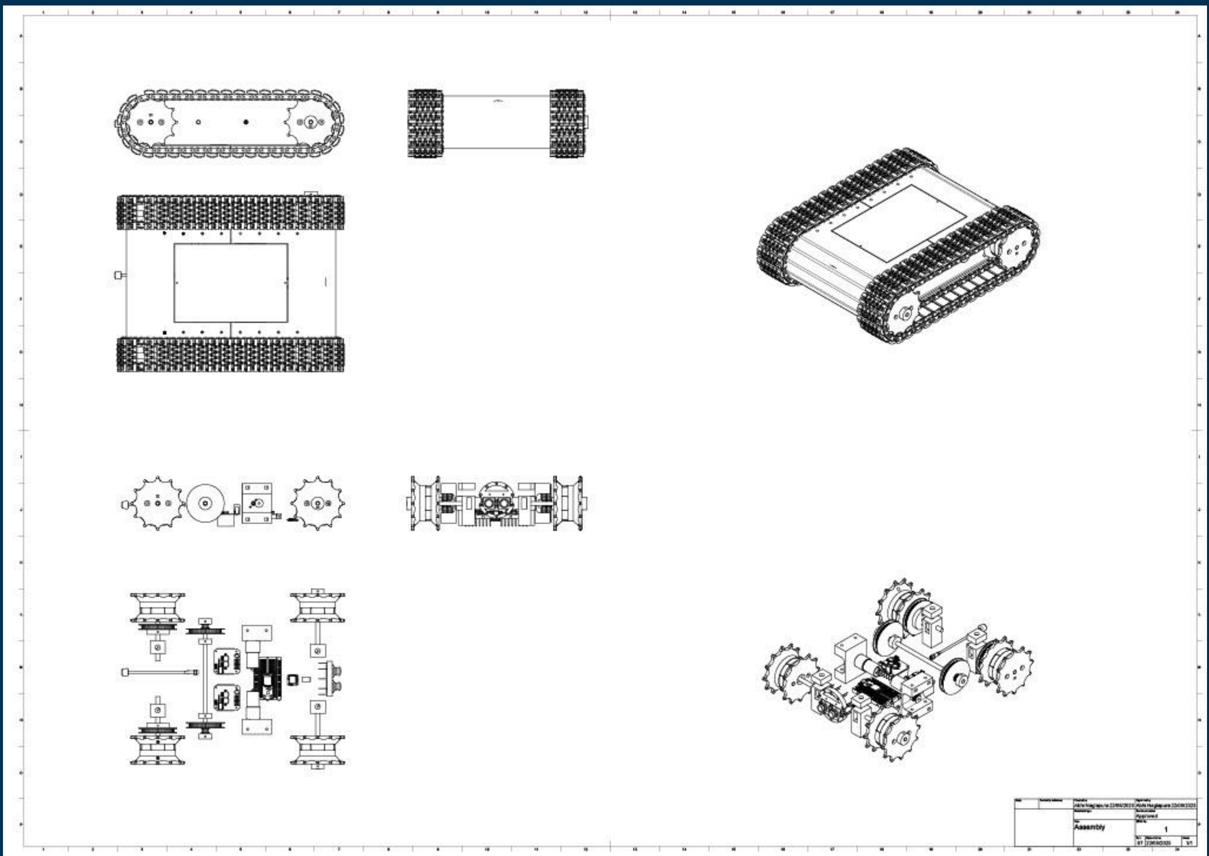
SEARCH & RESCUE AID ROBOT



Student: 36216603

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Project Proposal & Management

1.1 ID AND EXPLORATION OF THE NEED

SITUATION

In the face of devastating natural disasters such as tropical storms, tornadoes, and earthquakes, communities worldwide are often left shattered, necessitating extensive post-disaster recovery efforts. These catastrophic events frequently result in numerous casualties, particularly when survivors remain undiscovered by local emergency services. The need for small robots created expressly for search and rescue missions is growing in response to disasters, whether they are man-made or natural. These small, manoeuvrable devices have certain benefits that are essential for identifying and rescuing survivors in dangerous situations.

Small robots are first and mainly able to enter spaces that are too risky or difficult for human rescuers to reach. When a disaster strikes, there are frequently fallen structures, rubble, or small places left behind, making it very challenging for human responders to search for survivors. Small robots with cutting-edge sensors and cameras can navigate through confined places, climb over obstacles, and explore dangerous environments without endangering people's lives. This capacity increases the effectiveness of rescue efforts while reducing the risk of future harm to both victims and rescuers.

Furthermore, these robots have cutting-edge technology that improves their search capabilities. They can have microphones to listen for life signs, thermal cameras to recognise body heat signatures, and gas sensors to identify potentially harmful pollutants. Small robots give essential information that helps the rescue team locate survivors quickly and correctly by acquiring real-time data and transmitting it to them.

Additionally, their small stature makes it possible for them to travel farther in less time, increasing the likelihood that they will come across somebody in need.

Additionally, mini robots offer versatility in crisis settings because they can run independently or under remote human control. These robots can be used to gather data and evaluate the situation before rescue crews arrive at a place where it might be too unsafe or feasible for people to access. Their independence also allows them to search nonstop without being hindered by emotions or exhaustion, which can damage a person's effectiveness during protracted rescue operations.

This project aims to address this critical issue by designing a small robot capable of navigating beneath collapsed buildings and structures. Equipped with advanced camera systems, this robot will significantly contribute to locating survivors, thereby assisting emergency services in their rescue operations. The final selection of this design is justified by its ability to meet genuine needs and seize opportunities for positive impact.

The design of a resilient search and rescue robot for disaster-stricken areas aims to address the critical need for efficient survivor locations in the aftermath of natural disasters. By identifying genuine needs and opportunities, this project offers a detailed exploration of how such a robot can positively impact emergency services and affected communities. The selected design emphasizes durability, advanced camera systems, scalability, and affordability while promoting open-source accessibility for widespread adoption. By providing a comprehensive solution, this design project aims to make a substantial contribution to post-disaster recovery efforts, ultimately saving lives and mitigating the devastating consequences of these catastrophic events.

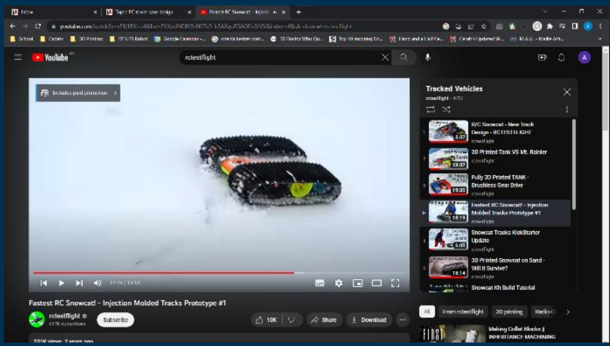
Mentors

Throughout my project, I had numerous mentors amongst my teachers. Primarily I got the help of Mr. Jin Son, my teacher for Design and Technology, as well as fromMr.r Rowan Simpson, my engineering teacher. While Mr. Son helped with the theory and the completion of the theoretical side of things, Mr Simpson was able to guide me the with mechanical and practical side of things with an in-depth knowledge of the engineering mechanics behind the inner workings.

Motivation

As a student currently studying engineering, I have quite a passion for making and fabricating working designs and products. Although I enjoy doing this, the HSC course does not require any practicals, and therefore not real-world applications of the knowledge learnt in classes. By coming up with this situation, I can put my learning into practice with a real-world scenario where engineering would be used for the genuine benefit of others.

I have long been a fan of making things physically, whether that be with Lego and clay, or metal and 3D printers. When browsing YouTube one day, I came across a channel called “rctestflight”. The video I watched was him designing a snowcat tank-style robot in a CAD/CAM software, and then making this physically. This sparked the idea that I could do something similar, yet smaller and for a legitimate reason. This video and others were a huge source of inspiration and motivation for the project, not to mention the countless creators who upload information that has been invaluable to the creation of my final product.



Evaluation

The designer has chosen to cater to the needs of NGOs and emergency services while having a custom-built evacuation robot. This will be quite a challenging project with many factors and obstacles throughout. Batteries, motors, and radio just to name a few. Additionally, the designer learnt multiple software's just for the project. Fusion 360, OnShape, Arduino IDE, and Premiere Pro just to name a few

1.2 Areas of Investigation

The designer will conduct research in the following areas to learn more about the design elements and abilities required to develop the suggested proposal. Justifications for why these areas will be investigated are provided along with the areas that will be studied.

Area	**Justification**	**Method**
Existing Products	- can help to ensure originality and prevent plagiarism - Foster ideas and	- internet research - asking emergency service personnel
Materials - what material - strength	- to find what material is best for each section of the robot in terms of cost, effectiveness, strength	- internet research - physical testing/experimentation
Production	- the method of production is important as there may be steps that cannot be done without prior planning - it is also important that specific tools are not required to make it, so it is more accessible	- internet research - planning - practise on prototype
Safety - for the user	- as this is an S&R robot, safety is a	- testing experimentation

- during production	major factor in making it an effective design	- internet research
Battery Requirements	- batteries are essential for the robot, so looking into what battery is best, safest, and cost-effective is essential	- internet research - asking others with RC vehicles/robots
Electronics	- electronics encompasses a wide range of things so finding the right boards and systems is vital	- internet research - asking others with RC vehicles/robots
Price	- as one of the criteria is making sure it is available to remote or rural areas, the design must be extremely cost-effective	- internet research
Accessibility in remote areas	- this is one of the criteria for success, so it is an important factor	- internet research - asking emergency service personnel

Evaluation

The investigations into these areas will give the designer a more solid understanding of how to fulfil the design need. It will allow the designer to gain more knowledge and skills needed to design and manufacture the evacuation robot.

1.3 CRITERIA TO EVALUATE SUCCESS

The designer must establish some characteristics that can be used to gauge the success of the final design to set going up a set of standards by which to measure achievement helps preserve priorities by giving people a focus. To determine the significance of the critical to be handled, a level of priority is assigned.

Criteria	**What Will Demonstrate Success**	**Justification**
Function	The device must be able to move under a building without losing signal to the user and without obstruction to its cameras	The product must function properly otherwise it will become obsolete
Cost	The device must be able to be made with devices that can be purchased or sourced from existing items	The cost must not exceed $1000 so that rural areas/countries can build one for use easily
Size	The device must be small enough to move under and into tight spaces that humans cannot access themselves	The product must not exceed the limit of an A4 page's surface area to increase effectiveness and areas for use
Productio n	The device must not require specific tools/The specialised parts must be easily transported	The product must not require specific tools to make it, so it is more accessible to rural areas
Safety	The device must not cause harm to the user or any surrounding people	As this is an S&R robot, safety is a major factor in making it an effective design
Environme nt	The device must not significantly negatively impact the environment and uses some parts that exist in common items	The production or use of this product should not negatively affect the environment to be more environmentally considerate and decrease the cost of the product

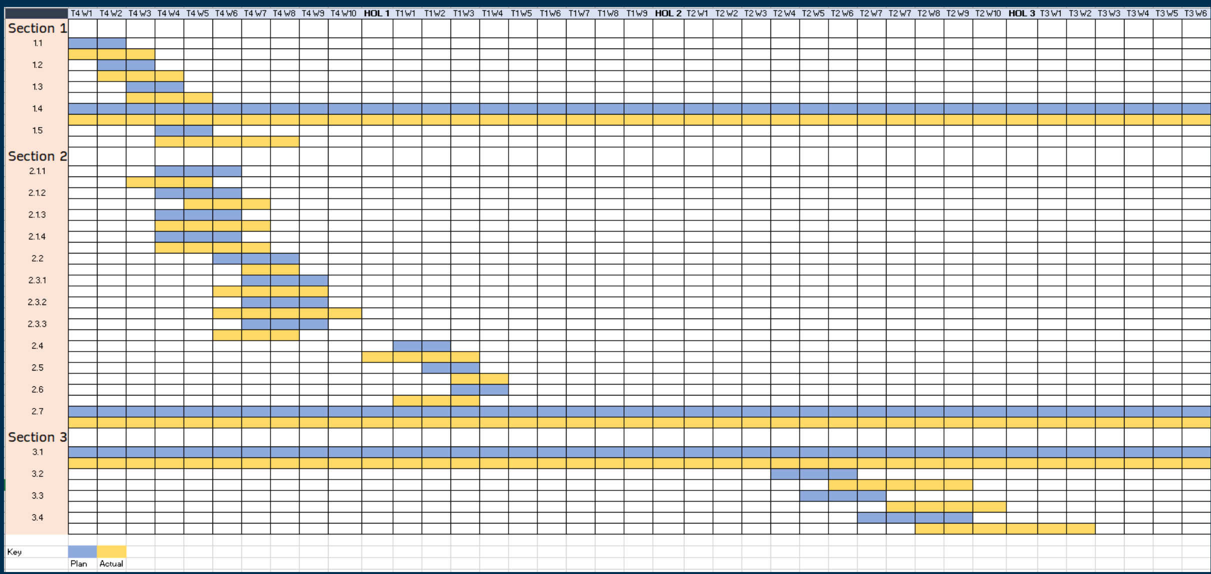
Time Managemen t	The device must be made within the timeframe of a high quality	The product must be made in the timeframe so it can be marked
Material	The materials used must be lightweight, cost-effective, strong, and durable	The material must be especially durable due to the rough environment it will be used in

Evaluation

This criterion is essential in making sure the parameters don't change throughout the project, thus lengthening the amount of time taken.

1.4 Action/Time Plan

The following Gantt chart will be used by the designer to track both his planned time management strategy and the actual amount of time he spends on each of the project's numerous components. It is believed that by adhering to the suggested strategy, the designer will be able to utilise his time as efficiently as possible and, as a result, complete his project.



Evaluation

The designer must account for tests and assessment schedules for his other HSC subjects. To be a successful project, the final due date is the 24th of August 2023. After the completion of the product, there will usually be some folio work to finish which needs to be accounted for.

1.5 Finance Plan

Below is a list of the materials and production costs associated with the major design project. To keep the total cost of the design below the allocated budget of $800, the financial strategy must be adhered to precisely. The estimated cost of the materials and procedures is provided in the form of a proposed financial plan. To compare how closely the initial finance plan was followed, a real financial plan is also provided. Halfway through the project, an assessment is done to assess how well the plan was carried out.

ITEM	**Initial Estimation ($)**	**JUSTIFICATION**
Motors	≤75	Motors are required to make the robot move and are an essential component
Filament/Main Material	≤80	This will make up the bulk of the project and the body of the robot
ESC/Motor Driver	≤80	Without a motor driver/ESC, the speed cannot be controlled
Bearings	≤20	Essential to make the tracks move smoothly
Chains	≤25	The main part of the tracks
Sprockets?	≤50	May or may not get these (can be 3D printed)
Hardware	≤20	Will be used to fix everything together
Cameras	≤100	An essential part of the 'search rescue function
Servos	≤20	Will move cameras around for better visibility without turning the whole robot
Antenna	≤50	To transmit the signals between the remote and the robot
Signal extender	≤50	To extend the signal beyond the basic capability
LEDs/Infrared LEDs	≤20	To light up the areas for regular and night vision cameras
		Total: ≤590

Item	Estimated ($)	Actual ($)	Profit/Loss ($)
BetaFPV LiteRadio 2 SE Radio Controller	100	89	P - 11
Matek ELRS-R24-D/ELRS-R24-S RX ExpressLRS 2.4GHz Nano Receiver	30	28.99	P - 1
ViFly Cam Switcher	20	16.99	P - 3
Matek CRSF-PWM-C CRSF To PWM Converter	20	16.99	P - 3
Rush Tank Tiny 5.8GHz VTX w/ Smart Audio	50	41.99	P - 8
Foxeer Razer Mini FPV Camera 1200TVL Low Latency Light	100	32.99 * 2 = 65.98	P - 34.02
Lumenier Double AXII 2 Long Range Antenna 5.8GHz Straight SMA RHCP	20	35.99	L - 15.99
Foxeer Lollipop V4 FPV Antenna 5.8G High Gain (Set Of 2)	30	29.99	N/A
10W Soldering Station 240VAC Duratech	50	32.95	P - 17.05
Standard (High Power) D.C. Motors 10200 RPM	60	23.95 * 2 = 47.90	P - 12.1
DexMRtiC 1PC SMA Male / Female RF Coax Adapter Connector Straight	3	1.08 * 2 = 2.16	P - 0.84
ALLiSHOP sma pigtail Jumper RP SMA female to U. FL	3	1.11	P - 1.89
SKYDROID 5.8Ghz 150CH FPV Receiver UVC 5.8G Dual Receiver Double	40	39.06	P - 0.94
MEGA2560 MEGA 2560 R3 (ATmega2560-16AU CH340G) AVR USB Board Development Board	20	15.25	P - 4.75
Double BTS7960 43A H-bridge High-power Motor Driver module	10	4.10 * 2 = 8.20	P - 1.80

RadioMaster R81 R84 R86 R86C R88 R161 R168 2.4G Nano Receiver Compatible FrSky	30	32.75	L - 2.75
MMCX to SMA/RP-SMA Female	3	1.16	P - 1.84
5mm Infrared Transmitting LED	25	2*10 = 20	P - 5
Spare Timing Belt for Filament Printers	15	11.95	P - 3.05
Cable Tie 300mm x 4.8mm pack of 100	10	19.95	L - 9.95
Flexible Light Duty Hook-up Wire (6 x 2m)	5	0.35*2*6 = 4.2	P - 0.8
Duinotech ESP32 Main Board with Wi-Fi and Bluetooth	50	44.95	P - 5.05
PLA+ Filament	120	102.40	P - 17.6
CLEAR ACRYLIC SHEET 4.5MM	50	37	P - 13
M5 x 50mm Zinc Plated Round Head Bolts and Nuts - 4 Pack	10	3.74 * 2 = 7.48	P - 2.52
M5 x 20mm Zinc Plated Round Head Bolts and Nuts - 10 Pack	25	3.82 * 10 = 38.2	L - 13.2
M4 x 35mm Zinc Plated Round Head Bolts and Nuts - 10 Pack	5	3.76	P - 1.24
M3 x 15mm Zinc Plated Round Head Bolts and Nuts - 20 Pack	10	3.82 * 3 = 11.46	L - 1.46
TOTAL	**914**	**797.81**	**P - 135.51**

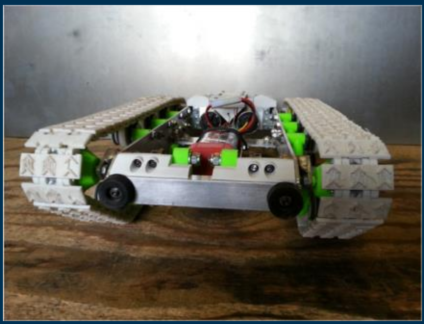
Evaluation

The estimated total and running total ended up just under the total budget of $800 which is a very good achievement. The researched prices were mostly the high-quality ones, however in the interest of time and money, cheaper ones were purchased.

Development & Realisation

2.1.1 Evidence of Creativity-Existing Ideas

https://www.thingiverse.com/thing:478164



P	M	I
Uses strong connections and hardware	Would be expensive to get the motors and hardware required / big design	Utilises realistic shock absorbers /suspension

P	M	I
Can be used with a common existing RC remote	Bulky track design	Unconventional track design

https://www.thingiverse.com/thing:2789361

https://www.thingiverse.com/thing:2952852

P	M	I
Small and simple to make	Weak joints and limited ability to traverse heights	Uses common and easily available parts

https://builtin.com/robotics/rescue-robots

P	M	I
Can get into very small spaces	Requires lots of joints and motors	Very good manoeuvrability

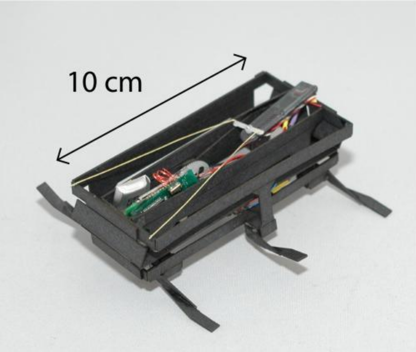
https://www.thingiverse.com/thing:4308626

P	M	I
Strong design, compatible with common RC remote	Big and bulky design	Uses drone motors that are geared down

https://www.popsci.com/technology/article/2011-03/six-robots-could-shape-future-

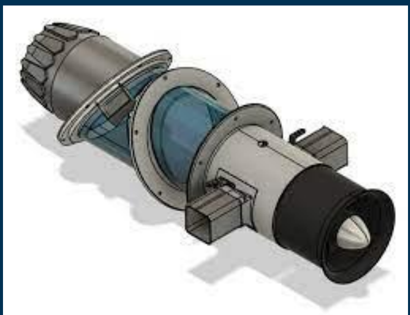
earthquake-search-and-rescue/

P	M	I
Gripping claw to deliver supplies, remove obstacles	Arm takes up a lot of space	Wheels are similar to feet but use belts and pulleys



P	M	I
Very small, compact, strong design	Would have difficulty going up, can get stuck in cracks	Uses mostly parts from a cell phone

https://grabcad.com/library/f-35b-vtol-3bsm-mechanism-test-1

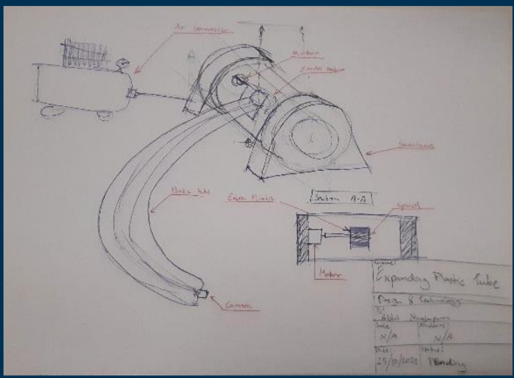


P	M	I
This joint could be utilised for 90° bends	Bulky design, only works with snake style robots	This was used on the F/35A fighter jet

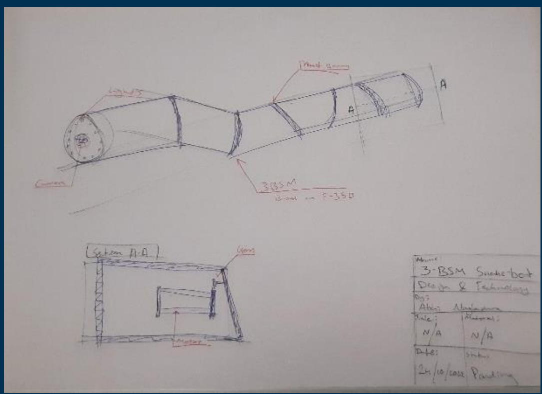
Evaluation

The designer researched a variety of possible designs and has enabled him to make many educated decisions about the final project.

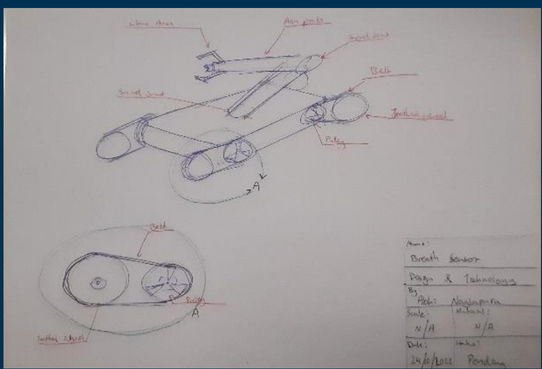
2.1.2 Evidence of Creativity- Ideas Generation



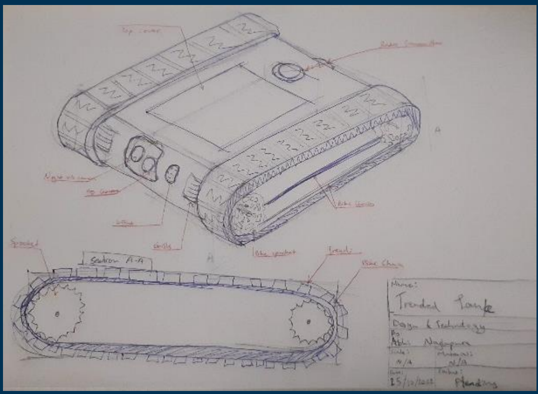
P	M	I
Very good against sharp obstacles	Difficult to manoeuvre around	Uses interesting mechanics that could be used



P	M	I
Can get into very small spaces	Requires lots of joints and motors	Very good manoeuvrability



P	M	I
Gripping claw to deliver supplies, remove obstacles	Arm takes up a lot of space	Wheels are like feet but use belts and pulleys



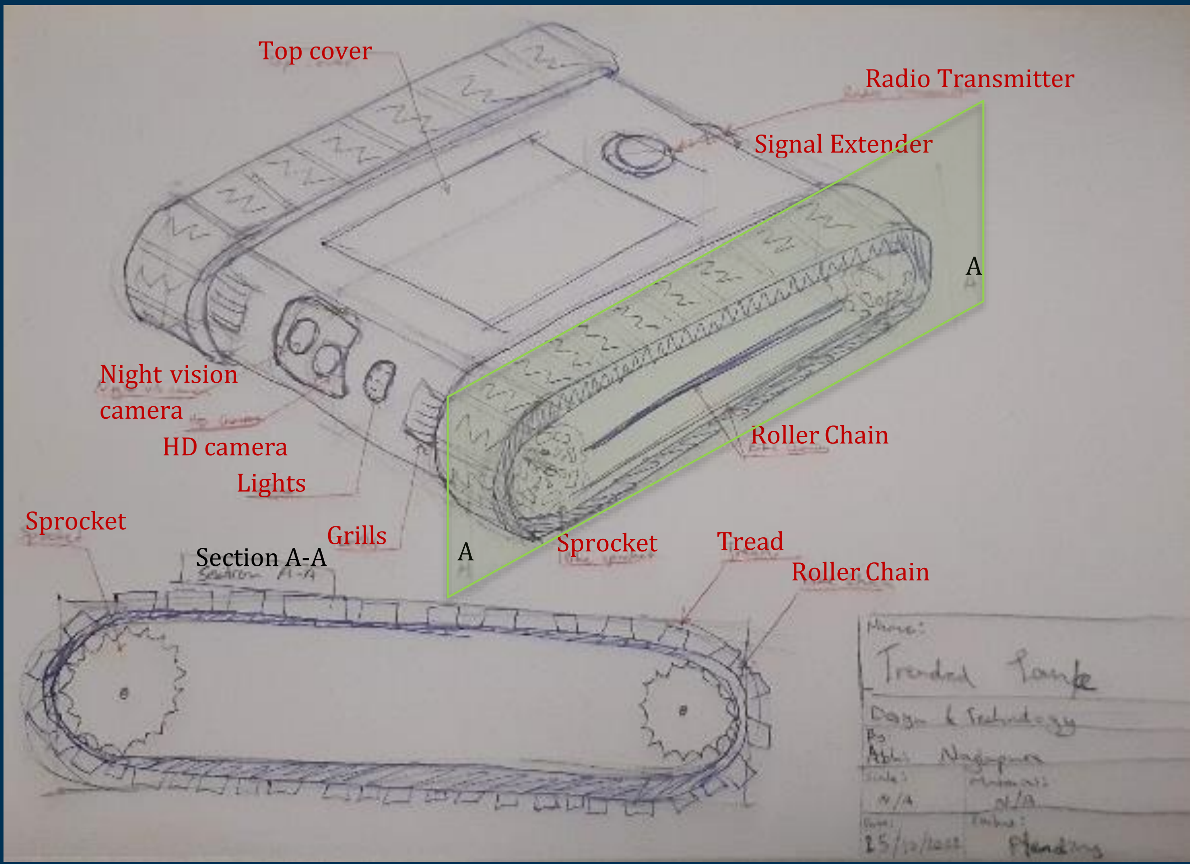
P	M	I
Small design, uses relatively easy to source materials	Major parts are 3D printed which reduces availability	Uses dual chains for each track to make it stronger

Evaluation

In summary, while all the designs are quite feasible, the final design at the bottom is the best idea. This is because of the simple shape and features that will be relatively easy to manufacture at a school tool shop with the budget.

2.1.3 Evidence of Creativity-Specific Elements

The following diagram is a detailed drawing made as an explanation to the different parts of the model



Evaluation

This is a much more detailed diagram, which allows the designer to explore it in depth. The final model ended up looking almost exactly like this.

2.1.4 Evidence of Creativity-Degree of Difference

The executive toy design's proposed design sketches are different from the designs shown in the 2.1.1 Exploration of Existing Ideas and 2.3.1 Design Ideas segments of the folio. These designs, while different from mine, contribute to the overall design concept. It does not violate copyright because I tweaked the original drawings to make them my own. Design elements like innovations have distinguished my own creation from those that are currently on the market.

Inspiration	Change
	This snowcat by rctestflight was a huge inspiration. The main changes I made was that the treads were more for gravel and rocks rather than snow. Additionally, there are cameras in an enclosed body with lights surrounding it.
	From this design I took the idea of using roller chains as the base of the tracks. This also gave me the idea to have two cameras, with one of the beings used for low light conditions.
	This type of RC boat has a simple locking feature on the lid which keeps water out but is easy enough to remove without tools. I was able to replicate this mechanism for my product.

	Most old drill presses use belt drives to either speed up or slow down the motor. I also used this system with GT2 belts to change the reduction ratio in my tracks.
	This simple servo gimble is an ingenious design which uses two lightweight 9g servos to have 4 degrees of freedom. I will try and incorporate this into the camera system so that it can move around.

Evaluation

Innovations found in this design were inspired by existing ideas such as the snowcat, belt drives, and gimbals. These concepts were combined to create a homogenous unique design project.

2.2 Consideration of Design Factors

Need

Small robotic tanks are crucial in earthquake-related crisis situations. Because of their small size, they can fit through small openings while collecting vital information and relaying it to rescue crews. They can undertake autonomous search and rescue operations thanks to their sophisticated equipment and sensors, which lower the danger to human rescuers and increase the likelihood of lifesaving. These tanks are essential for strengthening emergency response capabilities and enhancing general safety.

Function

The main purpose of this robot is to find survivors, so having working cameras in the front is essential to making sure it functions properly. This means that cameras must be researched and transmitters for this video. As well as this it should be remote controlled which means a high-quality transmitter and receiver must be used for it to work through rock and rubble.

Cost

Although this project can be made to the utmost highest standard with fully functioning everything, the budget is still in place which means that each part needs to be researched to make use that it is completely necessary, and it is the best value.

Size

As an evacuation robot, it needs to be quite small to fit in through rubble and rocks which is a key factor to keep in mind through designing.

Environment

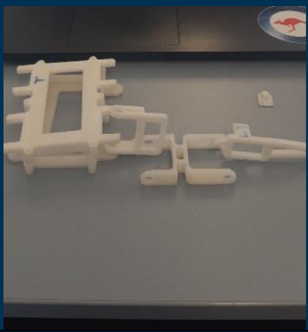
The working environment of the robot is quite harsh which means that body needs to be able to withstand this kind of conditions.

Evaluation

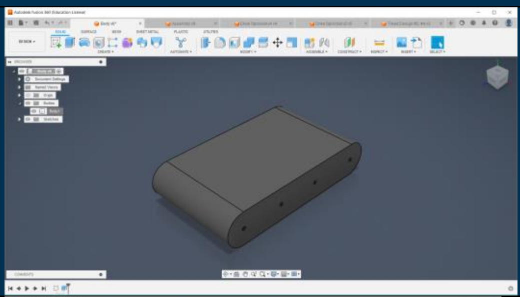
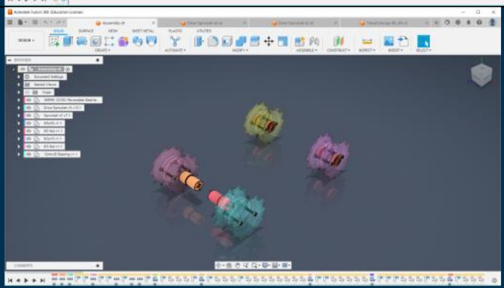
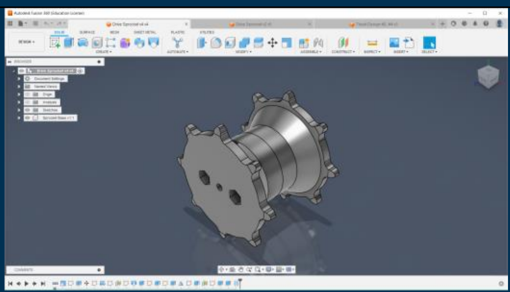
This an explanation of how each of the factors will be thought of in the final design.

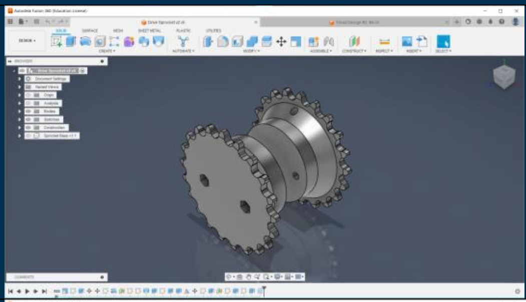
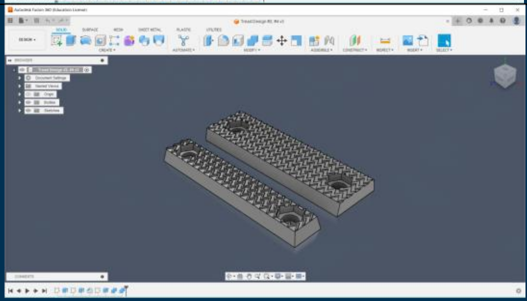
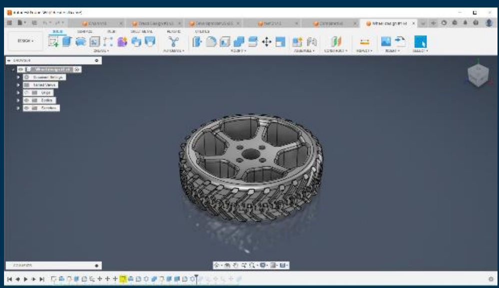
2.3.1 Appropriate Research and Experimentation of Design Ideas

These are the top concepts that came from both original concept generation and idea research. Through study and investigation, these ideas give a glimpse into what the ultimate product will be.

	This initial design was given to me Mr Holloway as a test. It comprises of a 3D printed frame with servos that acts a quadrupedal robot. Although this idea was quite unique and different to the others that I had seen, it didn't fit the criteria of being solid and capable of withstanding forces upon it.
	This design was reverse engineered from pictures and videos taken by University of California. This was designed to be a simple cockroach style robot that would cost less than a dollar and theoretically be quite indestructible. However, one of my main concerns was with the flimsy frame. Even though the creators at UC were able to manufacture a ridged body, the process was too complex for me to realistically recreate at school with the time and tools available.
	The design on the left is quite different to the others as it came in a kit and was designed to be a simple robotics lesson. The whole robot is based on an aluminium frame with simple dc motors and wheels. Although this a simple and cheap way to make a robot, it had no way of being controlled and was not able to mount a camera.

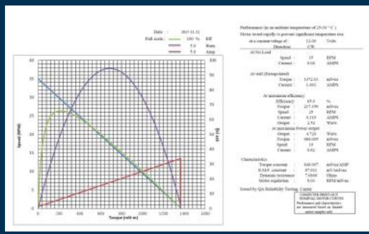
The following designs were only made of Fusion 360 and not made physically after consideration for different aspects.

	This simple design for the body was the initial idea, however I decided to abandon it as it would take far too much time and effort to design and make one, either through 3D printing, fabricating, or vacuum forming.
	The initial idea for the overall assembly was that the motors would drive the front sprockets, with idlers in the back. However, after doing some calculations, I realised that the motors wouldn't have enough torque to move such a heavy mass, and they would be moving much too fast. Additionally, the sprockets were far to flimsy.
	This sprocket design is one of the first that I made to drive the chains. It was scrapped after talking to Mr Simpson and realising that a bigger contact area and physical linkage between the two sides would be much stronger. The main axle was also widened to account for the higher torque load as mentioned in the above row.

	This design is perhaps my very first one and was scrapped for a quite simple reason. The teeth would interfere with the bolts that connect the treads to the chain. Thus, the sprocket had to have a gap for every other tooth.
	The two tread designs on the left are some that were made and printed to test out the grip strength on various materials that would be encountered. The design unfortunately did not have enough traction on the surfaces and kept slipping and therefore was scrapped. You will notice that there were two sizes, that is because I was not sure how many tracks per 10cm I wanted.
	Anther design I had initially was to skip all the tracks entirely and have wheels. However, after designing one wheels with treads, I quickly realised that it would be far too expensive to have motor that could drive such large wheels, even if they were commercially bought.

The following are things that were heavily researched due to their impact on the final design.

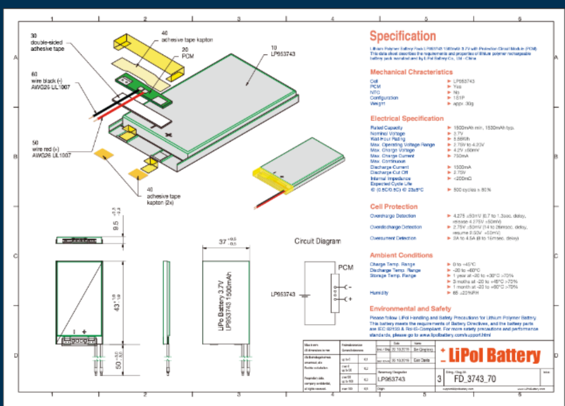
Motor torque

Using various equations engineering concepts, I was able to calculate a lot of specifications about the weight, speed, torque, power, current, etc. below is several equations and concepts I used as well as the torque graph of the motor. It is important that the current, torque and speed are carefully considered and calculates so as not to pull too much from the battery, damaging it and potentially creating a fire hazard. In one of the initial tests, the battery started to smoke as too much current was being drawn, which required a rethinking of the battery specs and the motor driver. Initially, a L293D motor shield, however it can only output a maximum of 1.2 amps which is not enough for the stall torque of the motor which is 1.693. this means I had to use a different one. I eventually settled on the BTS7960 which can output up to 42 amps which is well over my parameters. 

Although the mot can output quite a high torque due to the gearhead, I decided to use a belt and pully system to step it down with a ratio of 1:25. This means that the speed goes down by a factor of 25, however the torque goes up by that inverse factor. Using the equation, $t = \frac{60 \times P}{2\pi f}$, I was able to calculate that the maximum torque is around 30 Nm which is more that I will need for the vehicle.

Batteries

The most important part of any machine is getting power to it. This is most certainly the case with this project as well, with the motor needing a minimum of 5 V and the ESP32 also needing a minimum of 5 V, with both handling a peak current of 2 A. Considering that I was using mostly FPV components, I investigated LIPO batteries as they are quite a high capacity for a relatively reasonable price. However, the more I investigated them, the more dangers I came across. For example, in the following datasheet of a common LP953743 LIPO, there are many considerations to take into such as peak discharge, discharge rate, and storing voltage.



This meant that for the purposes of my project, it was unsuitable. The next battery I investigated was the LI-ION battery, more commonly found in phones and laptops. These have a higher power density which means that I could get smaller battery with a higher charge. However, the problem is that good batteries often cost quite a bit of money, such as Samsung 18650s being $8 each. Although it is possible to make a customer battery harness, it would require a spot welder, an in-depth knowledge into battery circuits and a lot more time, which made it so much more inconvenient.

This led to my last approach which was pre-existing batteries I could find around the house. Of course, AA and AAA exist, but the power density is not high enough. That’s when I came across the power tool batteries. They have a high-power density, a common voltage of 18V, with a capacity of typically 3 Amh, and they come with a battery eliminator circuit and overcharge protection-built in. on top of all of that, I already had a small Ryobi tool battery in my garage which consisted of 3 LI-ION cells. With that in mind, I chose the power tool as the battery for my project.

Microcontrollers

there are a lot of microcontrollers out there for both hobbyists and professionals, most common ones being raspberry Pi, Arduino, and the ESP32. The original idea was to use an Arduino UNO alongside a 2.4 GHz radio receiver to control the whole assembly, but that plan fell apart when the radios refused to pair together. The next plan was to use an Arduino Mega with a different radio system as the Mega has twice as many PWM pins which are needed for the motor driver. This also ended up in shambles when the radio system again failed.

After ditching the radio completely, I thought to use a raspberry Pi. It is a powerful microcontroller with a built in Wi-Fi chip and onboard CPU, meaning it is quite capable. The idea was to use a web interface as Wi-Fi has quite a long range and low latency. However, the complexity of the needed code was too much, as it involved embedding a HTML address into an Arduino sketch. This was so much, even my maths tutor who is currently studying software and programming at university couldn’t help me.

The final idea was to use an ESP32 for the whole brains. It’s a small controller with Wi-Fi and Bluetooth built into it. Additionally, it has plenty of PWM pins and can be programmed using the Arduino IDE. This made it quite a good controller. After buying one from Jaycar, I realised just how good it was. The coding was relatively easy, and it worked flawlessly.

FPV components

The easiest and best way I was able to have wireless cameras, was by using pre-existing FPV components. Since almost all analogue drones communicate via the 2.4Ghz range, any compatible part would work together. I wanted to have two cameras with one being for night vision which meant that it needed to switch between the two. I was able to find cheap circuit that would do just that which was quite convenient. After that I was able to find some decent cameras from a renowned FPV brand Foxeer, and a transmitter from Rush FPV. Overall, this section didn't need too much research into it, however ended worked very well.

Evaluation

It is quite clear that there are many things to think about when designing, not including the hours of work in Fusion 360 to create the designs. While working with this program, I gained many new skills and was able to use them to speed up my workflow. By utilising knowledge from HSC Engineering, a lot of the thought went into calculations and detailed models.

2.3.2 Appropriate Research and Experimentation of Materials

	Although not though of initially, I decided to try out bending some acrylic pieces for the main body. The two pieces on the right are some tests done to see if a small radius ben was achievable with the tool available, and as seen, it was. This would reduce the work needed for the body as it wouldn't need to be 3D printed or machined, greatly reducing the time.
	By using this video by CNC kitchen, I saved a lot of time in testing the strengths of different polymers that can be 3D printed with. The charts and graphs were very helpful in my meticulous decisions all throughout the project
	Aluminium is unique due to its low density and ability to withstand corrosion. Aluminium is typically used for structural components because of its high strength to ratio of weight. Alloy 5052 is where most sheet aluminium is sold. The shiny shine that metallic materials frequently have is alluring. The drawback is that it can be difficult to use.

	Two different varieties of acrylic exist: cast cells possesses remarkable quality, superb technical abilities, and strong strength. Simple to handle, machine, and construct. Extruded has excellent vacuum formability, making it perfect for uses that call for complicated shapes. Cell cast acrylic sheets are ideal for use in chassis construction because they have the best machining properties that make them workable with power tools or suitable for precision cutting with CNC type machines (easily laser cut or machined). Additionally, glass-like optical clarity is also available in acrylic, albeit at a fraction of the weight.
	A medium- or high-carbon steel that has undergone heat treatment, quenching, and tempering is frequently referred to as hardened steel. The production of metastable martensite because of quenching is decreased to the desired level during tempering. Typically, axle shafts undergo induction case hardening. This procedure involves heating a steel component's surface layer to create austenite, which is subsequently spray-quenched to create martensite. The outcome is a core that is still under tension and a hardened coating that is still under compression.

	The complete chassis can be put together and taken apart thanks to the use of metric-sized bolts and nuts to fasten sheets of material. As a result, it becomes possible to "flat pack," which entails that the finished product may even be manufactured in bulk and sent. Given that the bolt head will stick out from the material's surface, where the bolts are placed is crucial.

Evaluation

The designer has decided to use the materials listed above as they are the most suited to the task at hand for their many strengths and characteristics. Below are the tools used to shape these materials.

2.3.3 Appropriate Research and Experimentation of Tools and Techniques

	A real object is produced using the additive manufacturing technique of three-dimensional (3D) printing from a digital design. In order for the process to operate, thin layers of material—such as liquid or powdered plastic, metal, or cement—must first be laid down. Next, the layers must be fused together. For mass production, 3D printing speeds are currently unsuitable. The technology has, however, been utilised to shorten the lead time for developing prototypes of components and devices as well as the tooling required to produce them. Small-scale manufacturers greatly benefit from this since it lowers their costs and shortens the time to market, or the period of time between the conception of a product and its availability for purchase.
	Using revolving cutters, a milling machine is a flexible tool used in machining to remove material from a workpiece. A base, column, worktable, and spindle are some of its parts. There are two: horizontal and vertical. They are used in many sectors for accurate machining operations and can be manual or computer-controlled (CNC).

	In metalworking, a metal lathe is a tool used to shape and cut metal workpieces. To remove material and mould the workpiece into the appropriate shapes, it rotates the workpiece against a cutting tool. A bed, headstock, tailstock, carriage, and toolpost make up this machine. Bench lathes, engine lathes, and CNC lathes are just a few of the various sizes and types of metal lathes. They produce exact metal components by turning, facing, threading, and performing other operations.
	A bundle of tools called a tap and die set is used to create threads on metal surfaces. Both taps and dies for exterior and internal threads are part of it. The set's varied sizes and thread patterns enable users to make or fix threads of various lengths. It is frequently employed in plumbing, automotive repair, and metallurgy.
	A stationary tool called a drill press is used to create exact holes in a variety of materials. Base, column, worktable, spindle, and drill head make up this apparatus. Unlike portable drills, it delivers stability, accuracy, and control. It is frequently used for repetitive drilling operations in the metalworking, woodworking, and other sectors.

	A laser cutter is a device that precisely cuts, engraves, or etches materials using a focussed laser beam. It produces precise, detailed cuts and may be used on a variety of materials. Due to its efficiency, adaptability, and capacity for creating complicated designs, laser cutters are frequently employed by both businesses and individuals.
	A instrument for heating and bending acrylic sheets is called an acrylic bender. A heating element, bending surface, and temperature controls make up this apparatus. It is frequently used to manufacture curved or angled acrylic components in fields like signage and fabrication.

Evaluation

The designer has decided to use the tools listed in the table above. These have been chosen for their precision and repeatability which is important for moving parts in machines.

2.3.4 Appropriate Research and Experimentation of Testing Design Solutions

Test	Result
Strength test	The filament did not require a strength test as there was a very in-depth video explaining everything about the tensile and hardness of different polymers. PLA+ ended up as the best.
Grip test	The treads were all placed onto a chain and subjected to different material surfaces such as rocks, pebbles, gravel, and sand. The best design was #3 which had wide patterns and the larger width.
Bend test	The acrylic sheets bent very well with the sheet bender. The smallest radius I could get is approximately 2.5mmm, which is enough for what I need.

Evaluation

The designer did several tests to ensure the methods and materials were going to work for their jobs. This gives backup to support the decisions made.

2.4 Application of Conclusions

In the finished version of my MDP, the conclusions are applied. The designer was able to develop an understanding of the procedures that would need to be followed to manufacture my design through the exploration and testing of various materials, tools, and techniques. Extensive testing and experimentation inside Fusion 360 are clear in the solutions arrived at in response to the issues that cropped up in relation to the products' design. With reference to all the earlier analyses, all the conclusions reached were then applied.

Resource	**Conclusion**
Cameras	The cameras were excellent for the price that I paid and were well worth it. They had excellent quality and menus options.
Filament	The filament bought from Inkstation was of a very high quality and performed exactly as intended.
Acrylic	The acrylic sheets took some getting used to on the laser cutter with different settings, but they were very useful for quick prototypes and tests.
Steel	the steel shafts were tough to work with and it probably would have been fine to use mild hot rolled steel
Aluminium	The aluminium was much easier to work with than expected which was great for the small parts, so I didn’t break on of the taps.
3D printer	The 3D printers at school, worked very hard over the year and provided a lot of support. This was a very good decision.

Milling machine	Without the mill, I wouldn’t have been able to make flat spots or drill some of the holes, so it was quite essential.
Lathe	Without the lathe, I wouldn’t have been able to make the collars which ended up being needed for the sprockets.
Laser cutter	Without the laser cutter, some of the early prototypes wouldn’t have been possible so it was very useful.

Evaluation

Most of the descensions made were the right ones, which is good for the designer as it means not much time was wasted trying to fight alternatives.

2.5 Identification and Justification of Ideas and Resources Used

Idea/Resource	**Justification**
Resources	The usage of the internet as a source of knowledge and information was widespread. Through internet forums where people with similar interests may engage and exchange ideas, it can assist the designer with research and evaluation on the chassis design. When teaching students in the Design and Technology course, teachers serve as guides. They are excellent resources because they are familiar with the particulars of the MDP.
Materials	PLA+ is an excellent material due to its tensile strength and toughens as well as dimensional accuracy. Acrylic was used for the body due to its strength and ability to be laser cut for ease of use. Hardened steel shafts were use as they were free and very good for the axles. Aluminium was used as it is a great alloy which is lightweight yet strong.
Tools	the milling machine was used for the axles and collars as it is a high precision machine which makes for excellent repeatability and accuracy.

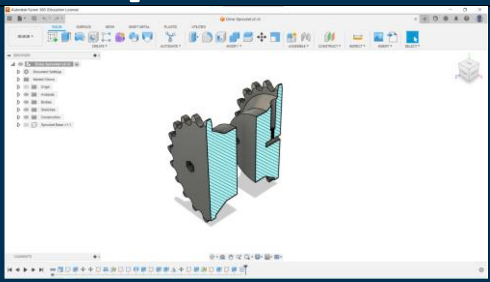
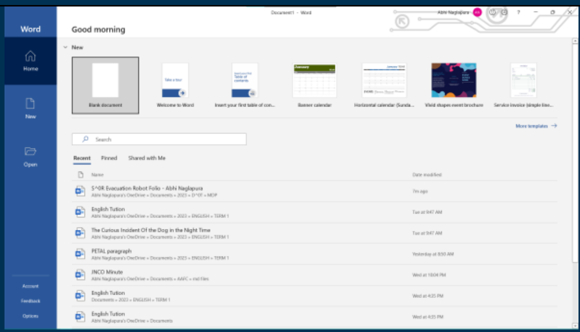
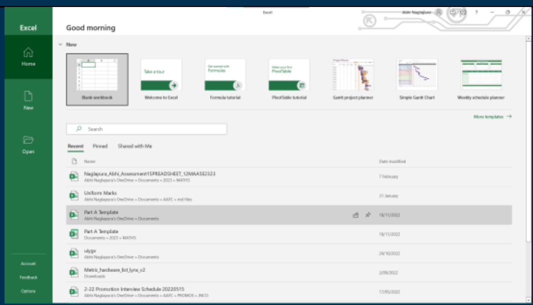
	The lathe was used for the collar as it makes them very easy to make with high precision. 3D printers were used extensively throughout the project as they are great for prototypes and making custom parts exactly as specified. The laser cutter was also used quite a bit as it is very fast and can make large flat pieces or patterns.

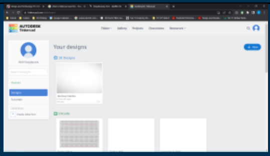
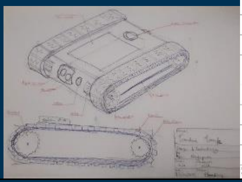
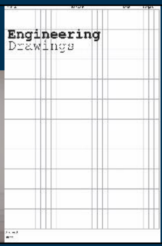
Evaluation

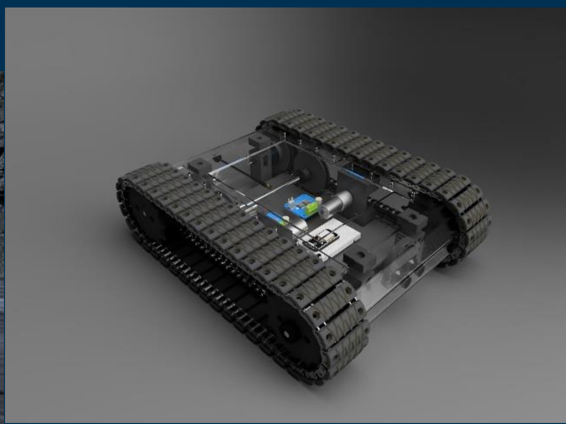
The designer has used lots of tools and materials together for the project. As they were all used for their own parts properly, it fits well and works together. Thus, the justification is valid.

2.6 Use of communication and presentation techniques

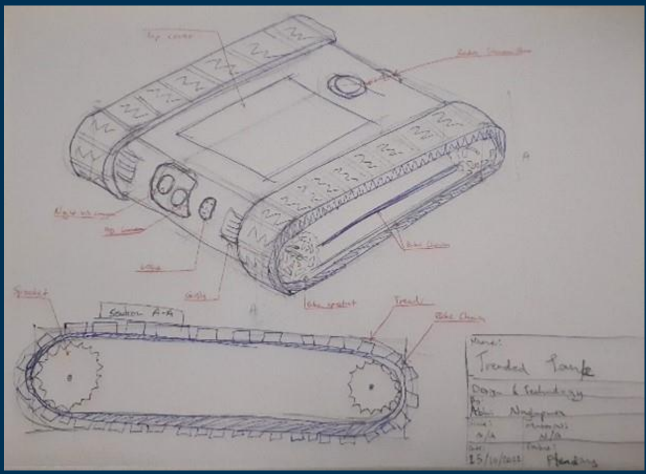
This folio uses a variety of ways to explain to the reader what took place during the entire design process, from first concepts to the finished result. All of these are the methods that the designer has employed.

Technique	Justification
	Fusion 360 is a software programme created by Autodesk that is used for commercial computer-aided design, computer-aided manufacturing, computer-aided engineering, and printed circuit board design. It is offered for Windows and macOS, while streamlined apps are offered for Android and iOS.
	A common word processing tool called Microsoft Word, sometimes known as MS Word, is used mostly for the creation of documents including brochures, letters, learning activities, quizzes, and tests, as well as students' homework assignments. One of the programmes in the Microsoft Office suite, it was first made available in 1983.
	Users of Microsoft Excel may format, arrange, and compute data in a spreadsheet. Data analysts and other users can make information easier to examine as data is added or altered by organising data using tools like Excel. The boxes in Excel are referred to as cells, and they are arranged in rows and columns.

	Almost 50 million people worldwide rely on the free web programme such as Tinkercad and OnShape for 3D design, electronics, and coding. Project-based learning can help students become more confident in STEM fields.
 	Drawings are essential for quick showcase of ideas that would otherwise take time. These can then be refined and built upon later.



Above are rendered pictures of the finished 3D model in Fusion 360

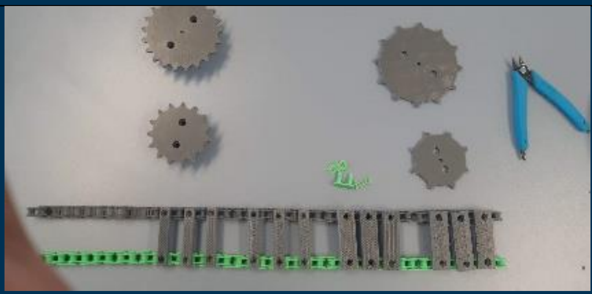


One of the first drawings made to show the idea and concept behind the project.

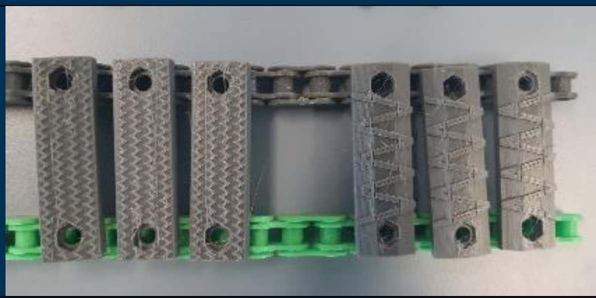
Evaluation

All these communication methods are essential to show to the end user how the design is meant to be used and how much work went into making it all happen. This is especially important for an HSC Major Work.

2.7 Evidence and Application of practical skills to Produce a quality project

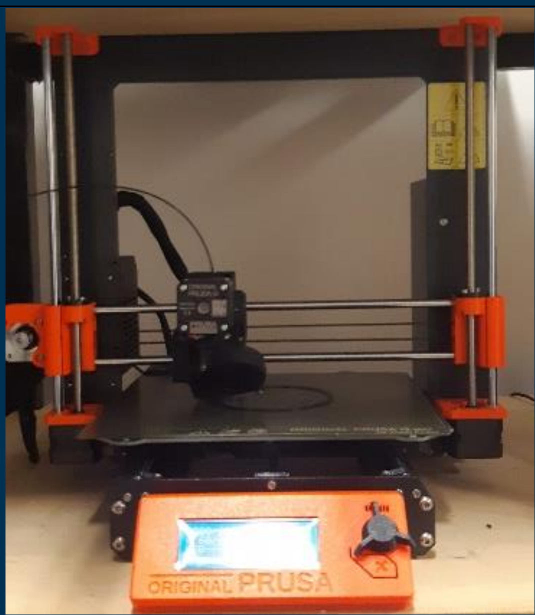


this step shows after some designing has happened. The fusion models have been shown in previous pages of the process to get to this. I just started to put together some treads

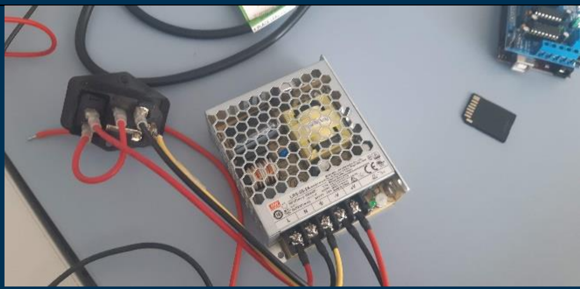
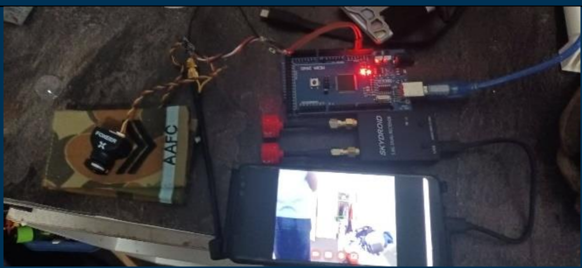


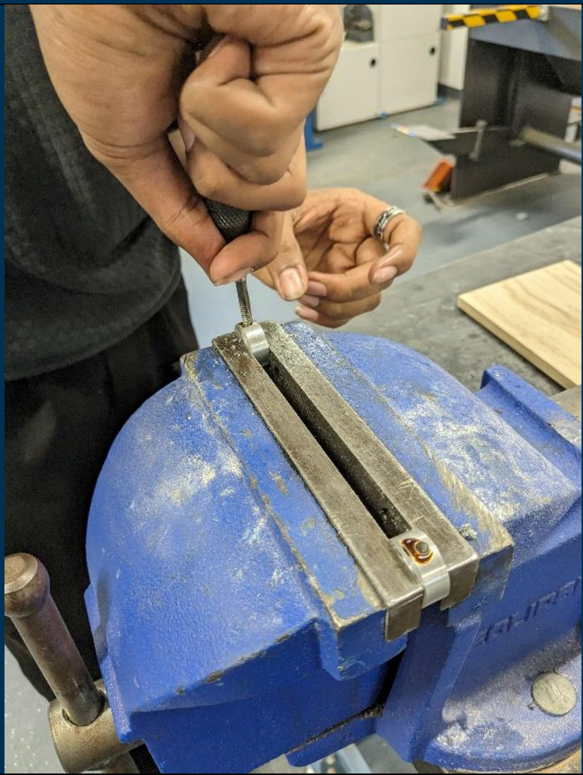
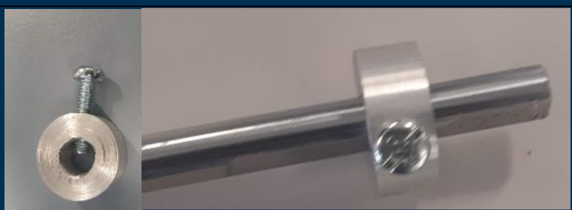
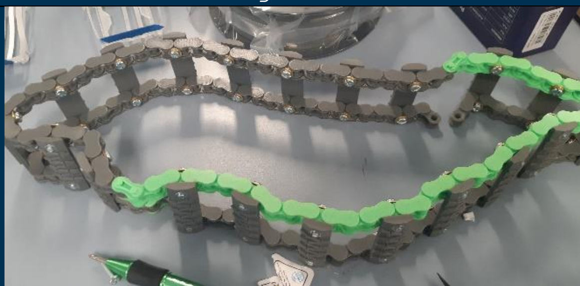
Here you can see the two different designs put together as a comparision side by side

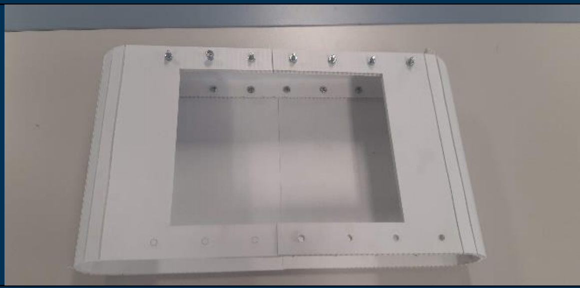
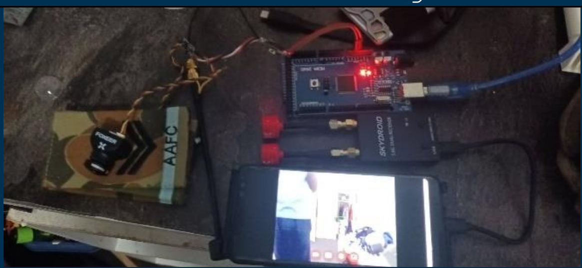
At this point I started to bolt the treads to the 3D printed chains to get a feel of how it would work at the end.

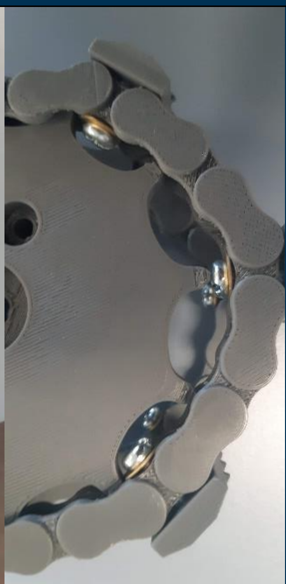


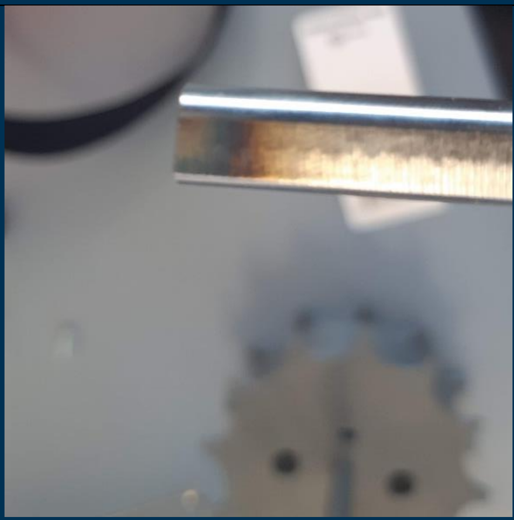
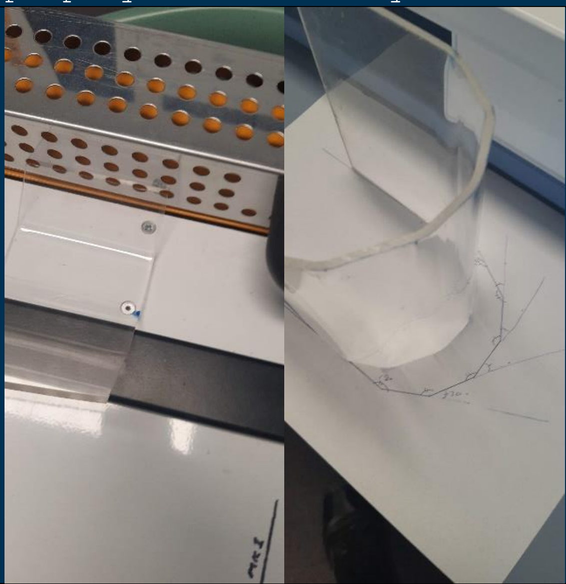
After some fiddling around, the Prusa printers started to work properly, which greatly sped up the process of getting parts

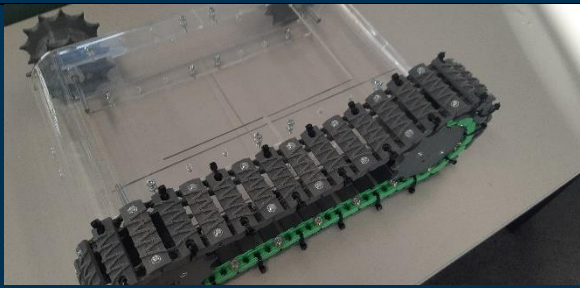
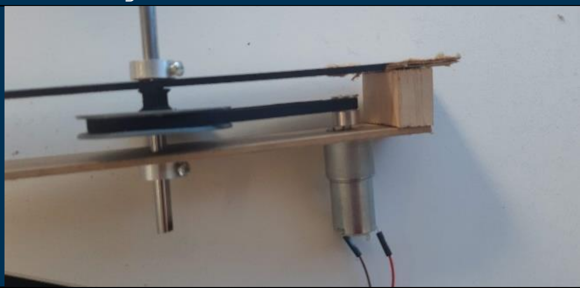
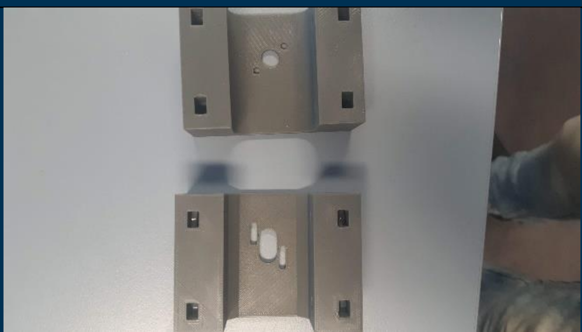
	
Here is after all the sprockets and pulleys were printed. It took quite a while to get the tolerances just right and fitting on the steel axles.	At this point I started to work on the elctronics side of it which took its sweet time deciding to work. The picture shows a 12 V power supply that I used in place of some batteries.
	 
After a lot of soldering and careful wiring, I finally got the camera system working. This whole thing took the better part of a couple of weeks, simply because I needed the parts to arrive.	On the right is the initial radio reciever, however it ended up being the wrong radio protocol, so I had to get a different one with a PWM converter as well, as seen on the left.

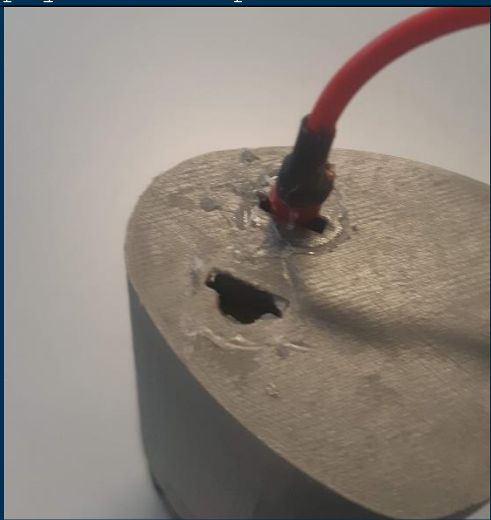
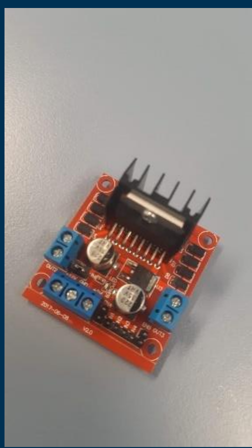
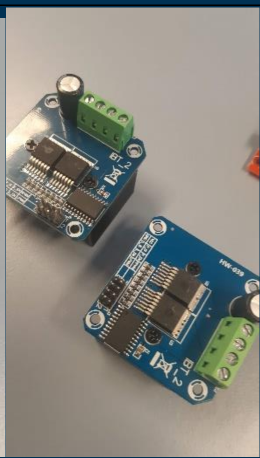
	
At this point I started to make some collar clamps for the axles so that the free moving sprockets wouldn’t fall off	This also meant I had to use the miling machine to make flat spots on the steel shafts for the set screws. It took a while because I had to use carbide insert tooling.
	
Here it shows how the collars work to tighten around the shafts	By now most of the treads were printed so I could put together the full chain. I also decided to use zpities for half of the them to save on weight and cost.

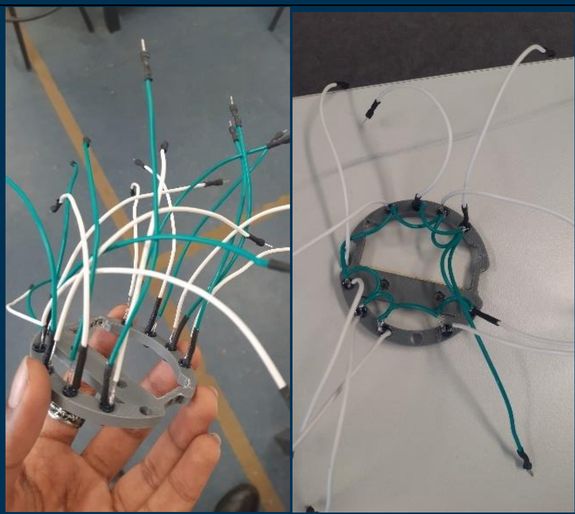
	
Now I started thinking about the main body. I used the sheet metal tool in Fusion 360 to create clat patterns that I prototypes onto corrugated plastic to make sure it works.	Lo and behold it does work and works very well. This means I can use acrylic and the sheet bender to make a much more solid body
	
Here are some quick tests that I did to make sure that the bender can do small radius turns without buckling.	These are the second motor drivers that I tested, the BTS7960. Worked pretty well for a while
	
Here the camera is wired up for 5V power and hooked up to the transmitter	Laser cut corrugated plastic to test out the body design
	

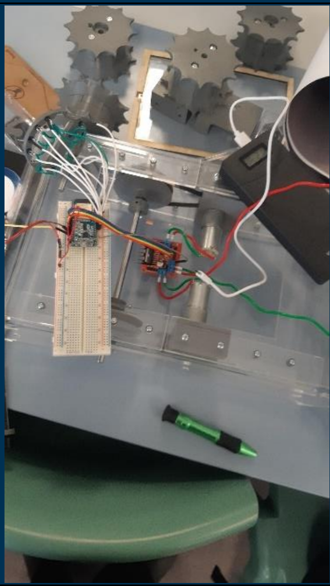
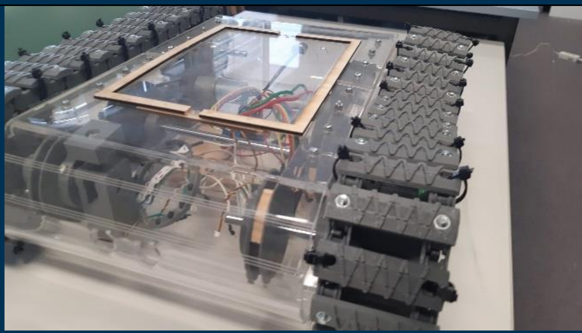
Bolted together and realised that it was too short and needed to be altered	
 	
Using the lathe to make more collar clamps out of aluminium as the steel one broke the m3 tap	Using a shop made jig to hold a piece while it was fixed
 	
The new sprocket size compare to the old one which didn't fit properly.	Close up of the teeth. A small change but made a world of difference.

	
Using the angle grinder, I cut the axles in half so they fit propely into the body.	Printed out holster for the battery. Ended up using a Ryobi tool battery for ease
	
Using 4.5mm acrylic for the final body with the plastic bender	I drew up a template to make sure the bends were at the correct angle.

	
Final bends finished	Put together with the chain
	
Altering a GT2 belt to make it the right size	Testing out the combined motor and belt pulley system.
	
Finished one side chain	Finsihed bothe side chain!
	
Printed out motor mounts. Integrated a tensioning system as the original one didn’t work properly	Light mounting system connected to the camera

	
Shaft support had to be adjusted with some laser cut plywood scrap	Idler sprocket with the bearing pressed in
	 
Using spade connectors to interface with the Ryobi battery	the new motor driver (L298N) vs old one which burnt out due to a dud (BTS7960)

	
Mess of electronics with ESP32 being connected	Soldering up the hookup wires for the LEDs
	
Most nerve racking part, takin off the infrared blocking glass	Finished soldering and realised I could use one wire for grounds, so I resoldered everything

	
Hooking up various componenets inside the main body	Finsihed the wiring up
	
Fixing some slack on the chains	Final desing completed!
	Beauty shots


Camera shots

Code

```
#include <L298NX2.h>
#include <DabbleESP32.h>

const uint8_t EN1 = 27;     //MotorA Enable
const uint8_t in1A = 12;    //MotorA IN1
const uint8_t in2A = 14;    //MotorA IN2
const uint8_t EN2 = 32;     //MotorB Enable
const uint8_t in1B = 25;    //MotorB IN1
const uint8_t in2B = 33;    //MotorB IN2

const int ir1 = 23;   //IR Pin 1
const int ir2 = 22;   //IR Pin 2
const int ir3 = 1;    //IR Pin 3
const int ir4 = 3;    //IR Pin 4
const int ir5 = 21;   //IR Pin 5
const int ir6 = 19;   //IR Pin 6
const int ir7 = 18;   //IR Pin 7
const int ir8 = 5;    //IR Pin 8
const int ir9 = 17;   //IR Pin 9

const int led11 = 16;   //LED Pin

const int cam = 13;   //Camera Switch Pin

int speedness = 0;    //Current Speed
int speedAmount = 1;  //Amount to increase by

L298NX2 motors(EN1, in1A, in2A, EN2, in1B, in2B);   //Motor
initialise

#define INCLUDE_GAMEPAD_MODULE
```

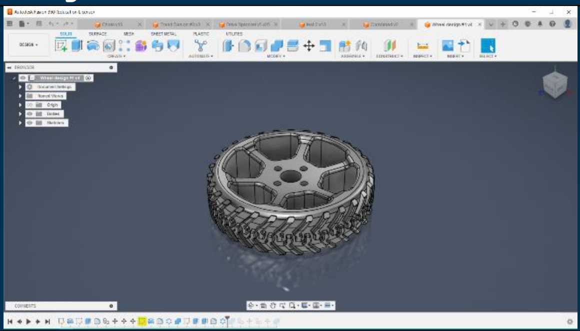
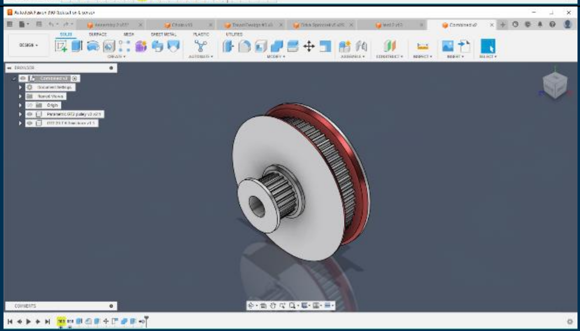
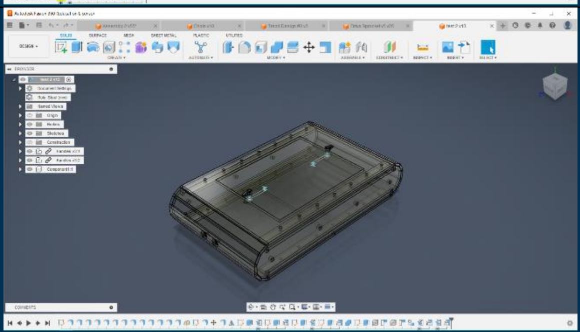
```
void setup()
{
  Serial.begin(9600);   //Start Serial Moniter at 9600 BAUD
  Dabble.begin("My Esp32");   //Bluetooth name "My ESP32"
  pinMode(ir1, OUTPUT);   //IR OUTPUT 1
  pinMode(ir2, OUTPUT);   //IR OUTPUT 2
  pinMode(ir3, OUTPUT);   //IR OUTPUT 3
  pinMode(ir4, OUTPUT);   //IR OUTPUT 4
  pinMode(ir5, OUTPUT);   //IR OUTPUT 5
  pinMode(ir6, OUTPUT);   //IR OUTPUT 6
  pinMode(ir7, OUTPUT);   //IR OUTPUT 7
  pinMode(ir8, OUTPUT);   //IR OUTPUT 8
  pinMode(ir9, OUTPUT);   //IR OUTPUT 9
  pinMode(led11, OUTPUT);   //LED OUTPUT
  pinMode(cam, OUTPUT);   //Camera Switch OUTPUT
}

void loop() {
  motors.setSpeed(speedness);   //Set current speed as 0
  Dabble.processInput();  //Start to collect input values
  {
    if (GamePad.isUpPressed())
    {
      motors.forwardA();    //move MotorA forward
      motors.forwardB();    //move MotorB forward
      speedness = speedness + speedAmount;      //gradually
increase speed
    }

    else if (GamePad.isDownPressed())
    {
      motors.backwardA();   //move MotorA backward
      motors.backwardB();   //move MotorB backward
      speedness = speedness + speedAmount;      //gradually
increase speed
    }

    else if (GamePad.isLeftPressed())
    {
      motors.backwardA();   //move MotorA backward
      motors.forwardB();    //move MotorB forward
      speedness = speedness + speedAmount;      //gradually
increase speed
    }
```

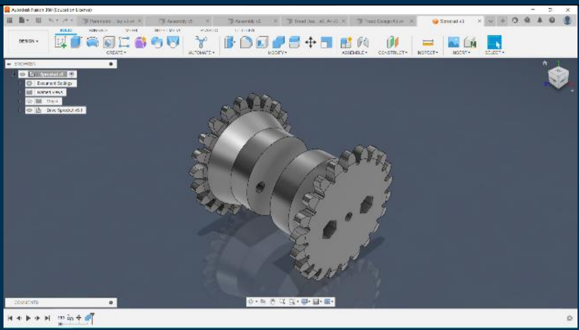
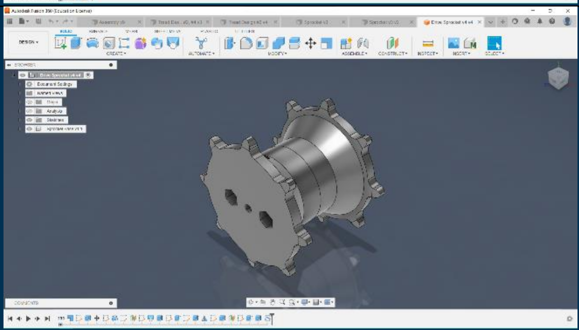
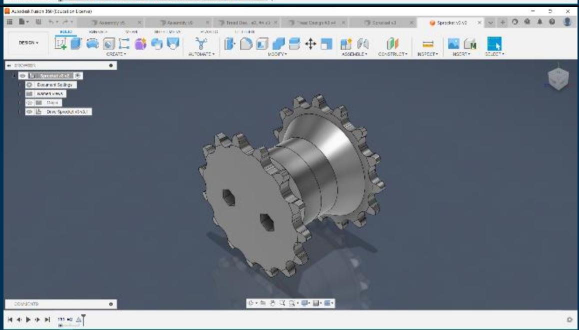
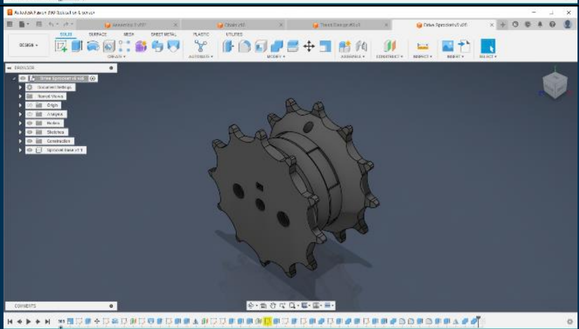
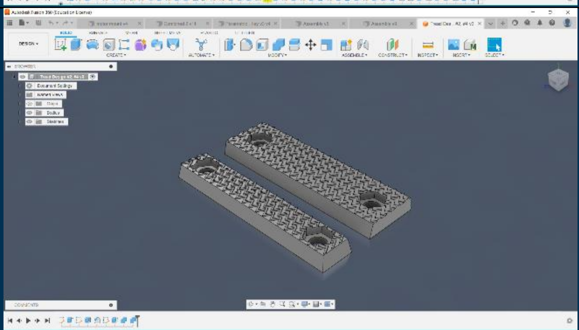
```
    else if (GamePad.isRightPressed())
    {
      motors.forwardA();    //move MotorA forward
      motors.backwardB();   //move MotorB backward
      speedness = speedness + speedAmount;      //gradually
increase speed
    }

    else if (GamePad.isTrianglePressed())
    {
      digitalWrite(cam, HIGH);    //Switch camera views
    }

    else if (GamePad.isCrossPressed())
    {
      digitalWrite(ir1, HIGH);    //Turn on IR 1
      digitalWrite(ir2, HIGH);    //Turn on IR 2
      digitalWrite(ir3, HIGH);    //Turn on IR 3
      digitalWrite(ir4, HIGH);    //Turn on IR 4
      digitalWrite(ir5, HIGH);    //Turn on IR 5
      digitalWrite(ir6, HIGH);    //Turn on IR 6
      digitalWrite(ir7, HIGH);    //Turn on IR 7
      digitalWrite(ir8, HIGH);    //Turn on IR 8
      digitalWrite(ir9, HIGH);    //Turn on IR 9
    }

    else if (GamePad.isCirclePressed())
    {
      digitalWrite(led11, HIGH);    //Turn on LED
    }

    else
    {
      motors.stop();    //Turn Motors off
      digitalWrite(cam, LOW);    //Turn off IR 1
      digitalWrite(ir1, LOW);    //Turn off IR 1
      digitalWrite(ir2, LOW);    //Turn off IR 1
      digitalWrite(ir3, LOW);    //Turn off IR 1
      digitalWrite(ir4, LOW);    //Turn off IR 1
      digitalWrite(ir5, LOW);    //Turn off IR 1
      digitalWrite(ir6, LOW);    //Turn off IR 1
      digitalWrite(ir7, LOW);    //Turn off IR 1
      digitalWrite(ir8, LOW);    //Turn off IR 1
      digitalWrite(ir9, LOW);    //Turn off IR 1
      digitalWrite(led11, LOW);    //Turn off IR 1
```

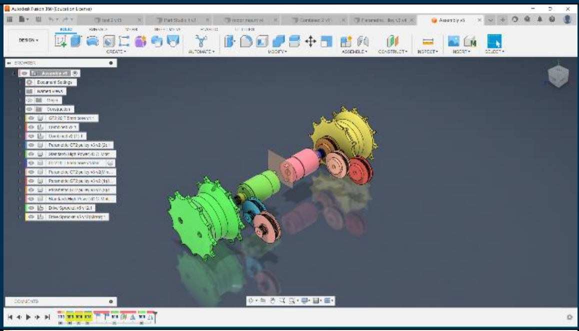
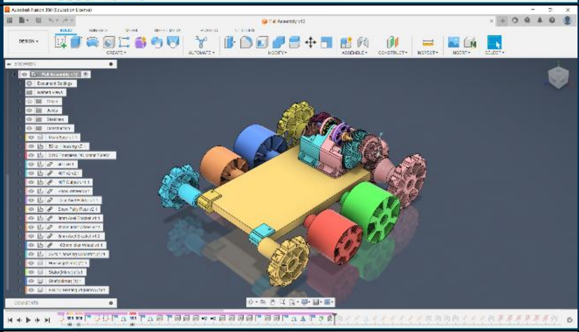
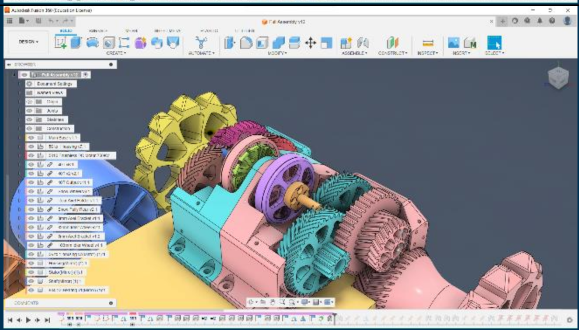
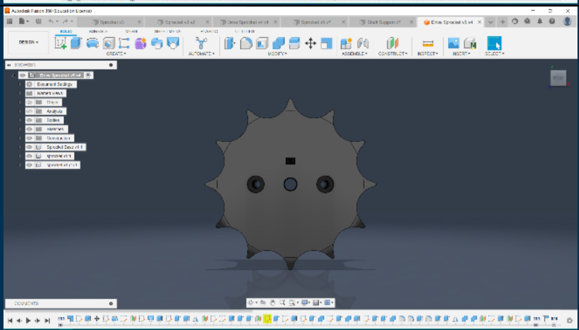
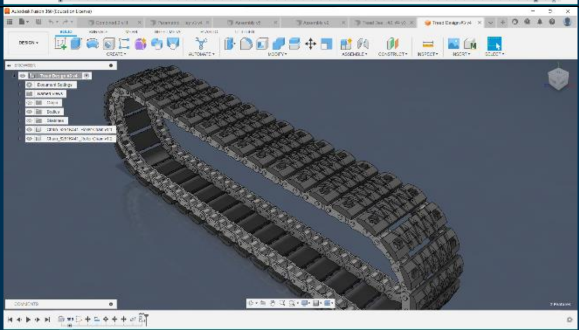
```
        }
    }
}
```

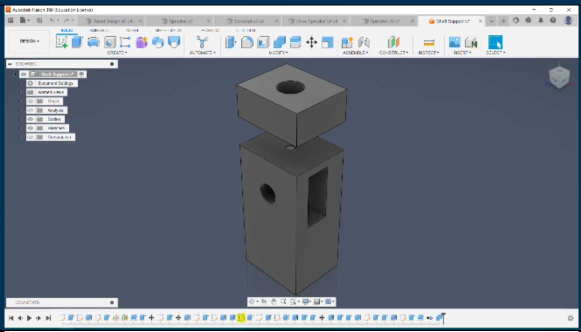
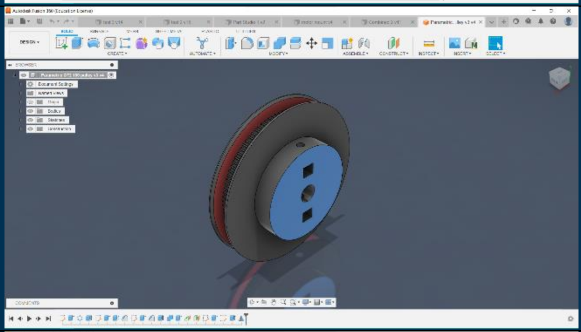
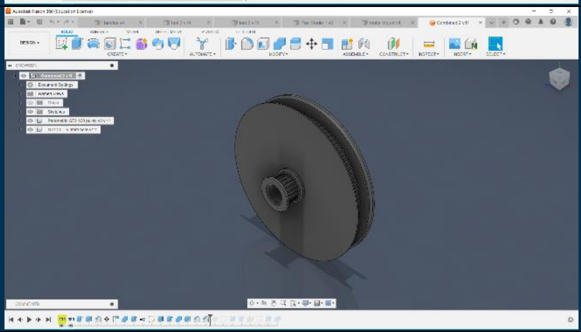
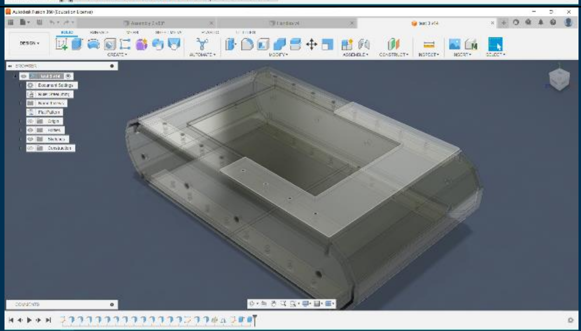
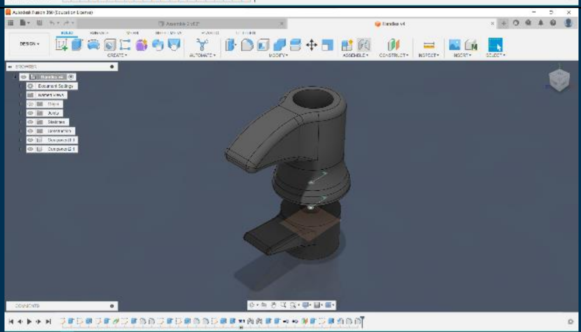
The code went through various itterations using the Arduino IDE and Github fo various relavent libraries. The above insert is in the Arduino version of C++ and the final code that has been uploaded to the ESP32.

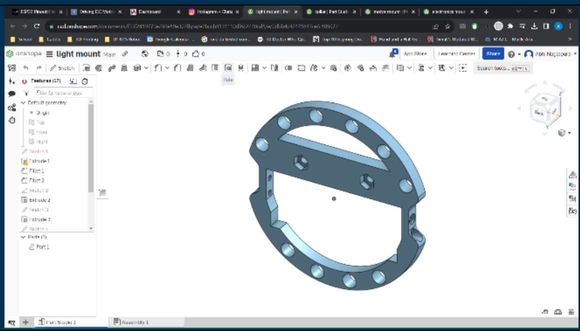
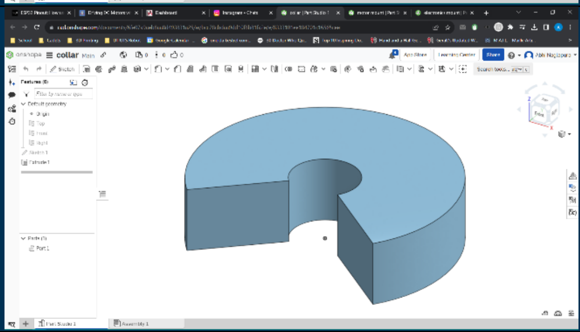
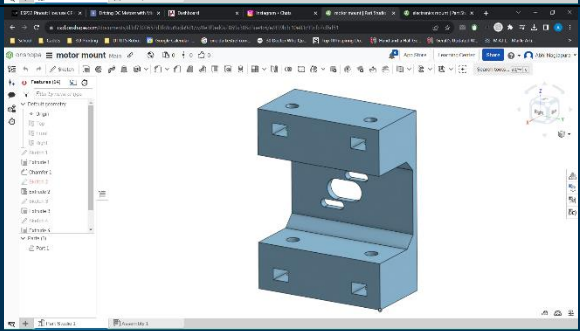
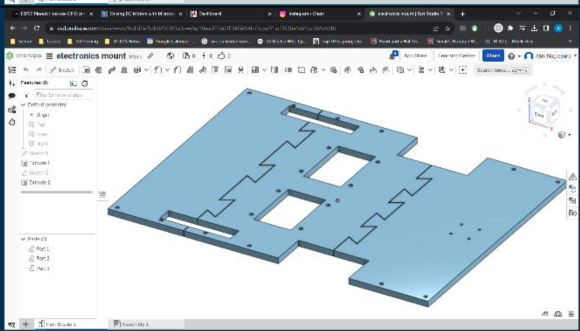
CAD Models

Image	Description
	Original Idea to use wheels
	Initial GT2 pulley model
	First test run of using the sheet metal software in Fusion 360

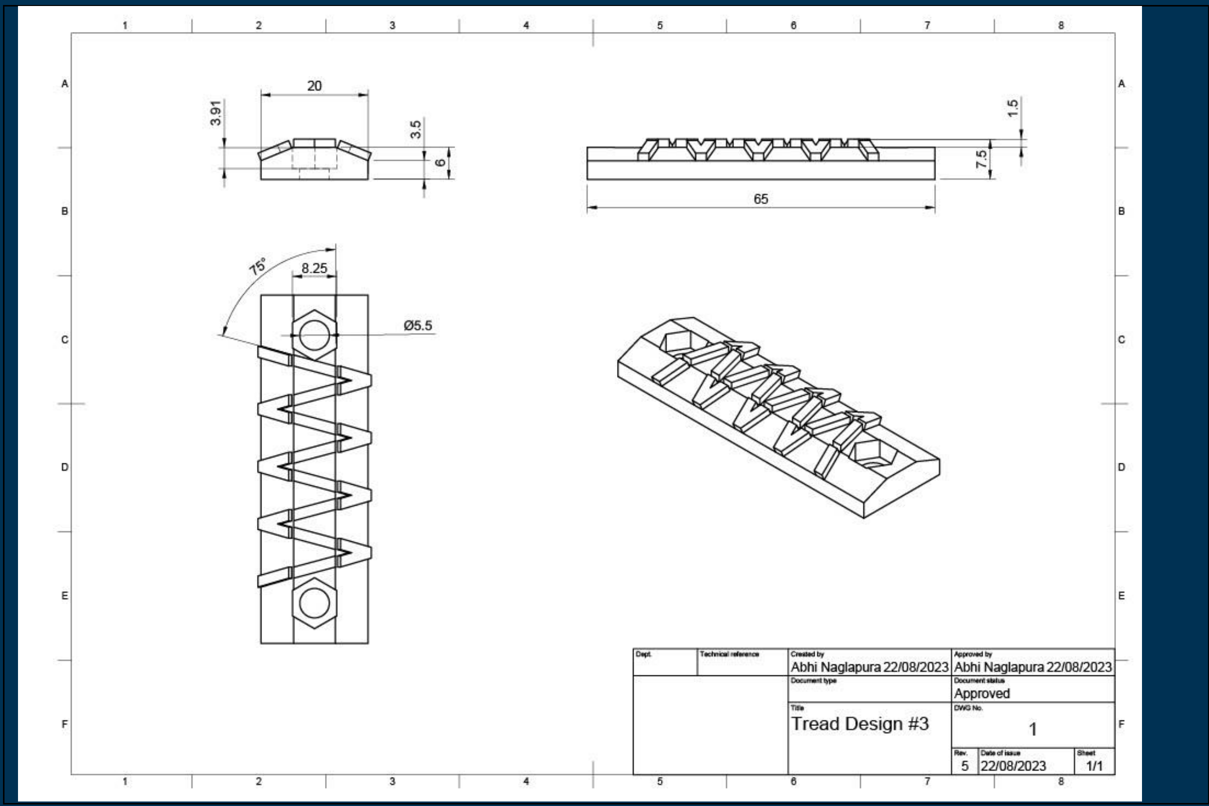
	Sprockey Design #1
	Sprockey Design #2
	Sprockey Design #3
	Sprockey Design #4
	One of the possible tread designs + sizes

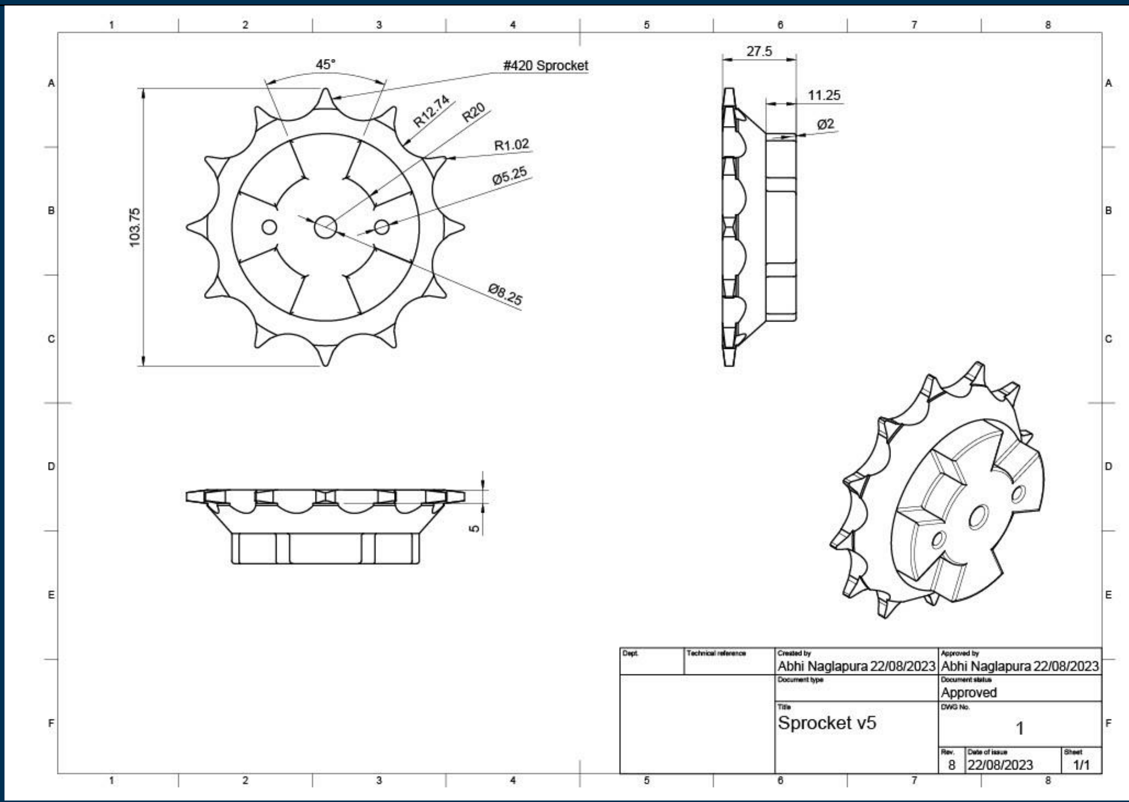
	Initial layout of assembly
	Another idea taking inspiration from rctestflight
	Close up of herringbone gear train
	Final sprocket model
	Tread design #3 was chosen

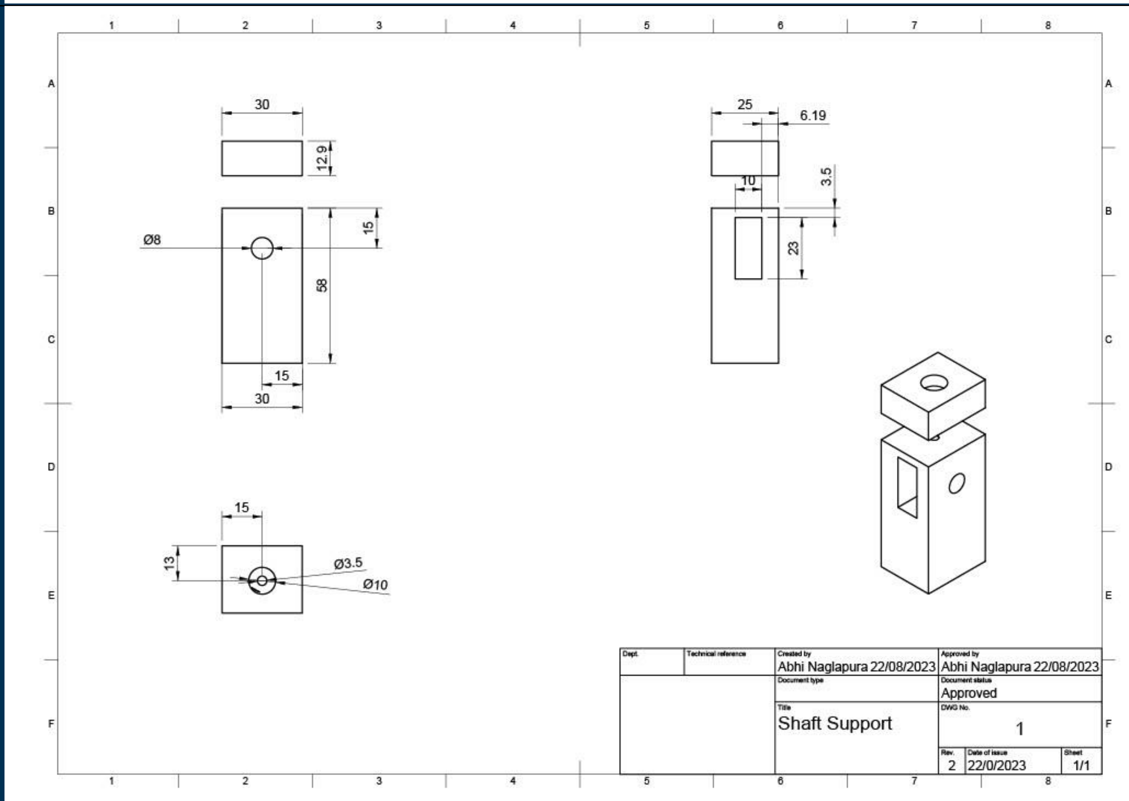
	Supporting mechanism for shafts
	GT2 driven pulley
	GT2 idler pulley
	Final model of body suing sheet metal tool
	Handle assembly for lid

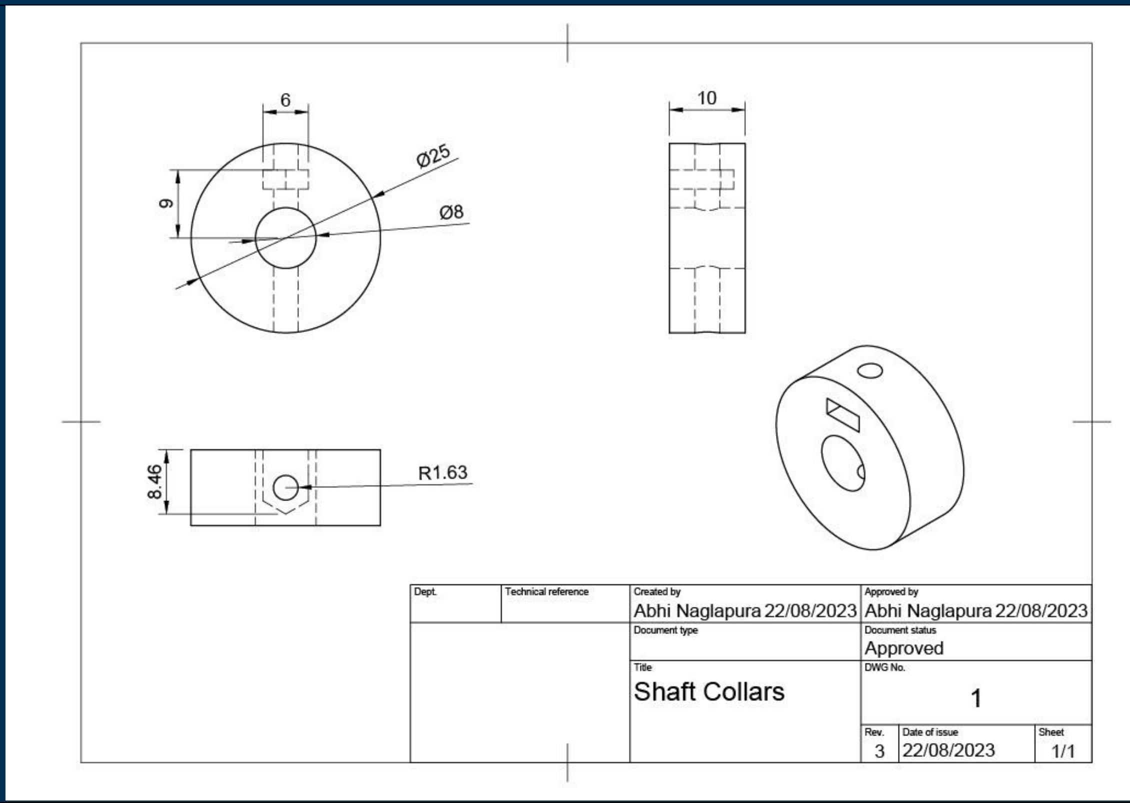
	Using onshape for the first time to test out its functionality compared to fusion. Mounting system for the lights
	Simple collar to prevent antenna for going into the body
	Motor mounting system with included tensioning
	Mounting plate for electronics

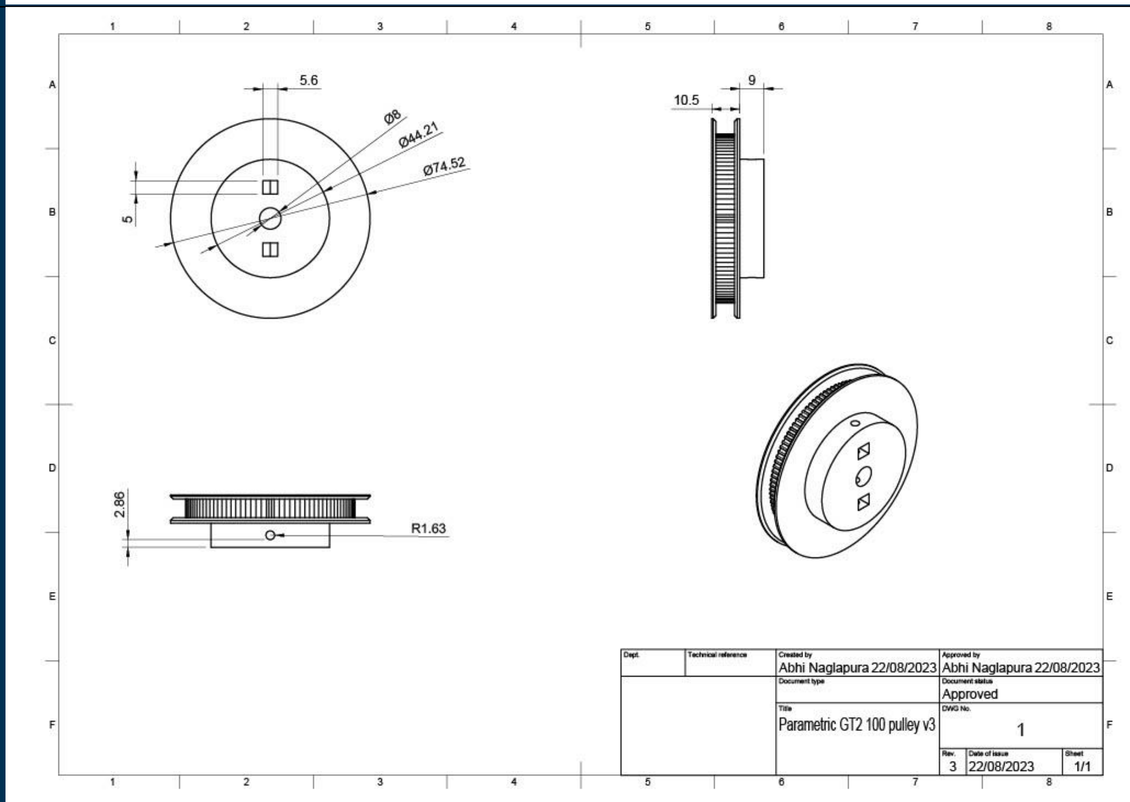
Engineering Drawings (larger versions printed out)




45°
#420 Sprocket
R12.74
R20
R1.02
Ø5.25
103.75
Ø8.25
27.5
11.25
Ø2
5
Created by
Abhi Naglapura 22/08/2023
Approved by
Abhi Naglapura 22/08/2023
Document status
Approved
Sprocket v5
DWG No.
1
Rev.
8
Date of issue
22/08/2023
Sheet
1/1


30
12.9
Ø8
15
58
15
30
25
6.19
10
3.5
23
15
13
Ø3.5
Ø10
Created by
Abhi Naglapura 22/08/2023
Approved by
Abhi Naglapura 22/08/2023
Document status
Approved
Shaft Support
DWG No.
1
Rev.
2
Date of issue
22/0/2023
Sheet
1/1


6
10
Ø25
Ø8
9
8.46
R1.63
Dept.
Technical reference
Created by
Abhi Naglapura 22/08/2023
Approved by
Abhi Naglapura 22/08/2023
Document type
Document status
Approved
Title
Shaft Collars
DWG No.
1
Rev.
3
Date of issue
22/08/2023
Sheet
1/1


5.6
Ø8
Ø44.21
Ø74.52
5
10.5
9
2.86
R1.63
Dept.
Technical reference
Created by
Abhi Naglapura 22/08/2023
Approved by
Abhi Naglapura 22/08/2023
Document type
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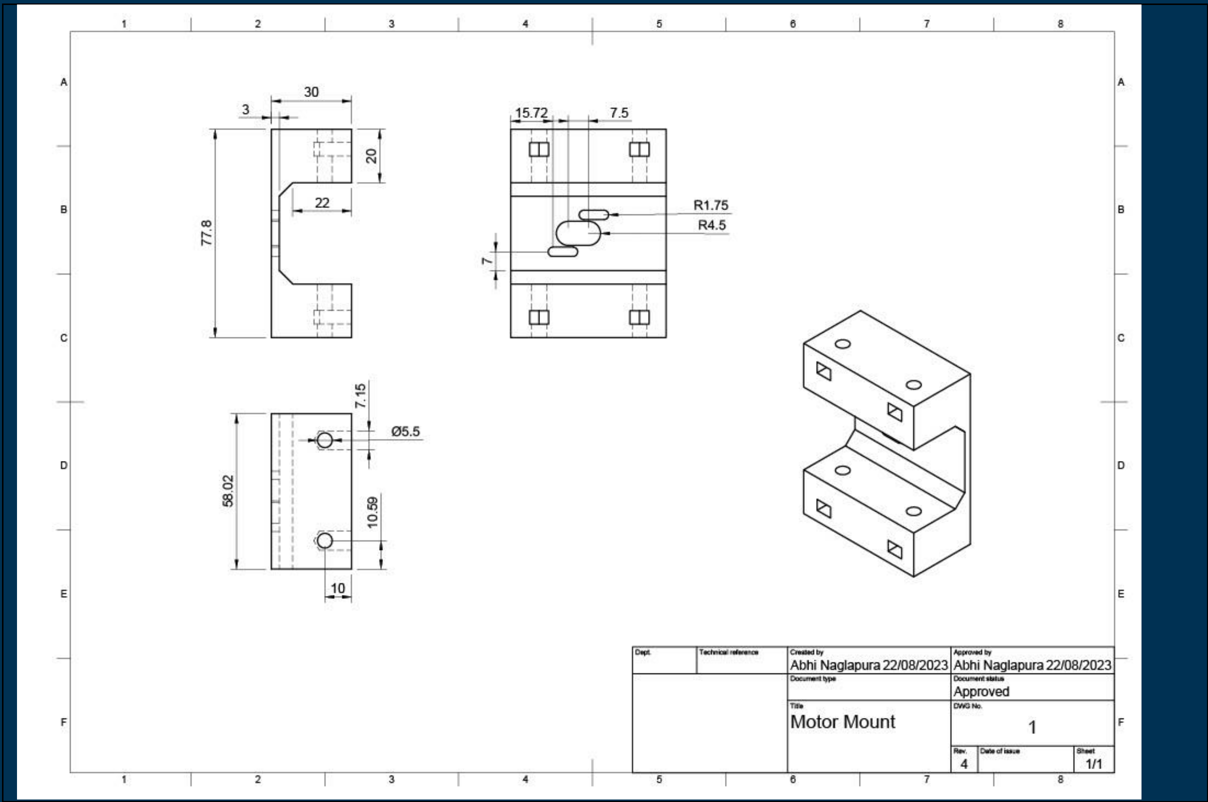
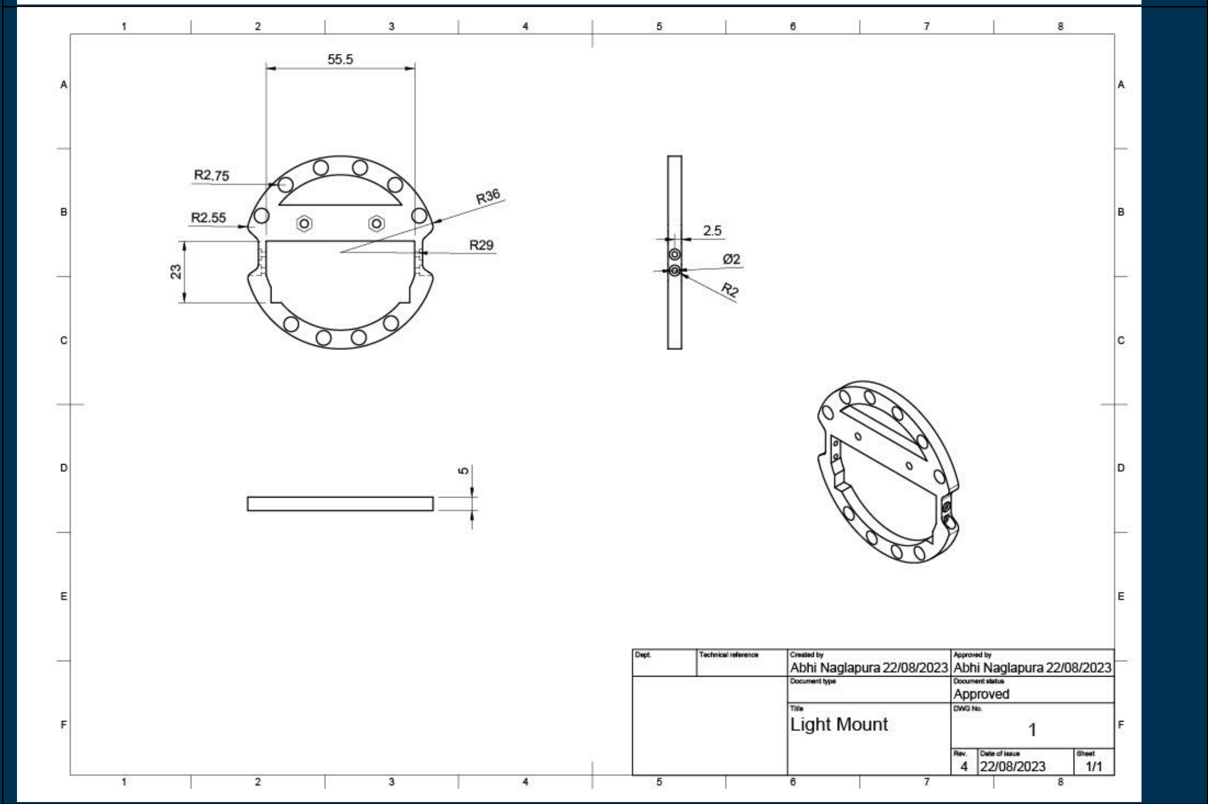
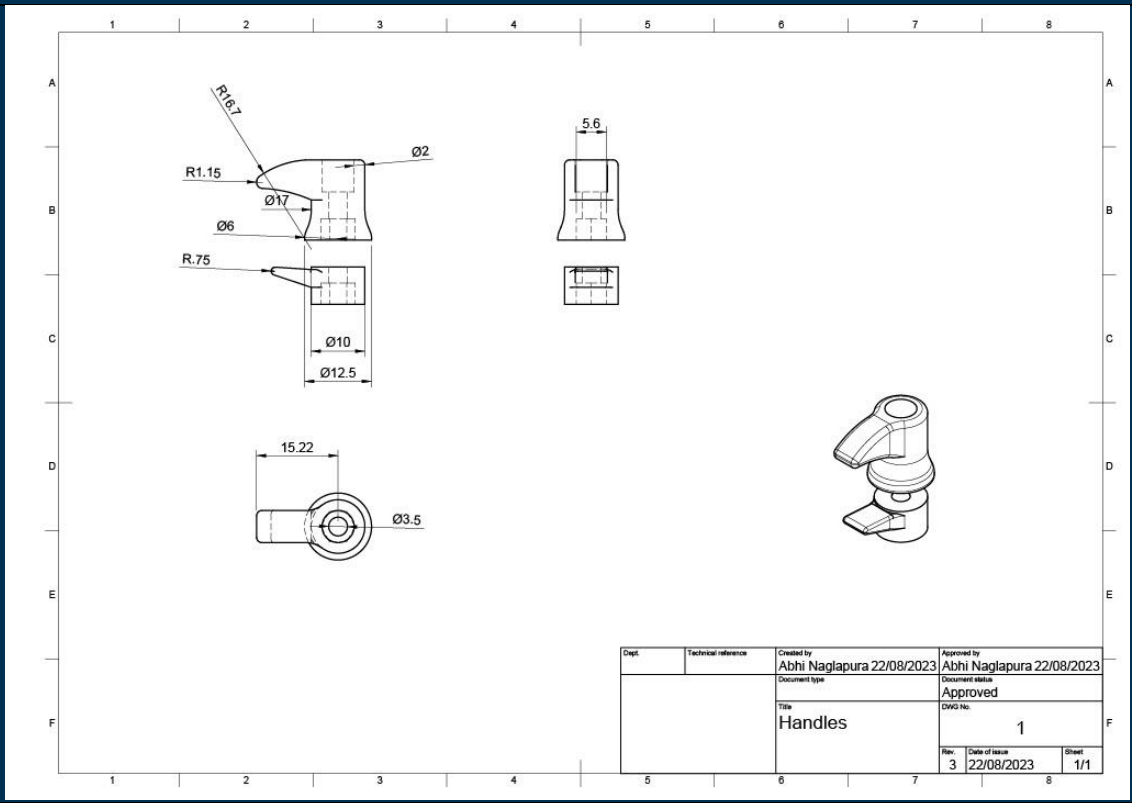
DWG No.
1
Rev.
3
Date of issue
22/08/2023
Sheet
1/1


30
3
20
22
77.8
15.72
7.5
R1.75
R4.5
7
7.15
Ø5.5
58.02
10.59
10
Abhi Naglapura 22/08/2023
Abhi Naglapura 22/08/2023
Approved
Motor Mount
1
4
1/1


55.5
R2.75
R36
R2.55
R29
23
2.5
Ø2
R2
5
Abhi Naglapura 22/08/2023
Abhi Naglapura 22/08/2023
Approved
Light Mount
1
4
22/08/2023
1/1


R16.7
5.6
Ø2
R1.15
Ø17
Ø6
R.75
Ø10
Ø12.5
15.22
Ø3.5
Dept.
Technical reference
Created by
Abhi Naglapura 22/08/2023
Approved by
Abhi Naglapura 22/08/2023
Document type
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Handles
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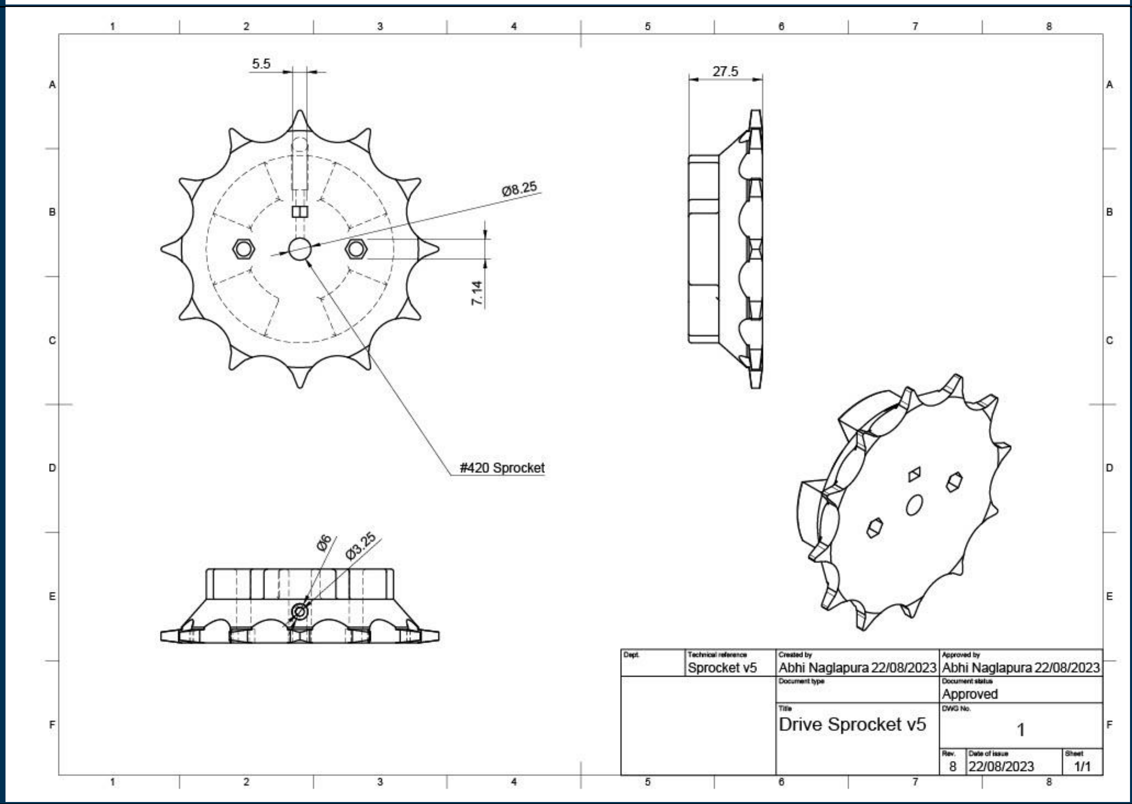
Rev.
3
Date of issue
22/08/2023
Sheet
1/1


5.5
27.5
Ø8.25
7.14
#420 Sprocket
Ø6
Ø3.25
Dept.
Technical reference
Sprocket v5
Created by
Abhi Naglapura 22/08/2023
Approved by
Abhi Naglapura 22/08/2023
Document type
Document status
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Title
Drive Sprocket v5
DWG No.
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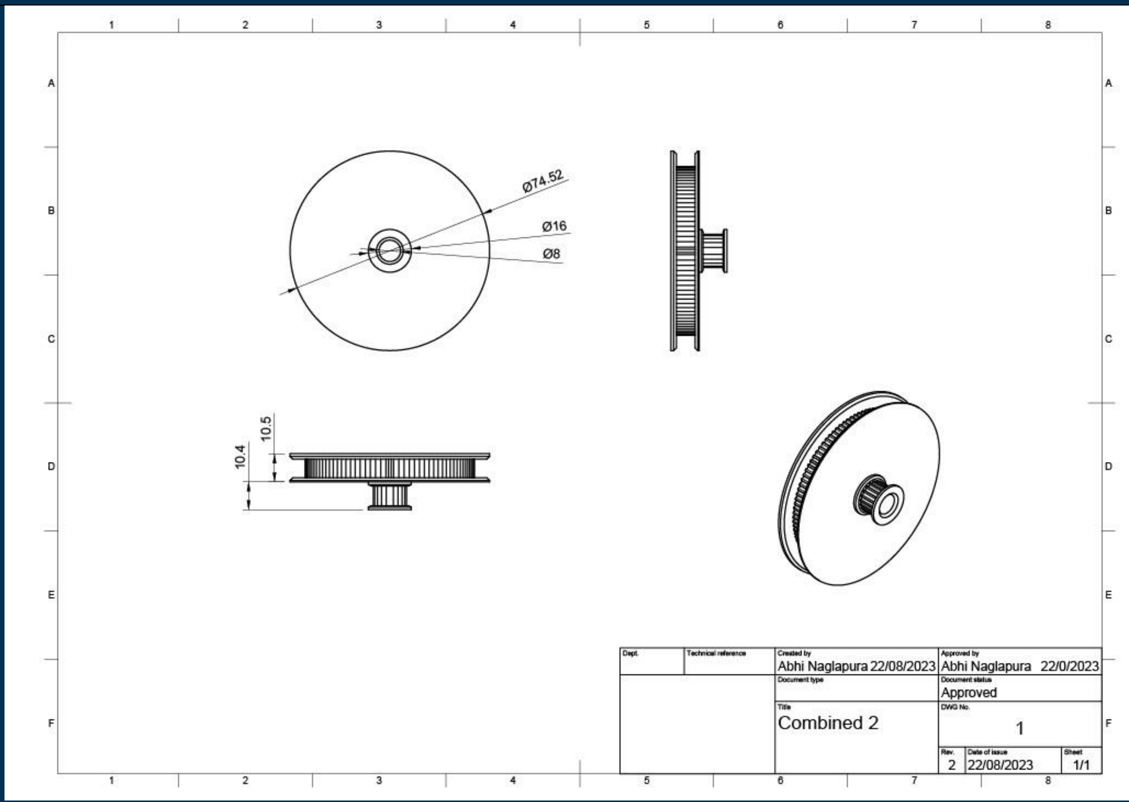
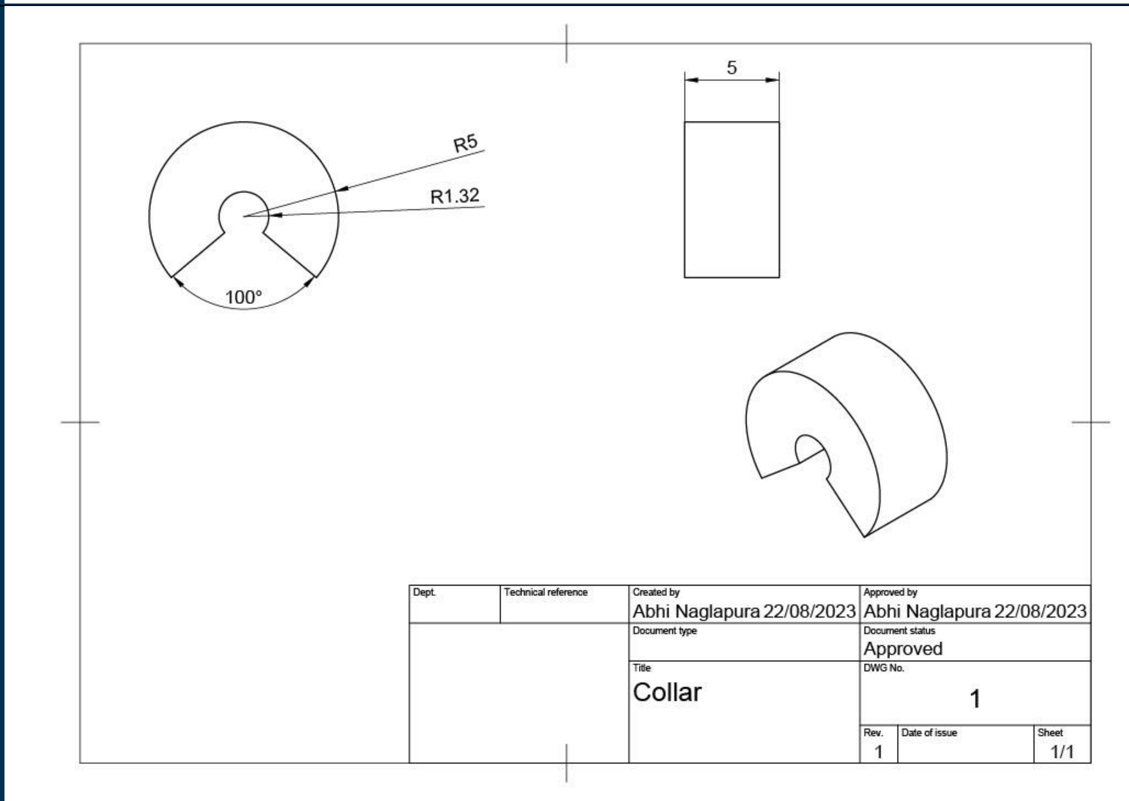
Rev.
8
Date of issue
22/08/2023
Sheet
1/1


Ø74.52
Ø16
Ø8
10.5
10.4
Dept.
Technical reference
Created by
Abhi Naglapura 22/08/2023
Approved by
Abhi Naglapura 22/0/2023
Document type
Document status
Approved
Title
Combined 2
DWG No.
1
Rev.
2
Date of issue
22/08/2023
Sheet
1/1


5
R5
R1.32
100°
Dept.
Technical reference
Created by
Abhi Naglapura 22/08/2023
Approved by
Abhi Naglapura 22/08/2023
Document type
Document status
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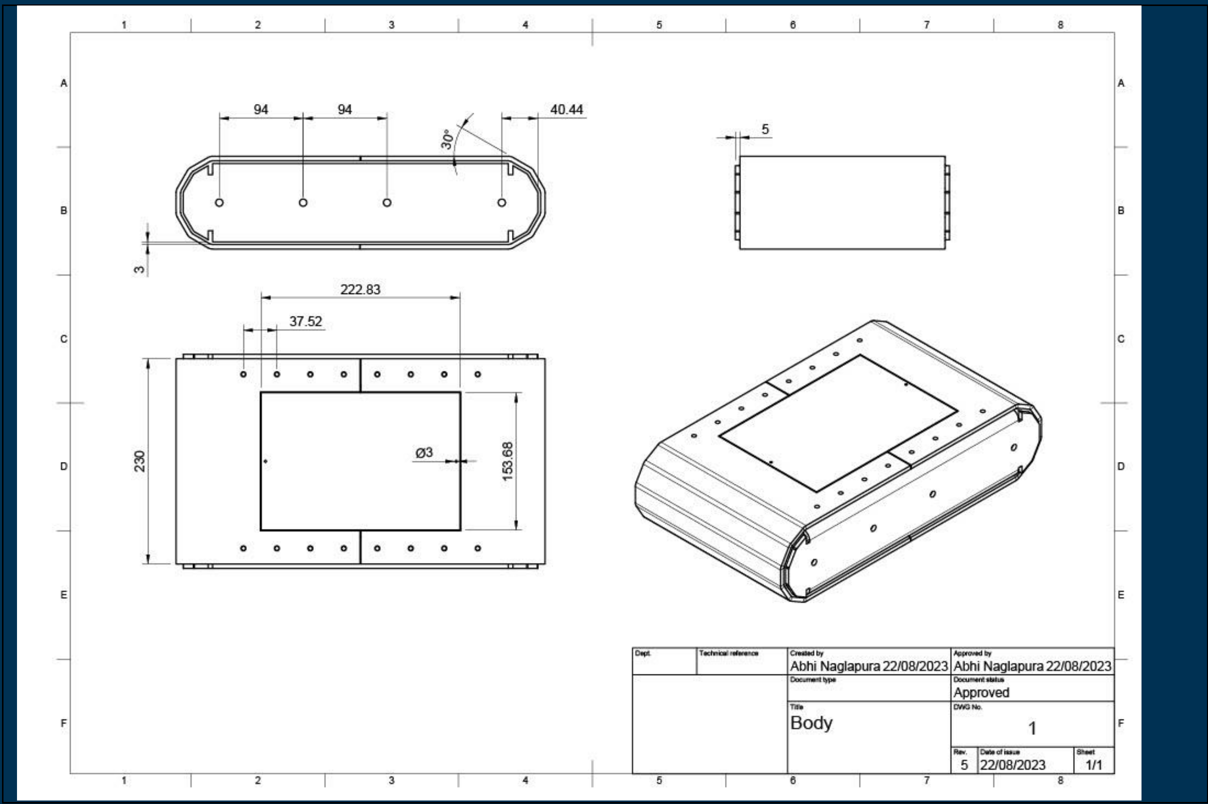
Title
Collar
DWG No.
1
Rev.
1
Date of issue
Sheet
1/1



EVALUATION

Overall, the designer faced many, many challenges along the way, with each one being a significant setback. However, managed to get it done while learning new skills along the way

Evaluation

3.1 Recording and application of evaluation procedures throughout the design project

The designer has made it obvious that Evaluation Textboxes have been used to highlight the evaluation of specific areas throughout this folio. Throughout this folio, the reader is allowed to read the designer's overall assessment of a variety of significant elements. Textboxes that adhere to the format displayed above indicate all significant evaluations that the designer underwent during his design process. Due to its emphasis on key evaluation areas, this approach of evaluation was successful. The designer can also assess how much evaluation he did throughout the design process by looking at these evaluations.

Section	Evaluation	Page Ref.
1.1	The designer has chosen to cater to the needs of NGOs and emergency services while having a custom-built evacuation robot. This will be quite a challenging project with many factors and obstacles throughout. Batteries, motors, and radio just to name a few. Additionally, the designer learnt multiple software’s just for the project. Fusion 360, OnShape, Arduino IDE, and Premiere Pro just to name a few	7
1.2	The investigations into these areas will give the designer a more solid understanding of how to fulfil the design need. It will allow the designer to gain more knowledge and skills needed to design and manufacture the evacuation robot.	9
1.3	This criterion is essential in making sure the parameters don’t change throughout the project, thus lengthening the amount of time taken.	12
1.4	The designer must account for tests and assessment schedules for his other HSC subjects. To be a successful project, the final due date is the 27th of August 2023. After the completion of the product, there will usually	13

	be some folio work to finish which needs to be accounted for.	
1.5	The estimated total and running total ended up just under the total budget of $800 which is a very good achievement. The researched prices were mostly the high-quality ones, however in the interest of time and money, cheaper ones were purchased.	16
2.1.1	The designer researched a variety of possible designs and has enabled him to make many educated decisions about the final project.	20
2.1.2	In summary, while all the designs are quite feasible, the final design at the bottom is the best idea. This is because of the simple shape and features that will be relatively easy to manufacture at a school tool shop with the budget.	22
2.1.3	This is a much more detailed diagram, which allows the designer to explore it in depth. the final model ended up looking almost exactly like this	23
2.1.4	Innovations found in this design were inspired by existing ideas such as the snowcat, belt drives, and gimbals. These concepts were combined to create a homogenous unique design project.	25
2.2	This an explanation of how each of the factors will be thought of in the final design.	27
2.3.1	It is quite clear that there are many things to think about when designing, not including the hours of work in Fusion 360 to create the designs. While working with this program, I gained many new skills and was able to use them to speed up my workflow. By utilising knowledge from HSC Engineering, a lot of the thought went into calculations and detailed models.	33
2.3.2	The designer has decided to use the materials listed above as they are the most suited to the task at hand for their many strengths and characteristics. Below are the tools used to shape these materials.	36
2.3.3	The designer has decided to use the tools listed in the table above. These have been chosen for their precision and repeatability	39

	which is important for moving parts in machines.	
2.3.4	The designer did several tests to ensure the methods and materials were going to work for their jobs. This gives backup to support the decisions made.	40
2.4	Most of the descensions made were the right ones, which is good for the designer as it means not much time was wasted trying to fight alternatives.	42
2.5	The designer has used lots of tools and materials together for the project. As they were all used for their own parts properly, it fits well and works together. Thus, the justification is valid.	44
2.6	All these communication methods are essential to show to the end user how the design is meant to be used and how much work went into making it all happen. This is especially important for an HSC Major Work.	47
2.7	Overall, the designer faced many, many challenges along the way, with each one being a significant setback. However, managed to get it done while learning new skills along the way	72

3.2 Analysis and evaluation of functional and aesthetic aspects of design

Evaluation of Function

Working Functions

Although most of the functions work, they key aspect of the robot moving around was not able to be completed on time. Being one of the key factors of success, it could be possible to say that the design was a failure, however as every component works, I would call it a relative success. The one reason it doesn't move is because the belts were unable to be tensioned and thus kept slipping. To fix this in the future, I would buy the belts and use unhardened steel shafts so I could secure everything properly. Overall, the robot works well with working wireless cameras and Bluetooth connectivity with both android and iPhone.

Ease of Use

As the robot was made to be used with a Bluetooth app, this makes it quite intuitive to control after learning which button is used for which function. The only things required are two devices, where one of them is either a phone or tablet. Thus, it serves the function of being easy to use where it is on the globe and no matter the conditions.

Maintainability

The robot was made entirely with off the shelf parts, save a few proprietary designs. The individual parts can be 3D printed and laser cut, or if need be, hand cut. All the electronics can be purchased from most major electronics retailers that ship around the world, which means that if the robot were to have a fault, it would neither be a major cost nor hassle to repair it. Additionally, the clear acrylic means that any faults that doo happen are easy to and fast to spot, with the lid being a simple twist handle. Thus, it fulfills the function of being easy to maintain no matter where it is being used.

3.3 Final evaluation with respect to the project's impact on the individual, society, and the environment

Impact on Society and individuals

As the final product is completely designed for the betterment of society and the individuals within it, it serves quite a large purpose.

As a search and rescue aid robot, the aim of this project it to have a positive impact on societies that live around areas of earthquakes, tropical storms, and similar natural disasters. A future aim for me would be to improve on my designs and make them as efficient as possible, so that it may be possible to patent and sell to NGOs (non-government organisations) that help with those types of scenarios. Those communities often have other hardships to deal with, so providing a means of potentially rescuing someone's loved ones, is quite a good impact to have on people.

My intention is to keep working on this over the years and contact industry professionals to make it the best it can possibly be. This way I can truly fulfill all criteria set out at the beginning of the project. Thus, my project may have the greatest positive impact of societies and individuals around the world.

Impact on Environment

Most of my project has been either 3D printed using PLA+ or acrylic, which means that it is not the most environmentally sustainable. This is because all these such plastics are derived from petroleum and emit large amounts of fossil fuels. If the design was to be mass – manufactured, I would looked into using an aluminium alloy such as 6061 which is commonly used in aircraft due to its strength-weight ratio. This would greatly cut down on the negative environmental impacts. From the designers point of view, there has been no planned obsolescence in the entirety of the project, it is built to last and hold up as long as it possibly can.

All these factors combined make it quite an environmentally friendly build, although not using such materials individually.

3.4 Relationship of the final product, system, or environment to the project proposal

In summation, the designer is very happy with the achievements made during this project. The project proposal suggested a search and rescue evacuation robot designed to aid people in need, specifically under a collapsed building. Numerous elements were considered during the design process to accomplish this goal, including component dimensions and cost.

The initial criteria had many facets to it, and although not all of them were met, I still think the project is considered a success. When it was first initialised, I realised the huge undertaking it would be, and yet I am quite pleased with the amount of work I have put into it and the results I have received from peers and mentors.

The designer has been successful in creating and building his own search and rescue aid robot by clearly illustrating the connections between the project concept and the finished result.

Overall, the designer is very happy with the final project and the achievements made throughout.