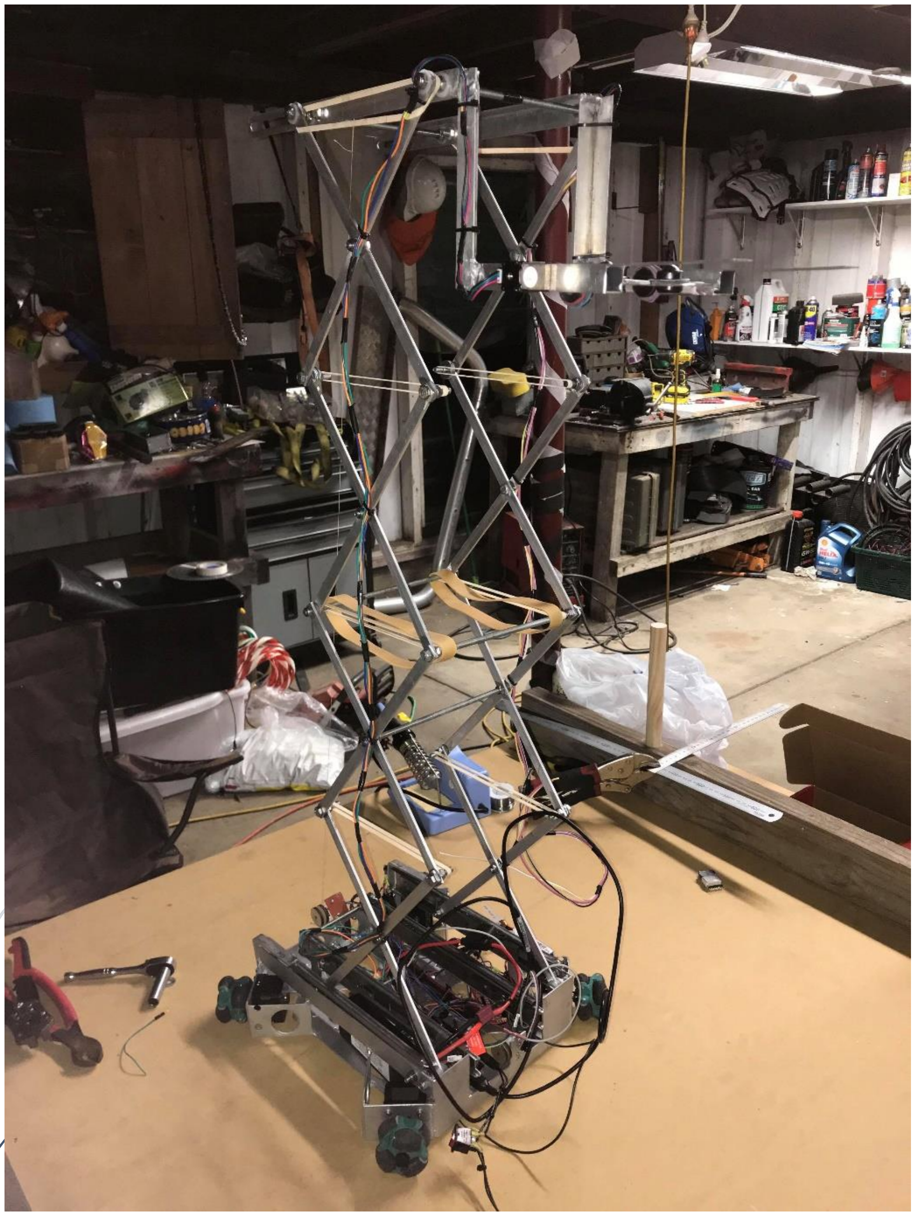
Warman Design and Build Challenge

EGB210 – Group 4.6

Semester 1, 2018



Name:	Student No:	Hours:	%:	Scaling:	Signature:
James Allen	N9950273	165	35	1.2	
Zac Potter	N7545002	165	35	1.2	
Sebastian Corta	N9956883	70	15	0.7	
Tim Power	N9967397	67.5	14	0.7	

Executive Summary

The people of Gondwana are currently in a severe drought, with all of the useable aquifers being completely dry. However, using new satellite and geotechnical technology they have managed to locate three other possible water bores, each having a powerpack and pumping station. To solve their current water supply issue, a team of engineers will investigate possible ways of relocating the most effective powerpack (Payload C) into their currently unusable aquifer. Through the means of an autonomous vehicle, a prototype model will be designed, modelled, refined, built and tested, with the final robot having the capability of relocating this powerpack.

In order to develop a feasible solution, the engineers firstly brainstormed a wide range of possible ideas, along with taking inspiration from pre-existing machinery and equipment. After the completion of this, they were able to develop a number of possible solutions to meet the requirements of the people of Gondwana. These were then evaluated and critically analysed to ensure that the most effective design was chosen.

After the completion of this ideation process, a number of prototype models were constructed. This step was crucial as it meant that any complex components or previously overlooked flaws were discovered. During this process, the wheel alignment and base were completely changed to ensure the robot would navigate Gondwana and end up in the exact locations as expected. Along with this, the lifting and rotating mechanisms were also modified to not only increase the consistency of the robot, but to also reduce the reliance on motors and focus on mechanical advantage instead. After the testing of these components, the construction could begin. This relied heavily on the skilled expertise of one of the team members, which ensured that a high quality and extremely heavy-duty robot was constructed. This was also slightly overengineered to account for any rough terrain, strong winds or other unexpected events on Gondwana.

After critical analysis of the final design, it was repeatedly tested on the model course. This design now ensured that it would effectively and consistently navigate all obstacles expected on the planet of Gondwana. Along with this, the other mechanical components were individually tested until they were consistently operating every time. All of these mechatronic components were then included into the final design, with the robot successfully completing the Warman Challenge course. This can now be presented to the people of Gondwana, to ensure they overcome the impending water scarcity and consequential famine.

Table of Contents

List of Figures

1. Define the Problem

The small planet of Gondwana is once again in the midst of a crisis requiring the expertise of a team of budding engineers. With their worst drought upon them, irrigation has dried up the aquifers that are normally abundant with fresh drinking water. Fortuitously, with the use of new satellite and geotechnical technology, another aquifer has been located that seems to hold enough water to overcome the impending water scarcity and consequential famine. High flow pumps have been installed in this aquifer bunker, however these have overloaded and subsequently exploded the once operational powerpack, rendering the only full aquifer unusable. The only way of fixing this issue is to autonomously relocate a powerpack from one of the three dry aquifers. (figure 1).

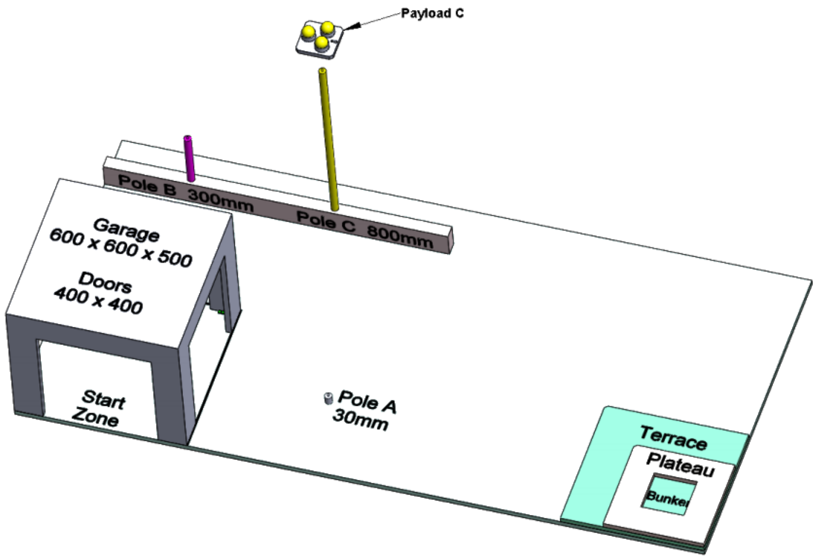


Figure 1: Warman Competition Track

These powerpacks vary in pumping capacity and flow rate, with the most effective of these being power pack C. Despite being the most effective payload, it is also the most complex to disassemble and connect. On the other hand, powerpack B and C are far easier to relocate, with no rotation or lifting mechanism needed. After considering the 3 possible options, a decision has been made to relocate powerpack C, however extreme care must be taken to ensure that it arrives safely or there will be devastating environmental impacts for the planet of Gondwana.

For the autonomous vehicle to successfully relocate powerpack C, 4 key processes are required. These include the manoeuvring of the vehicle, lifting mechanism to reach the payload, rotation of the powerpack and delivery system into the bunker. Although some of these design areas may require new and unique design concepts, others may benefit from pre-existing ideas.

2. Brainstorming and Problem Solving

To effectively develop a wide range of possible solutions to suit the design brief, an understanding of the processes involved in achieving the goal is required [1]. The development of a mind map, as shown in figure 2, focuses the ideation process on specific components of the design, breaks down each design process and component into varying possibilities, and ensures all potential solutions are considered.

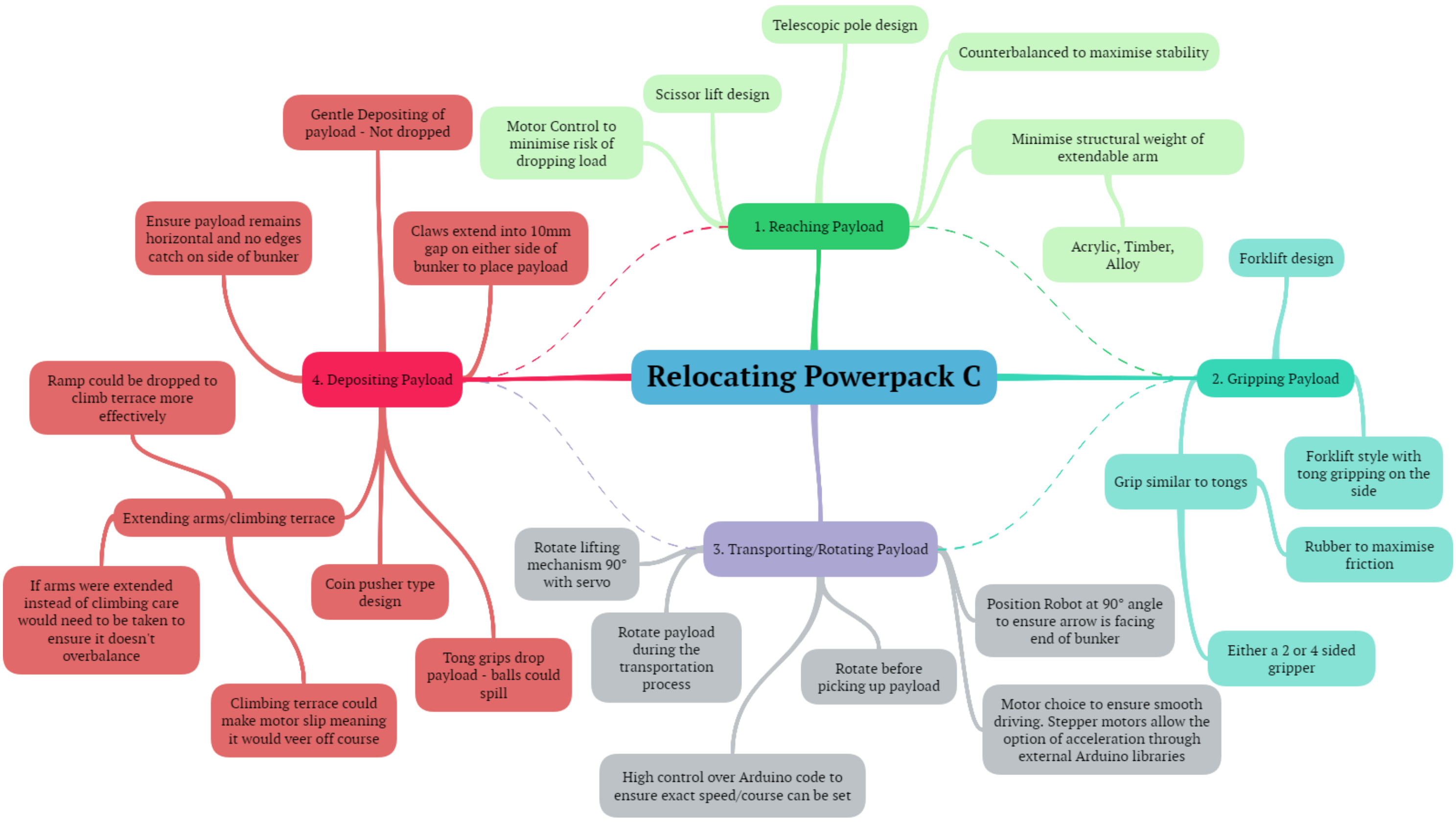


Figure 2: Payload C Mind Map

3. Researching the Problem and Generating Ideas

To effectively generate ideas relating to the design problem, it is important to consider the "Theory of Inventive Problem Solving" (TRIZ). This theory focuses on the study of patterns and existing solutions, rather than the belief that the best ideas will be spontaneous [1]. For this reason, when developing ideas to suit the design brief, research is required on a vast array of mechanical systems and machines that could be altered for the current project.

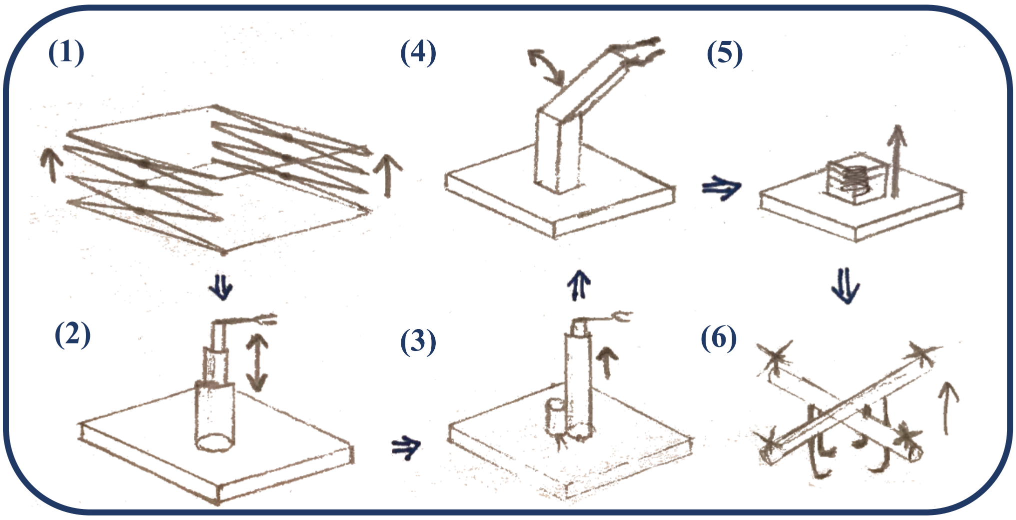
Before researching existing machines, a feature matrix must be constructed, with this being used to narrow and centralise the designs, based on the expressed needs from the people of Gondwana. This matrix is shown in Table 1, and is useful when considering design options.

Perceived Need	Feature
Must Have	- Extension capabilities to reach payload - Gripping mechanism to pick up payload - Rotation capabilities to place payload in correct position - Autonomous ability - Simple to construct
Strongly Desire	- Consistency to complete course
Marginally Desire	- Aesthetic appeal of the robot
Not Desired	- To complete task on an arbitrary size course with differing payload heights, sizes and collection and drop off points

Table 1: Feature Matrix

One of the most important aspects when beginning the design process is to study existing ideas. By considering machinery, equipment or any other mechanical system, inspiration can often be taken from these, allowing the chosen design components to be modified and used. These designs can often be the most effective solutions with significant thought having gone into them during their design process. The following figures depict a number of different design alternatives, with all of these containing useful features.

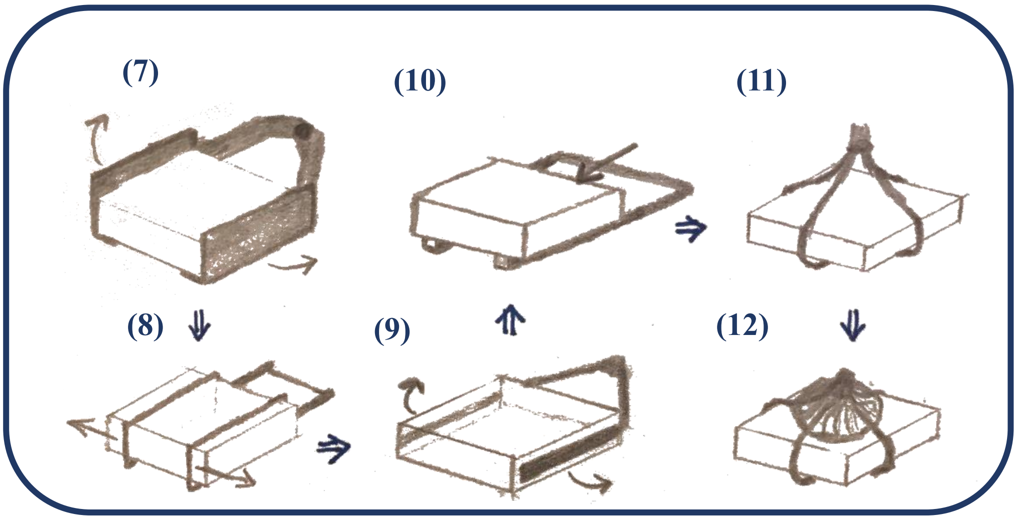
Reaching Payload



(1). Scissor Lift
(2). Telescopic
(3). Linear Actuator
(4). Bend Arm
(5). Spring Loaded
(6). Quadcopter Lift

Figure 3: Reaching Payload Designs

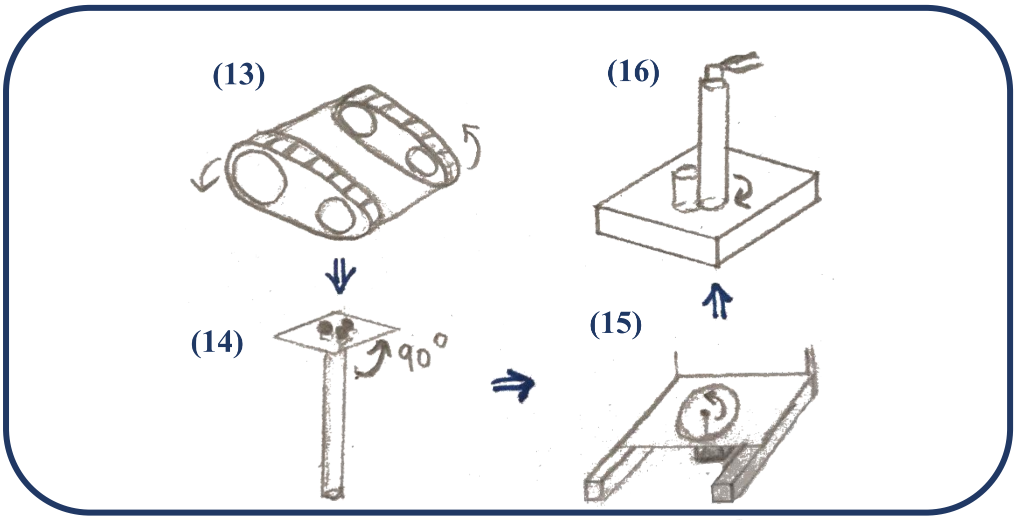
Collection Methods



(7). Support Finger Grip
(8). Slide Grip
(9). Unsupported Finger
(10). Fork Lift
(11). Claw Grip
(12). Covered Claw

Figure 4: Collection Method Designs

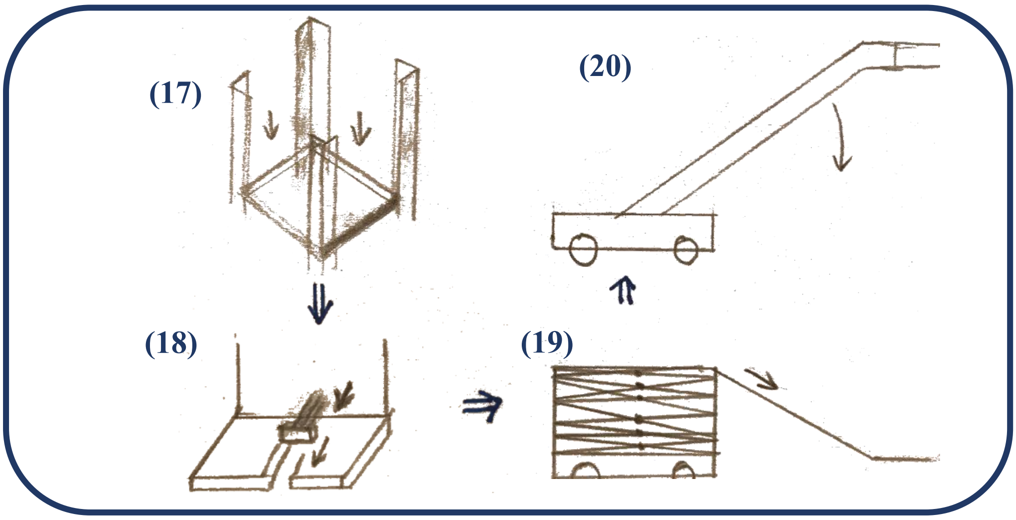
Rotating



(13). Skid Steer
(14). Before Pickup
(15). After Pickup
(16). Lifting Device

Figure 5: Rotating Designs

Depositing Payload



(17). 4 Panel Drop
(18). Push Design
(19). Gravity Slide
(20). Crane Arm

Figure 6: Depositing Payload Designs

After the analysis of different mechanisms to lift the payload, both the scissor lift and forklift design are the clear candidates for the lifting mechanism, however the difficulty in manufacturing must be taken into consideration. Therefore, the incorporation of both of these designs would be a more plausible solution to the problem.

4. Identify Criteria and Specify Constraints

As with any real-world problem, freedom is limited in certain aspects of a project, based on the requirements of the client's design brief. The most suitable solution must therefore satisfy all of these requirements [1]. To ensure the most effective idea is delivered, a design brief (Table 2) outlining the problem to be solved, along with its criteria and constraints has been provided.

Design Brief	
Client:	People of Gondwana
Designer:	Team 4.6
Problem Statement:	All aquifers with working power packs are now empty and the new aquifer which contains water currently has no powerpack
Design Statement:	Arrange a working power pack to be relocated from the now empty aquifer (Payload C) to the newly discovered aquifer (Bunker)
Constraints:	Warman Challenge: - Robot must be wholly contained in the 600x600x500mm start zone - Must have extension capabilities to reach 800mm high Payload C - Must be able to rotate payload 90° to ensure it is correctly deposited - Must operate smoothly to ensure no energy orbs are lost - Set time frame of 10 weeks - Maximum weight of 6kg - Maximum of 120 seconds provided for set up of device - Must complete task in 100 second time frame - Robot must be solely autonomous - Nothing can cover energy orbs Team-Based: - Budget – Maximum expenditure of $100 per person - Limited to skills possessed by team members Individual: - Work schedules further limit the time frame for completion
Deliverables:	An autonomous robot to safely relocate working power pack to newly discovered aquifer

Table 2: Design Brief for the 2018 Warman Challenge

Having generated a detailed design brief for the problem, it is now possible to create an accurate time frame for the project. This has been detailed in Table 3, with the weekly progress being an indicator of where the project should be at all times. This is a crucial step in ensuring the project is completed on time and in the most successful way possible.

	Project: Relocation of Payload C into Bunker										
Week:	3	4	5	6	7	8	9	10	11	12	13
Code of Conduct											
Brainstorming											
Design Process											
Collaborating Ideas											
Refining Ideas											
Testing Materials											

Construction											
Testing/Refining											
Warman Testing											

Table 3: Weekly Timeline for Project Completion

5. Explore Possibilities

Through the result of comprehensive brainstorming and research, and in conjunction with the development of a detailed design criteria and time line, it is now possible to explore all of the potential solutions. The particular nature of this project requires attention to both the individual components of lifting and gripping, rotating and transporting and the safe depositing of the payload, followed ultimately by the consideration of all the elements as a whole. In addition to design features, materials, basic technology and fabrication processes must be taken into account in order to meet the design brief (Table 4).

	Positives	**Negatives**
	Materials	
Steel	• Heavy duty and would provide useful counterbalance on the chassis	• Much harder to work with and may require welding
Alloy	• Much lighter than steel [4] • Would be far stronger than any plastic materials	• Harder to weld than steel – requires TIG welding [5] • Would not last as long as steel (subject to wear)
Acrylic	• Easily laser cut • Can be bent using a heat gun	• Shatters easily under compression
Timber	• Easily machined on most tools in Launchpad	• Could be quite heavy
	Design Tools	
SolidWorks	• Models designs effectively and allows any errors to be more easily noticed	• May not always present a real life representation of the design (E.g. joins may add extra width that were unaccounted for)
Tinkercad	• Allows circuits to be tested before attempting in real life	• Limited range of components that might be used in final arduino design (E.g. L298N motor drivers are not included, nor are bi-polar stepper motors)
Fritzing	• Allows circuits to be neatly drawn up (No limitation for components)	• Cannot debug circuit for mistakes – purely for modelling purposes

	Manufacturing and Fabrication Processes	
3D Printer	• Useful if unique components are required • Available at QUT Launchpad	• Slow to print items • Delay in printing due to high demand in Launchpad
Laser Cutter	• Extreme accuracy and very easy to use • Useful for acrylic and ply • Available at QUT Launchpad	• Delay in printing due to high demand in Launchpad
Welding	• Would be a strong and effective method if steel or alloy is used	• Requires training and practice • No welding is permitted at QUT

Table 4 Detailed analysis

Using the information gathered in the detailed analysis table, it is now possible to determine the most effective design technologies that can be employed throughout the project. It is clear from the material options that steel and alloy would be a highly effective choice for the design. Although the manufacturing of these materials would require offsite labour and training, this is made possible due to one team member being an experienced welder. Along with this, a wide array of hand tools and machinery are available for use in the QUT Launchpad. This therefore means that there are only minor limitations regarding the manufacturing and fabrication processes.

Having gained this knowledge, and along with the use of the detailed design brief above, a number of ideas generated in both the brainstorming and research phases can now be eliminated (Table 5). This will ensure when selecting an appropriate design, only feasible ideas will be considered.

Designs	Reason for Eliminating
Covered Claw Grip	Design brief states that the balls cannot be covered during the transportation process
Spring Loaded Lift	Would not operate smoothly meaning energy orbs would most definitely be lost
Quadcopter Lift	Far too complicated and would also likely result in energy orbs being lost
Crane Arm	May not keep the payload horizontal meaning energy orbs may be lost. Also may not fit in the garage

Table 5: Design Reduction Table

After thoroughly analysing all of the materials, basic technologies and fabrication processes, and eliminating a number of the possible design options, 3 possible solutions have been generated. These designs incorporate a mixture of ideas and consider the specific design brief to ensure all needs are met. Developing alternative solutions to a problem is an integral part of the engineering design process as it encourages lateral thinking to provoke innovative and creative design evolution.

Design Option 1:

The first design alternative considers a combination of different methods for the payload collection, delivery, transportation and rotation. For the tasks of collection and delivery, an appropriate method for grasping the payload is through the use of a claw grip. This would be effective in providing a wide degree of contact with the payload to ensure it is lifted off the pole and subsequently does not slip free. Its operation is controlled by a small dc motor, along with three spur gears to regulate the direction in which the claws will extend and retract (figure 7). It is orientated so that the two claw grips are positioned horizontally, such that the payload is held from either side. Payload C must be correctly orientated when delivered, with the arrows correctly aligning when positioned in the bunker. For this to occur, the claw itself must rotate 90 degrees on its axis. To cater for this, a small gearing system along with a motor is attached to the rear of the claw to allow for rotation. In regard to the delivery system, the claw grips simply open outwards releasing the payload into the bunker.

Figure 7: Payload Collection Choice [1]

In conjunction with the claw grip, a linear actuator is to be used as the lifting mechanism (figure 8). A linear actuator is capable of transporting heavy loads through the use of electric cylinders [1] and so allows elevation to the required height of 800mm in order to successfully collect the payload. It is positioned at the centre of the chassis for greater stability, and travels directly upwards. For these two methods to work collaboratively, a platform is to be fixed to the top of the actuator to provide a foundation for the arm of the claw grip. This will mean that the actuator and claw move together as one unit.

Figure 8: Linear Actuator for Lifting [4]

The transportation of the payload is crucial to its overall success in completing the task. The solution must be capable of manoeuvring the payload with great accuracy and providing sufficient contact with the ground for better stability and grip. To transfer motion from the motors to the ground, the chosen wheel arrangement for this design is similar to that of a skid steer (figure 11). Unlike most four wheeled devices, a skid steer operates in such a way that the wheels are mechanically locked in synchronization on each side, with the driver wheels being driven independently on each side [2]. This means that the robot will not require a separate steering system. Turning is achieved by differential steering, in which the left and right wheels are operated at different speeds and so it turns by dragging the wheels with fixed orientation across the ground. This particular method allows the device to turn with great accuracy so that the tasks of approaching both the payload and bunker can be carried out with great precision [2], as well as performing accurate straight-line movement.

For this method of transport to work, the front and rear wheels must be directly aligned for the rubber tracks to rotate around them. Additionally, the wheels on either side must be parallel with one another to allow the device to steer and change direction. To accommodate this, the chosen geometry for the chassis of the robot will be rectangular. This will be similar to an open lid box to provide a footing for which the motors and linear actuator will be mounted, as well as a place for all the electrical components to be secured during operation.

Figure 9: Skid Steer Design [6]

Like any real-world project, there are a number of physical constraints that the device must be capable of overcoming, as well as certain constraints as outlined in the design criteria. A key criterion is that the dimensions of the garage where the robot will start are immutable, requiring the design to definitely fit when placed in the starting zone. The linear actuator must therefore have appropriate extension capabilities to reach the 800mm high payload C.

Another constraint considered during the ideation process was the safe delivery of the payload to ensure no energy orbs were lost, concealed or damaged during the collection and delivery. The claw grip solution successfully complies with this. Another design specification is that the device is limited to a maximum of 6kg. The weight for this design solution with all of the individual components included, is estimated to be 5.2kg, which allows for the inclusion of any additional parts if necessary.

This solution appears to be a viable method for collecting and delivering the payload into the bunker, successfully fulfilling the basic design requirements and satisfying the project criteria. Table 6 outlines the strengths and limitations of the first design alternative, demonstrating a critical assessment of its ability to carry out the task at hand.

Strengths	Limitations
High degree of traction	Insufficient stability at full extension
High torque for the lifting device	Slow rotation
Sufficient extension capabilities	Ineffective payload release / placement
Accurate rotation	Limited minimum height (actuator dimensions)
Low centre of gravity	Possibly not strong enough to maintain grip of 440gram payload

Table 6: Design 1 - Strengths and Limitations

To effectively communicate the design, detailed sketches have been drawn as a visual representation of the robot (figure 10). An orthographic sketch of the front, side and top view displays the overall geometry of the design, with an isometric sketch being used to show the device from a 3-dimensional view for more effective visualisation.

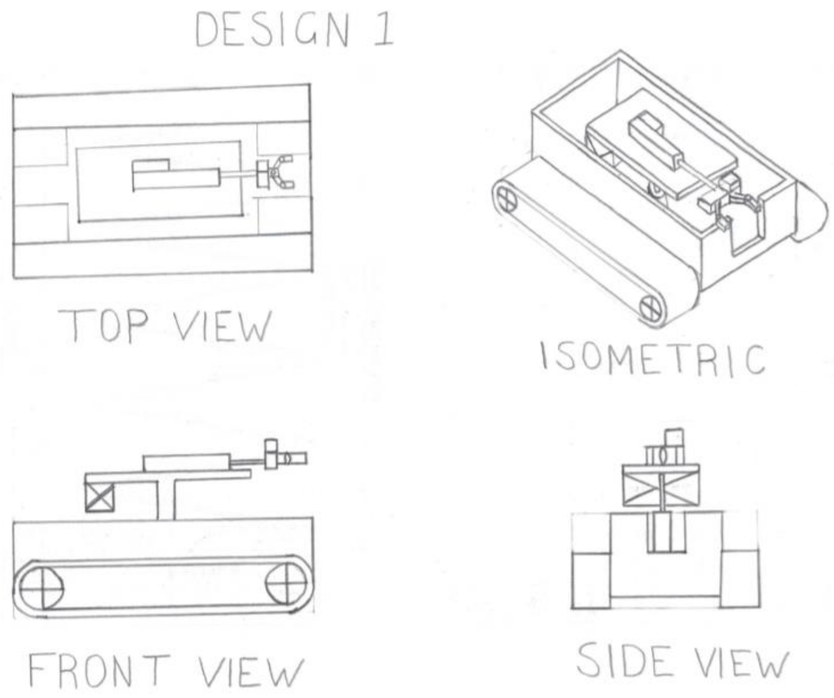


Figure 10: Design Option 1

Design Option 2:

The second design alternative incorporates a different combination of potential solutions for the collection, transportation and delivery system. The collection method for this design is similar to the first solution, however this design instead uses two claws instead of one. The orientation of the two claws is vertical, to allow four separate points of contact on the payload at all times. By providing a strong and secure grasp, this should help in preventing energy orbs from falling out during the collection and delivery. Like design option 1, the two individual claws are to be controlled by a small dc motor and 3 spur gears to regulate the direction the claws will operate. The motors must be synchronized so that the two claws operate at the same speed to ensure the payload is gripped on either side simultaneously. For the delivery stage, once the device is perfectly aligned with the bunker and is positioned at the correct height, the claws simply open out vertically and release the payload.

The chosen method for reaching the payload C is through the use of a scissor lift mechanism (figure 11). A scissor lift is an effective solution as it provides significant extension capabilities which can be increased or decreased depending on the number of cross members included [3]. When compressed, the entire scissor mechanism can be fully contained to a minimal height and is capable of extending to approximately 15 times the compressed height.

Figure 11: Scissor Lift [8]

A solution to cater for the specific direction in which the payload must be placed in the bunker, is the incorporation of drawer slides (figure 12). Drawer slides are an efficient method for extending an object to approximately double its original horizontal length. The extension of the roller slides will be controlled by a small dc motor positioned at the rear of the slides, with a pulley being used to wind this in. This means that when the payload has been collected, the drawer slides are extended backwards, allowing the payload to be successfully deposited.

Figure 12: Pushing Mechanism Drawer Sliders [9]

As shown in figure 13, the transportation for this design only uses 3 wheels, with two being used to drive the motors, and the other one being simply used as support. This provides greater lateral stability and ease of turning, as well as space for the electrical components to be concealed, however, it could hinder the accuracy of the device.

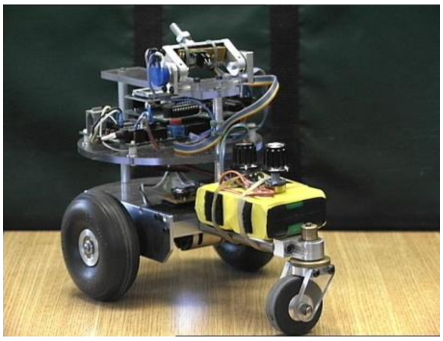


Figure 13: 3 Wheel Design [10]

This potential solution was designed to fit just within the garage dimensions, ensuring the strict design criterion is met. The scissor mechanism would be capable of reaching the height of the payload, but when compressed would not touch the roof of the garage. Similar to the design option 1, the way in which the claws are applied to the payload complies with all rules, ensuring the robot is not disqualified. The estimated weight of this solution should be around 5.8kg, also complying with the 6kg limit.

Table 7 critically assesses the strengths and limitations of design option 2.

Strengths	Limitations
Stable vertical support at full extension Quick rotation Accurate rotation Low centre of gravity Sufficient claw grip	Slow vertical extension Ineffective payload release / placement Slow linear movement Limited minimum height (scissor mechanism)

Table 7: Design 2 - Strengths and Limitations

Figure 14 shows sketches of the main functions and key components of design option 2. Orthographic sketches display the front, side and top views to show its overall geometry from different angles, with an isometric sketch showing the device from a 3-dimensional view to visualise its final appearance.

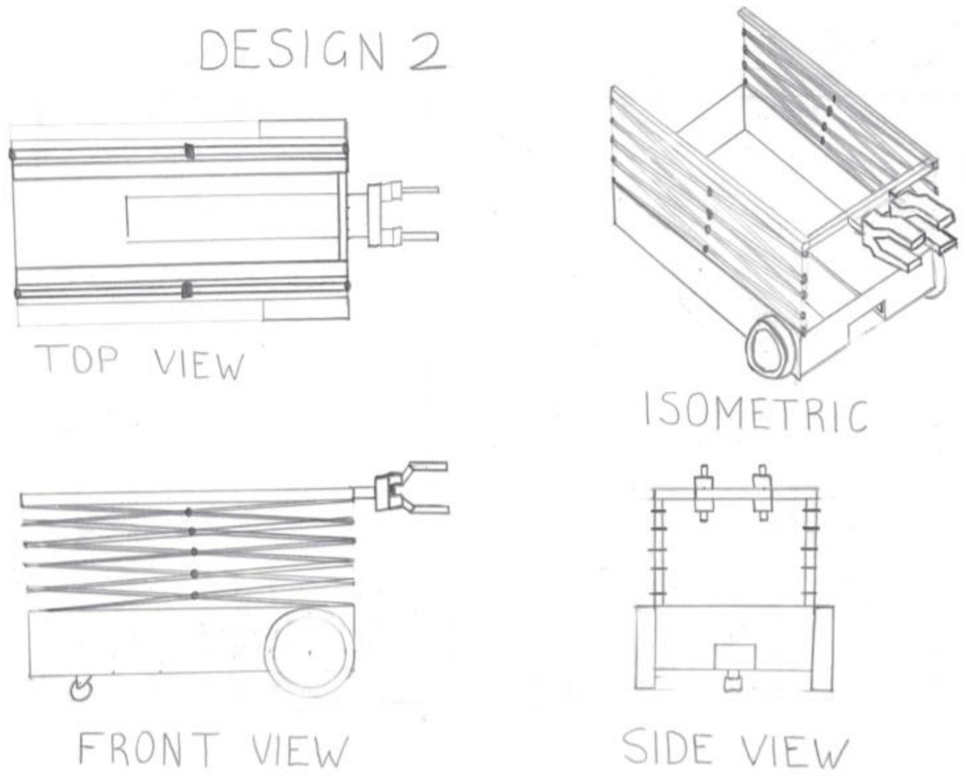


Figure 14: Design Option 2

Design Option 3:

The final alternative design incorporates a unique combination of methods for the collection, transportation and delivery of the payload, some of which were derived from the previous design solutions. The collection of the payload is made possible through the integration of a scissor lifting mechanism attached to forklift tines at the top (figure 15). As established in the design option 2, a scissor lifting mechanism is an effective method for elevation, providing enough extension to reach payload C. To lift this device, a small geared motor will turn inside a nut, gradually pulling the 2 ends of the scissor lift together, allowing the mechanism to move upwards. To physically collect the payload, a set of tines are used to support the payload from underneath, successfully lifting the payload from the aquifer where it is located. This means that the scissor lifting mechanism and forklift tines will operate simultaneously, with both travelling upwards to complete the required task.

Figure 15: Fork Lift Tines [11]

The solution for rotating the payload uses 2 small motors, with these being attached to the sides of the forklift tines. On the surface of the tines are four ball bearings (figure 18) sitting just below the payload, allowing the payload to freely rotate when the driver motors underneath the payload are activated. The idea behind this was derived from the basic operation of a Lazy Susan, using ball bearings to rotate a plate.

Figure 16: Ball Bearing Slider [12]

The chosen method for the payload delivery is a linear actuator, positioned in the centre of the chassis and facing the front of the device. This works in collaboration with the tines, such that when the scissor mechanism compresses to the very bottom, the payload is positioned directly in line with the actuator. When this occurs, the actuator is activated, pushing the payload off the tines and into the bunker. Overall, this design alternative successfully fulfils all of the necessary design specifications and safely complies with the Warman project criteria and constraints.

Table 8 sets out the strengths and weakness of design option 3, critically assessing its ability to carry out the necessary tasks.

Strengths	Limitations
• Stable vertical support at full extension • Quick and steady payload rotation • Accurate rotation • Low centre of gravity • Effective and accurate collection method – a small degree of error would be less of an issue than lifting mechanisms • Effective payload release	• Slow vertical extension • No method of adjusting payload if it is picked up out of line • Increased chances of error (multiple moving components) • Slow linear movement • Limited minimum height (scissor mechanism)

Table 8: Design 3 - Strengths and Limitations

Sketches of the main functions and key components of design option 3 are contained in Figure 17. The orthographic sketch displays the front, side and top views, showing its overall geometry from different angles, and an isometric sketch shows the device from a 3-dimensional view.

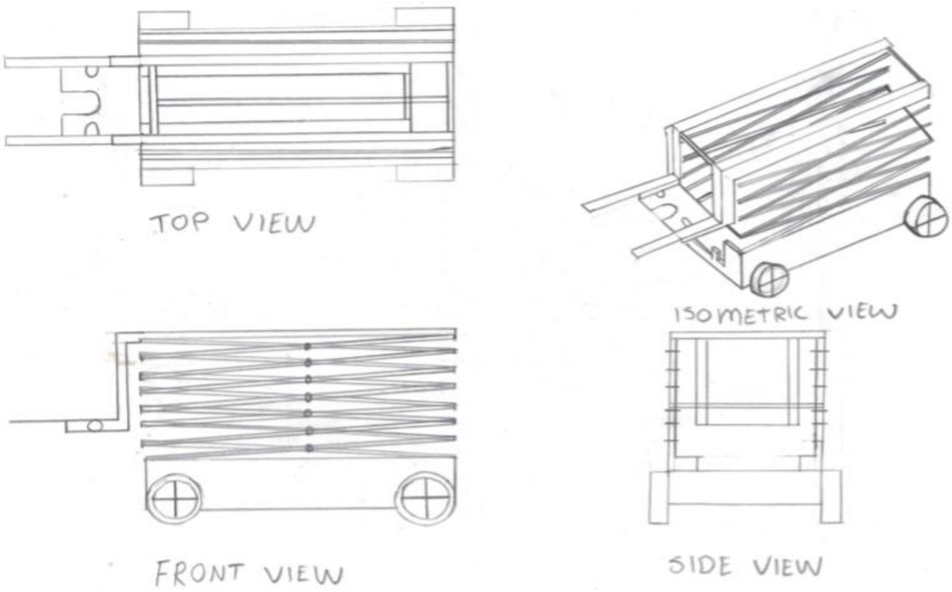


Figure 17: Design Option 3

6. Select Viable Approach

To select the most suitable a decision-making matrix must be constructed. As shown in the table below, design 3 is the most appropriate choice.

Criteria/specification	weight	Design 1	Design 2	Design 3
feasibility	5	4	4	5
Construction time	5	4	3	3
Simplicity	3	5	4	3
Operation time	4	4	4	5
cost	3	1	2	2
mass	5	3	3	3
size	5	4	3	4
Payload collection	5	3	4	5
Payload delivery	5	4	2	5
transportation	5	4	4	5
Total score		**36**	**33**	**40**

Table 9: Decision Making Matrix

7. Develop a Design Proposal

7.1 Detailed Description of Chosen Design

After selecting a viable approach for the problem, a design proposal must be developed to help prepare for the production of a prototype. This design proposal must break down all components of the machine and address each individual task, with careful consideration being given to ensure all parts operate and work in unison.

7.1.1 Base

7.1.1.1 Orientation

The base is the most important element when developing a conceptual design, as it is the starting platform for each mechanism or system. It must have a concise and thorough preconception to integrate all of the other operating systems. With the challenge rules limiting the maximum size of the robot to a 400x400x600mm rectangular box, these parameters must be taken into account when considering the dimensions for both the shape and orientation of the base. The base requires storage facilities for the batteries, motors, wiring and both the pushing and lifting mechanisms, and so a rectangular base will be the best option. This will ensure that any unused material that is not required for the small pulling motor mount can be simply cut out to allow a dispatching mechanism to successfully operate.

7.1.1.2 Material

With the base requiring the attachment of all the operating mechanisms, the materials used for each component must be carefully assessed. Perspex is readily available and is an easy alternative to metal for the base, however with several different operating systems being attached, fractures and cracks are a high possibility. Aluminium could be a viable option for the base as well, however this is more expensive then steel, harder to work with, and creates stress fractures from bending and flexing which could cause unwanted problems after rigorous testing [4].

The overall weight of the prototype must not exceed 6kg as outlined in the design criteria, however extra weight in the base would be helpful in maintaining stability when the scissor mechanism is fully erect and in contact with the payload. Therefore, to maximise the overall functionality of the base, sheet steel greater than 2mm thick is to be used to ensure it can be cut, shaped and welded to almost any desired shape, whilst always maintaining very high strength and rigidity.

7.1.2 Scissor Lift

7.1.2.1 Design

Designing the scissor lift mechanism requires multiple components to work together and perform in unison, so accurate tolerances and consideration on friction will be the main focus. Extensive background research on the designs used in everyday life shows that simple cross beams and hydraulic rams are used in most scissor lift mechanisms. To incorporate a hydraulic system into the prototype would require a large range of custom built components and would likely be very expensive. Other means of lifting may be achievable by using springs, threaded rods or linear actuators. A spring could be used, however there would be problems with the spring acceleration from the initial starting point, with a secondary system being needed to lower the scissor lift mechanism. Linear actuators and threaded rods use the same concept to raise and lower the mechanism, however the linear actuator is bulky and would require a large amount of room, whereas threaded rods could be directly attached to a small high torque motor. As this shaft turns, the threads wind a nut, with this being attached to the scissor lift mechanism allowing for extension. For the scissor mechanism to work correctly, one end must be fixed at the bottom of the mechanism and the other end must be free to slide towards the fixed point. The front end of the scissor must be the fixed end to ensure the payload is lifted directly up from that edge, which leaves the back end of the scissor mechanism to slide towards the front. Designing a system for it to slide back can be avoided by utilising a system that has the similar features, and modifying to suit this application. Drawer slides operate using the same concept and can be modified to fit the scissor lift requirements.

As payload C must be collected from a pole 800mm off the ground and delivered to a bunker 18mm high, this creates another challenge as to how the lifting mechanism will both collect and dispatch the payload. As the scissor lift has a minimum height that is directly proportional to the erected height, the raised height of the scissor lift must be calculated. This can be done by calculating the height required, and subtracting the base underneath the scissor lifting mechanism (800mm + 50mm to ensure lifts entirely = 850mm). This will be the height that the scissor lift must raise to collect the payload at the top of the mechanism. Unfortunately, if the payload is collected by the top of the scissor lift, it will not be able to lower to the bunker height. To overcome this, a stepped down fork must be used, which ensures when the scissor lift mechanism is fully lowered, the payload can be dispatched into the bunker. By using the stepped down forks, the scissor lift will require even more height to ensure these forks reach the payload.

7.1.2.2 Material

Strength, friction and stability are the key features to consider when selecting appropriate materials for the scissor lifting mechanism. The beams can be made from a wide selection of material, such as steel, wood, perspex, and aluminium. To reduce the torque required to lift the mechanism, the material should be both light yet also very strong. Timber and perspex are light materials, however they do not have a strong tensile strength as shown in table 9, whereas steel and aluminium have much higher tensile strengths. As aluminium is approximately half the weight of steel, this makes it the most viable material option for both the scissor lift beams and forks. Although it may be more subject to wear after excessive use, this will be overcome by using nylon washers to space the beams and decrease friction whilst operating.

MATERIAL	TENSILE STRENGTH (MPA)	DENSITY (KG/M^3)
STEEL	370	7850
WOOD	3 – 15	5 - 650
PERSPEX	75	1190
ALUMINIUM	310	2700

Table 10: Materials Comparison

7.1.3 Rotating Mechanism

7.1.3.1 Design

As payload C must be placed into the bunker with the arrow pointing to the end of the competition track, this means there must be some type of system for rotating the payload. Rotation can be achieved by having a wheel run around the outer edge of the payload, or by implementing a system to push the underside of the payload. Although turning the payload via the outer edges could be an effective method, the sharp non-curved edges on the payload make this method impossible. Rotating the underside of the load would likely increase the accuracy, and an even rotation can be achieved by using two motors that would oppose each other, rotating the payload in a perfect circle. If the rotating wheels are the only contacting points on the payload it will not sit evenly which would affect the operation of the motors. To overcome this, several multi directional wheels can be used to level the payload out and freely turn in any direction.

The use of two motors to rotate the payload evenly and efficiently is the best option, however the motor shafts cannot directly drive the rotations and will need a wheel to fit onto the motor shafts to ensure they only just exceed the resting height of the payload on the bearings. Using the resources available, 3D printing the wheels is the best option for the rotating wheels because of the ability to make it to any size or orientation needed. As it only needs to move a light weight, strength is not an issue.

7.1.4 Dispatching Mechanism

7.1.4.1 Design

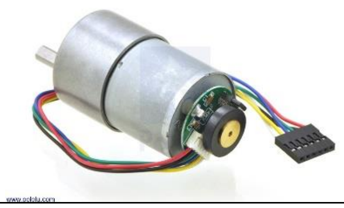
The payload is required to be dispatched into a bunker, which is 36mm off the ground and 18mm deep. Simplicity in the dispatching mechanism design is important as weight and usable space are limited. The fork lift tines concept, which was explored in design option 3, simply pushes the payload off the forks into the bunker and so is a strongly viable solution. As set out in design option 2, using drawer rollers and modifying them by joining the runners together would allow the pusher to simply slide along its rails. To keep the weight and used space to a minimum, a small high torque motor with a pulley can be used to wind in a string, therefore pushing the payload off the forks. This pulley can be custom made to suit the desired speed of dispatching by laser cutting wood or perspex to different diameters.

7.2 Mechatronic Design

In addition to the successful implementation of the mechanical aspects of the design, the mechatronic components are equally as important. These consist of the electronic components of the motors, motor drivers, arduino choice and batteries. Along with this, the implementation of the code is of high importance, with several key factors being essential for the successful operation of the code.

7.2.1 Motor Choice

The first consideration is the choice of motors used to drive the robot, elevate the scissor lift, rotate the payload, and dispatch the powerpack. In order to determine which of these will be the most useful for each component of the design, a comparison has been set out in Table 10 .

Motor Type	Positive Aspects	Negative Aspects
Stepper Motor 	- Allows micro step precision to the nearest 8th of a step – in the code a given number of steps is set. - Doesn't rely on time or battery power – operates until set number of steps have been met - Brushless motor so less chance of wearing out.	- Lower torque that standard DC motors - Quite heavy (NEMA 17 – 240grams)
Encoder Motor 	- Tracks the shaft rotations using sensors - Doesn't rely on time or battery power – operates until rotations have been completed.	- Not quite as accurate as stepper motors
Micro Metal Gear Motor	- Much higher torque - Very small and compact motor	- Purely rely on time – if the battery is low on charge the distance moved will vary

	✚ Wide array of gear ratios – lots of speeds to choose from	
Servo Motor 	✚ Can operate at very high torques ✚ Accurate step precision	✚ Can only rotate 180 degrees unless the servo is altered (potentiometer can be re-soldered and stopper pin removed).

Table 11: Motor Comparison [14]

Using this information, it is clear which motors would be the most suitable for each component of the robot. For the driving movement, either stepper motors or encoder motors are the only options that would ensure maximum accuracy. This is because they either rely on a set number of steps or revolutions being input, without any reliance on the current or voltage being drawn from the battery. After considering both motors, stepper motors were chosen, purely due to their micro-step precision.

Although micro metal gear motors were disregarded when considering the driving of the robot, they do however produce a very high torque for their small size which could be useful for the lifting mechanism. With the scissor lift requiring 2 motors being located in awkward vertical positions, these motors would be a perfect choice as they would fit into this space quite easily. Despite these motors being time oriented, this should not be a major issue seeing as they are only lifting and lowering the scissor lift where accuracy is of less importance.

The rotation of the payload does however require high accuracy precision. For this reason, a small, yet accurate precision type motor should be used. Although a servo motor would be a possible option, it is likely that a revolution of more than 180 degrees is required. Further research regarding stepper motors reveals that although the most common NEMA 17 motors are a heavy 240grams, smaller versions are available. The NEMA 8 stepper motor, weighing a mere 60grams, would be an accurate motor choice for this aspect of the design.

The final design aspect requiring motor control is the unloading of the powerpack. This motor would be purely required to twist a pulley, pushing a slider out of the robot. With this requiring little accuracy, a micro metal gear motor would again be a reasonable choice. This is because it could be simply operated until the sliders fall out of the runners, with no further operations being required after this.

7.2.2 Motor Drivers

Having decided on the most appropriate motor choices for each design component, the motor drivers were the next consideration. Table 11 presents several motor driver choices, with all relevant information being included.

Motor Drivers	Positive Aspects	Negative Aspects
L298N 	✚ Simple to use for DC motors – allows 2 for each board ✚ Can be used for stepper motors – 1 for each board ✚ Large heat sink to dissipate heat easily. ✚ Locally purchased	✚ If they are used for stepper motors, many drivers would be required

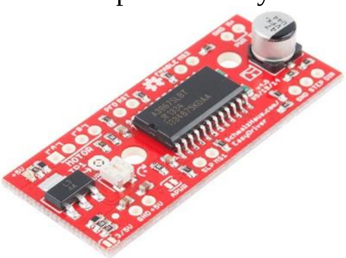
A3967 – Sparkfun Easy Driver 	✚ Designed for stepper motors – 1 per board but each board is quite small ✚ Defaults to 1/8th steps which means less coding is needed ✚ Input from 12-30V ✚ Relatively inexpensive	✚ Would get far hotter than L298N as there is no visible heat sink ✚ Must be purchased online
A4988 – Sparkfun Big Easy Driver 	✚ Designed for stepper motors – 1 per board ✚ Maximum motor driver voltage of 30V	✚ Almost double the price of the easy drivers. ✚ Slightly larger than the small easy drivers ✚ Must be purchased online

Table 12: Comparison of Motor Drivers [14]

Although all of the motor drivers listed above would be an appropriate choice for the stepper motors, the Sparkfun easy driver and big easy driver are a better option as they are actually designed for these motors. With the easy driver being only half the price of the big easy driver, yet still having all of the capabilities of this motor driver, this is the best choice and therefore is to be used for all stepper motors.

Despite the L298N motor driver being quite large and less useful for stepper motors, it would however be a suitable option for all the DC motors. Not only is it quite easy to use, it can also be purchased at most electrical shops such as Jaycar. This is a major benefit as it means no extras will need to be purchased as a backup.

7.2.3 Arduino Choice

There are only 2 arduino choices suitable for this task, with the first being an Arduino Uno, and the second being an Arduino Mega. Table 12 outlines the positive and negative aspects of each.

Arduino	Positive Aspects	Negative Aspects
Uno R3 	✚ Quite small compared to an arduino mega ✚ Included in Warman kit	✚ Limited number of digital pins ✚ Limited memory if large pieces of code are required
Mega 	✚ Much more memory ✚ Far more digital pins than arduino uno	✚ More expensive than arduino uno and not included in Warman kit

Table 13 Arduino Comparison [15]

Although the arduino uno is supplied in the Warman kit, this will not have enough digital pins due to the number of motors needed. For this reason, an arduino mega will be used. Despite this not being included in the supplied kit, one group member already owns this, meaning it will not need to be purchased.

7.2.4 Battery Choice

Battery Choice	Positive Aspects	Negative Aspects
Lead Acid 	- Can have a high capacity compared to other batteries - Relatively inexpensive - Tough and forgiving compared to Lipo batteries	- Limited number of digital pins - Limited memory if large pieces of code are required
Lipo 	- Very light and compact - High capacity for small size - Quick to charge	- Requires a smart charger capable of charging Lipo batteries - Not tough or forgiving – if terminals touch or if it is discharged too long then cells are destroyed - Quite expensive

Table 14 Battery comparison [16]

The advantages and disadvantages of different battery choices are contained in Table 13. Despite lead acid batteries being a clear standout for high capacity and durability, along with low cost, the weight of these would make it an unwise choice for the robot. With a weight limit of 6kg in total as stated in the design brief, this means that a lipo battery is the only appropriate choice. Therefore, care must be taken to ensure the voltage does not discharge below the cut off cell voltage of 3.2V per cell.

7.2.5 Final Mechatronic System

After considering all components of the mechatronic design, the final step before writing the code is to determine the wiring configuration and necessary features. By using the program Fritzing to draw up all of the circuit diagrams, it is possible to create a clear representation of the layout required. This is extremely important when connecting the motors to the motor drivers, and all relevant pins to the arduino.

Along with this, other features must be implemented to increase the durability and overall useability of the system. The first of these is the use of switches on both the battery and arduino battery. These simply require SPST switches to allow the connections to remain in place, without any risk of incorrect wiring if they were continually being pulled in and out. Figure 18 demonstrates how these are to be wired into the system to ensure it will successfully operate.

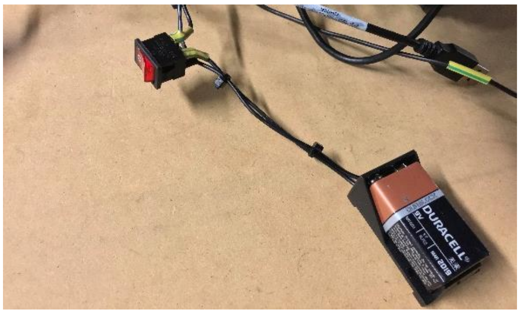


Figure 18: SPST Switch Wiring

Another key factor to be implemented is the use of an inline fuse to increase the durability of the lipo battery. This means that if an accident is to happen, where the positive and negative terminals touch, the fuse will be blown, and the battery will suffer far less damage. Figure 19 illustrates the wiring of this arrangement, with a 7A fuse being used.

Figure 19: 7A Inline Fuse

The final additional feature is a lipo low voltage alarm, as shown in Figure 20. This connects onto the cell balancer and can be set to the desired battery being used. As lipo batteries suffer damage if they are over-discharged, the incorporation of this feature means that whenever each cell drops below 3.2V, a loud alarm will sound, prompting the user to charge the battery before damage can occur.

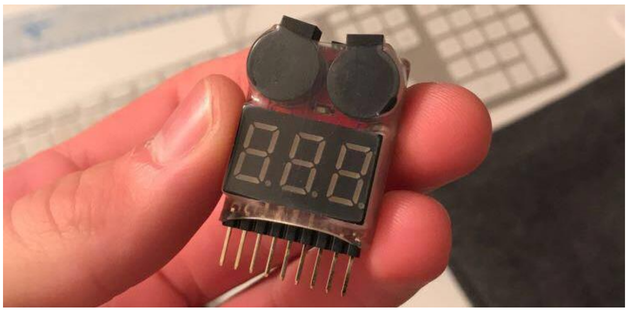


Figure 20: Lipo Low Voltage Alarm

7.2.6 Code

When implementing the code throughout the project, several key factors need consideration. As the robot is required to complete a set course once, the way the ‘loop’ function operates requires attention. Most loops written in arduino IDE generally repeat over and over, however in this situation it is to only operate once. In order to solve this issue, the function ‘exit(0)’ is implemented at the end of the ‘loop’ to essentially create an infinite loop to lock the system, therefore disabling the program from running any longer. This is a very useful command that means all functions can be implemented, with the loop then stopping once these have been completed.

Along with this, all stepper motors must run simultaneously, instead of one after the other. To overcome this issue, a while loop is used. For this to be successful, the function ‘distanceToGo’ from the ‘Accelstepper’ library is used. This function is of high importance as it checks whether the motors have completed their set number of input steps.

Therefore, by using this in a while loop and checking whether every motor had a distance not equal to zero (distanceToGo != 0), this ensures all motors would run at the same time. The full transcript of this code can be seen in appendix 4.

7.3 Detailed Cad Drawings of the Chosen Design

Detailed technical drawings of the finished product including dimensioned orthographic drawings of each part as well as a clear system level assembly drawing with labelled parts are set out Appendix 1 and 2. Created using the software Solidworks, an industry standard solid modelling computer-aided design and engineering program, the purpose of these drawings is to help define and illustrate the specific mechanical requirements and processes. They help communicate complex processes and structures in a way that it makes it clear and concise. Unlike artistic drawings, engineering drawings must be very explicit and contain little ambiguity. They should not be interpreted differently by different people but instead should focus on conveying information in a simple way. By doing so this eliminates the risk of misinterpretation of the drawing and what it is trying to illustrate and making sure everyone involved in the project has a clear understanding of the expectations and requirements.

7.2 Cost Analysis

Preparation of a detailed cost analysis, as shown in Table 14, is of vital importance as it ensures that the total cost of the build does not exceed the maximum budget of $100 each ($400 total).

Item	Price
Lipo Battery (RFI 3300MAH 14.8V 4S 30C)	$54.95
Nema 17 Stepper Motors (4x)	$48.00 ($12.00 each)
Nema 8 Stepper Motor (2x)	$58.64 ($29.32 each)
Sparkfun Easy Driver (6x)	$45.30 ($7.55 each)
Sheet Steel	$25.00
Aluminium Bar	$30.00
Threaded 6mm Rod	$6.00
Drawer Sliders	$15.00
Roller Bearings	$10.00
Aluminium Sheet	$30.00
TOTAL PRICE: $322.89	

Table 15: Cost Analysis

8. Make a Model or Prototype

With the initial design idea developed, the next process is to apply the theory of all the designed components in practice by making prototypes for each component to test and evaluate. The development of each protype model is extremely useful in determining how all of the components will work in unison.

8.1 Base

Although the base is to be made from steel, due to the difficulty in modifying and manipulating steel, a prototype of the base made from cardboard helps determine if the other mechanisms can fit inside the target dimensions. Clearly the sliding mechanism for the scissor lift would fit inside the base and there would be ample space to mount the sliders to the sides. The front of the slider could be fixed to the base by a nut and bolt because the slider would never get that far forward to foul with the bolt head, however mounting the rear of the sliding mechanism for the scissor lift using this method cannot be used due to the slider needing to move the entire way to the end of the slider rail. To overcome this issue of mounting the rear of the slider, a clamping bracket can be used by bending a piece of flat alloy (or in this case cardboard) at a 90° angle to clamp the top of the slider rail down whilst bolted to the base. This model can be seen in Figure 21.

Figure 21: Base - Cardboard Prototype

In order for the dispatching mechanism to operate successfully, the front of the base must be removed as this will allow the mechanism to push the payload off the forks. This preliminary modification to the design can be seen in Figure 22, with the final base being detailed in Figure 23.

Figure 22: Modification to Prototype Base

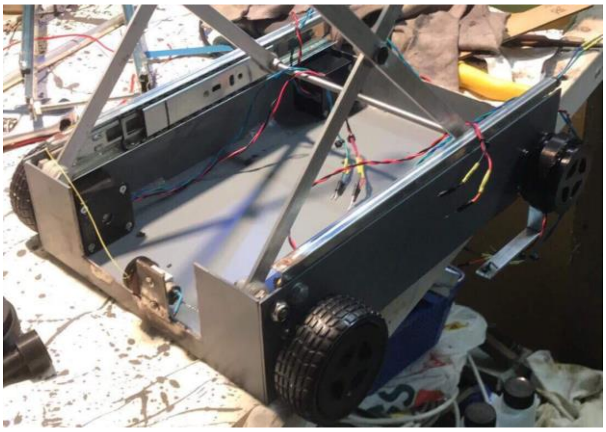


Figure 23: Steel Base

8.2 Scissor Lift Mechanism

A prototype of the scissor lifting mechanism makes it clear that both sides of the mechanism are unstable when using 1mm thick aluminium. A slight improvement occurs by joining the scissor lifting fames to its corresponding sides with threaded rod. With the mechanism unsteady at its full extension, the scissor beams are replaced with thicker 3mm aluminium flat bar to give more strength (Refer to Appendix 6 for supporting calculations). As shown in Figure 24, the addition of thicker beams and joining rods significantly increase the structural integrity that the mechanism needs.

Figure 24: Prototype Scissor Lift

With the prototype scissor mechanism built, it is possible to make a test model of the design for the lifting component of the mechanism. As shown in Figure 25, the vertical threaded rod is attached to the scissor lift mechanism through a nut, with this being welded to a section of tube that would fit over the joining rod of the scissor lift mechanism at the centre. This tube allows the rod to pivot if needed due to the centre moving towards the front as it extended.

Figure 25: Prototype Lifting Mechanism

The next component to be made is the fork lift mechanism, firstly out of carboard (Figure 26), and subsequently out of timber as this is not only light but quite easy to work with. However, as the payload is required to smoothly slide into the bunker, after countless hours testing it is determined that there is too much friction, so aluminium is instead used. The components that make up the forks are initially joined using pop rivets, which prove to be problematic as they would constantly move and not stay parallel with the opposite side. For this reason it is welded together to ensure there is no chance of it slipping during the competition (Figure 27).

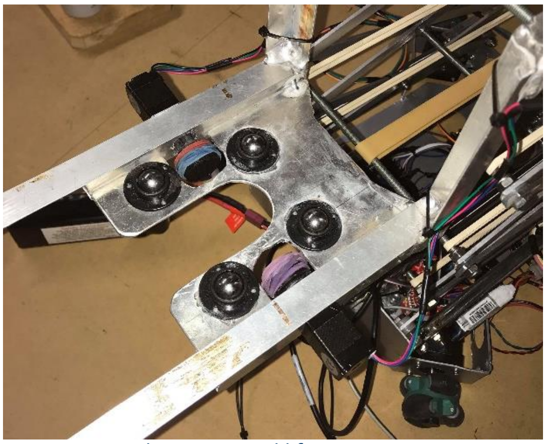


Figure 26: Cardboard Prototype

Figure 27: Aluminium Forklift

8.3 Rotating Mechanism

The concept for the rotating mechanism is to run two opposing wheels on the underside of the payload which would spin the payload. To apply this concept a prototype of this mechanism is made from wood as it is cheap and accessible. Both motors are mounted opposing each other at the same height and a wheel made to go onto each shaft. This prototype of the mechanism shows a flaw in the first concept design, in that the bracing of the lifting forks has a plate welded between the two forks which would foul with where the rotation wheels would run. To overcome this, sections of the plate that join the forks are cut out to allow the wheel to be mounted to the shaft, making it possible to install and remove when needed.

8.4 Dispatching Mechanism

For the same reason as the sliders of the scissor lift, the sliders for the dispatching mechanism cannot be bolted to any bracket to mount. This creates a problem because they need to be mounted at a certain height and also clear the rotation mechanism. This issue is overcome by brackets made from steel welded to the back of the slider which were then mounted to the bench to ensure the prototype was made level and could be tested.

8.5 Assembly

After a prototype of all the components is made, it is possible to assemble the individual components to construct a final prototype of the overall machine. A process for assembly and dis-assembly of the machine is required due to the large number of components fitting into a small confined space. Motors to fit for the driving wheels are first installed into the base. As it is difficult to install the dispatching device after installation of the scissor lifting mechanism, the scissor lifting mechanism is instead installed after the dispatching device is in place. The prototype is completely assembled and ready for testing and refining.

9. Testing and Evaluating

9.1 Movement

The first and most important component to be tested is the movement of the robot. After ensuring all coding and mechatronic implementation are operating successfully, the first to be tested is the 'forward' function. Testing shows the robot successfully driving forwards in a straight line, immediately stopping after the desired number of steps. The ability to accelerate and decelerate is shown to be extremely beneficial as it ensures that the motors are not instantly faced with high torque loads. Testing on the 'backwards' function produces a similar result, and neither of these let the motors slip a single step. Despite hopes that the 'left' and 'right' commands would work equally well, this unfortunately produces too much friction, therefore meaning the torque is too high for the motors, hence stalling these shafts. This means that the robot faces massive difficulties turning.

9.2 Lifting

The lifting mechanism is another important component that must be tested. After attaching a micro metal gear motor to a threaded rod and then supplying power to the motor, it is clear that this method for lifting will require too much torque for the motor. This system will therefore need to be completely redesigned, this time considering methods for decreasing high torque loads.

10. Refining and Evaluating

10.1 Wheel Choice

After thoroughly testing the prototype model, several refinements are necessary for the successful operation of the robot. The first, and most important of these refinements is the wheel style and configuration. With previous testing showing that turning is a major issue when the wheels are positioned in a parallel manner, an alteration to this design is crucial. When considering alterative designs, the key focus is on reducing friction when turning. Using mecanum wheels is one option as they allow far easier turning, being specifically designed to allow four-wheel drive robots to operate more successfully. By incorporating these into the current design, this would be an effective means of reducing the friction whilst attempting to turn.

Figure 28: Sparkfun Mecanum Wheel [17]

However, the price of these wheels range anywhere from $100 to $1000 each, with most of them being shipped from overseas. With the design criteria setting a strict budget of $100 per person, this would not be a feasible design alteration.

Omni wheels offer an effective alternative, with driving forwards and backwards being no harder than driving sideways. In fact, by using these wheels, turning would be even easier than travelling forwards and backwards, due to such little friction being created. These wheels are able to be sourced locally from an industrial shop on the southside of Brisbane for a reasonable price of $10 each. The only downside with using these wheels is that the original chassis base requires alterations for these wheels to be fitted. Figures 29 and 30 show how the original chassis is painstakingly altered.

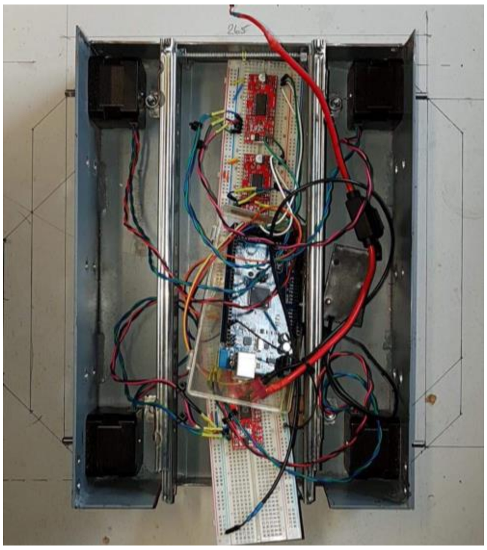


Figure 30: Modification to Original Chassis Base

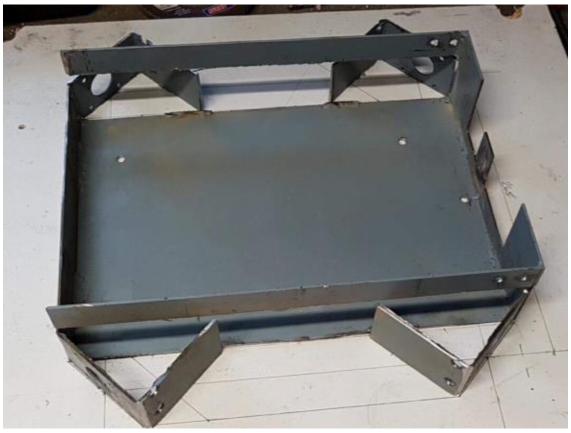


Figure 29: Newly Designed Base for Omni Wheels

After suitably changing the original base, the omni wheels are fitted to the stepper motors. It is immediately noted that these wheels allow the robot to exhibit extremely accurate turning, with it essentially pivoting directly from the center. The new concept can be seen in Figure 31, with this being ready for testing and further refinement.

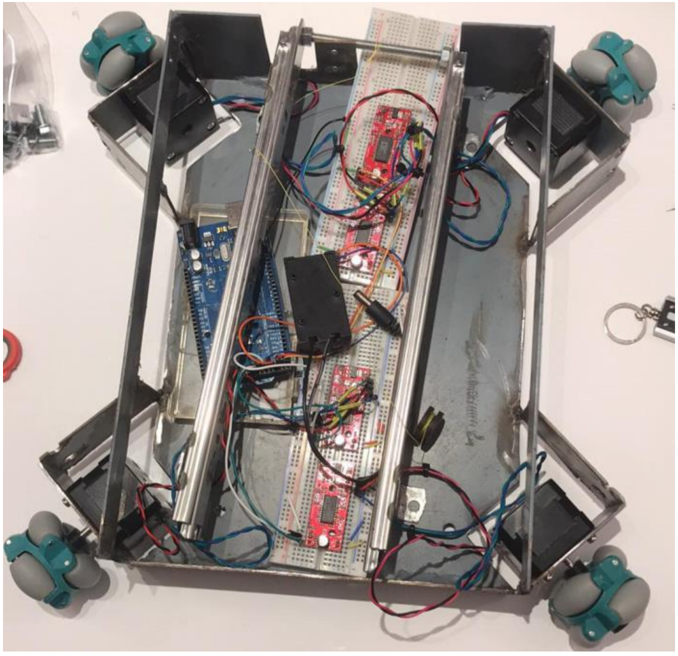


Figure 31: Omni Wheels Design Ready for Testing

Testing of this design reveals a major problem regarding the horizontal movement of the vehicle, with this being one of the mission critical aspects of the design. It can be seen that the wheels are made of a very shiny plastic, with this having a low coefficient of friction. The robot therefore would occasionally slip when driving forward, meaning it would not follow a perfectly straight path. Along with this, these wheels are designed for extremely heavy machinery, so each individual roller has no noticeable flex.

Brainstorming of ideas to fix this issue include incorporating some kind of suspension into the wheels. One option involves the use of a rubber bush between each welded motor holder and the base. This would essentially allow all corners to have equal contact with the ground always, therefore meaning it would most likely have very little slippage. Although this is workable, it would take a considerable amount of time, and bearing in mind the timeline matrix, is not feasible due to time constraints. An alternative solution involving simply taping each individual roller to add an element of flex and further friction could work, but would likely be an inconsistent approach to the issue. The adoption of a similar but improved option as a final alternative involves heat shrink being used, which would tightly grip around each roller, with no inconsistencies being present. It can be seen below how each roller has been removed and subsequently adjusted to increase the friction on each wheel.

Figure 32: Omni Wheel Roller Removed

Figure 33: All Rollers with Heat Shrink

After testing this newly refined wheel design, the forwards, backwards, sideways and rotation movements are observed to operate perfectly every time. This means that exiting the garage and driving around the course would no longer pose as an issue on test day.

10.2 Lifting Mechanism

Although the scissor and fork lift design seem to work quite effectively, the actual means of lifting is another mission critical aspect. In order to fix this issue, the first alteration to the design includes 2 vertical threaded rods to replace the initial horizontal positioning of the thread (see Figure 34). After testing this design, although far more effective, it is also quite unreliable. This is because if one of the motors ever gets out of synchronization, the threads would lock on the nuts, with the motors therefore stalling. Another issue with this method is that the thread would occasionally and also randomly put pressure on the nuts, also causing the motors to stall, despite these being extremely strong micro metal gear motors with over 2.5kg of torque.

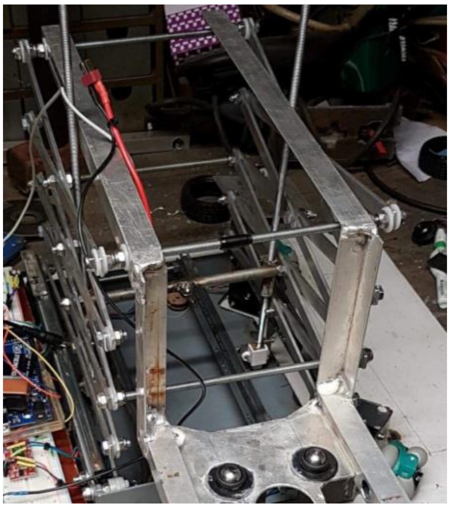


Figure 34: First Alteration to Lifting Mechanism

This design is subsequently altered, with the belief that the centering of these threads may solve the issue. Unfortunately, the issue of threads locking on nuts still remains an issue. Figure 35 shows the second unsuccessful modification.

Figure 35: Second Alteration to Lifting Mechanism

A third major alteration to the lifting system allows the single thread to loosely slide, with the hopes that this may stop the thread from locking (Figure 36). Despite this being reasonably effective, the occasional locking of this nut means that the consistency would not be of competition standard.

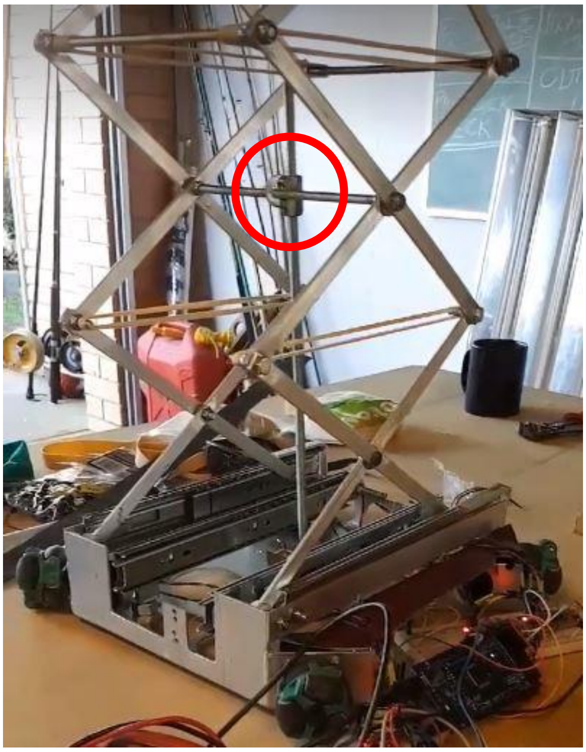


Figure 36: Third Alteration to Lifting Mechanism

The final and most successful alteration to the lifting mechanism uses stored energy in the form of elastic bands instead of threaded rods and nuts. This design simply releases the mechanism upwards when the pulley motor begins turning, and then pulls the scissor lift back down when the motor direction is changed. (See Figures 37 and 38.) This mechanism is not only the simplest design, but it would also be the most cost effective and fuel-efficient system for the people of Gondwana. This is due to it purely using a mechanical advantage of stored energy, with this being converted to kinetic energy when it reaches payload C

Figure 37: Final Lifting Mechanism (Compressed)

Figure 38: Final Lifting Mechanism (Extended)

11. Creating, Building and Constructing

After thoroughly testing all the protype models and refining these until they worked successfully, the final construction of the chosen design could begin, with the final CAD model being shown in Appendix . Safety is important in the construction of the final design, with risk assessments being used for any new manufacturing process or method. The robot that has been designed is constructed using many different materials and tools, with these being listed in Table 15.

<table>
<tr><th>Materials</th><th>Tools</th></tr>
<tr><td>
- Steel – Chassis Base
- Aluminium – Scissor and Forklift
- ABS Plastic – 3D printed components
- MDF Wood – Pulleys used for scissor lift and pushing mechanism
- Nylon – Washers used to reduce aluminium from rubbing
- Rubber – Used to help scissor lift rise
</td><td>
- Welder
- Grinder
- File
- Hammer
- Die Grinder
- Drill
- Dremel
- Screw Driver
- Spanners
- Tap and Dies
- Scribe
- Ruler
- Centre Punch
- 3D Printer
- Laser cutter
</td></tr>
</table>

Table 16: Materials and Tools

11.1 Base

The base needs to be made with a high level of accuracy and attention to detail to ensure all of the wheels contact the ground evenly for accurate and even movement whilst driving. Nine separate components on a large piece of 2mm flat sheet steel are marked out: 1x base, 1x front, 1x back, 4 motor mounts and 2x scissor lift mounts. All the holes are marked and drilled for the driving motor spigots, scissor mounts dispatch mounts and lifting mechanism mounts. Once all the holes are cut out, the pieces are cut using a grinder and dummy-fitted together with squaring magnets. With the base dummied up, a MIG welder is used because of the ability to quickly but accurately tack weld around each piece to lightly hold the base together. Before completely welding up the base for strength, further checking of the heights and alignments of the wheel spigots is done to ensure all measurements are correct and the base is perfectly square. All welds and drilling burs are ground to ensure no sharp edges for safety and to ensure no damage could occur to the motors.

11.2 Scissor Lift

Manufacturing of the scissor lifting mechanism is started by marking out each length of the scissor members and repeating 16 times. Once the members are marked at the correct length, they are cut and the holes then marked for the connecting bolts and drilled out. To reduce the friction between two members bolted together nylon washers are used in between and a 6mm bolt with a nylock nut shown in Figure 39 is used to ensure the member could not wiggle the nut loose during use. Because the two scissor mechanisms are separated and therefore pose the issue of being unstable at the fully erect height, to overcome this problem a 6mm threaded rod is used at every second scissor joint to go through and join both sides.

Figure 39 Nylock Nut [18]

As the scissor lift design requires one of the ends to be fixed, this is achieved by using a longer bolt at the front of the base and spacing it out appropriately to ensure the member is straight, fixing it to the base through a hole with a nylock nut. Because the opposite end of the scissor mechanism is required to slide towards the fixed end, drawer sliders are modified by cutting the inner slider down with a grinder so it fits inside the base and slides to the end freely. The sliders are fixed to the base at one end by a nut and bolt. At the end that requires the slider to pass over it, a bracket (made from strip aluminium because it is strong and easily bent) clamps over the top of the slider ensuring it is held down, as shown in Figure 40. Once the sliders are fixed into place the runners are lubricated using silicon lubricant to ensure smooth movement of the mechanism.

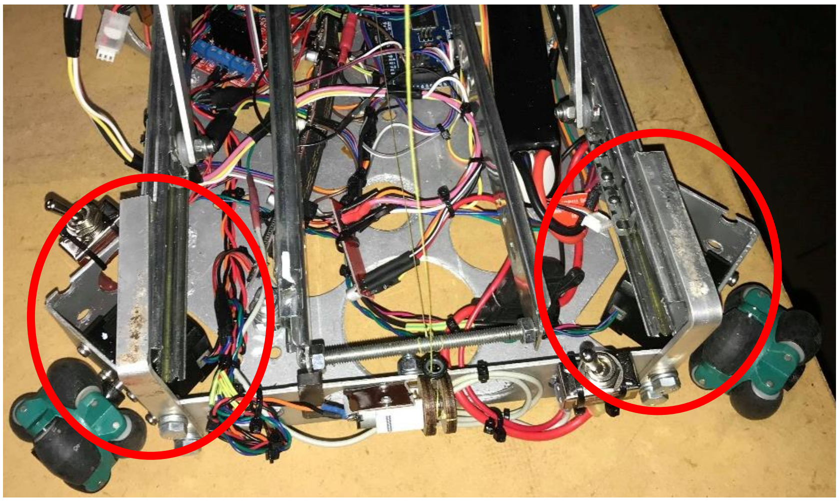


Figure 40: Mounting Bracket

Building the forks for the lifting of the payload begins by marking out the holes and lengths of the required aluminium L section and elongating the rear of the mounts to allow the scissor mechanism to freely move back and forwards inside the section whilst the front is fixed. The dropped down section of the forks is made using the same material, and box section aluminium is used for the actual protruding forks. The box section is cut down at the end to just the top face of the box section for the forks to be able to sit on the bunker. Once everything is marked and drilled, the forks are TIG welded together because of the difficultness in welding thin aluminium.

11.3 Rotating Mechanism

The rotating mechanism is incorporated into the building of the forks. Once the forks are welded together a support is marked out of 3mm alloy to go between the forks, with a section cut out for the pole to self-centre, as shown in Figure 41. Holes are also marked and drilled out of the joining plate before being welded into place in the centre of the forks box section. The holes in the joining plate are drilled to 22mm to allow 4 multi-directional wheels to be mounted to ensure the payload would rotate freely. Because these wheels are made from a plastic base, they are glued into place once the burs and sharp edges are removed by a file.

Figure 41: Cut Out for Pole

The motors that rotate the payload are fitted to the outside of the box section opposite each other, with a 16mm hole drilled through both sides of the box section for the motor spigots to locate on the outside and a hole on the inside for a wheel to attach to the shaft and protrude the resting height of the payload once collected. Due to the size and weight limitations of the motors being on the forks, small stepper motors have been used. This means that the mounting holes for the motors could not be used because they are too wide for the box section. To overcome this, super glue is used to fix the motors to the forks, as it would dry strong but be removable if needed in the future. Making the rotating wheel by 3D printing enables the creation of exactly what is required, particularly as there is nothing available to purchase and it is impossible to otherwise make a wheel to suit the application with the resources available.

11.4 Dispatching Mechanism

Manufacturing of the dispatch mechanism involves purchasing a pair of drawer slides similar to the ones used for the scissor lifting mechanism. The slides are taken completely apart and a thread tapped into the end of both sides for a threaded rod to be fixed between them to ensure they both extend evenly. Thread locker is also used to prevent the threaded rod wriggling loose when being operated. With both slides now fixed together, small L brackets are made to make the slides at the correct height to push the payload off the forks. The L brackets are made from 1mm sheet steel so they could bend or flex if needed and are welded to the slides and bolted to the base in the centre for easy installation and removal. A micro metal gear motor is mounted at the front of the base by two small bolts, with the shaft aligned at the same height as the threaded rod joining the dispatching mechanism. Utilising the laser cutter available at QUT, a pulley is drawn in SolidWorks in three separate pieces. The three pieces are glued together whilst on the motor shaft to ensure they are perfectly aligned, with the two larger pieces on the outside. A small hole drilled in the side of the outside piece allows a line to be tied through to allow the pulley to wind in the line, which in turn is attached to the threaded rod that joins the slides at the rear or the machine, inevitably pushing the payload off the forks. Braid is used as the line to pull the slides as it has easily accessible information on breaking strains and is readily available. 50lb braid is used after calculating the required force to move the object with a safety factor of 3. Once all the components are installed, the slides are cleaned and lubricated to decrease friction on the slides, making it easier for the dispatching mechanism to work.

12. Final Summary – Competition Results

After numerous design refinements and alterations, the final robot was not only extremely well built, but also very accurate and consistent in its operation. On the competition test day, the final score obtained by this device was 81.75, with this putting it in 1st position. Although this score was quite high, further alterations such as some kind of suspension for the wheels and sensors to detect the edges of the table should be incorporated into the design. However, the autonomous vehicle did complete the required task, therefore relocating the previously unusable power supply to the people of Gondwana, and therefore saving them from imminent starvation.

References

[1] S. O. J. H. John R. Karsnitz, “Engineering Design,” in *An Introduction*, New York, Delmar, 2009, p. Chapter 2.

[2] Bang good, “DIY 4DOF robot Arm Claw,” Bang Good , 2018. [Online]. Available: https://www.banggood.com/DIY-4DOF-Robot-Arm-Claw-Holder-With-Arduino-4pcs-Digital-Servo-p-1208203.html?cur_warehouse=CN. [Accessed April 2018].

[3] Thomson Actuators, “Linear Actuators,” Tomson Literature, USA, 2018.

[4] Gimson robotics, “Small Linear Actuator,” Gimson Robotics, 2018. [Online]. Available: https://gimsonrobotics.co.uk/categories/linear-actuators/products/gla750-12v-dc-small-linear-actuator. [Accessed April 2018].

[5] K. Nice, “Science.howstuffworks,” How Caterpillar Skid Steer Loaders & Multi Terrain Loaders Work, 03 June 2018. [Online]. Available: https://science.howstuffworks.com/transport/engines-equipment/skid-steer.htm. [Accessed May 2018].

[6] CAT, “Skid Steer Loaders,” CAT, 2018. [Online]. Available: https://www.cat.com/en_IN/products/new/equipment/skid-steer-loaders.html. [Accessed April 2018].

[7] Engineering 360, “Golbalspec.com,” Engineering 360, 2018. [Online]. Available: https://www.globalspec.com/learnmore/material_handling_packaging_equipment/material_handling_equipment/scissor_lifts. [Accessed May 2018].

[8] MP Industries, “Double Scissor Lift Tables,” MP Industries, 2017. [Online]. Available: http://www.industrialmaintenanceplatforms.com/double-scissor-lift-tables.html. [Accessed April 2018].

[9] Amazon, “Amazon Shopping,” 2018. [Online]. Available: https://www.amazon.com/Shop-Fox-D3031-100-Pound-Capacity/dp/B0000DD4A9. [Accessed May 2018].

[10] David P. Anderson, “nBot Balancing Robot,” 14 September 2013. [Online]. Available: http://www.geology.smu.edu/dpa-www/robo/nbot/. [Accessed May 2018].

[11] OLT Group, “Forklift Tynes For Sale,” Olt Group, 2017. [Online]. Available: https://oltgroup.com.au/used-forklifts-equipment/forklift-tynes-for-sale/. [Accessed May 2018].

[12] Robert Larson Company, “Work Bearings,” Robert Larson Company, 2016. [Online]. Available: https://www.rlarson.com/shop/woodworking/work-bearings-58-ball-set6-55load/. [Accessed May 2018].

[13] A. Hornbacher, “Steel Versus Aluminium,” Wenzel Metal Spinning, 2018. [Online]. Available: https://www.wenzelmetalspinning.com/steel-vs-aluminum.html. [Accessed May 2018].

[14] Robot Gear, “Robot Gear Australia Products,” Robot Gear Australia, 2018. [Online]. Available: https://www.robotgear.com.au/. [Accessed May 2018].

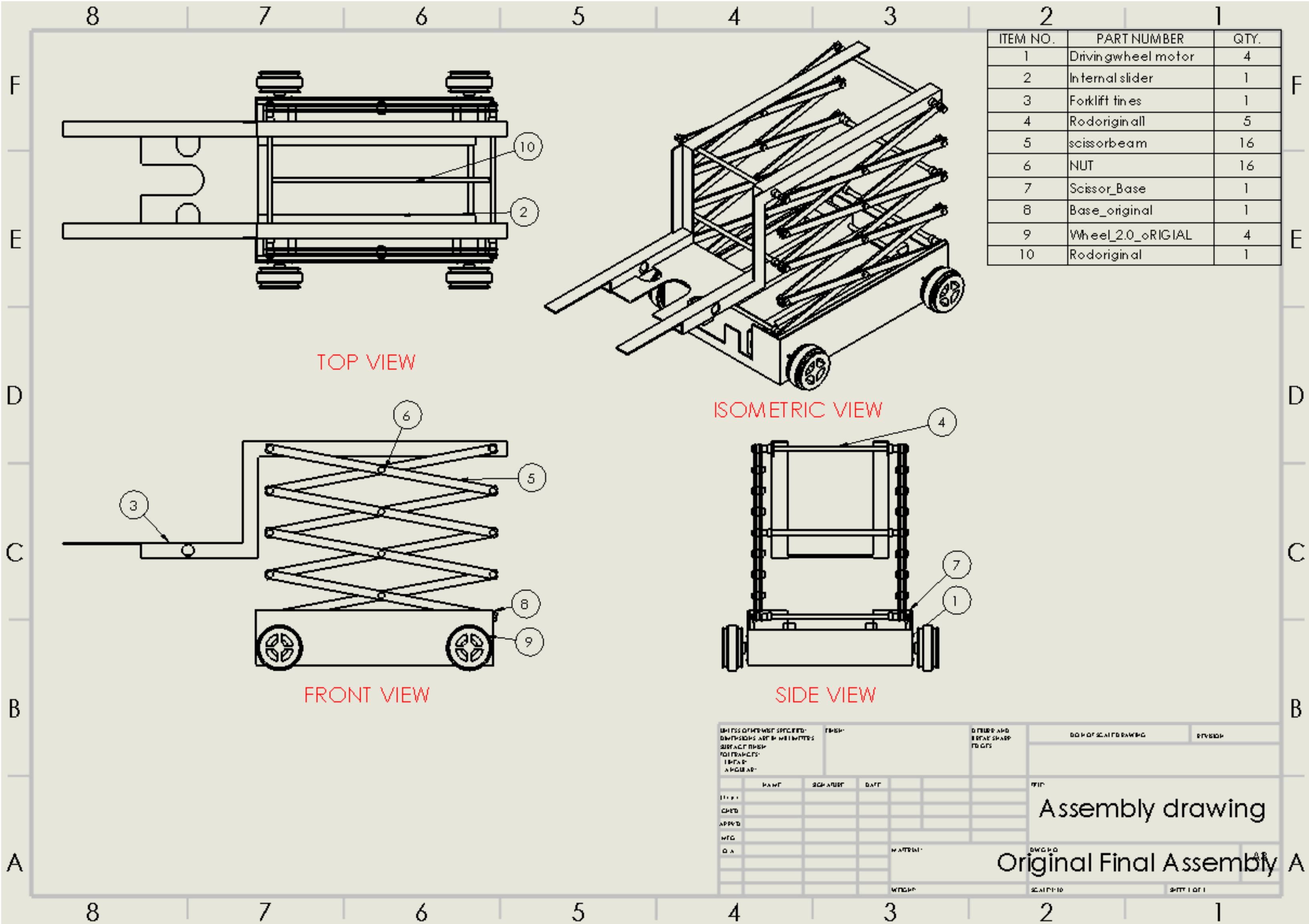
[15] AUS Electronics Direct , “Ardunio Modules,” AUS Electronics Direct, 2018. [Online]. Available: https://www.auselectronicsdirect.com.au/arduino/modules/. [Accessed May 2018].

[16] Hobby King, “Batteries and Chargers,” Hobby King, 2018. [Online]. Available: https://hobbyking.com/en_us/batteries.html. [Accessed May 2018].

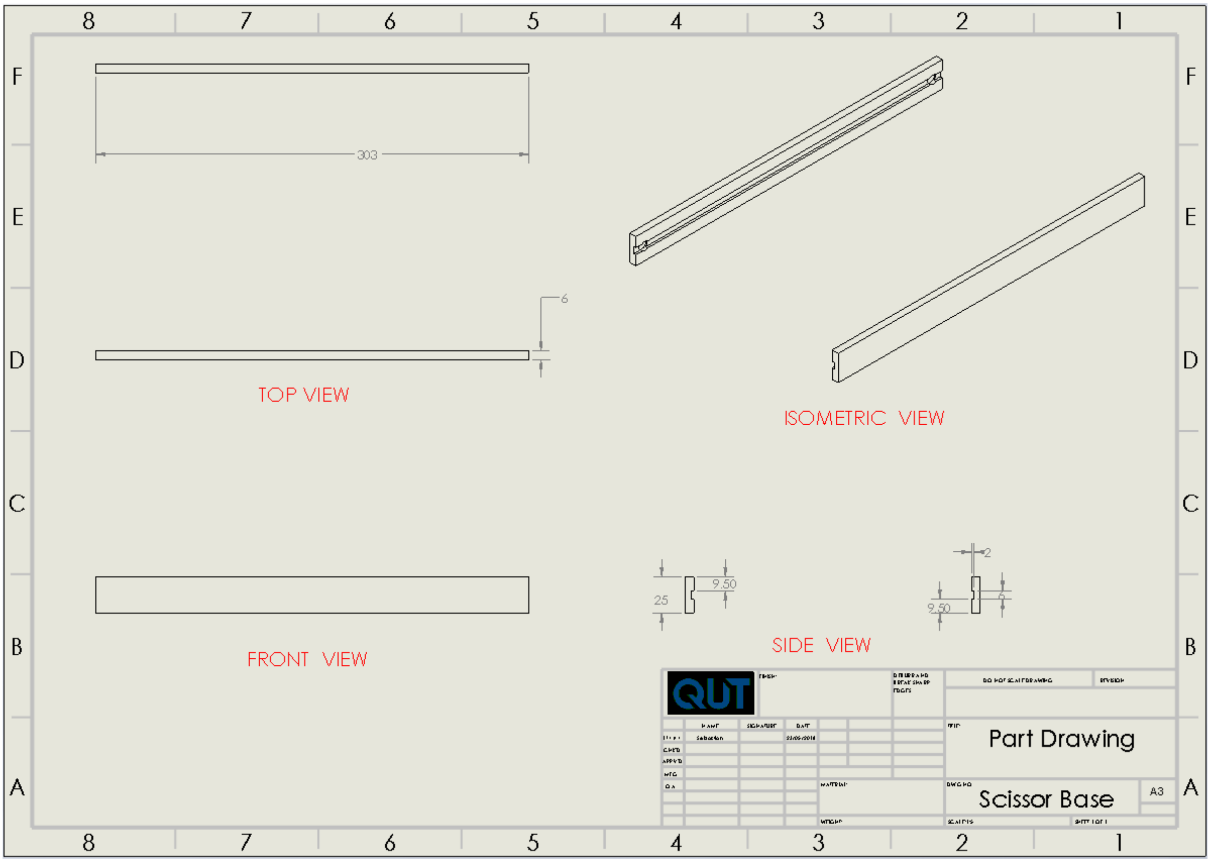
[17] Core Electronics, “Mecanum Wheels,” Sparkfun Australia, 2017. [Online]. Available: https://core-electronics.com.au/mecanum-wheels-4-pack.html?utm_source=google_shopping&gclid=EAIaIQobChMI1PfmxLu32wIVxQ0rCh2L1ghtEAQYAiABEgK7NPD_BwE. [Accessed May 2018].

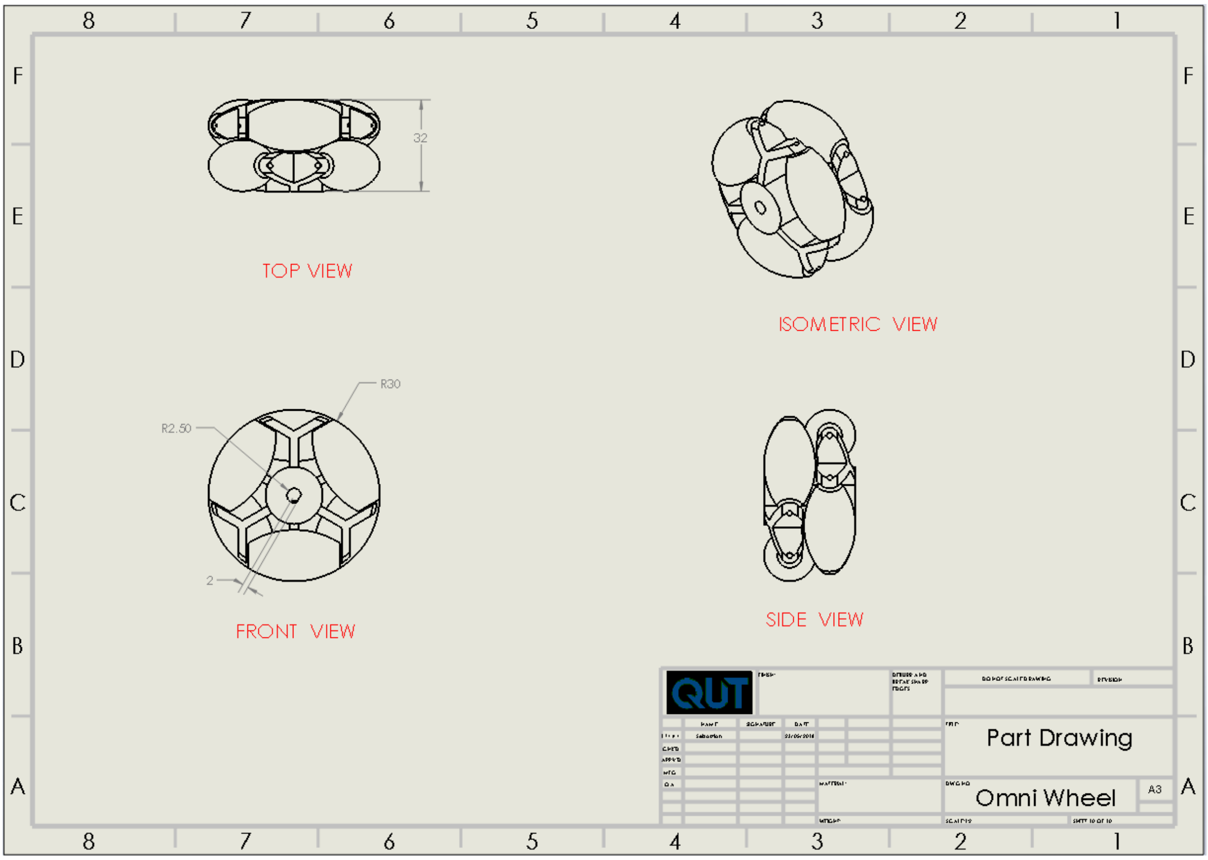
[18] Belmetric, “Metric Hardware and Automotive Specialty Supplies,” Belmetric, 2018. [Online]. Available: https://www.belmetric.com/fine-thread-c-3_752_1000_1010/nn20x15ss-nylock-nut-ss-p-10016.html. [Accessed May 2018].

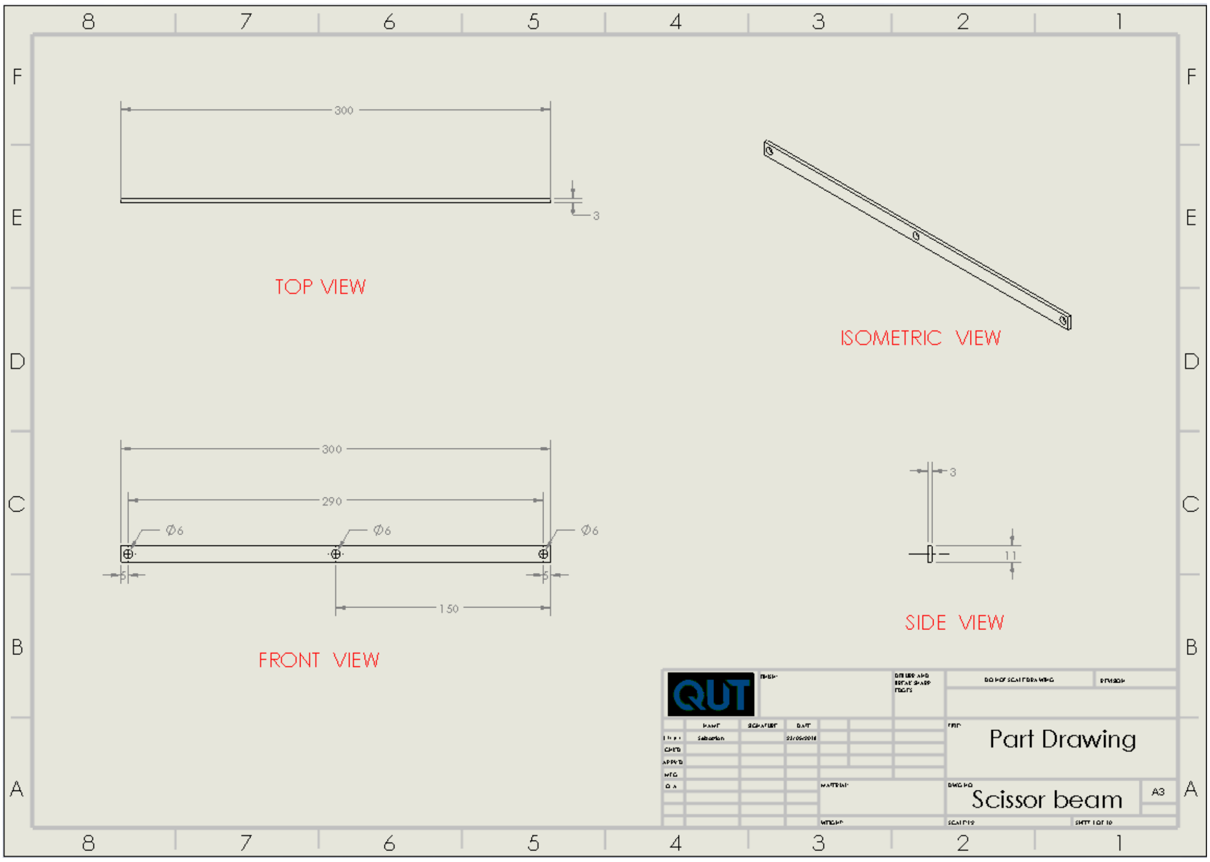
Appendix 1: CAD Drawing of Robot Before Refinement

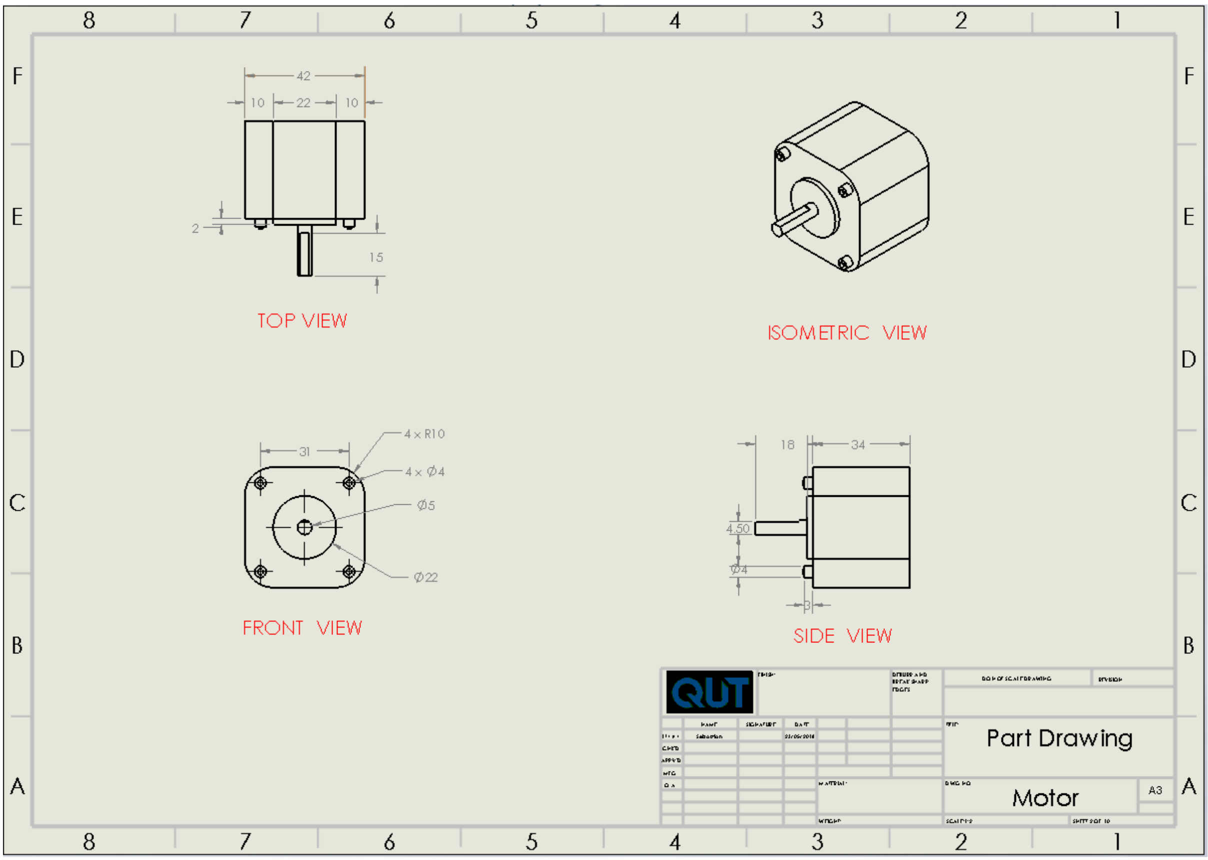


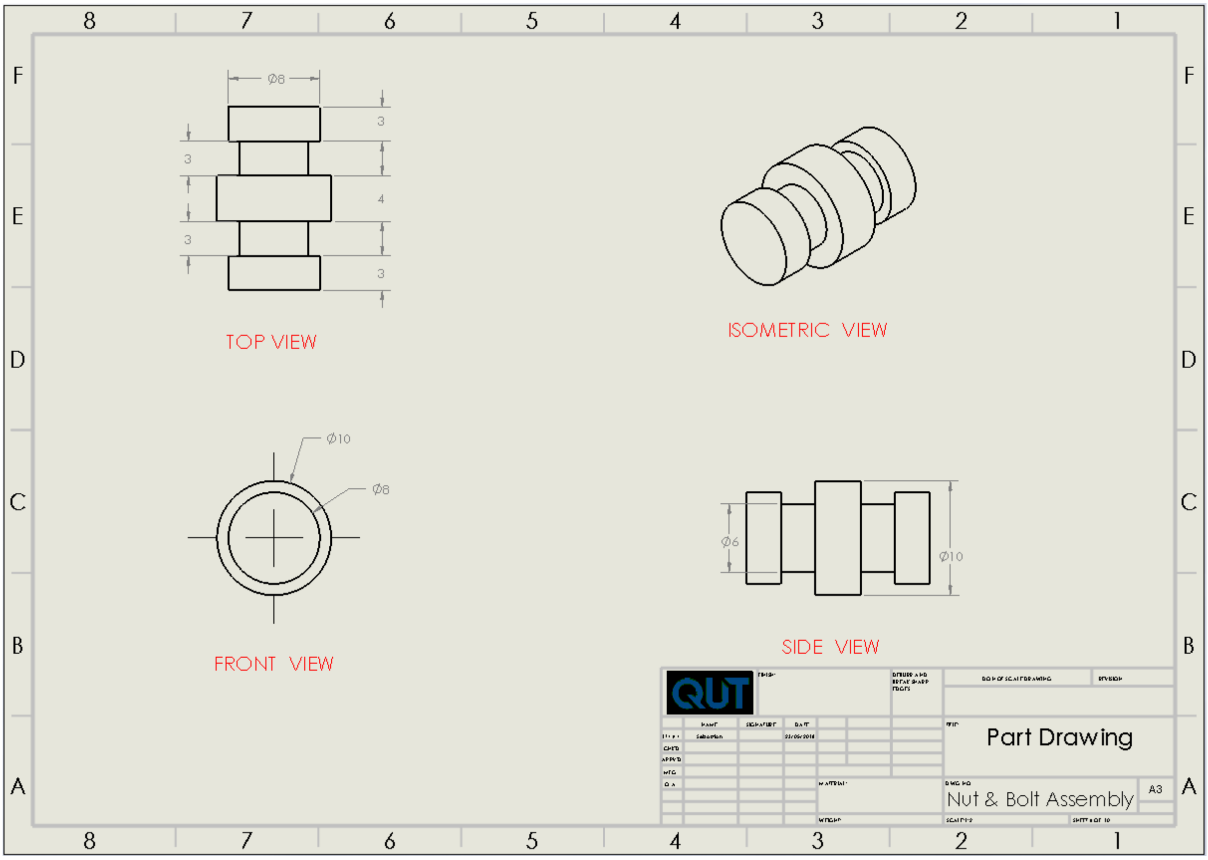
Appendix 2: Detailed CAD Drawings of Components

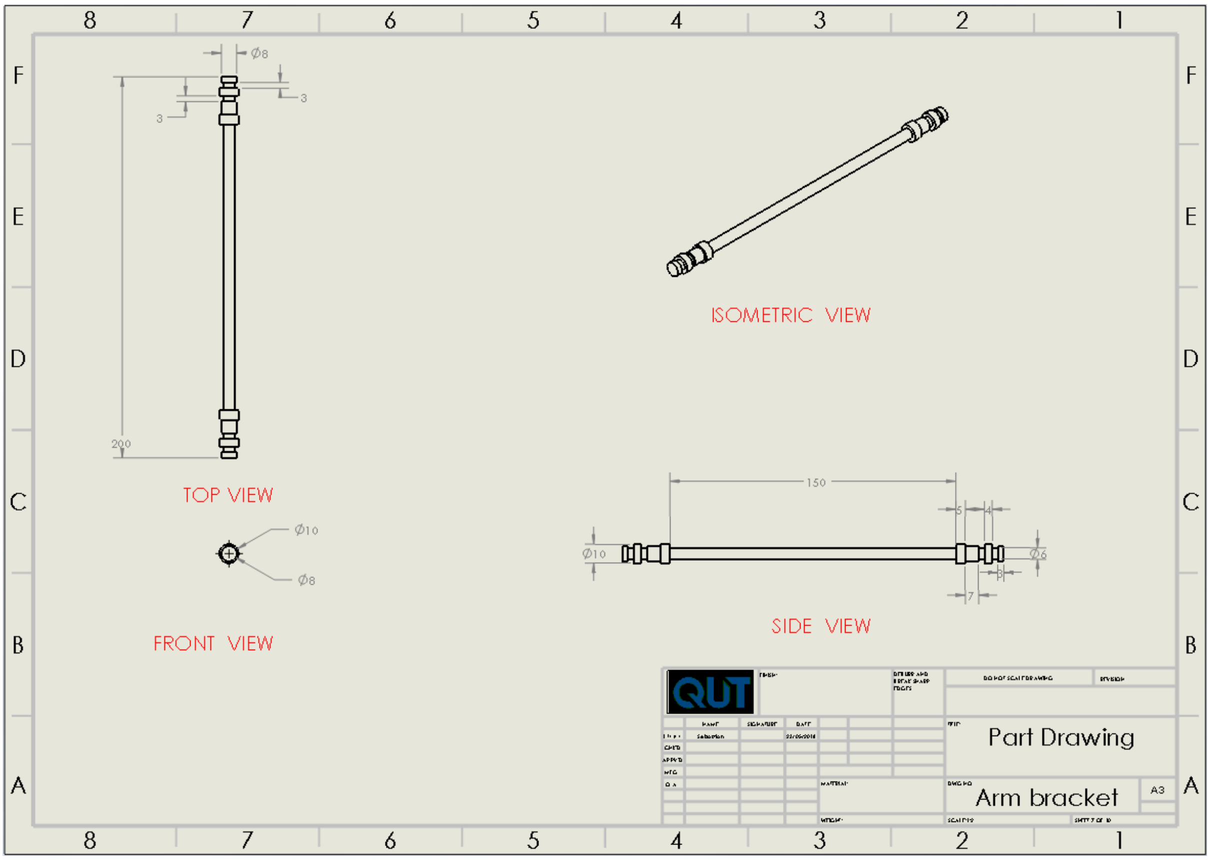


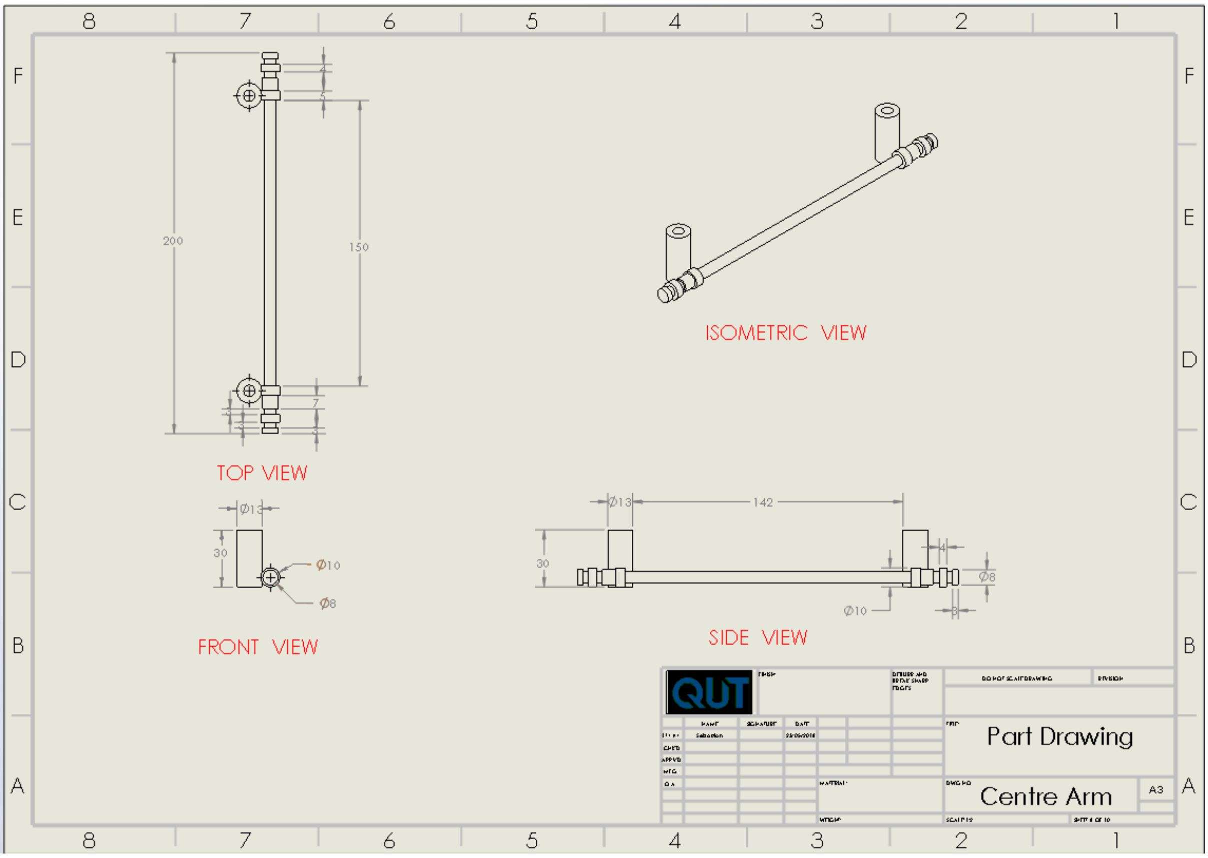


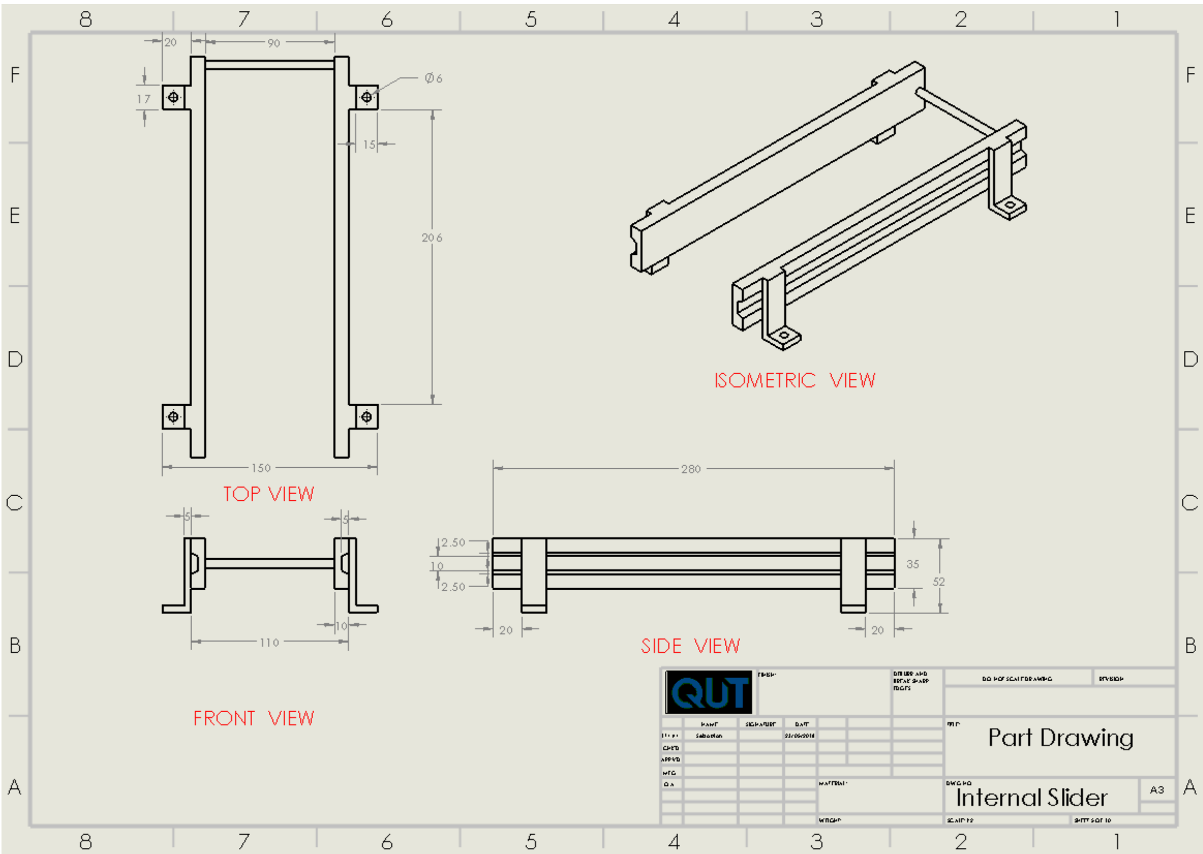

TOP VIEW
ISOMETRIC VIEW
FRONT VIEW
SIDE VIEW
QUT
Part Drawing
Scissor beam
A3

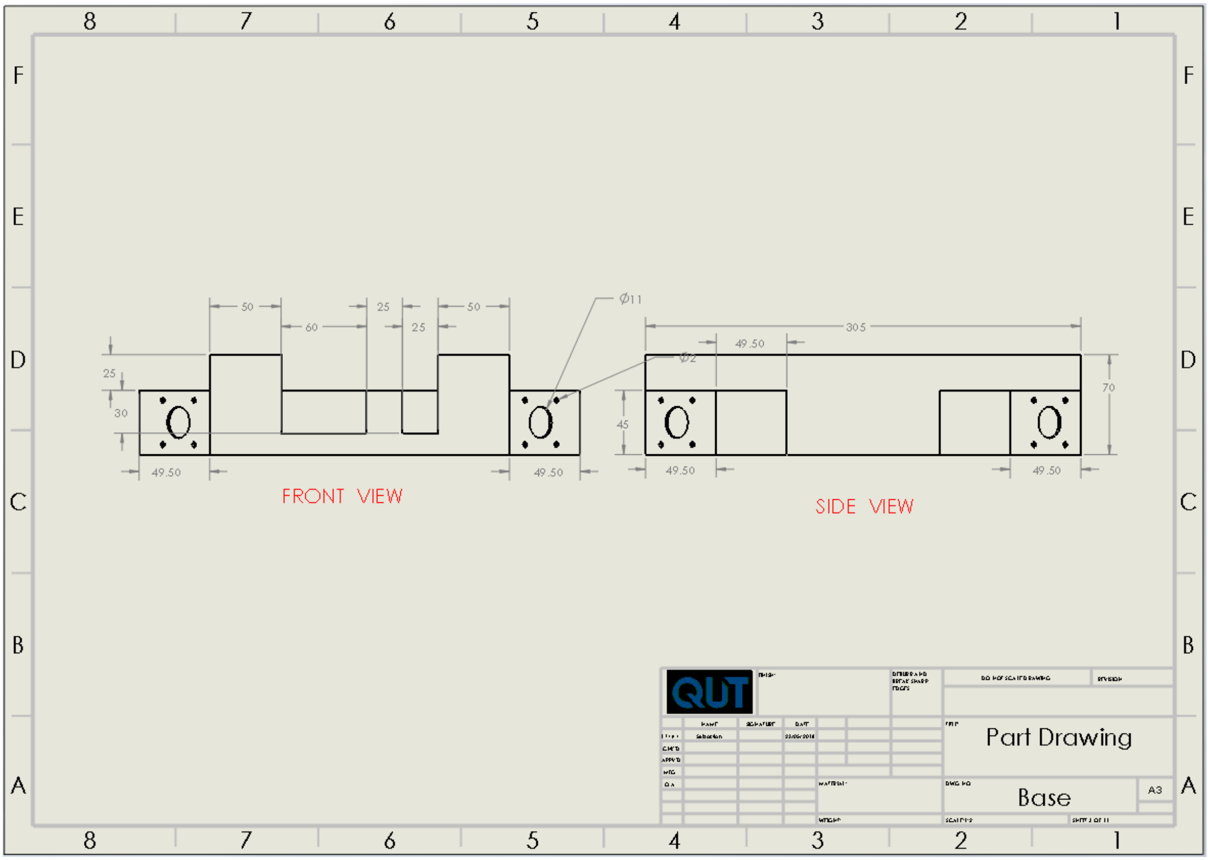

TOP VIEW
ISOMETRIC VIEW
FRONT VIEW
SIDE VIEW
QUT
Part Drawing
Motor
A3

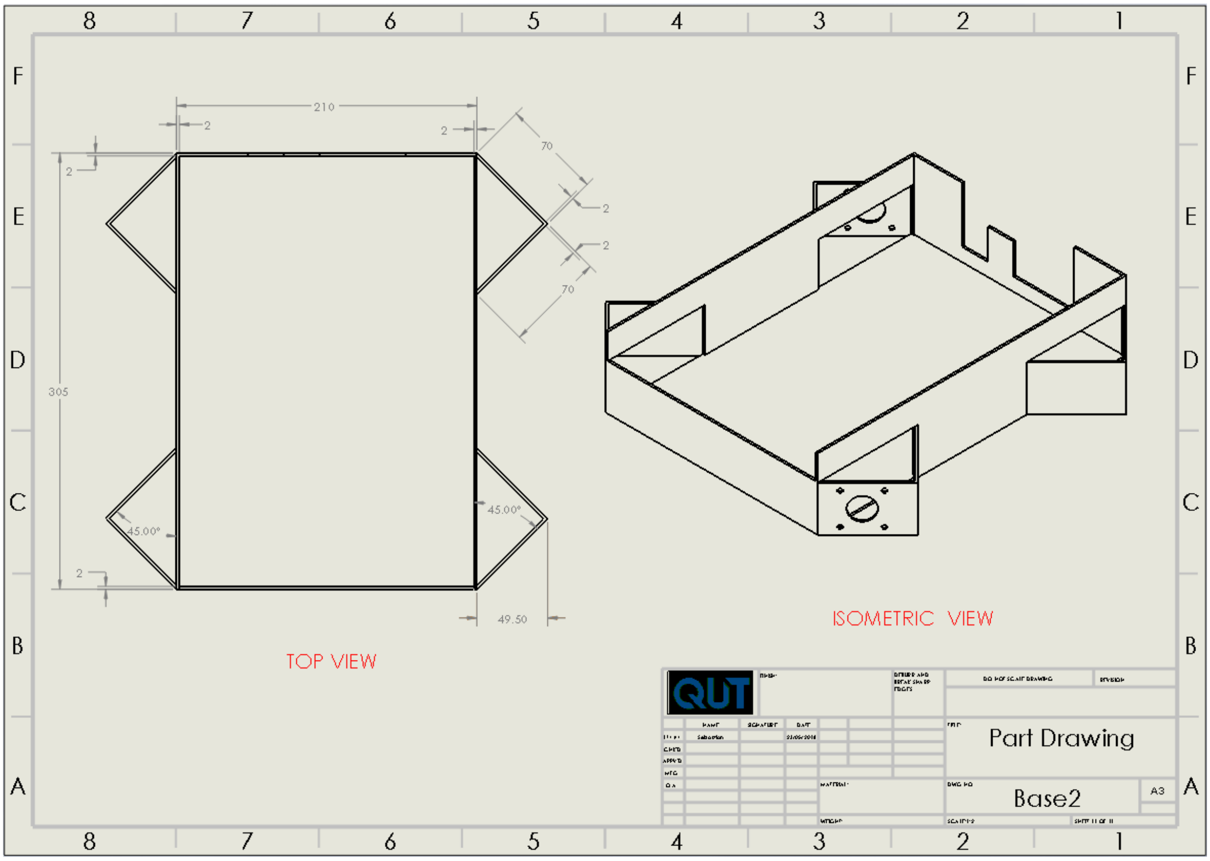

TOP VIEW
ISOMETRIC VIEW
FRONT VIEW
SIDE VIEW
Ø8
Ø10
Ø6
Part Drawing
Nut & Bolt Assembly
A3
QUT

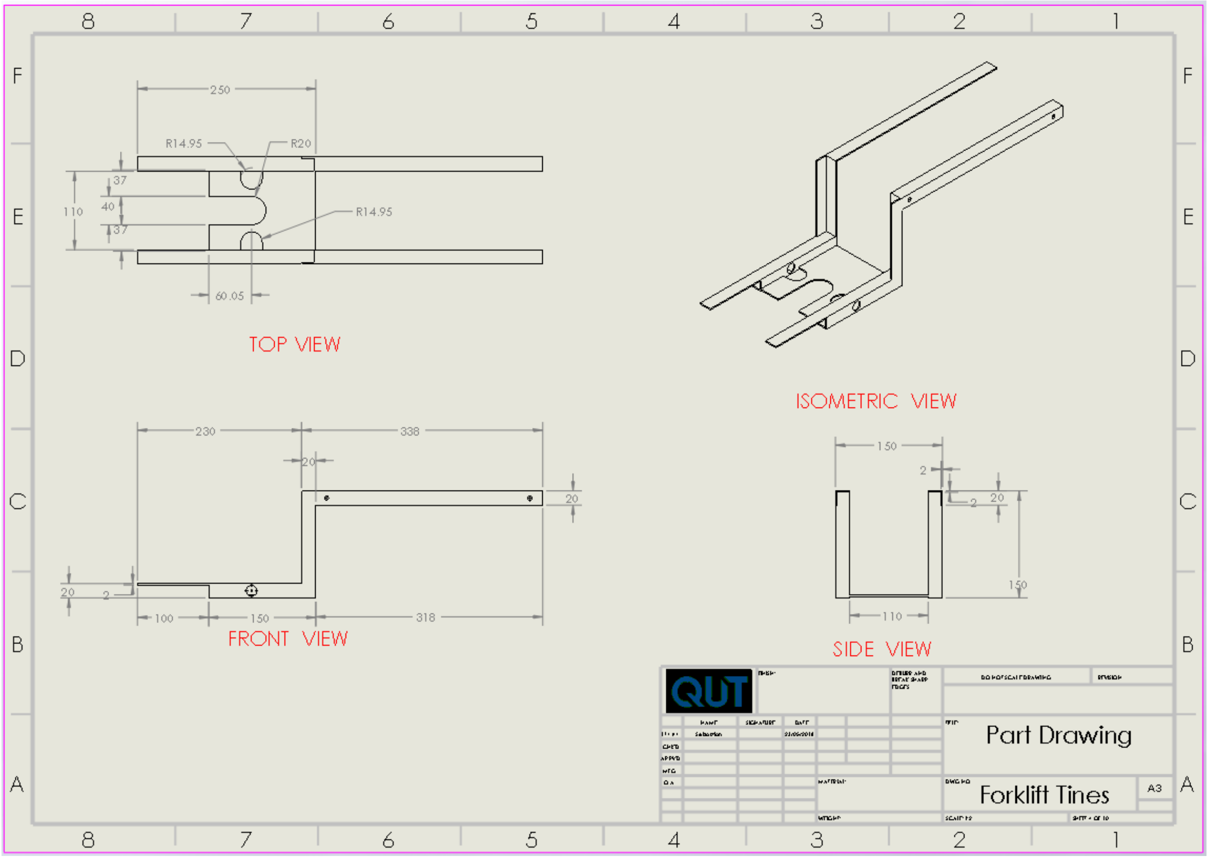

TOP VIEW
ISOMETRIC VIEW
FRONT VIEW
SIDE VIEW
Ø8
Ø10
Ø6
200
150
Part Drawing
Arm bracket
A3
QUT


TOP VIEW
FRONT VIEW
ISOMETRIC VIEW
SIDE VIEW
200
150
142
30
Ø13
Ø10
Ø8
QUT
Part Drawing
Centre Arm
A3

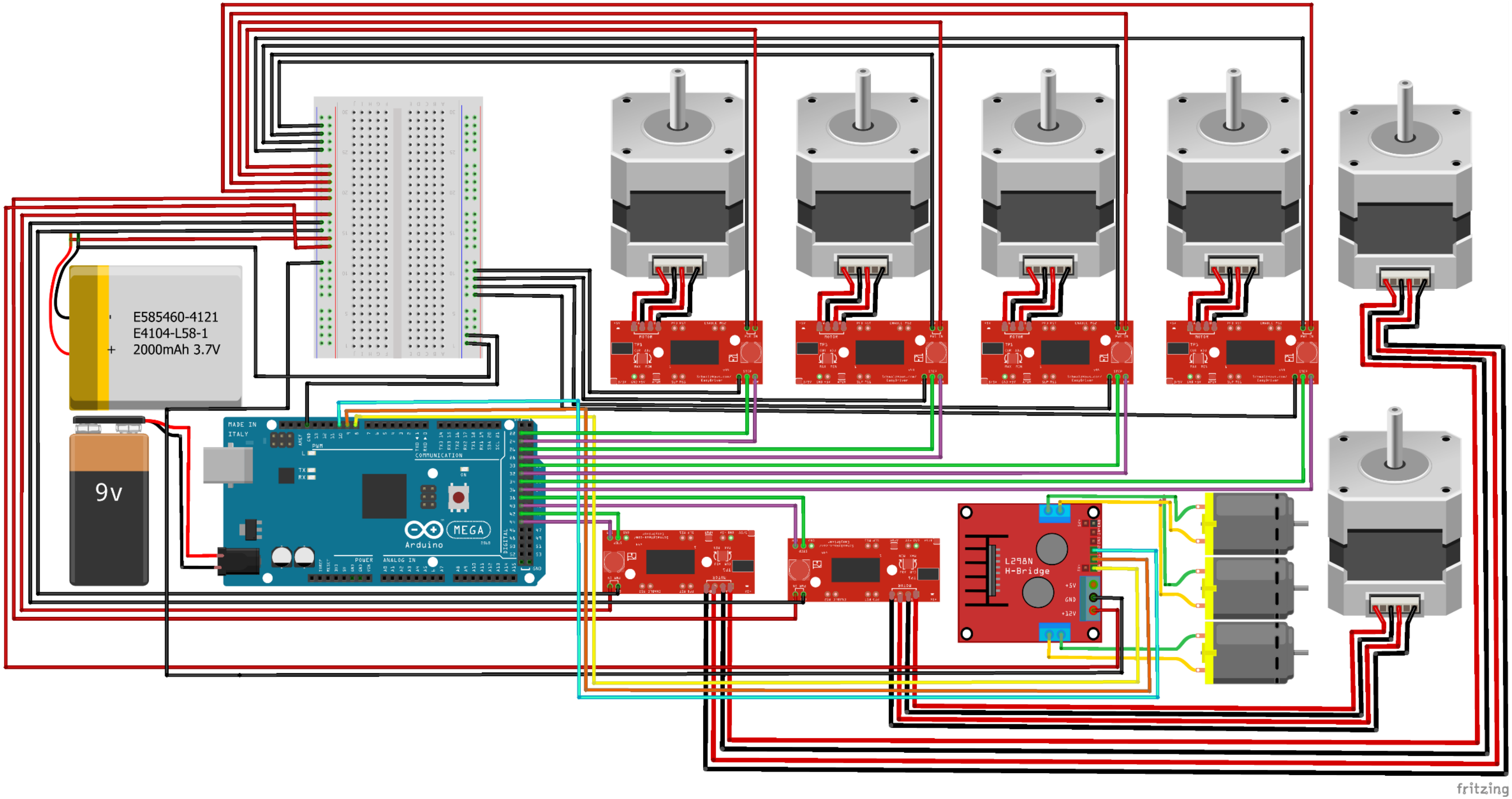

TOP VIEW
FRONT VIEW
ISOMETRIC VIEW
SIDE VIEW
20
90
17
Ø6
15
206
150
110
280
35
52
QUT
Part Drawing
Internal Slider
A3


FRONT VIEW
SIDE VIEW
Part Drawing
Base
A3


TOP VIEW
ISOMETRIC VIEW
Part Drawing
Base2
A3


TOP VIEW
ISOMETRIC VIEW
FRONT VIEW
SIDE VIEW
QUT
Part Drawing
Forklift Tines
A3

Appendix 3: Circuit Diagram of Electrical System



Appendix 4: Code

```
//---------------------------Group_4.6_Warman_Challenge-------------------------//

/*
The following Arduino code is written in C++ and compiled on Arduino IDE. This
code controls 4 NEMA 17 stepper motors to control the robot movement, 2 NEMA 8
stepper motors to rotate the payload, 2 micro metal gear motors to control the
scissor lift, and another micro metal gear motro to push the payload into the
bunker.
*/

//--------------------------------Include_Libraries------------------------------//

// Include any relevant libraries (Some are external such as AccelStepper)
#include <AccelStepper.h>

//-------------------------------Declare_Variables-------------------------------//

// Define a stepper and the pins it will use
AccelStepper stepper_FL(AccelStepper::DRIVER, 22, 24); // Front Right (FR) 22 step 24 dir
AccelStepper stepper_FR(AccelStepper::DRIVER, 26, 28); // Front Left (FL)
AccelStepper stepper_BL(AccelStepper::DRIVER, 30, 32); // Back Right (BR)
AccelStepper stepper_BR(AccelStepper::DRIVER, 34, 36); // Back Left (BL)

int enableA = 5;
int pinA1 = 6;
int pinA2 = 7;

int enableB = 10;
int pinB1 = 9;
int pinB2 = 8;

boolean run;

//-------------------------------Declare_Functions-------------------------------//

/* These functions must be declared before being used seeing as they are written
below where they are needed. */

void speed_acceleration(void);
void current_position_0(void);
void run_motors(void);
int forward(int forward_steps);
int backward(int forward_steps);
int right(int right_steps);
int left(int left_steps);
void turnOn_scissor(void);
void turnOff_scissor(void);
int scissor_lift_down(int time);
int scissor_lift_up(int time);
void setup_dc(void);
int right_sideways(int sideways_steps);
int left_sideways(int sideways_steps);
int push_forward(int time);
void turnOn_pusher(void);
void turnOff_pusher(void);
```

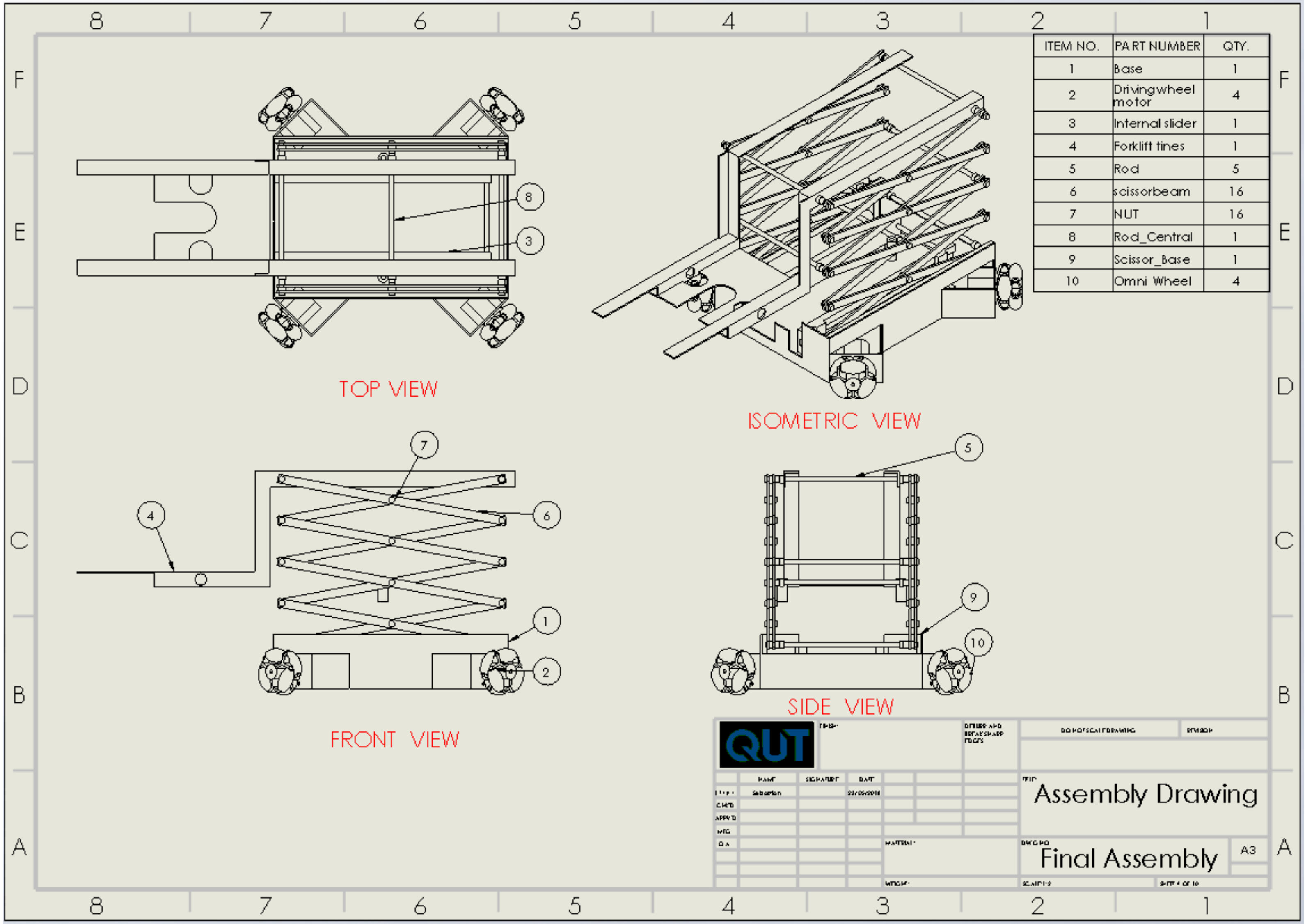
```
//------------------------------------Setup------------------------------------//

void setup(){
  speed_acceleration(); // Initialises speed and acceleration for all 4 steppers
  setup_dc();
}

//-----------------------------Necessary_Functions-----------------------------//

// This function initialises the speed and acceleration for all steppers - constant
void speed_acceleration(){
  // Front Right Speed and Acceleration
  stepper_FR.setMaxSpeed(2000);
  stepper_FR.setAcceleration(1000);

  // Front Left Speed and Acceleration
  stepper_FL.setMaxSpeed(2000);
  stepper_FL.setAcceleration(1000);

  // Back Right Speed and Acceleration
  stepper_BR.setMaxSpeed(2000);
  stepper_BR.setAcceleration(1000);

  // Back Left Speed and Acceleration
  stepper_BL.setMaxSpeed(2000);
  stepper_BL.setAcceleration(1000);

}

void setup_dc(void){
  // Lifting Motor
  pinMode(enableA, OUTPUT);
  pinMode(pinA1, OUTPUT);
  pinMode(pinA2, OUTPUT);

  // Pushing Motor
  pinMode(enableB, OUTPUT);
  pinMode(pinB1, OUTPUT);
  pinMode(pinB2, OUTPUT);
}

// Sets Current Position as 0 if Motor Has Moved
void current_position_0(void){
  // Set Current Position to 0 Whenever Function is Called
  stepper_FR.setCurrentPosition(0);
  stepper_FL.setCurrentPosition(0);
  stepper_BR.setCurrentPosition(0);
  stepper_BL.setCurrentPosition(0);
}
```

```
void run_motors(void){
  // While loop to run motors at the same time
  while (stepper_FR.distanceToGo() != 0 &&
  stepper_FL.distanceToGo() != 0 &&
  stepper_BR.distanceToGo() != 0 &&
  stepper_BL.distanceToGo() != 0){
    {stepper_FR.run();
    stepper_FL.run();
    stepper_BR.run();
    stepper_BL.run();}
  }
}

// Forward Movement - Simultaneous Motor Control
int forward(int forward_steps){
  // Set Current Position to 0
  current_position_0();

  // Specify Where Motors Move to
  stepper_FR.moveTo(forward_steps);
  stepper_FL.moveTo(-forward_steps);
  stepper_BR.moveTo(forward_steps);
  stepper_BL.moveTo(-forward_steps);

  // Runs Motors Simultaneously
  run_motors();
}
// Backward Movement - Simultaneous Motor Control
int backward(int backward_steps){
  // Set Current Position to 0
  current_position_0();

  // Specify Where Motors Move to
  stepper_FR.moveTo(-backward_steps);
  stepper_FL.moveTo(backward_steps);
  stepper_BR.moveTo(-backward_steps);
  stepper_BL.moveTo(backward_steps);

  // Runs Motors Simultaneously
  run_motors();
}

int left(int left_steps){
  // Set Current Position to 0
  current_position_0();

  // Specify Where Motors Move to
  stepper_FR.moveTo(left_steps);
  stepper_FL.moveTo(left_steps);
  stepper_BR.moveTo(left_steps);
  stepper_BL.moveTo(left_steps);

  // Runs Motors Simultaneously
  run_motors();
}
```

```
int right(int right_steps){
  // Set Current Position to 0
  current_position_0();

  // Specify Where Motors Move to
  stepper_FR.moveTo(right_steps);
  stepper_FL.moveTo(right_steps);
  stepper_BR.moveTo(right_steps);
  stepper_BL.moveTo(right_steps);

  // Runs Motors Simultaneously
  run_motors();
}

int left_sideways(int sideways_steps){
  // Set Current Position to 0
  current_position_0();

  // Specify Where Motors Move to
  stepper_FR.moveTo(-sideways_steps);
  stepper_FL.moveTo(-sideways_steps);
  stepper_BR.moveTo(sideways_steps);
  stepper_BL.moveTo(sideways_steps);

  // Runs Motors Simultaneously
  run_motors();
}
int right_sideways(int left_steps){
  // Set Current Position to 0
  current_position_0();

  // Specify Where Motors Move to
  stepper_FR.moveTo(-left_steps);
  stepper_FL.moveTo(-left_steps);
  stepper_BR.moveTo(left_steps);
  stepper_BL.moveTo(left_steps);

  // Runs Motors Simultaneously
  run_motors();
}

void turnOn_scissor(){
  digitalWrite(enableA, HIGH);
}
void turnOff_scissor(){
  digitalWrite(enableA, LOW);
}

void turnOn_pusher(){
  digitalWrite(enableB, HIGH);
}
void turnOff_pusher(){
  digitalWrite(enableB, LOW);
}
```

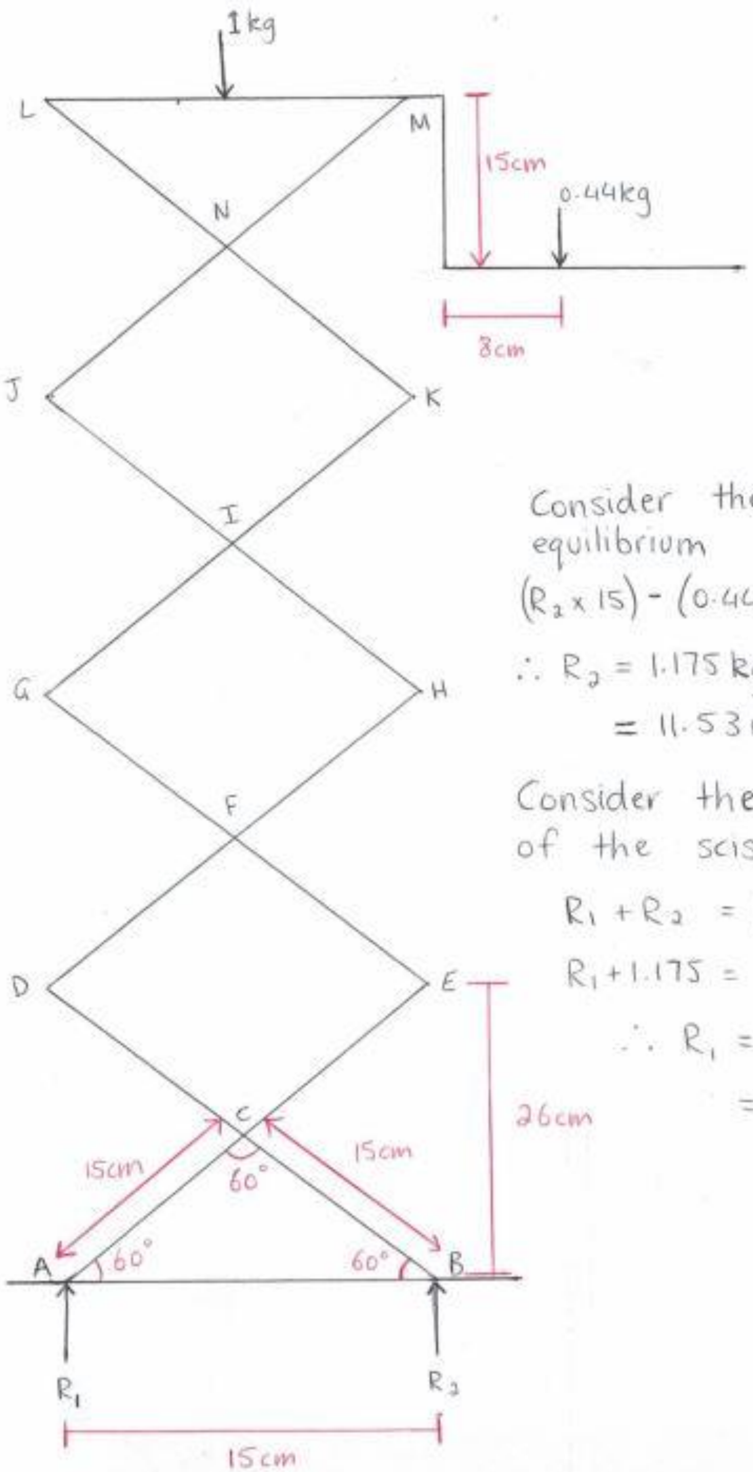
```
int scissor_lift_up(int time){
  digitalWrite(pinA1, LOW);
  digitalWrite(pinA2, HIGH);
  {delay(time);}
}

int push_forward(int time){
  digitalWrite(pinB1, HIGH);
  digitalWrite(pinB2, LOW);
  {delay(time);}
}

int scissor_lift_down(int time){
  digitalWrite(pinA1, HIGH);
  digitalWrite(pinA2, LOW);
  {delay(time);}
}

//----------------------------------------------------------------------------//
```

Appendix 5: Final CAD Model



Appendix 6: Scissor Lift Calculations

Total weight of scissor mechanism = 1kg
weight of payload = 440 g = 0.44kg



Consider the momentum equilibrium about A:

$$\left(R_2 \times 15\right) - \left(0.44 \times (8+15)\right) - \left(1 \times \tfrac{15}{2}\right) = 0$$

$$\therefore R_2 = 1.175 \text{ kg}$$
$$= 11.53 \text{ N}$$

Consider the vertical equilibrium of the scissor:

$$R_1 + R_2 = 1 \text{ kg} + 0.44 \text{ kg}$$
$$R_1 + 1.175 = 1 + 0.44$$
$$\therefore R_1 = 0.265 \text{ kg}$$
$$= 2.6 \text{ N}$$

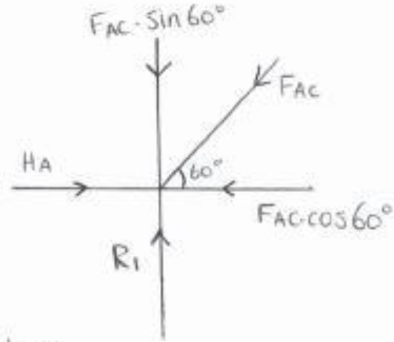
Consider the equilibrium of joint A:

$$F_{AC} = \frac{R_1}{\sin 60^\circ} = \frac{2.6\,N}{\sin 60^\circ}$$

$$\boxed{F_{AC} = 3\ N}$$

$H_A = F_{AC} . \cos 60^\circ$

$= 1.5$

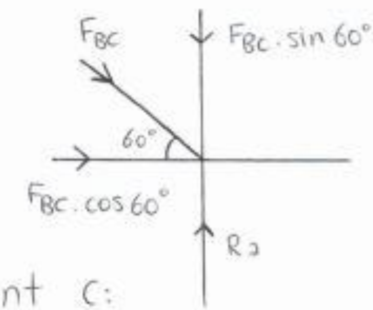


Consider the equilibrium of joint B:

$F_{BC} . \sin 60^\circ = R_2$

$$F_{BC} = \frac{R_2}{\sin 60^\circ} = \frac{11.53\,N}{\sin 60^\circ}$$

$F_{BC} = 13.31\,N$



Consider equilibrium of joint C:

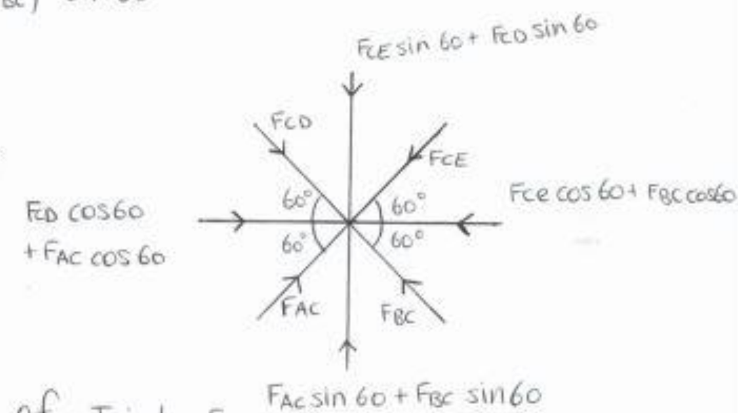
$(F_{CE} + F_{CD}) . \sin 60^\circ = (F_{AC} + F_{BC}) \cdot \sin 60^\circ$

$\therefore\ F_{CE} + F_{CD} = F_{AC} + F_{BC}$

Due to colinear force

$F_{AC} = F_{CE} = 3\,N$

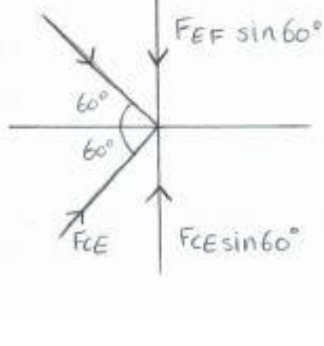
$F_{CD} = F_{BC} = 13.31\,N$



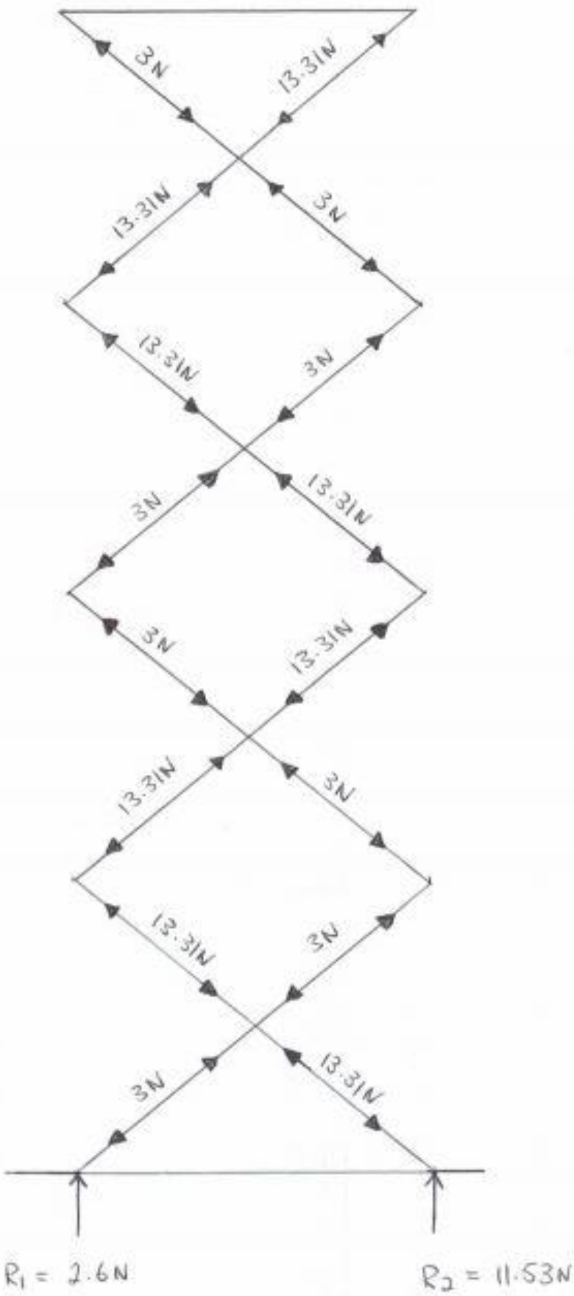
Consider the equilibrium of Joint E:

$F_{EF} \sin 60^\circ = F_{CE} \sin 60^\circ$

$F_{EF} = F_{CE} = 3\,N$



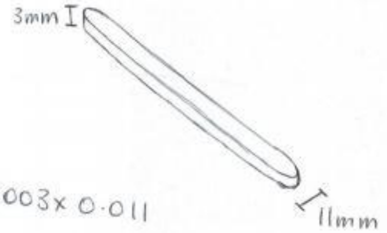
Due to symmetrical structure, the forces in all of the members are given as:



Validity of scissor mechanism:

$$\text{Yield stress} = \frac{F}{A} = \frac{\text{Force applied (N)}}{\text{cross-sectional area } (m^2)}$$

Area:



$\therefore A = 0.003 \times 0.011$
$= 0.000033\ m^2$

Force: The maximum force exerted on the scissor lift is 13.31 N

$$\therefore \sigma = \frac{F}{A} = \frac{13.31\ N}{0.000033\ m^2} = 403{,}333\ Pa$$
$$= 0.4\ MPa$$

The yield stress for aluminium is 270 MPa and so the scissor mechanism will not plastically deform when the load is applied

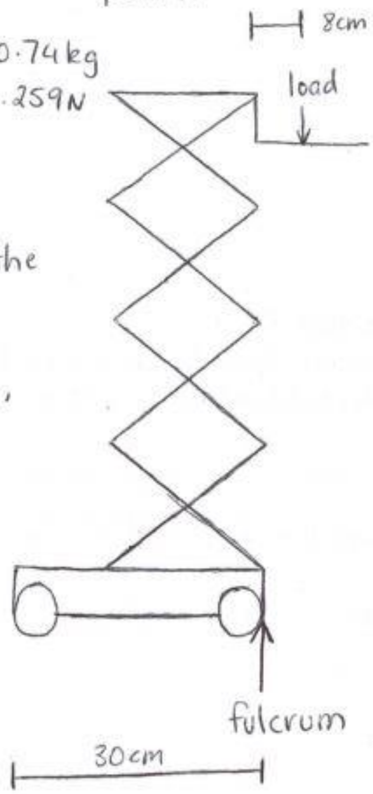
Validity of device stability:

The counterbalance weight required to counteract the amount of force acting down from the load can be calculated by finding the moment force around the fulcrum / pivotal point:

$M = F \times d$ load + tines = 0.74kg

$= 7.259N \times 0.08m$ = 7.259N

$= 0.581\,Nm$



Now, divide applied torque by the counterbalance distance:

Total length of device is 30cm,

$M = F \times d$

$0.581 = F \times 0.3$

$\therefore F = \dfrac{0.581}{0.3}$

$= 1.933\ N$

If total weight of device is 5.2kg without the load and tines included, then the force acting dow is 51.6N.

Thus, the weight of the device is sufficient enough to counteract the force of the load when the scissor mechanism is at full extension

Appendix 7: Risk Management Plan

Project Title: ***Group 4.6 Warman device manufacturing, testing and operation***

Project Type (tick appropriate box / boxes)											
UG Project **(Individual or Group)**	x	PG Project **(Individual or Group)**		Staff Research Project		Site Visit		Asset / Equip Procurement			
								Corporate Level Project			
UG Class Exercise		PG Class Project or Tutorial		Collaborative Project		Field Activity		Commercial Project			
UG Tutorial		PG Research Project		Work Activity		Social Networking		**Domestic**		**Overseas**	

Project Category (School / Portfolio / Discipline)							
CPME (Specify Discipline Below)		**Design** (Specify Discipline Below)		**Urban Development** (Specify Discipline Below)		**Research** (Specify Discipline Below)	
Teaching & Learning	x	**Faculty Operations**		**External Relations**	√	**Other (detail below)**	
Other							

Project/Work Details (Provide details of the exact nature of work – If space insufficient, add a page)

Attach copies of SOP, sketch, design, permit, authority or other relevant documents

Start construction of the project robot, I will start with that base and move onto the scissor mechanism then to the dispatching mechanism.

I will be cutting steel, grinding, welding, drilling and using hand tools to manufacture this robot.

HELP	**Project Location:** *7 Hill Parade Clontarf*	**Proposed commencement date** *1 March 2017*

Project Team Members names **Contact phone/mobile numbers** **Student ID No. If applicable** (Attach list if necessary)	**Names:**	**Student ID No.**	**Contact Phone / Mobile No.**
	Zac Potter	7545002	0424830135
	James Allen	N9950273	0477881961
	Tim Power		

	Sebastian Corta		
Project Supervisor/s **(Name & Phone number)**	**Name/s:** *Zac Potter* *James Allen*	**Phone No:** 0424830135 0477881961	
Valid to / Review by: 31/05/2018	**Actual Review Date** 23/05/2018	**Reviewed By:** James Allen Zac Potter	**Signature**

Use the hyperlinks in this document to access additional information, guidance notes and common project hazards, risk & controls contained in CP097.

Risk Assessment and Risk Register

(How to conduct a Risk Assessment)

No	Hazard, Activity, Task, or Process (Go to Hazard Categories)	Identified Risks	Risk Level Initial	Proposed Control Measures (All control measures must comply with legislative requirements and follow the Control Hierarchy.	Residual Risk Level Final	Notes / Remarks 1) Who is responsible to implement controls? 2) Latest implementation date? 3) Other relevant detail.
1	Grinding	Fire, burns, damage to property, eye damage	3H	No flammable liquids around, eye and hand protection must be used	2M	1. Zac Potter 2. 01-03-18 – 23-05-18
2	Welding	Fire, burns, damage to property, eye damage, fumes	4A	No flammable liquids around, eye and hand protection must be used, good ventilation must be used in the area, welding shields for rays	3H	1. Zac Potter 2. 01-03-18 – 23-05-18
3	Drilling	Burns, eye damage	3H	No flammable liquids around, eye and hand protection must be used	1L	1. Zac Potter 2. 01-03-18 – 23-05-18
4	Filing	Eye damage, splinter	1L	Eye and hand protecting must be worn	1L	1. Zac Potter 2. 01-03-18 – 23-05-18
5	Soldering	Burns and fumes	3H	Ventilation fans should be used and gloves can be worn	2M	1. James Allen 2. 01-03-18 – 23-05-18
6	Electronics (14.8V battery)	Burns and fires	3H	Extreme care must be taken so no short circuits occur. Charge Lipos outside – always keep and eye on them.	2M	1. James Allen 2. 01-03-18 – 23-05-18
7						

Risk Assessment Conducted By (Author)	Name (Print)	Appointment	Student No (If Applicable)	Signature	Date
	James Allen				

I certify that I have consulted with appropriate personnel and have considered professional advice and/or relevant information in conducting this assessment and have obtained necessary approvals, permits, licences as applicable to the project.		

APPROVAL ***Note> Individuals approving this document accept responsibility for the appropriateness of controls and for the validity of the Risk Management Plan.***					
	Name		**Appointment / Title**	**Signature**	**Date**
Approved By	Zac Potter	Group leader			

Distribution:

- **Original (Hard Copy) held by Author for duration of project and must be available to management, health and safety personnel, WH&S QLD Inspector or other authorised person on request.**
- **Electronic or Hard Copy held by Approver for the duration of the project.**

Risk Calculator

Likelihood: How likely is it to happen?	**Consequences: How severely it hurts someone (if it happens)?**				
	Insignificant (no injuries, no damage)	**Minor** (first aid treatment only; damage / spillage contained at site)	**Moderate** (medical treatment; damage / spillage contained but with outside help)	**Major** (extensive injuries; loss of production; significant impact)	**Catastrophic** (death; toxic release of chemicals; extensive damage)
Almost certain – expected to occur in most circumstances	3 H	3 H	4 A	4 A	4 A
Likely – Occurs frequently in most circumstances	2 M	3 H	3 H	4 A	4 A
Possible – Has been known to occur in certain circumstances	1 L	2 M	3 H	4 A	4 A
Unlikely – could occur at some time but improbable	1 L	1 L	2 M	3 H	4 A
Rare - may occur but only in exceptional circumstances	1 L	1 L	2 M	3 H	3 H

Score and Statement	**Action**
4 A: Acute	ACT NOW to eliminate or reduce risk – URGENT - do something about the risks immediately. Refer to management if outside your scope to control. Proceed only with the greatest caution.
3 H: High	Implement controls to remove or reduce the risk before proceeding. Refer to management if outside your scope to control. Seek advice, stay focused and remain aware.
2 M: Moderate	Proceed with caution and monitor progress closely. Follow safe work procedures. Stay focused and remain aware.
1 L: Low	Proceed with activity. Record and review if any equipment/ people/ materials/ work processes or procedures change. Remain aware.

Appendix 8: Meeting Minutes

Meeting Minutes - EGB210 (Team 4.6)				
Attendees: James Allen, Zac Potter, Sebastian Corta, Tim Power **Minutes:** 60 **Date/Time:** 9-10am, 12/03/18 **Location:** S Block – Level 5				**Absent:** Sue Hall
No.	**Topics:** What was discussed?	**Action:** How can/were these topics addressed?	**Who:** Who is responsible for each task?	**Due:** When must each topic be completed by?
1.	Pairing of group members for brainstorming sessions	Each group member to find a like-minded partner	Group	During the meeting
2.	Assign payload to each sub group	Negotiations between sub groups allowed for the smooth assignment of payloads to pairs (James and Zac – Payload C, Seb and Tim – Payload B)	Each sub group through the interaction with the entire group	During the meeting
3.	Organise times for brainstorming sessions	Communicate with partner to organise a suitable time	Each pair of students	During the meeting
4.	Group discussion of major project	Collaborate ideas and share any current queries (Sketches were shown to group and recently purchased stepper motors and motor drivers were passed around. Rules regarding payload C were also discussed to ensure everyone was on a similar level)	Group	During the meeting
5.	Ideation process	Everyone should consider possible ideas that could be of use	Each student from the group	Within the next week before meeting 2

Meeting Minutes - EGB210 (Team 4.6)

Attendees: James Allen, Zac Potter, Sebastian Corta, Tim Power

Minutes: 60

Date/Time: 9-10am, 19/03/18

Location: S Block – Level 5

Absent:

Sue Hall

No.	**Topics:** What was discussed?	**Action:** How can/were these topics addressed?	**Who:** Who is responsible for each task?	**Due:** When must each topic be completed by?
1.	Talk through how the brainstorming sessions went	Communicate with partner to organise a suitable time	Each pair of students	During the meeting
2.	Group discussion of major project	Collaborate ideas and share any current queries. Provide additional ideas for each payload to all members of the group to maximise creativity and functionality of designs	Group	During the meeting
3.	Ideation process	Everyone should consider possible ideas that could be of use	Each student from the group	Within the next week before meeting 3
4.	Robot Base	Shapes were discussed so Zac could make a start on this	Zac	Before next week

Meeting Minutes - EGB210 (Team 4.6)				
Attendees: James Allen, Zac Potter, Sebastian Corta, Tim Power **Minutes:** 60 **Date/Time:** 9-10am, 02/04/18 **Location:** S Block – Level 5				**Absent:** Sue Hall
No.	**Topics:** What was discussed?	**Action:** How can/were these topics addressed?	**Who:** Who is responsible for each task?	**Due:** When must each topic be completed by?
1.	General Robot Design	Zac completed this base and brought in the welded product. This was passed around, so ideas could be shared.	Group	During the meeting
2.	Begin Coding	James will begin coding the stepper motors so when the base is completed it can start driving.	James	Before next week

Meeting Minutes - EGB210 (Team 4.6)				
Attendees: James Allen, Zac Potter, Sebastian Corta, Tim Power **Minutes:** 60 **Date/Time:** 9-10am, 16/03/18 **Location:** S Block – Level 5				**Absent:** Sue Hall
No.	**Topics:** What was discussed?	**Action:** How can/were these topics addressed?	**Who:** Who is responsible for each task?	**Due:** When must each topic be completed by?
1.	Code was shown to group and wheels were fitted to stepper motors	All code was completed, and the wheels were 3D printed. This will allow testing to begin.	Group	During the meeting
2.	Times to meetup and being construction was discussed	Present time tables and any work schedules. This will allow suitable times to be found.	Group	During the meeting

Meeting Minutes - EGB210 (Team 4.6)

Attendees: James Allen, Zac Potter, Sebastian Corta, Tim Power **Minutes:** 60 **Date/Time:** 9-10am, 23/04/18 **Location:** S Block – Level 5	**Absent:** Sue Hall

No.	**Topics:** What was discussed?	**Action:** How can/were these topics addressed?	**Who:** Who is responsible for each task?	**Due:** When must each topic be completed by?
1.	Mechatronics	James presented the device so the team could see it driving – this helped with the ideation process of other components	Group	During meeting
2.	Construction	Zac presented his work to the group and demonstrated how it would all be working.	Group	During meeting

Appendix 9: Time Sheets & Contributions

Zac Potter:

EGB210 Warman Project Timesheet

			Lecture Recess 1							Lecture Recess 2							Week 7						
			2/04/2018	3/04/2018	4/04/2018	5/04/2018	6/04/2018	7/04/2018	8/04/2018	9/04/2018	10/04/2018	11/04/2018	12/04/2018	13/04/2018	14/04/2018	15/04/2018	16/04/2018	17/04/2018	18/04/2018	19/04/2018	20/04/2018	21/04/2018	22/04/2018
WBS	Tasks	Total Hours	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S
1	**Problem definition and background**	0																					
1.1	Defining the Background and Context	0																					
1.2	Specification of Project Scope	0																					
1.3	Writing Problem Definition Section	0																					
2	**Literature review**	0																					
2.1	Finding Appropriate Literature and Research	0																					
2.2	Summarising and Contextualising Information	0																					
2.3	Definition of design criteria	2		2																			
2.4	Writing Literature Review Section	0																					
3	**Conceptual design with minimum 3 design alternatives**	0																					
3.1	Design Creation and Ideation	2		2																			
3.2	Design Sketching / Solid Modelling	1			1																		
3.3	Strengths and Weaknesses Research	1			1																		
3.4	Design Selection	2		1	1																		
3.6	Writing Conceptual Design Section	0																					
4	**Design specification section**	0																					
4.1	Prototype testing and analysis	32										8							5				
4.2	Technical drawing	0																					
4.3	Construction plan	2			2																		
4.4	Writing Analysis Proposal Section	10																					
5	**Document preparation**	0																					
5.1	Formatting Report	0																					
5.2	Risk analysis	3	2							1													
5.3	Editing Report	0																					
6	**Warman build**	0																					
6.1	Building devise and sourcing components	100	6		4	7					4			6			3						
7	**Team meeting**	0																					
7.1	Participating	6																					
7.2	Preparing Agenda, Minutes, Documentation	0																					
7.3	Planning	4	1		2						1												
		165																					

		Week 8							Week 9							Week 10						
		23/04/2018	24/04/2018	25/04/2018	26/04/2018	27/04/2018	28/04/2018	29/04/2018	30/04/2018	1/05/2018	2/05/2018	3/05/2018	4/05/2018	5/05/2018	6/05/2018	7/05/2018	8/05/2018	9/05/2018	10/05/2018	11/05/2018	12/05/2018	13/05/2018
WBS	Tasks	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S
1	**Problem definition and background**																					
1.1	Defining the Background and Context																					
1.2	Specification of Project Scope																					
1.3	Writing Problem Definition Section																					
2	**Literature review**																					
2.1	Finding Appropriate Literature and Research																					
2.2	Summarising and Contextualising Information																					
2.3	Definition of design criteria																					
2.4	Writing Literature Review Section																					
3	**Conceptual design with minimum 3 design alternatives**																					
3.1	Design Creation and Ideation																					
3.2	Design Sketching / Solid Modelling																					
3.3	Strengths and Weaknesses Research																					
3.4	Design Selection																					
3.6	Writing Conceptual Design Section																					
4	**Design specification section**																					
4.1	Prototype testing and analysis			3									2	8					6			
4.2	Technical drawing																					
4.3	Construction plan																					
4.4	Writing Analysis Proposal Section																					
5	**Document preparation**																					
5.1	Formatting Report																					
5.2	Risk analysis																					
5.3	Editing Report																					
6	**Warman build**																					
6.1	Building devise and sourcing components				2						6										3	
7	**Team meeting**																					
7.1	Participating				1																	
7.2	Preparing Agenda, Minutes, Documentation																					
7.3	Planning																					

		Week 11							Week 12							Week 13						
		14/05/2018	15/05/2018	16/05/2018	17/05/2018	18/05/2018	19/05/2018	20/05/2018	21/05/2018	22/05/2018	23/05/2018	24/05/2018	25/05/2018	26/05/2018	27/05/2018	28/05/2018	29/05/2018	30/05/2018	31/05/2018	1/06/2018	2/06/2018	3/06/2018
WBS	Tasks	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S
1	**Problem definition and background**																					
1.1	Defining the Background and Context																					
1.2	Specification of Project Scope																					
1.3	Writing Problem Definition Section																					
2	**Literature review**																					
2.1	Finding Appropriate Literature and Research																					
2.2	Summarising and Contextualising Information																					
2.3	Definition of design criteria																					
2.4	Writing Literature Review Section																					
3	**Conceptual design with minimum 3 design alternatives**																					
3.1	Design Creation and Ideation																					
3.2	Design Sketching / Solid Modelling																					
3.3	Strengths and Weaknesses Research																					
3.4	Design Selection																					
3.6	Writing Conceptual Design Section																					
4	**Design specification section**																					
4.1	Prototype testing and analysis																					
4.2	Technical drawing																					
4.3	Construction plan																					
4.4	Writing Analysis Proposal Section			8	2																	
5	**Document preparation**																					
5.1	Formatting Report																					
5.2	Risk analysis																					
5.3	Editing Report																					
6	**Warman build**																					
6.1	Building devise and sourcing components	3		6	4	8	6			5	4		9		4	4		6				
7	**Team meeting**																					
7.1	Participating																5					
7.2	Preparing Agenda, Minutes, Documentation																					
7.3	Planning																					

Signatures:

Name 1 Zac Potter

Name 2 James Allen

Name 3 Tim Power

Name 4 Sebastian Corta

63

James Allen:

EGB210 Warman Project Timesheet

WBS	Tasks	Total Hours	Lecture Recess 1							Lecture Recess 2						
			2/04/2018	3/04/2018	4/04/2018	5/04/2018	6/04/2018	7/04/2018	8/04/2018	9/04/2018	10/04/2018	11/04/2018	12/04/2018	13/04/2018	14/04/2018	15/04/2018
			M	T	W	T	F	S	S	M	T	W	T	F	S	S
1	**Problem definition and background**															
1.1	Defining the Background and Context	0														
1.2	Specification of Project Scope	0														
1.3	Writing Problem Definition Section	0														
2	**Literature review**															
2.1	Finding Appropriate Literature and Research	1														
2.2	Summarising and Contextualising Information	0														
2.3	Definition of design criteria	0														
2.4	Writing Literature Review Section	0														
3	**design alternatives**															
3.1	Design Creation and Ideation	0														
3.2	Design Sketching / Solid Modelling	0														
3.3	Strengths and Weaknesses Research	0														
3.4	Design Selection	0														
3.5	Writing Conceptual Design Section	0														
4	**Design specification section**															
4.1	Prototype testing and analysis	40														
4.2	Technical drawing	0														
4.3	Construction plan	0														
4.4	Writing Analysis Proposal Section	0														
5	**Document preparation**															
5.1	Formatting Report	8														
5.2	Risk analysis	0														
5.3	Editing Report	32														
6	**Warman build**															
6.1	Building device and sourcing components	78														
7	**Team meeting**															
7.1	Participating	6														
7.2	Preparing Agenda, Minutes, Documentation	0														
7.3	Planning	0														
		165														

WBS	Week 7							Week 8						
	16/04/2018	17/04/2018	18/04/2018	19/04/2018	20/04/2018	21/04/2018	22/04/2018	23/04/2018	24/04/2018	25/04/2018	26/04/2018	27/04/2018	28/04/2018	29/04/2018
	M	T	W	T	F	S	S	M	T	W	T	F	S	S
1														
1.1														
1.2														
1.3														
2														
2.1	1													
2.2														
2.3														
2.4														
3														
3.1														
3.2														
3.3														
3.4														
3.5														
4														
4.1	8				6	4								
4.2														
4.3														
4.4														
5														
5.1														
5.2														
5.3														
6														
6.1	6	5			6	6						4	5	
7														
7.1														
7.2														
7.3														

WBS	Week 9							Week 10						
	30/04/2018	1/05/2018	2/05/2018	3/05/2018	4/05/2018	5/05/2018	6/05/2018	7/05/2018	8/05/2018	9/05/2018	10/05/2018	11/05/2018	12/05/2018	13/05/2018
	M	T	W	T	F	S	S	M	T	W	T	F	S	S
1														
1.1														
1.2														
1.3														
2														
2.1														
2.2														
2.3														
2.4														
3														
3.1														
3.2														
3.3														
3.4														
3.5														
4														
4.1													5	5
4.2														
4.3														
4.4														
5														
5.1														
5.2														
5.3														
6														
6.1				4		2		3				4		
7														
7.1														
7.2														
7.3														

WBS	Week 11							Week 12						
	14/05/2018	15/05/2018	16/05/2018	17/05/2018	18/05/2018	19/05/2018	20/05/2018	21/05/2018	22/05/2018	23/05/2018	24/05/2018	25/05/2018	26/05/2018	27/05/2018
	M	T	W	T	F	S	S	M	T	W	T	F	S	S
1														
1.1														
1.2														
1.3														
2														
2.1														
2.2														
2.3														
2.4														
3														
3.1														
3.2														
3.3														
3.4														
3.5														
4														
4.1												8		
4.2														
4.3														
4.4														
5														
5.1														4
5.2														
5.3														4
6														
6.1			6		2							6	5	6
7														
7.1														6
7.2														
7.3														

WBS	Week 13						
	28/05/2018	29/05/2018	30/05/2018	31/05/2018	1/06/2018	2/06/2018	3/06/2018
	M	T	W	T	F	S	S
1							
1.1							
1.2							
1.3							
2							
2.1							
2.2							
2.3							
2.4							
3							
3.1							
3.2							
3.3							
3.4							
3.5							
4							
4.1			4				
4.2							
4.3							
4.4							
5							
5.1							4
5.2							
5.3	3	1				10	14
6							
6.1	5	3					
7							
7.1							
7.2							
7.3							

Signatures:

Name 1: [illegible]

Name 2: [illegible]

Name 3: [illegible]

Name 4: [illegible]

Sebastian Corta:

EGB210 Warman Project Timesheet

WBS	Tasks	Total Hours	Lecture Recess 1							Lecture Recess 2							Week 7						
			2/04/2018	3/04/2018	4/04/2018	5/04/2018	6/04/2018	7/04/2018	8/04/2018	9/04/2018	10/04/2018	11/04/2018	12/04/2018	13/04/2018	14/04/2018	15/04/2018	16/04/2018	17/04/2018	18/04/2018	19/04/2018	20/04/2018	21/04/2018	22/04/2018
WBS	Tasks	Total Hours	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S
1	**Problem definition and background**																						
1.1	Defining the Background and Context																						
1.2	Specification of Project Scope																						
1.3	Writing Problem Definition Section																						
2	**Literature review**																						
2.1	Finding Appropriate Literature and Research																						
2.2	Summarising and Contextualising Information																						
2.3	Definition of design criteria																						
2.4	Writing Literature Review Section																						
3	**Conceptual design with minimum 3 design alternatives**																						
3.1	Design Creation and Ideation	12																					
3.2	Design Sketching / Solid Modelling																						
3.3	Strengths and Weaknesses Research	4.5																					
3.4	Design Selection	2																					
3.6	Writing Conceptual Design Section	1																					
4	**Design specification section**																						
4.1	Prototype testing and analysis																						
4.2	Technical drawing	30																					
4.3	Construction plan																						
4.4	Writing Analysis Proposal Section																						
5	**Document preparation**																						
5.1	Formatting Report	1																					
5.2	Risk analysis																						
5.3	Editing Report																						
6	**Warman build**																						
6.1	Building devise and sourcing components	16.5	3				2			1							2		1	1.5			
7	**Team meeting**																						
7.1	Participating	3	1														1						
7.2	Preparing Agenda, Minutes, Documentation																						
7.3	Planning																						
		70																					

WBS	Week 8							Week 9							Week 10						
	23/04/2018	24/04/2018	25/04/2018	26/04/2018	27/04/2018	28/04/2018	29/04/2018	30/04/2018	1/05/2018	2/05/2018	3/05/2018	4/05/2018	5/05/2018	6/05/2018	7/05/2018	8/05/2018	9/05/2018	10/05/2018	11/05/2018	12/05/2018	13/05/2018
WBS	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S
1																					
1.1																					
1.2																					
1.3															-						
2																					
2.1																					
2.2																					
2.3																					
2.4																					
3																					
3.1																					
3.2																					
3.3																					
3.4																					
3.6																					
4																					
4.1																					
4.2																					
4.3																					
4.4																					
5																					
5.1									1												
5.2																					
5.3																					
6																					
6.1	1.5							2									2	0.5			
7																					
7.1	1																				
7.2																					
7.3																					

WBS	Week 11							Week 12							Week 13						
	14/05/2018	15/05/2018	16/05/2018	17/05/2018	18/05/2018	19/05/2018	20/05/2018	21/05/2018	22/05/2018	23/05/2018	24/05/2018	25/05/2018	26/05/2018	27/05/2018	28/05/2018	29/05/2018	30/05/2018	31/05/2018	1/06/2018	2/06/2018	3/06/2018
WBS	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S
1																					
1.1																					
1.2																					
1.3																					
2																					
2.1																					
2.2																					
2.3																					
2.4																					
3																					
3.1											1	1	6			1	3				
3.2																					
3.3														1	1		2.5				
3.4														1	1						
3.6															1						
4																					
4.1																					
4.2			5		7				6	8					4						
4.3																					
4.4																					
5																					
5.1																					
5.2																					
5.3																					
6																					
6.1																					
7																					
7.1																					
7.2																					
7.3																					

Signatures:

Name 1 Zac Potter

Name 2 James Allen

Name 3 Tim Power

Name 4 Sebastian Corta

Tim Power:

EGB210 Warman Project Timesheet			Lecture Recess 1							Lecture Recess 2							Week 7							Week 8							Week 9							Week 10							Week 11							Week 12							Week 13						
			2/04/2018	3/04/2018	4/04/2018	5/04/2018	6/04/2018	7/04/2018	8/04/2018	9/04/2018	10/04/2018	11/04/2018	12/04/2018	13/04/2018	14/04/2018	15/04/2018	16/04/2018	17/04/2018	18/04/2018	19/04/2018	20/04/2018	21/04/2018	22/04/2018	23/04/2018	24/04/2018	25/04/2018	26/04/2018	27/04/2018	28/04/2018	29/04/2018	30/04/2018	1/05/2018	2/05/2018	3/05/2018	4/05/2018	5/05/2018	6/05/2018	7/05/2018	8/05/2018	9/05/2018	10/05/2018	11/05/2018	12/05/2018	13/05/2018	14/05/2018	15/05/2018	16/05/2018	17/05/2018	18/05/2018	19/05/2018	20/05/2018	21/05/2018	22/05/2018	23/05/2018	24/05/2018	25/05/2018	26/05/2018	27/05/2018	28/05/2018	29/05/2018	30/05/2018	31/05/2018	1/06/2018	2/06/2018	3/06/2018
WBS	Tasks	Total Hours	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S
1	**Problem definition and background**																																																																
1.1	Defining the Background and Context	1.5																														1.5																																	
1.2	Specification of Project Scope																																																																
1.3	Writing Problem Definition Section	0.5																														0.5																																	
2	**Literature review**																																																																
2.1	Finding Appropriate Literature and Research																																																																
2.2	Summarising and Contextualising Information																																																																
2.3	Definition of design criteria																																																																
2.4	Writing Literature Review Section																																																																
3	**Conceptual design with minimum 3 design alternatives**																																																																
3.1	Design Creation and Ideation	14																																																						1	1	6	2		1	3				
3.2	Design Sketching / Solid Modelling	6																																																								2	2		2					
3.3	Strengths and Weaknesses Research	4.5																																																									1	1		2.5				
3.4	Design Selection	2																																																									1	1						
3.6	Writing Conceptual Design Section	1																																																										1						
4	**Design specification section**																																																																
4.1	Prototype testing and analysis	2																																																			2													
4.2	Technical drawing	15																																																4				4.5	5.5					1						
4.3	Construction plan																																																																
4.4	Writing Analysis Proposal Section																																																																
5	**Document preparation**																																																																
5.1	Formatting Report	1																														1																																	
5.2	Risk analysis																																																																
5.3	Editing Report																																																																
6	**Warman build**																																																																
6.1	Building devise and sourcing components	17	3				2			1							2		1	1.5				1.5							2								0.5	2	0.5																								
7	**Team meeting**																																																																
7.1	Participating	3	1														1							1																																									
7.2	Preparing Agenda, Minutes, Documentation																																																																
7.3	Planning																																																																
		67.5																																																															

Signatures:

Name 1 Zac Potter

Name 2 James Allen

Name 3 Tim Power

Name 4 Sebastian Corta