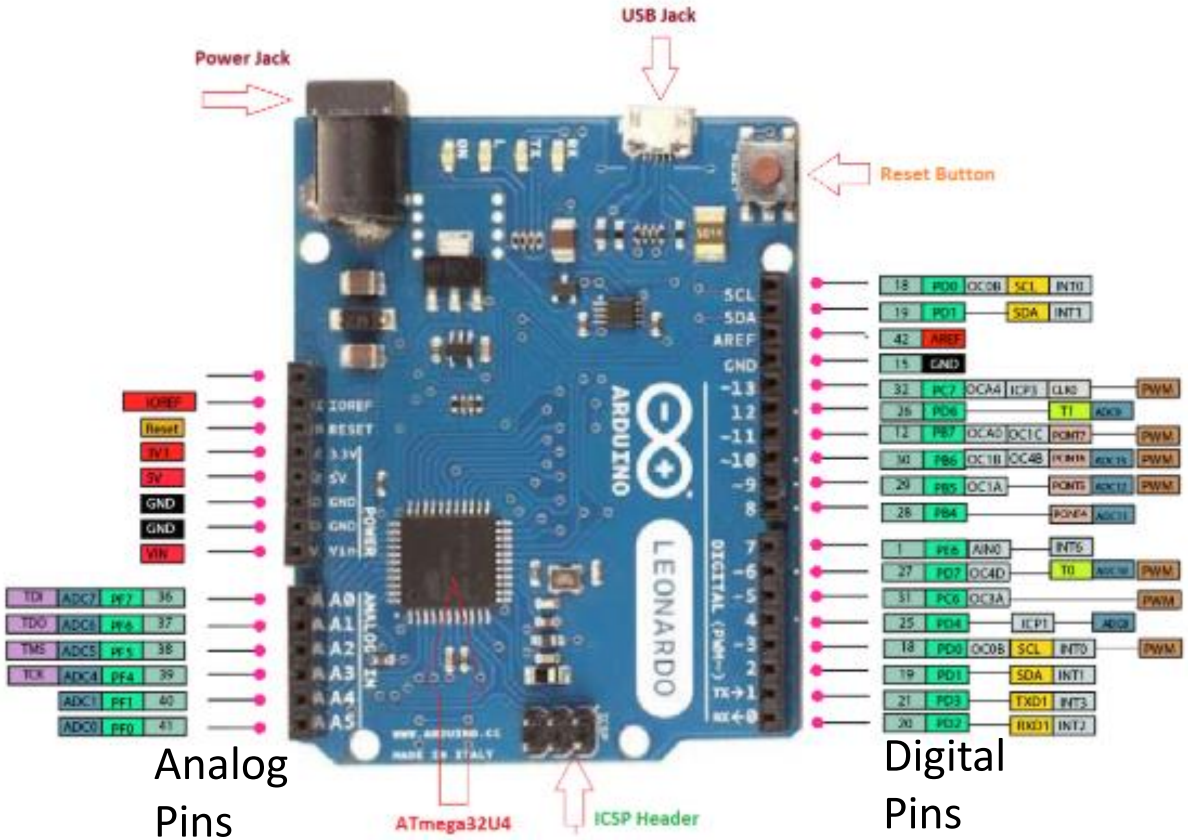
The Arduino Leonardo is more convenient to use when testing components or code, since the connection is Micro-USB so my phone cable is compatible. In addition, having more digital and analogue pins is preferable, since it is less likely that they are all used.

While the Arduino microcontrollers feature analogue inputs, the **Raspberry Pi 3B+** is purely digital. An Arduino microcontroller is needed with the Raspberry Pi, as the Raspberry Pi can only operate with digital signals. Hence, an Arduino's analogue pins are essential for the pressure transducer and any other analogue electrical components. Furthermore, the coupling of these microcontrollers makes more pins available, since most of the pins on the Raspberry Pi will be occupied with the display. Lastly, an **Access Point** allows the in-built WiFi of the Raspberry Pis to communicate between each other. Socket Programming is later demonstrated for this feature. While the Arduino is programmed in C++, the Raspberry Pi features a variety of programming languages such as Python, R and Mathematica.

Continue to Arduino Diagrams

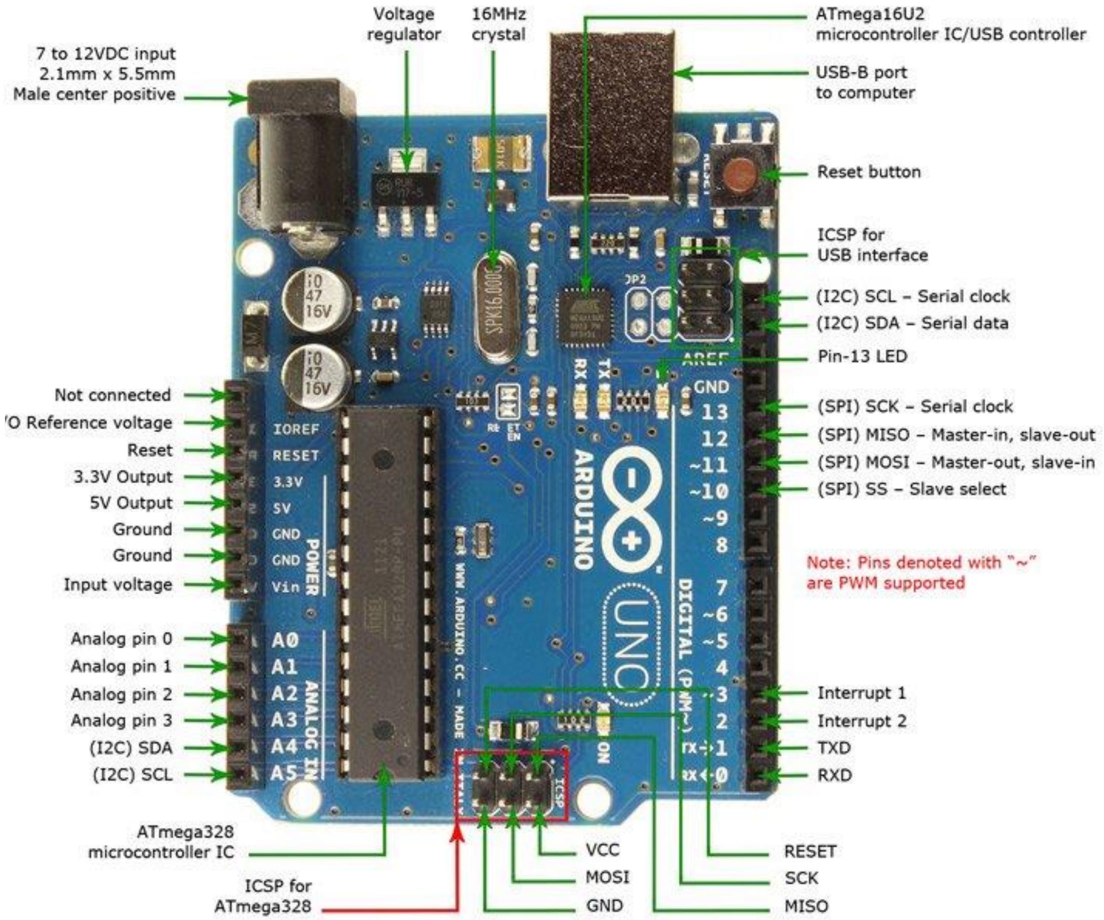
Arduino Diagrams

Arduino Leonardo



https://www.theengineeringprojects.com/2018/10/introduction-to-arduino-leonardo.html

Arduino Uno

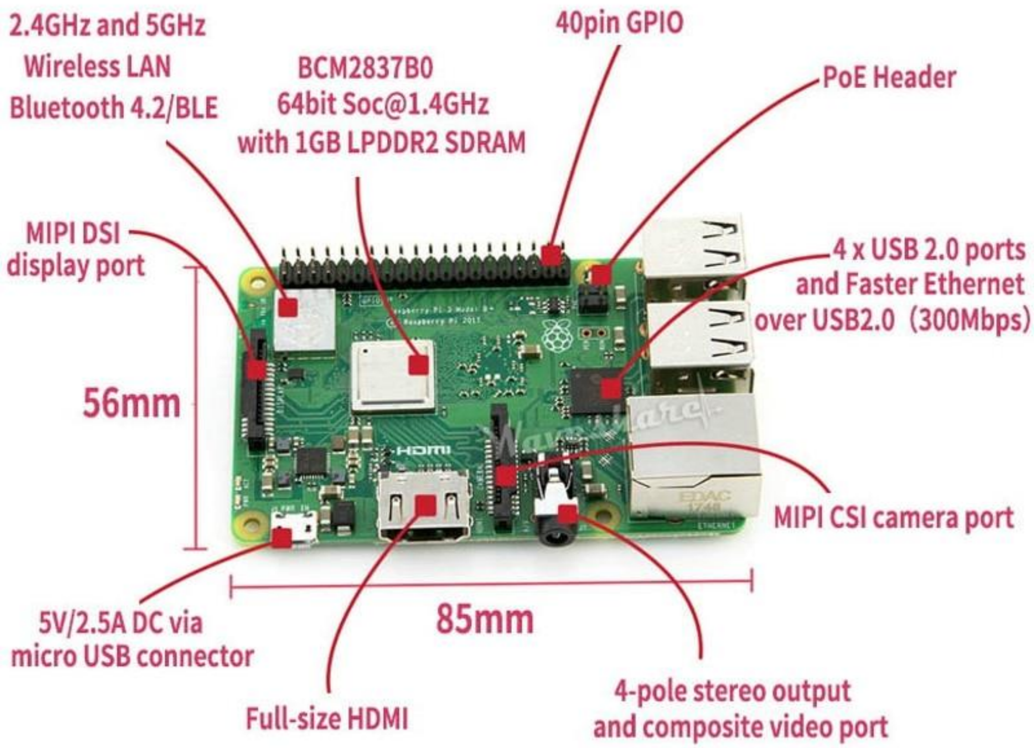


https://www.jameco.com/Jameco/workshop/circuitnotes/CN-arduino-uno.html

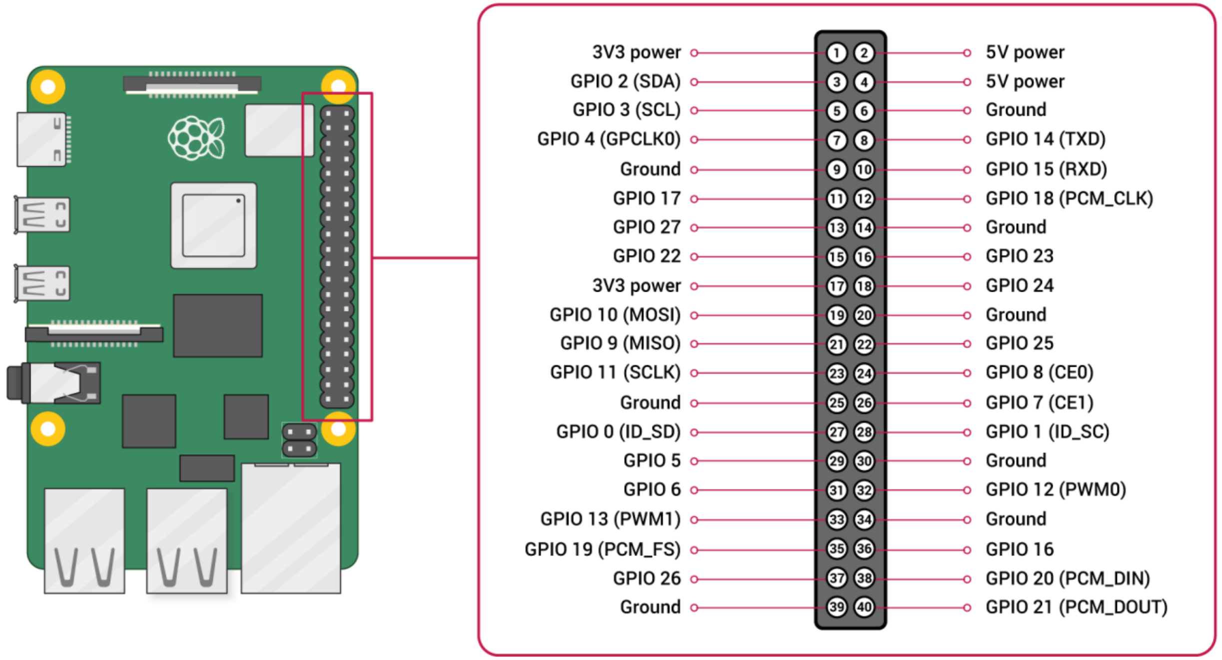
[Continue to Raspberry Pi 3B+ Diagrams](#)

Components Criteria 2 Criteria

Raspberry Pi 3B+ Diagrams



https://www.aliexpress.com/item/32912913415.html

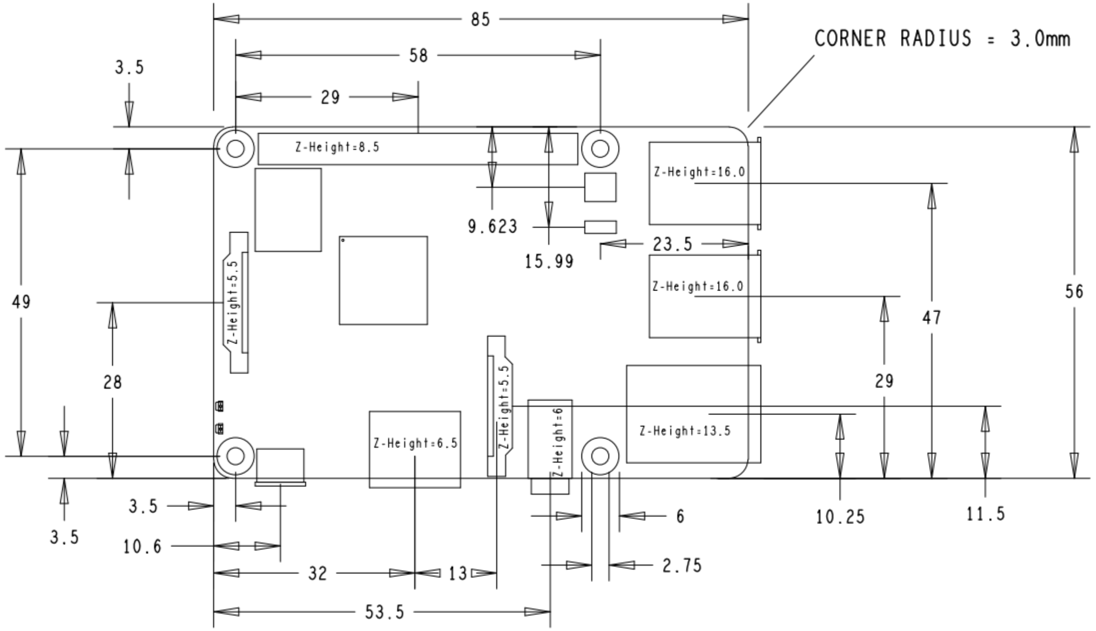


https://www.raspberrypi.org/documentation/usage/gpio/

Continue to Microcontrollers Dimensions Diagrams

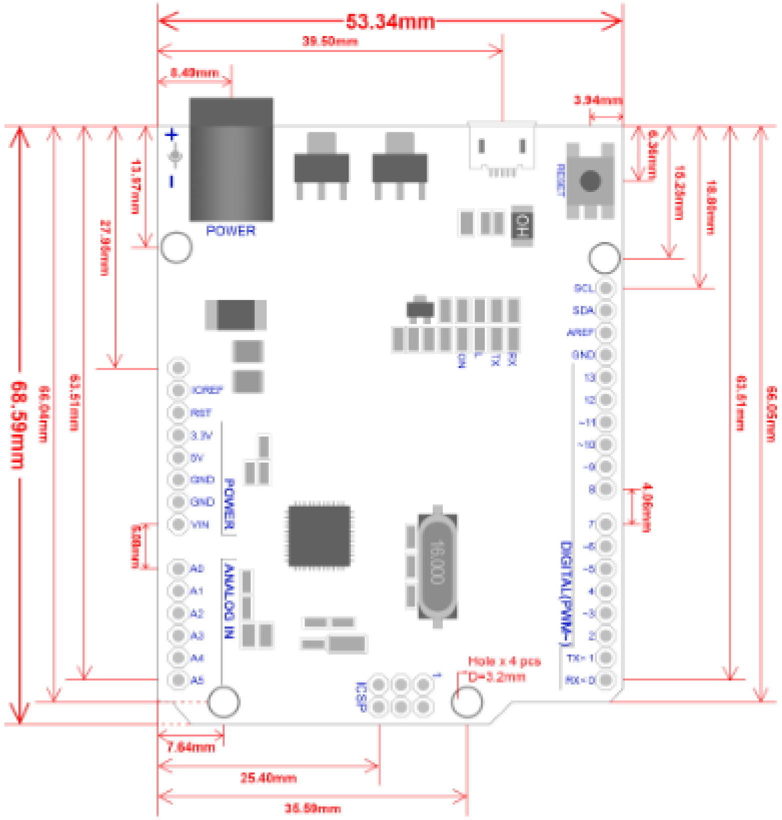
Microcontrollers Dimensions Diagrams

Raspberry Pi 3B+



https://www.raspberrypi-spy.co.uk/2018/03/introducing-raspberry-pi-3-b-plus-computer/

Arduino Leonardo

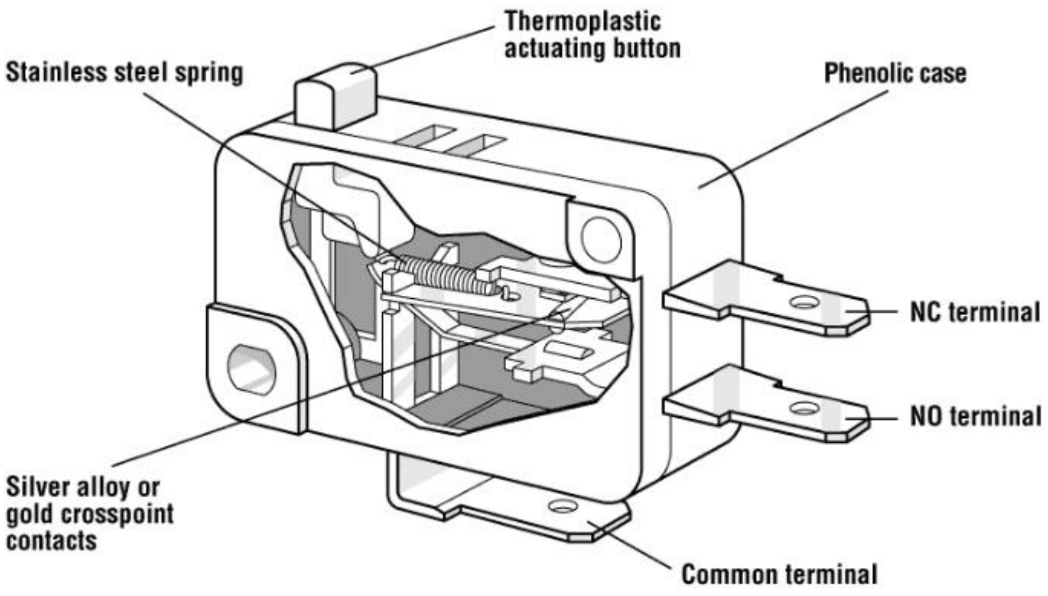


https://robotdyn.com/leonardo-r3-atmega32u4.html

Limit Switch

Limit switches close or open a circuit, by either breaking or connecting their electrical connection.
The lever, when pushed by an external force, moves the contacts inside. Consequently, a microcontroller reading the NO terminal can identify at what instances the limit switch is pressed down, since it will read a HIGH being the circuit connected to the NO terminal is closed.

Limit Switch Diagram



https://www.firgelliauto.com/blogs/news/how-to-use-an-external-limit-switch-with-a-linear-actuator

Actuator Comparison

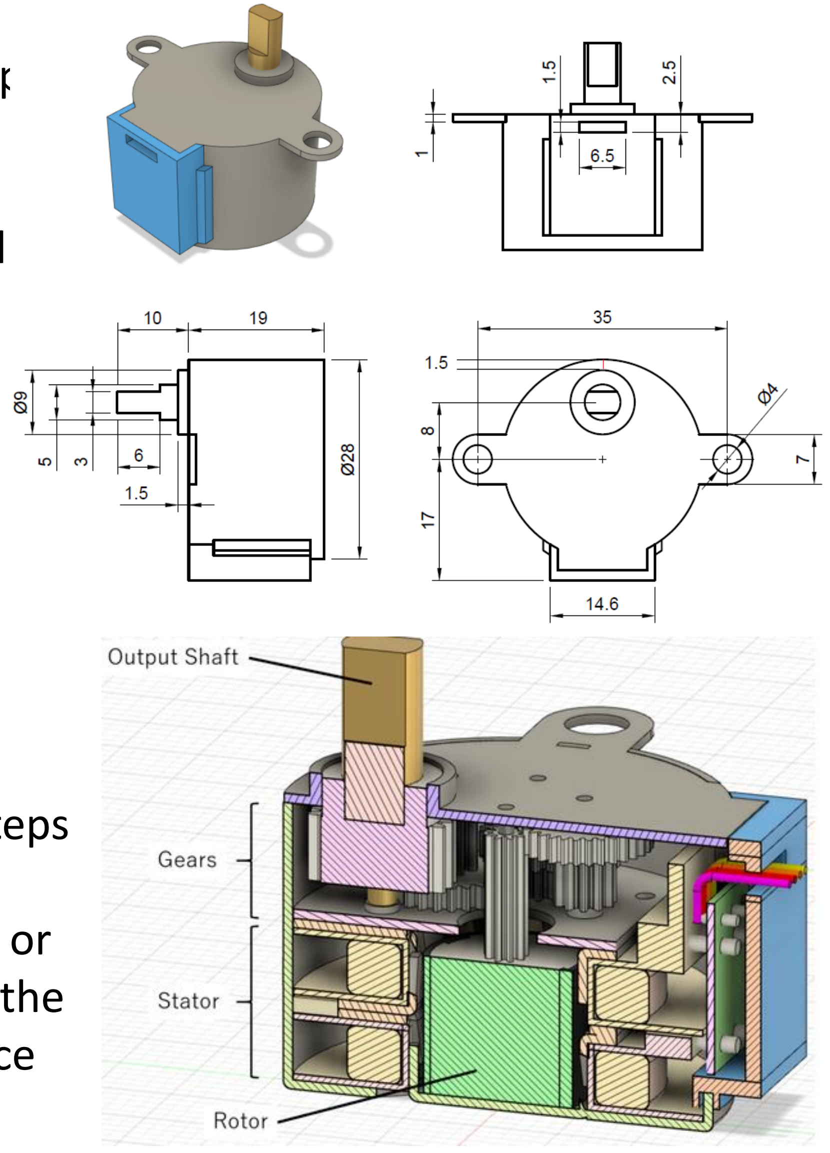
Actuator	Advantages	Disadvantages
Brushless DC Motor	Relatively quiet More efficient High durability and less maintenance	Harder to control Motor does not provide any feedback regarding rotation speed
Stepper Motor	Precise positioning, since the high pole count encourages accurate steps Precise speed control, since it offers accurate steps High torque at low speeds Easy to control, using a stepper driver	Relatively loud, but varies on usage Limited torque when operating at high rotation speeds Low efficiency and constantly draw maximum current May skip steps, suggesting that an external feedback component is still needed
Servo Fundamentally different to stepper motor and brushless motor, as servos have a constrained rotational degrees	High output power Easy to use, as controller performs calculations Efficient	Require tuning to optimise the feedback loop More complex to program Motor may overheat, damaged from constant overload

Stepper Motor

The 28BYJ-48 Stepper Motor is selected for the product. Using the stepp motor in a rack and pinion setup, the angular motion is linearized.

According to adafruit, this stepper motor is low power and has minimal surges in current than DC motors and servos (which use DC motors). Hence, it is not risky to power the stepper motor from the 5V line of the microcontroller, but only if the microcontroller is powered from a reliable supply of at least 1A.
The Data Sheet of the Stepper Motor and Drive Kit is here.
The Data Sheet of the Stepper Motor is here.
A stepper motor is an electric motor with a shaft that rotates by performing steps; a certain degrees. This is performed by the internal structure of the motor, which utilises the many magnets and coils to determine the exact angular position of the shaft through how many steps have been executed.
The basic working principle of the stepper motor is that energising one or more of the stator phases, through current flowing in the coil, leads to the rotor aligning with this new field. Supplying different phases in sequence therefore rotates the rotor to a specific final position.

Stepper Motor Design & Exploded View



https://cookierobotics.com/042/

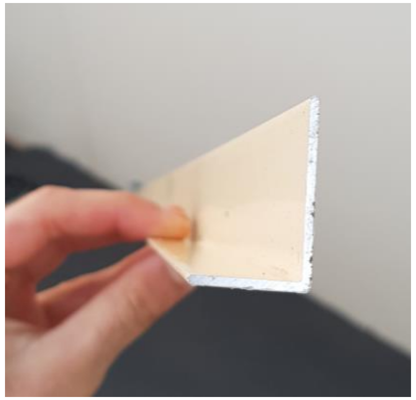
Steel Angle Brackets

To fasten the supports of the gantry to the base, as they are perpendicular to the base steel angle brackets will be used for a firm connection with screws. The steel brackets below are from a Meccano set and are 1mm thick.

4-March-2020

Alternatively, as a backup I have available 32mm x 20mm x 2mm powdered aluminium brackets without holes.

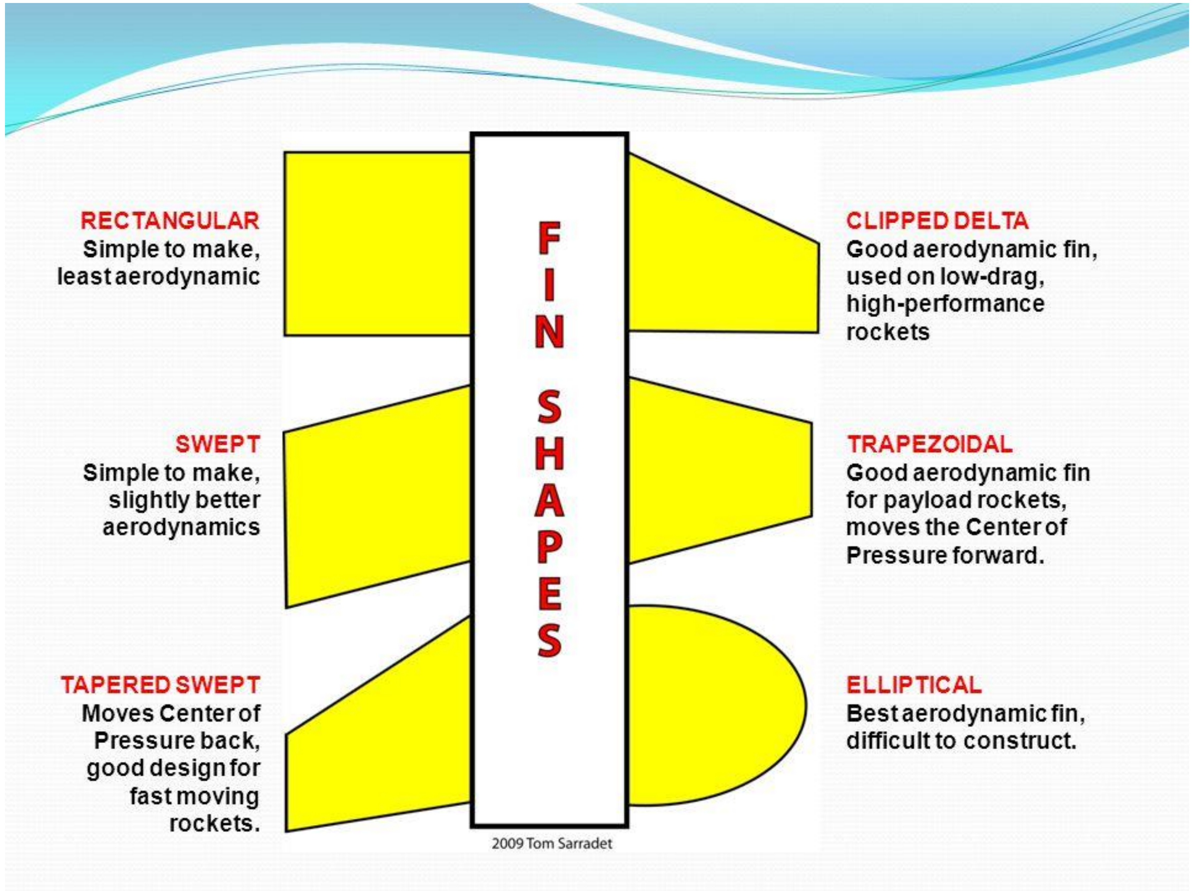
4-March-2020



As mentioned by many sources steel is stronger than aluminium. So while the steel brackets are 1mm thick and the aluminium bracket is 2mm thick, their strength may not be that much different.
Although steel is three times as heavy as aluminium, as the brackets are so small their weights are insignificant and would not be a useful argument for one or the other.
Lastly, the meccano brackets are more convenient to use as they are cut and ready whereas the aluminium bracket would need to be cut and then holes drilled for the screws.
Hence, I will use the meccano brackets for the gantry. However, as there are the limited meccano brackets on hand, I will use the aluminium brackets if I realise I need more brackets.

Rocket: Fins

As the elliptical shape is the most aerodynamic, I select this shape to minimise drag on the rocket and maximise the performance.
Although it may be a tricky shape to construct, the 3D printer or laser cutter is capable of accurately forming an elliptical shape.



https://slideplayer.com/slide/15138774/

Rocket: Parachute Ejection

At Water Bottle Rocket Hybrid Parachute Deploy Mechanism Tutorial, AIR FLAP PARACHUTE DEPLOYMENT MECHANISM 7/13 version as well as Build a Parachute Deploy System for Water Rockets Tutorial, there are a limitless number of online tutorials on making an electrically controlled parachute ejector.

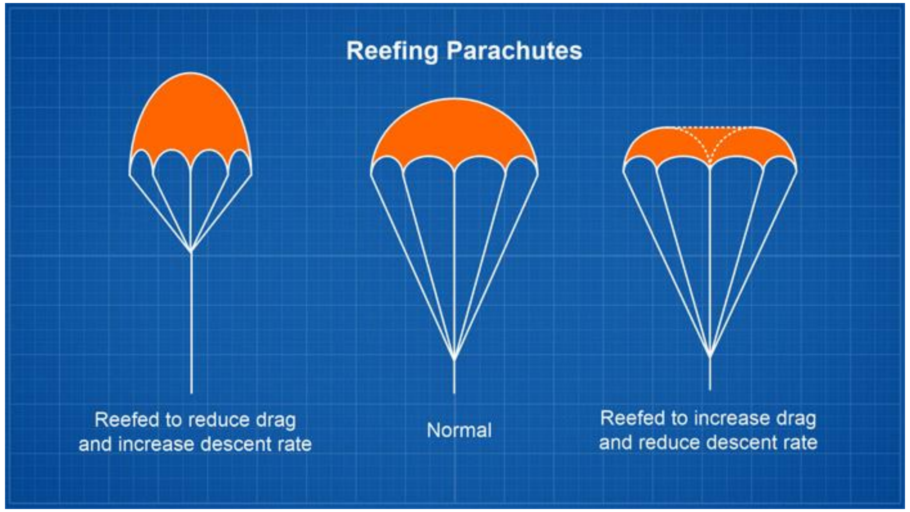
For model rockets, they use a detonator that is powered to eject the parachute from the combustion of the fuel. Such a simple idea allows the nose cone to be ejected and the parachute to eject. On the other hand, electrically ejecting the parachute with a complex system of elastic bands and servos has the risk of failure. The small risk of the parachute not ejecting properly, or at all, indicates a major threat to the rocket's reusability, since a crash would likely destroy most of the rocket. So while many tutorials propose electrically releasing the parachute, there are some concerns and alternatives to evaluate.

However, after thinking through physics and logic, flaps could be the ideal way to go. Adding flaps to the nose cone of the rocket may add air resistance, since the bottom of the nose cone comes to a larger radius, so has a wider surface area. However, when falling, the flaps of the nose cone will also add air resistance to the nose cone. Consequently, as the rocket falls, the nose cone will naturally disengage the rocket (since it is not tightly secured) and the parachute will therefore release.

The simplistic idea not only minimises mechanical risk from failure, but reduces the weight of the rocket. Doing so will allow the rocket to reach greater speeds and reach a higher altitude, emphasising how powerful the compressed air is to launch the rocket.

Rocket: Parachute

The parachute has many factors, such as the placement and attachment of string and the radius of the parachute. As the parachute needs to be light to minimise the weight force of the rocket, there is a consideration of integrating a toy parachute with the system. Diagnostic testing can be used to improve the parachute to ensure it is strong enough and will provide enough drag force to allow for a safe recovery momentum.
However, creating a parachute from scratch with umbrella fabric provides an attractive component. The material is strong and lightweight, 18g, and the string can be securely stitched. Diagnostic testing is essential to evaluate the durability of the parachute and the string, to ensure that the potential tension from drag is reasonable for the component. Lastly, reefing parachutes provide effective methods to increase drag and thereby reduce descent rate. Compared to a normal parachute, increasing drag with the same size parachute will reduce the land momentum (a success criteria), however, windy days are more risky since the descent will be affected greater.



http://www.aircommandrockets.com/day177.htm

Rocket: Power Supply

The Raspberry Pi 3B+ needs a 5V 2A power supply. The Raspberry Pi can be safely powered with 5V ± 5% at a minimum of 1.3A, through the GPIO header pins 2, 4 and GND. Furthermore, a Single Pole Single Throw (SPST) can be wired to conveniently turn the power off and on when needed. The recommended power supply is 5V and 2.5A, but that accounts for 1.2A to the USB ports, which leaves 1.3A for the Pi itself. So as I only need to power the Raspberry Pi and some sensors, a minimum 1.5A supply should work.

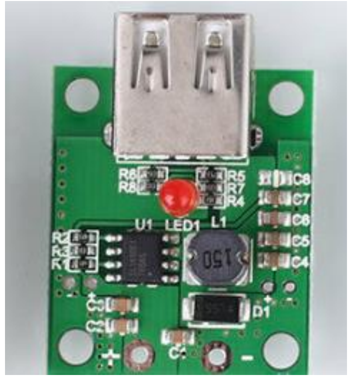
Voltage Regulator

As the input voltage of the voltage regulator is between 5V to 20V, wiring two 18650 batteries in series will combine their 3.7V to provide 7.4V which leads to the regulator providing a steady 5V 2A to the Raspberry Pi. The voltage regulator has an output of 5V and 2A, so prevents the power supply from damaging the Raspberry Pi and electronics.
Voltage regulators are an integrated circuit (IC) that regulate the unregulated input voltage and provide a constant, regulated supply of electricity.
Voltage regulators operate with a variety of methods. The linear voltage regulator automatically operates by a feedback loop, while considering changes in the supply and load, to maintain a constant output of electricity.
The Data Sheet of the voltage regulator is here.

On and Off Switch

https://www.instructables.com/id/Raspberry-Pi-powered-by-battery/

Voltage Regulator



https://www.ebay.com.au/itm/264359216208

Rocket: Power Source

Capacitors are lighter and their composition is less harmful than batteries. In addition charging and discharging does not wear them out, unlike batteries. While batteries offer higher energy densities, super capacitors have higher power densities.

The specific energy of a supercapacitor ranges from 1Wh/kg to 30Wh/kg, 10–50 times less than Li-ion. The output of the energy from a battery is constantly high then drops rapidly when the charge depletes. On the other hand, a supercapacitor has a linear discharge so the power reduces over a short period of time.

Discharge Characteristics of Stored Energy

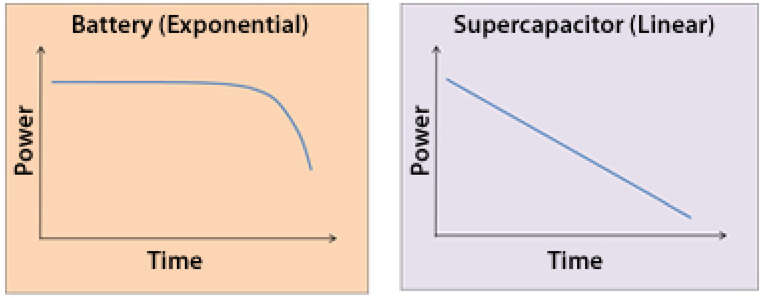


Figure 1: Discharge curve of Battery. Eponential discharge provides steady power to the end.

Figure 2: Discharge curve of supercapacitor. Linear discharge prevents the full use of energy.

https://batteryuniversity.com/index.php/learn/article/discharge_methods

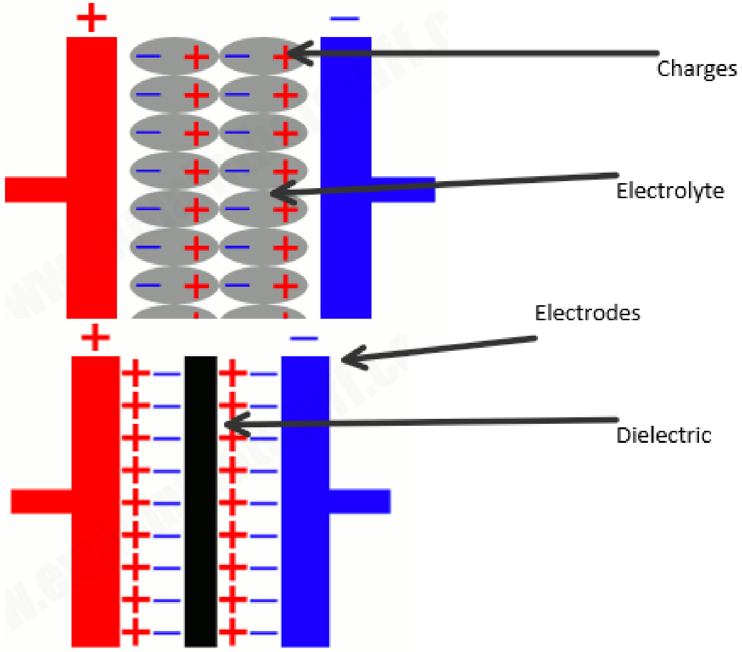
The graphs above emphasise that the power from a supercapacitor reduces with a linear shape. Consequently, supercapacitors are ideal for a quick charge needed to support a short-term power need while batteries provide long-term energy.

The more appropriate power supply device are batteries rather than supercapacitors as the output is preferable from batteries where it is constant until the battery is depleted unlike supercapacitors. High amount of power is unneeded for operating the rocket, as 2A at 5V is more than enough to operate the Raspberry Pi with its sensors. Although the charge time is incredibly quick, time management can be employed to ensure the batteries are charged before they are needed for a launch. Furthermore, the batteries use is not extensive so poses no threat to their cycle life, so effectively supercapacitors are not favourable for the product.

Rocket: Power Source

Batteries have two electrical terminals, electrodes, separated by a chemical substance, an electolyte. Chemical reactions within the battery convert chemicals into other substances and releases electrical energy in the process. When the chemicals are depleted, the reaction ceases indicating the battery is dead as no more current is produced. Rechargeable batteries can be recharged as the reactions can occur in either way allowing the flow of electricity into a battery to be stored then released at a later point in time.
On the other hand, capacitors use static electricity rather than chemistry to store electricity. Capacitors utilise two conducting metal plates with an insulating material between them, called dielectric. Charging a capacitor increases the amount of positive and negative charges on the plate while the separation prevents the charges from interacting so that energy can be stored. The purpose of the dielectric is to prevent conducting plates from coming in contact, allowing for a more compact design and higher capacity. The capacitance, ratio of separated electric charge that can be stored with respect to the voltage difference, improves as dielectrics reduce the electric field strength so effectively the charge is the same with a lower voltage.
Supercapacitors are like ordinary capacitors but have a greater plate area while the distance is much smaller. They are built from different materials and structured slightly different to store different amounts of energy.
The plates are made from metal coated with a porous substance that increases the effective area allowing more charge to be stored than a flat surface could allow. Furthermore, while ordinary capacitors have plates separated with a relatively thick dielectric made of potentially mica or even air, supercapacitors take a different approach. Both plates soaked in an electrolyte are separated with a very thin insulator. When charged, an opposite charge forms on either side of the separator creating an electric double-layer. Consequently, super capacitors have a larger surface area from porous coating while effectively utilising a double layer of charges as demonstrated in the Figure 1.

Figure 1: Capacitors Diagram



Rocket: Batteries

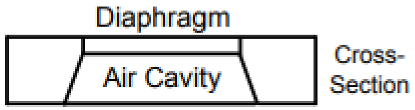
The specific energy, energy per unit of mass, indicates how long the battery can be used when run at a 10W (5V, 2A) so can compare the capacity of the batteries per unit of mass. For instance, an average value of the specific energy of lithium-ion batteries is approximately 140 Wh/kg while the average of Lead Acid is 40 Wh/kg. So to run a lead acid battery for the same amount of time as a lithium-ion battery, the mass of the battery has to be 3.5x heavier. As the weight is a significant consideration to maximising the performance of the rocket, lithium-ion batteries are ideal as they have the best specific energy.
Coupled with this, their low toxicity and being maintenance-free gains additional merit to using lithium-ion batteries. Furthermore, their high cell voltage compared with these other batteries minimises the required number of batteries to supply enough voltage to the system. Lastly, lead acid batteries are a disadvantage to use due to their incredibly slow recharge time compared to viable other battery options.
Considering these points lithium-ion batteries are superior to these other options of batteries for this product, as they minimise the weight of the power supply device and are easy to use with fast charging time.

Specifications	Lead Acid	NiCd	NiMH	Li-ion[1] Cobalt	Manganese	Phosphate
Specific energy (Wh/kg)	30–50	45–80	60–120	150–250	100–150	90–120
Internal resistance	Very Low	Very low	Low	Moderate	Low	Very low
Cycle life[2] (80% DoD)	200–300	1,000[3]	300–500[3]	500–1,000	500–1,000	1,000–2,000
Charge time[4]	8–16h	1–2h	2–4h	2–4h	1–2h	1–2h
Overcharge tolerance	High	Moderate	Low	Low. No trickle charge		
Self-discharge/ month (room temp)	5%	20%[5]	30%[5]	<5% Protection circuit consumes 3%/month		
Cell voltage (nominal)	2V	1.2V[6]	1.2V[6]	3.6V[7]	3.7V[7]	3.2–3.3V
Charge cutoff voltage (V/cell)	2.40 Float 2.25	Full charge detection by voltage signature		4.20 typical Some go to higher V		3.60
Discharge cutoff voltage (V/cell, 1C)	1.75V	1.00V		2.50–3.00V		2.50V
Peak load current Best result	5C[8] 0.2C	20C 1C	5C 0.5C	2C <1C	>30C <10C	>30C <10C
Charge temperature	–20 to 50°C (–4 to 122°F)	0 to 45°C (32 to 113°F)		0 to 45°C[9] (32 to 113°F)		
Discharge temperature	–20 to 50°C (–4 to 122°F)	–20 to 65°C (–4 to 149°F)		–20 to 60°C (–4 to 140°F)		
Maintenance requirement	3–6 months[10] (toping chg.)	Full discharge every 90 days when in full use		Maintenance-free		
Safety requirements	Thermally stable	Thermally stable, fuse protection		Protection circuit mandatory[11]		
In use since	Late 1800s	1950	1990	1991	1996	1999
Toxicity	Very high	Very high	Low	Low		
Coulombic efficiency[12]	~90%	~70% slow charge ~90% fast charge		99%		
Cost	Low	Moderate		High[13]		

https://batteryuniversity.com/learn/article/secondary_batteries

Rocket: Sensors

Barometer



http://sensys.acm.org/2014/papers/p191-sankaran.pdf

Contains a diaphragm that's formed through a capacitive plate which is in contact with the atmosphere. The atmospheric pressure is measured through the magnitude the diaphragm is deformed due to the pressure. Hence, higher air pressure leads to greater deformation, so a higher barometer reading. Air pressure is related to altitude and temperature by:

Hypsometric formula

$$h = \frac{\left(\left(\frac{P_0}{P}\right)^{\frac{1}{5.257}} - 1\right) \times (T + 273.15)}{0.0065}$$

https://keisan.casio.com/exec/system/1224585971

Where: h is metres, T is degrees Celsius

As such, the barometer can accurately evaluate the height of the rocket using the barometer.

The Data Sheet for barometer BPM280 is here.

The Data Sheet for the 9-axis sensor MPU-9250 is here.

9-axis Sensor

Gyroscope

Three separate vibratory MEMS rate gyroscopes, detect rotation about the x-, y- and z- axes. When a gyro is rotated about its axes, the Coriolis Effect leads to a vibration that is sensed by a capacitive pickoff. This signal is amplified, demodulated then filtered to produce a voltage proportional to the angular rate. Individual on-chip Analog-to-Digital

Accelerometer

There are separate proof masses (masses with known quantity used for reference in measuring an unknown quantity) for each axis. Acceleration along a certain axis causes displacement on the corresponding proof mass, and the capacitive sensors measure the displacement differentially. When the component is placed on a flat surface, it will measure 0*g* on the x-axis and y-axis, but +1*g* on the z-axis.

Magnetometer

Uses highly sensitive Hall sensors for detecting terrestrial magnetism in the three axes, which involves a sensor driving circuit, a signal amplifier circuit, and an arithmetic circuit that processes data from each sensor.

The 9-axis sensor, MPU-9250, has 9 axes since the component has a gyroscope, accelerometer and magnetometer in all three axes. The data collected from the sensor will feed the program to take the integral of the acceleration over time, to evaluate the velocity at a given point in time. In addition, the altitude by the barometer can be cross referenced with the integral of velocity with respect to time, to evaluate the displacement.

Rocket: Raspberry Pi Camera v1

A camera lens takes in light rays and uses glass to redirect them to a focal point, forming a sharp image. The lens's focusing system positions the glass piece closer or farther from the sensor to adjust the lens for a clear image. Each sensor is composed many millions or red, green and blue pixels. Light hitting the pixels converts into energy, which the camera then measures to determine the colour. As each pixel has a colour value, the camera can form images by processing all of the megapixels.
The Raspberry Pi Camera has a small and lightweight design. The camera module connects via the CSI connect specifically for interfacing to cameras.

Data Sheet of Raspberry Pi Camera here.

Hardware Specifications

Category	Camera Module v1
Net price	$25
Size	Around 25 × 24 × 9 mm
Weight	3g
Still resolution	5 Megapixels
Video modes	1080p30, 720p60 and 640 × 480p60/90
Linux integration	V4L2 driver available
C programming API	OpenMAX IL and others available
Sensor	OmniVision OV5647
Sensor resolution	2592 × 1944 pixels
Sensor image area	3.76 × 2.74 mm
Pixel size	1.4 µm × 1.4 µm
Optical size	1/4"
Full-frame SLR lens equivalent	35 mm
S/N ratio	36 dB
Dynamic range	67 dB @ 8x gain
Sensitivity	680 mV/lux-sec
Dark current	16 mV/sec @ 60 C
Well capacity	4.3 Ke-
Fixed focus	1 m to infinity
Focal length	3.60 mm +/- 0.01
Horizontal field of view	53.50 +/- 0.13 degrees
Vertical field of view	41.41 +/- 0.11 degrees
Focal ratio (F-Stop)	2.9

Design Ideas & Alternatives

Launch System
Gantry
Screen and Programming
Rocket

Design ideas were produced using the modelling software: Sketchup. This allowed me to create components and even subsystems as a 3D model, while producing the files to later use to 3D print.
For basic designs of specific components, drawings, diagrams and images are used.

http://imatrixsol.com/16_shop.html

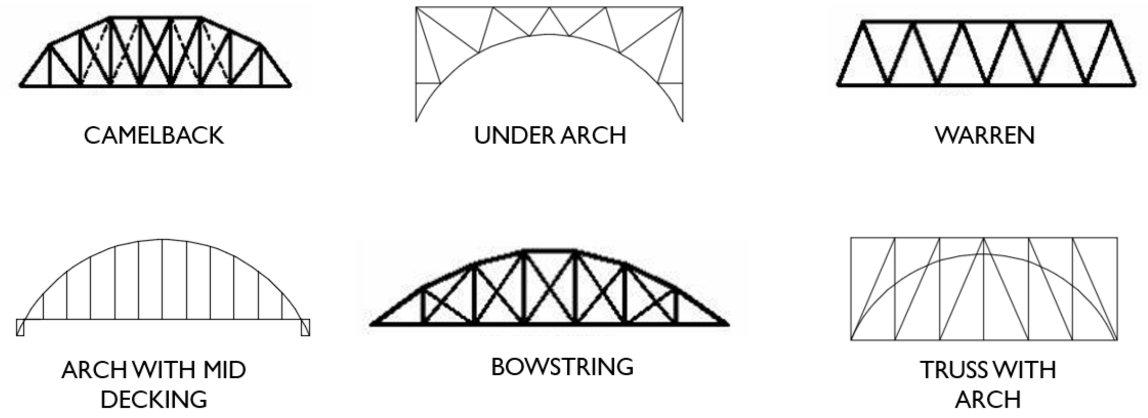
The Need for Design Alternatives

At times I consider a variety of designs then select the most favourable option.
The process of evaluating the advantages and disadvantages of each design, then comparing the designs, encourages flexible designing and production. Similarly, the comphresenvise evaluation inspires the best idea for the specific task.
For instance, some ideas may not be feasible due to time constraints regarding unexpected situations from the pandemic, so these design alternatives may become a solution to a problem.
Similarly, another instance is that when an idea fails, the design alternatives may prompt a successful design as they use a different approach.

Why design alternatives?

For a majority of my subsystems, there will be several different designs. This is important as it will allow me to be adaptive within my design and allow me to produce the best system situated for the specific task. For example if one design alternative is too difficult to make or is not feasible, I can quickly swap to another design alternative to compensate for it.

For example for subsystem 1, I found out that the joystick controller is a lot easier and allows for me to maintain more control than the toggle button controller. If I only had a single design it would of hindered my progress with making my project.



https://cefns.nau.edu/capstone/projects/CENE/2015/SteelBridge/DesignAlternatives.html

By having several different designs it allows me to be adaptive when an idea fails. For example there are all bridges however they are all different designs.

Design Ideas: Launch System

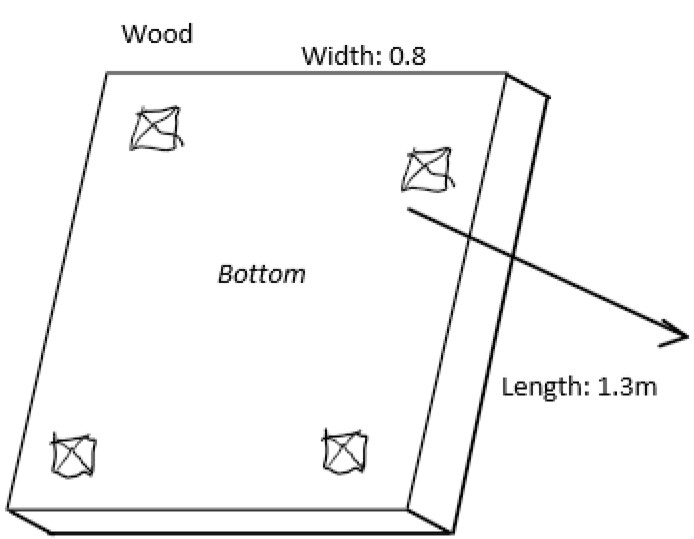
Design Ideas: Gantry

Design Ideas: Rocket

Design Ideas: Screen & Programming

Microcontrollers Connecting
Data Collection
User Interface

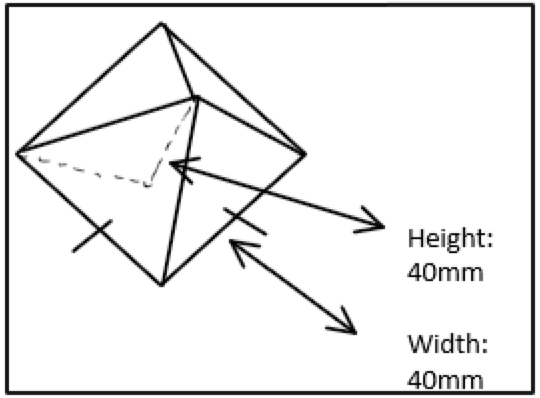
Design Ideas: Base

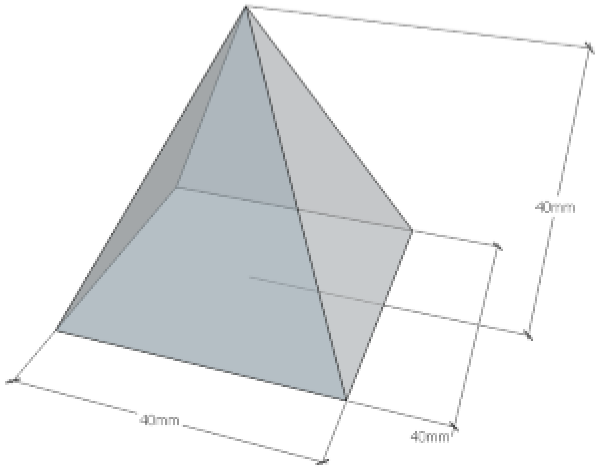


3D printed
100% infill

Secured to base using super glue

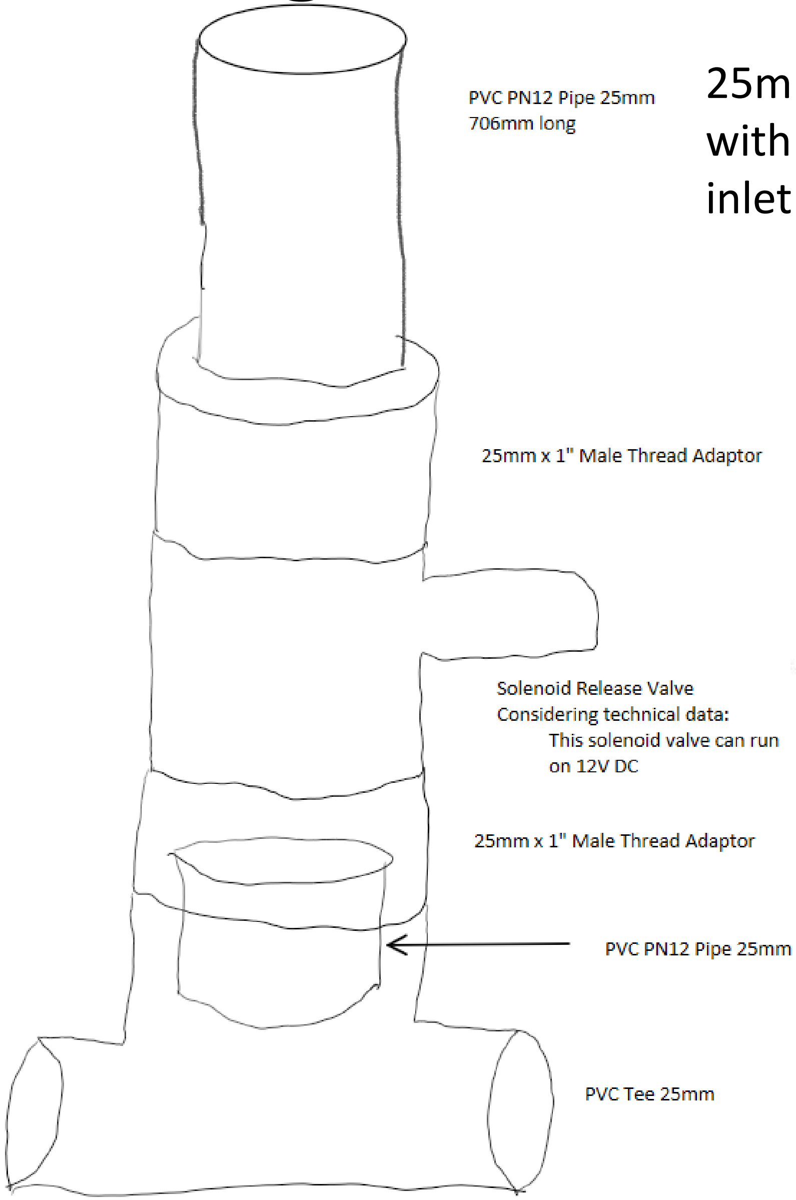
Stabilization



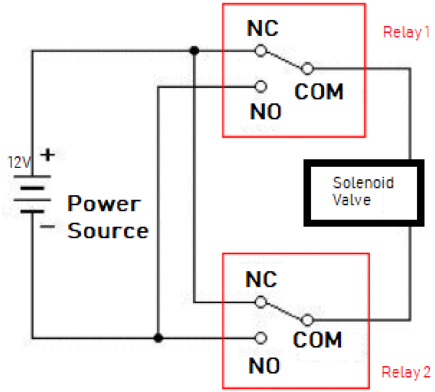


As explored earlier when researching materials, the selected material for the base is marine plywood for its strength, durability, ease of use and local availability (making it convenient). For more on why I select marine plywood, go back to [plywoods research](#).

Design Ideas: Release Pipe 12V DC



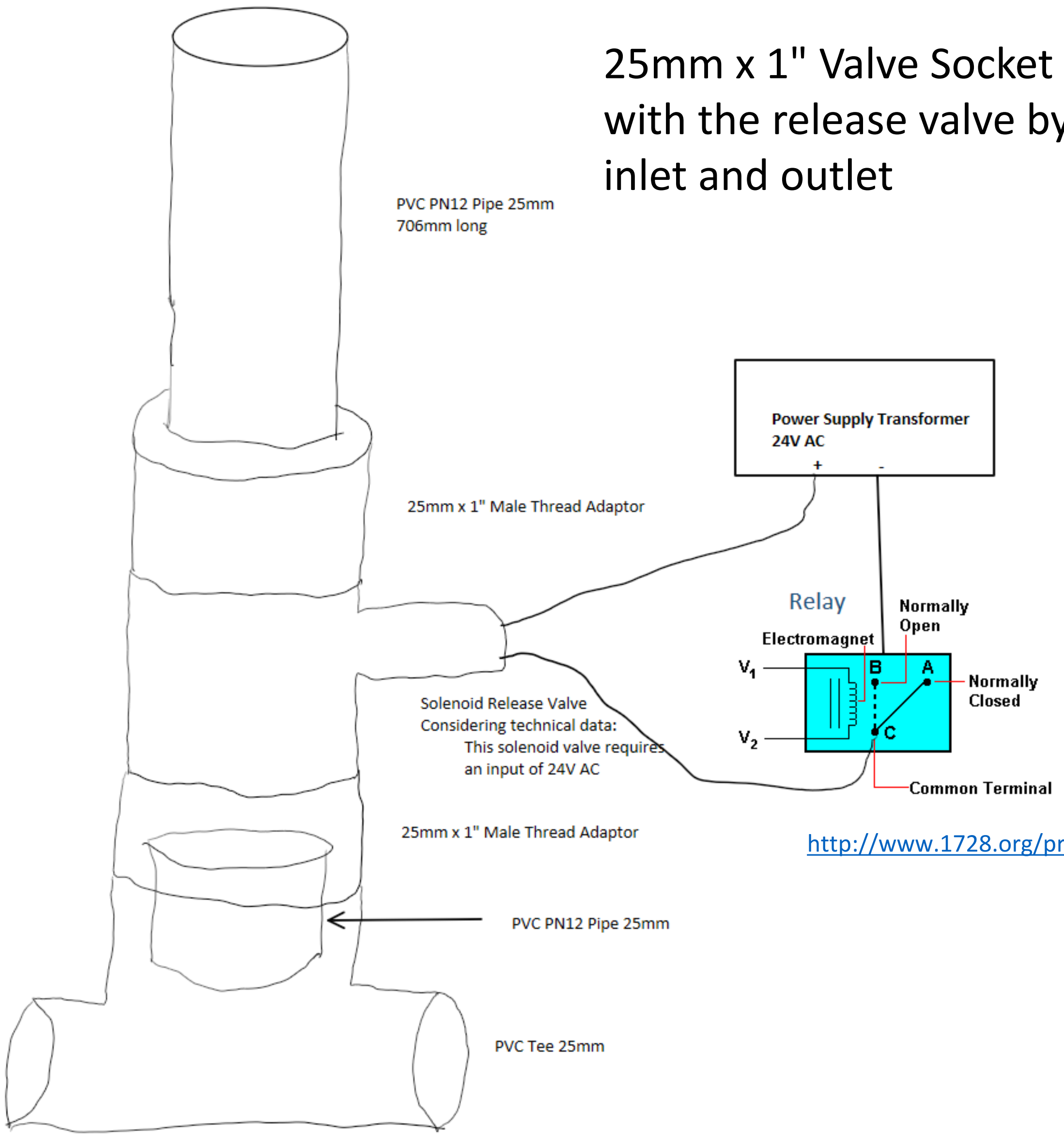
25mm x 1" Valve Socket can be used to connect 25mm pipe with the release valve by screwing a valve socket to the valve inlet and outlet



The solenoid valve is a latching type, indicating (as explained under the solenoid component research) that the armature is released from the latched position by turning on the current, but in the opposite direction. Hence, the two relays to the left are essential to run the solenoid valve as they allow to reverse the current and to send current when the microcontroller desires.

Design Ideas: Release Pipe 24V AC

25mm x 1" Valve Socket can be used to connect 25mm pipe with the release valve by screwing a valve socket to the valve inlet and outlet



http://www.1728.org/project3.htm

As researched earlier, the direct acting solenoid is only open while current is running through the solenoid. Hence, one relay is needed to switch the current on and off to control the solenoid valve.

Design Ideas: Solenoid Selection: Size

Pressure is defined as the force exerted on a surface divided by the area over which that force acts.
P = F/A, or F = PA, where P is pressure (Pa), F is Force (N) and A is Area (m^2)
As F = PA, F ∝ A meaning the force exerted on the surface is directly proportional to the area of the surface. By using a larger release pipe, the area inside of the pipe is greater and can be calculated by $A = \pi r^2$ indicating that by increasing the diameter of the release pipe from 3/4" to 1" the area and so force will increase.

$r_1 = 1/2"$, $r_2 = 3/8"$

$$
\begin{aligned}
A_1/A_2 &= \pi*(1/2)^2 /(\pi*(3/8)^2) \\
&= 1/4 / 9/64 \\
&= 1/4 * 64/9 \\
&= 64/36 \\
&= 16/9 \\
&= 1.78
\end{aligned}
$$

This rough calculation indicates the area and force will increase by 78% and since the force is directly proportional to the acceleration of the rocket then the rocket will speed up faster during take off. A faster speed off will allow the rocket to reach a greater velocity, suggesting that the flight time and maximum height will be greater.

The ideal solenoid valve has a 1" threaded connection as this connects with a larger diameter male thread adaptor that fits with the release pipe.

Design Ideas: Solenoid Selection

The difference in selections is the specific model of the solenoid valve and its requirements for the input voltage, that being a 12V DC solenoid valve or a 24V AC solenoid valve.

The advantage of running the 12V DC solenoid valve is that the same power supply unit as the compressor can be used, rather than buying an additional 24V AC power supply transformer to operate the release valve.

As such, the 12V DC solenoid valve is likely more cost-effective as an additional power supply unit is unneeded. Similarly, the overall weight, cost and production is reduced being there are less components needed.

In terms of maximum working pressure, these release valves are the same, that being around 181 PSI which is substantial for safety. Their size are relatively similar, as both have 1" connections (ideal as explained in the previous slide on size). Similarly, both are readily available for purchase from a range of stores.

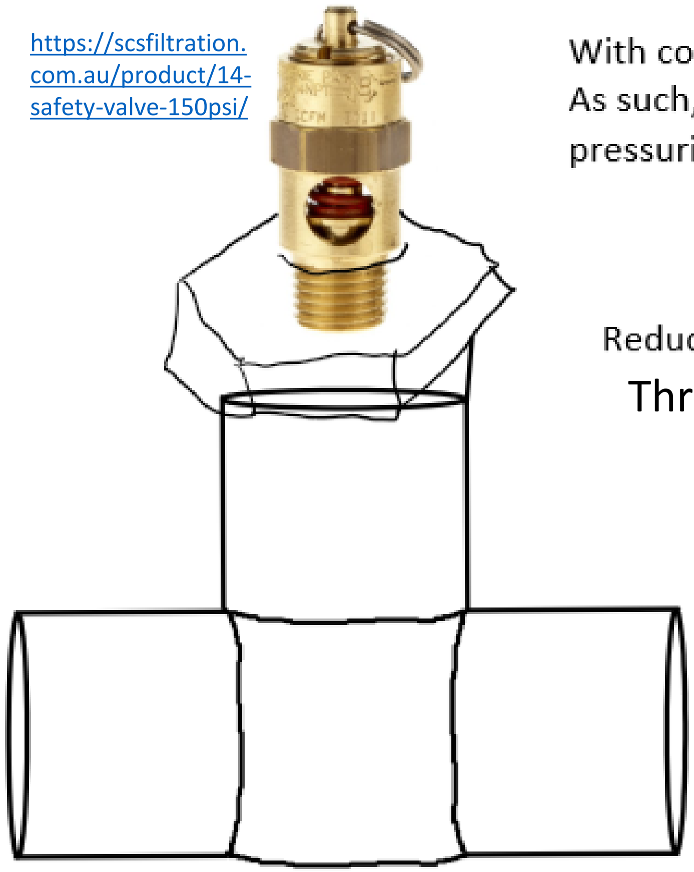
Lastly, the latching type of solenoid valves is preferred over the direct acting type. For the direct acting type, as a high amount of current is constantly flowing to keep the valve opened, these valves are less efficient and waste electricity from the generation of heat and sound. On the other hand, latching solenoids are favoured for their efficiency, faster operating speed and pulling force.

Solenoid Valve Data Sheet of the final selected solenoid valve. The product is locally available on the other side of Melbourne rather than in China, suggesting that this will support local businesses and quicker shipping.

Design Ideas: Relief Valve

Pressure Relief Valve 150psi

https://scsfiltration.com.au/product/14-safety-valve-150psi/



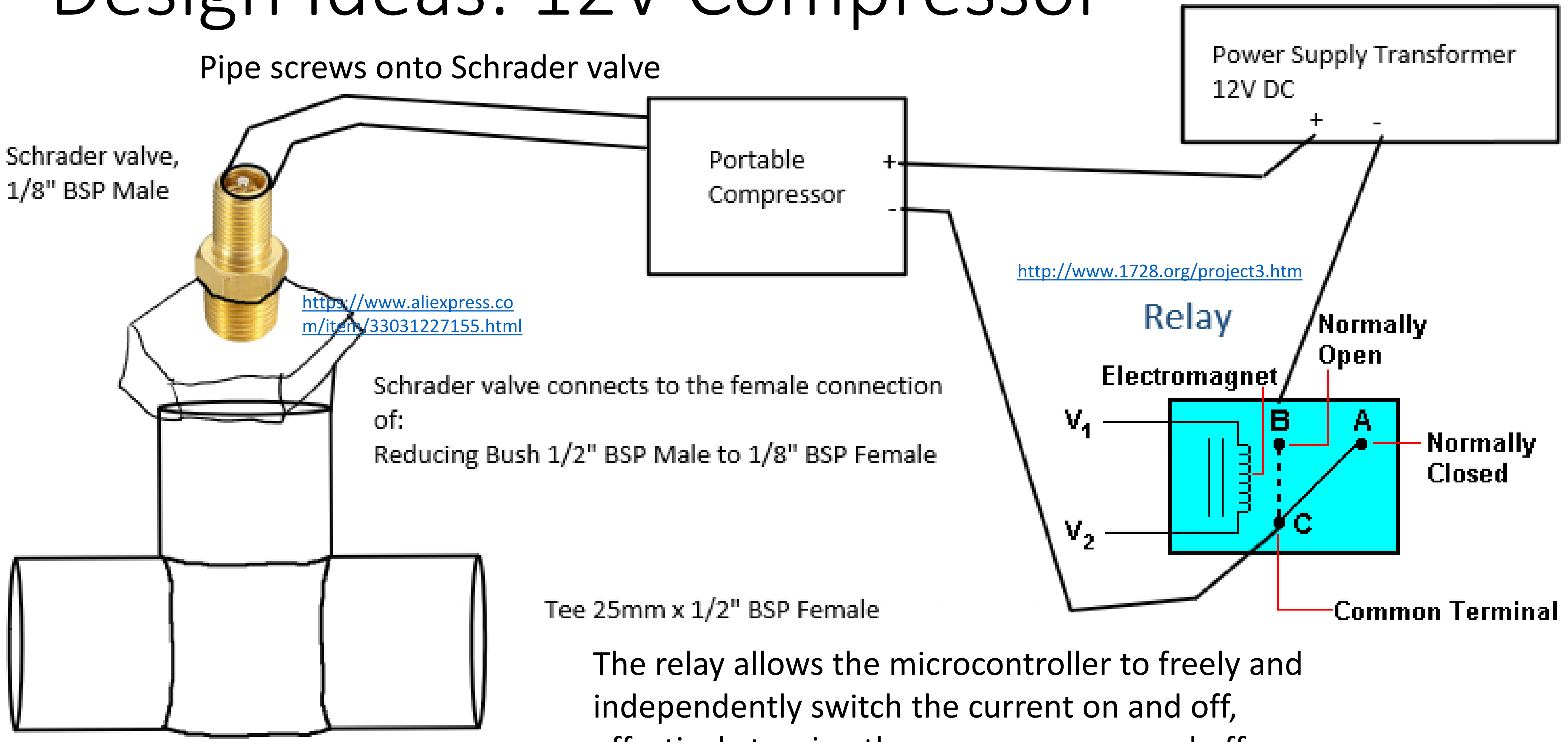
With considerations of the technical data of the parts, the maximum pressure of the system is 150PSI As such, a pressure relief valve set to 150psi will be installed to protect the system from over-pressurization by releasing system air to the atmosphere

Reducing Bush 1/2" to 1/4"

Threads are all BSP

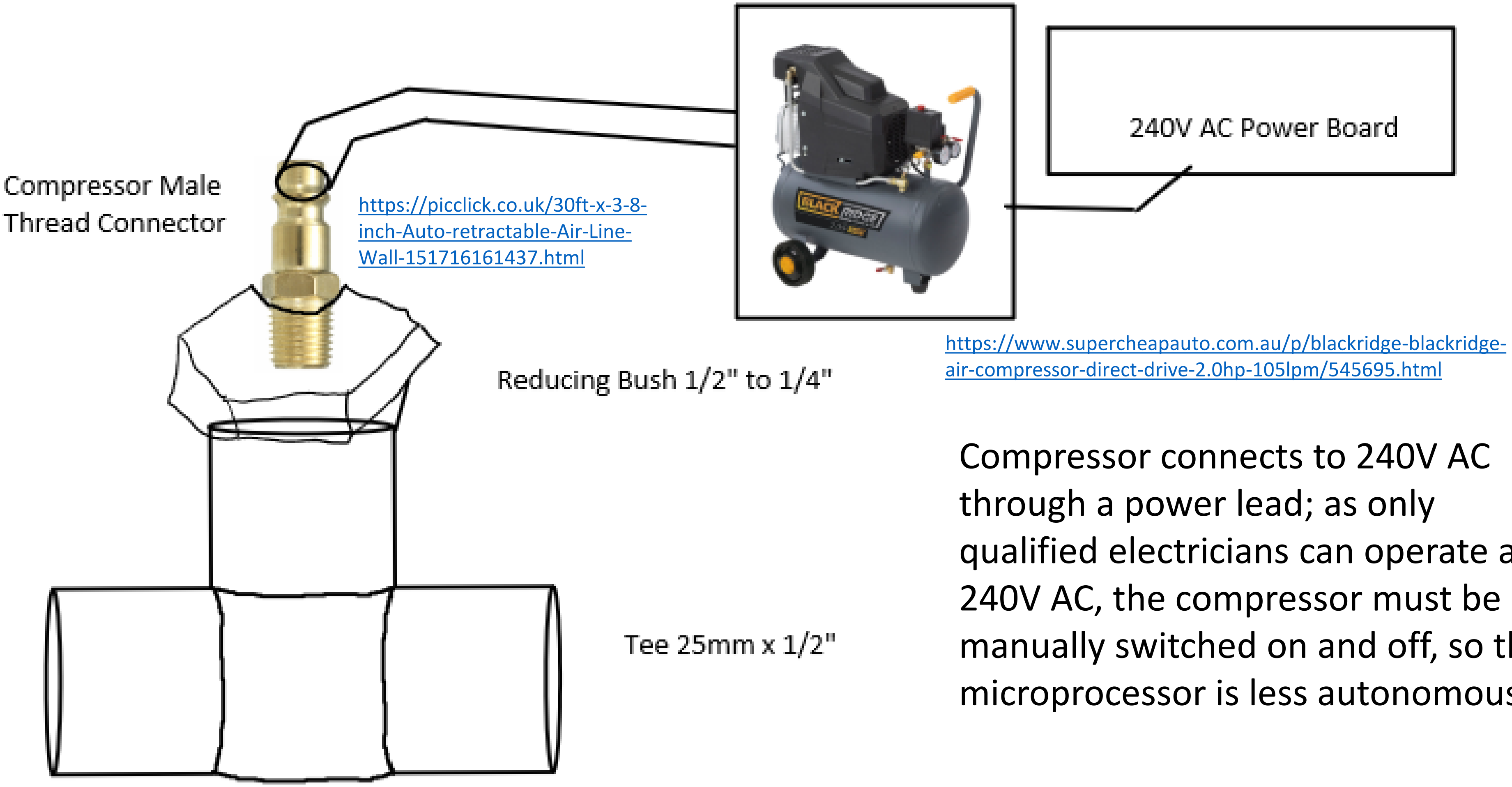
Tee 25mm x 1/2"

Design Ideas: 12V Compressor



The relay allows the microcontroller to freely and independently switch the current on and off, effectively turning the compressor on and off.

Design Ideas: 240V AC Compressor



Compressor connects to 240V AC through a power lead; as only qualified electricians can operate at 240V AC, the compressor must be manually switched on and off, so the microprocessor is less autonomous.

Design Ideas: Compressor Selection

One compressor selection is the 12V DC compressor, permitting the use of a relay to open and close the circuit to turn the compressor on and off electronically. A drawback with the 240V AC compressor is that the compressor cannot be electrically switched on and off by the microprocessor, so effectively the system is less automatic and would require the operator to switch the compressor on and off when indicated.
However, the 240V AC compressor makes use of a 2HP electric motor so can compress air at 105L/min, three times faster than the portable compressor with a flow rate of 35L/min. In addition, using the compressor could eliminate additional components to store the compressed air as the compressor has an air tank.
Unfortunately, the maximum pressure of the system is limited to around 110PSI if the 240V AC compressor is selected whereas the maximum pressure with the 12V DC compressor is 150PSI. The difference being the 12V compressor offers a higher working pressure than the 240V AC compressor.
They both have a male connection that allows the hose from the compressor to be secured tightly.

The 12V compressor was selected as the connection screws onto a Schrader Valve, establishing a tight and strong joint. The lightweight and compact model eases transportation and the overall size of the project. The direct drive design is attractive as, using a relay, the 12V power supply can be electrically switched on and off safely by the microcontroller. Although compression will take longer, the additional time required is not incredibly significant but allows for a higher working pressure, leading to more powerful launches, than possible using the 240V AC compressor. Similarly, the automation of the system in operating the compressor is favoured rather than prompting the user to run the compressor.

Design Ideas: Tank Material

1.698/2 = 0.849 cm radius
*0.849*0.849*3.14*600=1,357.9/1000=1.358L*
$51 of copper pipe = 1.4L
Specifications according to Bunnings

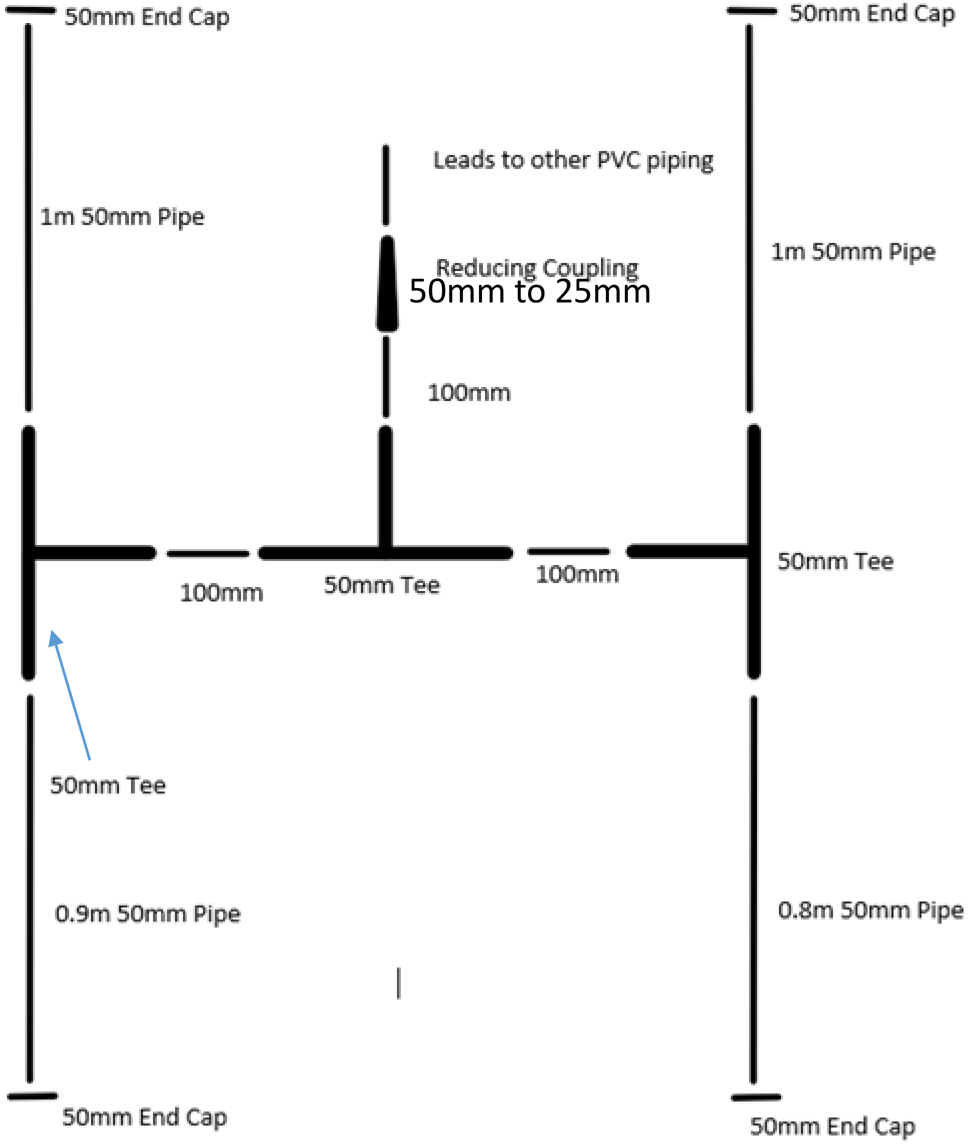
Selection of wall thickness 3.91mm yields inside radius of 2.624cm
*2.624*2.624*3.14*240=5,188.8194/1000=5.1888L*
$35 of galvanised steel pipe = 5.2L
Specifications according to Bunnings

There is the consideration that metal is strong and has a maximum operating pressure of 16.4MPa (2379PSI) at -29 to 38 degrees Celsius. However copper pipes are too expensive to reach the desired volume of air, but galvanised steel is possible. Storing 10.4L would cost $70 with galvanised steel, with the maximum operating pressure 16 times greater than the maximum pressure the system would encounter so effectively a high safety factor.
Meanwhile PVC design v2 would cost $43 for the pipes, storing 9L of air with a maximum operating pressure of 174PSI including a safety factor of 2.145. So while the safety factor is less than the safety factor of galvanised steel, the maximum pressure the pipes have to store is within a safe range and is cost effective.
Furthermore, galvanised steel is over 5kg/metre while the PVC pipes are 1kg/metre so effectively the transport of a galvanised steel tank down the stairs and outdoors to perform launches is riskier as the system is heavier, requiring more strength and creates a risk to the feet and toes.
Ultimately, PVC is preferable as it is light, so easy to transport, while being cost effective without posing a safety risk in regard to operating pressure.

Design Ideas: PVC Pipes

The maximum diameter of pipe offered by Bunnings and Reece with a pressure rating of PN12 is 50mm.
The volume of the pipe is directly proportional to the radius of pipe with a square relationship. Hence, the same volume of pipe can be achieved with a quarter of pipe length if the radius were doubled. For instance, if PN12 100mm pipe could be bought and used then the length of the pipe would become a quarter of the length if PN12 50mm pipe were used.
The benefits of using wider pipe are that less connections are required, suggesting the system will be more efficient as there will be less losses. By having less connections, the development of the PVC subsystem would be quicker and cost-effective since more connections requires more money to purchase and time to glue together. Since the pipe is wider going from the wide 100mm pipe to the required 25mm pipe that leads to the 1" release valve and other connections alludes to the difficulty of finding and connecting a reducing coupler that reduces the diameter of the pipe from 100mm to 25mm. Likely, two reducing couplings would have to be used going from 100mm diameter to 50mm diameter then from 50mm diameter to 25mm diameter. As such, money would be wasted in purchasing 50mm pipe since there would be a large amount of excess just to connect these two reducing couplings together.
After researching local companies that sell PVC pipe, I concluded that Vinidex's products were the right fit while Bunnings and Reece had a constraint on the maximum pipe diameter while being PN12 rated. After contacting Vinidex, it was discovered that they do not do cash transactions and deal with the public. Consequently, I realised I was only left with Bunnings and Reece to source the PVC from. Comparing prices, Reece was more expensive but offered some unique and useful products that were not available at Bunnings. Their products will be used to produce the PVC subsystem with a design that minimises the amount of connections but ensures the final product will be transportable and appealing to the eye rather than one long pipe that can be difficultly transported.

Design Ideas: PVC Tank v1



15 connections

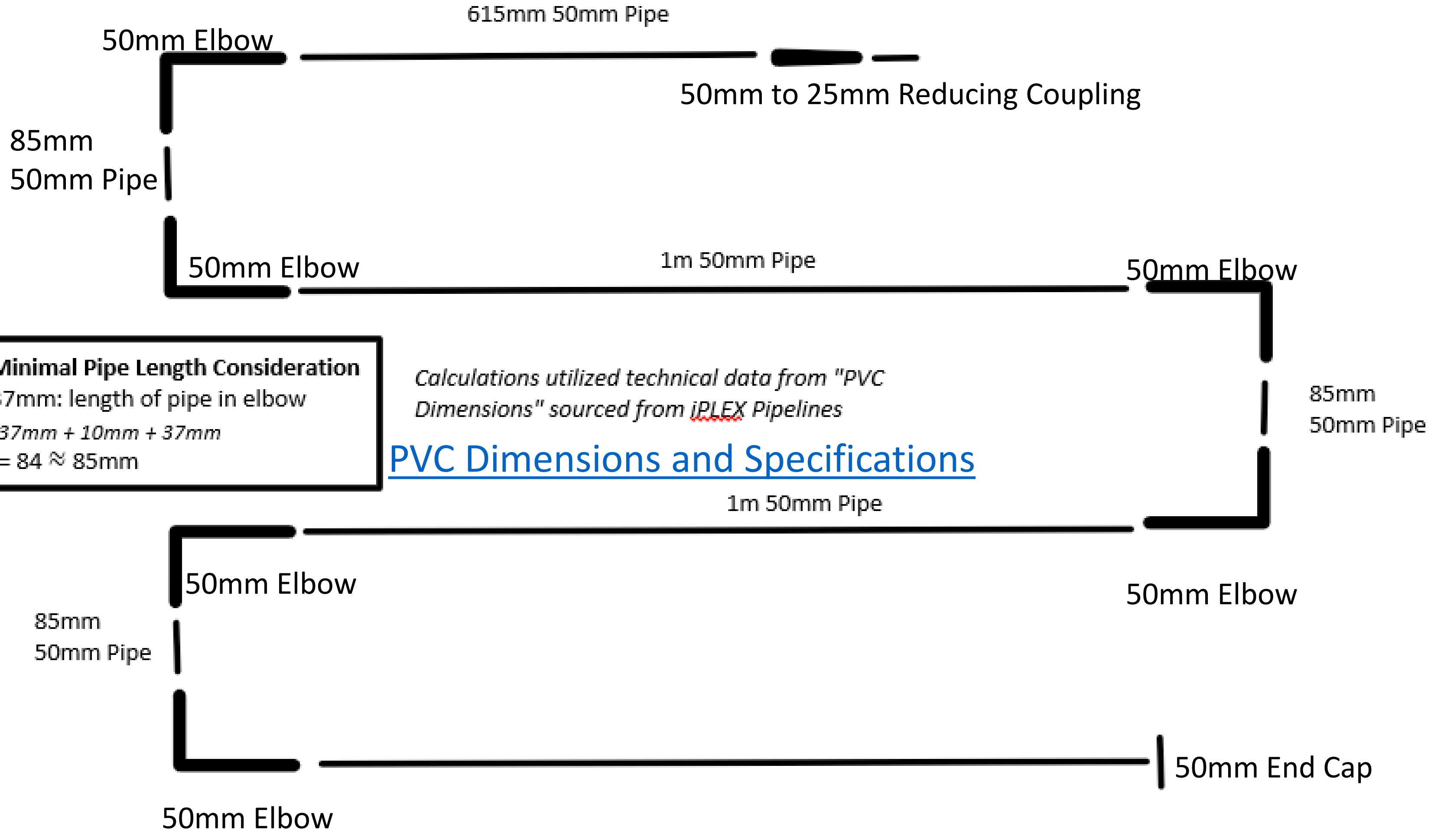
Item	$	$
50mm Pipe 1m x 4	43.28	
50mm Tees x 3	14.37	
50mm End Caps x 4	14.28	
50mm to 25mm Reducer	13.57	85.50

Minimal Pipe Length Consideration
37mm: length of pipe in tee and reducing coupling
37mm + 10mm + 37mm
= 84 ≈ 85mm

Calculations utilized technical data from "PVC Dimensions" sourced from iPLEX Pipelines

PVC Dimensions and Specifications

Design Ideas: PVC Version 2



Minimal Pipe Length Consideration
37mm: length of pipe in elbow
37mm + 10mm + 37mm
= 84 ≈ 85mm

Calculations utilized technical data from "PVC Dimensions" sourced from iPLEX Pipelines

[PVC Dimensions and Specifications]

Cost

Item	$	$
50mm Pipe 1m x 4	43.28	
50mm Elbows x 6	23.40	
50mm End Caps	3.57	
50mm to 25mm Reducer	13.57	83.82

Volume from Pipes
53.7/10/2=2.685cm radius
2.685*2.685*3.14*400/1000=9.0548 L

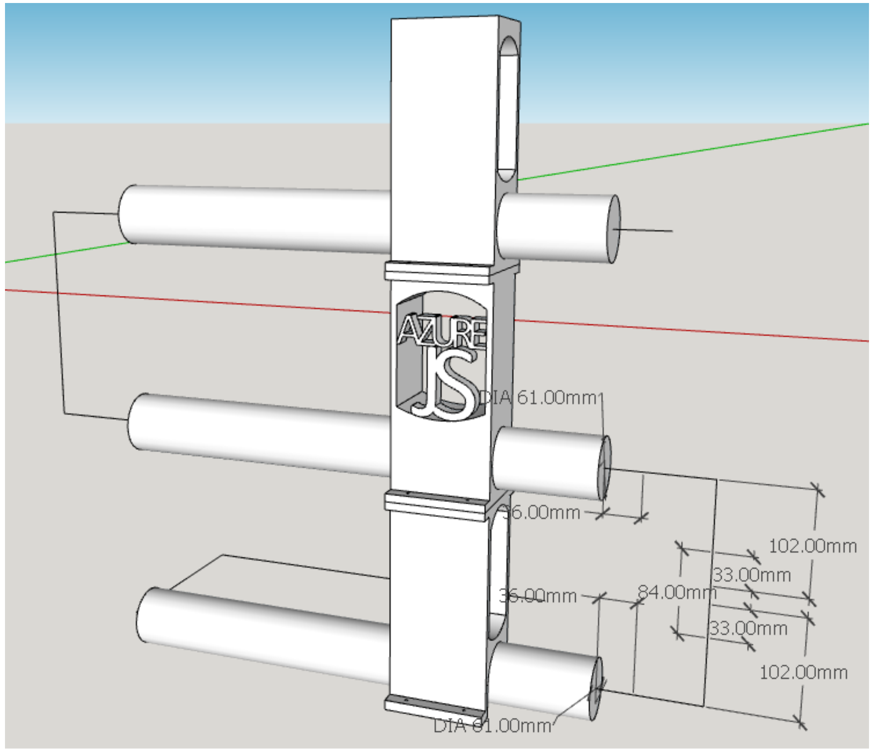
Design Ideas: PVC Tank Selection

Comparing the PVC designs, v1 and v2 are similar in price with v2 costing $1.70 less while offering the same tank volume in a compact design. The dimensions of the base required for design v2 is overall shorter in comparison with design v1, saving wood and allows transport to be easier as moving a compact structure is easier in tight corners.

V2 is further compacted by orientating the PVC pipes vertically. As modelled in Figure 2, the 3D printed strain relief component structurally supports the PVC pipes to vertically orient.

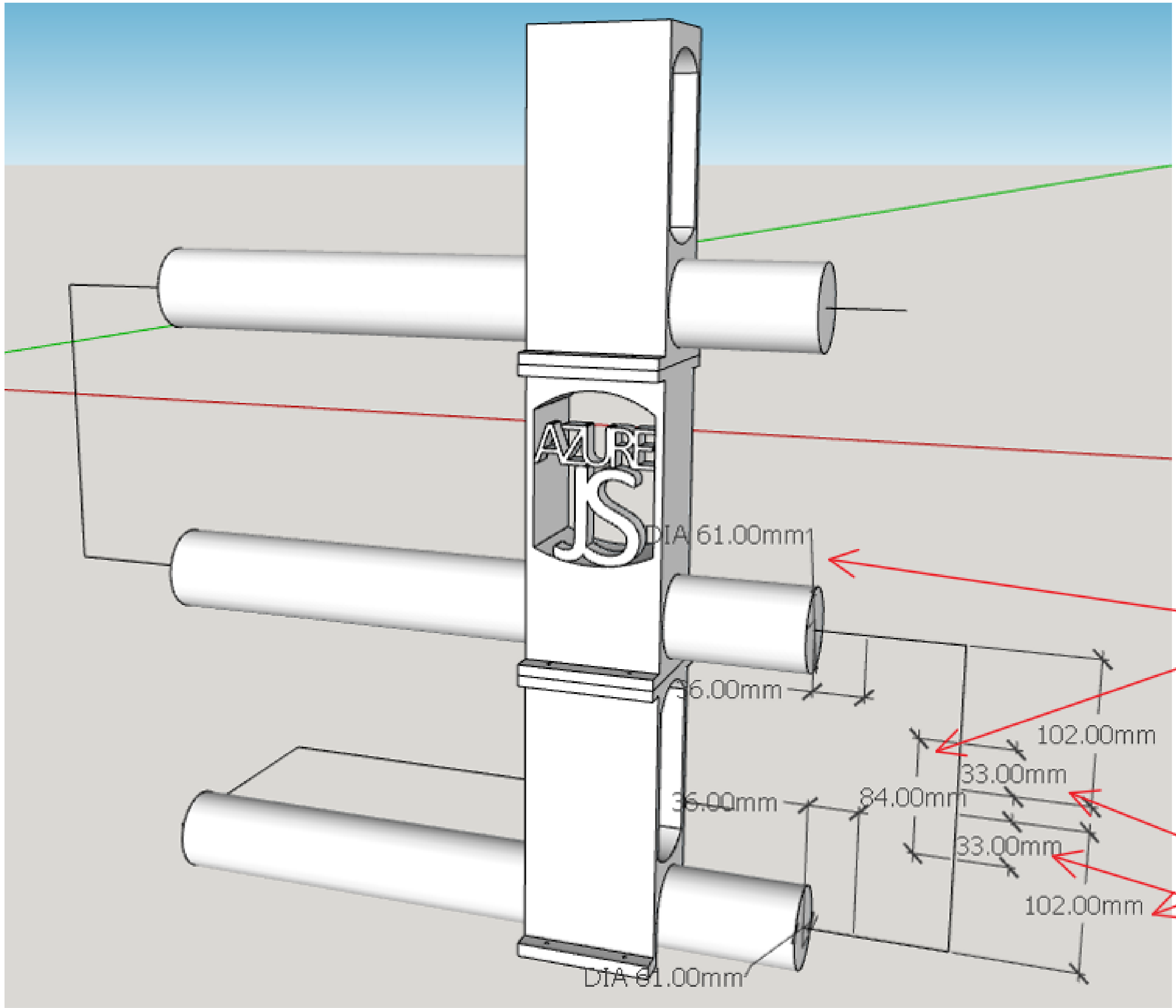
The strain relief component is further explorer in the following slide.

Figure 2



Design Ideas: PVC Strain Relief: Part 1

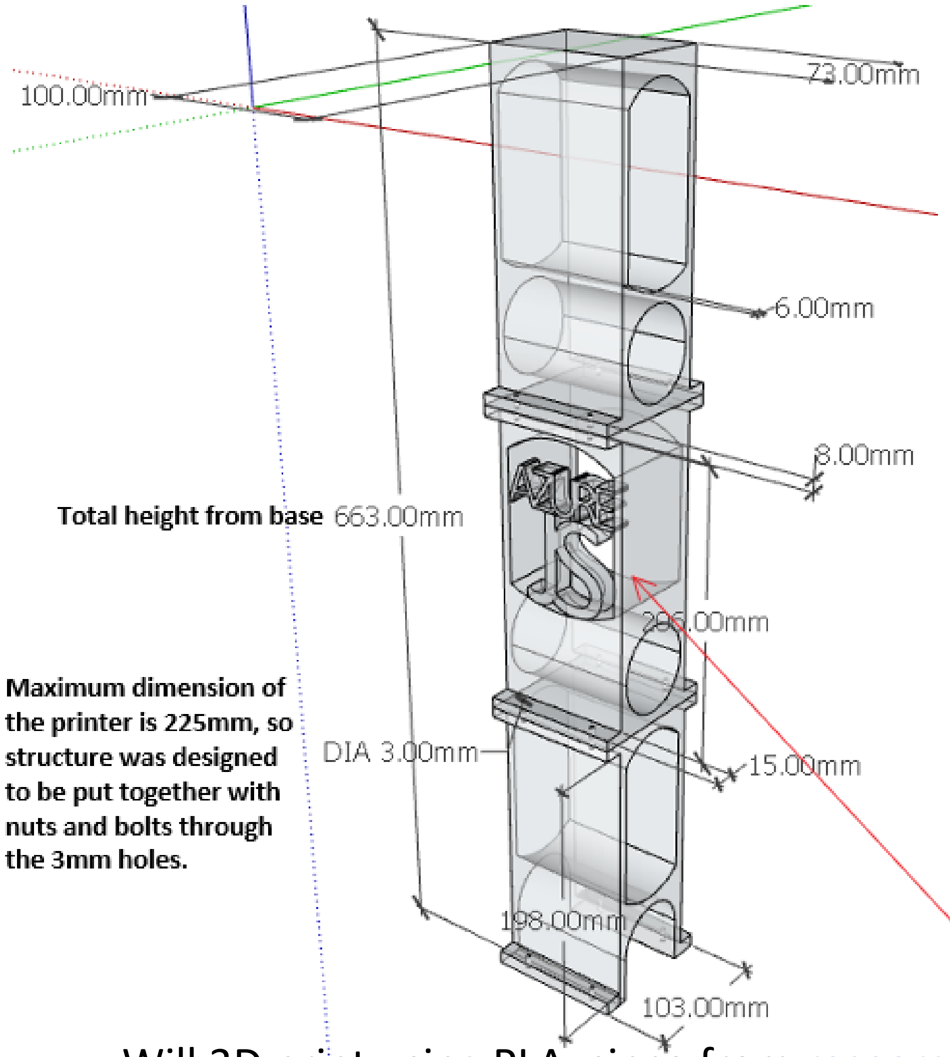
PVC rotated vertically up for a compact design
PVC clamp and interlocking structure will provide strain relief to the PVC pipes. Furthermore the top provide a mounting location for the Raspberry Pi and its screen. A 0.9m cable can then be used to connect the Raspberry Pi to the Arduino located near the electronics to minimize wire length.



84mm pipe goes into elbow 36mm and 33mm on the other side
Outside diameter of 50mm pipe is 61mm
Height of elbow is 102mm, no matter which end is bottom
However, height will vary by 3mm as one side goes into pipe 3mm more!
The vertical connection (i.e. horizontally flat) will always be the 33mm side to keep consistent and develop precise designs

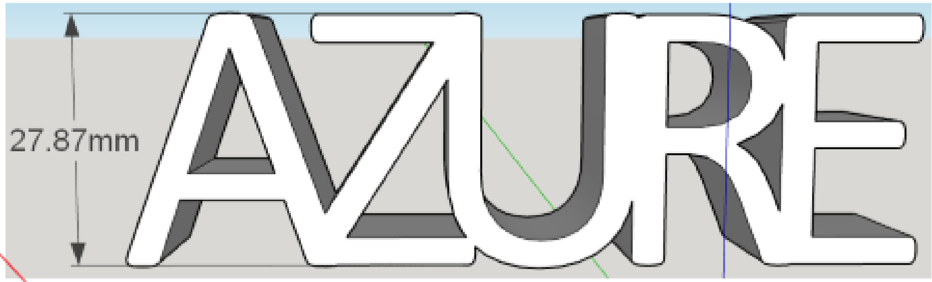
Continue to Part Two

Design Ideas: PVC Strain Relief: Part Two

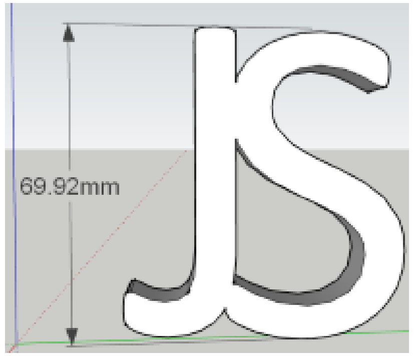


Maximum dimension of the printer is 225mm, so structure was designed to be put together with nuts and bolts through the 3mm holes.

Will 3D print using PLA, since from [research](#) PLA is stronger and stiffer. These characteristics are significant to a structural component as using PLA allows it to withstand greater loads before breaking, compared to if ABS is used as the filament.

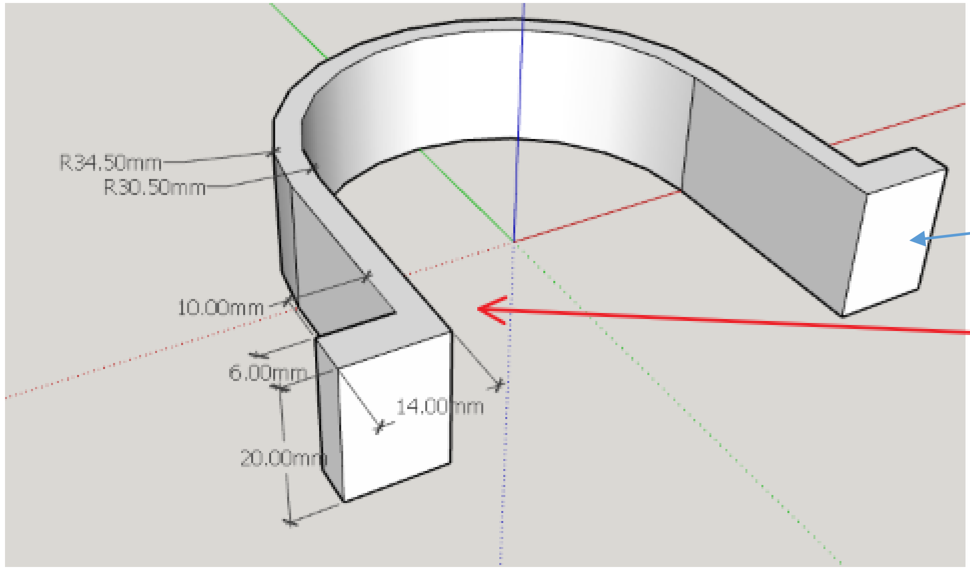


These 3D printed letters can be separately printed then bonded with each other and the structure with acetone. This is to brand the product, as Azure is the company name and JS are the initials of the owner and CEO.



Design Ideas: PVC Clamp

Essential to hold the PVC in position on the base
3D printed



Place to drill then screw into base

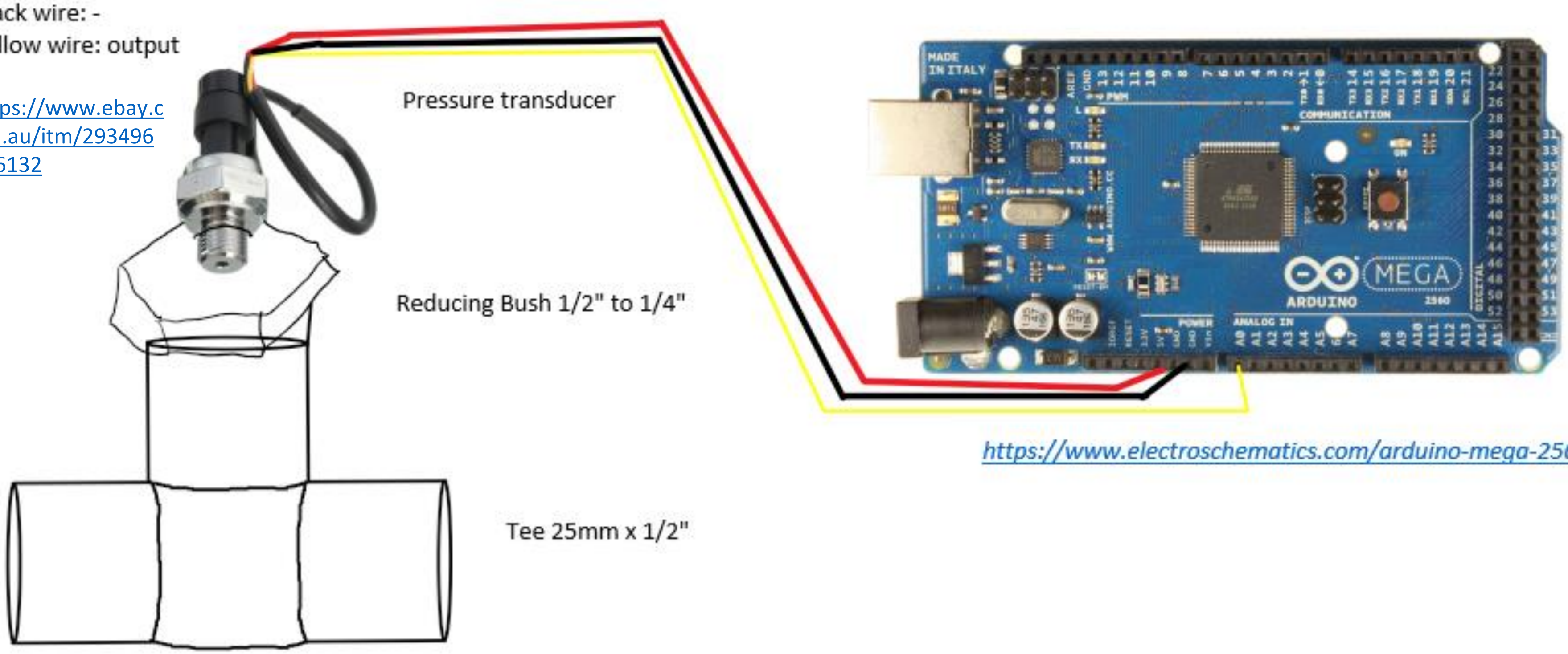
Additional 4mm taking into consideration the thickness of the elbow
Since the pipe is fitted in the elbow, the pipe's height is 4mm from the base

Uses technical data from PVC Dimensions and Specifications to design the PVC clamp

Design Ideas: Pressure Transducer

Red wire: +
Black wire: -
Yellow wire: output

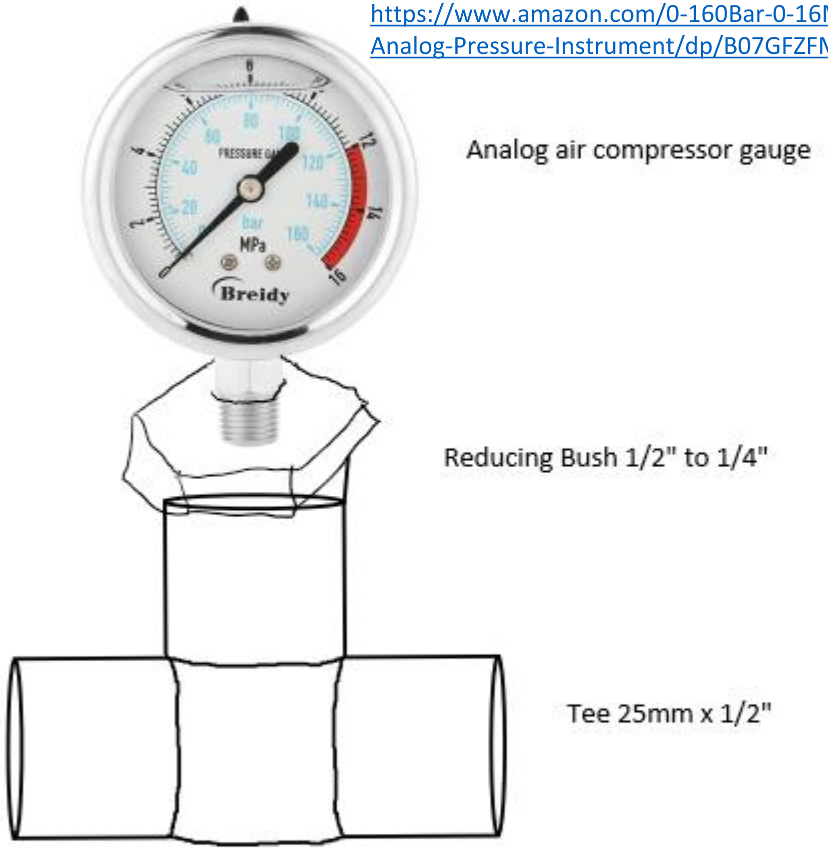
https://www.ebay.com.au/itm/293496206132



https://www.electroschematics.com/arduino-mega-2560-pinout/

Design Ideas: Pressure Gauge

https://www.amazon.com/0-160Bar-0-16Mpa-Analog-Pressure-Instrument/dp/B07GFZFMJ3

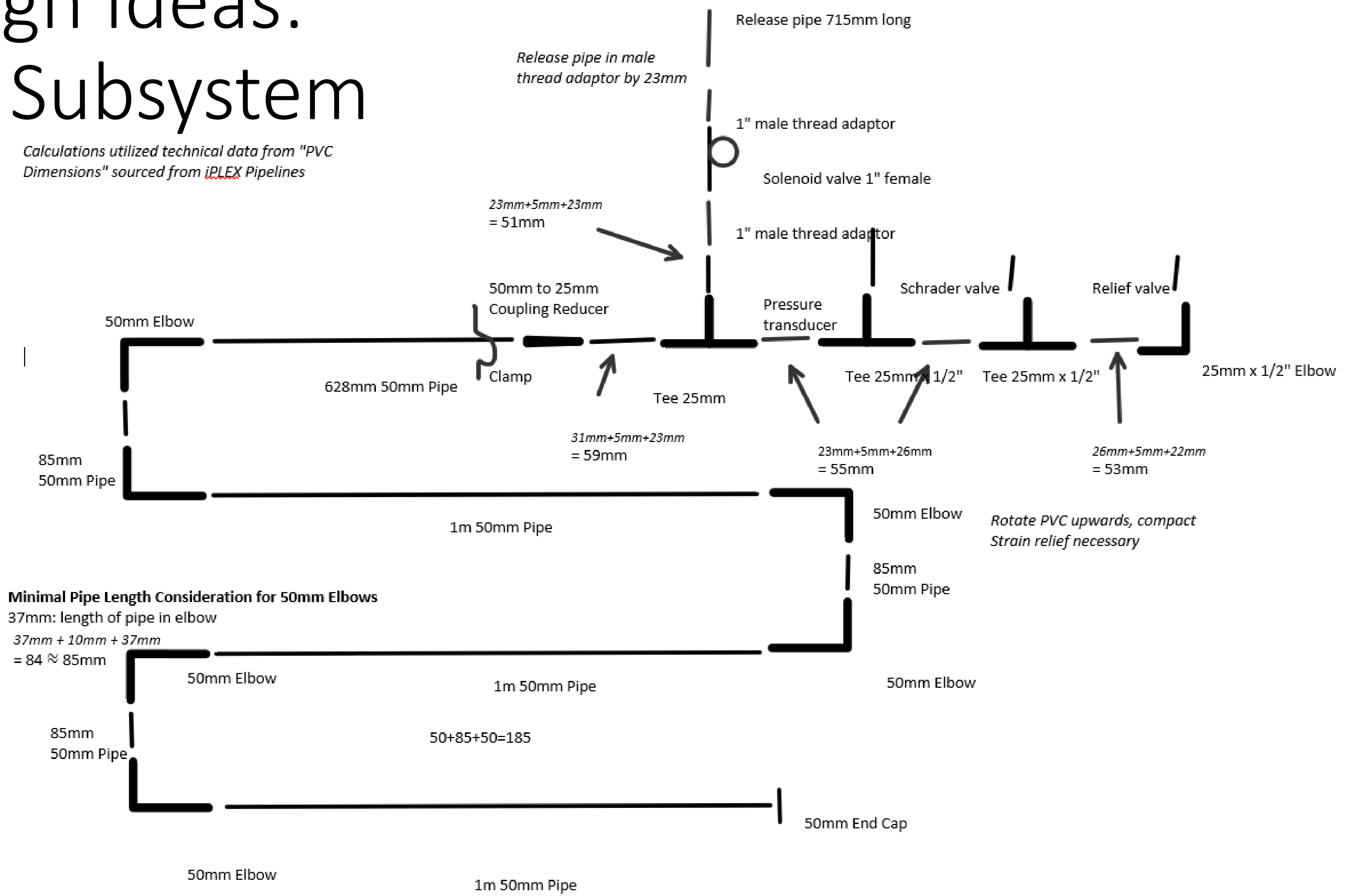


Design Ideas: Pressure Measurement Selection

An analogue pressure gauge would be cheap and easy to install.
However, a digital pressure transducer provides useful data to the system so that the air pressure can be monitored, limited to a certain setting and graphed. Similarly, the microcontroller has independence and can operate autonomously rather than relying on the user to keep an eye on the pressure gauge.

Design Ideas: PVC Subsystem

Calculations utilized technical data from "PVC Dimensions" sourced from iPLEX Pipelines



Design Ideas: Actuators

Servo Motor

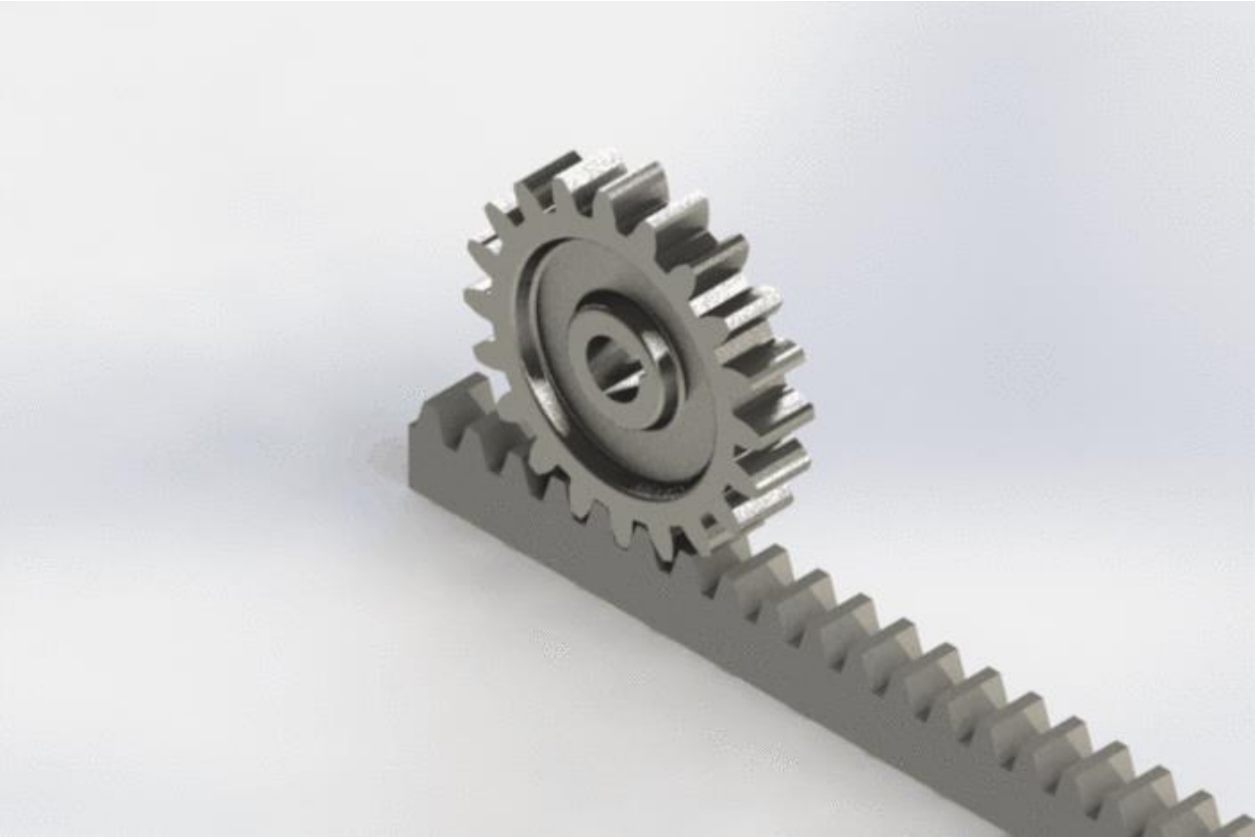
26-April-2020

Servo rotates the gantry

26-April-2020

Representation of rocket

Gear Rack and Pinion



Gear rack and pinion extends and retracts the gantry

https://www.pinterest.com.au/pin/88523948904591922/

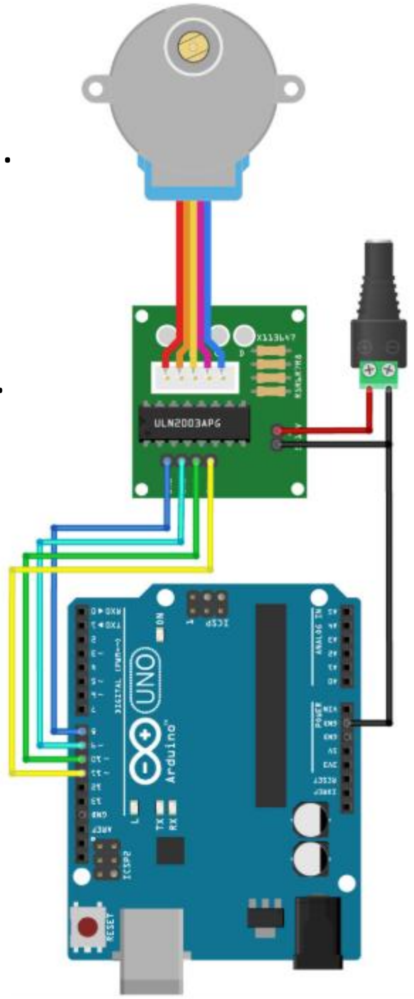
Design Ideas: Actuator Selection

The crane-like system that extends out to the rocket with the claw to provide stability and support will have gravity acting upon it so needs to have a strong connection to the tower to ensure the crane itself is stable. Similarly, the actuator of the system must be precise and careful as over extension or rotation would result in the crane colliding with the rocket and potentially leading to damage.

Considering these, the rack and pinion gear design is the suitable design. The crane can be well-supported by the tower whereas this is more difficult as the servo design must allow the crane to rotate smoothly indicating the servo design is less favourable.

Again, the rack and pinion gear design is preferable as limit switches can be easily used to determine when the crane has extended far enough and a motor can be used to create linear motion with the gear rack. Unlike this, the servo is required to generate torque to rotate the entire crane and for such a design to be precise and position the angle of the crane to line up with the rocket would prove more difficult than the linear motion of the rack and pinion gear design.

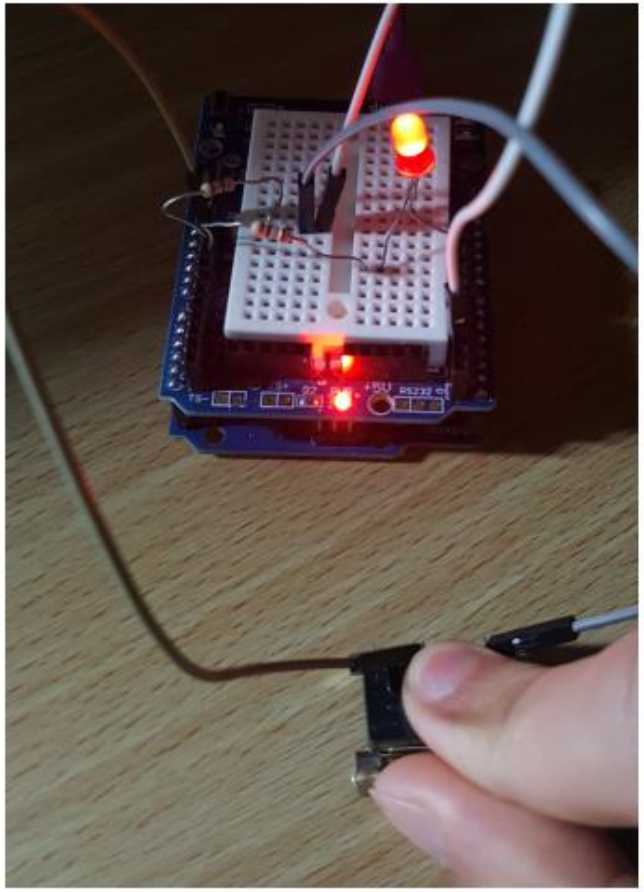
Ultimately, the servo design would be harder to implement than the rack and pinion gear design and has more risk of failure or imprecision.



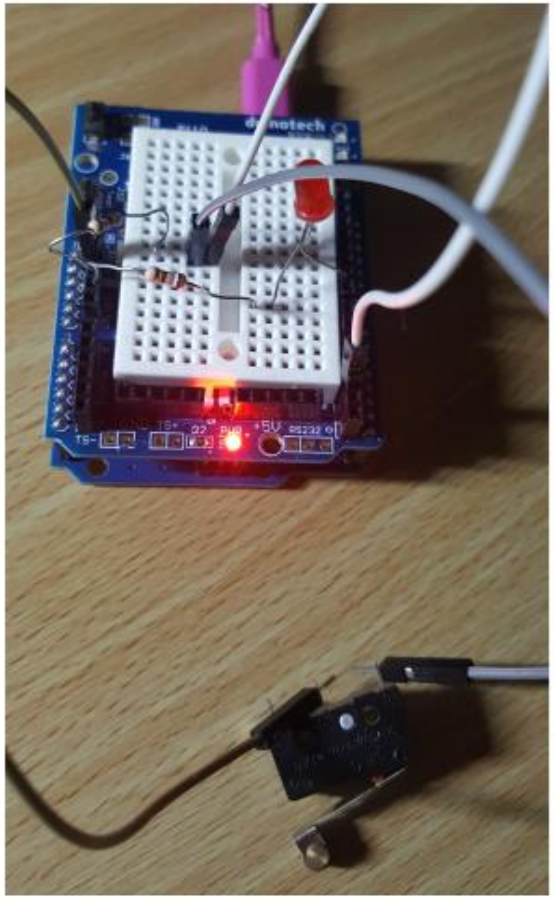
ULN2003 Driver Board	Connection
IN1	Pin 8 Arduino
IN2	Pin 9 Arduino
IN3	Pin 10 Arduino
IN4	Pin 11 Arduino
–	Logic GND Arduino
–	GND power supply
+	5 V power supply

Design Ideas: Feedback – Limit Switches

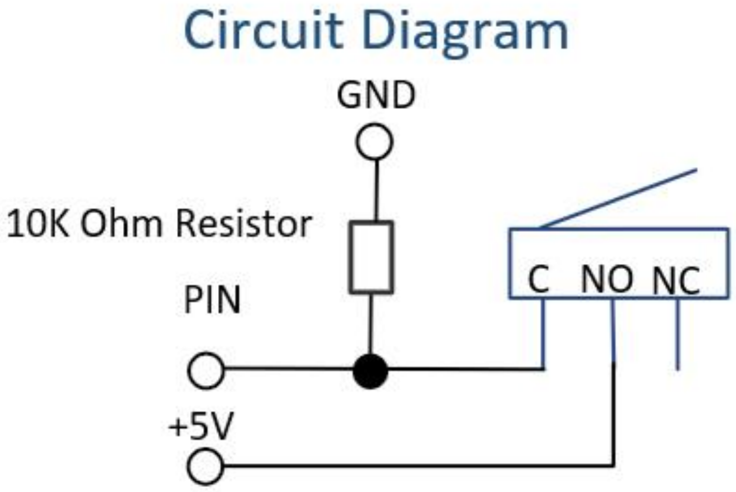
Limit switches are used to signal the gantry crane has reached its final position



26-April-2020



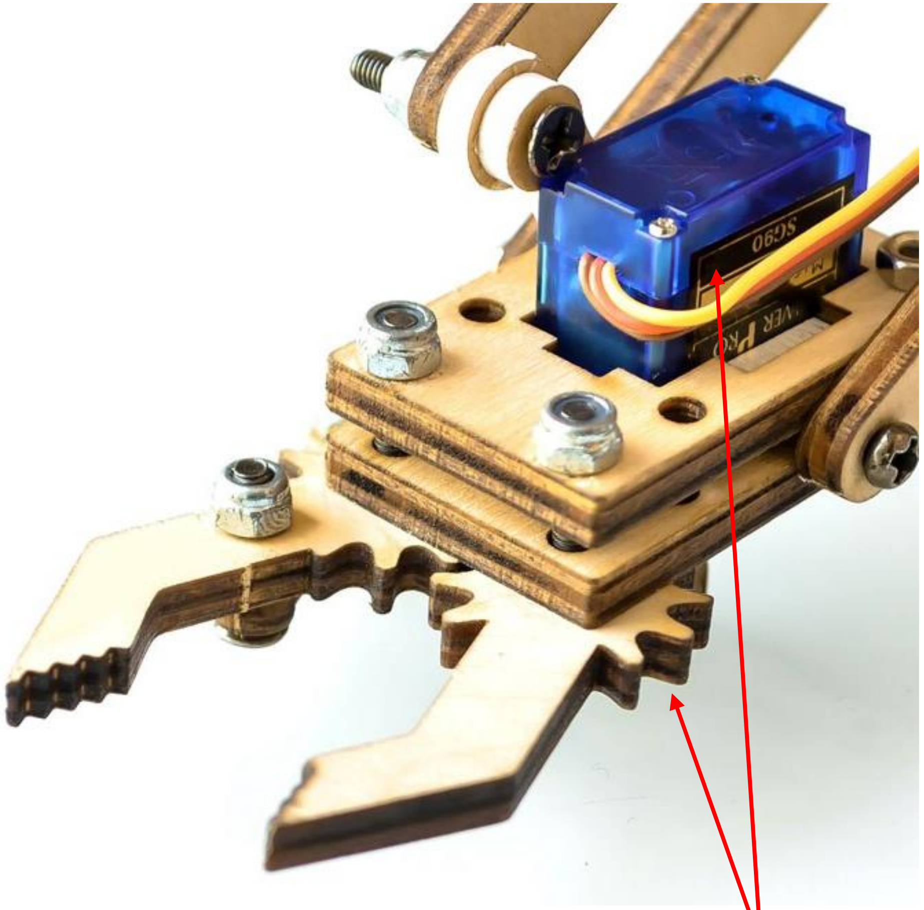
26-April-2020



The test above demonstrates that when the limit switch is pressed down, the microcontroller reads HIGH from the limit switch so turns on the LED (indicating it would stop the stepper motor.)

Design Ideas: Clamping

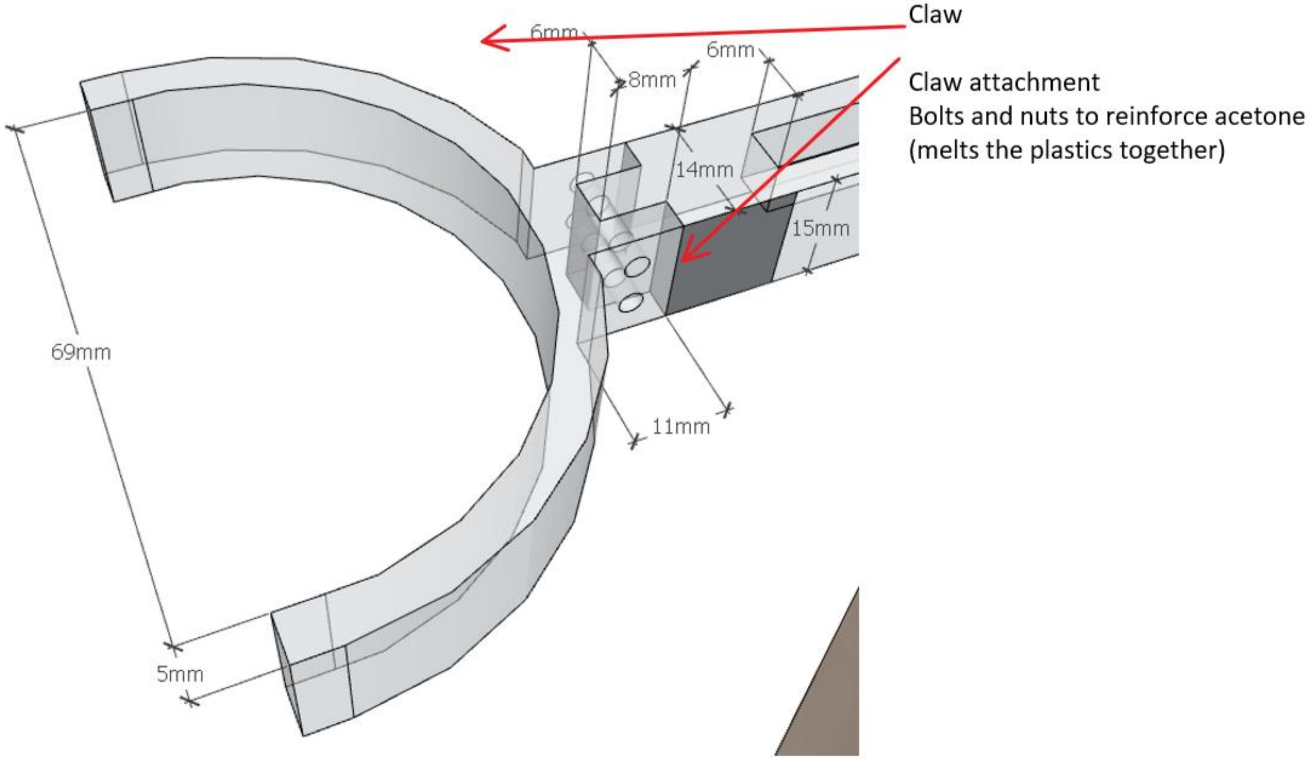
Active Clamping



https://www.aliexpress.com/i/32960950941.html

Active clamping example above utilises a servo motor and gears to open and close the claws

Passive Clamping



Design Ideas: Clamping Selection

I have chosen passive clamping rather than active clamping to save time (approximately a week) to ensure more important aspects of the project are completed in this difficult situation, due to the pandemic.

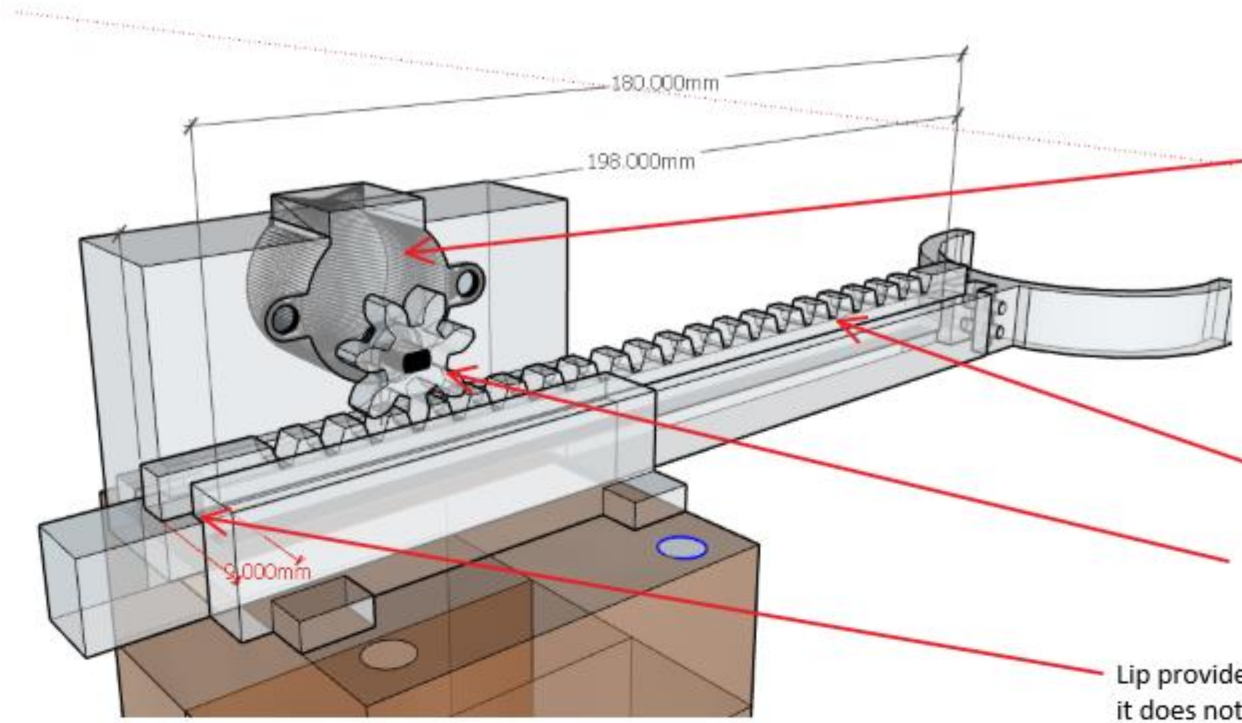
Benefits of Passive Clamping rather Active Clamping

- Passive clamp design is simple to print and quick to connect to the gantry crane system
- Clamp's size can be minimal to improve the ability of the system in providing support and stabilising the rocket
- Cost effective as requires minimal plastic and no additional electronics

Disadvantages of Passive Clamping rather Active Clamping

Complex system utilises a servo and gears to 'squeeze' and hold the rocket in position, indicating that active clamping can enhance the ability to provide support to the rocket. This gear system would take additional materials and time to design then construct.

Design Ideas: Gantry Subsystem



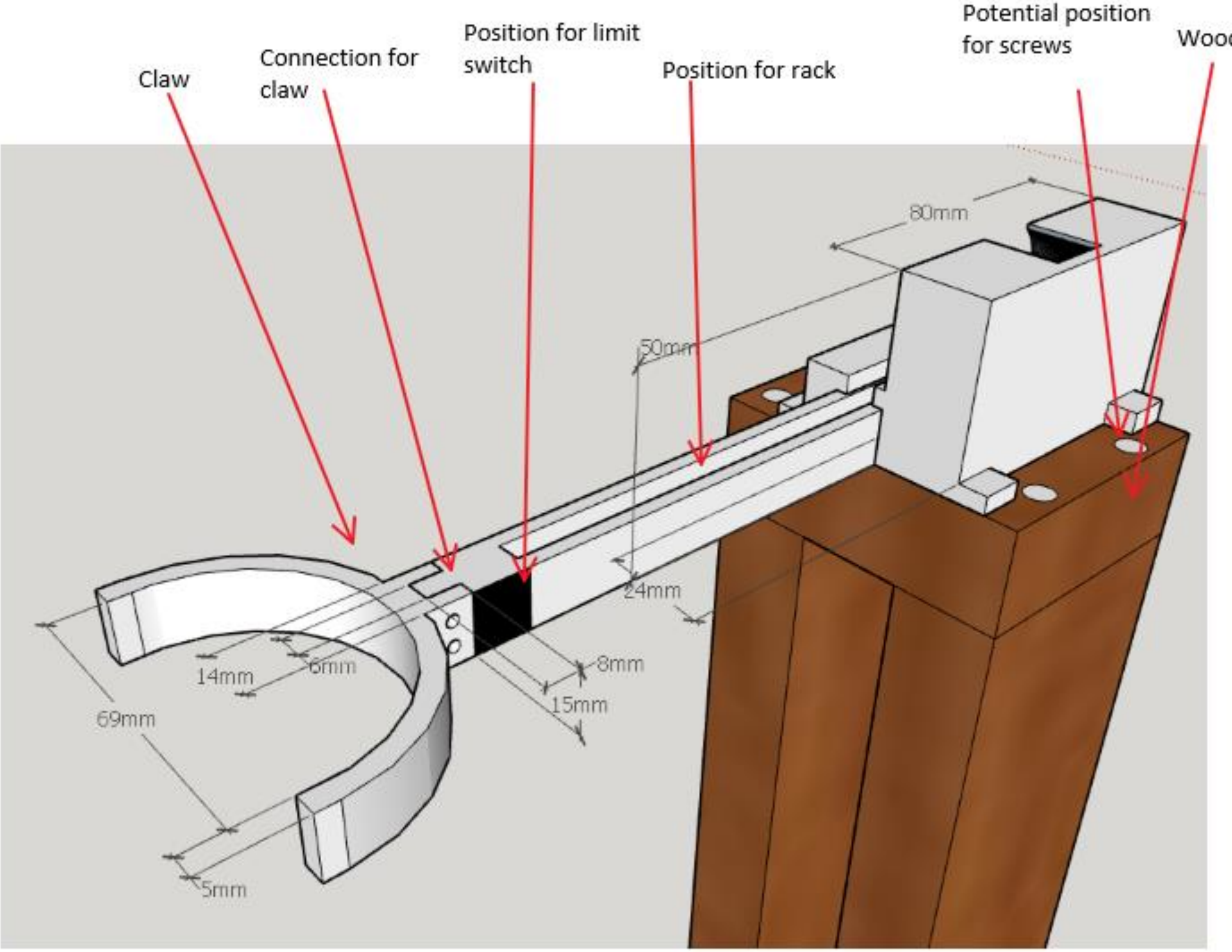
Stepper Motor modelled with true dimensions to simulate the gear setup

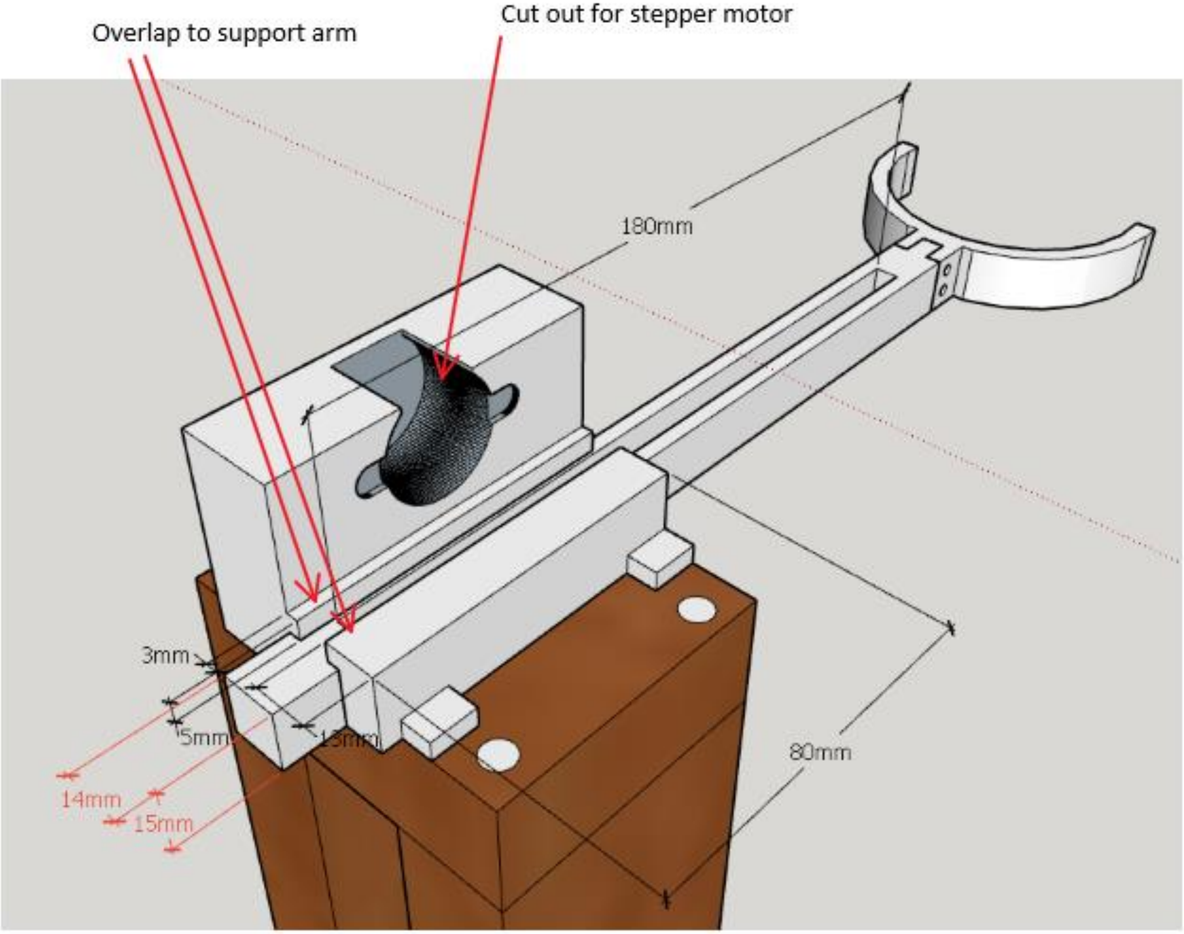
Gear Rack

Pinion

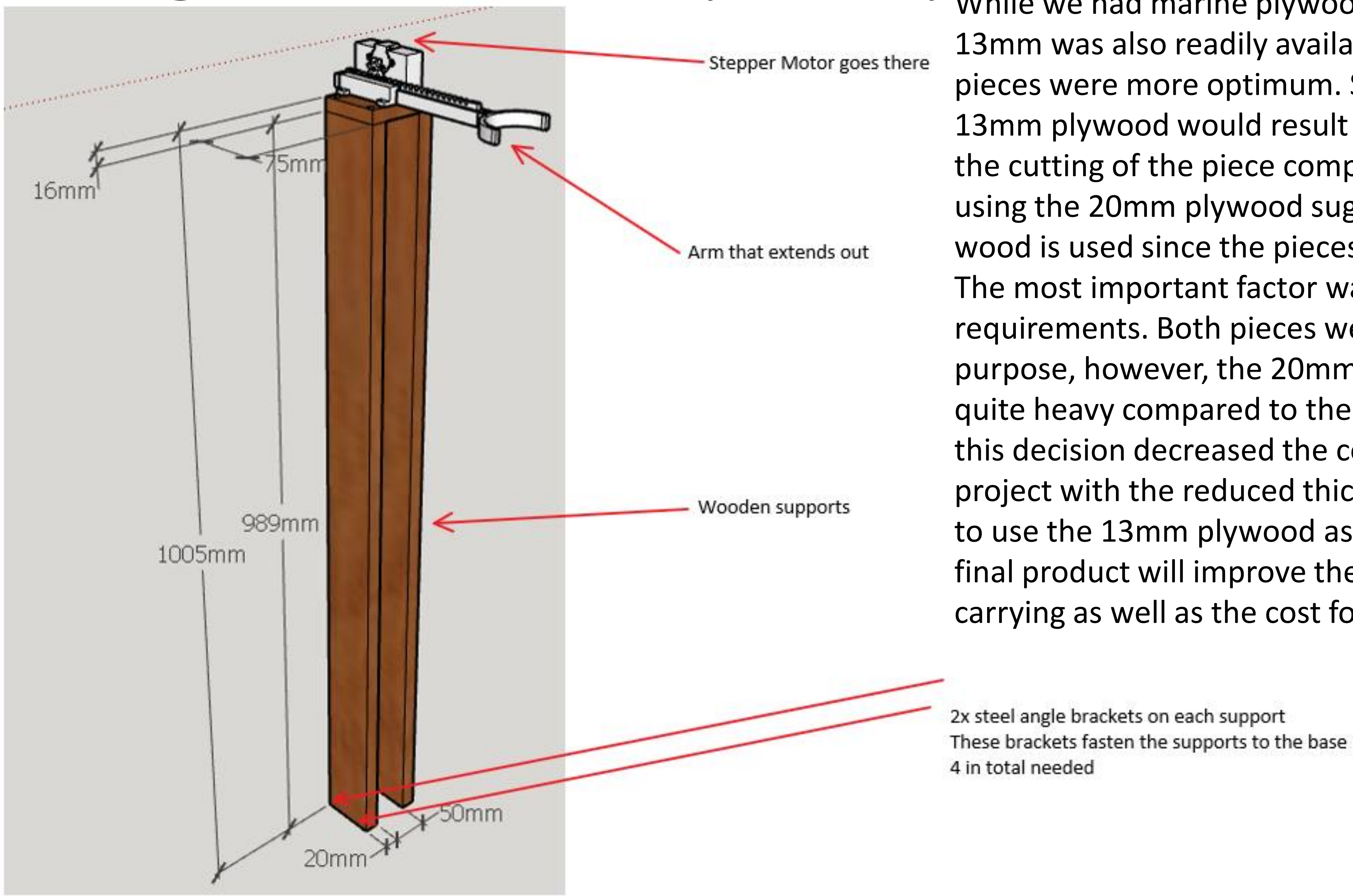
Lip provides support to the crane, ensuring it does not angle downwards, while allowing the crane to extend and retract

Design Ideas: Gantry Subsystem





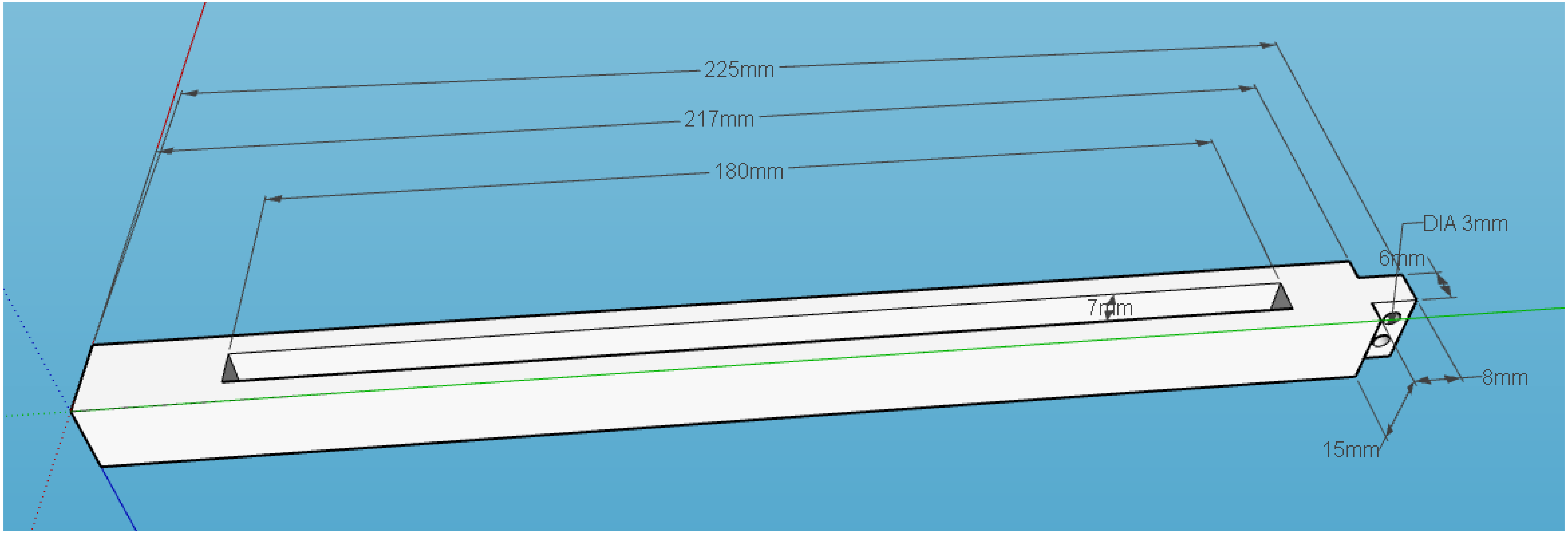
Design Ideas: Gantry Subsystem



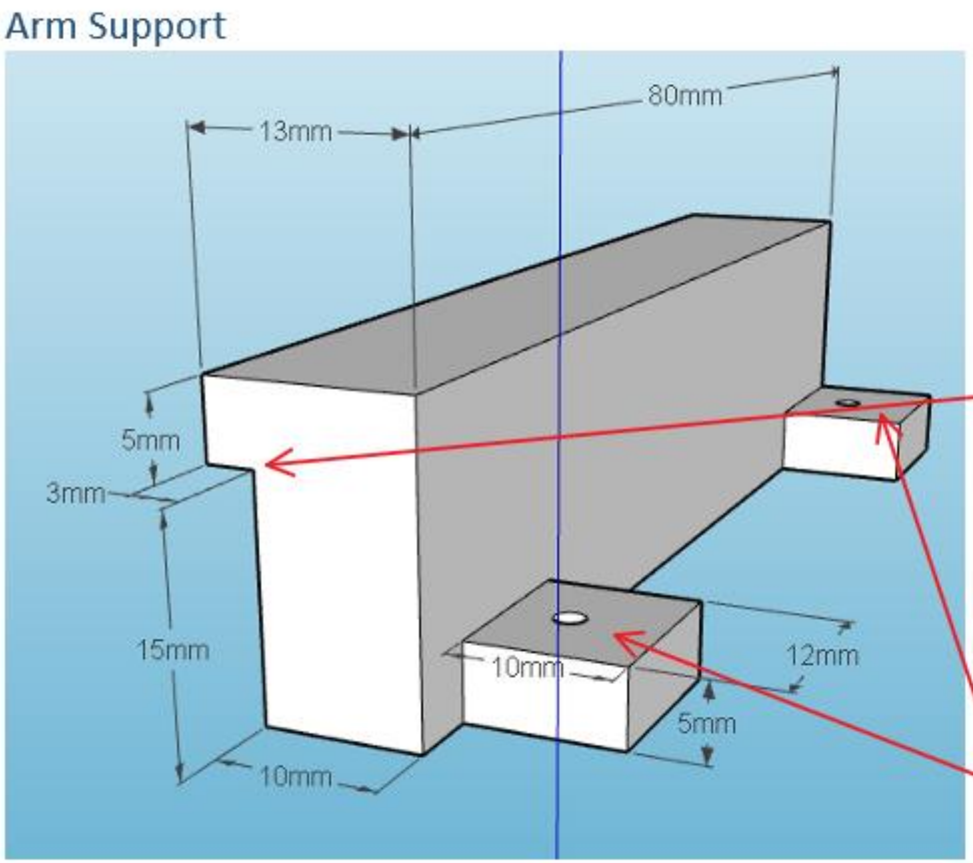
While we had marine plywood 20mm thick available, 13mm was also readily available and the size of the pieces were more optimum. Similarly, the cutting of the 13mm plywood would result in less wood unused from the cutting of the piece compared with the 20mm. Also, using the 20mm plywood suggests a greater amount of wood is used since the pieces are thicker.

The most important factor was the weight and strength requirements. Both pieces were strong for the requiring purpose, however, the 20mm plywood was naturally quite heavy compared to the 13mm plywood. As well, this decision decreased the consumption of wood for the project with the reduced thickness. Ultimately, I decided to use the 13mm plywood as reducing the weight of the final product will improve the ease in transporting and carrying as well as the cost for materials.

Design Ideas: Arm/Crane



Design Ideas: Arm Support



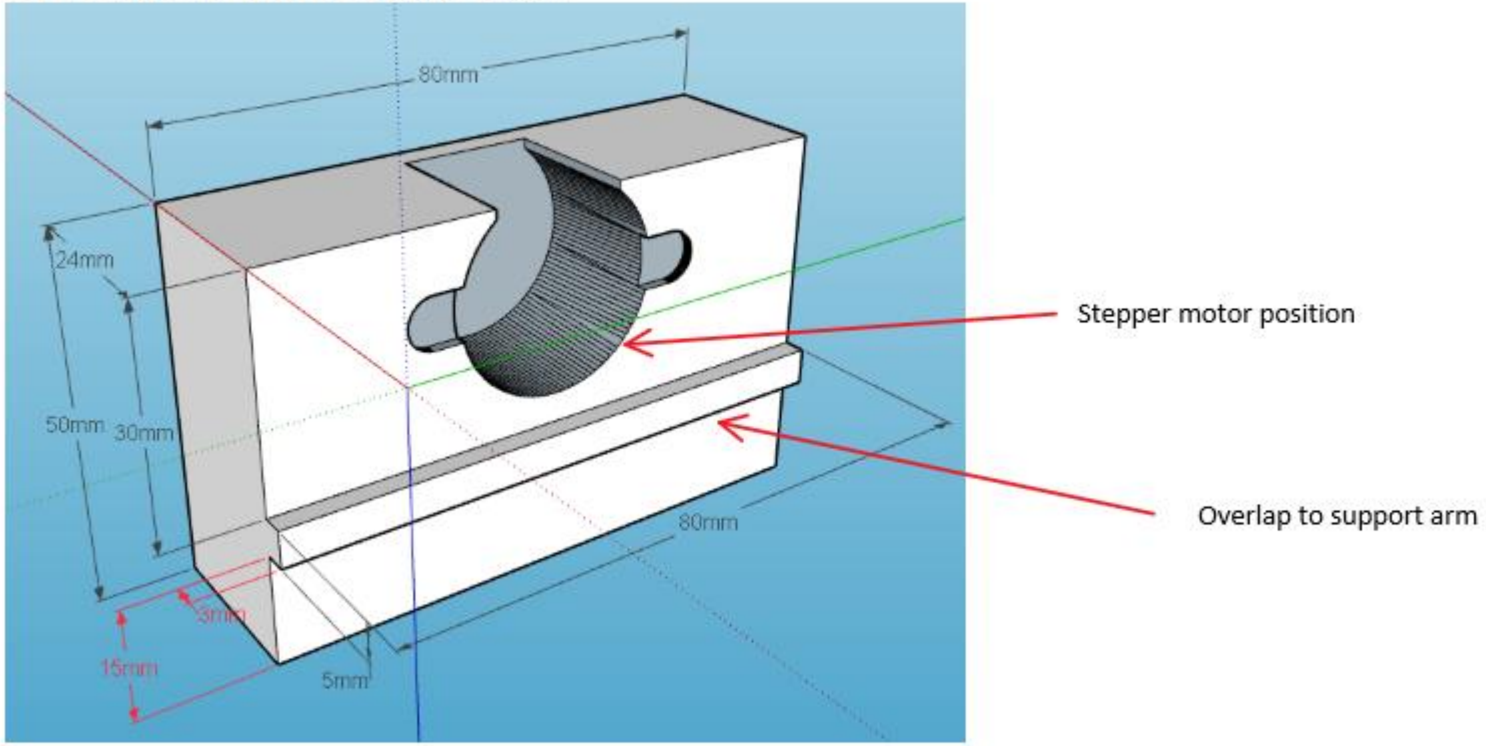
Overlap to support arm

2mm hole printed
Screw is 4mm diameter, so will fasten securely

Holes for screws to fasten component to the wooden base

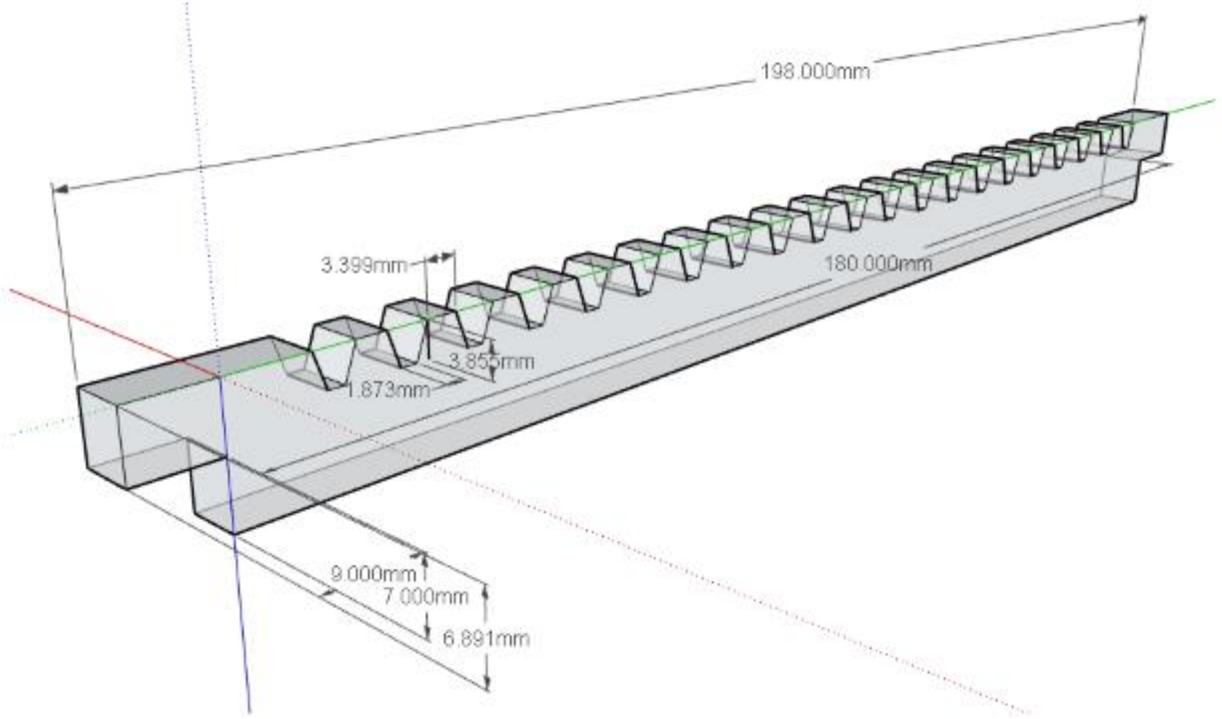
Design Ideas: Arm Support with Stepper Motor

Arm Support with Stepper Motor

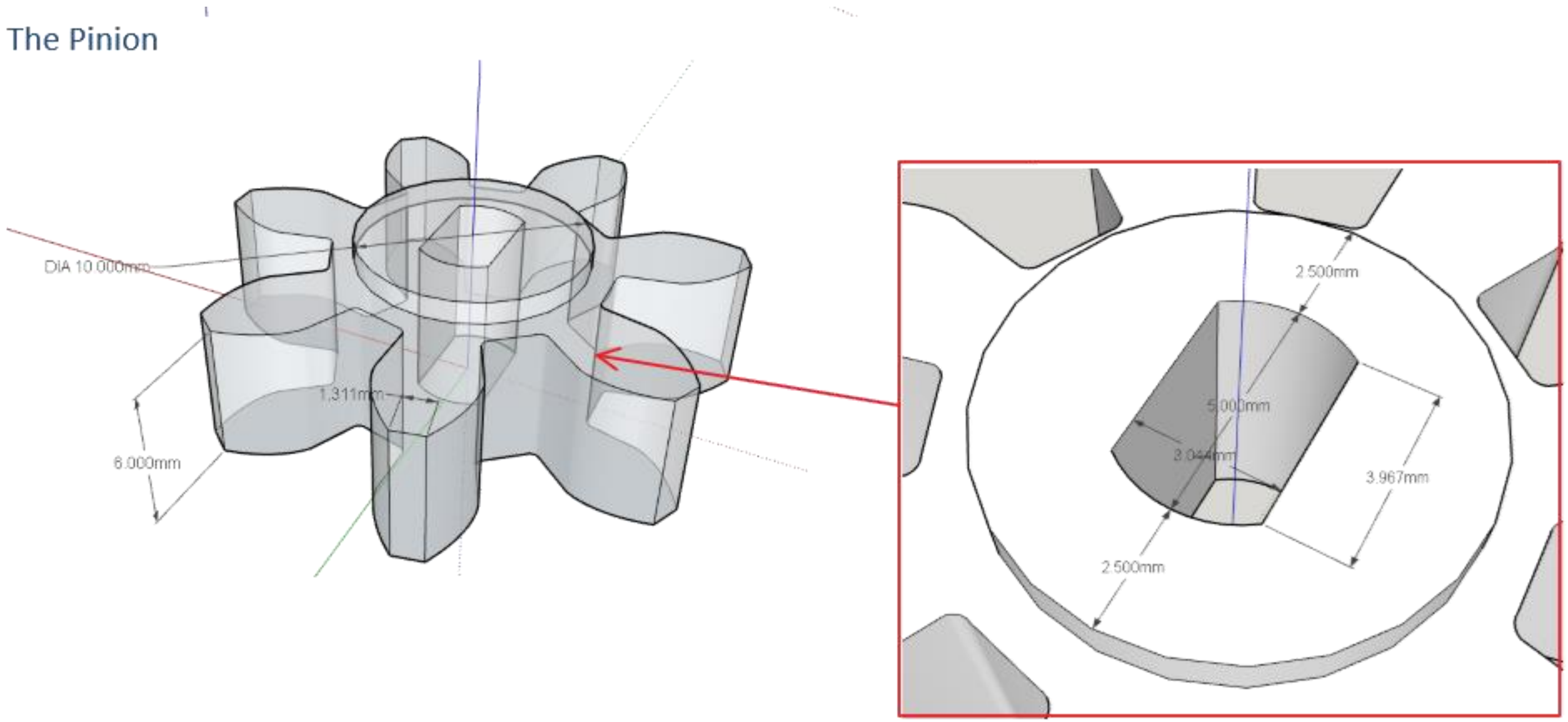


Design Ideas: Gear Rack

The Gear Rack



Design Ideas: Pinion

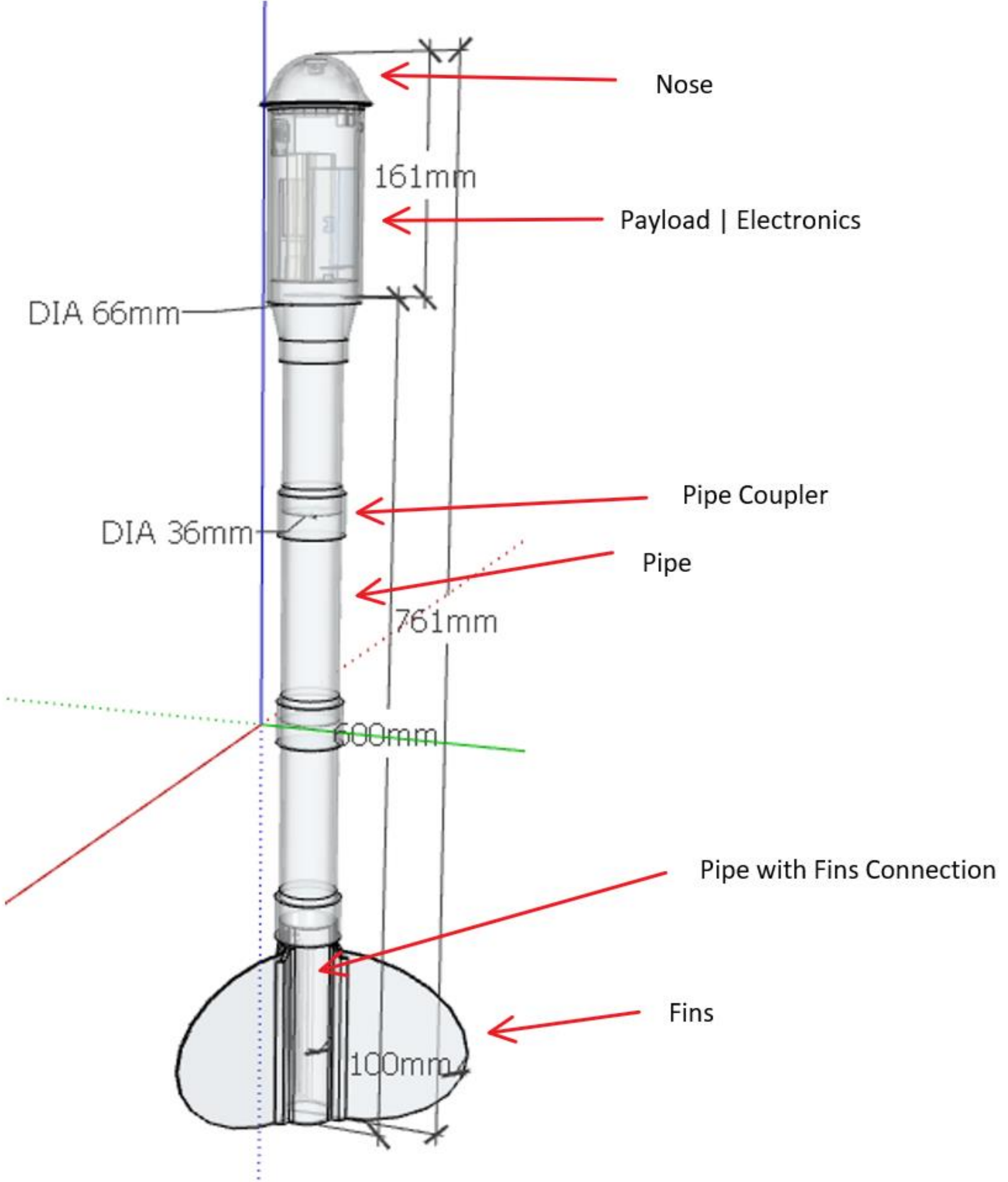


Design Ideas: Gear Production

Engineers measure the compressive strength by loading a block of wood parallel to the grain until it breaks, and the bending strength by loading a block perpendicular to the grain
Yield Strength is the stress a material can withstand without permanent deformation or a point at which it will no longer return to its original dimensions (by 0.2% in length). Whereas, Tensile Strength is the maximum stress that a material can withstand while being stretched or pulled before failing or breaking.

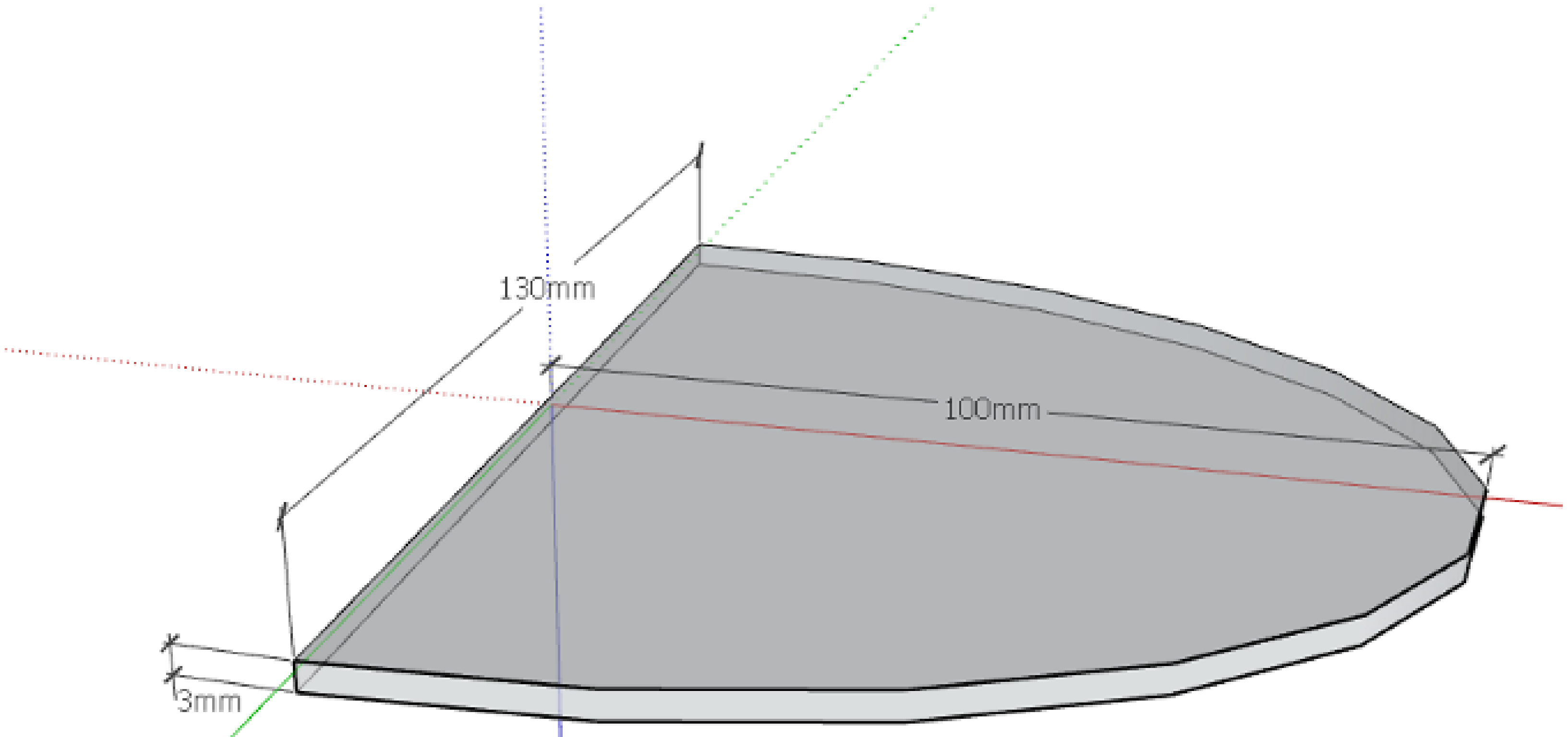
	Tensile Strength (Yield)	Tensile Strength (Ultimate)	Compressive Strength	Bending Strength
ABS	1890 - 9430PSI	3210 - 8270PSI		
Hickory - very high.			9210	20200

So while ABS is weaker than the wood, Hickory, due to the time constraints of the project I will choose to 3D print the gear. Should the printed pinion not perform to an acceptable degree, then the pinion will be laser cut. However, as class time is so limited it is easier to 3D print the pinion as I can start the 3D print, taking a minute of my time, then continue with other work.
Another option is to use the CNC machine, to produce a pinion out of brass. While learning to use the machine is intriguing, again due to time constraints I cannot over extend myself and fall behind in production.

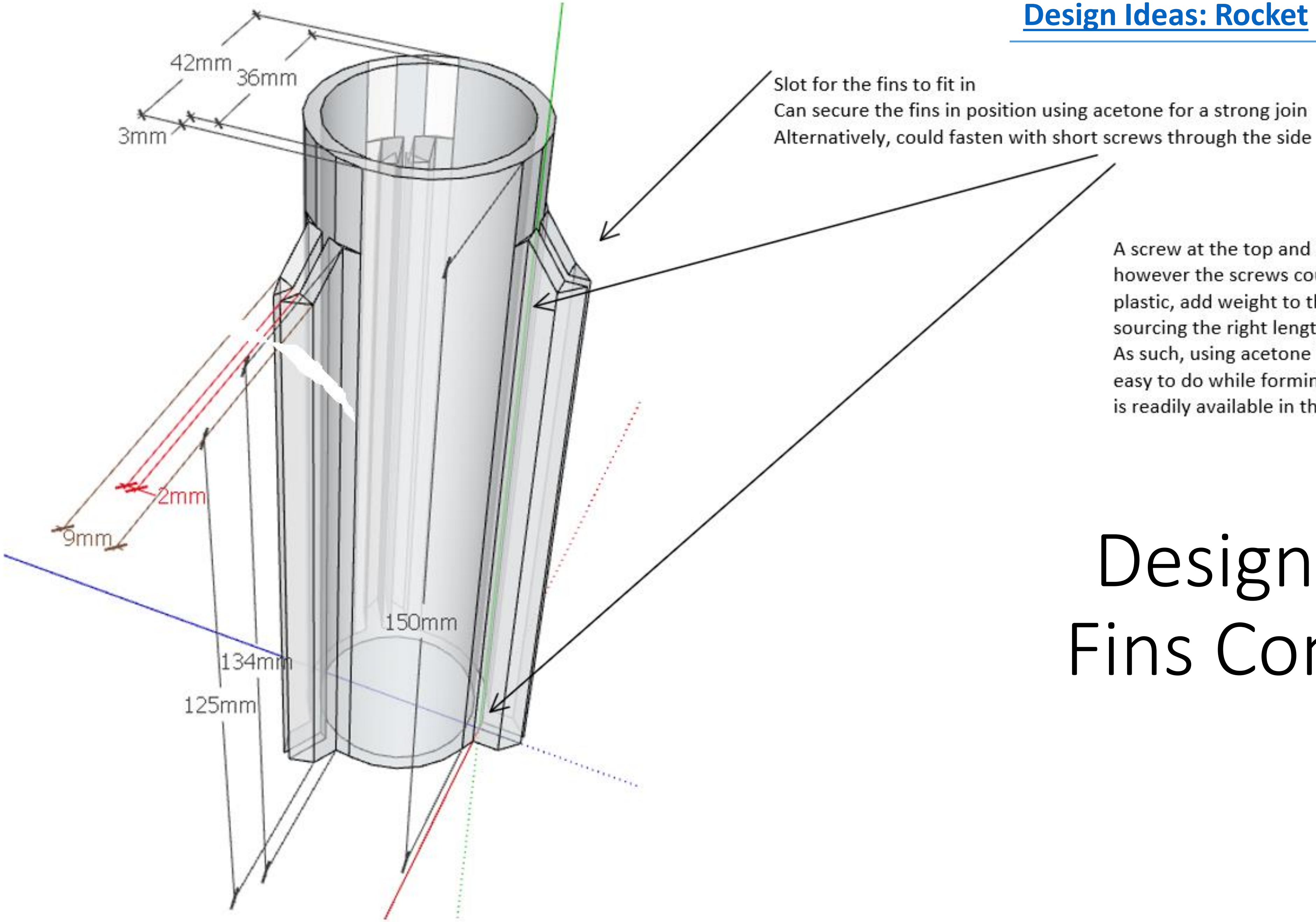


Design Ideas: Rocket

Design Ideas: Fins

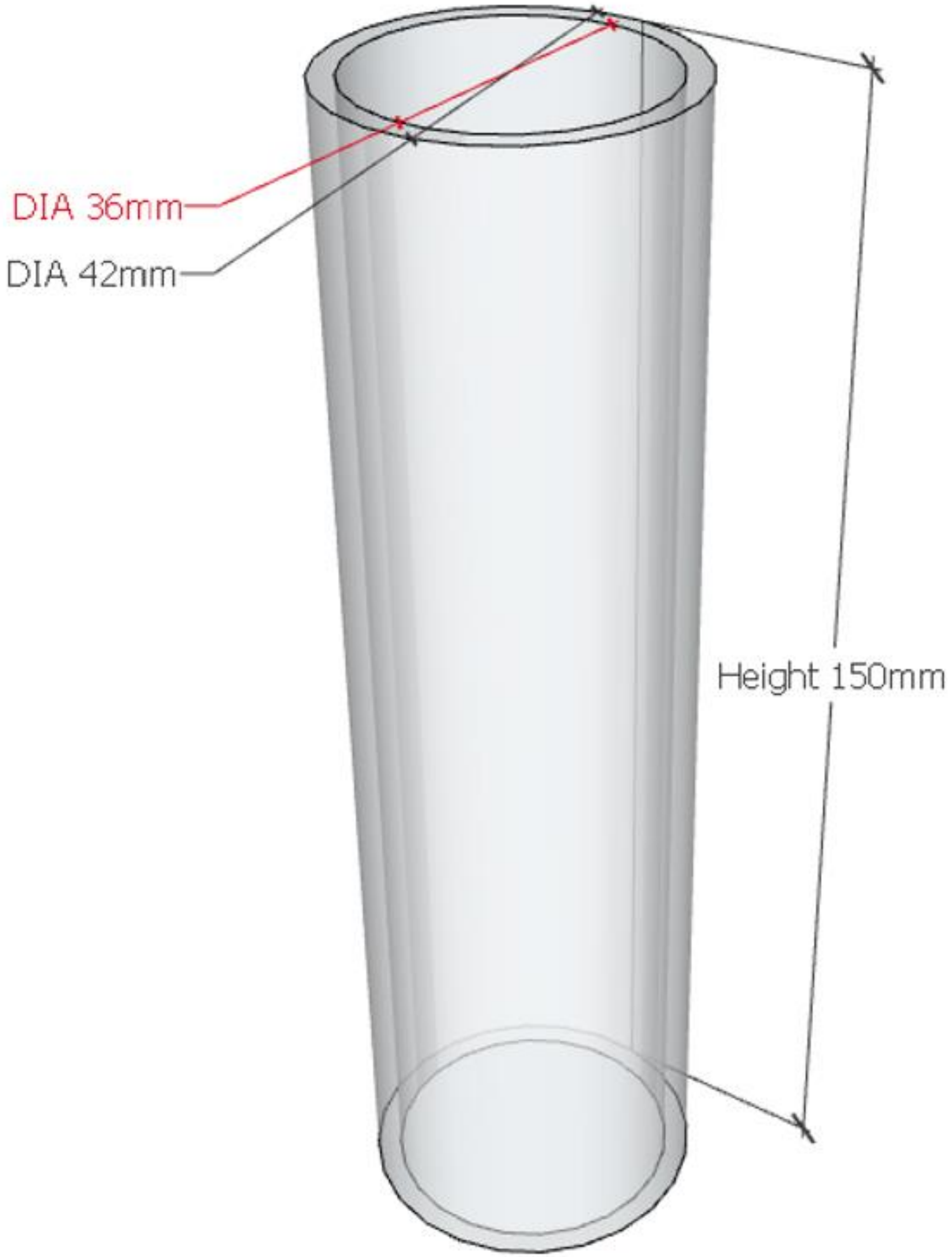


Or potentially 2mm depending on accuracy of 3D printing
Risk that setting the thickness to 2mm will print thinner than 2mm and not tightly fit in the fins slot
Rather use thickness of 3mm and potentially have to sand it to fit in tightly but securely



A screw at the top and bottom secures the fin in place, however the screws could reduce the strength of the plastic, add weight to the rocket and is more difficult in sourcing the right length and size.
As such, using acetone is the preferred method as it is easy to do while forming a strong join and the acetone is readily available in the workshop.

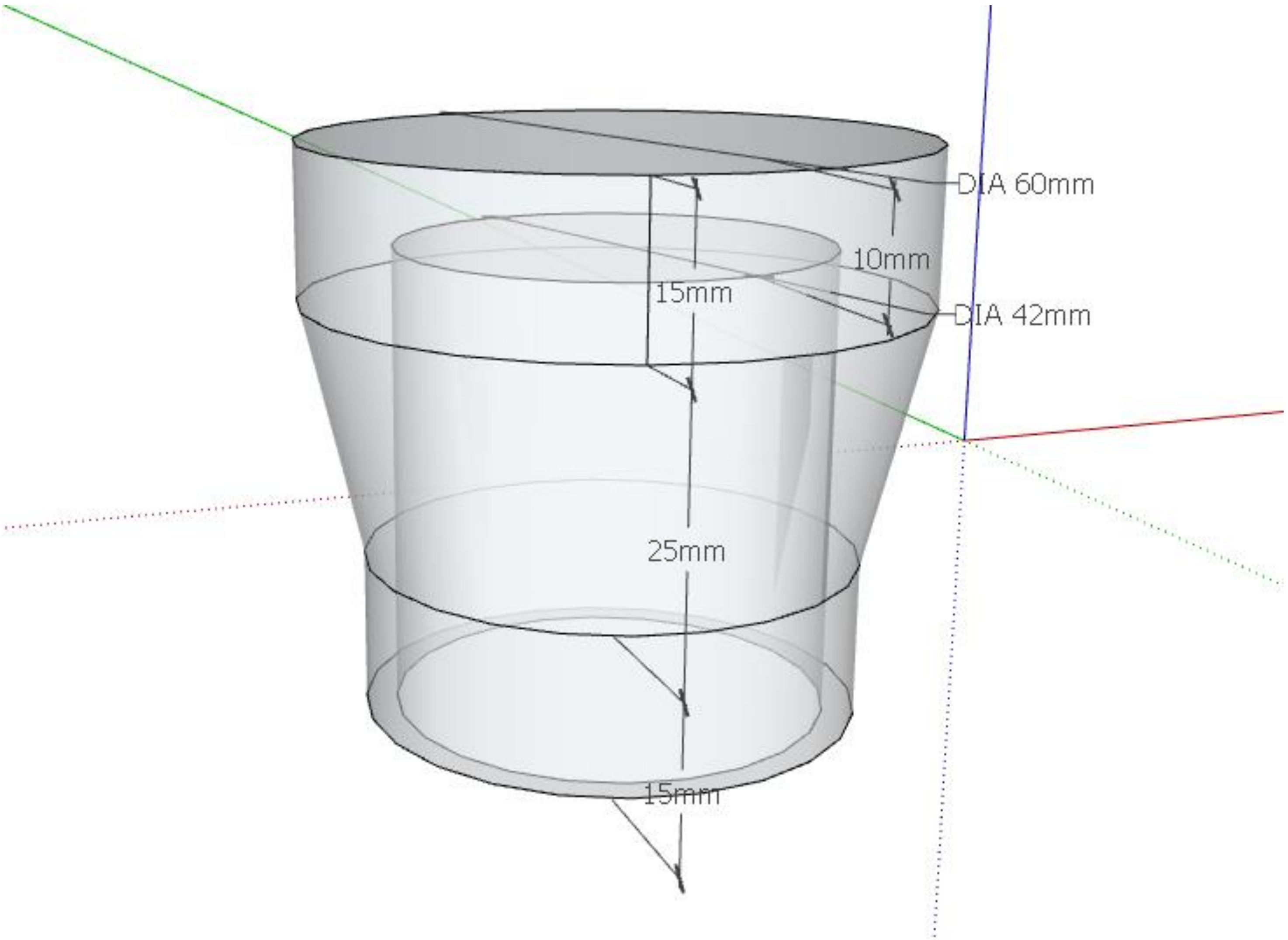
Design Ideas: Fins Connector



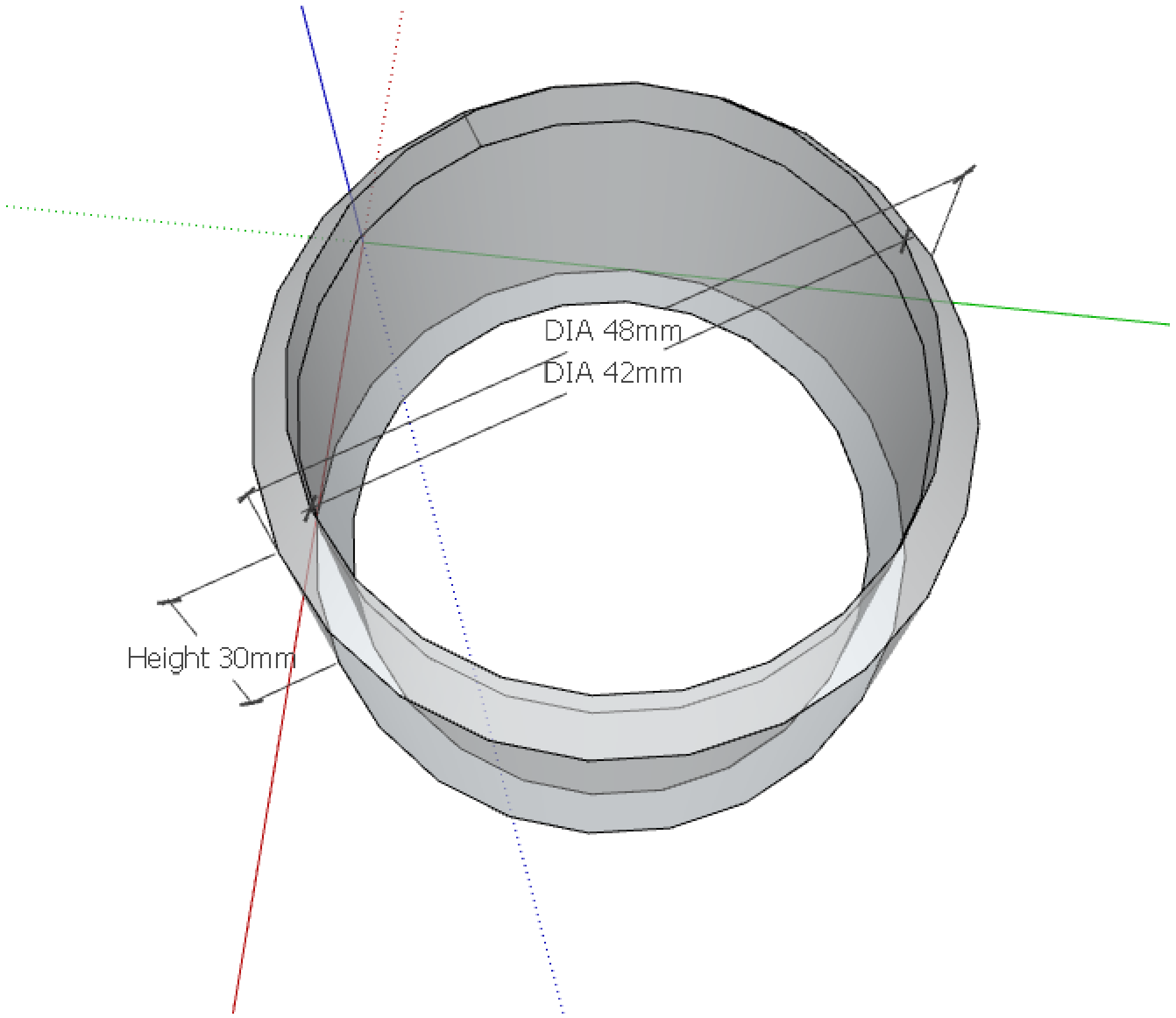
Design Ideas: Pipe

Limited to the maximum height the 3D print will print to
As such must print the rocket's body with a maximum height of 150mm

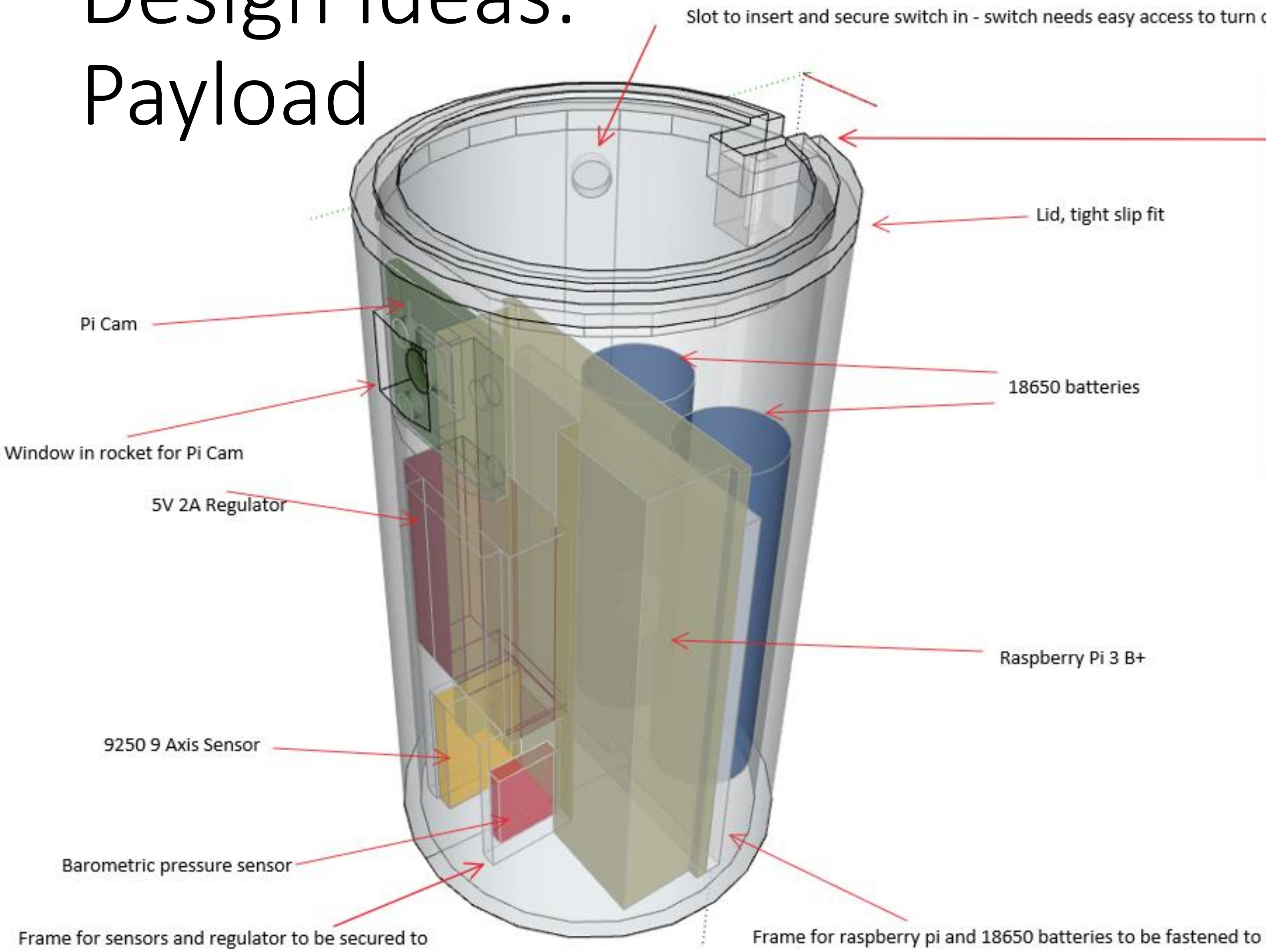
Design Ideas: Expander

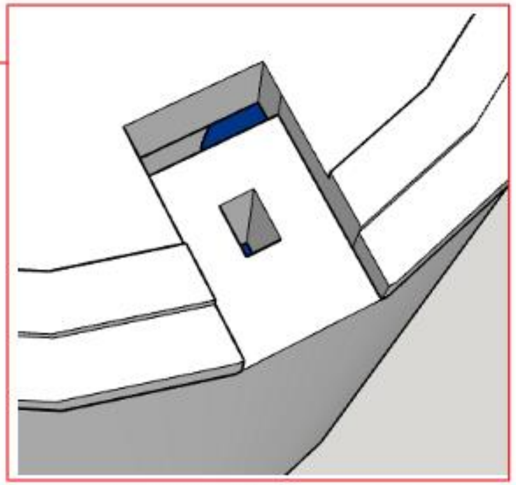


Design Ideas: Pipe Connections



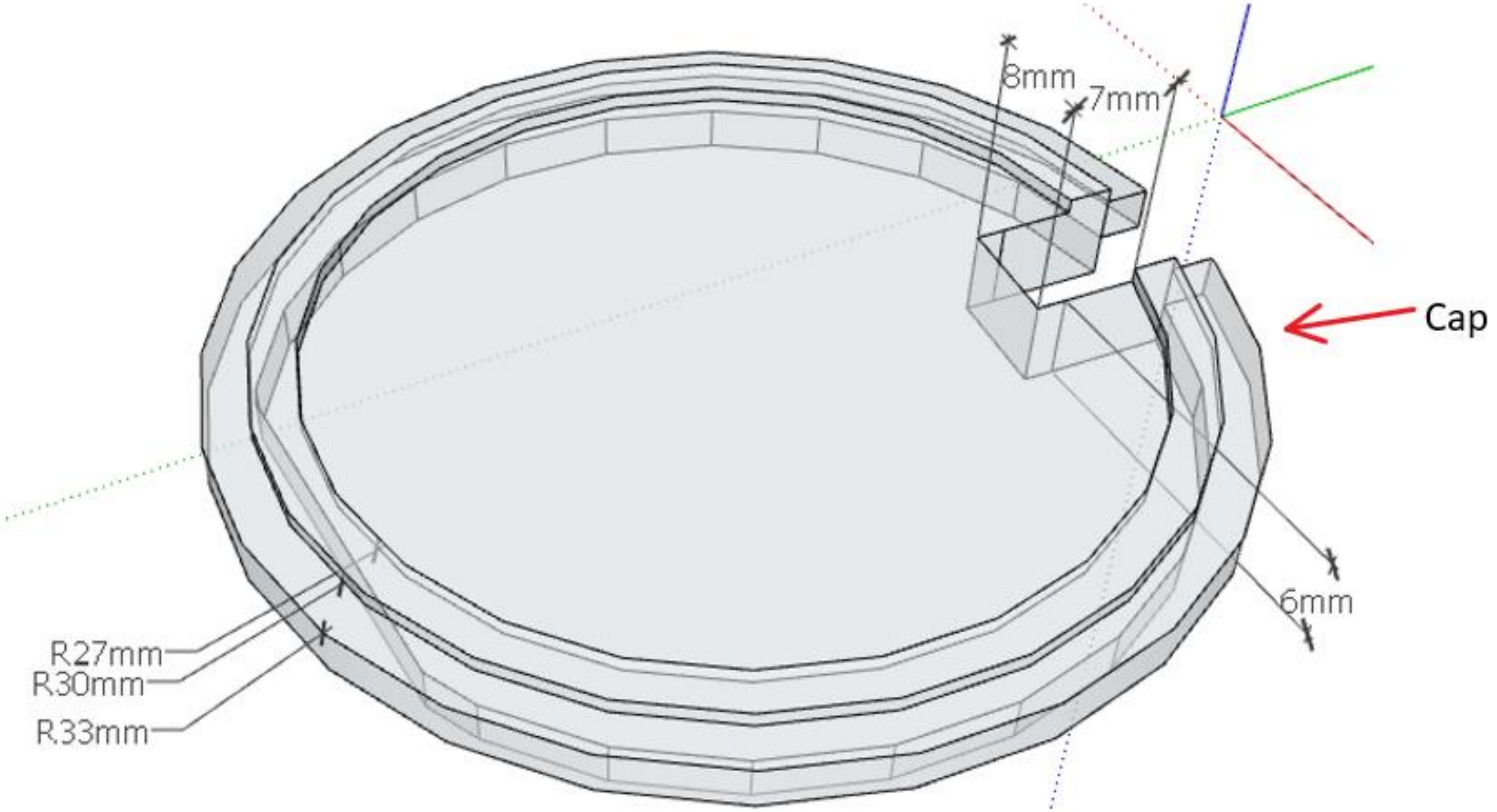
Design Ideas: Payload



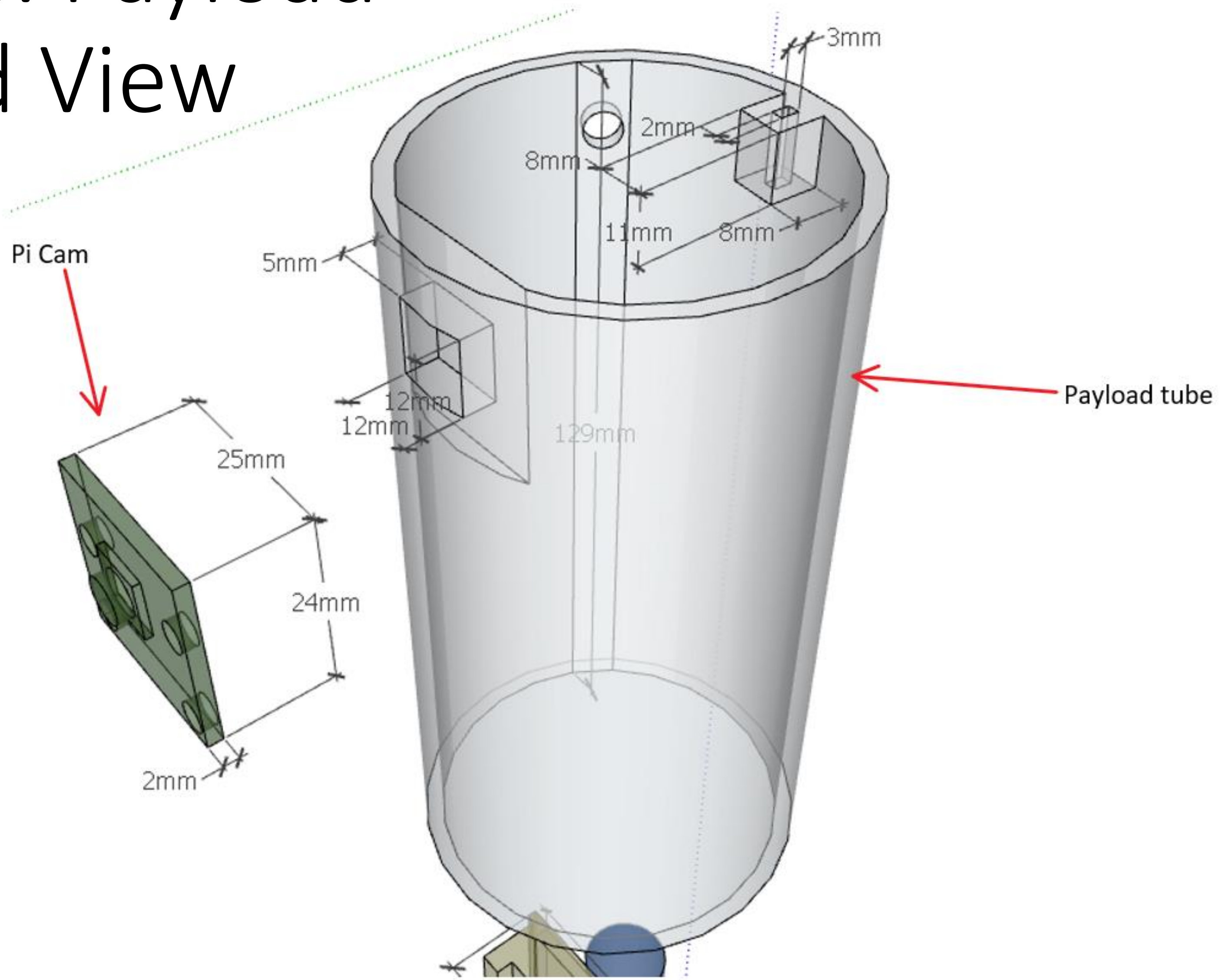


Connection for parachute to main rocket pipe

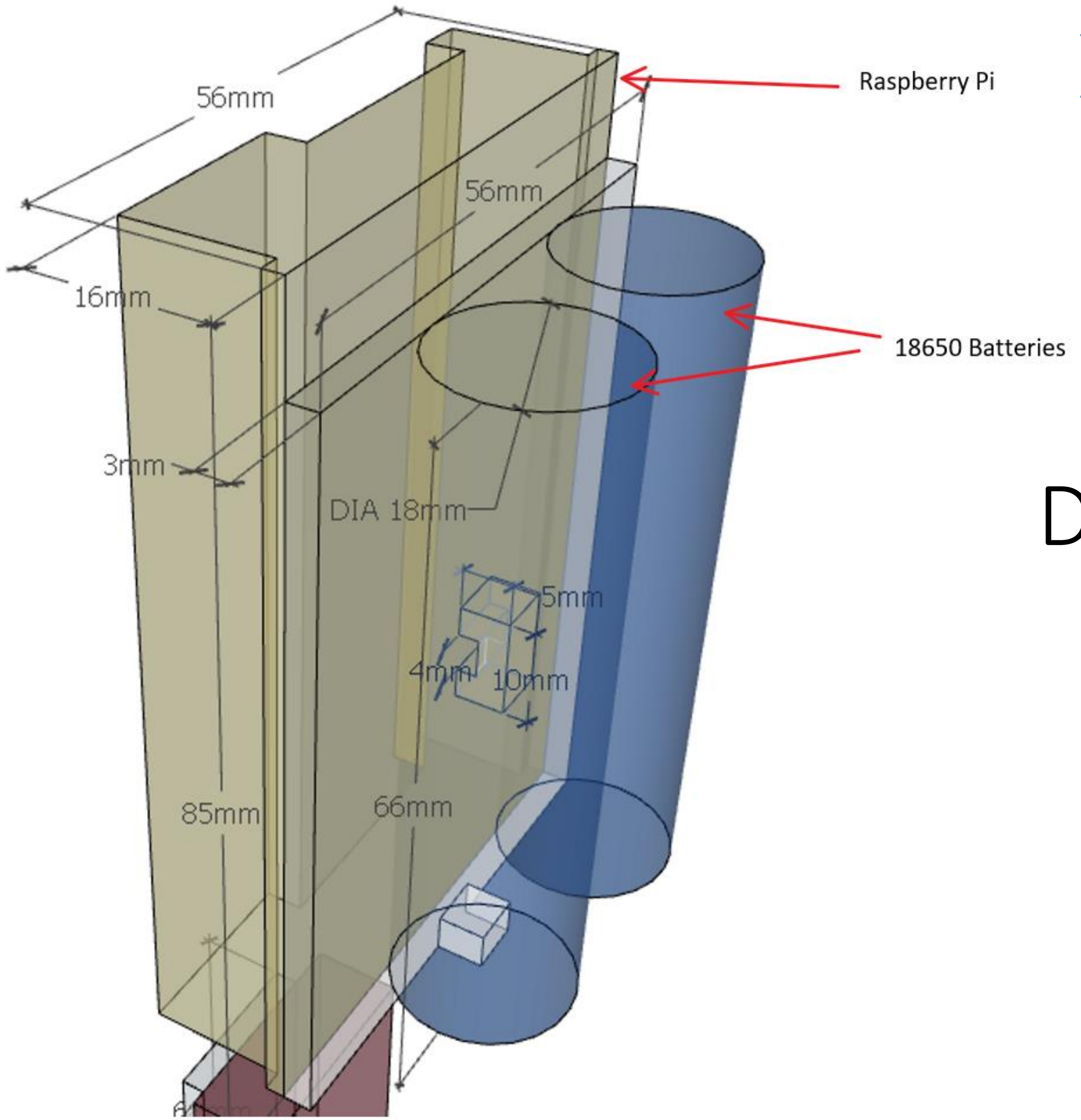
Design Ideas: Payload Exploded View

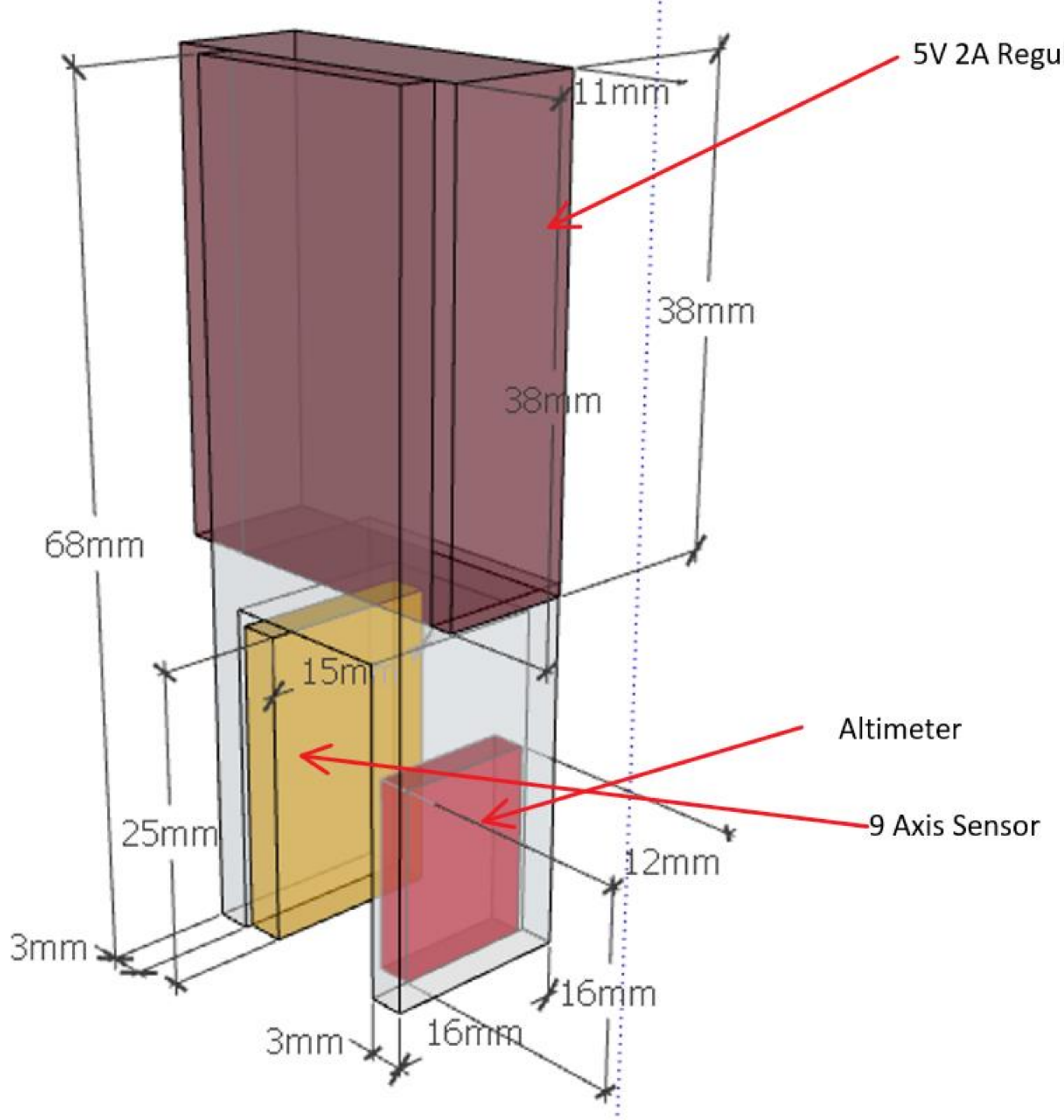


Design Ideas: Payload Exploded View



Design Ideas: Payload Exploded View





Design Ideas: Payload Exploded View

Design Ideas: Power Supply

18650 Li-ion Battery

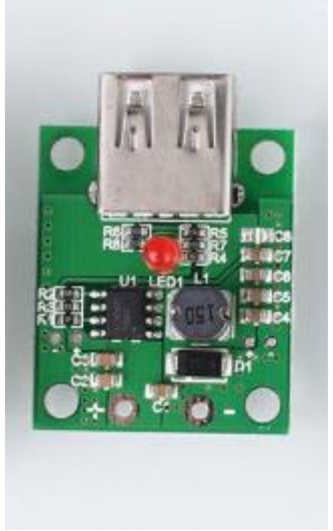
66x18mm(length x body diameter)

https://myozgadgets.com.au/10pcs-37v-6000mah-18650-unprotected-rechargeable-li-ion-battery

2x 18650 wired in series connect to the regulator
Provides 5V 2A to the raspberry pi and electronics

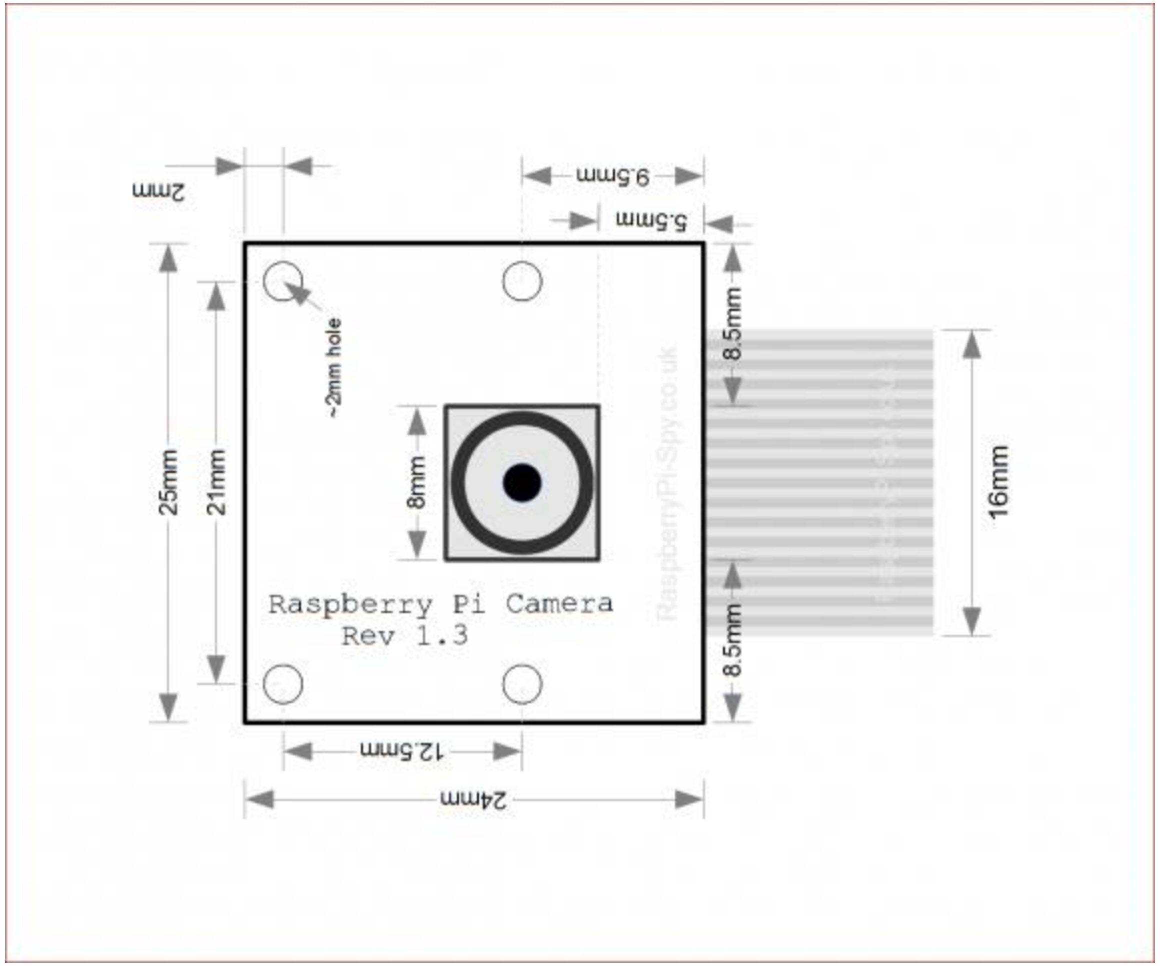
Voltage Regulator

38 x 29 x 11mm



https://www.ebay.com.au/itm/264359216208

Design Ideas: Pi Camera Diagram



https://blog.adafruit.com/2013/05/24/64677/

25 × 24 × 9 mm
3g
The measurements from the diagram aided the designing of the payload to position the Pi Camera.

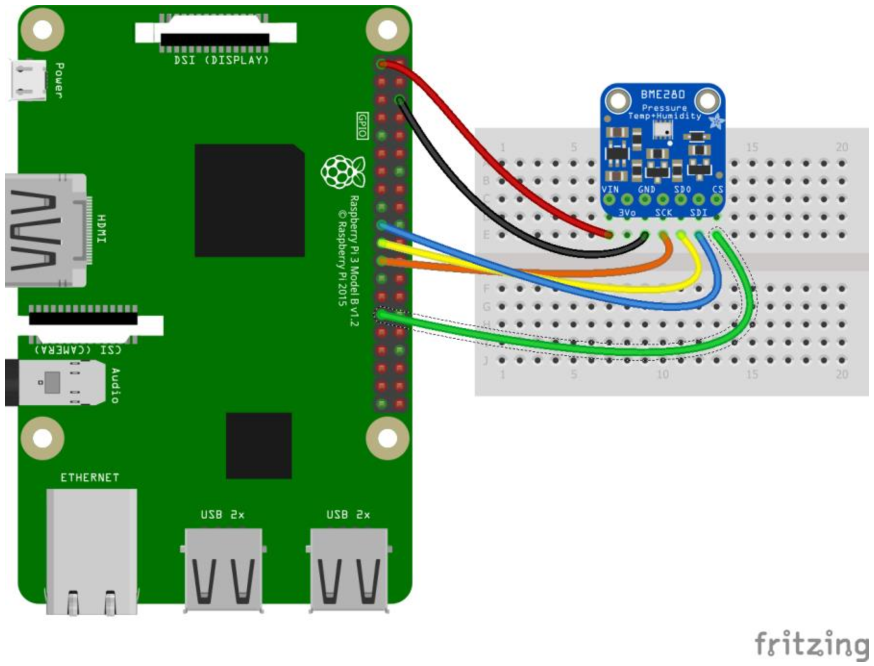
Design Ideas: Switch

Adds a switch to turn the batteries on and off
Diameter of the hole needed to secure the switch is 6mm
So, 3mm radius

https://www.jaycar.com.au/spdt-sub-miniature-toggle-switch-solder-tag/p/ST0300

Design Ideas: Sensors

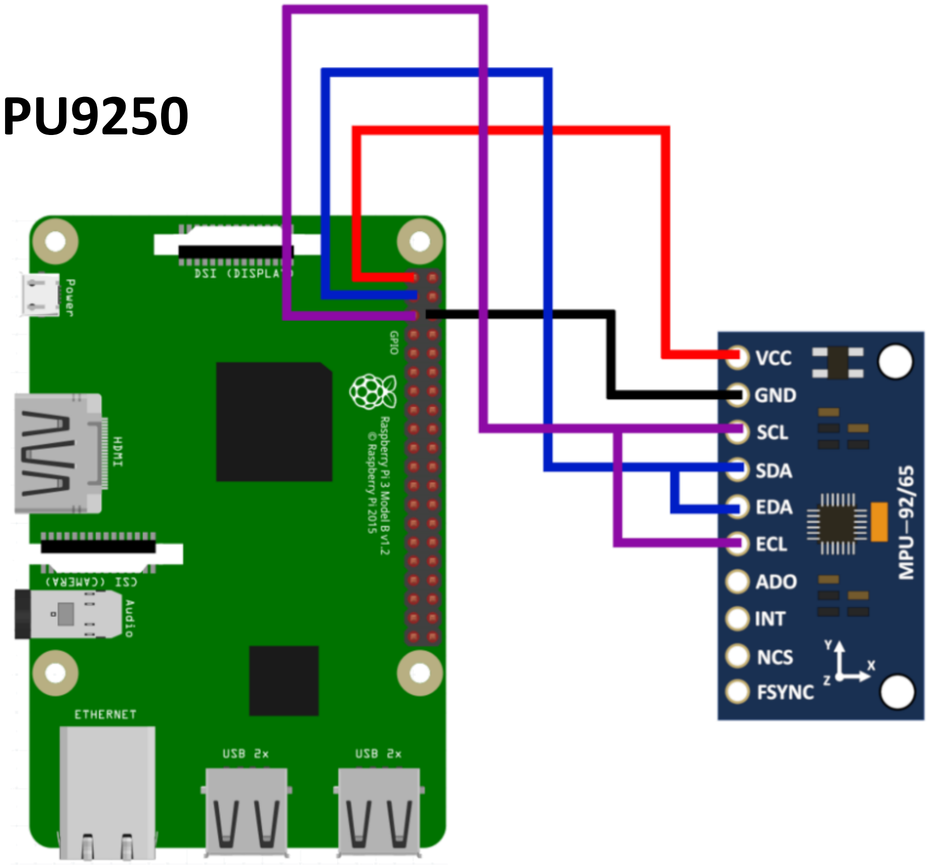
Barometric pressure sensor



https://learn.adafruit.com/adafruit-bmp280-barometric-pressure-plus-temperature-sensor-breakout/circuitpython-test

12mm x 16mm x 2.9mm
1.3g

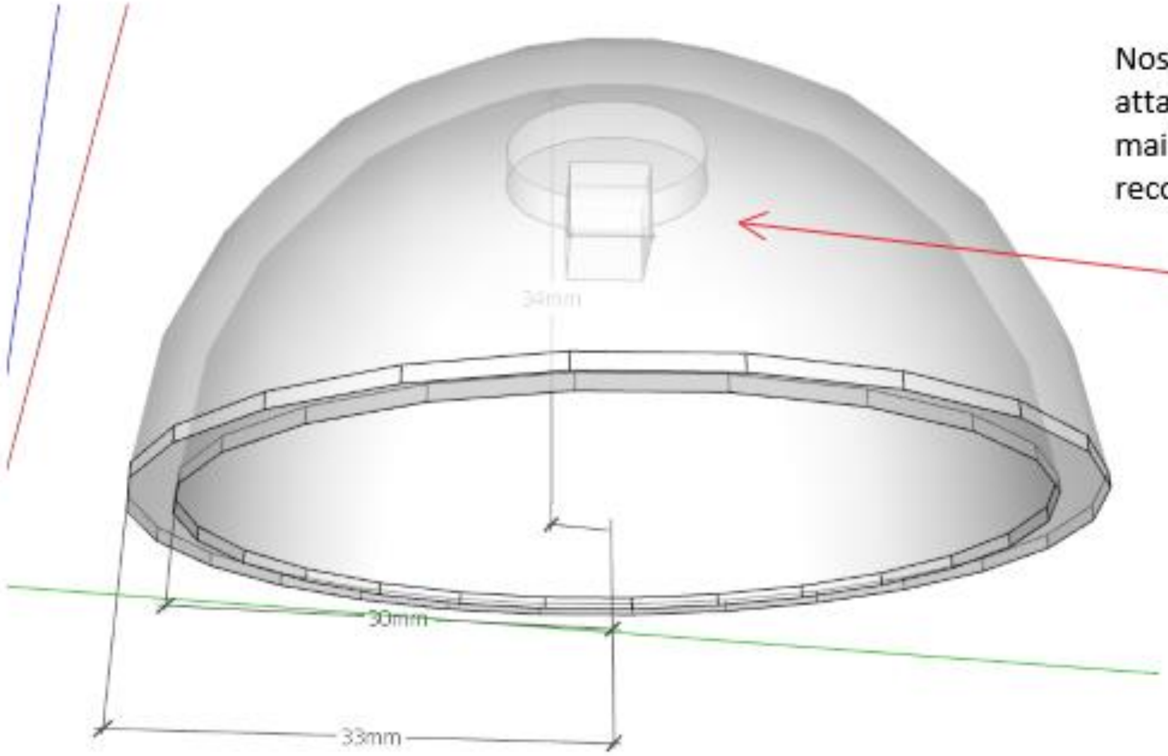
MPU9250



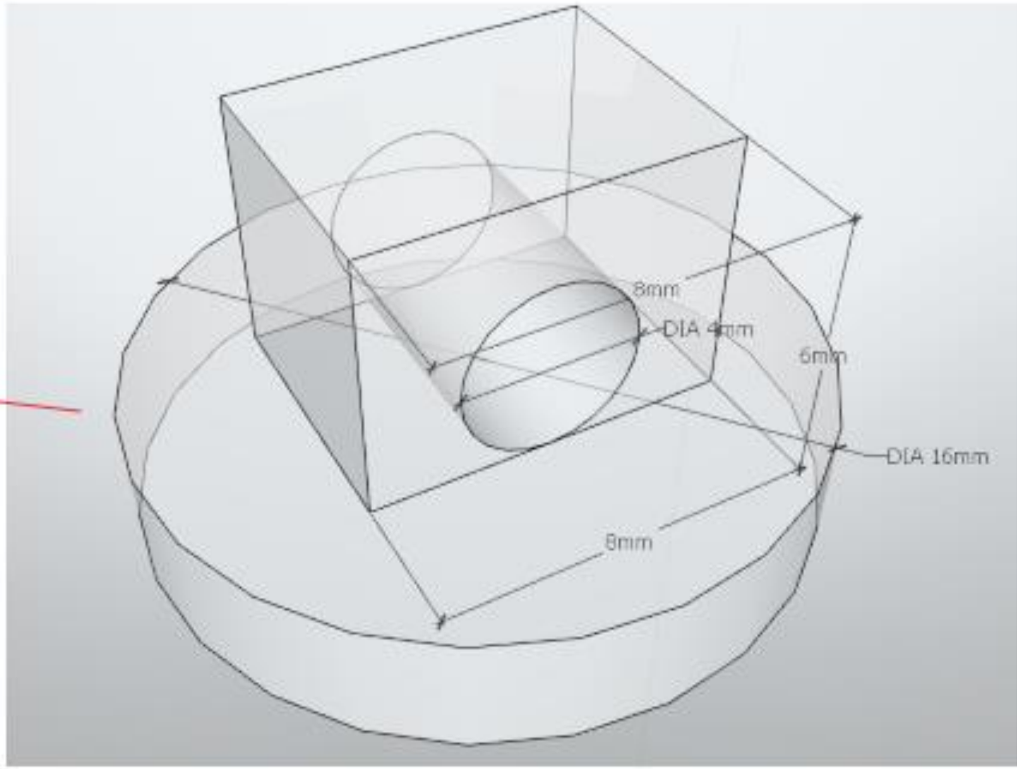
https://makersportal.com/blog/2019/11/11/raspberry-pi-python-accelerometer-gyroscope-magnetometer

25.5mm (1.004") long x 15.4mm (0.606") wide
2.72g

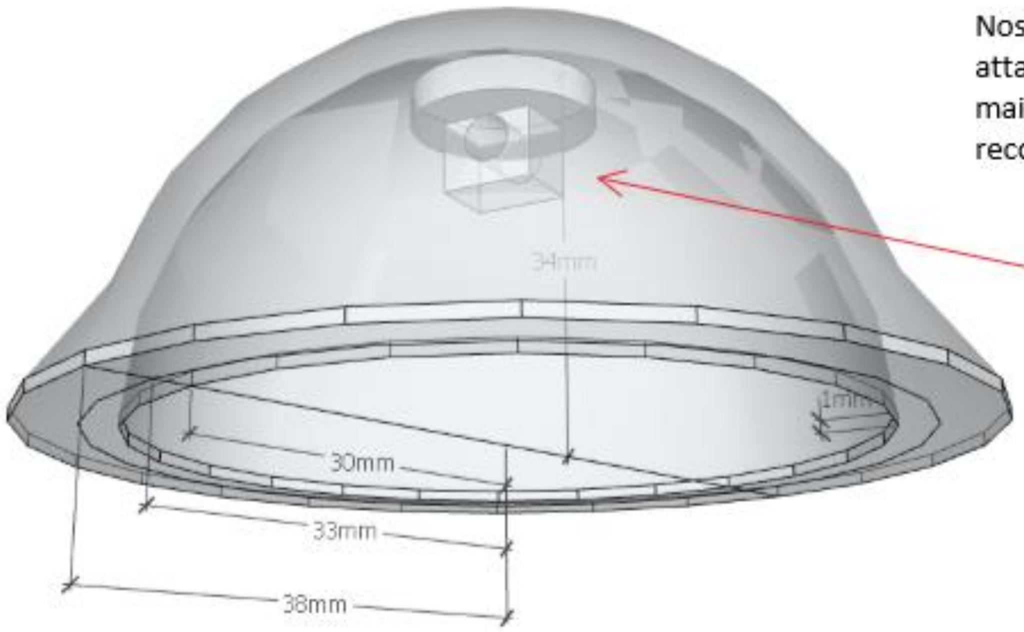
Design Ideas: Standard Nose Cone



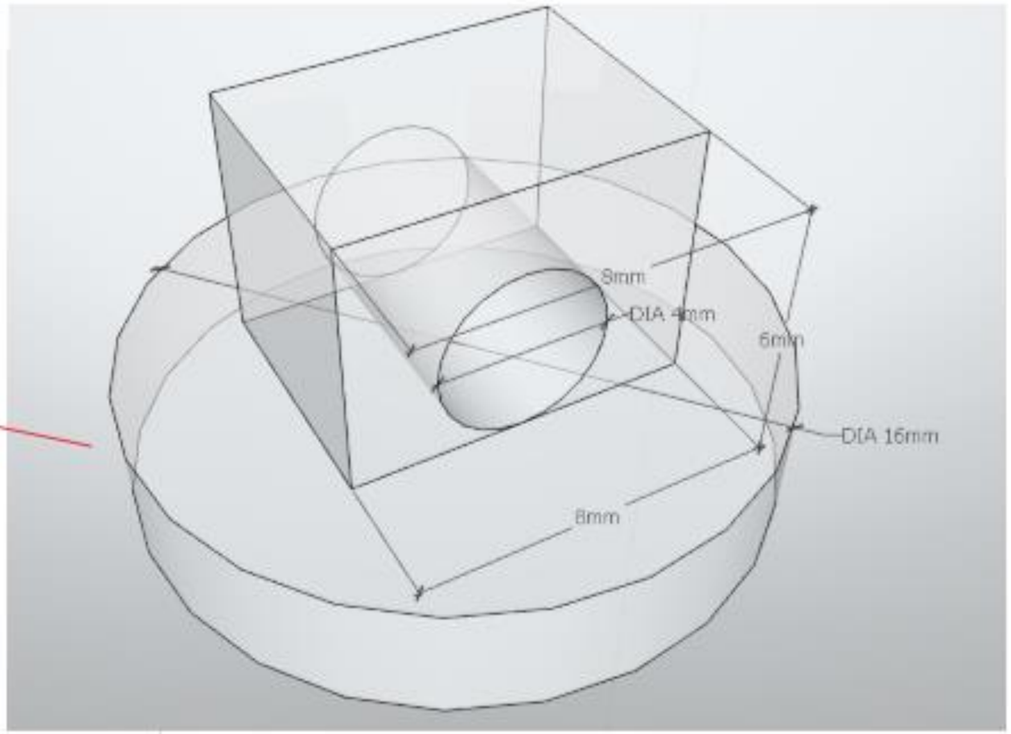
Nose attachment to main rocket for recovery



Design Ideas: Flaps Nose Cone



Nose attachment to main rocket for recovery



Design has 5mm flaps to increase air resistance on the nose during freefall to ensure the nose detaches from the rocket releasing the parachute.

Design Ideas: Nose Selection

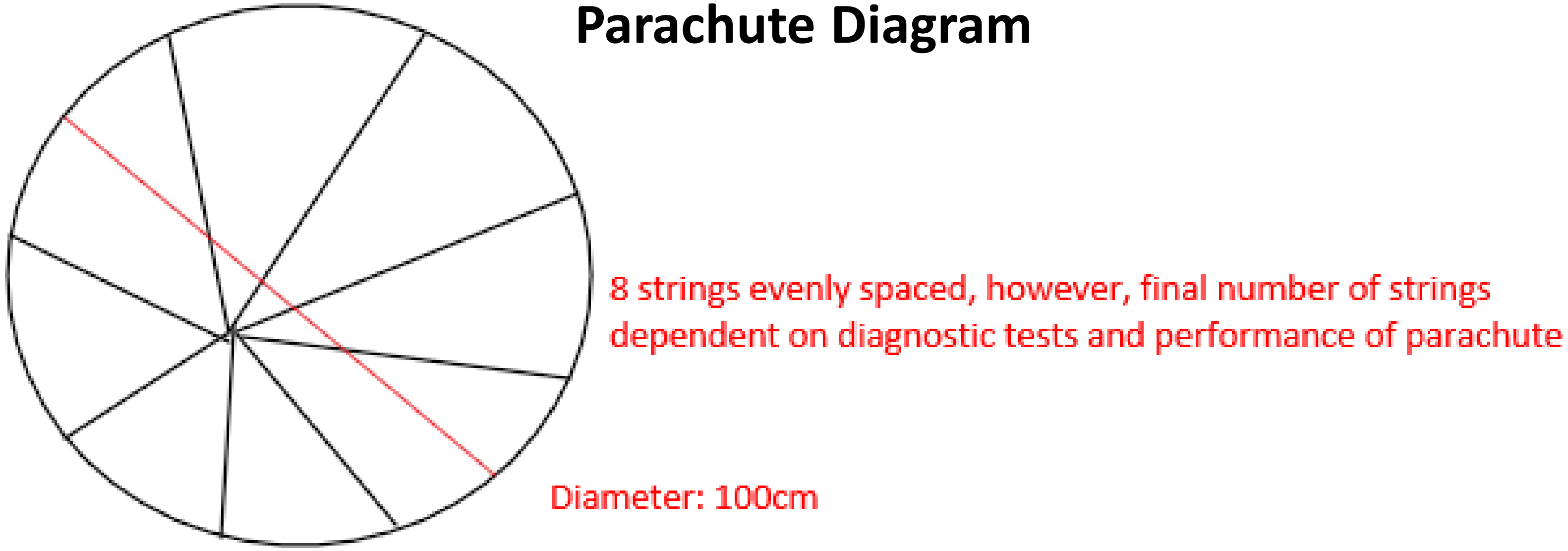
The flaps nose design is the same as the nose normal design, only with the added flaps. Through diagnostic testing of the nose normal model, whether the flaps are needed will be determined by evaluating how easily the nose falls off which should result in releasing the parachute. At this point, nose flaps will be used unless testing suggests that the nose normal design will reliably separate from the rocket during freefall. However, I expect that having some flaps will improve the reliability that the nose detaches so that the parachute releases.

Other considered solutions to the potential issue of the recovery system not releasing could be to detach the nose with a mechanical system, making use of possibly a solenoid valve, servo, magnets, springs or elastic bands. The added weight of components and risk of mechanical failure resulting in recovery failure lead to the preference of adding flaps to the nose normal design for a reliable, cheap and timely design.

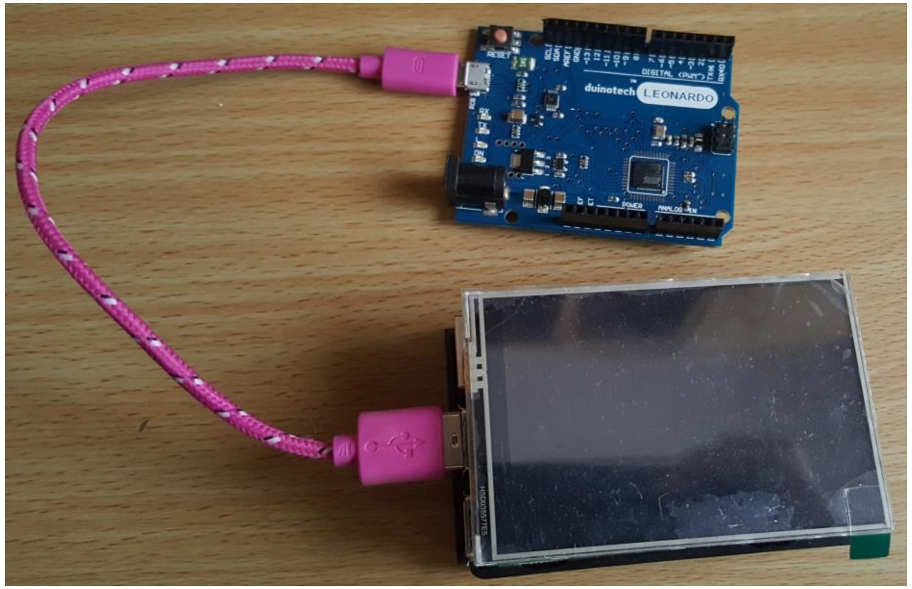
Design Ideas: Parachute

I will select to use a reefing parachute design for a parachute of 1m diameter with 8 strings evenly placed, since as from the research, reefing will reduce landing momentum and potential damage when the rocket lands.

Parachute Diagram



Design Ideas: Connecting



The Serial feature can be utilised to communicate between the Raspberry Pi and Arduino microcontroller. The USB cable is used to transfer the data for communication. Some example code:

Arduino code

Upload this code from your computer to your Arduino, using the Arduino IDE.

```
void setup() {
  Serial.begin(9600);
}

void loop() {
  Serial.println("Hello from Arduino!");
  delay(1000);
}
```

Setup code; Serial.begin() initialises Serial communication with parameter baud rate at 9600

Continuously sends the same string on a new line every 1000ms

https://roboticsbackend.com/raspberry-pi-arduino-serial-communication/

Raspberry Pi Python code

```
#!/usr/bin/env python3
import serial

if __name__ == '__main__':
    ser = serial.Serial('/dev/ttyACM0', 9600, timeout=1)
    ser.flush()

    while True:
        if ser.in_waiting > 0:
            line = ser.readline().decode('utf-8').rstrip()
            print(line)
```

import the serial library

Serial communication is initialized using the parameters for the serial device name; baud rate (must be same as Arduino's baud rate); timeout duration for reading data

flush any input and output buffer to avoid receiving or sending irrelevant data at the beginning of the communication.

infinite loop

If there is data, reads the data then decodes using the method utf-8. Finally rstrip() removes trailing characters from the string, such as \r or \n

Prints the data to the screen

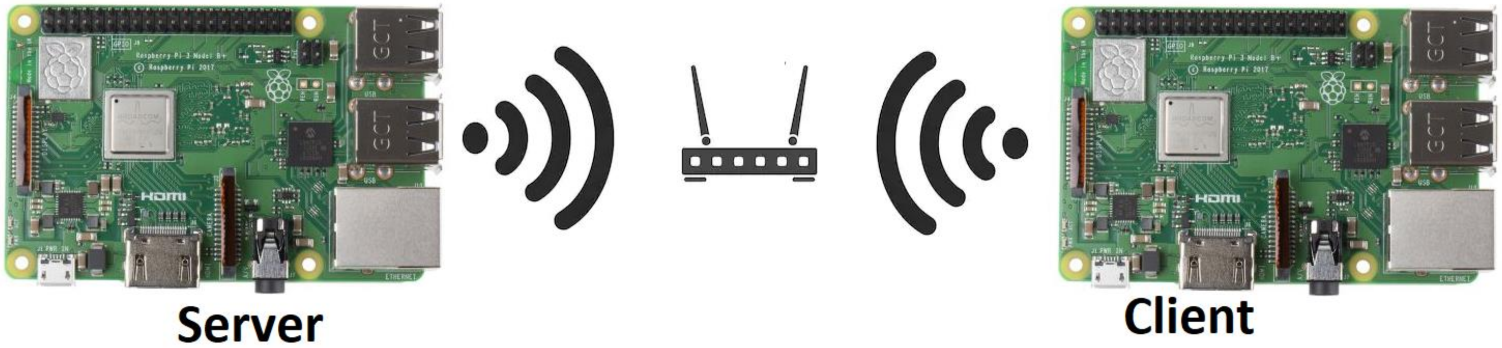
https://roboticsbackend.com/raspberry-pi-arduino-serial-communication/

Design Ideas: Data Collection

Synchronous

Can use the built in Wi-Fi to connect to an access point. Using socket programming, the server raspberry pi (with the screen connected) opens a socket and accepts the connection from the client raspberry pi (that is in the rocket) allowing wireless communication and live streaming of sensor data and photos.

Synchronous Method using Wi-Fi



https://au.rs-online.com/web/p/processor-microcontroller-development-kits/1373331/
https://www.shutterstock.com/search/wifi+symbol

Asynchronous

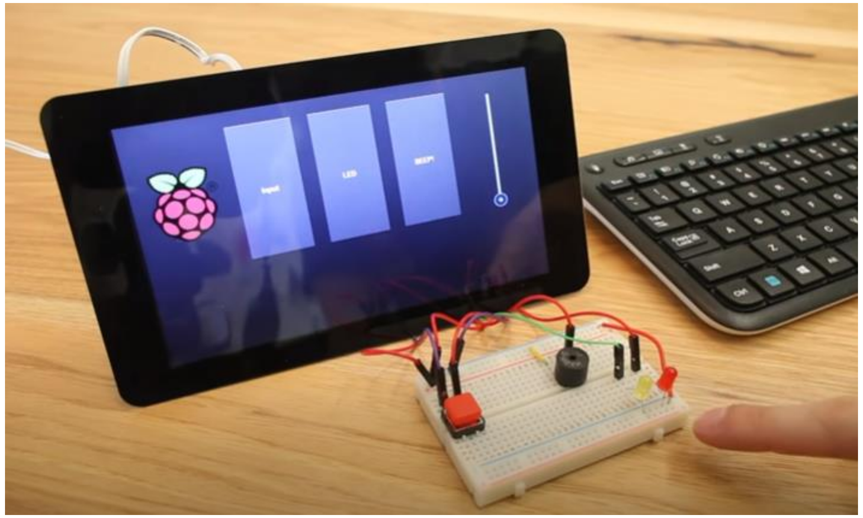
Records data locally on the Raspberry Pi in the rocket. Sensory data is recorded in a table while the images are saved in the same folder labelled with their flight time stamp. After flights, the data can be retrieved from the Raspberry Pi and then presented, analysed and interpreted.

I have chosen to locally store the data rather than utilise a Wi-Fi connection to save time programming a complex system where the data is live streaming. While the asynchronous system reduces the timeliness of the data since the data is not automatically presented and analysed during the flight, the data will still be later accessed from the Raspberry Pi and then these procedures can occur. As such, by implementing the quicker option time can be saved and utilised for necessary aspects of the project. However, if time permits, I will attempt to trial aspects of the synchronous system and gauge whether I can fully implement the synchronous concept within the time constraints.

Design Ideas: User Interface

Using Mathematica, a user interface is possible through graphic functions including a vast range of built in functions that can generate understandable and complex graphs from just a few arguments. Using these graphic elements, buttons can be used to select settings and run the system while displaying up-to-date information such as the pressure of the system.
Mathematica has a range of benefits as the language supports complex and detailed customization of the user interface, leading to a professional and functional interactive display. Behind the scenes, Mathematica supports External Languages so encourages the integration of Python scripts so can be utilized to manage network sockets and perform tasks suited to Python.

There are many GUI widgets for Raspberry Pi that encourage GUI development. The snippet from the YouTube clip depicts the interactive interface that changes the state of GPIO pins. Using Kivy or other GUI development languages for Python, there is less customization as they utilize a grid layout. Although there are built in functions, ultimately the lack of customization limits how professional and useful the GUI can be.
Fortunately, I discovered Tkinter for Python, which supports both a grid and pack placement method meaning there is a great amount of customization. Both Mathematica and Tkinter will provide comprehensive options and functions to suit any project. I intend to trial part of the user interface using Tkinter and Mathematica to then compare and evaluate the best application.



https://www.youtube.com/watch?v=Eah3Zq18OyM

Planning

I intend to produce the prototype by separating the system into smaller subsystems. Consequently, I can focus on each small subsystem individually then integrate the subsystems together. However, I can focus on many subsystems at once by preparing 3D print files at the start of the lesson for the rocket then continuing with the PVC subsystem. Similarly, then once at home I can work on programming the user interface.

A Gantt Chart will be used to plan my progress during the year. A Gantt Chart will allow me to easily make out the time allocate for each tasks. Furthermore throughout the year I can conveniently use the Gantt Chart to keep on track of the project and manage my time properly. Similarly, by having planned the next aspect to work on, I can prepare the relevant materials before I finish the previous aspect.

The subsystems and specific tasks relating to the subsystem will be planned in the Gantt Chart with their dates and required materials or other subsystems. For instance, some aspects of the user interface cannot be tested without the completion of the PVC subsystem.

Since unexpected errors or mistakes may arise, the Gantt Chart tries to offer flexibility in time management to overcome these issues while working with constrained time allocations for each subsystem to complete the project.

The pandemic lead to the first school closure towards the beginning of the year, so the year was already starting off very different from what was planned. Hence, I decided to adjust my Gantt Chart, since it was impossible to get back on track to what was originally planned. Similarly, the VCAA announced the adjusted study design to take into consideration the unforeseen closure and loss of practical time. The original Gantt Chart is here, and the following slides explore the revised Gantt Chart.

Continue

Criteria 3 Criteria

Planning – Gantt Chart

Gantt Chart lets me select what week to view, hence focusing on the tasks are due that week

Calendar layout demonstrates how long each task has left and what upcoming tasks are, encouraging good time management and adequate preparation

Systems Engineering SAT Project: Air Pro

Azure

Jaicquinn Strafo

Project Start: Fri, 31/1/2020

Display Week: 2

Sections as Criteria 1; Research then Development to help focus on exactly needs to be done.

Progress % to easily view pending and completed tasks

Start and end dates

TASK	REQUIRES	PROGRESS	START	END
Criteria 1				
Design Brief		100%	31-Jan	6-Feb
Research				
Potential Solutions		100%	7-Feb	12-Feb
Work Plan (timeline regarding Research)		100%	13-Feb	13-Feb
Programming				
Data Collection		100%	14-Feb	21-Feb
Arduino & Raspberry Pi		100%	19-Feb	24-Feb
Mathematica & UI		100%	22-Feb	3-Mar
Storage and Release of Air		100%	4-Mar	24-Mar
Rocket		100%	25-Mar	14-Apr
Gantry		100%	15-Apr	5-May

Feb 3, 2020 | Feb 10, 2020 | Feb 17, 2020 | Feb 24, 2020 | Mar 2, 2020 | Mar 9, 2020 | Mar 16, 2020 | Mar 23, 2020

Continue

[Criteria 3](#) [Criteria](#)

Planning – Gantt Chart

Systems Engineering SAT Project: Air Pro

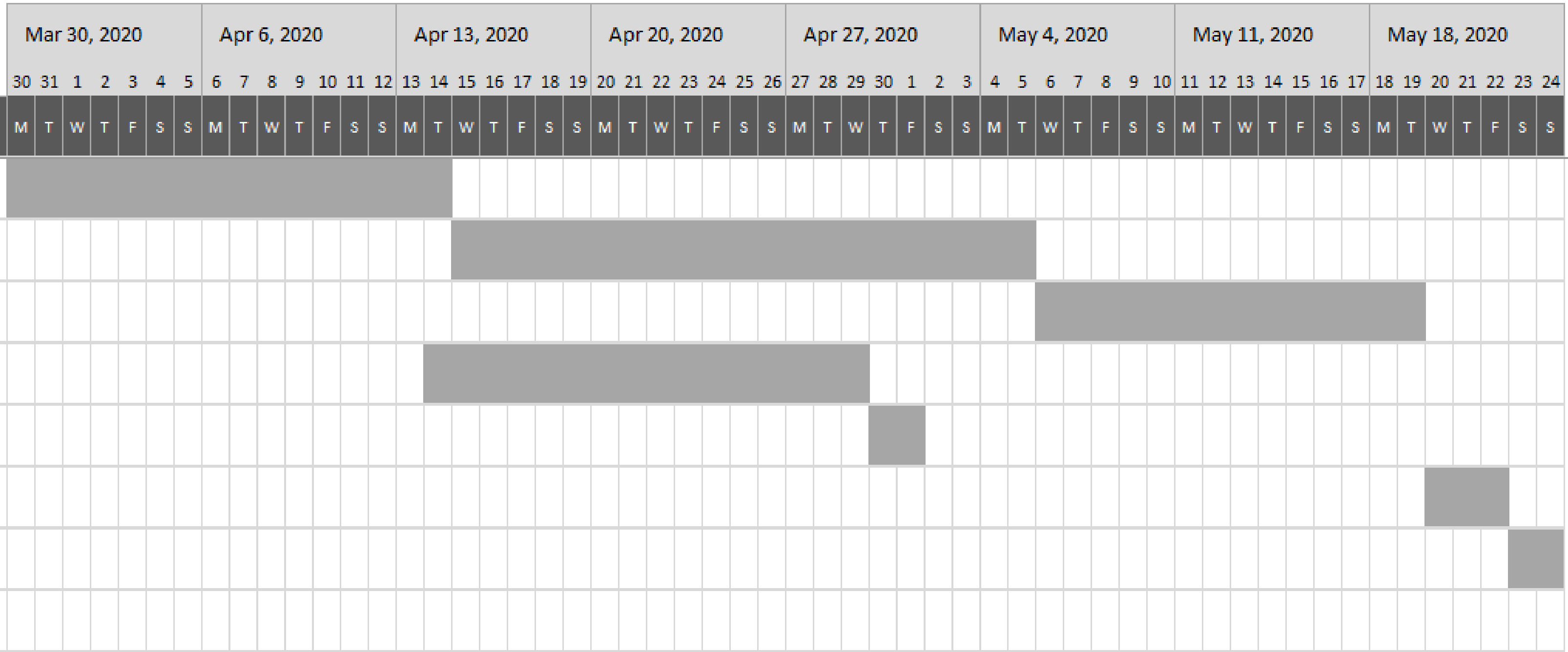
Azure

Jaicquinn Strafonda

Project Start: Fri, 31/1/2020

Display Week: 10

TASK	REQUIRES	PROGRESS	START	END
Rocket		100%	25-Mar	14-Apr
Gantry		100%	15-Apr	5-May
Evaluate Chosen Options		100%	6-May	19-May
Sourcing Parts		100%	14-Apr	29-Apr
Data Sheets of Parts		100%	30-Apr	1-May
Risk Assessment		100%	20-May	22-May
Finalisation of Work Plan		100%	23-May	25-May
Development				



I allowed adequate time to source parts by commencing this while still researching other areas. I hoped to source parts as soon as possible considering the confusion and chaos during the pandemic.

[Continue](#)

Criteria 3 Criteria

Planning – Gantt Chart

Systems Engineering SAT Project: Air Pro

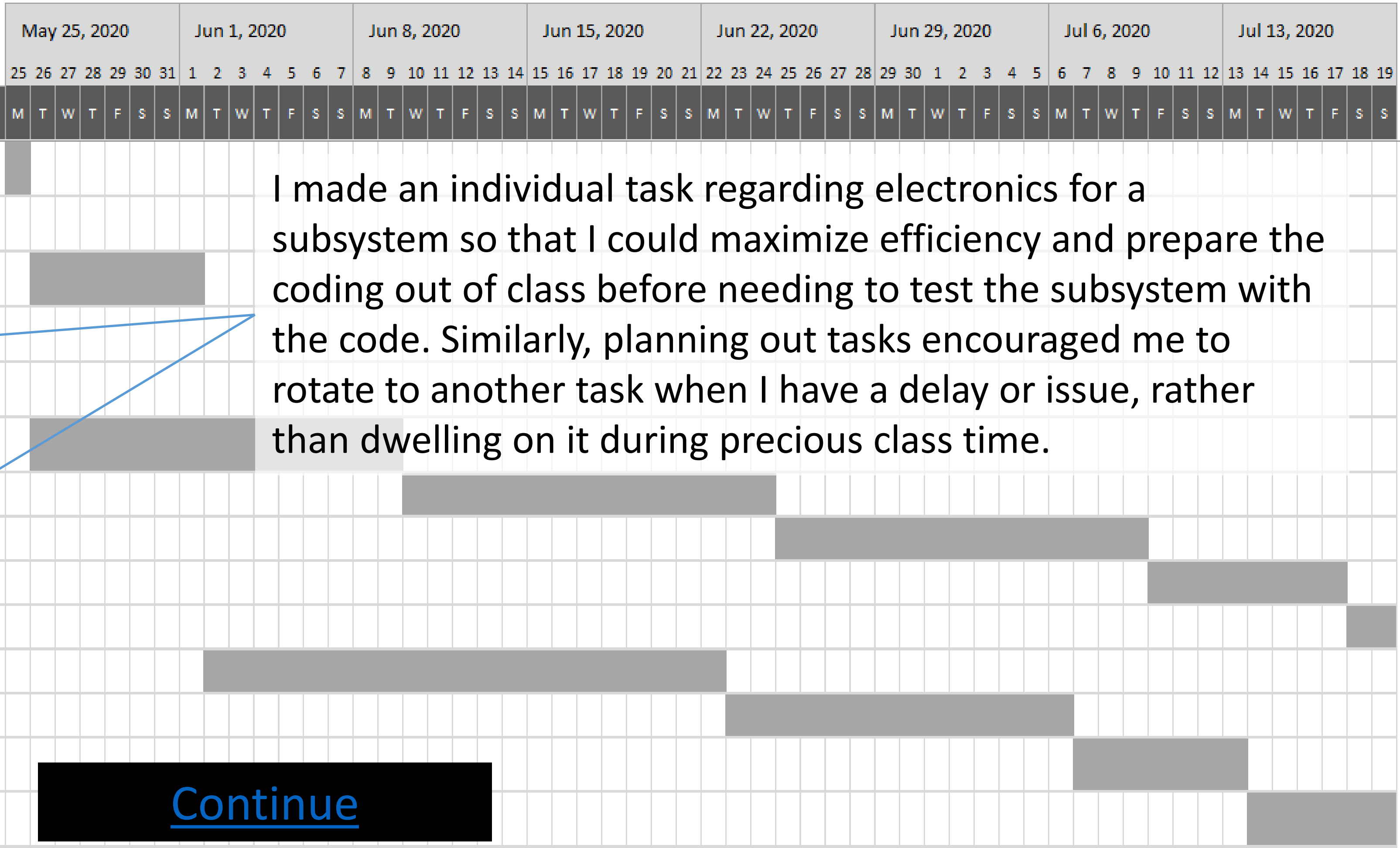
Azure

Jaicquinn Strafonda

Project Start: Fri, 31/1/2020

Display Week: 18

TASK	REQUIRES	PROGRESS	START	END
Finalisation of Work Plan		100%	23-May	25-May
Development				
The Platform/Base	Wood, 3D Printed Pyramids	100%	26-May	1-Jun
PVC Mechanics	PVC related components, 3D Printed Clamp	100%	27-Jul	17-Aug
PVC Electronics	PVC Mechanics	50%	18-Aug	24-Aug
3D Printing of Rocket Fins		100%	26-May	9-Jun
Rocket Body & Connector		100%	10-Jun	24-Jun
Rocket Payload		100%	25-Jun	9-Jul
Assembly of Nose		100%	10-Jul	17-Jul
Sand and Construct Rocket		100%	18-Jul	31-Jul
Construction of Gantry Tower		100%	2-Jun	22-Jun
Gear Development		100%	23-Jun	6-Jul
Crane Construction		100%	7-Jul	13-Jul
Assembly with Electronics		100%	14-Jul	20-Jul



I made an individual task regarding electronics for a subsystem so that I could maximize efficiency and prepare the coding out of class before needing to test the subsystem with the code. Similarly, planning out tasks encouraged me to rotate to another task when I have a delay or issue, rather than dwelling on it during precious class time.

Continue

Criteria 3 Criteria

Systems Engineering SAT Project: Air Pro

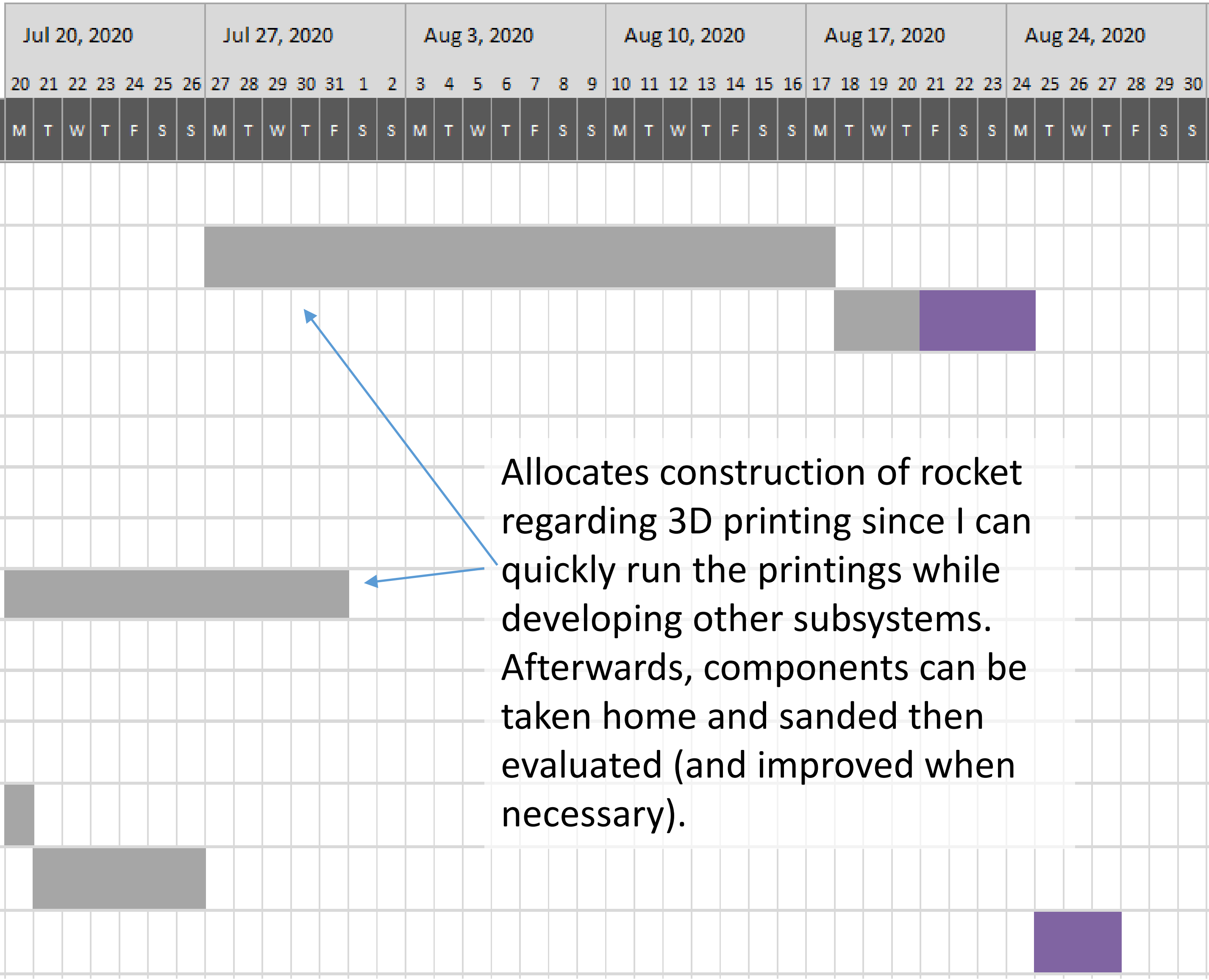
Azure

Jaicquinn Strafonda

Planning – Gantt Chart

Project Start:	Fri, 31/1/2020
Display Week:	26

TASK	REQUIRES	PROGRESS	START	END
The Platform/Base	Wood, 3D Printed Pyramids	100%	26-May	1-Jun
PVC Mechanics	PVC related components, 3D Printed Clamp	100%	27-Jul	17-Aug
PVC Electronics	PVC Mechanics	50%	18-Aug	24-Aug
3D Printing of Rocket Fins		100%	26-May	9-Jun
Rocket Body & Connector		100%	10-Jun	24-Jun
Rocket Payload		100%	25-Jun	9-Jul
Assembly of Nose		100%	10-Jul	17-Jul
Sand and Construct Rocket		100%	18-Jul	31-Jul
Construction of Gantry Tower		100%	2-Jun	22-Jun
Gear Development		100%	23-Jun	6-Jul
Crane Construction		100%	7-Jul	13-Jul
Assembly with Electronics		100%	14-Jul	20-Jul
Testing of Gantry		100%	21-Jul	26-Jul
Position & Secure Gantry Legs		0%	25-Aug	27-Aug



Risk Assessments

Risk Assessment: Matrix

			Potential Consequences				
			L6	L5	L4	L3	L2
			Minor injuries or discomfort. No medical treatment or measureable physical effects.	Injuries or illness requiring medical treatment. Temporary impairment.	Injuries or illness requiring hospital admission.	Injury or illness resulting in permanent impairment.	Fatality
			Not Significant	Minor	Moderate	Major	Severe
Likelihood	Expected to occur regularly under normal circumstances	Almost Certain	Medium	High	Very High	Very High	Very High
	Expected to occur at some time	Likely	Medium	High	High	Very High	Very High
	May occur at some time	Possible	Low	Medium	High	High	Very High
	Not likely to occur in normal circumstances	Unlikely	Low	Low	Medium	Medium	High
	Could happen, but probably never will	Rare	Low	Low	Low	Low	Medium

https://www.examspm.com/2016/08/16/risk-matrix-template/

Risk Assessment: Soldering

The risk assessment of soldering without training, disregard to surroundings, not inspecting the equipment and not being prepared for potential fires or burns indicates high risk, since the likelihood is likely while the consequences are moderate such as burns and fire outbreaks.

Accident due to inappropriate behaviour or incorrect procedure: Risk of burns or fire from contact with soldering iron	Never touch the element of the soldering iron and return the soldering iron to the stand when not being used rather leaving it on the workbench. Ensure the soldering iron is switched off after use. Follow correct procedure when soldering, including the use of clamps or tweezers to hold wires being soldered Do not operate the soldering iron in a position where others around could evoke an incident, that is keep space between others and ensure cables are not on the floor potentially causing someone to trip while leading to burns from the soldering iron being pulled
Electrical Shock: Damaged cable	The soldering iron should have a visual inspection prior to use for faulty wires, plugs or damage to the cable. Any damage should be flagged with the soldering iron taken out of use. Soldering irons should be switched off after use.
Inhalation of chemicals in solder fumes: Soldiering in an enclosed or small area.	Ensure soldering is conducted in a well ventilated area with large amount of work space to place the soldering iron away from the user and fumes are away from the users head so they do not breath much in.
Fire: Flammable materials – causes injury and destruction	Use soldering iron on fire resistant or fire-proof surfaces Stay vigilante while soldering and prior to soldering to identify and remove potential sources of ignition
Minor Burns or Fires Accident: Burns from contact with material being worked on or directly with the iron	Know where the First Aid Kit or Fire Extinguisher is and how to use these items These items may both be necessary in dangerous situations, allowing for fire to be quickly removed and potential burns aided.

After considering the above and implementing these key ideas to soldering practice, the likelihood becomes unlikely with only minor consequences reducing the risk assessment to low.

Risk Assessment: Hammer & Mallet

Moderate consequences, such as broken fingers, are possible to occur when using hammers and mallets suggesting the risk assessment is high.

Maintenance: Tools are damaged	Inspect the equipment before use, to ensure it is not damaged and parts are secure. Check that the handle is secured tightly to the head, particularly as mallets can become loose. Replace or fix loose or damaged handles to ensure the equipment operates as intended and does not lead to injury from damaged equipment.
Safety Protection: Goggles	Wear safety goggles when striking materials, as projected fragments or dust could cause injury to eyes.
Weight: Consideration of how heavy the tool is	Use a hammer of appropriate weight for the task at hand to ensure the swings are natural and the force exerted on the object is from the weight of the hammer. At the same time, do not use a hammer too heavy to swing since it could lead to damage to the upper body from bad form and potential injury from such a situation, for instance dropping the hammer on a foot leading to a broken toe in the unlikely event.
Skill with Equipment: Accuracy and precision when striking	Do not wear gloves to reduce likelihood of the tool slipping out of the hand. Ensure patience and concentration is taken to keep fingers away from the target area, preventing the fingers from being hit. However, position fingers and target with consideration to prevent contact with the tool in the case the tool were to slip off the target.

However, by using undamaged tools with goggles while being vigilante of the weight of the hammer and the position of fingers can the possible consequences become minor, minimising the risk assessment to low.

Risk Assessment: Sawing

Risk assessment of high if a user were to ignorantly rush sawing without clamps and consideration of the equipment or their position of fingers leading to the possibility of moderate injury.

Use of Equipment	Ensure user has an understanding of how to position the tool and use - keeps hands well away from the cutting edge, particularly to provide adequate space between the hand and the blade in the event the blade slips from the cutting area so that the blade does not make contact with them Furthermore, strong but not rushed motions can improve sawing as these careful motions are less likely to lead to accidental slipping and injury compared to weak, quick sawing that puts the user and others at risk For protection, wear glove on the non-sawing hand.
Injury	Use equipment with space between others to reduce likelihood of another person coming into contact with the blade. While transporting the saw, walk cautiously to not trip or collide with others to prevent accidental cuts from the blade in such situations. Knowledge of where the first aid kit is vital in the emergency of injury to timely treat cuts and bleeding.
Maintenance	Before use, check the blade to ensure the blade is not damaged and is secure to the handle. Consider the sharpness of the blade - a dull blade needs to be sharpened before use as a sharper blade is less likely to slip during sawing and cause an accident. Regular maintenance is necessary to keep the blade sharp.
PPE	Wearing goggles are necessary to protect the eyes from dust and fragments of the material being cut. Depending on the material, consider wearing a mask or respirator as PVC, when cut, may emit small particles that irritate the throat and lungs. Similarly, PVC when heating to its melting point emits chlorine gas that is dangerous to breathe in.
Clamps	Use of clamps are necessary to ensure the material remains in position, reducing the likelihood of accidental injuries as the material does not slip or move in any direction. Similarly, use of clamps places hands less at risk as without clamps a hand would be at greater risk while holding the material in position.

However, by sawing with strong and careful motions using a sharp blade with adequate clamps and eye protection can the likelihood of risk become rare with minor consequences minimising the risk assessment to rare.

Risk Assessment: Drilling

Drilling without considering the below leads to the possible event of minor consequences, yielding a medium risk assessment.

Person Protection Equipment	Wear goggles to protect eyes from dust or other projected substances. If equipment is loud, wear ear muffs.
Dust	Drill in open areas, preferably with air flow, to prevent the accumulation of dust generated from drilling posing risk to health. Wear dust mask if necessary.
Electrocution	Do not operate equipment in wet environments Inspect equipment and leads for damage before use and do not use if damaged
Entanglement	Ensure hair, loose clothing and jewellery is kept clear of moving parts when using equipment
Drilling	Use appropriate guard and ensure the guard operates as intended, for instance a drill chuck guard. Keep hands and body clear of moving parts during use and maintenance Ensure drill parts and work pieces are undamaged and secure appropriately prior to drilling
Slips	Clean work bench before and after use to minimise chance of materials slipping due to build up of waste. Secure materials appropriately prior to drilling to prevent slipping while drilling.
Drill Bit Temperature	Use the drill appropriately and conservatively as the drill bit can get hot during extensive and intense drilling. Allow the drill bit to cool before handling.

Putting these considerations into practice, the likelihood of minor consequences is almost eliminated, so rare, resulting in a risk assessment of low.

Risk Assessment: Circular Saw

There are many hazards to consider, such as kickback and other hazards leading to lacerations, inhalation of dust from material cut, ear injury from noise levels or eye damage from projectiles. Overall, it is possible for serious injury leading to a high risk in the use of the circular.

Kickback	Likely circular saw incident caused by kickback, referring to situations where the blade becomes jammed by the material being cut. From this, the circular saw retracts backwards out of the cut, leading to the blade to make contact with anything in its path such as the operators body.	Ensure blade is sharp and undamaged Use the appropriate blade for the material being cut Only start cutting without being forceful but steady once the saw reaches full power Operate the saw with two hands, with one on the trigger switch and other on the front handle Clamp and secure the material being cut Adjust the depth of the saw cut to be as shallow as possible Check and remove any nails or screws from the material prior to cutting Do not twist the saw to manipulate or check the alignment Stand to the side when cutting material to avoid the saws path during kick back Ensure the blade guard operates as expected
Projectiles	High risk in being struck by projectiles from the blade or material sawed.	Wear protective eyewear Ensure the blade guard operates properly and freely to enclose the teeth as well as possible Check that the retracting lower blade guard returns to the starting position before placing the saw down Ensure the upper and lower blade guard are clean of sawdust Do not force the retracting lower guard in the open position
Usage	Improper and unsafe setting up of the circular blade and use can increase risk and likelihood of cuts	Ensure not to overtighten the blade-locking nut Keep cord safe during use and stowed to reduce tripping hazards Do not operate a saw that vibrates or functions in an unusual or unsafe way Do not carry around the circular saw with fingers positioned near or on the trigger switch Only saw in comfortable and large spaces Watch the blade stop rotating completely before placing the blade down, as the blade may travel along the surface
Personal Protective Equipment		For dust protection, wear an appropriate dust mask For noise protection, wear appropriate hearing protection for the magnitude of noise produced during sawing
Lacerations		Operator needs to be trained to properly use the circular saw Conduct of the tool must be in compliance with the manufacturer's instructions Keep body parts and hands clear of the blade during operation and maintenance Ensure protective guarding are installed and function as expected
Slips, Trips and Falls		Wear appropriate footwear Maintain a clean and clear work area around the machine to reduce likelihood of slips, trips and falls

The above control measures aim to reduce and eliminate the risks and hazards as effectively as possible. From this, proper conduct moderate injury is still possible as the circular saw is a rotating, handheld blade. However, the likelihood of such instances occurring is rare so the risk is low. In other circumstances, the risk is eliminated as dust inhalation, eye and ear damage cannot occur with proper protective equipment in place. Similarly, a clean work space with appropriate foot wear heavily reduces the likelihood of accidental slips, trips and falls. So with these control measures, the potentially dangerous circular saw can be used with a low risk.

Risk Assessment: Mitre Saw

Moderate injuries and consequences are possible when using the miter saw as the circular blade spins quickly. Hence, a high risk assessment.

Impact and cutting injuries	Operator should appropriately know how to operate the miter saw The miter saw should only be used in compliance with the manufacturer's specifications Keep hands and body parts clear from the rotating blade Check appropriate guarding is installed and operational Check that the cutting wheel is securely installed and the blade does not wobble during use Back out frequently during deep cuts to allow the blade to clean itself and cool
Noise and Vibration	Wear appropriate PPE - gloves and hearing protection Take breaks from continuous operation, as the noise and vibrations can be strenuous Conduct periodic maintenance for smoother performance and less vibrations
Fire, Explosion & Electrocution	Ensure equipment is maintained and in good condition prior to use Do not operate faulty equipment Do not operate miter saw in a flammable atmosphere or near combustible substances Remove hidden hazards such as electrical wiring and piping prior to use
Slips, Trips and falls	Wear appropriate footwear Maintain a clean and clear work area around the machine to reduce likelihood of slips, trips and falls
PPE	Wear protective eyewear to protect eyes from dust and projected particles Consider wearing a dust mask depending on the situation - air flow and amount of dust likely to be produced (dependent on material cut and the cuts themselves)

Risk Assessment: Super Glue

The health hazard associated with the applying of super glue are skin irritation, serious eye irritation and may cause respiration irritation. As it is likely of minor consequences while applying super glue, the risk associated when used incautiously is high.

Inhalation	Sensitive individuals can incur allergic reactions or asthma-like symptoms from prolonged or repeated exposure. If such a situation arises, move the individual to fresh air and if their breathing has stopped, apply artificial respiration or oxygen as necessary while having a doctor called for. Avoid breathing vapors by using outdoors or in well-ventilated areas.
Skin Contact	As the super glue bonds with skin in seconds, recommended not to pull bonded skin apart. Rather, soak with warm soapy water then gently peel apart with if needed a blunt instrument. Note that cured adhesive does not pose a health hazard when bonded with the skin, just wash with soap and water and seek medical attention if irritation continues further. As cyanoacrylates release heat when they solidify, if a large drop on skin produces enough heat to burn the individual seek medical attention.
Eye Contact	Rinse eye straight away with warm, running water for at least 15 minutes, to help stop the bonding of the adhesive with the eye proteins. Cover the eye until the adhesive has un-bonded with the eye. Potentially the eyelids will bond and if so release eyelashes with warm water from a soft, absorbent material such as a pad.
Directions of Safe Use	Remove the cap and cut the tip of the nozzle. Ensure not to apply pressure on the tube while removing the nozzle tip. Apply glue to one of the surfaces, with around 1 drop for every 4 cm^2 Press the materials together and hold in place if needed until the glue sets.
Personal Protective Equipment	Wearing goggles can prevent super glue from entering the eye. Gloves can prevent contact between the adhesive and the skin on the hands. However, note that the gloves typically finish around the wrist so past the wrist is unprotected. Wash skin and hands after use. Wear protective clothing during use.

With these measures in place, likelihood of skin contact is almost eliminated while eye contact and inhalation is eliminated through the use of protective goggles and only using in well-ventilated areas to prevent an accumulation of vapor. As such, rare minor consequences would occur at most improving the risk in using safety glue to low.

Risk Assessment: Acetone

The chemical, acetone, is used as a solvent for plastics but is a hazard class danger flammable liquid, category 2, eye irritation, category 2 and specific target organ toxicity-single exposure, category 3. Hence the use of acetone has possible moderate consequences if not handled correctly. Therefore, has a high risk assessment.

First aid measures	Eyes –immediately flood the eye with plenty of water for at least 15 minutes and get medical attention. Ingested – wash out mouth with water. Do not induce vomiting. Keep warm and at rest. Get medical attention urgently. Skin – remove contaminated clothing and wash skin thoroughly with water. If irritation persists get medical advice. Inhalation –Remove from exposure. Keep warm and at rest and get medical attention.
Extinguishing Fire	Suitable methods of extinguishing the fire include water spray, alcohol resistant foam, dry chemicals or carbon dioxide but do not use water jet. Fire creates toxic gases/ vapours/fumes of carbon monoxide (CO) and Carbon dioxide (CO^2) so do not breathe in the smoke. Preferably, eliminate the possibility of a fire by removing potential causes of ignition and flammable objects from the workspace
Storage	Avoid inhaling vapour and contact with eyes, skin and clothing. Store in original packaging and keep container tightly closed when stored away. Keep stored in a cool area away from sources of ignition or heat and prevent accumulation of static charge.
PPE	Engineering Controls – Local exhaust ventilation. Eye/face Protection – Goggles. Hand protection – Viton rubber or PVA gloves. Skin protection – Overalls necessary when handling large quantities. Respiratory protection – if high vapour concentrations wear respiratory protection
Waste Procedure	Dispose of waste and residues in accordance with local authority regulations; treat material and container as hazardous waste.

The likelihood of an incident occurring is rare as proper procedures are followed to minimise the possibility. At the same time, PPE is worn and the user is prepared to respond to any accident reducing the severity to minor by timely taking action to fix the situation.
Thus, the risk assessment has been minimised to a low.

Risk Assessment: 3D Printing

Moderate consequences, such as illness from inhalation of fumes from the 3D printer, are unlikely while minor injuries are likely to occur from the use of the 3D printer particularly when scraping off the prints with sharp tools from the hot baseplate. Hence the risk assessment without appropriate measures is

Burns	During operation, keep mechanics enclosed by having the printer door shut so no contact occurs with the user and the hot, moving parts of the printer. Allow printer and printed parts to cool before removing 3D print and avoid contact with components of the printing chamber. The nozzle of the 3D printer can reach high temperatures of between 200 to 300 degrees Celsius. Any burns should be cooled with cold running water.
Cuts	Gloves and eye protection (goggles) necessary when finishing the 3D prints. Cut away from the body when using sharp tools and position fingers away from the blade while considering the direction the blade will travel if it slips. Know where and how to use the first aid kit to treat cuts and minimise bleeding.
Moving Parts	Ensure hair, loose clothing and jewellery is kept clear of moving parts when using equipment
Fire Hazard	Ensure active smoke alarm is in operation to alert of the event of a fire. Position the 3D printer with no flammable objects in close proximity and keep safety equipment in a convenient location in the event of a fire.
Fumes from Printer	Keep distance from 3D printer during operation to reduce risk of inhalation of fumes. Regular maintenance of the 3D printer and cleaning after use can reduce the amount of fumes produced. Use printer in a ventilated area and used recommended filament at appropriate temperatures.
Electrical Shock	Inspect cable prior to use and ensure it is undamaged. Also check that the cable is properly connected to the power point and printer before turning on the printer.

Minor injuries can still occur, such as cuts when scrapping off the 3D print from the platform, however the occurrence of such incidents when cutting carefully and following other procedures allow the possibility of risk to be minimised to rare improving the risk assessment to low.

Risk Assessment: Silicon Aerosol Spray

Aerosol Spray Safety Specifications

From the silicon's safety sheet, hazard statements are:
Extremely flammable aerosol.
Pressurized container: may burst if heated.
Causes skin irritation.
May cause drowsiness or dizziness.
Toxic to aquatic life with long lasting effects.

Considering these, the use of the silicon aerosol without the appropriate measures is possible to result in moderate injuries so has a high risk in using.

First Aid Measures	**Eyes:** hold eyelids apart and flush continuously with water. Continue to flus until advised to stop by a Poisons Information Centre, a doctor, or after no less than 15 minutes. **Inhalation:** If inhaled, move away from contaminated area. Type A (Organic vapour) respirator or an Air-line respirator (in poorly ventilated areas) can be used to protect respiratory system. **Skin:** If contact occurs, remove contaminated clothing and wash skin and hair with running water. Flush with water until advised to stop by a Poisons Information Centre or a doctor. **Ingestion:** Consult a Poison Information Centre on 13 11 26 (Australia Wide) or a doctor (at once). If swallowed, do not cause vomiting.
Inhalation	Avoid inhaling by using in well ventilated areas - to reduce likelihood, open windows and doorways or use mechanical extract ventilation
Flammable	The product is flammable and may travel some distance so could potentially come into contact with an ignition source. Ensure vapor levels are below the recommended exposure standard to prevent risk of ignition. Do not spray on an open flame or other ignition source - keep away from any heat, sparks, open flames and hot surfaces. Do not pierce of burn the contained as it is pressurized.
PPE	Hands: wear nitrile or neoprene gloves. Wash hands after use. Body: When large quantities are in use or where heavy contamination is likely, wear coveralls. Respiraatory: Type A-Class P1 (Organic gases/vapours and Particulate) respirator) necessary in high vapor levels. Eyes / Face: Wear splash-proof goggles.

The use of the spray in areas where no ignition sources are present eliminates the possibility of ignition leading to a fire. Furthermore the personal protective equipment reduces the risk to the user during use. However, ensure the spray is directed away from body and face to reduce exposure and contact.
With these control measures, risk of use is rare with insignificant consequences so low assessment.

Criteria

Risk Assessment: Laser Cutting

Fumes	Laser cutters generate fumes and vapours that can be highly toxic so are equipped with a fume exhaust system and filtration system to prevent damage to the machine and user's health from these fumes by venting these outdoors. Before use, ensure the air filter and exhaust system are operation and filters must be changed regularly. Do not cut a material not approved by the manufacturer. Ensure the room has air circulation to ensure the air exhaust system can function properly.
Materials	Materials containing chlorine, such as PVC, produce extremely toxic fumes when laser cut or engraved so should never be used. Materials the Emblaser 2 can cut are depicted below, from: https://3dprintingsystems.com/download/Emblaser-2_Web.pdf

Laser Cutter User Manual

By considering the above, personal protective equipment will eliminate possible eye damage while fumes are safely vented outside to prevent damage to the user's health and the likelihood of a fire occurring is very rare. The use of the advised materials by the manufacturer and Emblaser 2's feature MIA almost completely eliminates the possibility of ignition of material. Although electrical failure and malfunction is still slightly possible, the likelihood is very rare so the risk assessment by following these procedures becomes low.

Risk Assessment: PVC Bursting

PVC plastic is brittle and from repeated, high pressure pressurisation of the PVC tank can lead to the PVC bursting leading to fragments of PVC propelled, leading to moderate injuries.

To minimise the chance of risk, the PVC will be bought brand new and prior to use will be inspected for cracks or damage. As the duration of use is a short period of time and within a reasonable margin of its working pressure, the likelihood is rare.

A pressure relief valve of 150PSI will also be installed to ensure that the system never exceeds this pressure. The parts used in the system are rated up to 150PSI or above, indicating the likelihood of failure of parts and for PVC to burst is very rare. Particularly, the PVC used is rated at least PN12, with a maximum operating pressure of 174PSI including a safety factor of 2.145.

Considering these factors, the risk assessment of the PVC bursting is low as the likelihood has been minimised and would be very rare.

Instruments and Equipment

General

Multimeter is an electronic instrument that measures a range of values, being the voltage, current and resistance of a circuit. I used the multimeter at times to validate that the circuitry was wired correctly by placing the probes in the appropriate locations and observing the response. If the response was not as expected, the issue may have been a wire was loose or misplaced.

https://sydneytools.com.au/product/fluke-fluke115-electrician-truerms-digital-multimeter

Other tools used include hammers, screw drivers, Stanley knives and pliers.
A range of power tools and saws were considered, and the most appropriate tools from the research was used.

The **electric drill**, a power tool, was used at times to quickly screw or drill hence reducing the manual labor and time needed. When using the electric drill, I ensured to drill a start hole into the Marine Plywood before applying the screw to prevent splintering and to provide a guide for the screw.

Hand Saws

Hacksaw

Originally designed to cut metal, but can be suitable for cutting other materials commonly plastic. Plumbers may use hacksaws to cut plastic pipe.

Basic Handsaw

Suitable to cut wood but can be damaged when used to cut hard materials so strongly not recommended

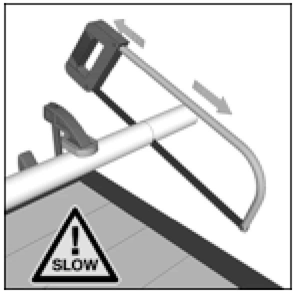
Backsaw aka tenon saw

The end is stiff providing more control and precision in cutting. Similarly, the narrow blade and metal reinforcing reduces the ability of the blade to bend while cutting. As such these are suitable for precise and straight cuts, such as in woodwork.

Coping Saw

The thin narrow blade is useful to perform precise, intricate and even curved cuts. As the blade is stretched on the metal frame, the design helps in cutting curves.

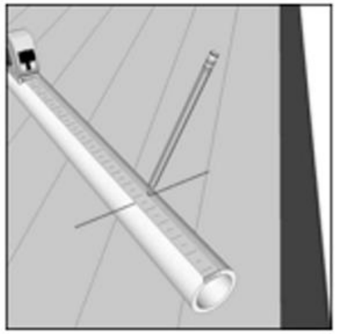
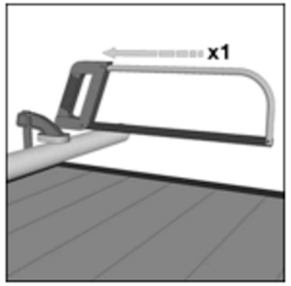
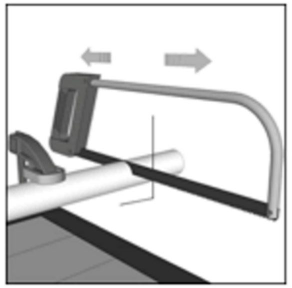
References for images on this slide:
https://powertoolsguyd.com/saw-uses/
https://www.fullertool.com/product/standard-hacksaw-12-in/



tting PVC by Hand

The hacksaw is suitable to cut plastic pipe as the design of the hacksaw lets the cutting be easy and versatile in how the PVC is cut. Hacksaws, unlike wood saws, have a thinner blade and smaller teeth allowing for precise cuts. However, after cutting the PVC with the hacksaw it is necessary to de-burr the pipe. To de-burr the pipe, use a heavy grade sandpaper or a sharp knife and run this along the inside edge of the pipe to remove these rough edges.

The steps to cutting PVC with a hacksaw safely are as follows.

Step 1	With a tape measure and sharp pencil, mark where to cut.	
Step 2	Clamp the PVC to a solid surface.	
Step 3	Check that the adjustment nuts on the hacksaw are hand-tight, but do not over-tighten. Using a loose blade will cause the cut to not be straight and potentially cut down the diameter of the pipe.	
Step 4	Start with the rear of the blade on the marking then draw the blade backwards to start penetrating the material. Continue until this results in a defined notch in the pipe that is suitable to guide the saw through repetitive back and forth motions.	
Step 5	Slowly cut with back and forth motions and keep the blade straight. Perform relaxed but controlled motions, allowing the saw to do the cutting rather than add extra force. Do not rush these motions as this may lead the cutting off course.	
Step 6	Slow down when the blade reaches the bottom. Complete the cut smoothly at an angle to prevent the PVC from creating a rough edge due to a small section of PVC being torn out or broken behind the blade, a similar issue to wood splintering at the end of a cut.	

https://formufit.com/pages/how-to-cut-pvc-pipe

Power Tools

Table Saw

Circular table saw blade is fixed in position and rotates at high speeds while the material is pressed against the rotating blade producing a cut.

Widely used in woodworking industry and can cut wood, plywood, medium-density fibreboard, plastic and soft metals.

Advantages: Can produce a variety of cuts; Quick and easy to use

Disadvantages: Not easily portable and large; One of the most dangerous tools

Circular Saw

The circular saw is handheld with a rotating blade that is pushed across the material to cut through it. Hence, the material needs to be secured and stationary while the saw blade travels across.

Advantages: Portable; can cut through long pieces of wood and soft materials; Can be fairly precise

Disadvantages: Not so precise unless aided with setup guide rails or straight edges

Jigsaw

The blade on a jigsaw aims downward and the jigsaw is specifically for cutting curved or otherwise non-straight cuts but can also cut straight.

Advantages: An all rounder - can cut curves, decent precision, handheld, range of materials; Can be used to cut internal profiles only needing a start hole for the blade to enter

https://www.finepowertools.com/saws/power-saw-types-their-uses/
https://www.bunnings.com.au/diy-advice/home-improvement/tools-and-skills/types-of-power-saws-and-their-uses

How to Cut Marine Plywood

The circular saw was chosen to cut the marine plywood. The decision came with consideration to safety, ease of use, compatibility with the material, timeliness and the tools available at the workshop. The circular saw can cut through long pieces of wood with ease, allowing the long cuts for the base to be performed quickly under constrained class time. Furthermore, the use of the circular saw is safe with a low risk assessment when used appropriately. As straight cuts are needed and the imprecision of these cuts would not impact the functionality of the base, the circular saw is perfect for the job.

To operate the saw, two hands are needed, and the rear handle has the trigger for the circular blade operation.

The baseplate of the saw rests flat on the surface of the material. All saws have an automatic blade guard that enables when the blade is in use.

Directions to Use

Ensure the wood is held carefully in place for good cuts and to operate safely.

Suggests to cut wood on the floor on top for elevation - perhaps other wood

Adjust the edge of the blade along the edge of the board so that it's just barely deeper than the thickness of the wood and lock it down

Easiest method for making cuts is to freehand - make a line as a guide and follow it throughout; ideal for cuts that don't need to be critically precise

The base has two notches that indicate exactly where the blade will cut. One is for a 90 degree cut and the other is for bevels.

Wear eye protection, hearing protection and dusk mask.

Squeeze the trigger and start feeding the wood into the saw

After the blade is spinning, position your body to the side not directly behind the saw

Follow the line using the notch for reference or look at the blade

The blade guard will automatically enable while the blade is operating

Set the saw down carefully and let the saw stop rotating

Cutting PVC using Power Tools

To transport the 50mm PVC pipe from home to school, the long 3m pipes were cut down to the designed lengths of two 1m pipes, a 630mm pipe, a 200mm pipe and two 85mm pipes. While the hacksaw could have been used, the process would have been time consuming as the pipe was 50mm.

The drop saw was used as the cuts were quick to execute and were square. The 25mm pipe was cut with the hacksaw as the hacksaw allowed for better precision and control over the positioning of the cut as well as the blade was thinner. This was necessary as the 25mm PVC pipes had to be precise since the design of the 25mm pipes was minimal in length and risked that the pipe was too short to completely connect in the fittings. Doing this, the design allowed for one 1m 25mm pipe to be needed rather two as it was borderline whether to buy one or two. Hence, the design saved money and excess.

Directions to use the Miter Saw

1. Measure and mark a line for where to cut the material
2. The miter saw is designed to be adjusted to make angled cuts. Loosen the handle at the front of the saw and adjust the angle accordingly, set to 0 degrees since we want to cut the PVC straight.
3. Look down the edge of the blade to align the blade with the marking. Be sure to cut on the waste side of the line.
4. With safety glasses and hearing protection, hold the PVC pipe firmly and flush against the backing fence of the saw. Hold down the trigger and bring the circular saw down onto and through the PVC pipe confidently. Ensure to go slower at the start and end. Let the blade up and release the trigger, waiting for the blade to stop rotating before moving the PVC pipe.

Prime & Glue PVC

1. Prime the fitting first, go few times around to get enough coverage
2. Do the same with the PVC pipe

Ensure to spread even layers around the pipe

3. With the glue, apply first to the PVC pipe and go a few times around again
1. Apply to the fitting a few times around
2. When inserting, give it a quarter of a turn once you've started pushing it in
3. Hold for 30 seconds to ensure there is no pushback
4. Use a rag to wipe off excess glue so it doesn't eat away at the PVC pipe

PVC Threaded Connections

Connecting - with PTFE Tape

Use white PTFE tape at least 3mm thick

Wrap in same direction as the thread to ensure when screwing on the thread does not unravel

Make sure the threads are clean, then hold the fitting in your left hand and align the edge of the tape over the threads so that its parallel to the end of the fitting

Cover the first thread but don't apply past the edge of the fitting

Press down on the end of the tape with the left-hand thumb and tightly wrap in a clockwise direction

As you wrap, stretch the tape slightly to force it down into the threads without slicing through the tape

Each successive wrap should cover half of the width of the wrap below it

After 2 to 3 rotations, press down on the tape where you want to make the break and pull it

Smooth the loose end of the tape down into the threads

Tighten with fingers to a maximum of 2 full rotations - anymore will apply unwanted stress to the female side of the connection

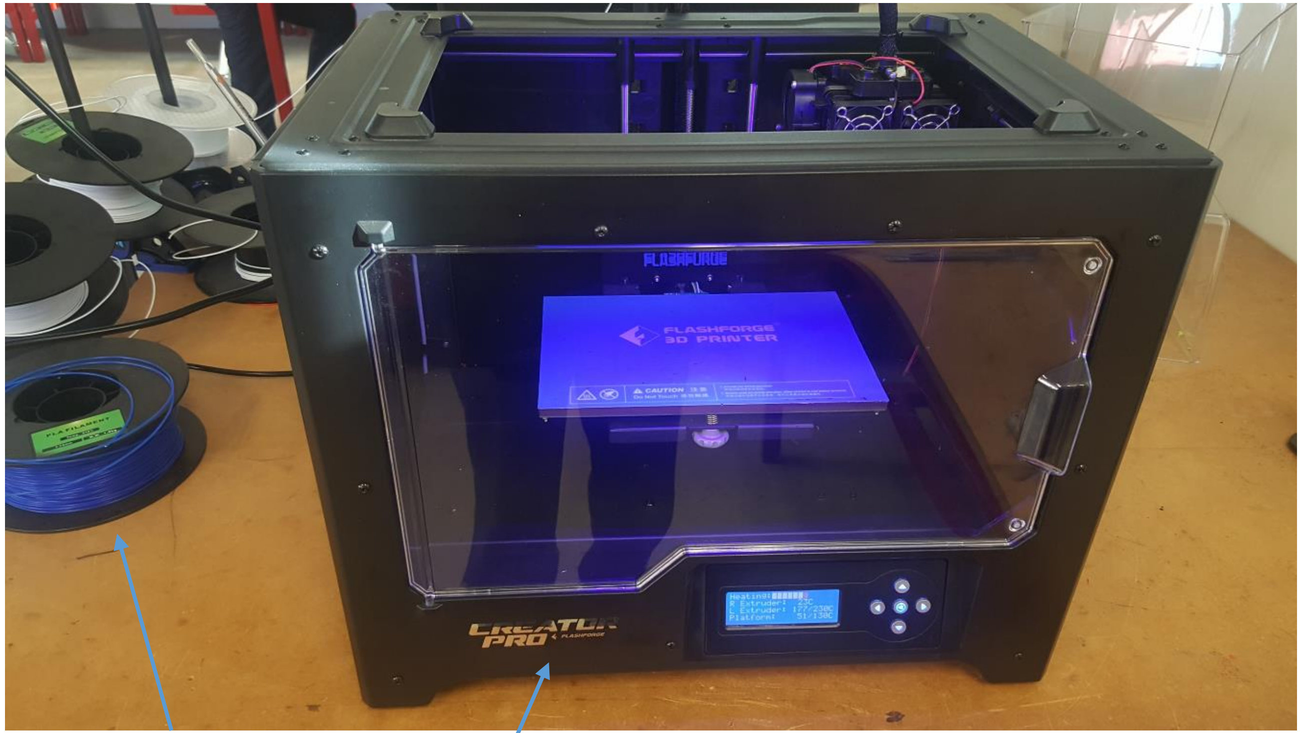
For valves, they only require half or one full turn past finger tight when tightening the connection

When connecting a male attachment made of metal to a female PVC attachment, be careful not to overtighten the connection as doing so can damage the PVC pipe since the male thread is metal and is stronger than the PVC

Super Glue

1. Sand surfaces to develop a good surface contact area to maximise the strength of the bond
2. Apply super glue to surface of materials being bonded
3. Sets within 60 seconds and cures hard within two hours - use clamps to hold surfaces tightly together to develop a strong bond
4. Once cured, residue visible can be cleaned with acetone

3D Printer: Creator Pro Dual Head



Wheels of filament on clamps; Aerosol spray applied to reduce friction and encourage rotation of coil

3D Printer

28-8-2020

A 3D printer is a machine in which is able to fabricate physical objects in a 3-dimensional plane.
3D printers create three-dimensional objects using layers.
3D printing involves layering materials to create components.
The material used to create the object influences the final characteristics and properties.

User manual is here.

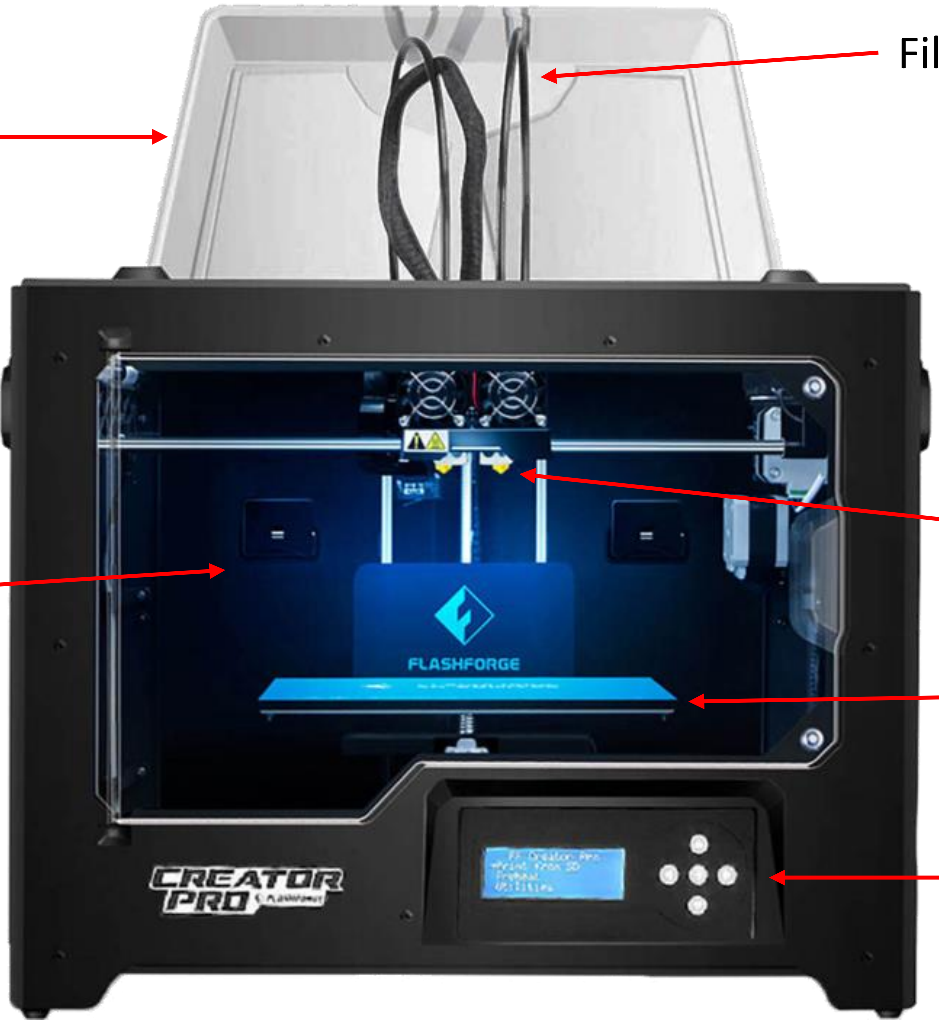
Continue

3D Printer Diagram

Lid to store heat and maintain ideal conditions for filament cooling

Side handles for transport

Door – helps maintain ideal conditions and reduces risk



Filament protective tubing

Extruders

Heated build plate

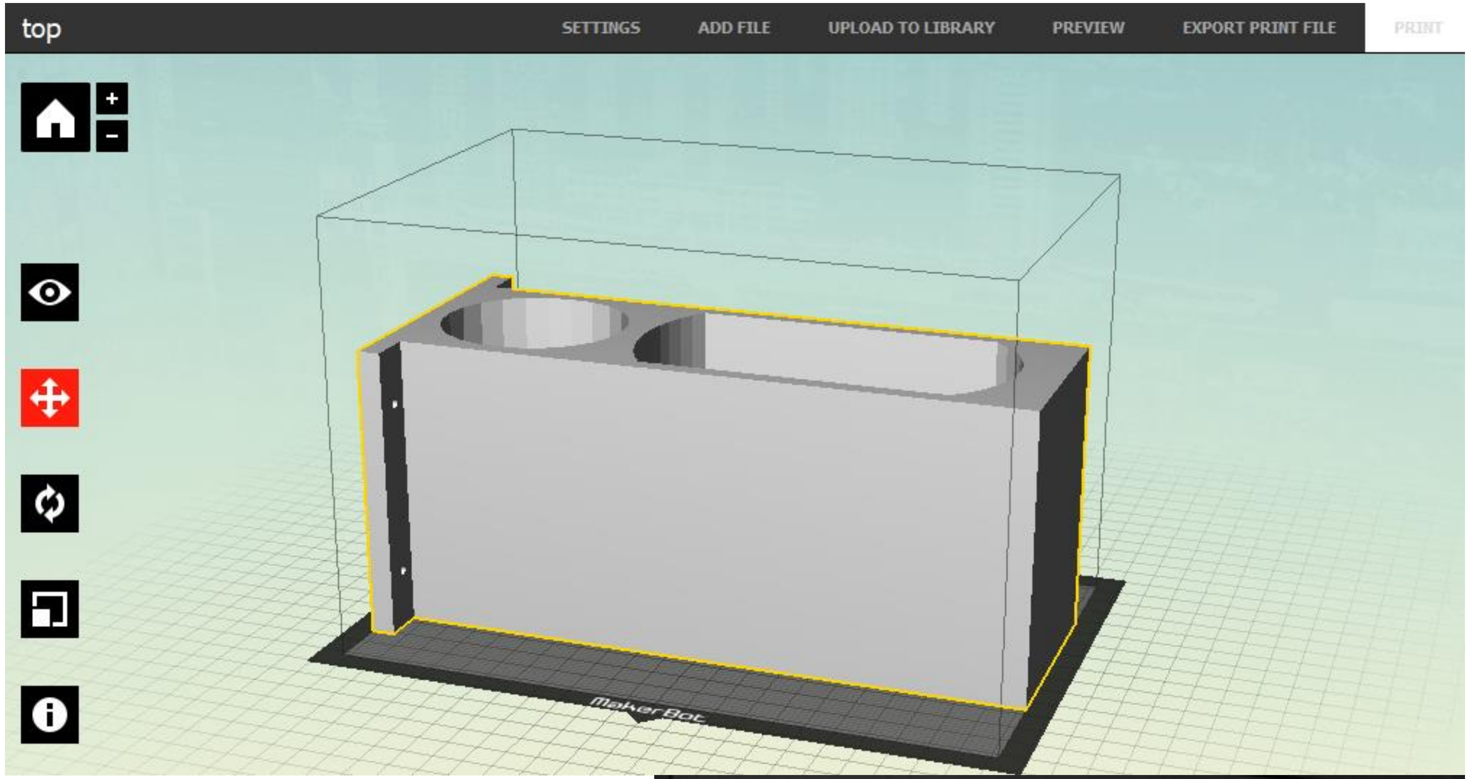
LCD Interface and Controls

https://3dprintersuperstore.com.au/products/flashforge-creator-pro

Continue

How to Produce 3D Printed Components

I designed components in 3D using Sketchup, then exported the component as a .stl file.
I then "Add File" in MakerBot and can adjust the settings of the 3D printer as well as the orientation and position of the component on the platform.
Afterwards, I select Export Print File and the file generated can be put on an SD card and inserted into the 3D Printer.
Alternatively, if the laptop is connected and remains wired to the 3D printer, I could select the Print option. However, the print stops when the laptop disconnects.



To print from the 3D Printer, first insert the SD card. Then I select Print from SD (using the controls); Choose the file to print; Hit Enter.
The printer commences preheating the platform and extruder to the set temperature, then will print the file.

Continue

https://www.flashforge.com/product-detail/4

3D Printer Settings

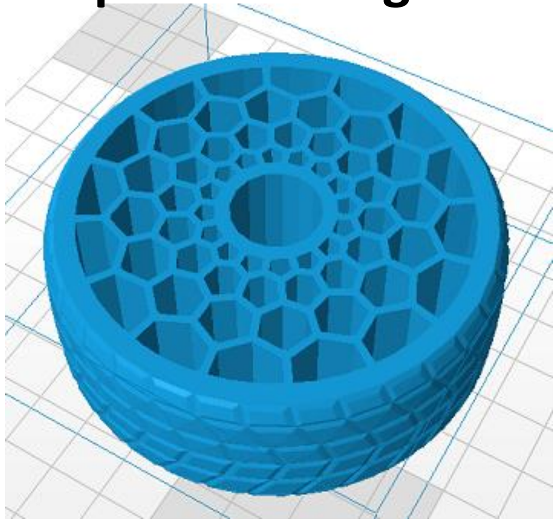
Layer Height

The exact height of each layer of plastic extruded. **FDM printers:** Shorter vertical layer results in a thicker horizontal line, and a taller vertical layer results in a thinner horizontal line. This can throw off precision in the horizontal plane, especially in small moving parts sometimes used by print-in-place mechanisms. Lower layer height: slow print down however more layers provide higher detail. Extreme detail from smaller layer heights provides smooth prints - layers become less obvious and prints become smoother, rather than rough and visible. Thus can ensure prints required very smooth finish, i.e. axles or print-in-place mechanisms, are as smooth as possible by reducing layer height - increase detail, reduces print speed so be wary.

Number of shells

A shell is the outer wall of a designed component. Shell thickness refers to the number of layers that the outer wall will have before infill printing commences. The higher the setting is for shell thickness, the thicker the outer walls of your object will be. Obviously, thicker walls make for a sturdier object, so if strength is a quality that you're after, it pays to increase the shell thickness appropriately. Decorative designs do not usually require strength, so increasing the shell thickness in these instances provides no useful benefit and can distort the design of the object being printed.

Component using Shell



https://rigid.ink/blogs/news/6-key-3d-printing-slicer-settings-you-need-to-know

Continue

3D Printer Settings

Infill

Fill density or infill is a measure of the amount of material that will be printed inside the outer shell of the component. Fill density is usually measured as a percentage of the entire component, rather than a unit of measure.
Objects with more infill are stronger and heavier than an objects with less infill. Therefore, modifying infill for the specific component is essential to make use of the designed purpose and characteristics of the object.

Print Speed

Refers to how fast the print head travels while extruding filament. The optimal speed depends on the object printing and the filament material. Simple objects with less detail can be printed faster without issue. However more intricate objects are produced with higher quality from slower print speeds, as print speed can affect the adhesion to print surface. Consequently, high speeds may cause under or over extrusion and other issues. Thus experiment with the print speed to determine what is ideal for the given component.

Continue

Levelling Build Plate

Why Levelling is Important

If the platform is too far from the nozzles, or if the platform is not balanced so one part is farther than another part, the 3D prints may not stick properly. When the build plate is too close to the extruder nozzles, it can result in the filament being blocked from being extruded out of the nozzles. Furthermore, the Kapton tape covering the platform and the aluminium surface underneath can be damaged by the extruder. Hence, it is necessary to level the platform to ensure best performance of the 3D printer and that the component prints perfectly.

How to Level

There are four knobs below the build platform that lower and raise the build plate. Tightening the knobs, using a clockwise rotation, moves the platform away from the extruder nozzles. Loosening the knobs, using an anticlockwise rotation, moves the platform closer towards the extruder nozzles.

The perfect distance between the extruder nozzles and the build plate is equal to the thickness of the MakerBot Support card that comes with the printer. While levelling, only move two knobs during a step, as moving only one knob can cause errors in the calibration. Ensure to follow the specific instructions by the leveling tutorial. To access the levelling tutorial, go on the LCD interface navigate to Utilities then Level Build Plate.

After completing the tutorial, the build plate should be levelled.

https://www.flashforge.com/product-detail/4

Continue

Maintenance

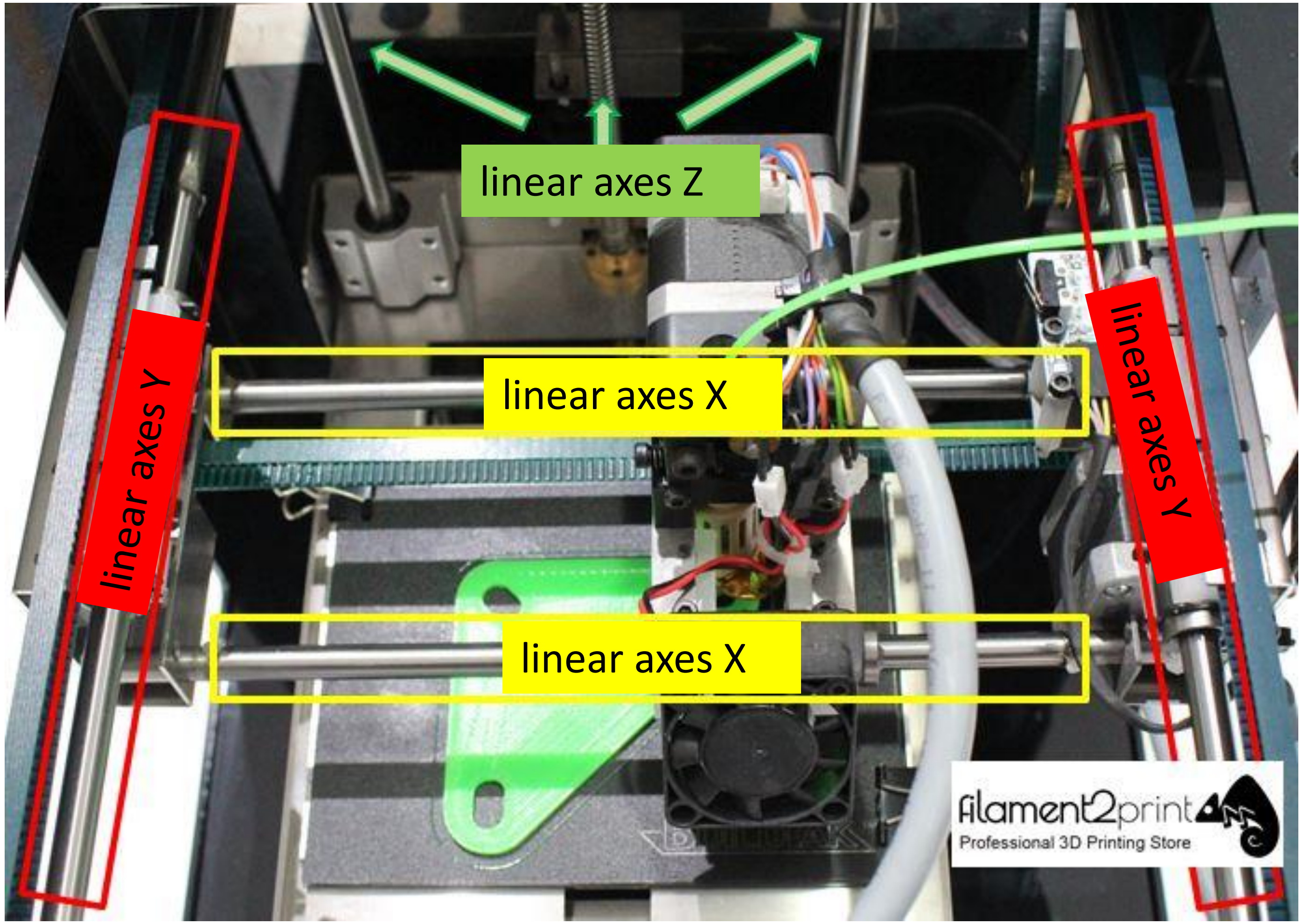
Taking apart the printer head is beneficially, from time to time, to remove excess clogged material and improve the performance of the extruder. To do this, the bolts can be undone to take apart the extruder head. A soft brush is appropriate to delicately clean the mechanical components.

Lubrication is necessary periodically to reduce friction and wear between the moving parts. For 3D printers, lubrication with specifications suitable for the 3D printer is critical as the lubricant impacts the performance of the printer and the final product.

By lubricating the rods and moving parts, the accuracy in positioning the print head improves as there is less friction acting against the movement.

Furthermore, this can improve component life from reduced wear.

The moving parts to specifically lubricate during regular maintenance are emphasized in the photograph to the right.



https://filament2print.com/gb/blog/13_importance-3D-printers-lubrication.html

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Lubricant Spray

Some lubricants are designed for specific applications and cannot be used with all materials. Incompatible lubricants can cause plastics to lose their form or structural integrity or become discolored. There may be additives in the lubricant that cause the chemicals to react with plastic. For instance, solid additives such as graphite weaken a plastic component so should not be used for the 3D printer. Furthermore, aging resistance relates to how as lubricants age they are more likely to harm plastics. Long-term plastic applications need synthetic lubricants as they have a high aging resistance so will not damage the 3D printer over time. Silicon is one example of a synthetic lubricant.

Silicon lubricants tend to be suitable for plastic components, so the following product was determined suitable from its specifications: CRC Aerosol 808 Silicone Spray Multi-Purpose Enhancer, Lubricant & Protectant from
The specifications mention that the optimum lubricity temperature range is between -38˚C to 290˚C providing additional merit to the use of the product as the temperature range of the printer is within this range. The aerosol spray is suitable to lubricate the 3D printer without damaging the plastic.

Directions

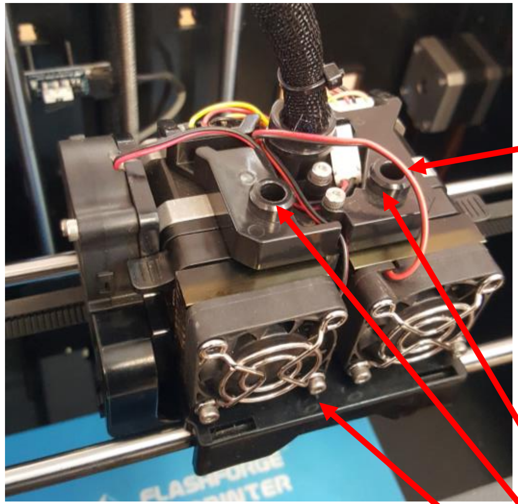
1. Shake can well before use.
2. De-energize equipment before applying.
3. Best performance when used on a clean surface.
4. Spray a light , even film.

Continue

Loading and Unloading Filament

https://www.flashforge.com/product-detail/4

LCD Interface



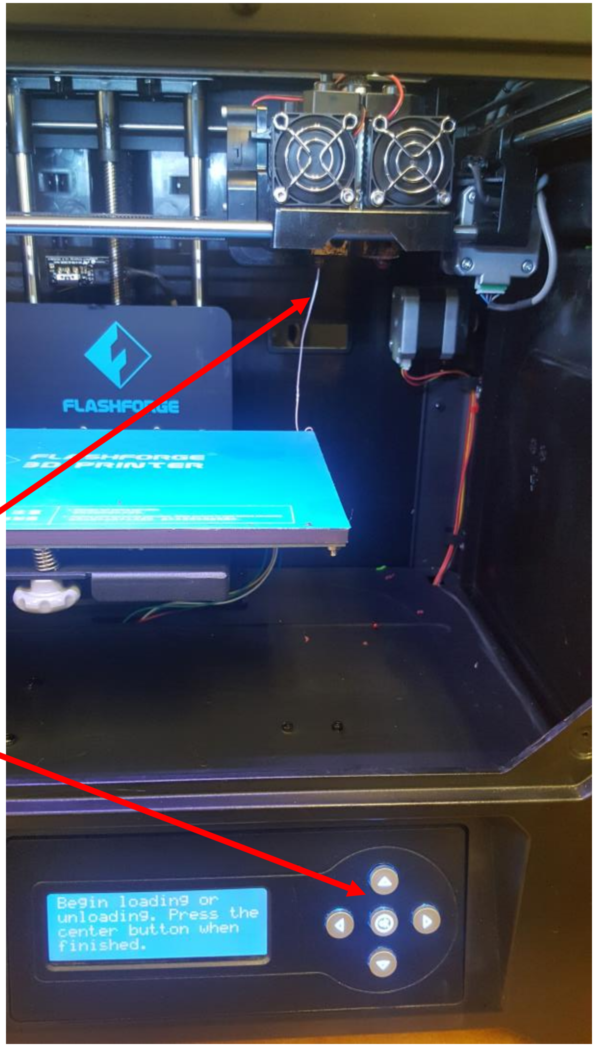
28-8-2020

Plastic loading mechanism: right left

Fans with shield

Continue

To load and unload filament from the 3D printer, first navigate to Utilities on the interface.
To load filament on the right extruder, select Change Filament > Load Right.
Then feed the filament through the extruder head in a vertical fashion. Stop the process by pressing the middle button once when the filament comes out of the extruder.
To unload filament on the left extruder, select Change Filament > Unload Left. When the preheating completes, remove the filament guide tube and delicately pull the filament out.



28-8-2020

3D Printer Problems

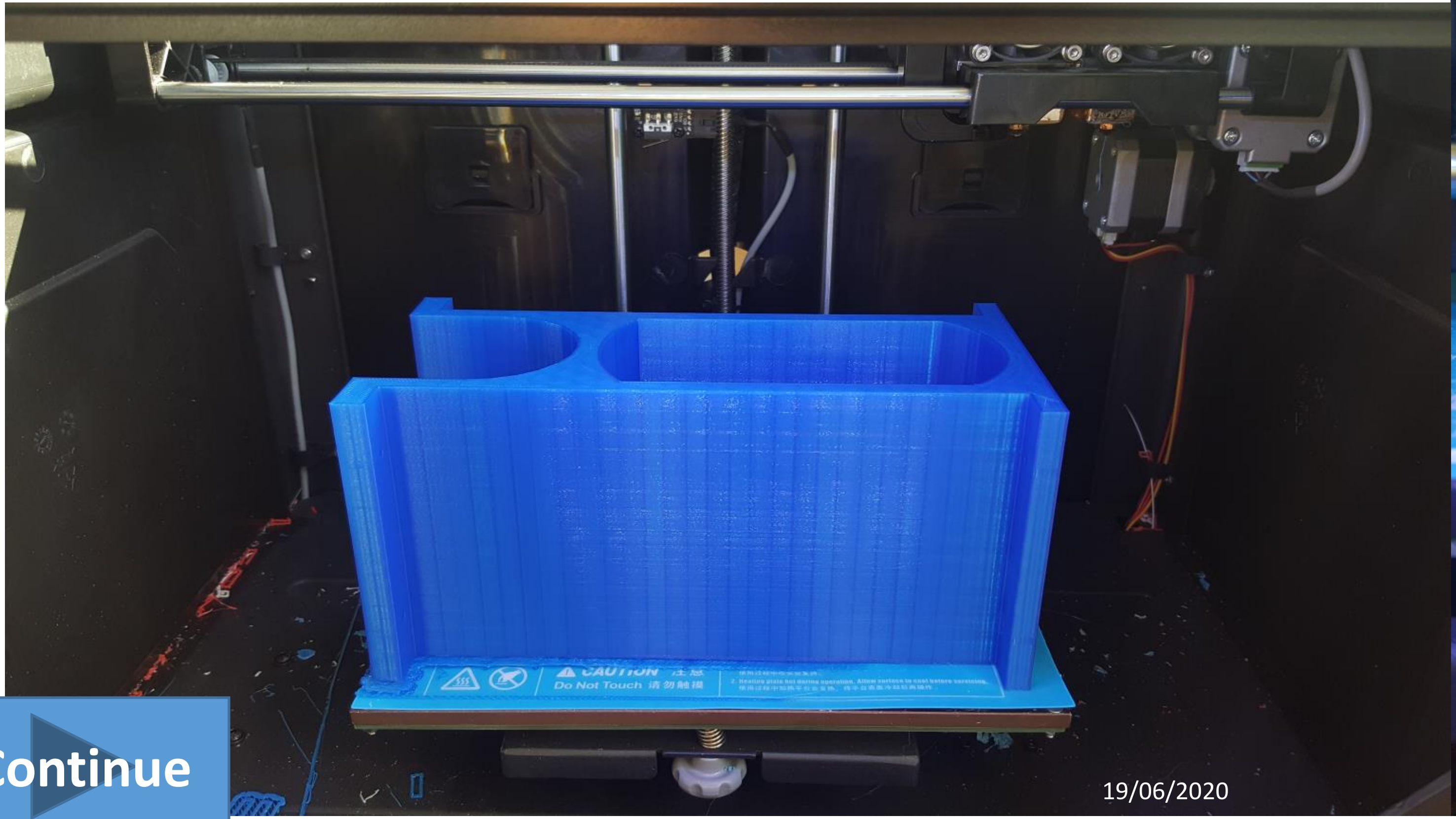
At times, misprints occur as the 3D printer fails to continue to print the component. This sometimes occurs at the beginning or during the printing, and may stem from the baseplate needing levelling or due to the filament being tangled and not consistently being available.
Sometimes loading fails as the filament is not inserted in the 3D printer correctly, or because the printer ha clogged up with plastic fragments. Hence reloading the plastic or, for the long term, dismantling the printer and cleaning the mechanical parts.
Models may incorrectly print as the 3D printer program misreads the 3D design. At times, the 3D design may be falsely read to have a gap or be hollow, when in fact that should be a solid. These issues from my experience generally stem from, in Sketchup, shapes or lines within the 3D shape.

Another issue was that the cables were rather loose and that a little bit of a knock could cause the 3D printer to lose power, hence stop printing. After noticing some prints were incomplete because of this, I promptly installed a strain relief for the cable on the 3D printer to prevent the cable from coming out accidentally. Indeed, I did not have another incomplete print due to this issue afterwards.
Hence I'm relieved by taking this response to the printing failures.

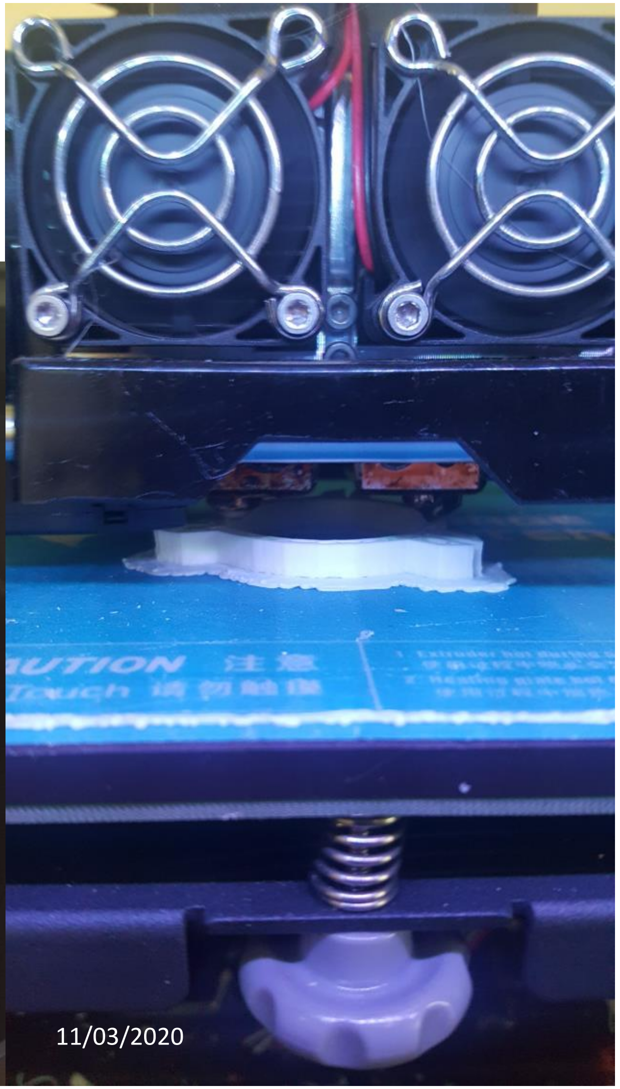
Continue

3D Printer Maintenance

A variety of components, using either PLA or ABS, were printed. The extensive hours of use indicates that the printer needs attention regarding maintenance to continue to perform well.



19/06/2020



11/03/2020

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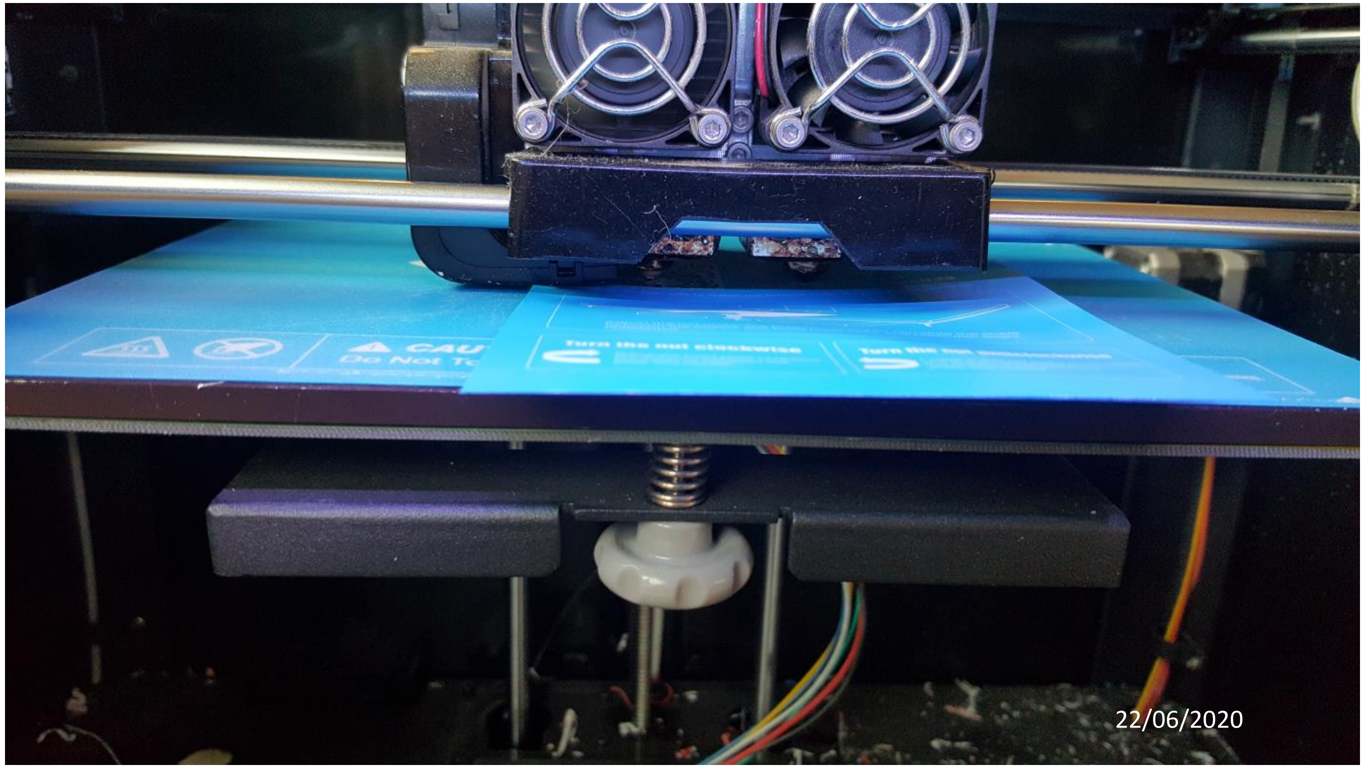
3D Printer Maintenance



Following the levelling tutorial, I levelled the 3D printer platform to improve the performance and quality of the components after concerns over the quality of the 3D printer component. Doing so was rewarding from the high quality prints.

Continue

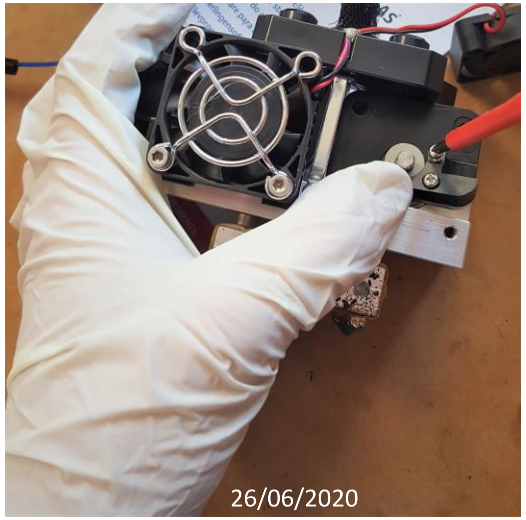
The platform covering was well-used, so I preheated the platform to ease the removal of the mat. Afterwards, I carefully lifted a corner with a scrapper and removed the mat then wiped away remaining glue. Finally, I applied a new mat and ensured to remove any air bubbles. Consequently, printing was easier and safer.

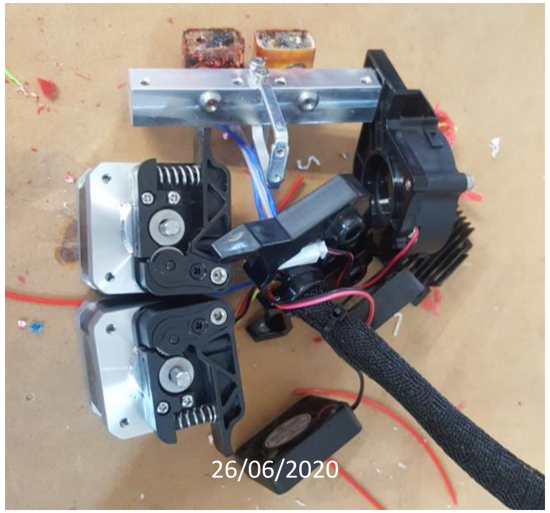
3D Printer Maintenance

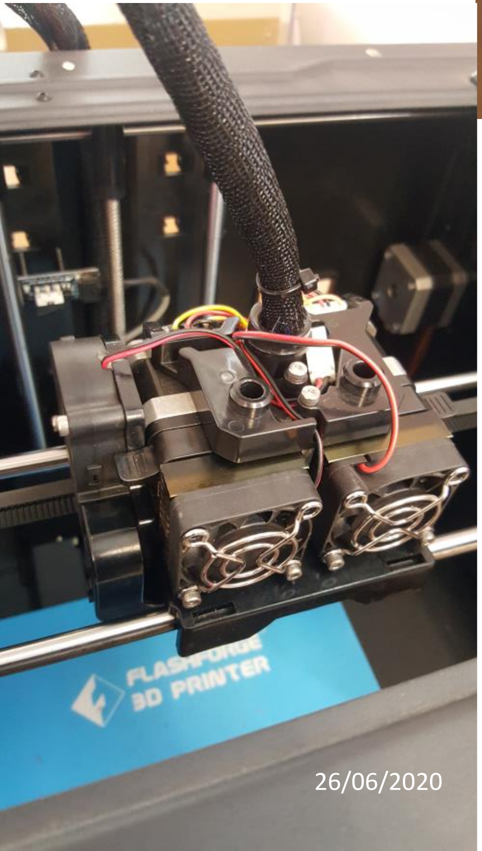
Following the research on how to lubricate the 3D printer, I began to periodically lubricate the 3D printers with the silicon spray to ensure smooth operation and high performance.
As the window was open and the room is large, I was not concerned about inhaling the fumes from the spray. Furthermore I made sure to aim the spray bottle properly and not to spray myself.
Lastly, I washed my hands after usage.
Although class time is valuable to working on the project, maintenance of equipment is essential to maintaining the performance of the equipment. Furthermore lubricating the rods lucky takes 10 minutes, so the maintenance is worth the time.

Continue

3D Printer Maintenance



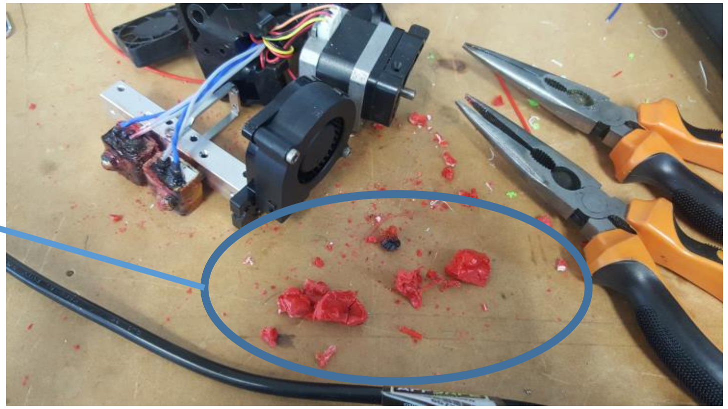




I first removed the extruders from the 3D printer and took the parts apart. Finally, with these parts separated, I could access the stepper motors and extruder heads. I cleaned the stepper gears and removed the excess filament that was blocking the extruders, using pliers.

Following this, I reassembled the 3D printer.

This maintenance fixed the blocked extruders due to a large amount of clogged plastic. I first noticed a slight smell of smoke, preluding to the prediction that there was clogged plastic in the extruders causing the printing issues. Although the maintenance took many lessons, it was integral to ramp up printing production by having the printer operational at a high degree.



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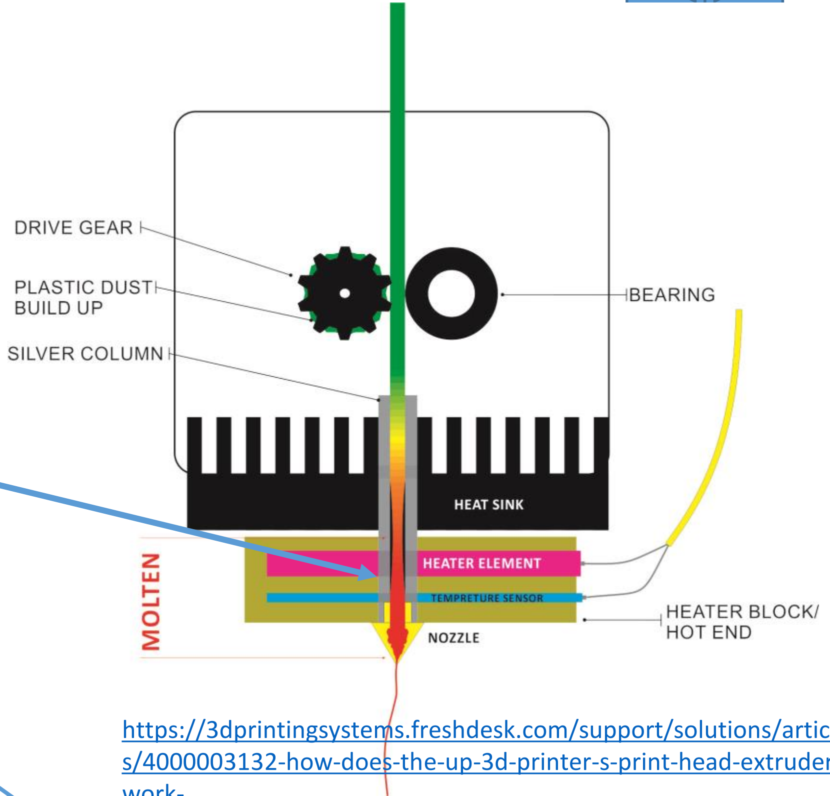
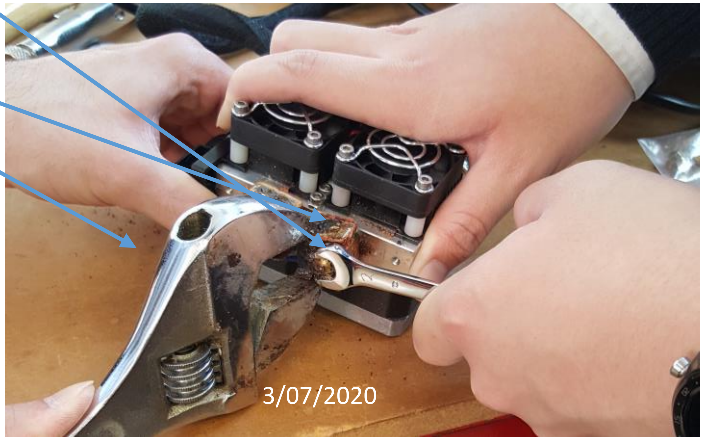
3D Printer Maintenance

More printer maintenance was required, with the root cause located as the extruder head being clogged, hence the issue was at:

I used a spanner of the appropriate size to unscrew the printer head. A large spanner was needed during this operation, as rotating the printer heads could cause damage to the heater block if not held steady. Hence I worked with a fellow engineering student to remove the printer head safely.



https://3dprintingsystems.freshdesk.com/support/solutions/articles/4000003132-how-does-the-up-3d-printer-s-print-head-extruder-work-



Continue

3D Printer Maintenance

As the printer heads were clogged, we tried to initially use a heat gun to attempt to soften the plastic for removal.

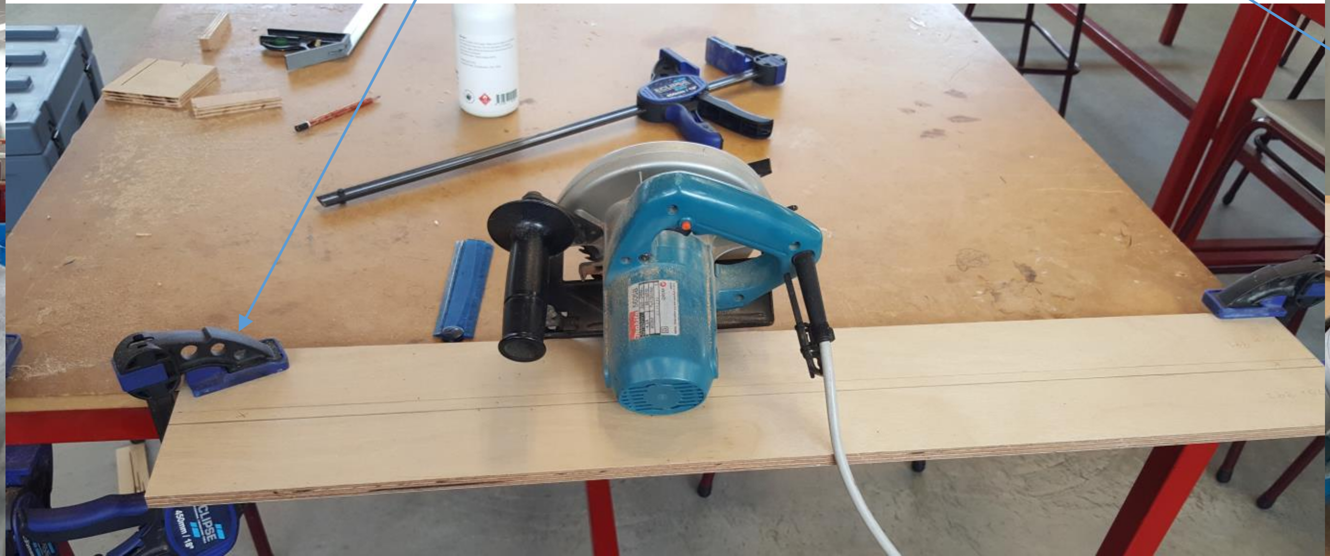
After these attempts failed, I left the components in some acetone to soften the plastic. Afterwards, I successfully used thin needles to extract the plastic from the printer heads.
Hence the 3D printer was fixed and the components were recovered, rather than thrown away. Although I could have simply thrown those components away and replace them with new parts, it is not sustainable to the environment and financially to do so, especially when the fix was not overly time consuming.
Following this, the project was benefited as I could use the 3D printer to develop quality components.
PPE including gloves (as photographed) and goggles to protect myself from acetone. Similarly, I conducted myself in a wide, ventilated room to eliminate risk relating to the acetone fumes.

OH&S Requirements

As these photographs indicate, I use the proper PPE when operating. Furthermore I use clamps where appropriate to hold the wood in place.
While using machinery, I demonstrate proper and safe conduct particularly by keeping my body parts away from the blade. Hence I could conduct myself with minimal risk to myself and others. My prior research of the relevant risk assessments and processes is essential to do so.


1-06-2020


10-7-2020


10-7-2020


3-06-2020


10-7-2020

Production of Prototype

PVC Construction
Gantry Construction
Rocket Construction
Programming

Maximising Efficiency and Time

Using the work plan as a guide, I made a new page on my OneNote before each lesson with a specific list of a variety of tasks to complete. While not all of these task are completed, I used these tasks to promptly work as soon as I got into the classroom. Similarly, to minimise thinking, I included what 3D prints were a priority and prepared their files beforehand so that the time spent using the 3D printer was minimised, providing more time for other tasks such as using the circular saw.

11/06/2020
17/06/2020
18/06/2020
19/06/2020
22/06/2020
23/06/2020
25/06/2020

11/06/2020

Tuesday, 9 June 2020 3:29 PM

- [x] Mark dimensions of gantry on wood
- [ ] Cut the wood
- [x] Get angles for gantry too!
- [x] Bring superglue for spikes
- [ ] Buy remaining PVC parts - 1 last part
- [x] Design PVC strain relief structure
- [ ] Print structure
- [x] Print gears

3D Prints

1. Print fin
2. Print support structure
3. Find wood

17/06/2020

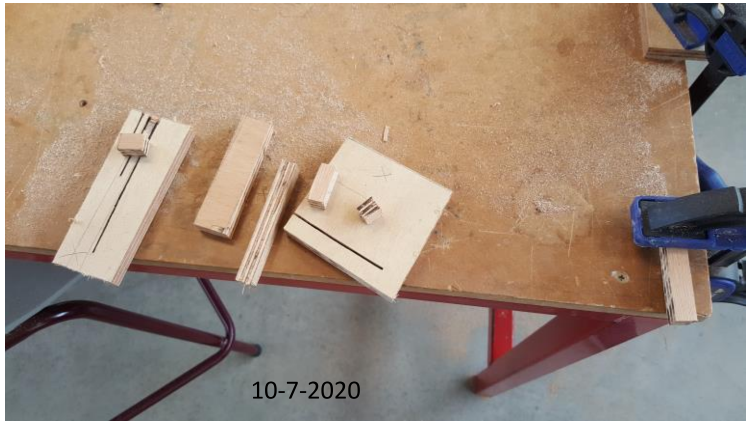
Thursday, 11 June 2020 10:35 AM

- [x] Use appropriate size drill bit to slightly expand the hole of the pinion
- [x] Secure gear to stepper motor
- [ ] Clamp wood to bench
- [ ] Prepare myself safely to use circular saw - goggles, ear muffs, mouth mask, remove tie and blazer
- [ ] Have cloth handy to promptly clean up dust
- [ ] Cut wood with circular saw, remember cut on X side
- [ ] Use sandpaper to clean wood and remove splinters
- [ ] Drill small holes then put screws in to secure base to support
- [x] Print gear rack!!
- [ ] Print tests 2mm and 3mm fins with modified settings; ensure cover is on!
- [x] Needs some screws for connecting supports to base; 8mm long ideally; 8x
- [x] Screws for baseplate to support; 20 to 25mm long; 4x
- [ ] Print fins with PLA as ABS is more prone to warping

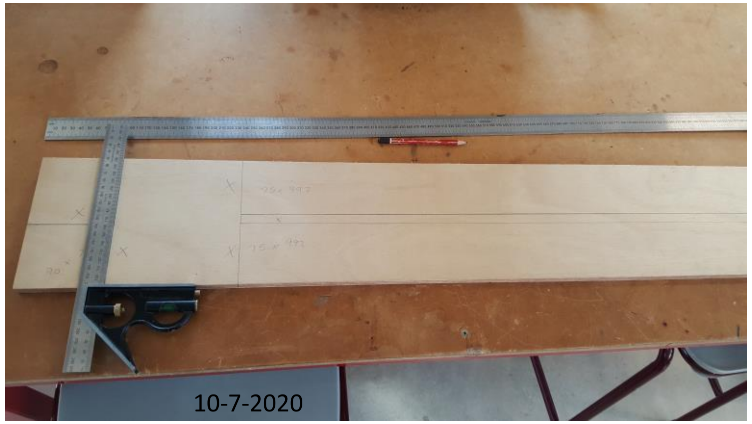
Wood done in this lesson

Over weekend to prepare for lesson find the steel angle brackets and a replacement SD card
Furthermore, continue with the prints for the gantry and hope to fit some in for the rocket

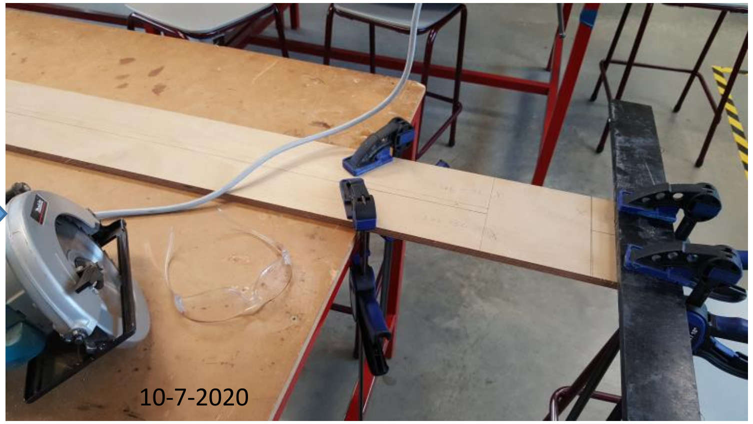
Gantry Construction



As this was my first time operating the Circular Saw, I used scrap pieces of wood to practice and improve my skills so that the gantry wood was cut well.



Measured and marked out using a ruler and square ruler



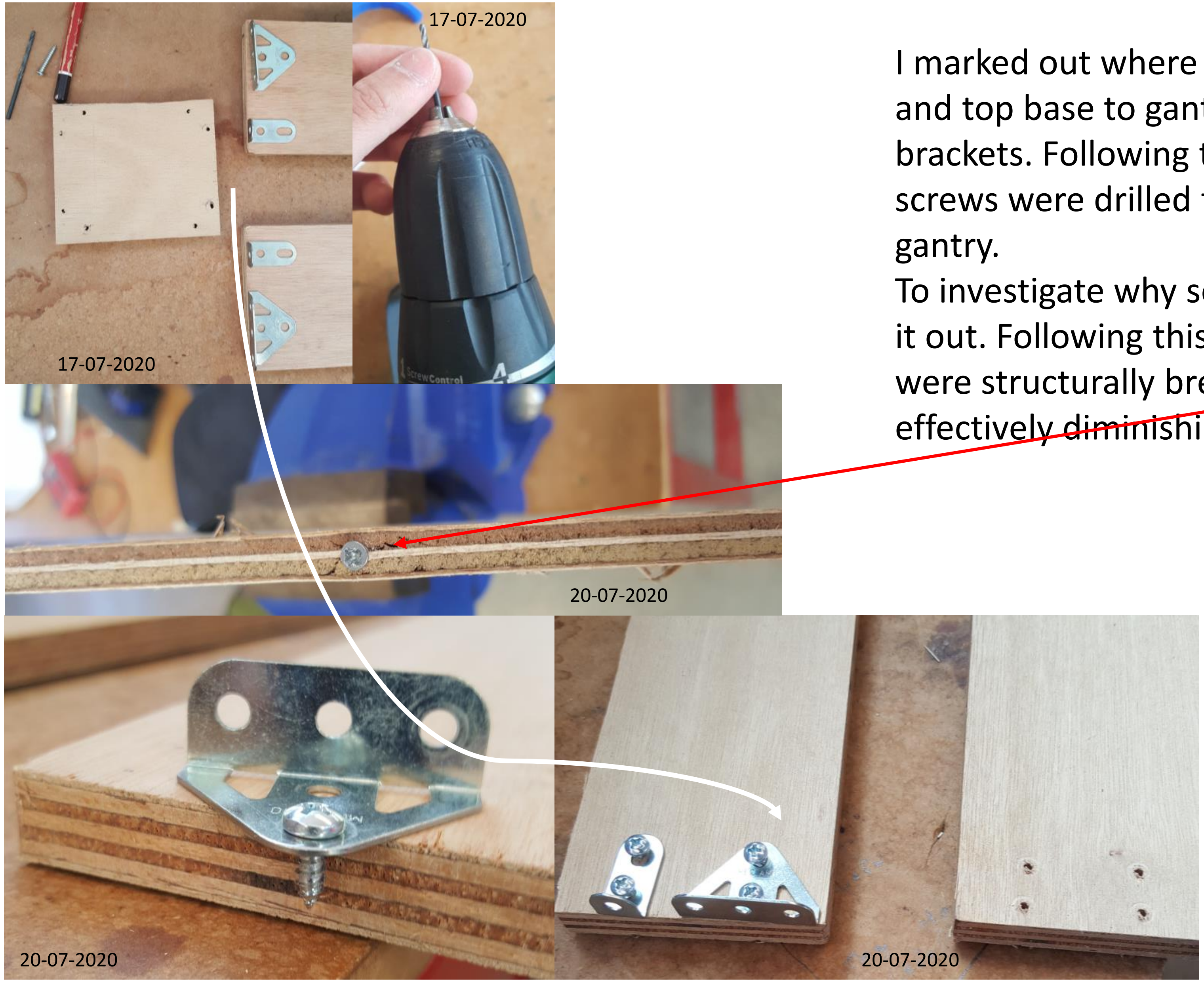
Clamped wood and clamped railings to guide the Circular Saw

Similarly, wood was clamped but here no railings were used.

After completion, I ensured to clean and sanitise my workspace.

Continue

Gantry Construction



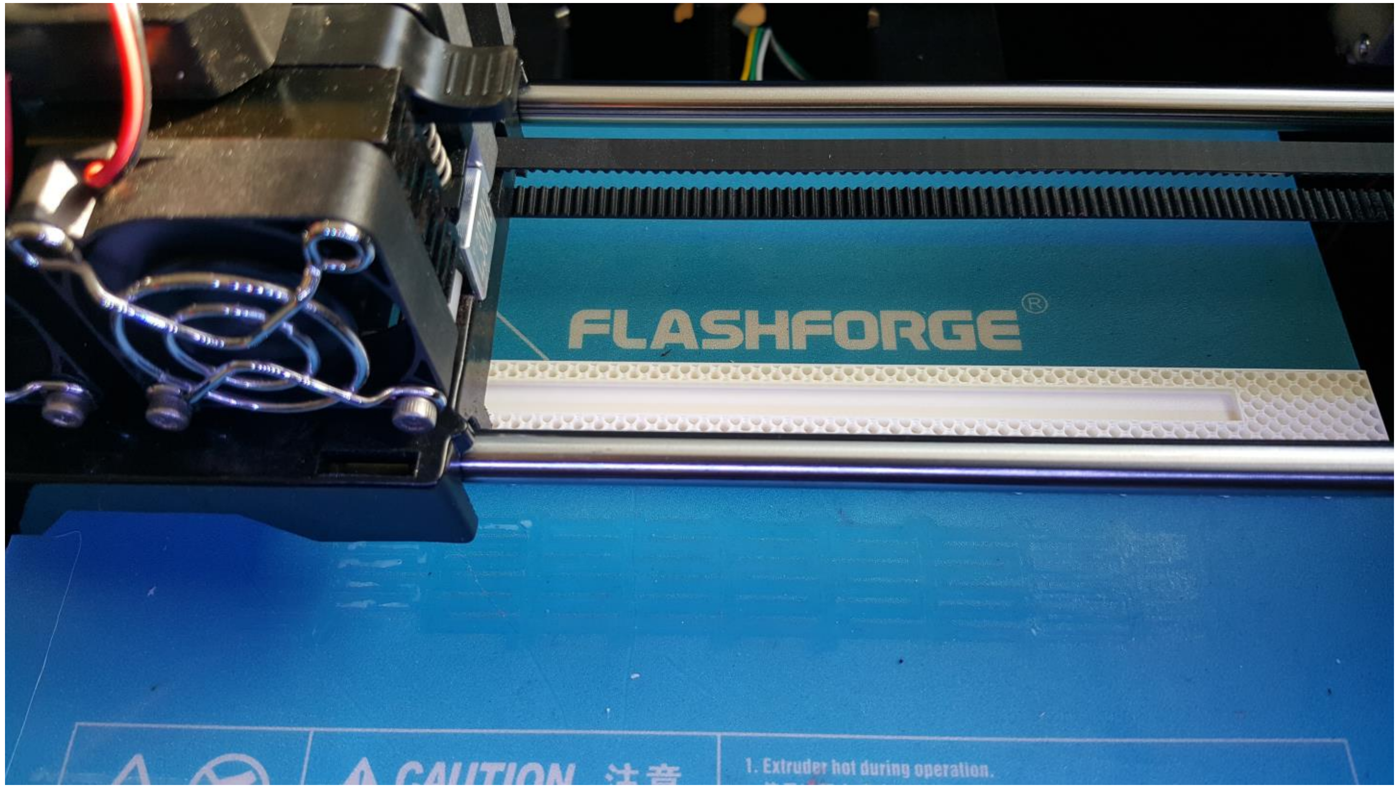
I marked out where the screws will go for the crane supports and top base to gantry supports, as well as for the right angle brackets. Following this, as the photograph demonstrates, the screws were drilled to fasten the right angle brackets to the gantry.

To investigate why screwing between the layers is wrong, I tried it out. Following this, I observed how the layers of the test piece were structurally breaking. Hence I realised the screw was effectively diminishing the structural integrity of the plywood.

From the experience I gained during the project, I would now prefer to operate the drill with a lower torque setting. Doing so can ensure that the screws are drilled with more skill (i.e. screws are less damaged by the drilling). However I am glad I did not drill the screws tightly until the position of the brackets was confirmed.

Continue

Gantry Construction

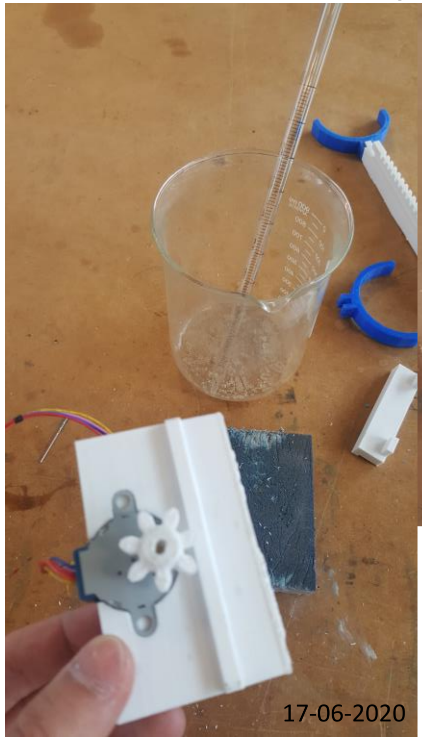


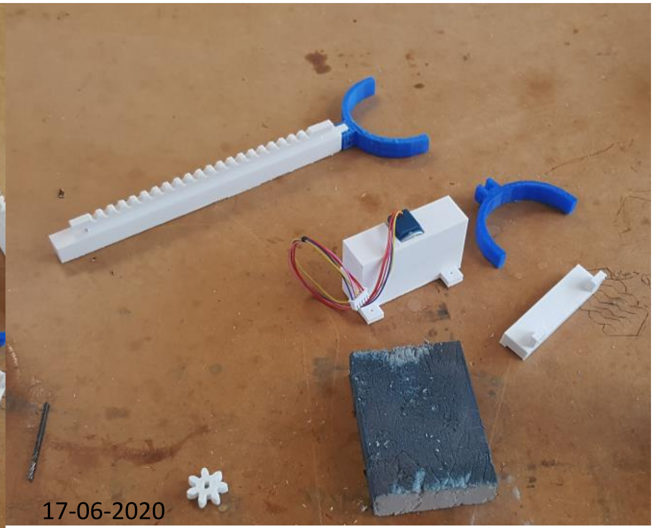
The gantry parts were 3D printed.
I consistently used white filament as I felt it made the component look more elegant.

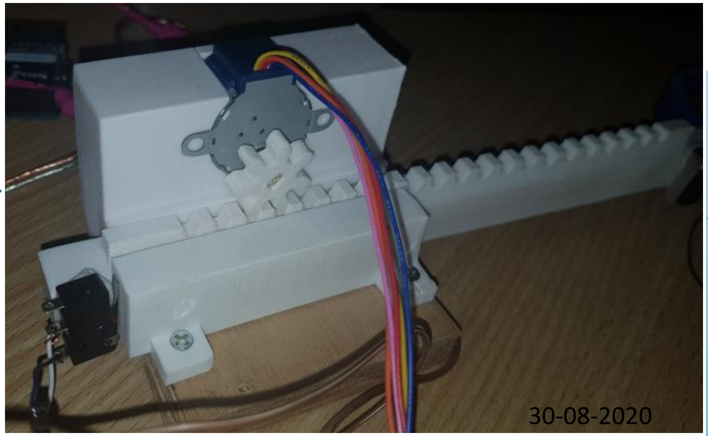
The component being 3D printed in the photograph was the crane / arm.
As the photograph reveals, the component has a honeycomb infill. I would not use 100% infill since even 10% infill provides sufficient strength. Furthermore 100% infill would consume more filament and the consume would be heavier, adding to the work required for the stepper motor to slide the arm.

Continue

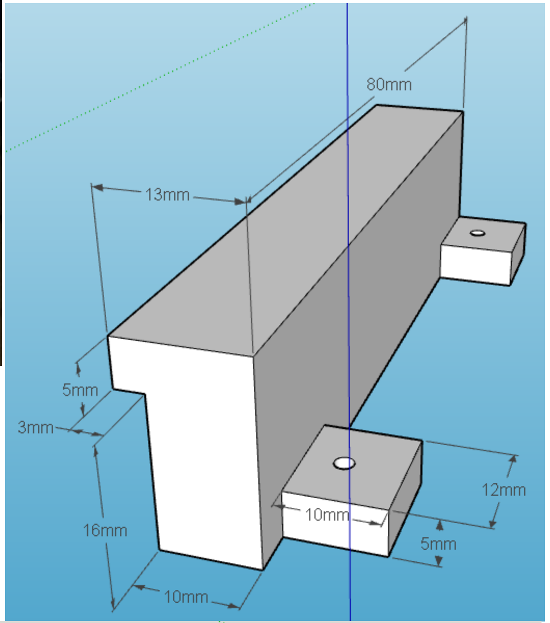
Gantry Construction







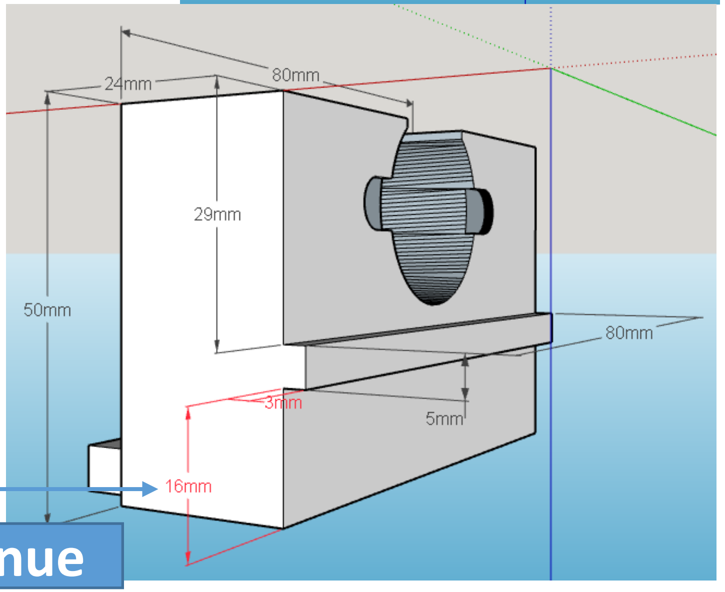
Crane Support



The 3D printed components of the gantry printed well. Unfortunately, the hole in the pinion was too narrow to properly fit on the stepper motor, even after using acetone to soften the plastic, so I reprinted the gear with a slightly larger hole.

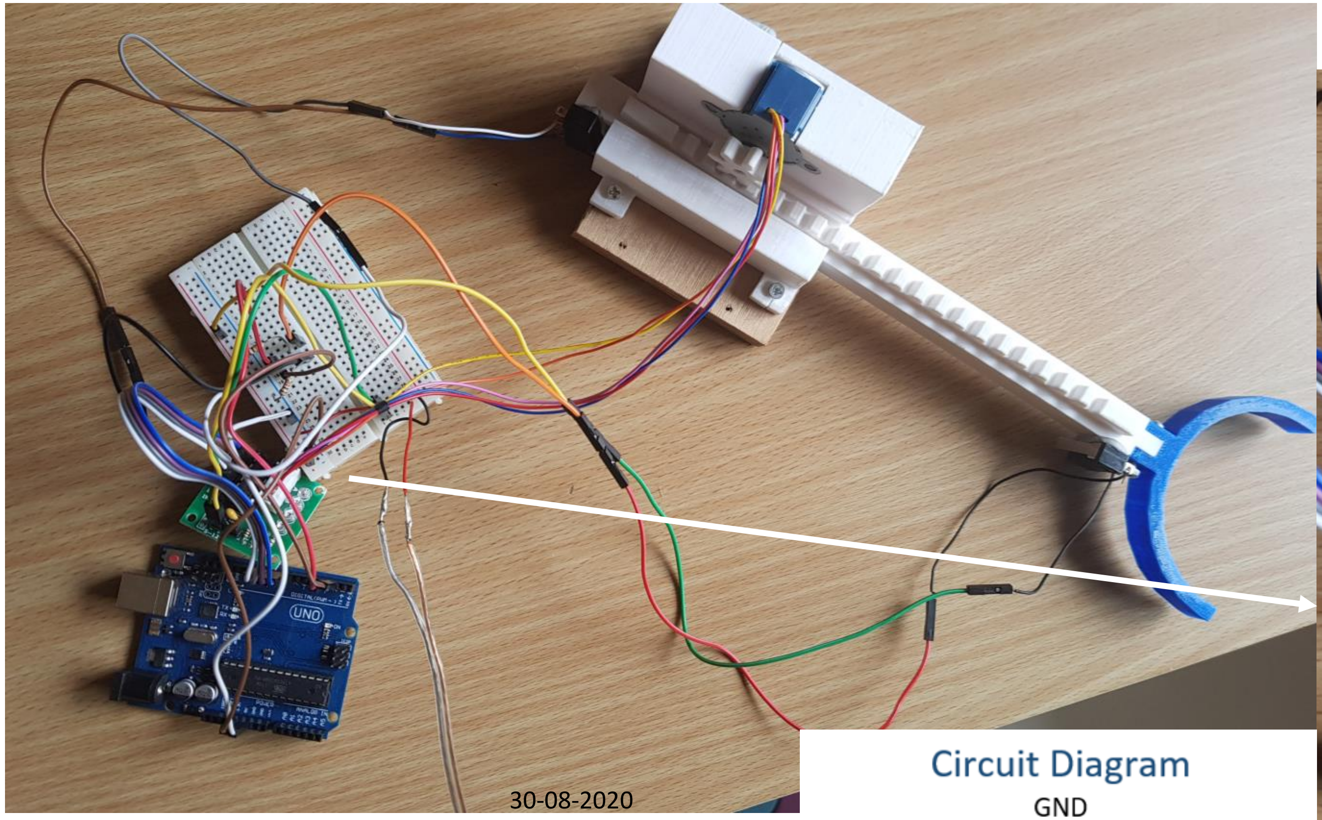
Another concern was that, despite sanding, the crane did not smoothly slide. I realised the crane's supports were pressuring the crane and restricting the movement. Consequently, I added 1mm to the height of the lip of these supports to provide adequate space for the crane to freely slide.

I proudly secured the crane's claw to the crane. This design functions flawlessly and the holes aligned, allowing for the bolts and nuts to fasten the claw to the crane easily. The component was printed separately due to the dimension restrictions of the 3D printer lacking the needed length. This aspect was efficiently produced without error, so I was satisfied I went with passive clamping rather than active clamping.

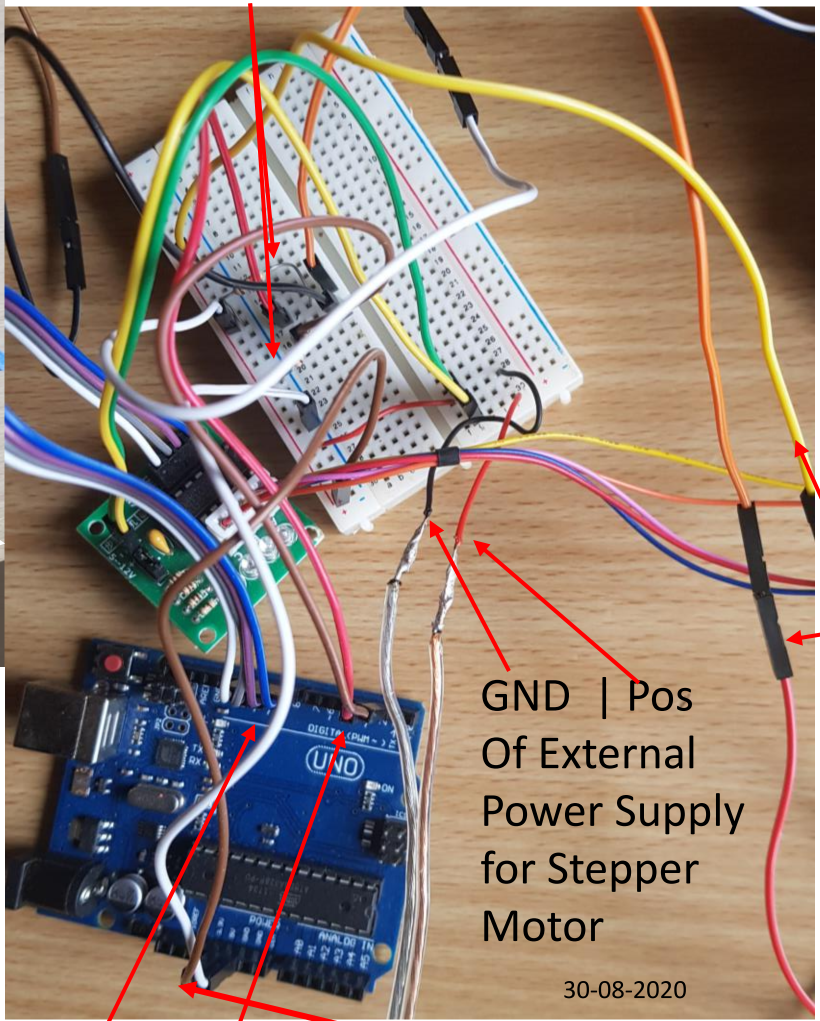


Continue

Gantry Construction

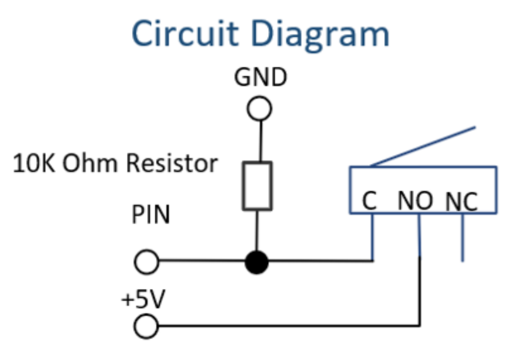


10 kΩ +/-5% resistors



NO; COM of limit switch

GND | Pos Of External Power Supply for Stepper Motor



The circuitry of the gantry subsystem had no problems; I followed the designed circuitry for the limit switches. The wires connecting to the limit switches were extended to ensure they were not strained as the crane extended and retracted.

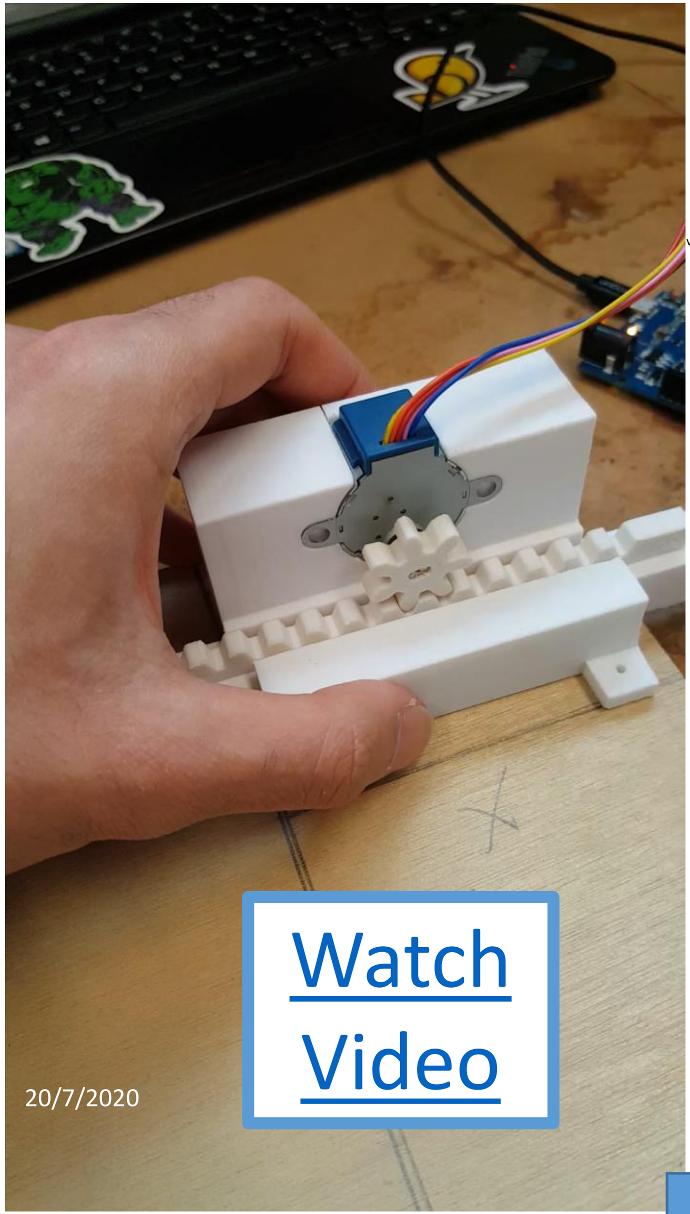
Continue

Stepper Motor Pins
Limit Switch Pins

Brown: 5V
White: GND

Gantry Construction

#include <Stepper.h> using the default stepper library: failed to operate the stepper motor. While the stepper motor had electricity running through it, the library did not produce a turning effect. Instead, I successfully programmed the stepper motor operation manually, which was the quickest solution as there were not many support articles on situations like mine but I did investigate tutorials on operating the stepper motor manually.



Watch Video

20/7/2020

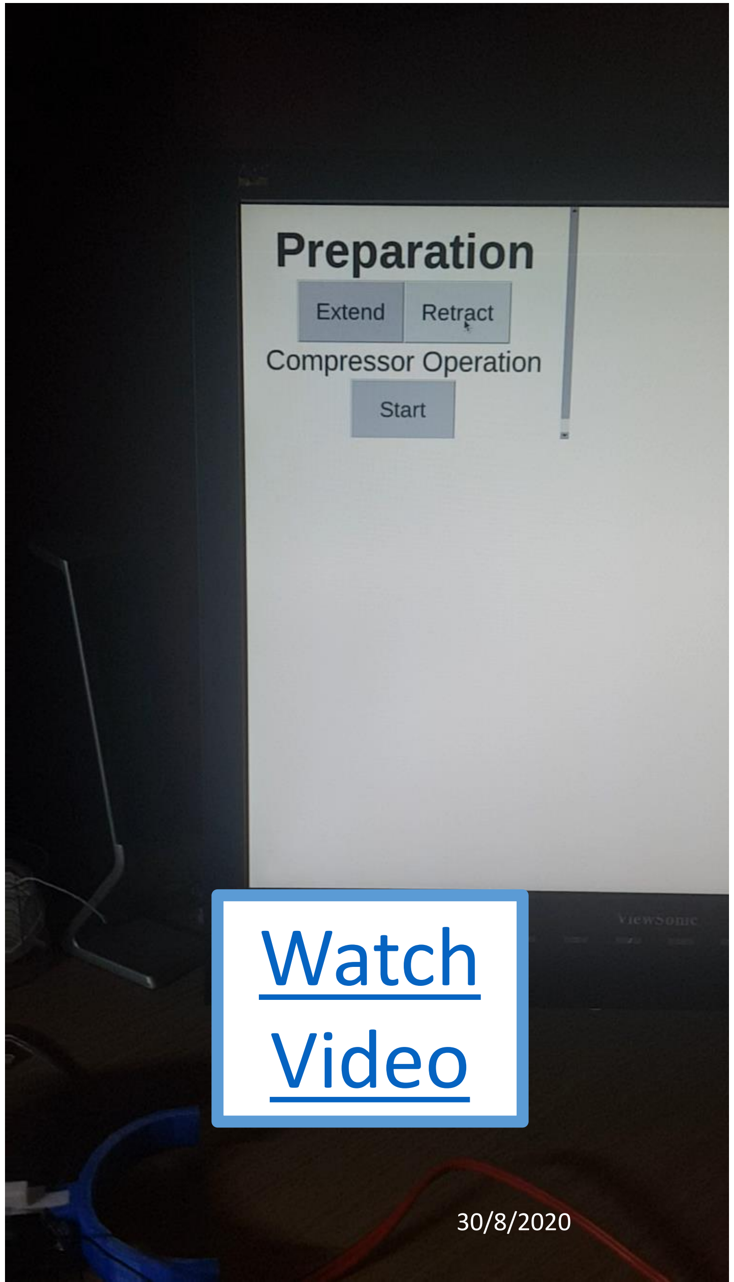
```
void OneStep(bool dir){
 if(dir){
  switch(step_number){
   case 0:
    digitalWrite(STEPPER_PIN_1, HIGH);
    digitalWrite(STEPPER_PIN_2, LOW);
    digitalWrite(STEPPER_PIN_3, LOW);
    digitalWrite(STEPPER_PIN_4, LOW);
    break;
   case 1:
    digitalWrite(STEPPER_PIN_1, LOW);
    digitalWrite(STEPPER_PIN_2, HIGH);
    digitalWrite(STEPPER_PIN_3, LOW);
    digitalWrite(STEPPER_PIN_4, LOW);
    break;
   case 2:
    digitalWrite(STEPPER_PIN_1, LOW);
    digitalWrite(STEPPER_PIN_2, LOW);
    digitalWrite(STEPPER_PIN_3, HIGH);
    digitalWrite(STEPPER_PIN_4, LOW);
    break;
   case 3:
    digitalWrite(STEPPER_PIN_1, LOW);
    digitalWrite(STEPPER_PIN_2, LOW);
    digitalWrite(STEPPER_PIN_3, LOW);
    digitalWrite(STEPPER_PIN_4, HIGH);
    break;
  }
 } else {
  switch(step_number){
   case 0:
    digitalWrite(STEPPER_PIN_1, LOW);
    digitalWrite(STEPPER_PIN_2, LOW);
    digitalWrite(STEPPER_PIN_3, LOW);
    digitalWrite(STEPPER_PIN_4, HIGH);
    break;
   case 1:
    digitalWrite(STEPPER_PIN_1, LOW);
    digitalWrite(STEPPER_PIN_2, LOW);
    digitalWrite(STEPPER_PIN_3, HIGH);
    digitalWrite(STEPPER_PIN_4, LOW);
    break;
   case 2:
    digitalWrite(STEPPER_PIN_1, LOW);
    digitalWrite(STEPPER_PIN_2, HIGH);
    digitalWrite(STEPPER_PIN_3, LOW);
    digitalWrite(STEPPER_PIN_4, LOW);
    break;
   case 3:
    digitalWrite(STEPPER_PIN_1, HIGH);
    digitalWrite(STEPPER_PIN_2, LOW);
    digitalWrite(STEPPER_PIN_3, LOW);
    digitalWrite(STEPPER_PIN_4, LOW);
  }
 }
 step_number++;
 if (step_number > 3) {
  step_number = 0;
 }
```

The gantry program is long, but here is an explanation of how it works:

- I define all the variables
- In Setup, I declare pinModes (limit switches are Inputs and Stepper Motor is outputs). Also starts Serial Communication
- Function Calibrate starts the Stepper Motor to move the gantry to the extended position until the limit switch is activated, indicating it is done
- Function goRight starts extending the gantry and sends the expected ETA of completion using the number of steps required and time difference between each step
- Function goLeft instead retracts the gantry
- Function stepperMotion checks the limit switches, if motion is complete, and takes one step in the necessary direction
- The loop calls stepperMotion, then checks for new commands from the Serial Communication
- Function aStep considers the time elapsed between now and the last step to determine whether it is time to take the next step. This method, rather than using delays, encourages the program to read and take action to new data from Serial Communication rather than waiting at delays
- Finally OneStep takes an Boolean argument which determines the direction of rotation. Furthermore, the step number is updated and kept within 0 to 3.

Continue

Gantry Construction



Watch Video

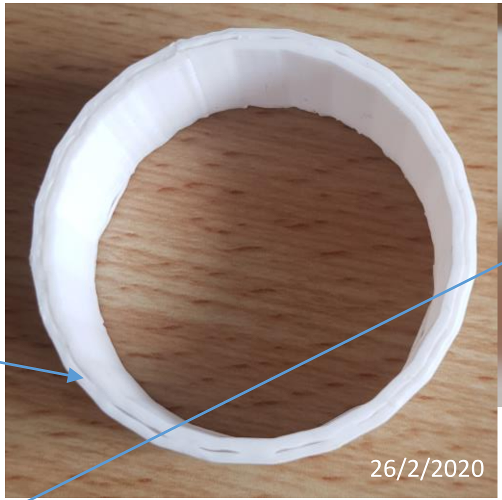
Using Python Tkinter with a button, the program uses Serial Communication explored later to communicate to the Arduino code explored earlier to respond.

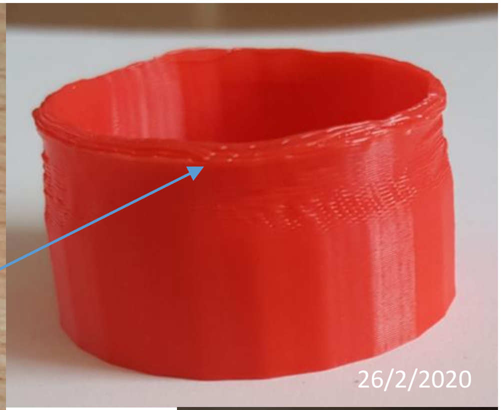
The gantry slowly moves to emphasise the mechanical operation and programming regarding the limit switch. As the limit switch encounters the plastic component, the switch clicks and the microcontroller reads the limit switch to realise that the gantry is at the final position. Hence encourages the use of the initial design and of using the stepper motor rather than the servo, considering that the gantry can extend or retract and provide support to the rocket without damaging through over extension.

Success. The user interface's big buttons are user friendly, especially when operating on the touch screen. Furthermore the responsive nature of the user interface was satisfying. Hence supports the initial fundamental concept of the user having control over the prototype to perform actions, such as moving the gantry.

Rocket Construction

The first step was to determine the minimal width of the pipes, while having a strong component.
I tested and observed that too thin and the plastic does not bond together properly, indicating that the component is structurally weak and could break after some usage.
Furthermore perhaps due to the colour difference of the filament, I noticed that red filament was more prone to warping than white filament. Note that the filament for the structure components of the rocket was ABS as ABS has higher impact strength and is less dense, reducing the weight.
Ultimately, I concluded with the ideal settings and produced the perfect components that balanced the thickness and strength with the weight.
Although this took some trial and error, it was well worth the effort to explore the ideal settings. The process was made quicker from the initial research, as I understood how varying the settings impacted the trialled component printed. Furthermore I had an insight to the recommended settings for the filament.





Continue

Rocket Construction

Material	Minimum Wall thickness	Infill	Shells	Layer Height	Build Plate Temperature	Extruder Temperature	Speed Extruding	Speed Traveling
ABS	3mm	20%	1	0.2mm or 0.1mm for some prints (e.g. nose cone - curvy)	110 °C	230 °C	75 mm/s	100 mm/s

Material

ABS is lighter than PLA, meaning the rocket's weight can be minimized to maximize the acceleration of the rocket Furthermore, ABS is more durable and has four times higher impact resistance according to this source although the print time may be slightly longer as ABS requires higher temperatures.
Another consideration is that PLA is biodegradable unlike ABS, however ABS can still be recycled.

Temperature

Considering the research, ABS requires a build plate within 90 °C to 110 °C, so 110 °C is adequate. Similarly, the extruder temperature should be 210 °C to 250 °C so 230 °C is appropriate.

Minimum Wall Thickness, Infill, Shell, Layer Height

The combination of settings, with infill 20%, wall thickness 3mm and shell 1mm, prints a strong yet light model rocket with the consideration of print accuracy.
The layer height is generally 0.2mm to print quality parts in a timely manner. At times 0.1mm will be used, for instance for the nose of the rocket, as some parts require extra detail to ensure a quality print.

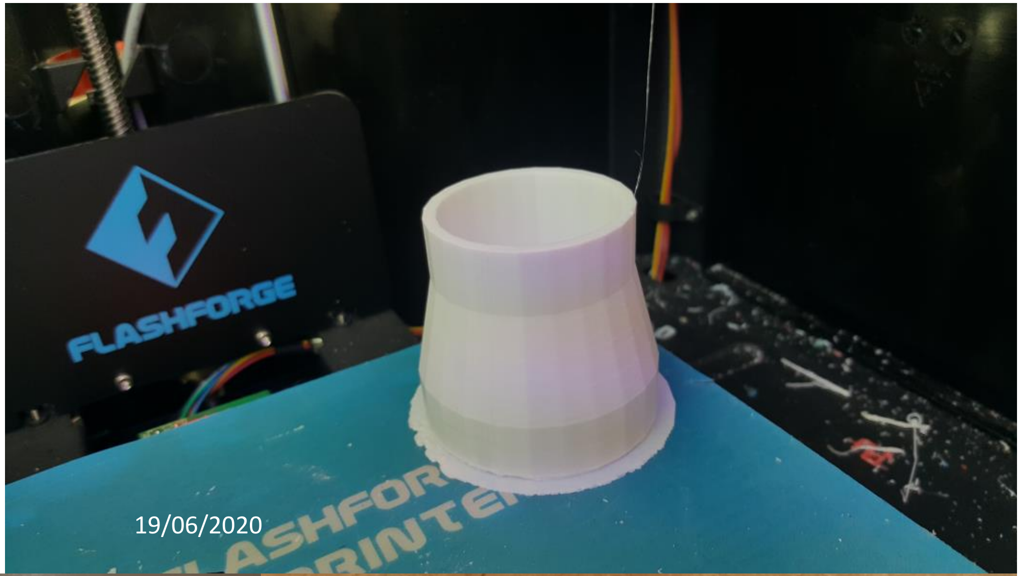
Speed

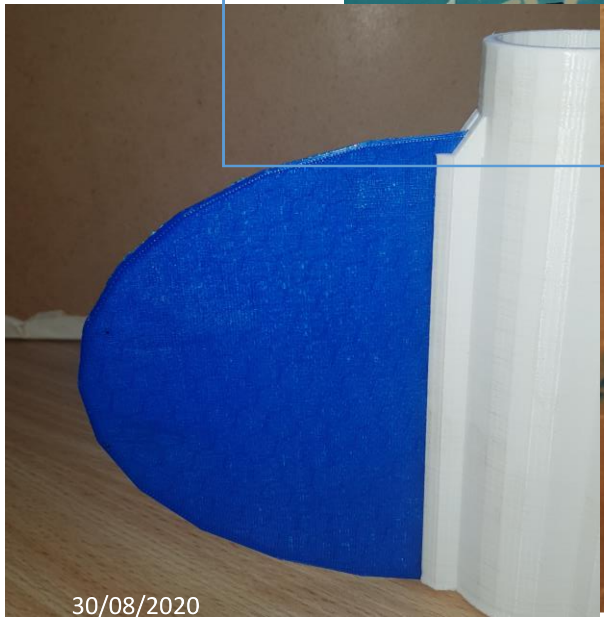
The speed settings used were tested and found they were ideal to print in a timely manner while not leading to issues including insufficient cooling or layer misalignment

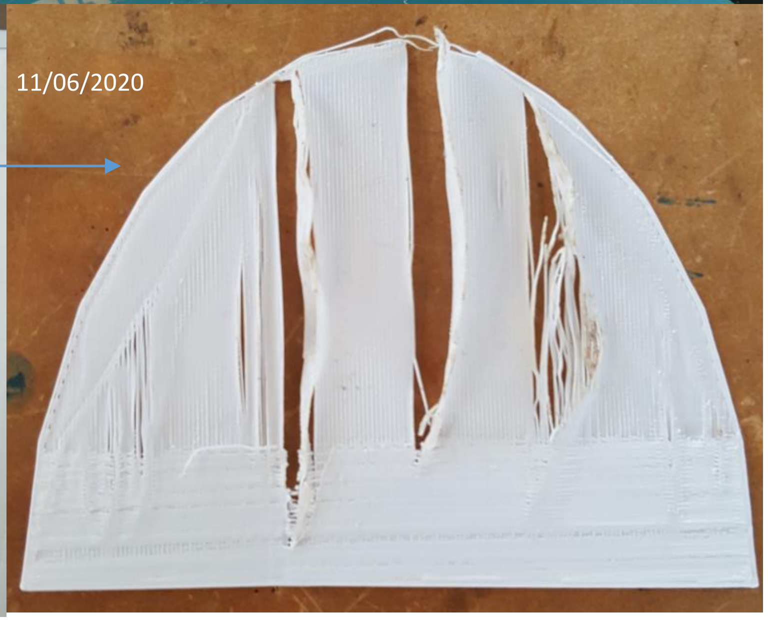
Continue

Rocket Construction

While the rocket's expanding connection printed smoothly with the curves to minimise air resistance, the fin did not print well.
As the fin is so thin and has a high surface area, warping likely lead to this outcome.
Instead, I changed to blue PLA and increased the thickness by 1mm. As the photograph reveals, the fin printed perfectly. The thickness was spot on, allowing the fin to tightly fit in the gap of the rocket's body connector as designed.
Using acetone, the plastics can be fused together to make the component one. However, such a complex component could not be printed as one particularly due to the size restrictions of the 3D printer. Hence I stand by my design to fit the fin within a groove to connect it to the rocket.



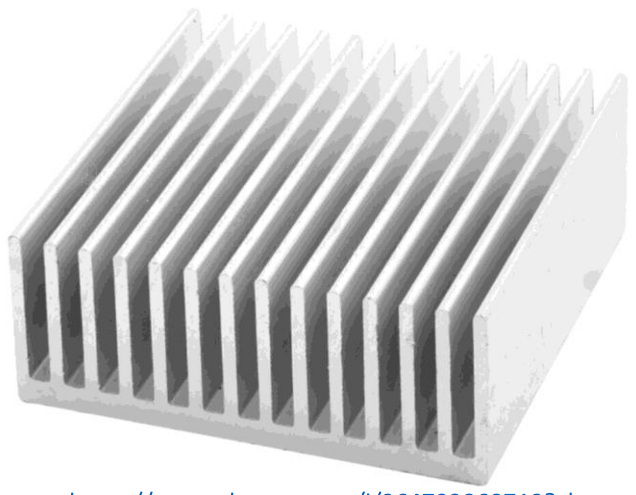




Continue

PVC Construction

Early on in the production stage the compressor was tested through the diagnostic testing. As the experiment revealed, I felt it was dangerous for the compressor to run for more than 700s, due to overheating. Consequently, I decided to source additional heat fins to increases the surface area of the fin indicating that the rate of heat transfer increases. Moving on, I focused on sourcing and preparing the PVC pipes and attachments for the construction. I was delayed and had to continue to working on other aspects of the prototype, as I suffered unexpected delays in component receival. Bunnings took almost a month longer than their initial ETA of a special elbow not stocked in stores, while the pressure transducer took 3 months to arrive. Worst of all, I gave up on waiting on the Schrader valve to arrive from China so I locally sourced the component at double the cost. However, this decision is justified by the fact that this allowed me to complete the PVC subsystem in a timely manner, particularly before the second closure. These unexpected delays are primarily a direct or indirect consequence of the pandemic.



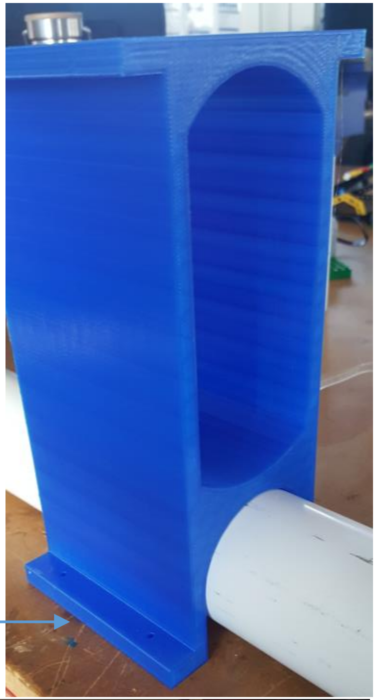
https://www.ebay.com.au/i/264793868713?chn=ps

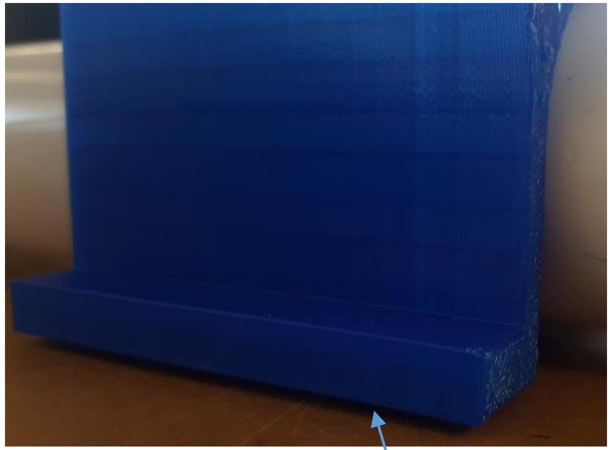
Continue

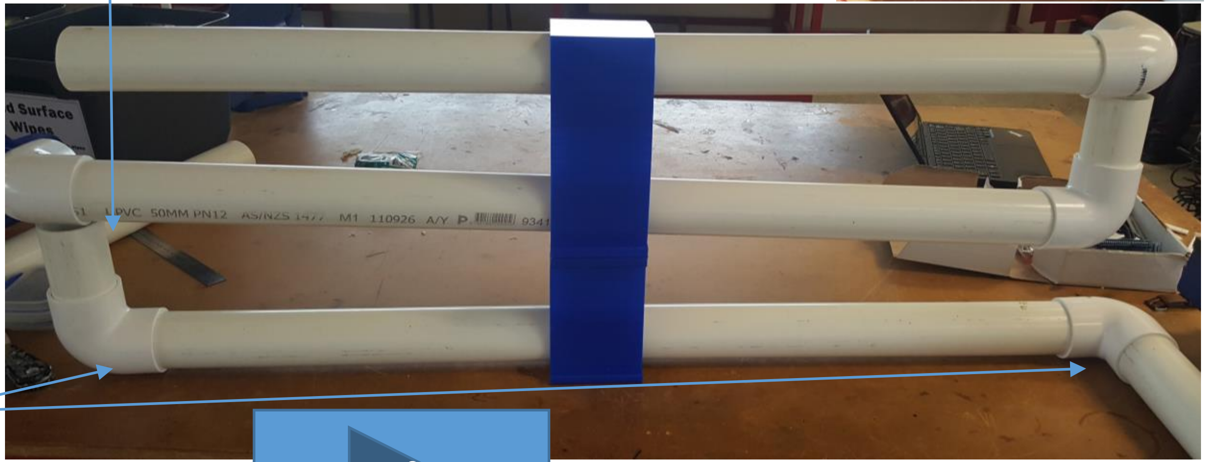
PVC Construction

However, I continued my production efficiently and eventually collected all of the components. While waiting, I performed a test fitting of the PVC available and realised my 3D printed component had been inaccurately designed.

While the initial design was flawed, I simply (and quickly) modified the design in my own time at home and reprinted the relevant components while working on other aspects. Testing the new design demonstrated that the pipes align, while the bottom of the PVC strain relief sits on top of the PVC pipe and the base. Hence I efficiently dealt with the design flaw to produce a perfected strain relief structure.







The PVC pipes clearly do not align; I mistakenly designed too much gap for the length of PVC pipe

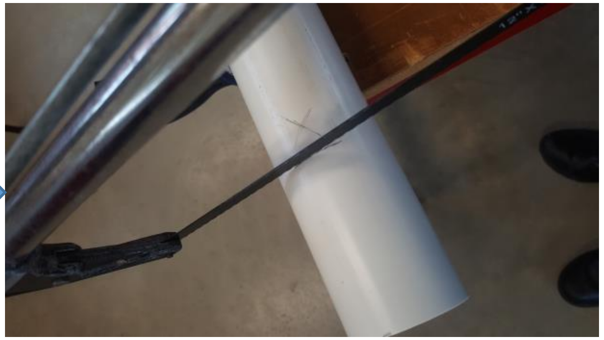
The elevation of the PVC pipe caused by the elbows was not taken into account

Continue

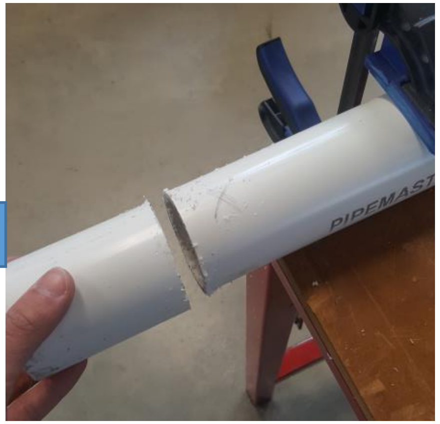
PVC Construction

1. I cleaned the PVC pipes and fittings, paying extra care to clean the threads of any threaded fittings.
2. I carefully operated the drop saw to effortlessly cut the 50mm PVC pipes, saving class time and easing transport to the workshop from home.
3. Following this, I marked out and cut the remaining PVC pipes using the hacksaw at school. This took multiple lessons, but the thinner blade of the hacksaw than the drop saw minimised the loss of the PVC pipe (which needed to be conservative as I required nearly all of the 1m pipe bought)
4. The sandpaper deburred the PVC pipes. Waste went into the bin and the workspace was cleaned.
5. Finally, I had prepared the PVC pipes and fittings for the bonding stage.

1-06-2020



3-06-2020



3-06-2020

3-06-2020

3-06-2020

3-06-2020

Continue

PVC Construction

I used PVC primer and cement to bond the PVC pipes and attachments together, following the correct process of applying primer then the cement. Unexpectedly, the brush to apply the primer was missing from the bottle (unfortunately other students from past years must have misplaced it). Hence I had to improvise on the spot by using some bandage wrapping, a wooden stick and tape to apply the primer. Although this was inconvenient, minimal time was lost due to this situation as I promptly looked for a substitute.

The improvisation was successful and then I applied Teflon Tape to screw the threaded components together, including the solenoid release valve, Schrader valve, pressure relief valve, coupling reducers and pressure transducer. These components were carefully tightened, however, I considered the warnings of many tutorials that overtightening could damage the components and joint. My application of the PVC primer and cement was calmly and confidently performed as I had made notes and steps from researching.

10-07-2020

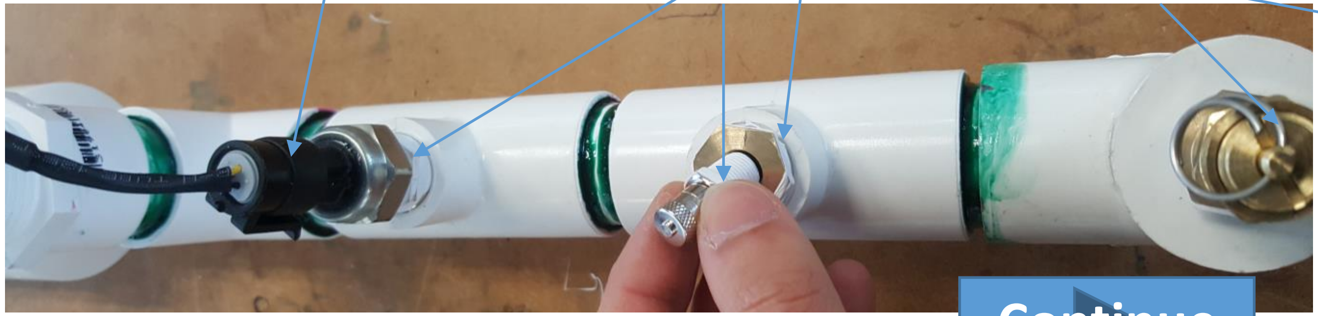
PVC Cement | Primer

6-02-2020

6-02-2020

Brass Coupling Reducer

Pressure Transducer Schrader Valve 150 PSI Relief Valve



16-07-2020

16-07-2020

16-07-2020

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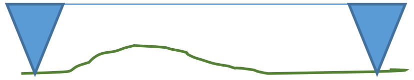
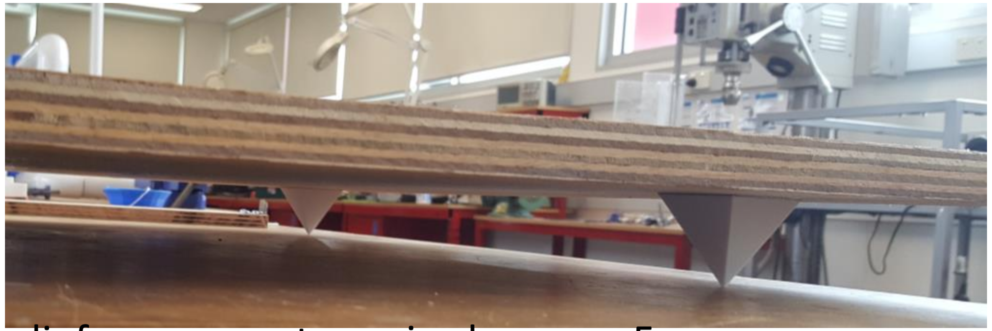
Continue

PVC Construction

Diagram 1



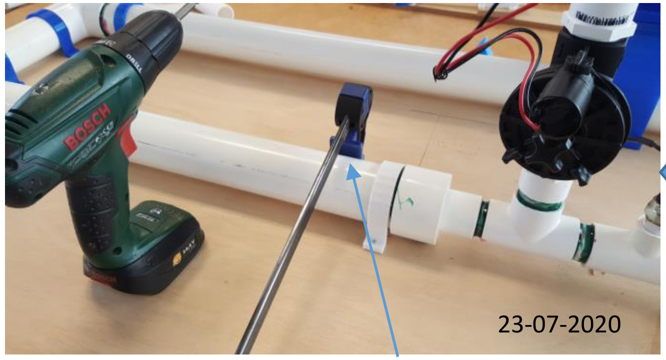
I 3D printed spikes and used super glue to bond them to the base. The concept demonstrated it was successful, as the base was stable and elevated from the ground. Hence during use the spikes will prevent the base from becoming so dirty, minimising annoyance and frustration for experimenters. Furthermore in areas where, overall, the ground is slightly unlevel these spikes can allow the base to be setup horizontally flat and stable, as demonstrated in Diagram 1.



21-07-2020

Holes were drilled using the puncher to indicate where the clamps or strain relief component required screws. From there, I screwed the strain relief component together and drilled the screws into the base to secure the PVC pipes and components to the base. Unexpectedly, a screw broke while I was drilling into the plywood. Although I did make a pilot hole, perhaps it was not deep enough and the torque setting was too high. Hence the remaining screws were drilled with a deeper pilot hole and slower torque setting, to prevent more issues. However at times screwing using the drill was difficult due to not enough room for the drill due to the designed position of the screws. This was fixed by screwing by hand until the drill had enough room to drill on a slight angle, but I wish I initially designed more room for screwing.

23-07-2020

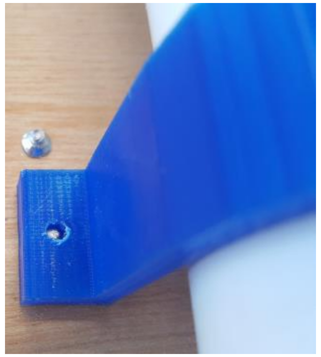


23-07-2020

Clamp straightens PVC pipes while 3D printed clamps were positioned and fastened

23-07-2020

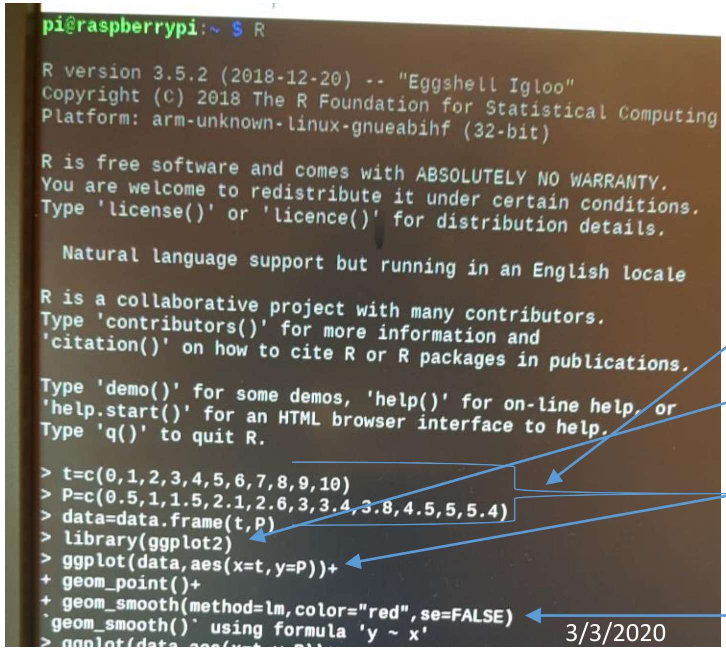
23-07-2020



23-07-2020

Programming R

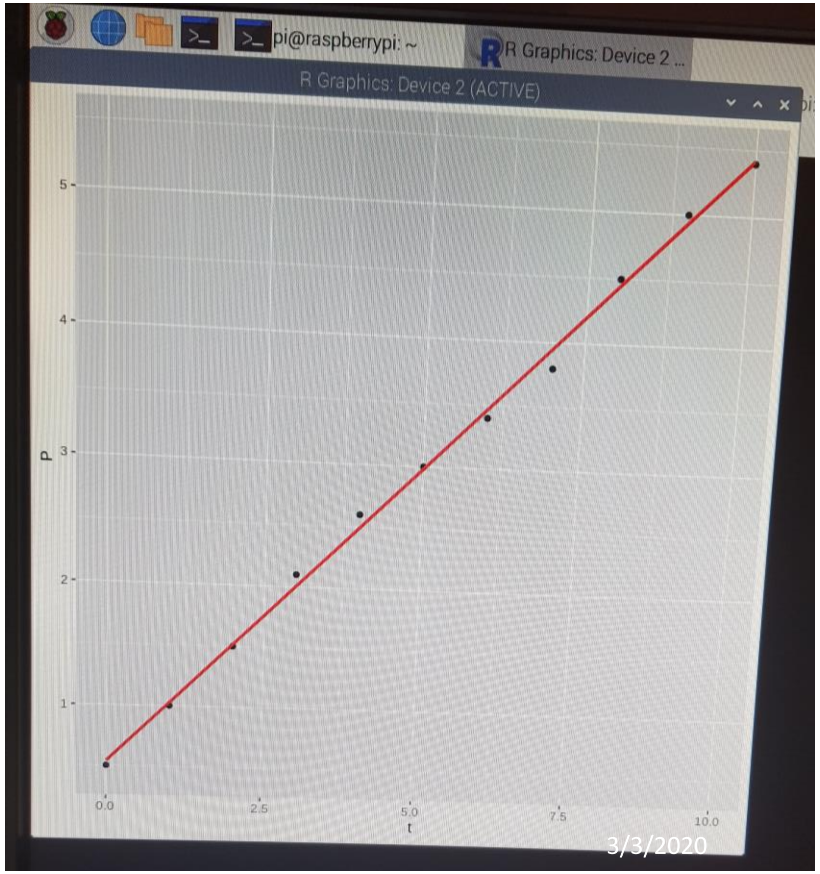
I explored the programming language R, using the Raspberry Pi. R is globally recognised for its uses in data analysis and computation. The inbuilt functions and wide variety of libraries encourage many applications of R. I learnt how to do the basics and if I had more time, I could have used Python to integrate R with the user interface to provide understandable and timely analysis of the flight performance and compression.



3/3/2020

Made a graph of the data and added a trend line

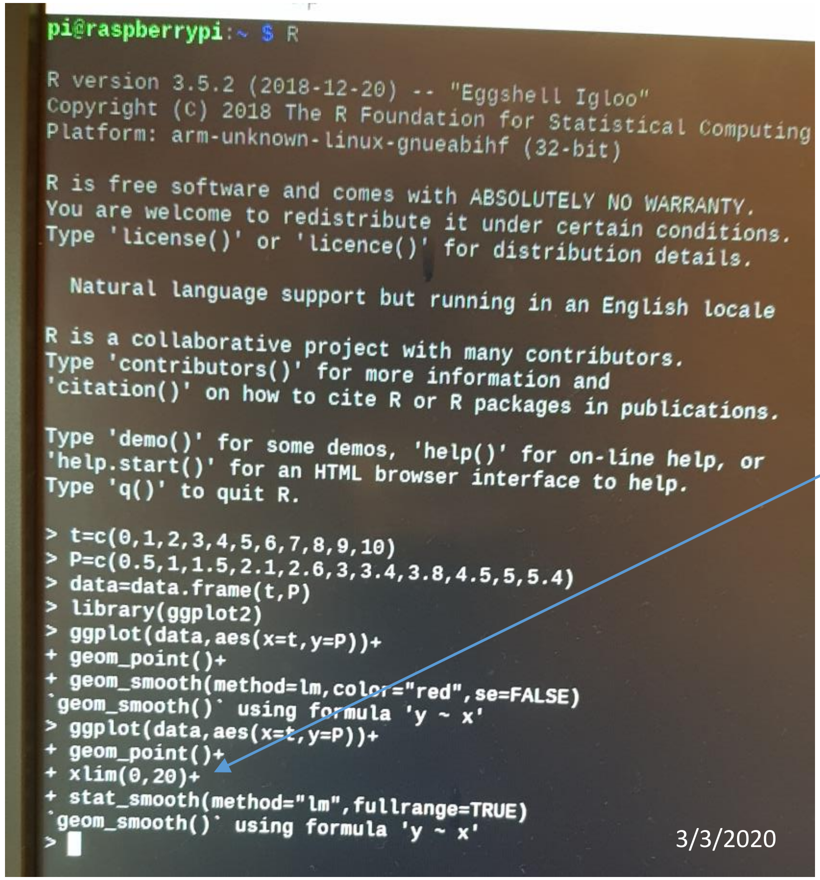
- Made some data to use
- Imported the needed library
- Plotted the data using the appropriate function, declaring which data to use and for what axis
- Geom_smooth() with arguments for the method (linear), red colour and not to display confidence interval around smooth



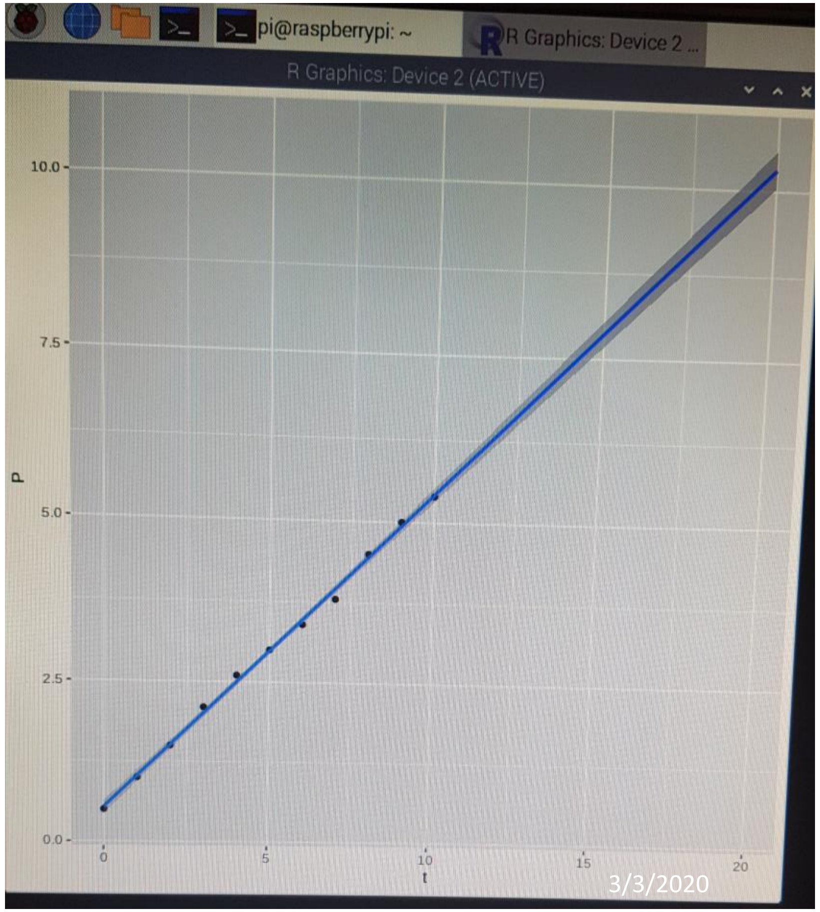
3/3/2020

Continue

Programming R



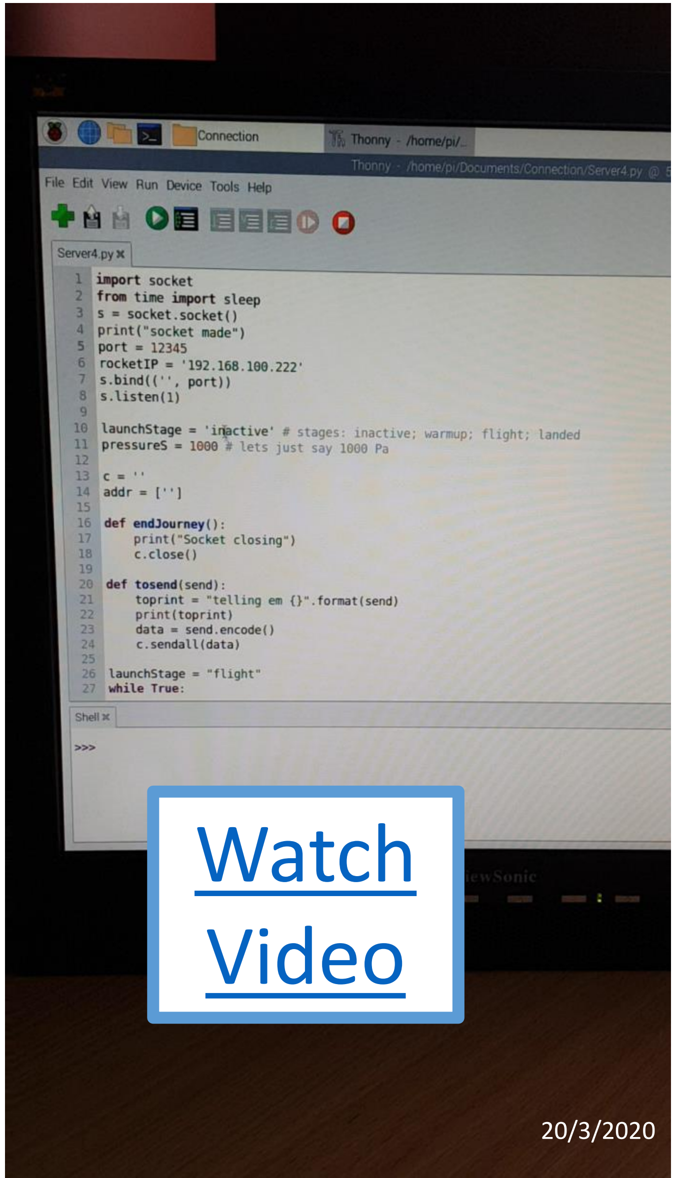
While similar to the previous code, I used xlim(0,20) to force the domain of x to be from 0 to 20. As the data goes from 0 to 10, the trend line effectively predicts the future values with a line of best fit, maximum and minimum (since se by default is true). Also, the trend lines were blue since the colour was not declared (blue is default).



Continue

Programming - Sockets

Server Initialisation



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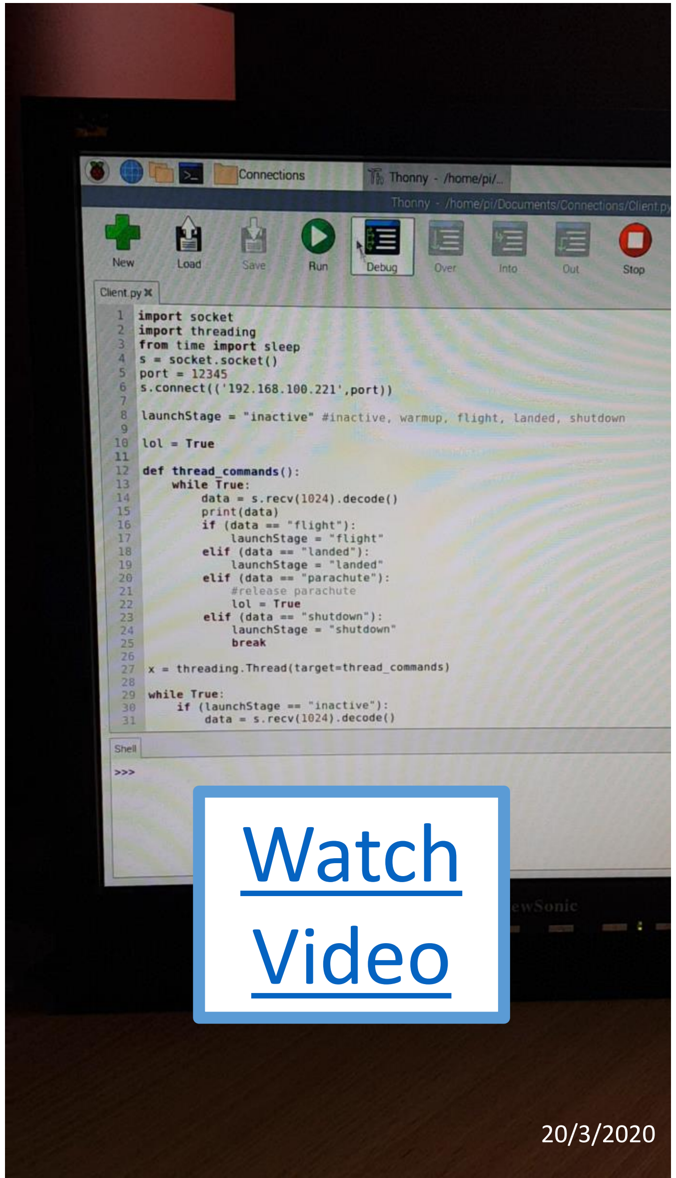
20/3/2020

Client Initialisation (different Raspberry Pi)



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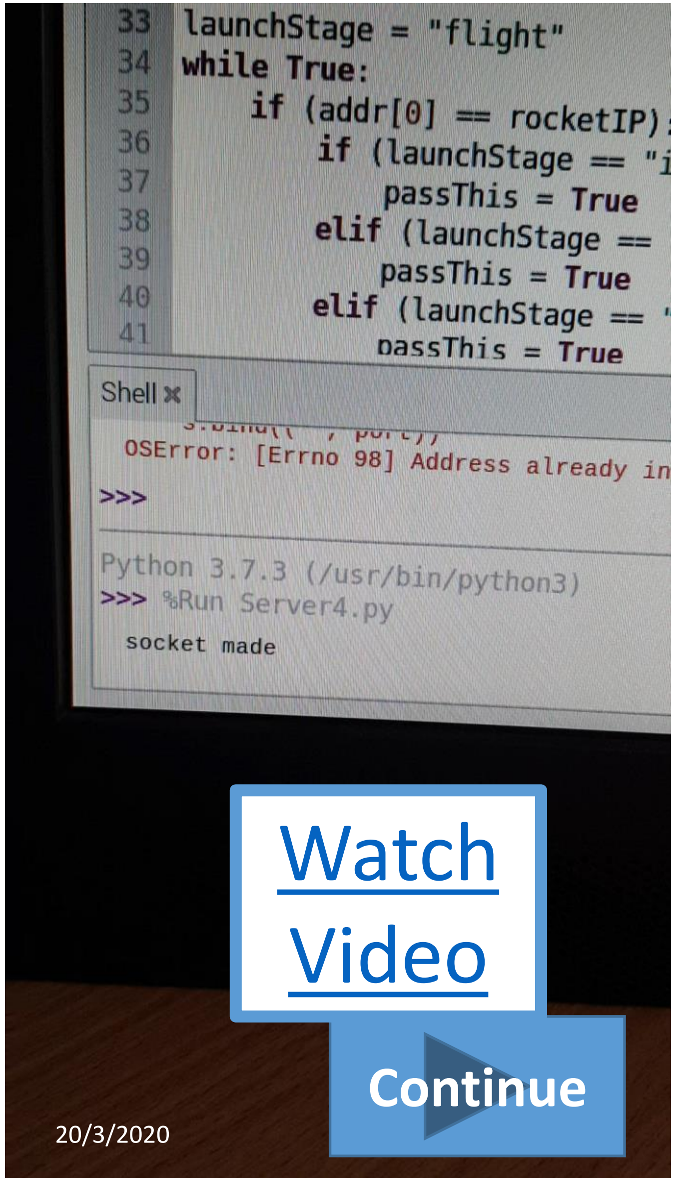
20/3/2020

Server



[Watch Video](#)

20/3/2020

Continue

Programming - Sockets

The server program is here and the client program is here. *Converted from .py to .txt

As the program is extensive, a brief explanation is that the main Raspberry Pi with the screen uses socket programming to communicate with the rocket Raspberry Pi throughout the flight for synchronous data exchange. The programming cannot be done in Mathematica due to a lack of support for sockets, so Python is used. An explanation of the sockets programming is here (server code on the left and client code on the right). The coding was modified to run as a test as the sensors were not available and to focus more on socket programming.

```
import socket
s = socket.socket()
port = 12345
rocketIP = '192.168.100.222'
s.bind(('', port))
s.listen(1)
c, addr = s.accept()
data = send.encode()
c.send(data)
```

Gets the library

Starts the socket

Declares the port and rocket. I used the access point settings to allocate this specific IP addres to the client.

Binds socket to the specific port

Listen tells the socket library to only queue one connection (being the server will only connect to the one client)

Prepares data as variable send for sending

Sends the data

Continue

```
import socket
s = socket.socket()
port = 12345
s.connect(('192.168.100.221',port))

x = threading.Thread(target=thread_commands)

data = "I am flying!{}".format(n)
s.send(data.encode())

s.close()
```

Connects to the server (specific IP address set on access point, same port as server)

I used threading and a “while True:” to continuously check for new data from the server while another part of the client code sends data relating to flight performance

Closes the socket

Programming Serial Communication

```
import config as co
co.ser = serial.Serial('/dev/ttyACM0', 9600, timeout=1)
co.ser.flush()

if (co.ser.in_waiting > 0):
    line = co.ser.readline().decode('utf-8').rstrip()
    print("Pressure: ")
    numb = float(line)
    print(numb)
    if (numb >= pressureS):
        ready = True
        print("Pressurised!")
        launchStage = "flight"
```

Starts Serial communication with Arduino connected by USB

Receives data and decodes the data

Prints the pressure (for testing purposes)

Checks whether the current pressure meets the launch requirements

Summary of Socket Programming and Serial Communication

The Raspberry Pi can communicate with both the Raspberry Pi in the rocket (the client) and the Arduino operating the electronics on the ground.
Hence the user interface can use the Serial Communication to release the pressure and launch the rocket at will (once pressurised logically) and then timely receive the data for computation.

Photograph from Client Pi Camera to Server Pi

23/3/2020

I then made a server program and client program that records that data, including the photographs. While I successfully recorded the data into a spreadsheet, the photograph bytes were too complex to compute as the packets were at times incorrectly processed, resulting in failed photograph file computations. So after much agonizing, the photographs could not be continuously successfully sent through socket programming and had to be locally stored on the client (asynchronous) but one individual photograph using basic programming worked. Similarly, the sensor data was successful. Due to time constraints, I did not have enough time to study bytes and packets and image files to perfect the code and chose the asynchronous method to then focus on more important aspects.

Continue

Programming the Screen

This included studying and testing in Python and Mathematica. I had many difficulties regarding the programming languages, from basic to complex levels. Generally, I would search online to find information such as properties of a text label for Python Tkinter to style and position the label how I would like. At other times, I needed a complex understanding of Mathematica to dynamically run the interface.

Ultimately, I found Mathematica to be inappropriate for the user interface. I found the application lagging at times due to the many dynamics used on the Raspberry Pi. On the other hand, I utilised normal, continuous loops in Python. I felt Mathematica was not suited to make a user interface that could also run continuously in the background, checking for new data from the Serial or Socket communication. Furthermore I realised I needed to use the external languages feature to use Python in Mathematica, as Mathematica's networking socketing does not connect to clients through WiFi but only locally. In doing so, I encountered many problems, primarily the fact that I needed the interface to respond to these communications and that variables in the external language function would not save into the Mathematica root program. While learning is of importance, I should have strategically decided and focused on one user interface sooner to efficiently spend time. However the many tutorials and articles researched and read during the initial research made both languages quick to learn and experiment in. Furthermore I efficiently used class time by prioritising what could be done during class and not at home for class time, so the screen was basically completely developed at home.

While I did find the built in functions to Mathematica useful at times, such as the pressure gauge, I decided that the Python user interface was more suited to the task. A demonstration of these interfaces are in the following slides.

Program for Mathematica | Program for Python (converted to .txt)

Continue

Using the 3.5" Display

Setup (requires internet)

sudo rm -rf LCD-show

git clone https://github.com/goodtft/LCD-show.git

chmod -R 755 LCD-show

To Change to the Display

cd LCD-show/

sudo ./LCD35-show

To Revert to the Monitor

cd LCD-show/

sudo ./LCD-hdmi

To Rotate

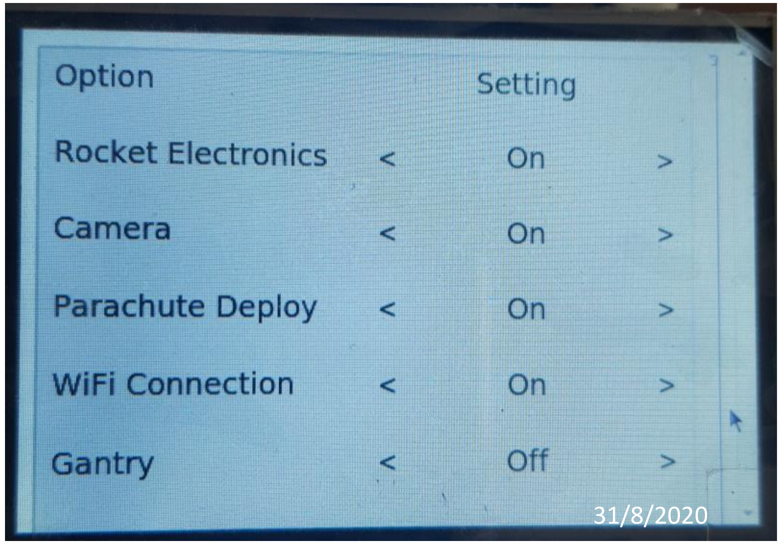
cd LCD-show/

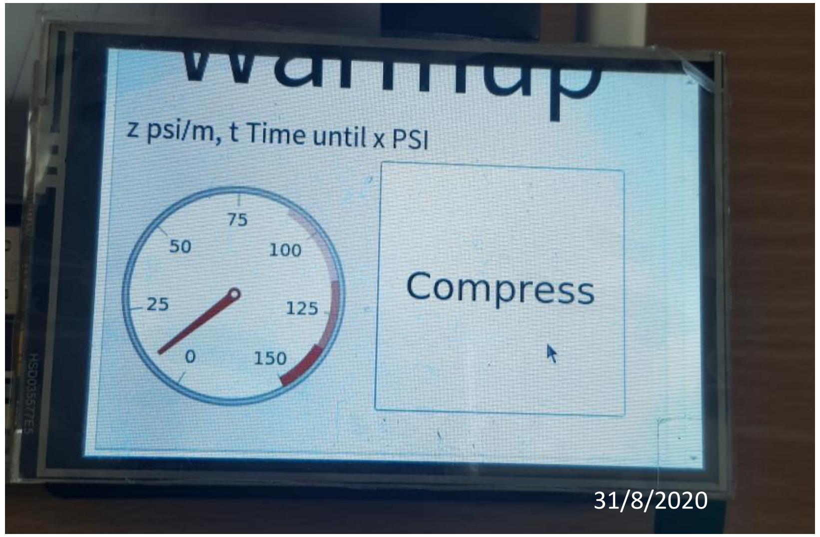
sudo ./rotate.sh 90

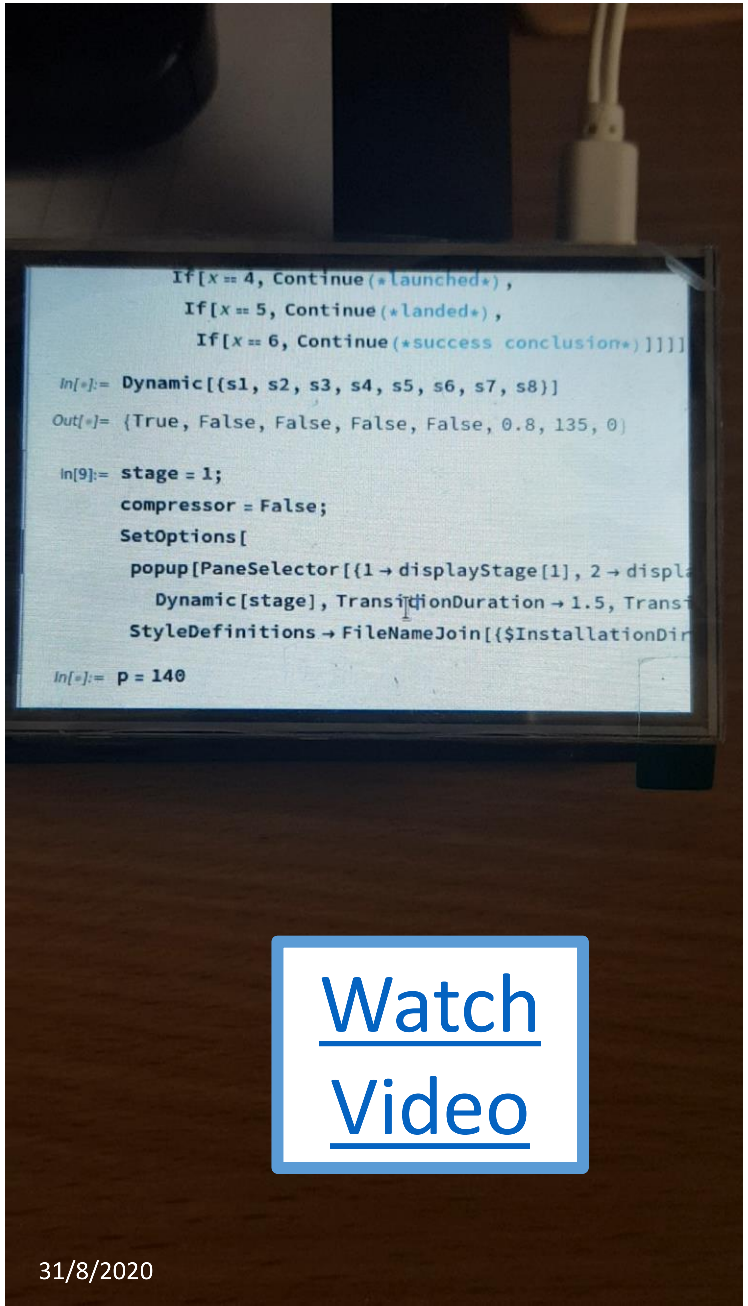
Can be 90; 180; etc

Continue

Mathematica UI







[Watch Video](#)

[Continue](#)

Python UI

Going through some of the Tkinter code from the python UI file:

```
self.configure(bg="white")
title = tk.Label(self.scroll.main, text="Azure", font=controller.title_font, bg="white")
title.pack(side="top", fill="x", pady=0)
```

Modifies the background colour to white

Declares title as a label, with a given parent, text, font and font colour

Positions the label using the pack method, where it fills the parent frame with no padding in the y-axis, fills the entire space assigned to it along the x-axis and that the side to pack the widget against is the top

Using the above code explained, the title "Azure" is generated.

Diagnostic Testing

I completed one diagnostic test:
Compressing Air

These diagnostic tests were not completed due to the pandemic and change of study design, being to an aspect of the project than the completion of the project:
Parachute – not completed since an aspect of the project was developed and testing the parachute required the rocket to have been completed with reasonable time spare for improvements

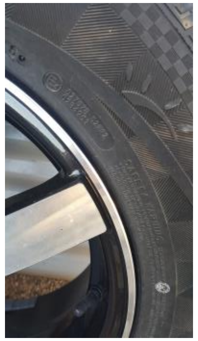
Rocket Power Supply

Socket Communication

Compressing Air

Aim –
The aim of the experiment is to test the performance of the compressor, regarding time and temperature, to compress air in a variety of volumes as well as establish a relationship between PSI and time.
Hypothesis –
I hypothesize that the compressor will overheat while compressing air and will need to cool down before continuing to prevent damage

Equipment –
A car tire (30L), a bike tire (1.65L), 2x Cables, the 12V compressor and the Power Supply Unit
Measuring Equipment – Camera device to record pressure over time.



Method –
Connect the compressor to the bike tire
Turn on the compressor and pressurize to 35 PSI (risk of damaging bike tires from over- pressurization)
Record the PSI over time in intervals of 5 PSI
Repeat the experiment with the car tire up to 35 PSI

Continue

Compressing Air Results

Using records of the PSI over time, with a snippet of the video here, the tables for the bike and tire pressure with respect to time were produced.

Bike Pressure over Time

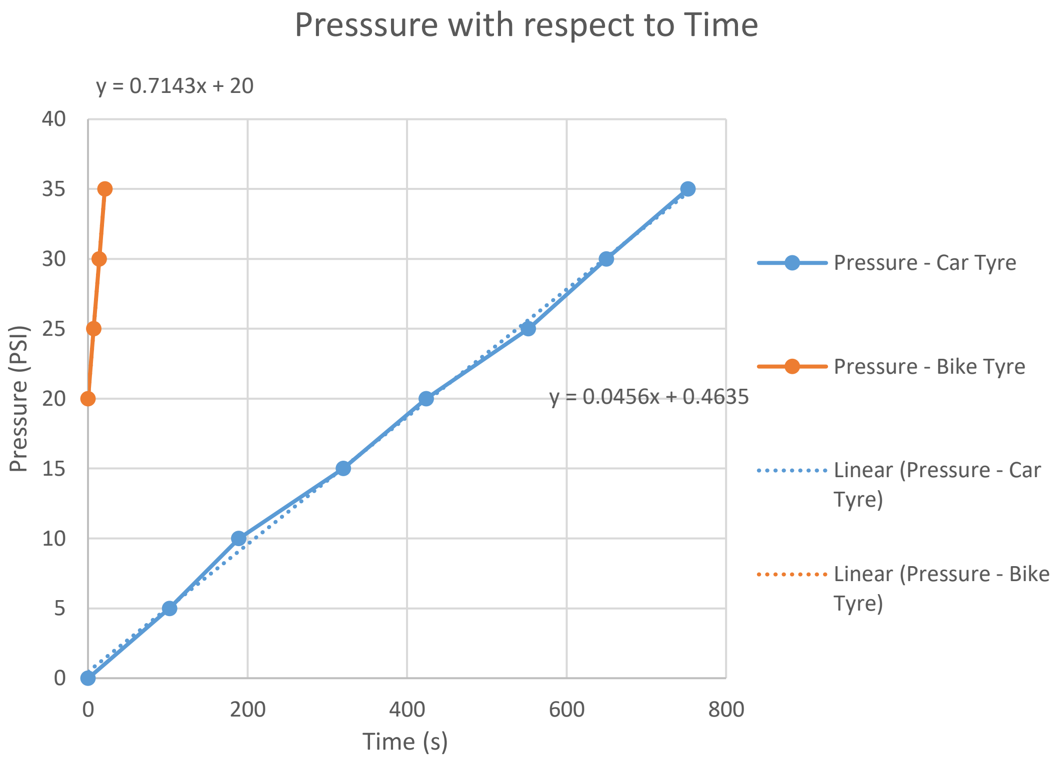
Time	Pressure
0	20
7	25
14	30
21	35

Tire Pressure over Time

Time	Pressure
0	0
102	5
189	10
320	15
424	20
552	25
650	30
752	35

Observations

When the compressor had ran for 752s, it was incredibly hot and promptly turned off as some smoke from the compressor was observed.



Continue

Compressing Air Discussion

PV = nRT is the ideal gas law, where P is pressure, V is volume, n is amount of substance, R is ideal gas constant and T is temperature. As the flow rate from the compressor into the volume over time is equal, the ratio of the gradients between PSI with respect to time of the bike tire compared to that of the car tire should be equal to the ratio between the bike tire and car time volume. The car tire has 30/1.65 = 18 times more volume than the bike tire, so with the same flow rate the car tire's rate of change of pressure over time is theoretically 18 times slower than the bike tire.
Comparing the gradient of the trend lines calculated by Excel, the gradients bike:car= 0.7143/0.0456 = 15.7
Hence, the car tire rate of change of pressure with respect to time was approximately 16 times slower than that of the bike tire. Due to inaccurate measurements and errors, particularly what the exact volume of the tires are, the theoretical factor was greater than what the results demonstrate.

Compressing Air Conclusion

Considering the observation of smoke after operating the compressor for 752s, I will extend the cooling fans of the compressor to enhance the cooling of the compressor. Similarly, out of precaution for the life of the compressor, after 700 seconds of operation the program will automatically allow the compressor to cool down. Reflecting over the design considerations, I can add a simple thermistor to measure the temperature of the compressor, using the Arduino, to closely monitor the compressor's temperature and to ensure the compressor does not overheat.
Lastly, using the data I can deduct how long the compressor will take to compress to 150 PSI for the selected volume of the PVC air tank (that being 9L).
0.7143 * 1.65/9 = 0.130955
0.0456 * 30/9 = 0.152
(0.152+0.130955)/2= 0.1414775 PSI/second
Hence, I can deduct that after 700 seconds the PSI will be 700*0.1414775=99PSI
After 60 seconds, for the cool down of the compressor, it will take another 360 seconds to reach 150PSI.
In total, the results suggest that to reach maximum pressure, the compressor will take 1120s (18 minutes 40s). This estimate provides a reasonable time frame to reach 150 PSI, supporting the selected air volume.

https://www.amazon.com/Aluminum-Heatsink-Amplifier-Transistor-Semiconductor/dp/B073QS338W

Parachute

Aim –

The aim of the experiment is to test the design alternatives of the parachute to evaluate, then make necessary changes, to meet the success criteria of a safe landing momentum

Hypothesis –

I hypothesize that the parachute employing a reefed design will have a slower descent rate, which fulfills the success criteria regarding the landing momentum, than the normal parachute design.

Design alternatives regarding parachute stems from research regarding parachutes

Equipment –

The prototype (PVC subsystem and rocket subsystem); Payload Electronics; One parachute employing the standard design and another parachute reefed

Grass is soft so the force exerted on the rocket by the ground is less; Necessary in case testing encounters a significant error

Method –

Setup the prototype on a grass area with minimal or preferably no wind and no rain

Pressurize the PVC tank

Attach the standard parachute design to the rocket

Put the rocket into position on the launch pipe

Once pressurised to 100 PSI, open the solenoid valve to launch the rocket

After the rocket lands, retrieve the rocket and record the data from the flight

Conduct three trials using the standing parachute design then repeat using the reefed parachute design

Multiple trials to reduce random error and the impact of wind on the results

Rocket Power Supply

Aim –
The aim of the experiment is measuring the output of the voltage regulator with the two 18650 fully charged as the power source
Hypothesis –
I hypothesize that the output of the voltage regulator is 5V 2A

Equipment –
- Multimeter
- Two 18650 Batteries
- Voltage regulator
- Wires

Method –
Connect the 18650 Batteries with the voltage regulator
Connect the Multimeter to the output of the voltage regulator
Over 60 seconds, measure and record the current from the voltage regulator
After, for 60 seconds, measure and record the voltage from the voltage regulator
Repeat twice

A primary focus of running this test is to ensure that the power supply to the Raspberry Pi can operate for a reasonable time frame at 5V±5% and at least 1.3A, since these are the minimum requirements as researched

Socket Communication

Aim –

The aim of the experiment is to determine the time delay of communication between the Raspberry Pi server and Raspberry Pi client during Socket Communication

Hypothesis –

I hypothesize that the latency is 5ms

Equipment –

- 2x Raspberry Pi
- Access Point
- 2x Power Supply Units for Raspberry Pi

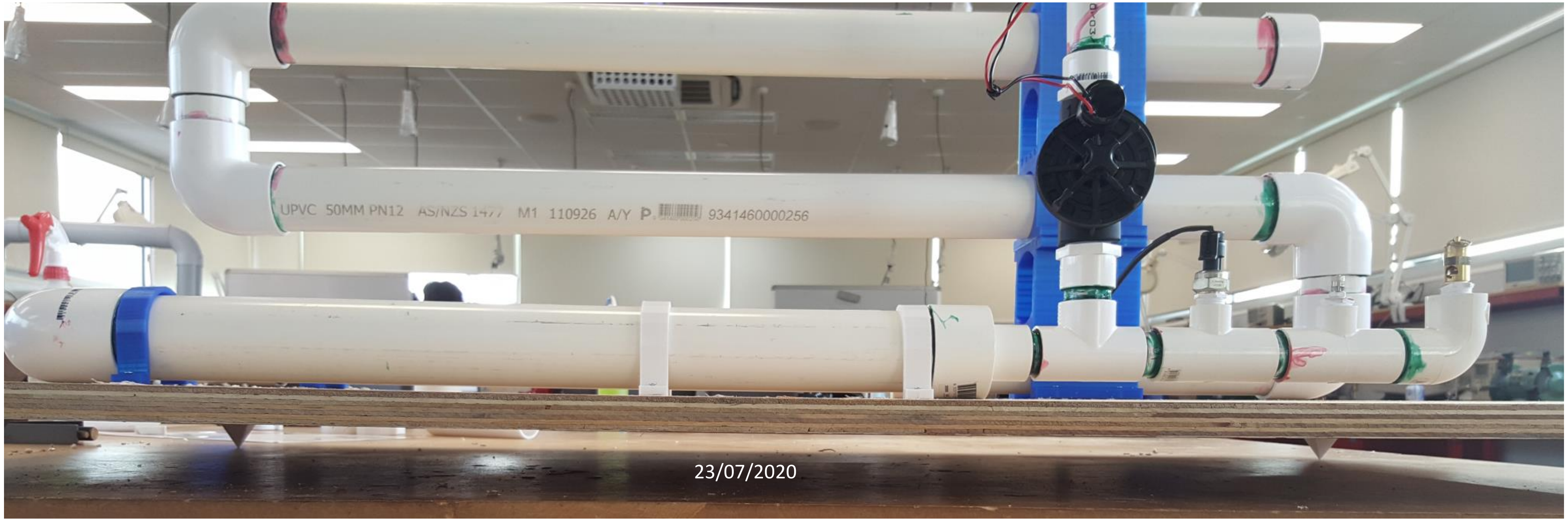
Method –

Develop a test program that evaluates the difference in time between when the data is sent, and the data is processed by the receiver. Hence the program could be based off the difference in time, with the data sent as the start time then the receiver can compare the difference in times.

This diagnostic test would evaluate the performance of the rocket during launches and could easily be included in the data transfer of the rocket's performance. Due to the time constraints of the adjusted project, the rocket was not launched so this test was not conducted. However it would be significant to the flights since it may reveal that at certain altitudes during the launch, that the time difference increases and even exceeds the 10ms requirement.

Completion of Prototype

PVC Subsystem

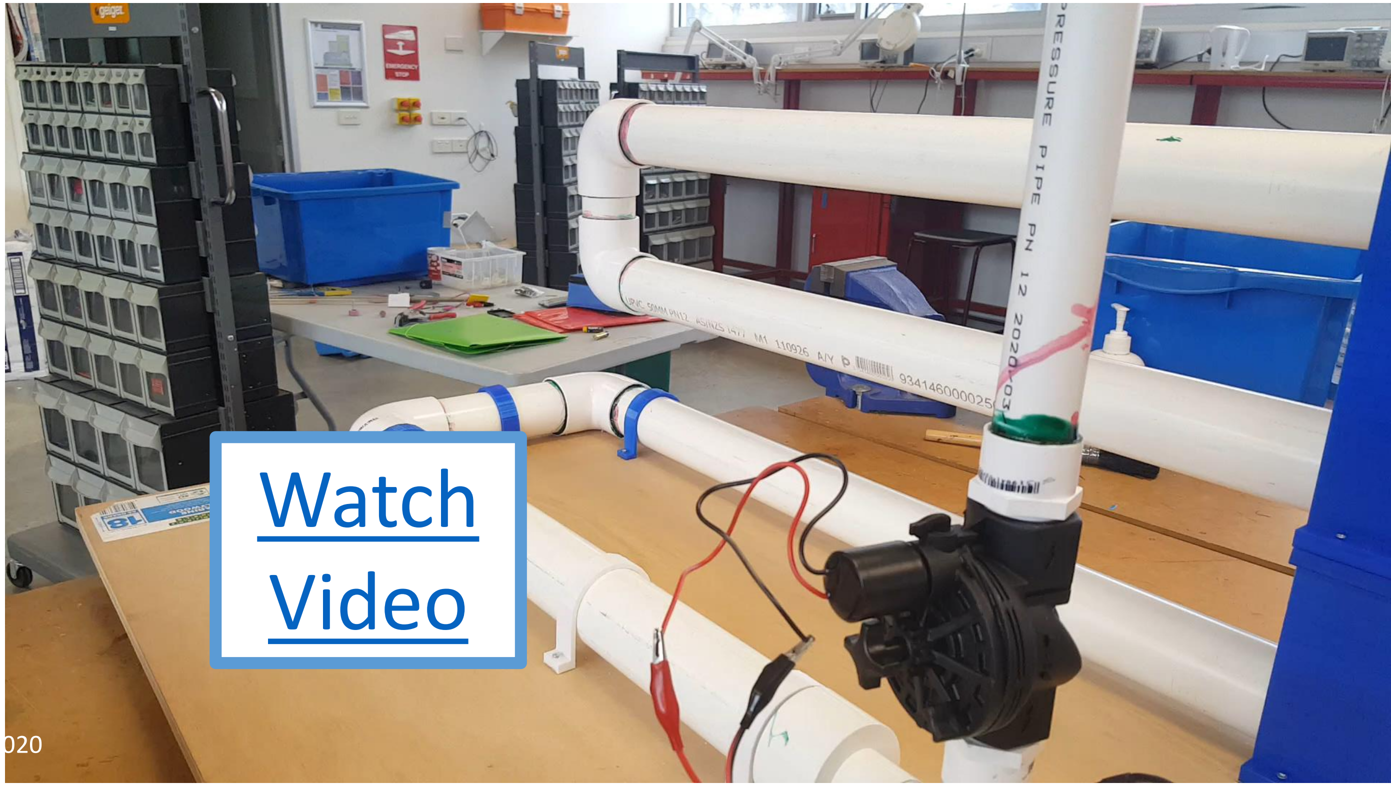


At the end, I noticed that the weight of the components made the base bend slightly. Hence I recommend that in the future two spikes are positioned along the middle of the base.

Continue

PVC Subsystem

In the end, I managed to complete the PVC subsystem and tested releasing the compressed air. This was around the time when the school closed for the second time, preventing further development on the prototype. Otherwise, I could have developed the circuitry and executed the programming more. Here, I closed the solenoid valve, ran the compressor to 30 PSI, then reversed the wires and opened the solenoid valve. As you can hear from the recording, the compressed air is suddenly released. [Promptly, the evil laughter begins]. Hence the design of the PVC subsystem captured and compressed air effectively to produce a great force reflected by the noise produced. However considering the time constraints



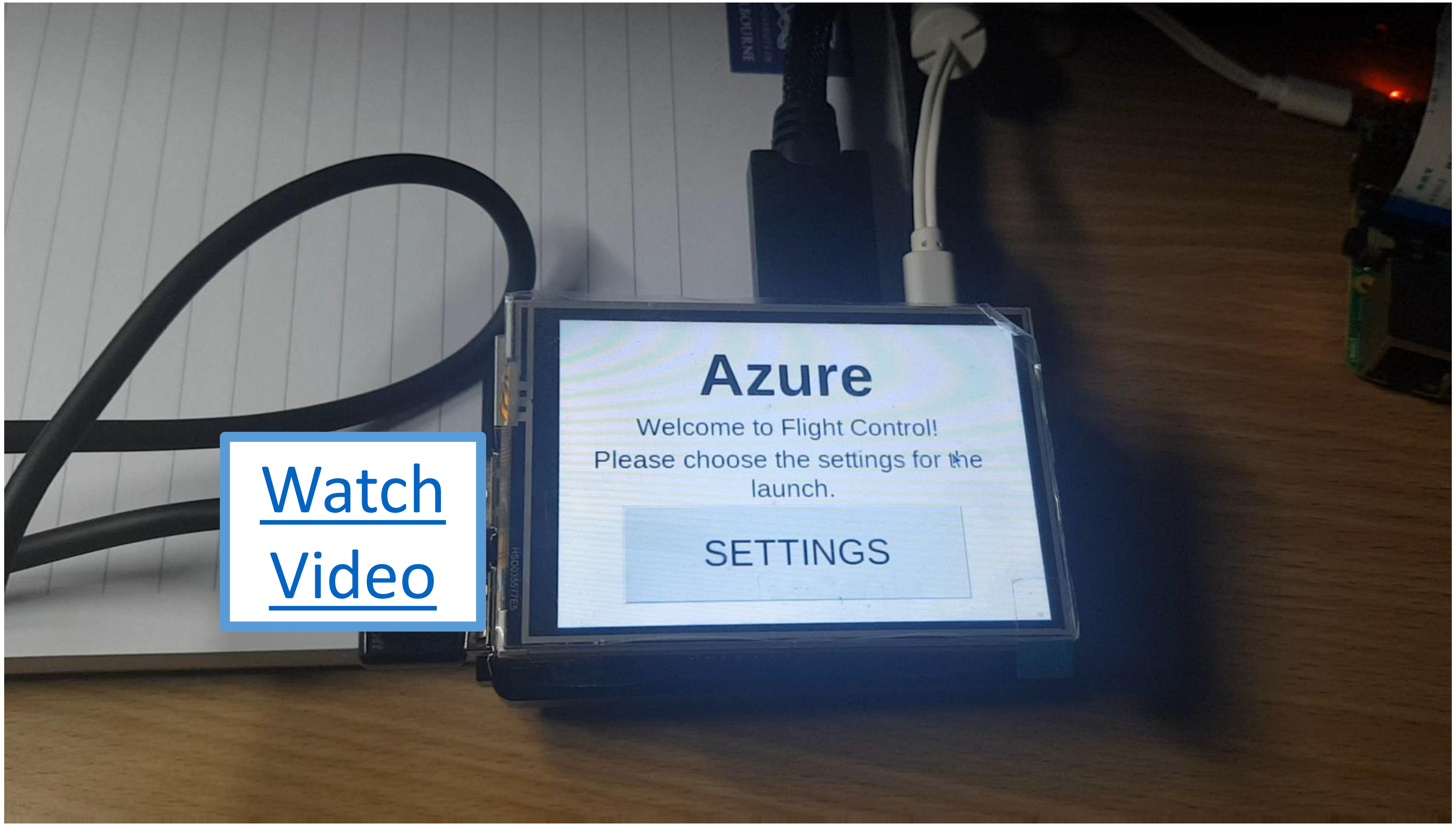
I could potentially have conducted launches by saving time if I had changed the storage system to a 240V compressor. The school closures prevented the final testing of the system, meaning I cannot quantify the performance of the system by the original criteria.

I can confidently say that the launch system can compress and store air, as the trial demonstrated. A valid success criteria could be that the prototype can compress air to 150 PSI, the maximum. Furthermore demonstrations reveal that the user interface and Raspberry Pis timely receive and respond to data through Serial and Socket Communication (demonstrated by the prompt print of data and responsive stepper motor). However, given the time constraints, could not timely send photographs successfully as this lead to error.

Continue

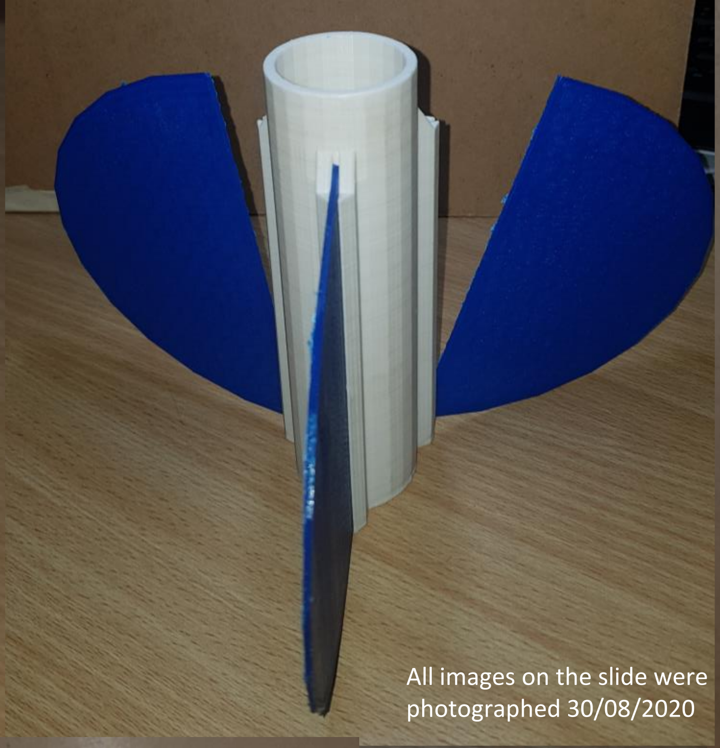
Gantry and User Interface

Demonstrates the first stages of the user interface to launch the rocket, featuring a variety of settings to choose and a user friendly method to specifically select.
The gantry successfully operates and automatically stops.
I felt the user interface was remarkably easy to use, however the scroll bar could have been wider.
Furthermore it could be useful to indicate a progress bar of the gantry's movement, for the user to have an ETA.

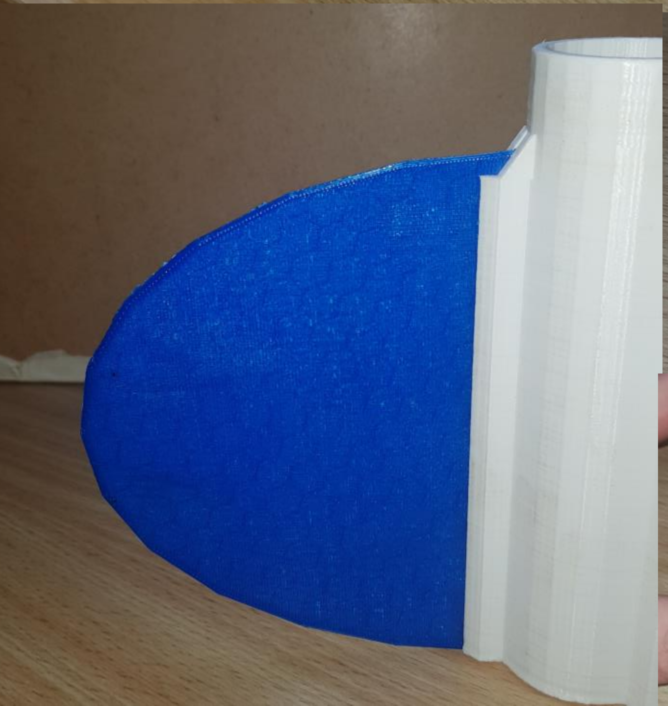


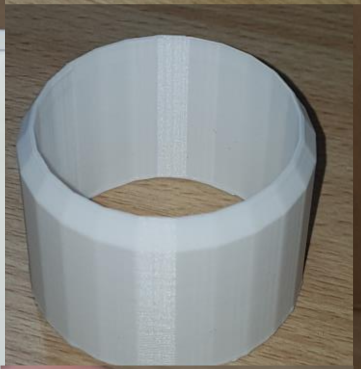
Lastly I felt that a circuit board and soldering would be essential for launches as the slightly messy wiring can come loose during transportation. Hence unexpected errors may arise and could even be considered a safety risk.

Rocket



All images on the slide were photographed 30/08/2020



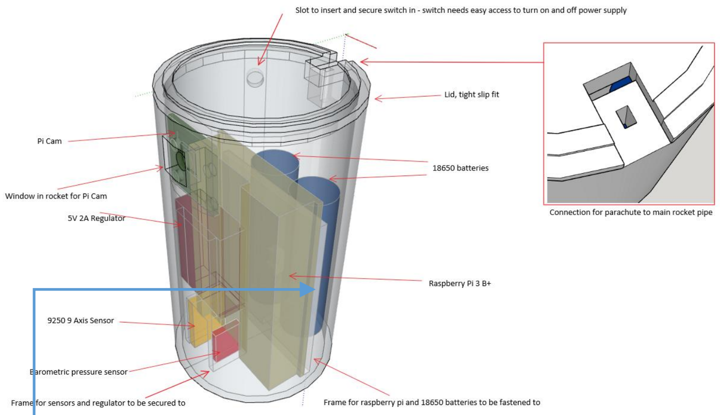


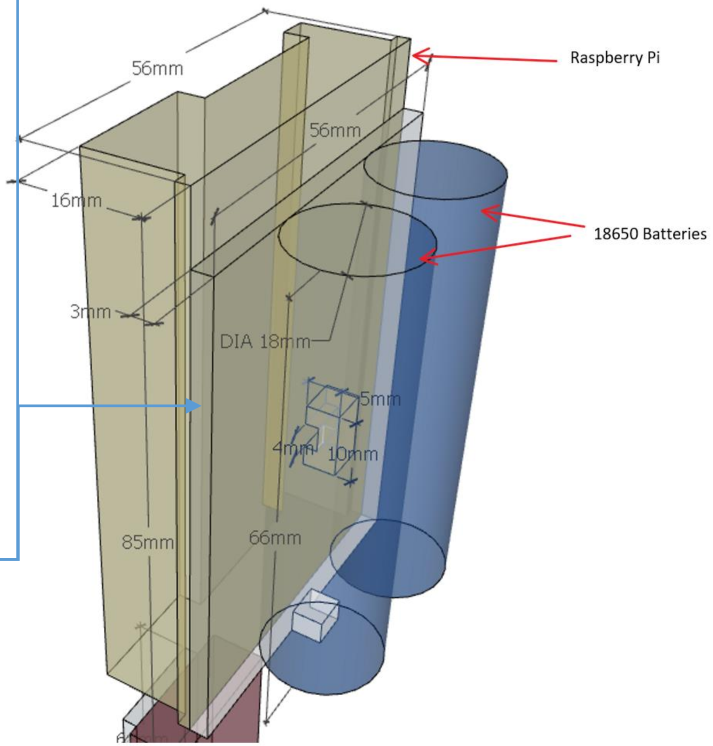
Continue

Rocket

Although there was not much time to focus on the rocket, as I decided to dedicate the minimal class time available to the PVC subsystem and gantry subsystem, I am proud of the final rocket. The production of the programming demonstrated that the socket programming was capable of timely transmitting data to the Raspberry Pi server.

Due to the adjusted work plan and focus of the project being on an aspect, the rocket was not a primary objective of the project so testing could not be completed. The limited time allowed for the rocket to be printed in class while other subsystems were developed, so the evaluation criteria regarding the rocket cannot be evaluated. However I still noticed in the limited time spent that the design of the payload was not easy to access regarding the batteries. I recognised that having a frame to pull would require more plastic, so more weight, but how the payload is now makes it difficult to remove the batteries without taking the payload structure off leading to wear. Hence potential slippage during launches over time as the plastic components become loose. Instead, I could add a groove to the bottom of the plastic that the payload sits on for the support plastic of the Raspberry Pi to sit in. Furthermore, the component can continue and fit into a groove of the rocket's lid. Hence the payload would be secure, but easy to access rather than glued together using acetone as initially planned.





Criteria

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