Mohamed Rammal Engineering Portfolio

Hello, I'm Mohamed Rammal, final year MEng Mechanical Engineering student at UCL. Since my youth, I've had a strong passion for robotics and assembling components together. In the following pages, I showcase projects I've undertaken since high school up until recent projects I'm still working on.

List of Projects

1 UCL Eco-Marathon (2021 - 2022)

The goal of the UCL Eco-Marathon team is to build the world's most efficient prototype vehicle. For over a year and a half I led the division that developed the hydrogen powertrain of the car. The powertrain was composed of: 1x 60W PEM Fuel Cell, 8x 200F 3V Supercapacitors in series (25F, 24V Capacitor Bank), 1x Brushless DC Motor, 3x Safety Relays, and 1x Custom Powerboard PCB. I also oversaw the design of the telemetry systems and the wiring loom that provided the driver with live data readings.

Figure 1: The Eco-Marathon Vehicle

1.1 Powerboard PCB

When designing the PCB, the aim was to include as many components as possible to reduce the need of extra wiring harness length and weight which would negatively affect the efficiency of the vehicle. Therefore, I wrote a list of all components that can be near to each one another, and then drew a rough sketch of how they could be connected.

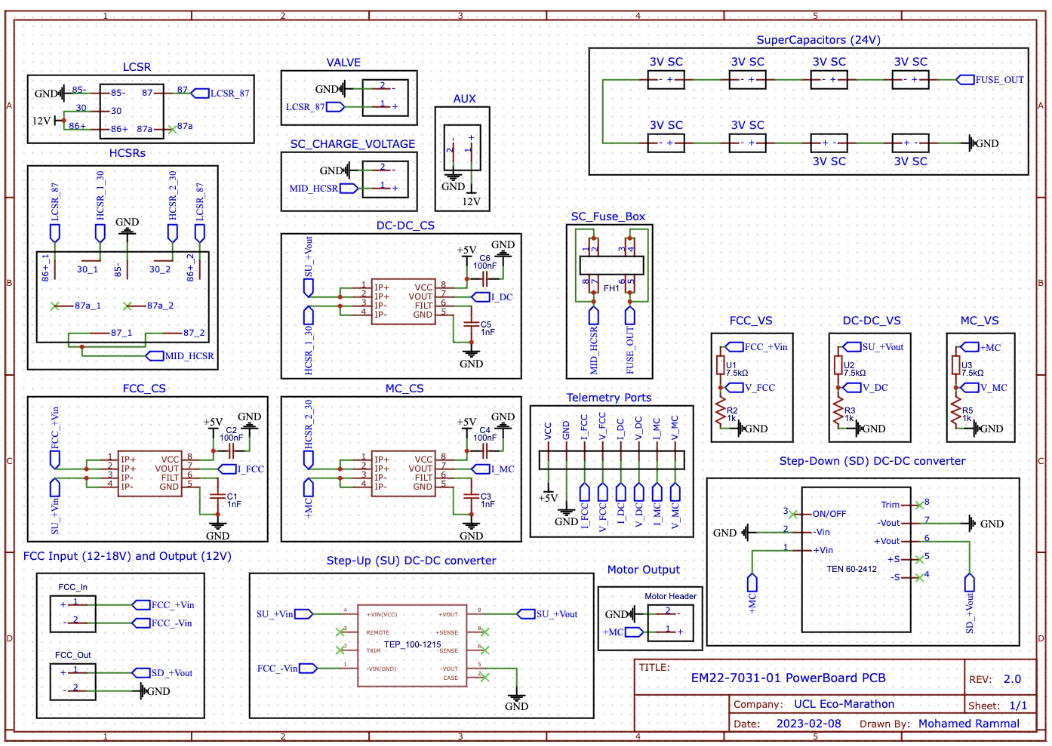


Figure 2: PCB Schematic using EasyEDA

The output voltage of the Fuel Cell Controller (FCC) varies between 12V and 18V DC depending on the load. Since the DC motor and the Supercapacitor Bank both run at 24V, a step-up DC-DC converter was required. The Supercapacitors are connected in parallel, providing a hybrid power supply to the motor. In fact, when accelerating, there is a high-power demand that the FCC cannot meet, which will be directly supplied by the Supercapacitors. When coasting, the FCC will supply small amounts of energy to the motor to keep it running and the rest will go to the Supercapacitors to charge them. By regulations, the Fuel Cell must power itself, which means that a parallel line must run from the mainline to provide a voltage back to the Fuel Cell. Given that the input voltage to the FCC is 12-14V, a step-down DC-DC converter was required. 3 safety relays were used to cut off the main power line between FCC, Supercapacitors, and the Motor / Motor Controller. The first safety relay is powered by a 12V auxiliary battery and is connected in series with the shutdown switches and the hydrogen sensor. The output of that relay controls the other 2 relays. These 2 relays are connected in series on the main line before and after the Supercapacitor Bank node to effectively isolate the Bank from the circuit. This means that whenever a safety switch is activated, the main safety relay disconnects the other 2, cutting off power in the main line. The efficiency of those components was monitored by using a current sensor and a voltage divider to evaluate power before and after, thus determining the power losses. The voltage divider's role is to reduce the incoming voltage from 12V or 24V to a voltage <5V to be read by the ADC pin on the Arduino, or any other telemetry board. Using EasyEDA, the hand drawn sketch was turned into a schematic which was then manufactured into a PCB.

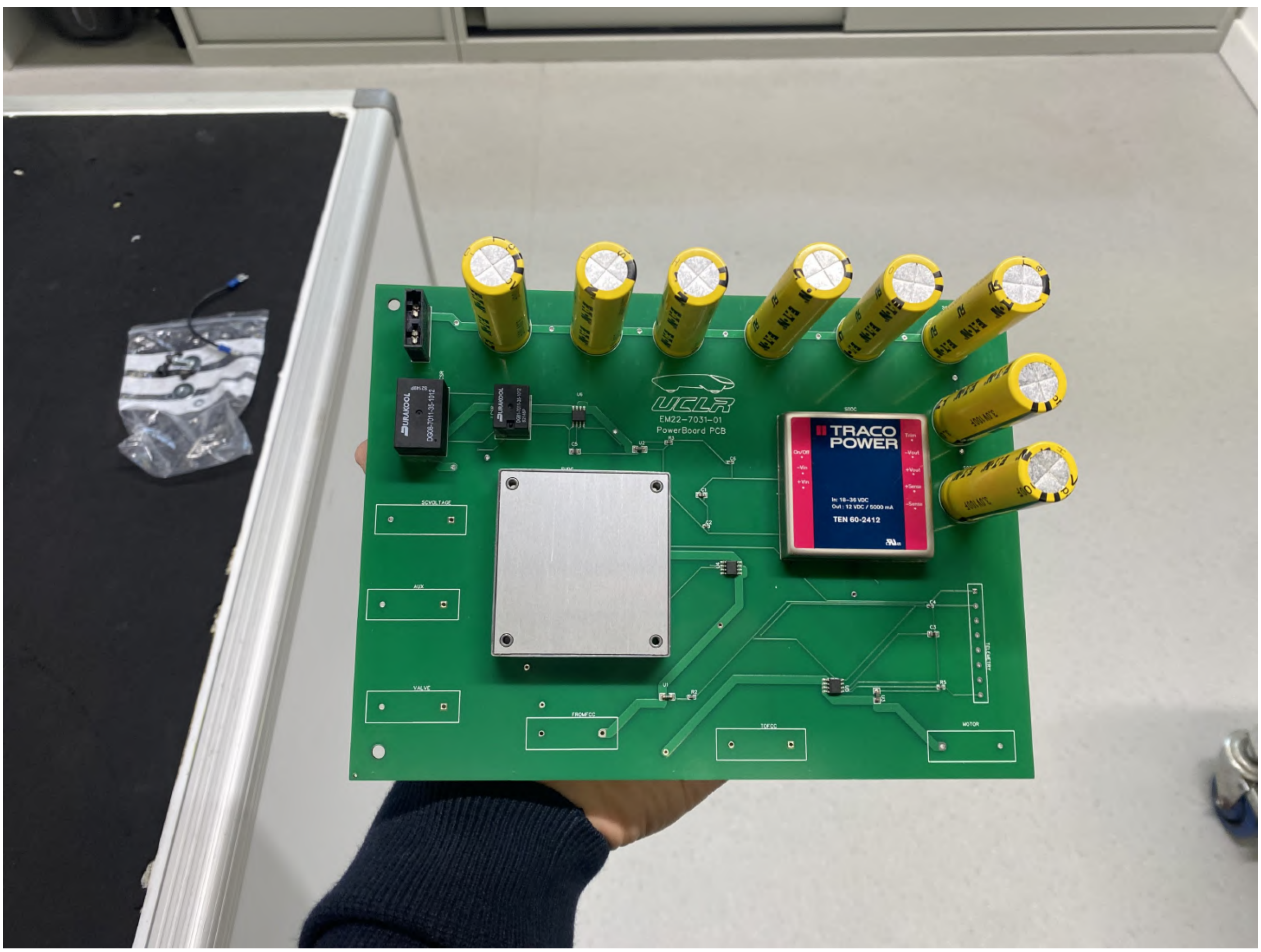


Figure 3: Assembled PCB

1.2 Wiring Harness / Loom

Instead of having clumsy wiring running through the car, I decided to design a wiring harness. This ensures that cables can be removed quickly and easily to test systems outside of the car. Wires are also protected in the unlikely event of a fire or loose sharp part flying around by sleeves and heat shrink tubing. I used DT and DTM DEUTSCH automotive connectors since they're cheap, reliable, and are widely available. I considered using expensive Mil Spec connectors (AS-ASL series) but decided against it since their applications are for extreme environments (vibration and temperature) which are not experienced by the Eco-Marathon car going with a top speed of 30 kmh. Like the PCB, I sketched the layout of the harness then drew it on RapidHarness.

For assembly, we installed the relevant components in the car then traced a path using a rope, which we then laid out on a sheet of plywood. This ensured that the cables we're using are neither too tight nor too loose. The loom was modular, which meant that it was divided in subsections to easily replace one in case of a failure or design change.

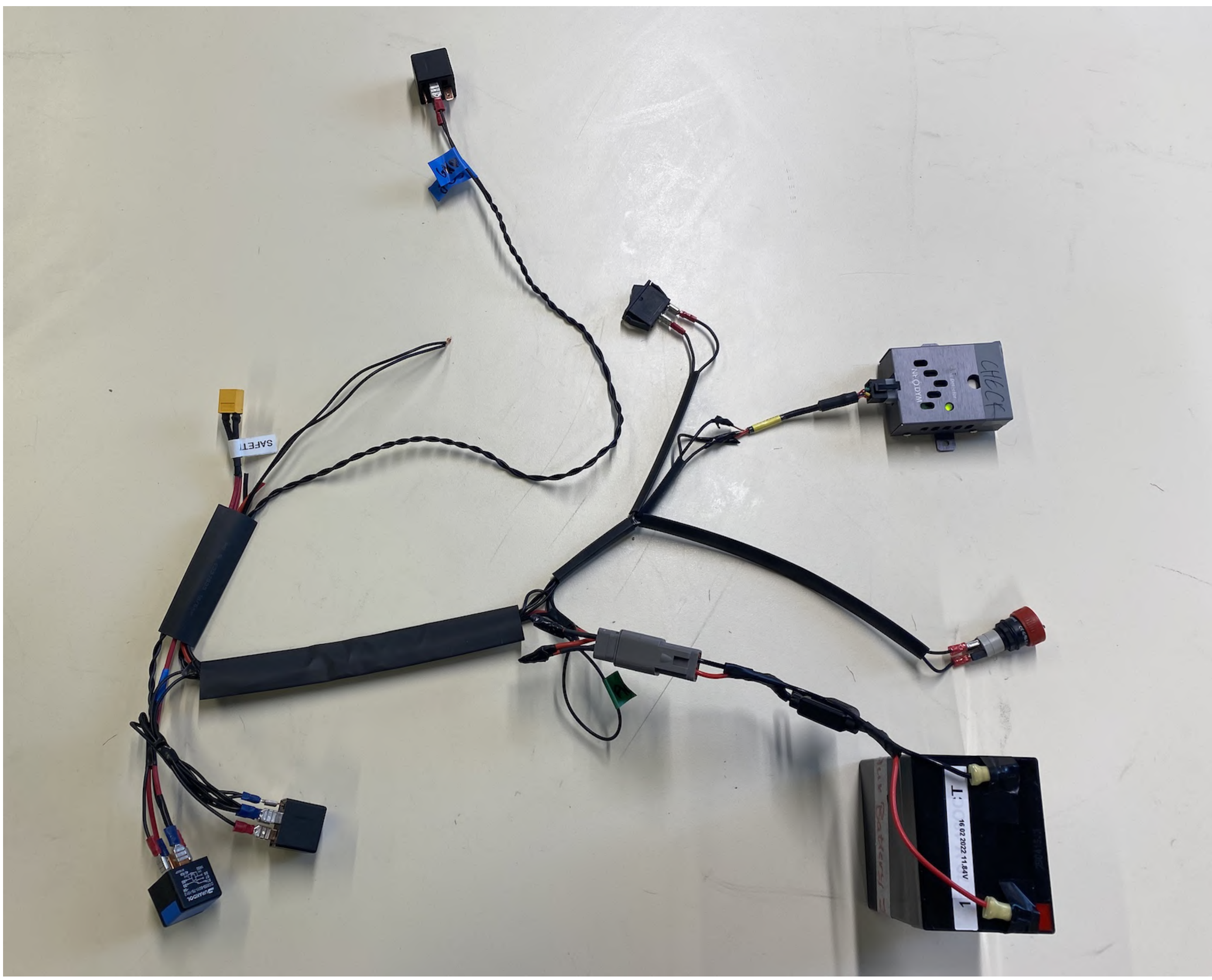
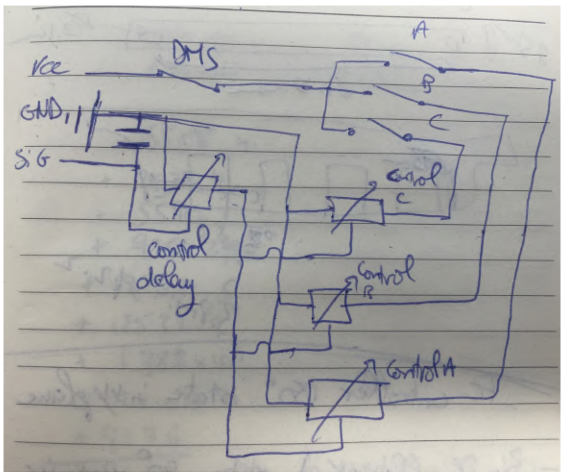


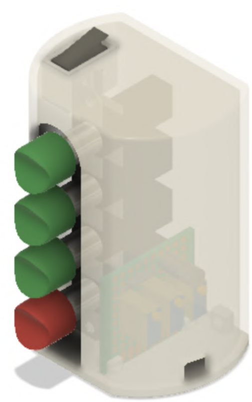
Figure 4: Safety harness used: 1x External emergency shutdown switch, 1x Driver shutdown switch & 1x Hydrogen sensor (in case of a leak). The relays will cut the current flowing into and out of the supercapacitors as well as the direct flow between the fuel cell and the motor controller. Also stops the power supply into the fuel cell which immediately shuts the hydrogen shutdown valve.

1.3 Throttle Design

To maintain high efficiency, it is better to run the motor at a constant speed. This means that the throttle input from the driver must remain the same, given that the track is mainly flat and does not require any braking and acceleration. This said, I designed a small board to give the driver 3 throttle position options that they can press and leave on until the end of the race. Using an interlock switch, the driver can easily change between throttle positions, allowing them to go faster or slower to maintain the target time. I included a limit switch that acts as a “Dead Man Switch” (DMS) and must always be pressed to allow the current to flow in the circuit. To avoid sudden acceleration when going from 0% to 100% throttle, I included an RC low pass filter circuit to smoothen the throttle input to the motor controller. I then designed the outer casing to match the fist’s grip.



(a) Schematic of EM Throttle



(b) CAD model of EM Throttle

Figure 5: The green buttons represent controls A,B and C and their throttle % can be controlled via potentiometers. The red button is part of the interlock mechanism and disconnects all buttons if pressed. The DMS is represented by the grey button on top

2 UCL Formula Student (2022 - Present)

The UCL Formula Student team's goal is to build a single seater student race car. Each year, we compete in the FSUK competition at the Silverstone circuit. For the past 2 years, the team has been running on ICE power delivered by a 4-cylinder Honda CBR600 engine. My main role in the team is to develop simulation models for the car to estimate lap time and investigate the effect of small setup changes on overall performance. I also occasionally work with the design and electronics teams.

2.1 Lap Time Simulation and Performance

At first, I used OptimumLap to generate basic Lap Time Simulations. I implemented our engine's Torque/RPM curve alongside the car's general parameters like weight, wheelbase length and drag/lift coefficients. This allowed us to validate new aero concepts by having a sensitivity analysis showing us that we only gain 0.01s by adding a 10kg underbody that increases downforce.

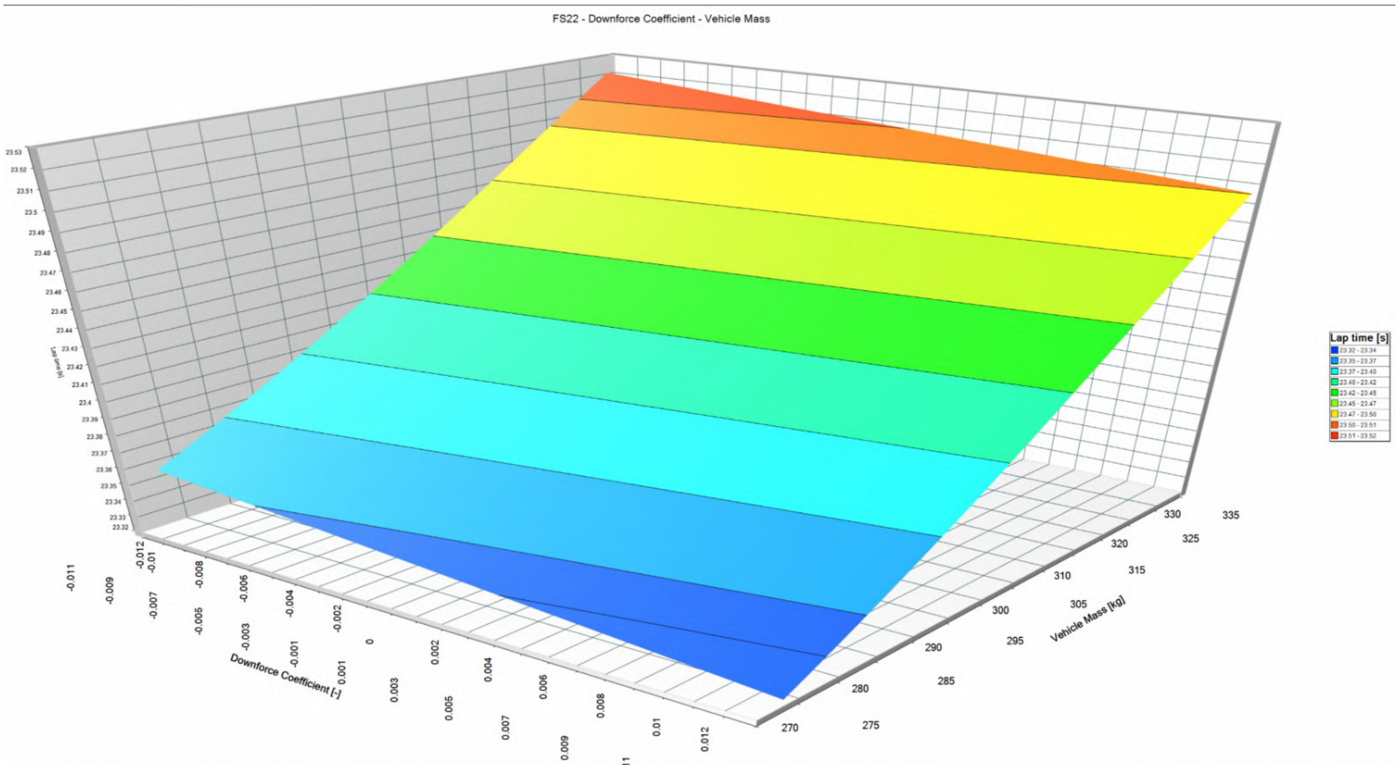


Figure 6: Lap Time Sensitivity using OptimumLap (Left column is Lap Time (s))

I then used IPG Carmaker to accurately model the car by specifying the location of the Centre of Mass of all major components. We were also now able to visualise the car's performance on a virtual track and have a clear idea of how it would behave in the different layouts presented. I was also able to vary setup-specific parameters like the toe and camber angles and directly observe the change in Lap Time over the layouts. IPG Carmaker also presented the option to monitor much more parameters on the car such as yaw rates and tyre temperatures to name a few.

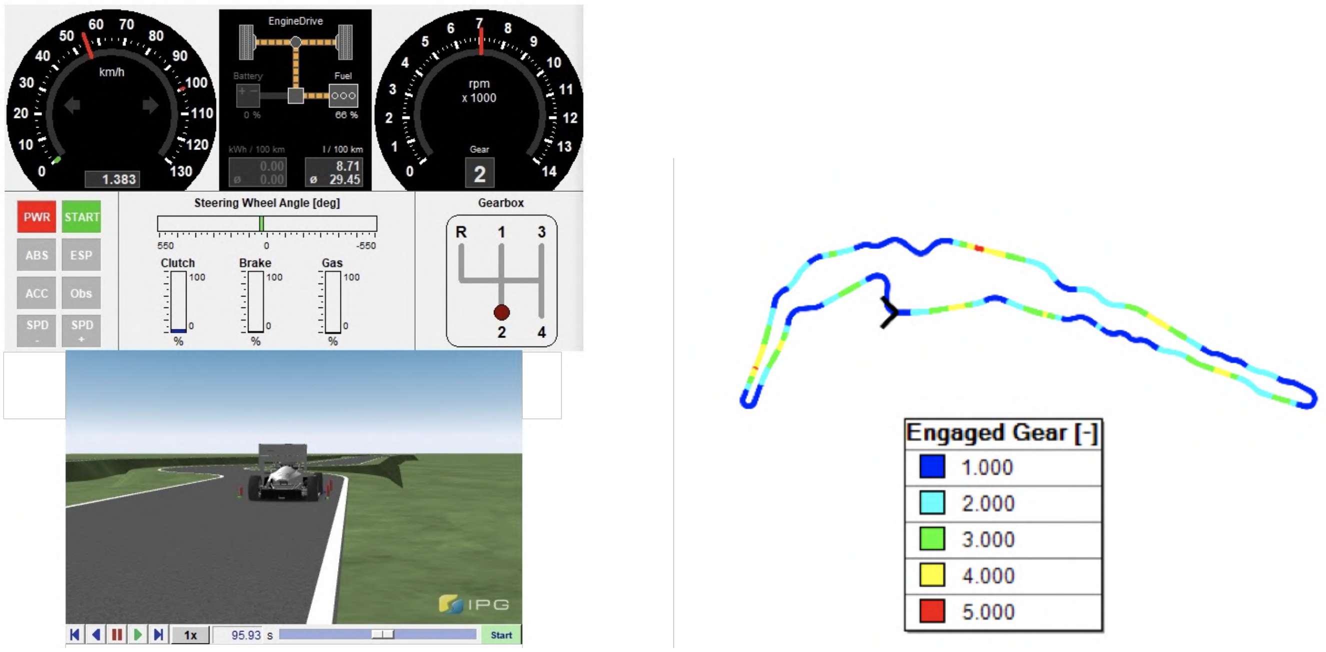


Figure 7: Using IPG Carmaker (Left) and OptimumLap (Right) to model and simulate the car on the racetrack

Finally, the UCL Formula Student team has been involved in the IMechE Sim Racing Series where different universities race against each other virtually. My role as race engineer is to test different setups and identify which ones perform better for each car and track. I also help drivers identify which areas of the track they can improve their lap times on.

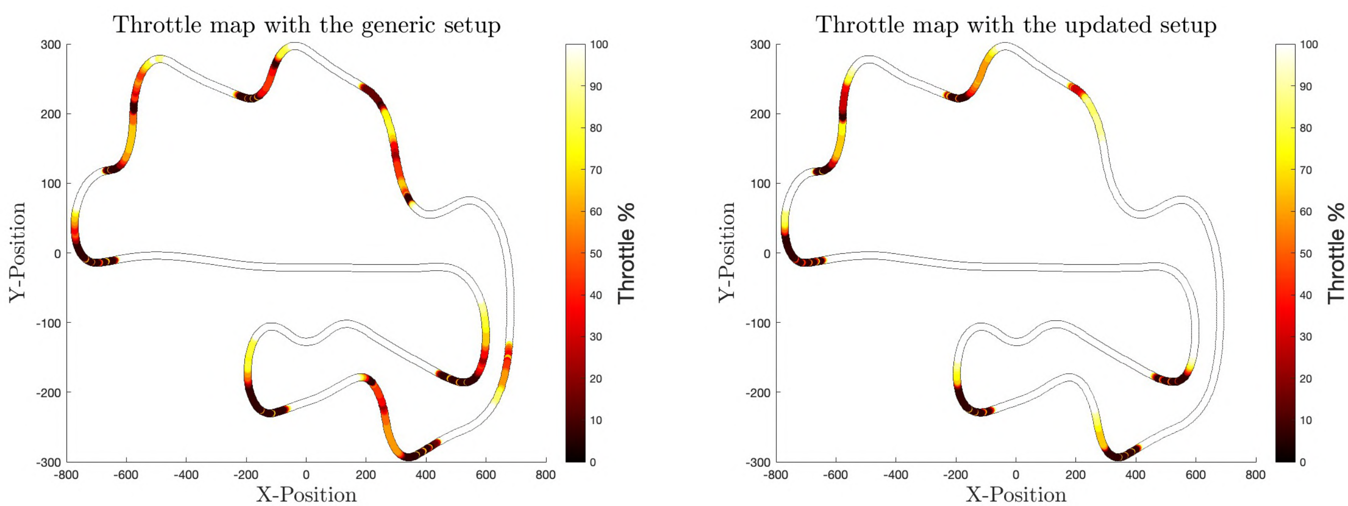


Figure 8: Improving lap times by observing driver throttle input in different sub-sectors around the circuit of Mugello

2.2 Design & Manufacturing

Being a relatively small team of 20 students, I carried on small design and manufacturing tasks with the team to allow designers to focus on larger assemblies. One of the components I designed and oversaw the manufacturing of is the Brake Over-Travel Switch (BOTS) mount. The BOTS is located behind the brake pedal and will activate the safety relays that will shut down the engine in case the brake pedal fails (travelling over its intended range). In the design, I considered the mounting on the brake pedal box as well as loading conditions of 20kg of force. After consulting the technician responsible for manufacture, I had to remove some weight saving features to make it easier to manufacture.

Figure 9: Fully manufactured and assembled BOTS

I have also been cutting steel sheets using a WAZER waterjet cutter. I prepare the machine carefully by running pre- and post-cutting maintenance procedures such as tank purging and abrasive re-filling. The cut parts are then welded on the chassis and most components fasten onto them.

3 Curricular Projects (2020 - Present)

Throughout my Mechanical Engineering degree at UCL, I have had exposure to several individual and group hands-on projects that developed my technical (CAD design, CAM manufacturing, 3D printing, etc. . .) and soft skills (teamwork, presentation, project management, etc. . .)

3.1 3rd Year Project: Enhancing Physio-Therapeutic Recovery with Exercise Assisting Device

In my latest academic year, I completed my design project titled: "Enhancing Physio-Therapeutic Recovery with Exercise Assisting Device." I started the project by looking into the market to determine the key features the designed device needs to have. I also identified the target user group and specified the exercise to test the device (dumbbell raise for wrist healing). Then I evaluated different sensors to choose the most appropriate by finding a compromise between accuracy and performance. Afterwards, I designed a casing to package all the components in to fit around a wrist.

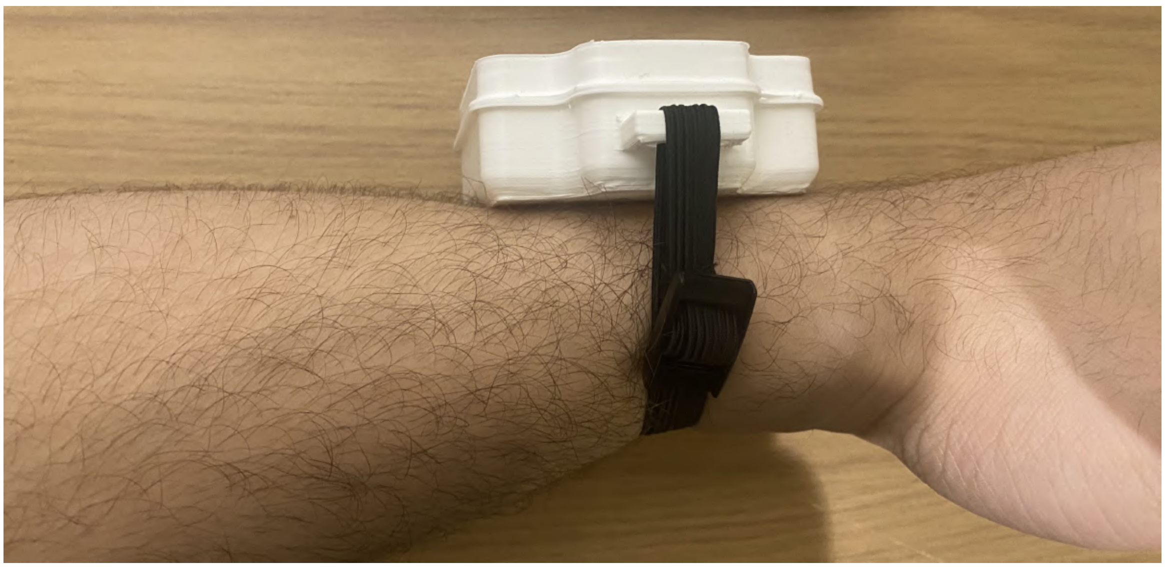
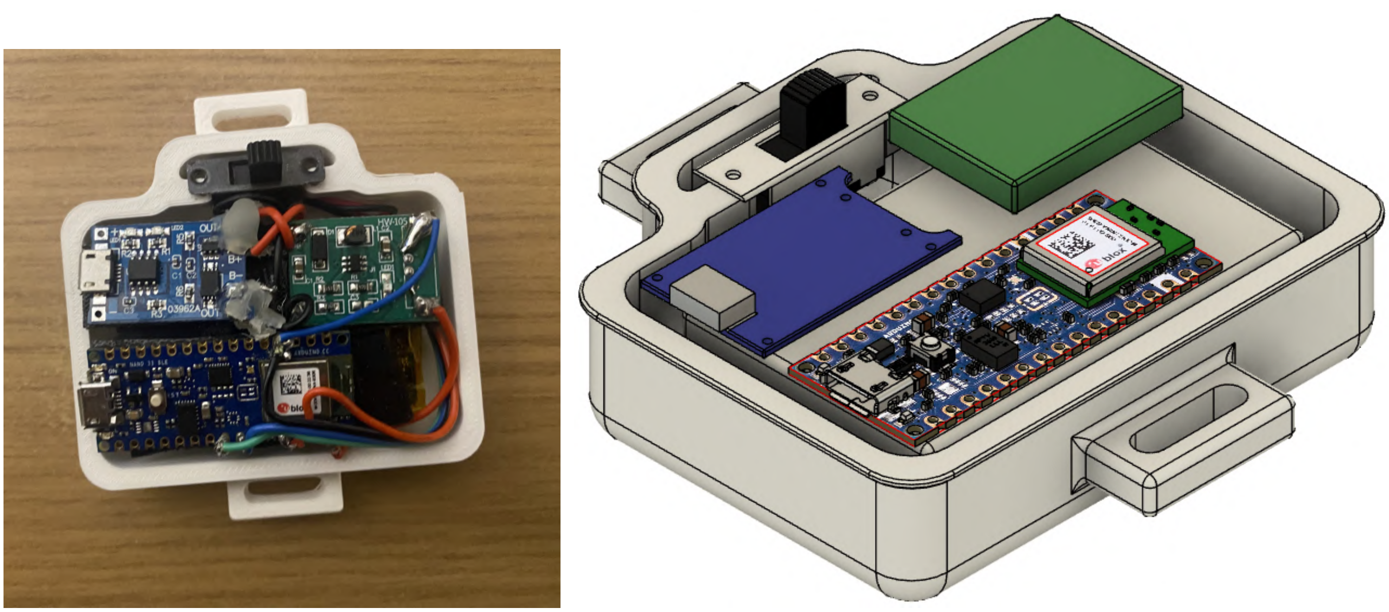


Figure 10: Wrist Fitting



(a) Final Package

(b) CAD Model

Finally, I built a simple User Interface that outputs the position of the hand relative to the specified path set by the doctor or physiotherapist. This allows the user to actively check whether they're performing the exercise properly. I coded the UI using a combination of Arduino code (to interpret data from sensors and send it to the patient's phone or tablet via Bluetooth) and JavaScript to build the online tool.

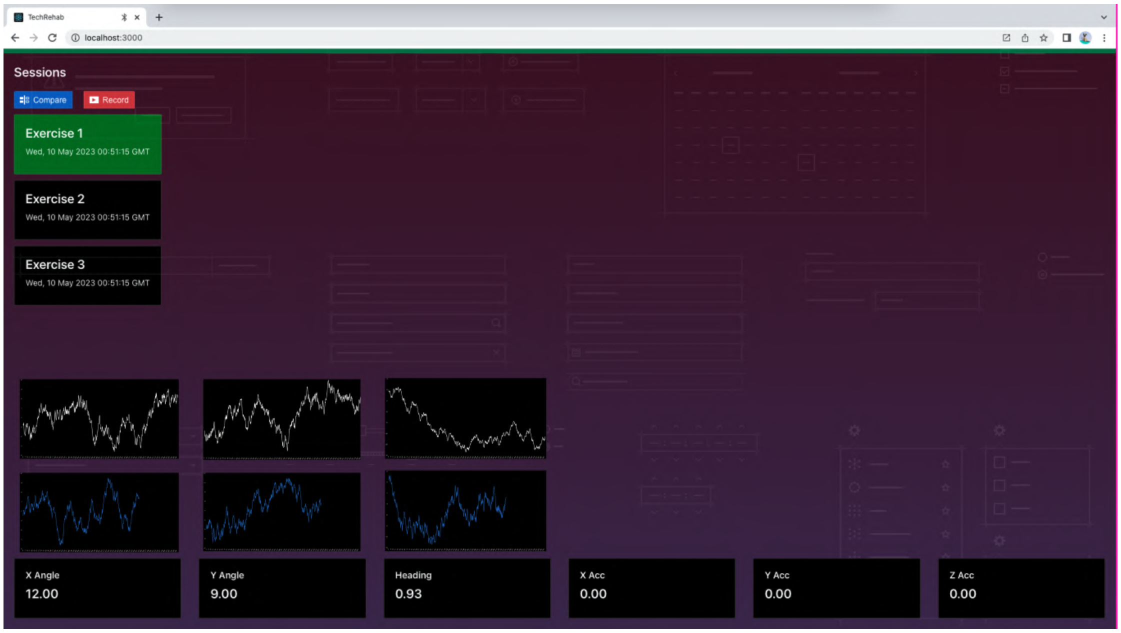


Figure 12: User Interface example

3.2 IMechE Design Challenge - Year 1

One of the modules I took in my first year was titled "Design and Professional Skills". As part of this module, I worked in a group of 5 to design a "Repeatable Vehicle" that can move forward, hit a wall, and return to its initial position without using any control units (i.e. no programming, all mechanical). Our design included a mechanical clock device (in blue) that converts linear displacement into rotational displacement and can store the equivalent of 3m of longitudinal movement.

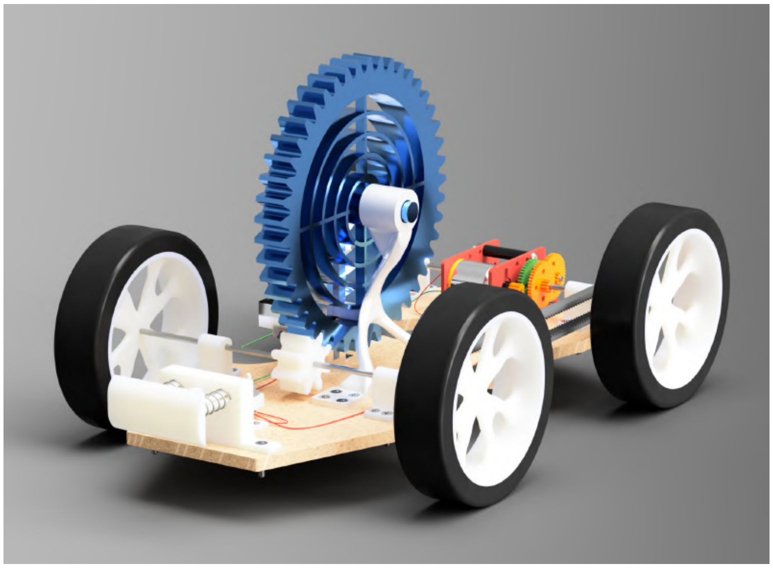


Figure 13: Full Vehicle Assembly

My role within the team was to use Topology Optimisation and Generative Design tools to minimise components' mass where possible. This is to reduce the overall weight of the vehicle and thus decrease the effect of rolling resistance and inertial forces. The first components I worked on was the wheels. Using Topology Optimisation, I was able to study the force distribution on the wheels and remove excess mass accordingly.

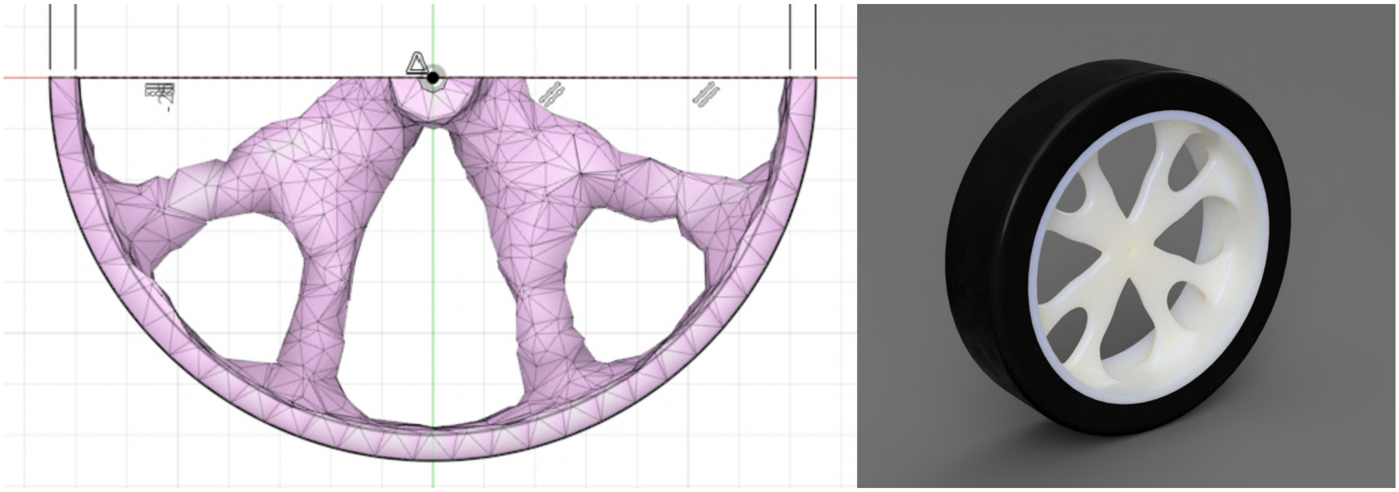


Figure 14: Redesigned Wheel from Topology Optimisation

I also redesigned rigid supports using Generative Design and maintained a safety factor of 1.3.

Figure 15: Support modelled using Generative Design

3.3 IMechE Design Challenge - Year 2

In my second year, our team decided to participate in the IMechE Design Challenge again. That year's challenge was to design and build a line launcher able to fire a squash ball into a small target from 6m away. We used linear springs to store the elastic potential energy and launch the ball with the required kinetic energy to maintain an optimal trajectory. We guided the ball via a gantry on an aluminium extrusion to minimise friction losses and increase accuracy.

Figure 16: Spring-Gantry Assembly

As electronic control was allowed for this year's version, I decided to change roles and explore the domain of electronics and programming. I programmed an Arduino to control various actuators and sensors. I then coded a script to calculate optimal angles for launch, accounting for air resistance, dependent on the distance and height of the target.

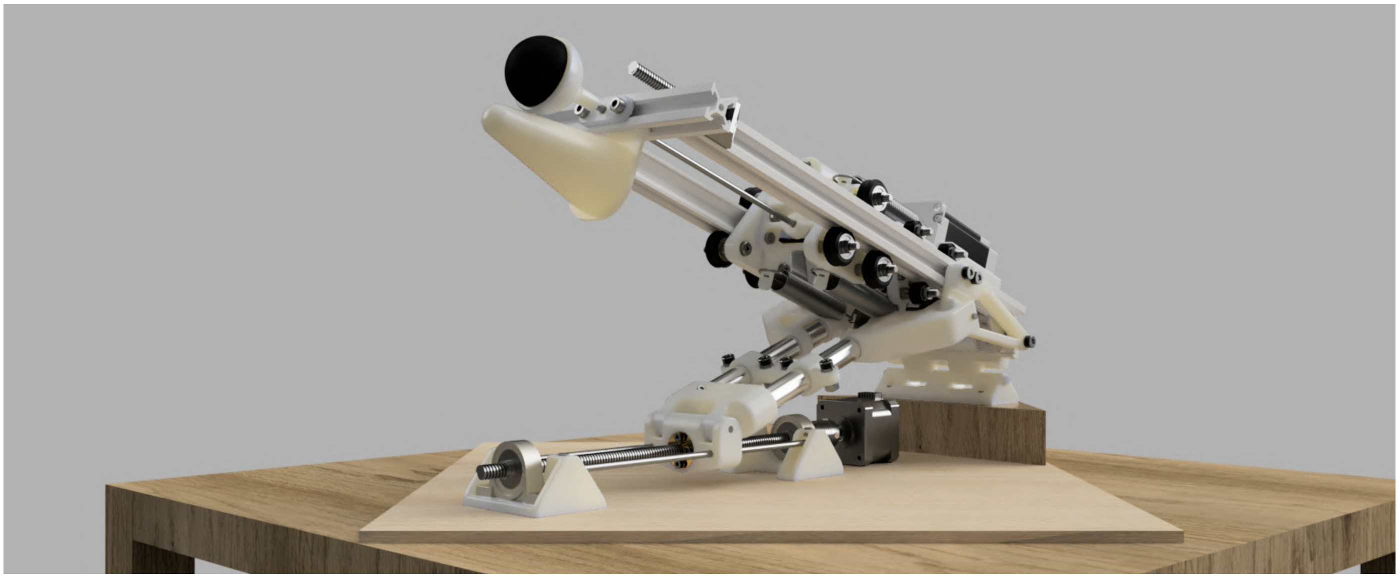
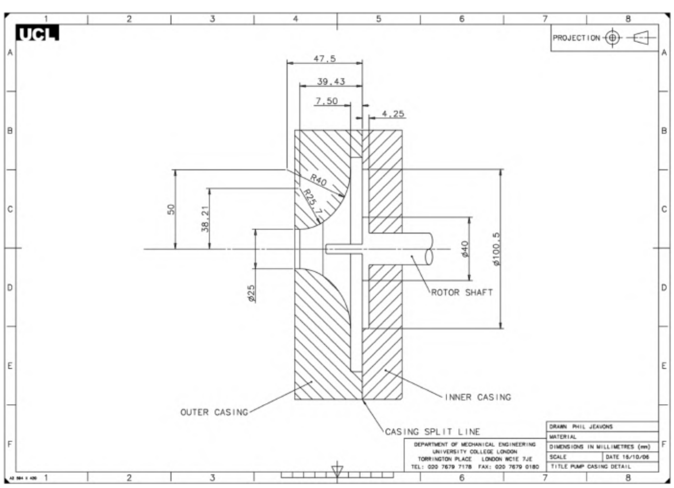


Figure 17: Full Launcher Assembly

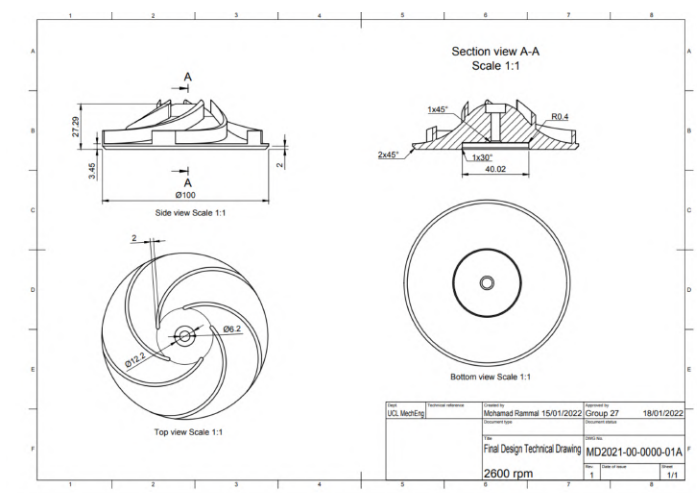
3.4 Design for Manufacture

During my second year, I also took a module titled "Design for Manufacture". The first project I had was to design an impeller to fit in an airplane turbine. The first stage consisted of specifying the load cases encountered in that hot and high speed environment of the plane. This led to the material selection which I chose as titanium. I then designed a prototype to fit a lower scale testing rig to evaluate its performance and efficiency. The prototype's manufacturing was constrained to SLS 3D printing. This said, I had to alter the prototype slightly to account for tolerances during manufacturing. My prototype reached the highest efficiency at 44.6%.

Figure 18: Manufactured Impeller Prototype



(a) Impeller Housing Technical Drawing



(b) Impeller Technical Drawing

The aim of the second project was to design a lightweight wall bracket that is easy and quick to manufacture using a 3-axis router. The material and loading conditions were pre-selected, so I used Generative Design to optimise the shape of the bracket by removing as much mass as possible. I then used the built-in CAM workspace to program the router's operations efficiently.

Figure 20: 3D-printed prototype of the wall bracket

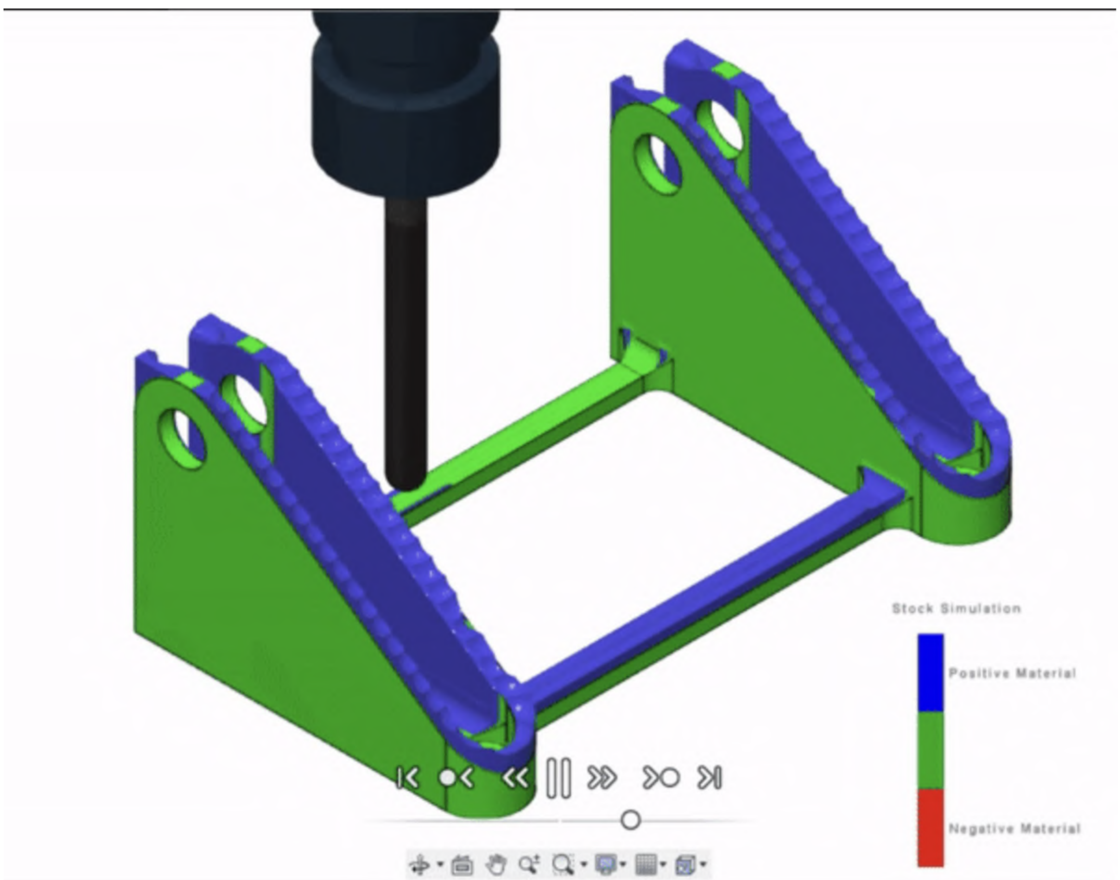
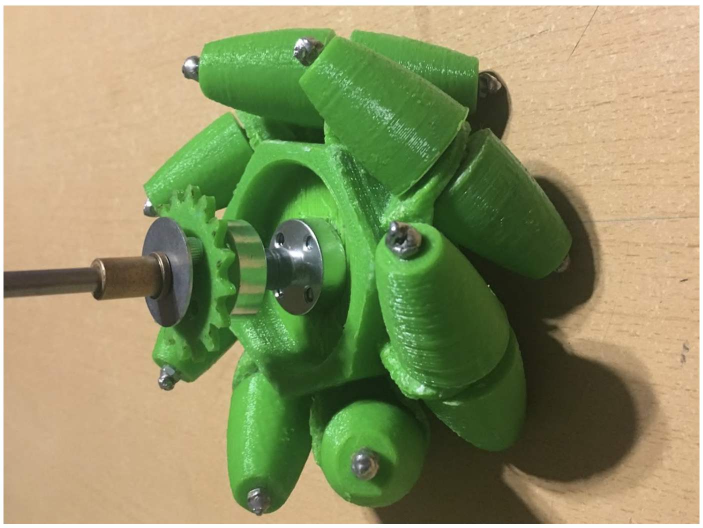


Figure 21: CAM preview

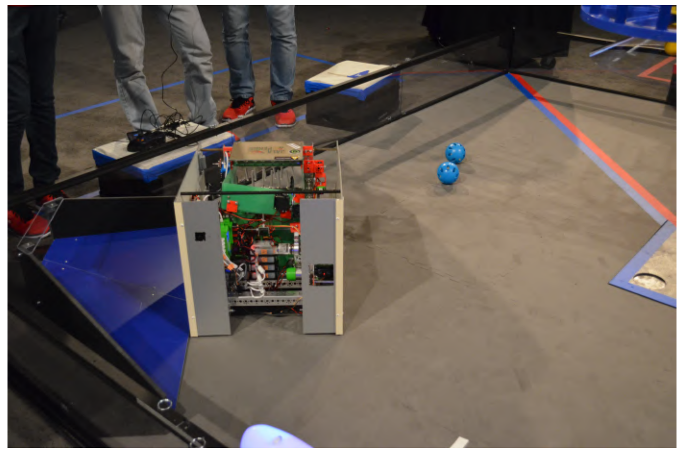
4 FIRST Tech Challenge (2015 - 2018)

During high school, my brother and I started a robotics team to participate in the FIRST Tech Challenge competition. Each year, we build an 18-inch cubed robot that can accomplish different tasks based on that year's challenge. For more information about the FTC please visit their website at: https://www.firstinspires.org/robotics/ftc

Our most successful season came in 2017 where we won the Best Mechanical Design and National Championship which earned us a spot at the World Championship in Houston, TX. There, we earned the Judges' Award as the most inspiring and hardworking team. This was the result of countless hours working on innovative solutions to overcome our budget limitations.



(a) Full assembly of a 3D printed Mecanum Wheel



(b) The 2017 season's task was to collect balls from the ground and shoot them into an elevated basket. This was achieved by building an easily manoeuvrable drivetrain, mounting a fast collection system and assembling an accurate "ball shooter"

An example of this can be seen in the image above. Needing a swift and manoeuvrable drivetrain to quickly change directions and collect scoring elements, we opted for mecanum wheels. Instead of pouring our budget on buying four wheels, we decided to 3D print and assemble our own custom mecanum wheels which took around 24h/wheel.