FORMULA STUDENT
STEERING WHEEL

Project Summary

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Product Design Engineering MEng
Final Year Project 21/22

PROJECT OVERVIEW

UGRacing Collaboration:

This project was completed with UGRacing (UGR), the University of Glasgow's Formula Student team with the aim of improving last year's steering wheel.

The steering wheel has been designed for the 2022 Combustion racing car in preparation for competing at the Formula Student UK (FSUK) competition in July 2022. Every year UGR design, build and race a Formula Student car.

FSUK is an engineering competition run by the Institution of Mechanical Engineers, also known as IMechE. The competition is designed to encourage young people to delve into the world of engineering by designing, funding, and manufacturing a formula-style single seat race car.

Every year, over 100 Universities from around the world compete in static and dynamic events within combustion, electric and driverless categories. The event is held at Silverstone Race Circuit based in Northamptonshire, England

Problem Definition:

The existing steering wheel had multiple issues identified within the design.

1. The display screen was visually blocked by the wheel and was a significant problem for smaller drivers.
2. The gear shifter, the rocker switch button located on the right of the wheel, was poorly positioned, which caused an overstretch of the thumb to engage the mechanism. Those with smaller hands struggled to reach the gear shifter, which could lead to incorrect gear changes or loss of control of the car.
3. The panelled sheet, housing the gear shifter, caused a potential risk of the thumb becoming stuck. This could affect the driver when having to exit the vehicle quickly and potentially hurting their thumb when turning the wheel through a full lock.
4. The shape and positioning of the wheel caused interference with the driver's legs when turning the wheel through 180°. Taller drivers were significantly affected by this design issue and caused them to sit in uncomfortable positions when turning the wheel.

Project Objectives:

1. An integrated display unit positioned to be seen by any driver
2. Ergonomic handles for comfort and control of the car
3. Quick and efficient gear changes through the design of flappy paddles
4. A suitable base plate design that does not collide with the drivers' legs

Driver Involvement:

At each FSUK competition, 6 drivers are required to compete from each Formula Student team. Throughout the entire project current and previous drivers have been involved within the design process to provide insight into the existing wheel and provide feedback for the new developed design.

FSUK Rules:

A large factor of this project was the implication of the rules set by FSUK. The 2022 rules document extended to over 130 pages. However, the relevant rules affecting the steering wheel, driver egress and fasteners have been outlined below:

T 2.6 Steering	
T 2.6.5	The steering wheel must be attached to the column with a quick disconnect. The driver must be able to operate the quick disconnect while in the normal driving position with gloves on.
T 2.6.7	The steering wheel must have a continuous perimeter that is near circular or near oval. The outer perimeter profile may have some straight sections, but no concave sections.
T 4.11 Driver Egress	
T 4.11.1	All drivers must be able to exit to the side of the vehicle in less than 5 s with the driver in the fully seated position, hands in the driving position on the connected steering wheel (in all possible steering positions) and wearing the required driver equipment as in T 13.3. The egress time will stop when the driver has both feet on the ground.
T 10.2 Securing Fasteners	
T 10.2.1	All critical fasteners must be secured from unintentional loosening using positive locking mechanisms.

RESEARCH

Industry Interviews:

Panasonic JAGUAR RACING · FORMULA E · FIA · WILLIAMS ADVANCED ENGINEERING

Design Manager

"To advise for the handles, a good recommendation for changing the thickness for different hand sizes would be to use tennis grip tape. Adds grip to the handle, with a soft but firm feel".

"Recommendation of a 4-5mm Aluminium plate or 5-6mm Carbon plate. These materials would likely have more than enough structural integrity but would still be worthwhile to do an FEA analysis. It would be recommended to make the wheel as large as possible with considerations of the cock pit sizing and the interaction with the drivers legs. The larger wheel will provide more control to the driver over the car".

JAGUAR · LAND ROVER

Human Factors Subject Matter Specialist - Driver Environment

"For button placement on the front of the wheel create a zone covering the 5th (female) to 99th (male) percentile measurements, then the buttons can be positioned anywhere within that zone".

"The buttons should be placed for regular use to focus on a future proof design".

"5th female percentile is the industry standard"

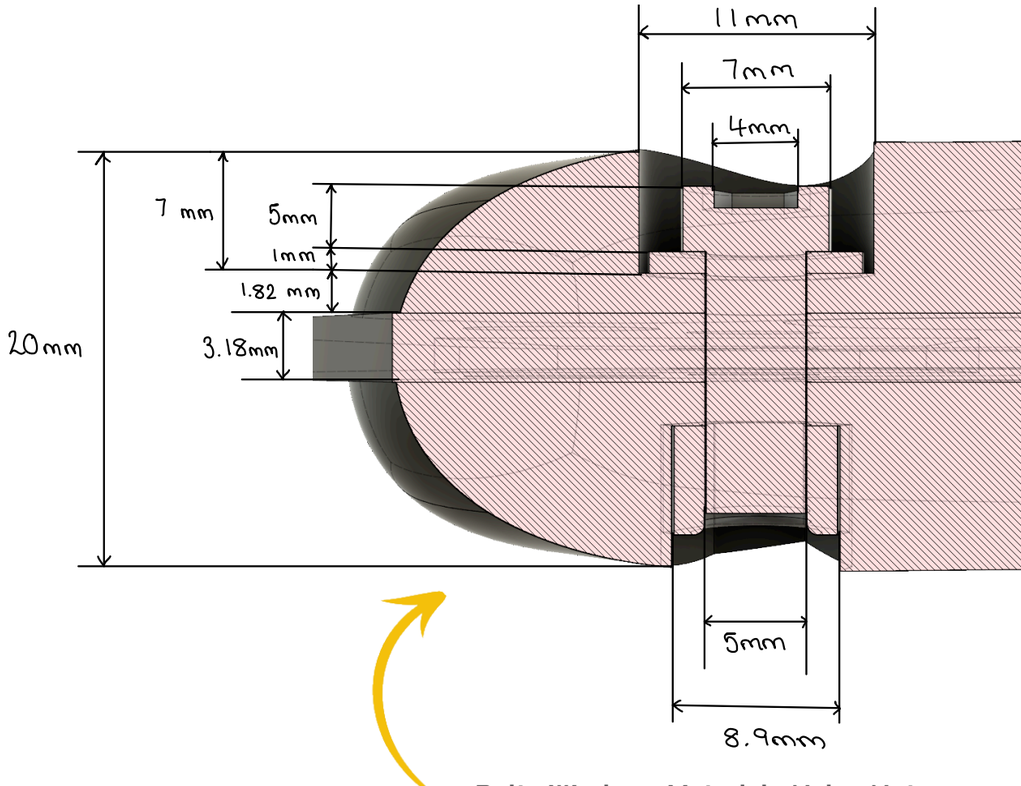
"The design intentions for the new wheel are strong and the main recommendation is to prototype consistently".

Materials, Manufacture & Assembly:

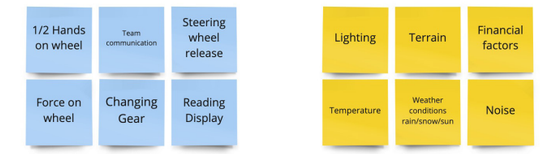
GRANTA EduPack was used to explore possible material options for each component. Material choice was chosen based on the mechanical properties, sustainability aspects, cost, and availability. Both UGR and the Glasgow School of Art (GSA) Workshop had a selection of materials for prototyping and final assembly building.

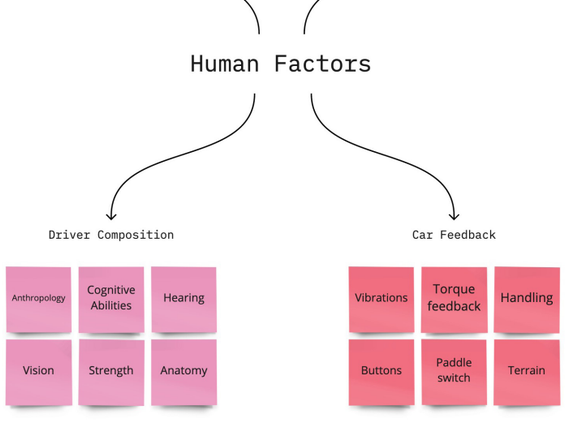
Manufacturing methods were explored such as, laser cutting, 3D printing, injection moulding and die cutting. Considering that the wheel is a single unique product, certain processes could be ruled out and therefore 3D printing became the main manufacturing process for the project.

The assembly of the wheel must be efficient with easy access being offered for electronic maintenance. The components must be securely fastened and able to withstand vibrations. Therefore, the use of Nyloc nuts was used for all main fasteners on the wheel as recommended by FSUK in the rules.



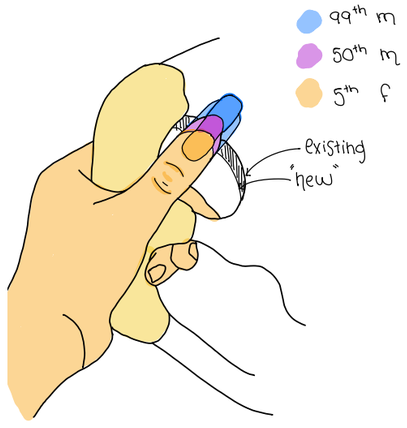
Bolt - Washer - Material - Nyloc Nut

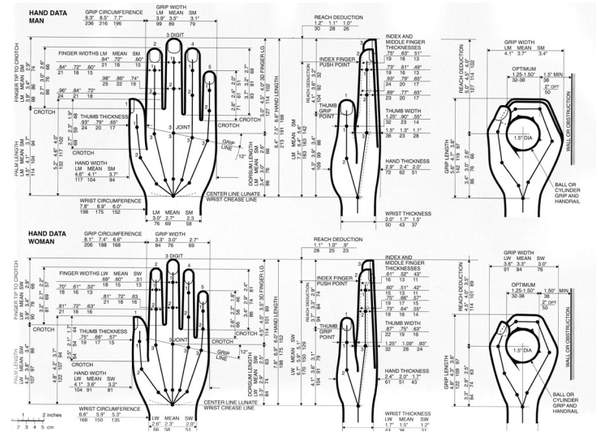




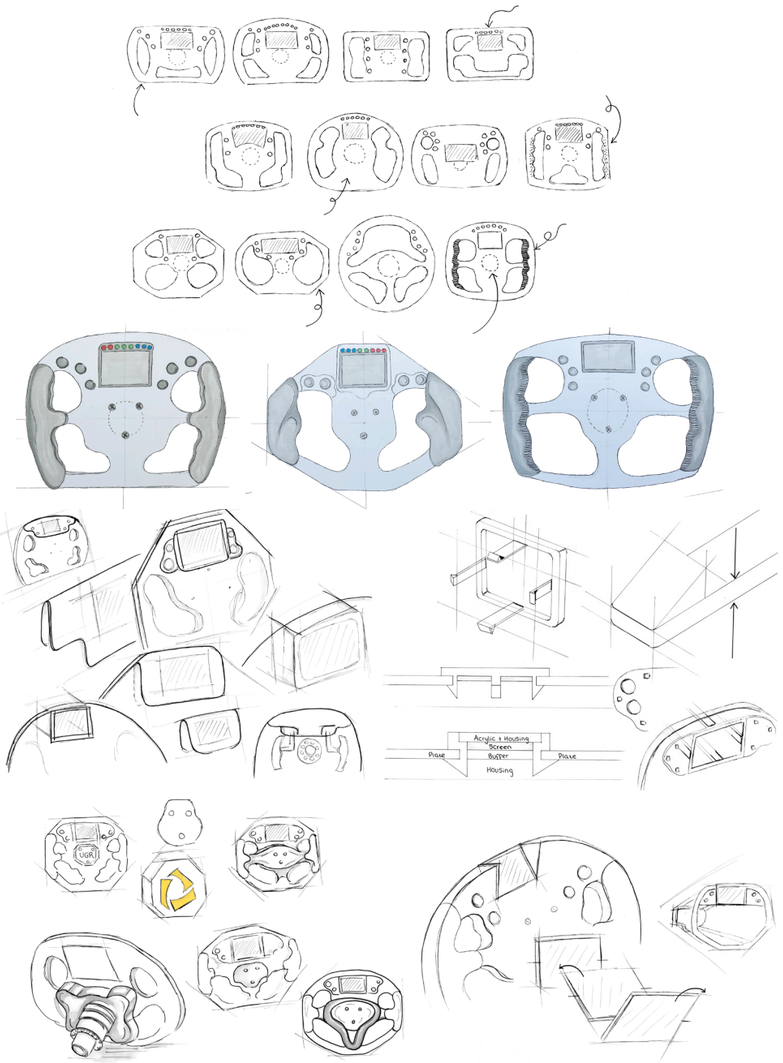
Human Factor Project Evaluation:

The human response to shock and vibration can cause performance degradation, discomfort, and potentially harm, although it can also induce feelings of exhilaration and be an important part of the sporting experience. Anthropology plays a vital role in designing an inclusive product. By factoring in the range of sizes of people, we can improve their individual performance by maximising on their efficiency interaction with the product.





CONCEPT IDEATION



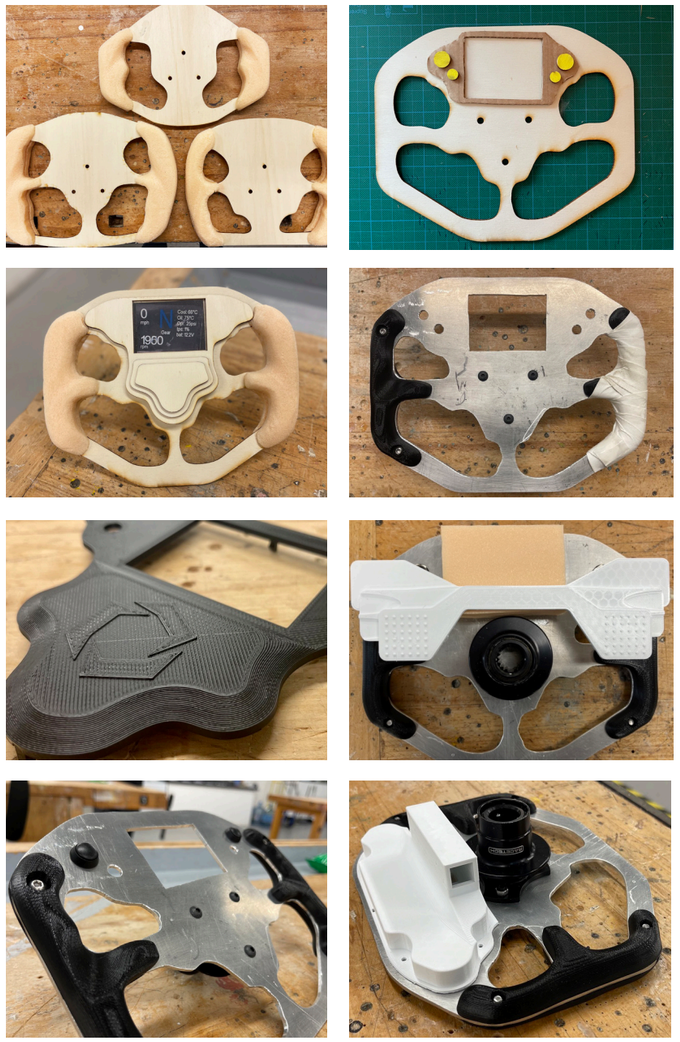
Initial 2D Ideation:

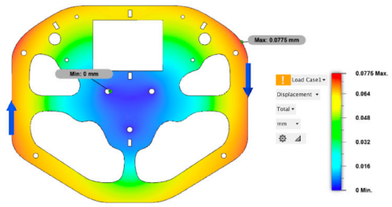
Sketches were used from early stages in the project through to the late development stages as they helped boost creativity. Sketches allow for quick ideas to be noted down giving multiple options for further refinement.

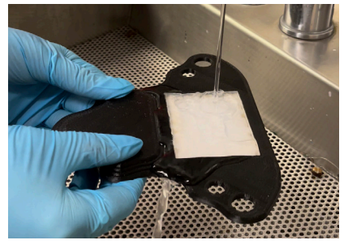
To progress from 2D sketches, Fusion 360 was used to bring the 2D concepts into a 3D perspective.

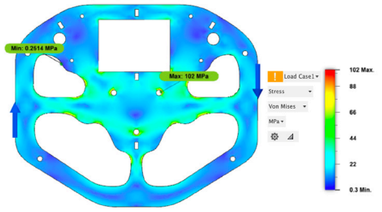
3D Prototyping:

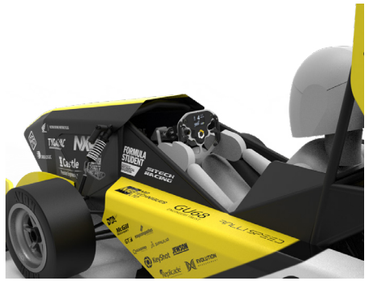
Prototyping began using simple materials such as cardboard, foam and plasticine then progressing to metal and plastic in the final developments. Quick iterative prototyping, using readily available materials, helped decide sizing and placement of components. How the drivers' hands interacted with the wheel was extremely important as that would also decide how well the driver would perform when in the car racing.
Laser cutting and 3D printing was the main manufacturing method used in later development stages, which helped lower project costs. Precise models were created and allowed for tolerances to be accurately marked up for the final model build.











Final Model Testing:

User testing was a key milestone within the project, receiving detailed feedback from old and new drivers about each development stage. Testing was completed using the appropriate kit, such as wearing racing gloves, and within a suitable environment.

Simulations were generated to explore linear and non-linear problems through Finite Element Analysis (FEA), to observe material behaviour under potential failure loads. The deflection rate of the flappy paddles were critical simulations to ensure that these components would not fail when in a racing environment.

DESIGN FEATURES

1

Base Plate:
The base plate is the foundation of the steering wheel, connecting all components onto one solid body. The shape was influenced by the UGR logo. As part of the rules stated in section 1.2.2, the plate must have a continuous perimeter. This is the sole purpose of the bottom part of the wheel.

2

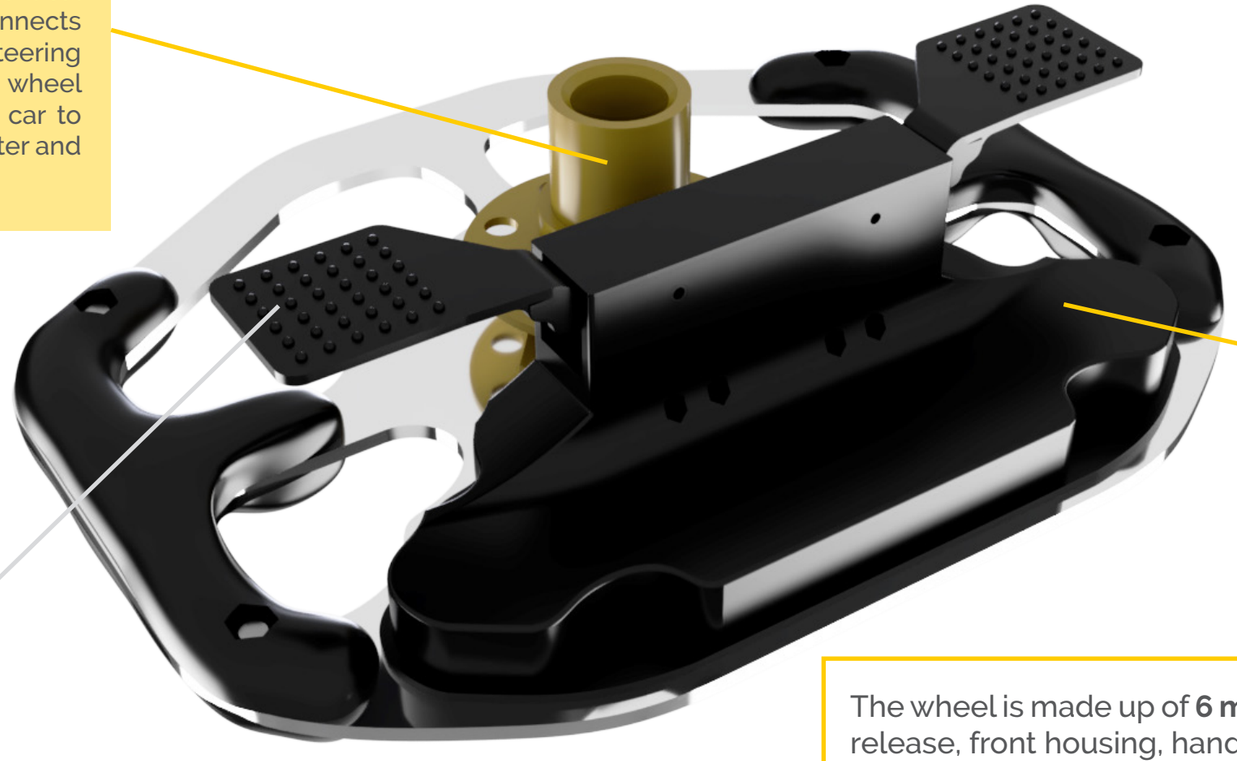
Ergonomic Handles:
The handles have been ergonomically designed to follow the natural grooves of the hand to maximise driver control. The handles will be attached with M5 Nyloc nuts and made in 3D printed PLA.

3

Front Housing:
The front housing component was introduced with the main purpose of housing the LCD display screen. Additionally, to the screen, the front housing has 2 push buttons that will select engine modes, launch control and screen modes.

4

Quick Release:
The quick release is attached to the centre of the base plate. It is a critical safety component that connects the steering wheel to the steering column. It allows the steering wheel to be disconnected from the car to allow room for the driver to enter and exit the car quickly.



5

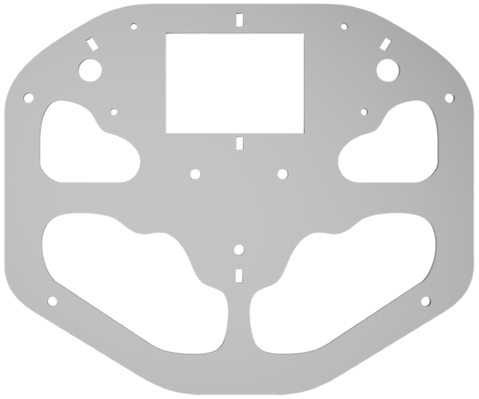
Rear Housing:
The rear housing acts to contain all electrical wiring of the LCD display, push button and flappy paddle gear selection. This has been designed for easy access to the electronics for maintenance purposes.

6

Flappy Paddles:
The flappy paddles are secured within the rear housing. A section of the housing is secured with a dovetail joint which provides access to the microswitches. The flappy paddles are attached with a pin screw, allowing them to pivot when pressed. This allows the driver to change gear.

The wheel is made up of **6 main components**: The base plate, quick release, front housing, handles, rear housing, and flappy paddles.

COMPONENT DETAILS



Material	Al 7075-T6
Cost	3.51 – 4.38 GBP/kg
Density	2.77e3 – 2.83e3 kg/m^3
Fatigue Strength	152 – 168 MPa
Yield Strength	460 – 530 MPa

Technical Analysis:
Stress analysis was conducted to ensure the base plate could withstand the level of forces experienced during a race. Both radial and torsional force are exerted directly onto the handles when the car is operated by the driver, likely causing deflection and shearing effects.

The steering wheel and steering column will be able to withstand a **660N** radial force and up to a minimum of **100Nm** torsional force.

Materials & Manufacture:
The plate will be manufactured through waterjet cutting, due to its ability to cut with high precision and give an excellent surface finish.

The plate was designed to minimise weight. However, as part of the FSUK rules, the plate must have a continuous perimeter. This is the sole purpose of the bottom part of the wheel.

The properties of Al 7075-T6 were adequate for the base plate design and offered high performance, it was readily available and had a significantly high yield strength which is greatly desired for a high impact environment.

Base Plate:

1

1. The design was influenced by the UGR logo
2. The wheel had to have a continuous perimeter based on the rules set by FSUK.
3. Aluminium 7075 was chosen for its excellent mechanical properties.
4. The inner cut out shapes were influenced by the corners at the F1 Silverstone race circuit.

Handles:

2

1. Ergonomically designed using the Fusion 360 freeform tool.
2. M5 bolts were used, as they were already being used for the quick release, therefore this would reduce the number of unique components.
3. Nyloc nuts were used to secure the handles, preventing them from becoming loose when driving.
4. Grip tape was used to wrap around the handles as it provides more comfort and grip for the driver. It will also help subdue vibrations.

Technical Analysis:
The handles will experience a level of vibration when the car is in motion. Referring to rule T 10.2.1, a critical fastener must be used to prevent the handles from become loose during operation.

After conducting an interview with the Design Manager, at **Williams Advanced Engineering Formula E**, they strongly recommended the use of grip tape to provide more comfort and ultimately reduce the level of vibration transmitted to the driver's hand

Materials & Manufacture:
The handles were shaped using the form tool in Fusion 360. Due to the unique shape created the only manufacturing options were 3D printing, casting, or injection moulding. Injection moulding would have been the best option however, due to the small number of components being manufactured, this process would become impractical.

The accessibility and time frame of manufacturing played a vital role in the progression of the project; therefore, 3D printing was chosen due to easy access to 3D printers in the University and with team sponsorship from 3D printing companies.

The manufacturing process chosen was 3D printing, therefore the material choice has been directed towards plastics. Focusing from a sustainability aspect, the desired material would be biodegradable, made from renewable materials, produces no fumes when printing and requires minimal energy to produce and manufacture, therefore **PLA** was chosen.

COMPONENT DETAILS

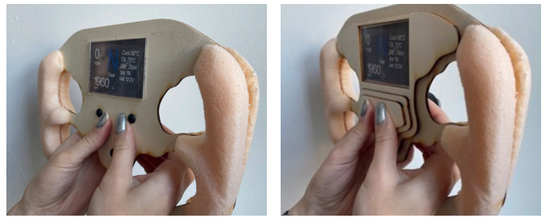
Front Housing: 3

1. Shape follows the outline of the base plate for cohesion.
2. Silicone sealant used for waterproofing for its ease of application, fast curing time and excellent waterproof resistance.
3. Countersunk features for the push buttons improving the integration with the housing.
4. Brass inserts used to stop bolts being visible on the outer surface resulting in a neater finish.
5. UGR logo used to promote the team and cleanly pulls the full design together.

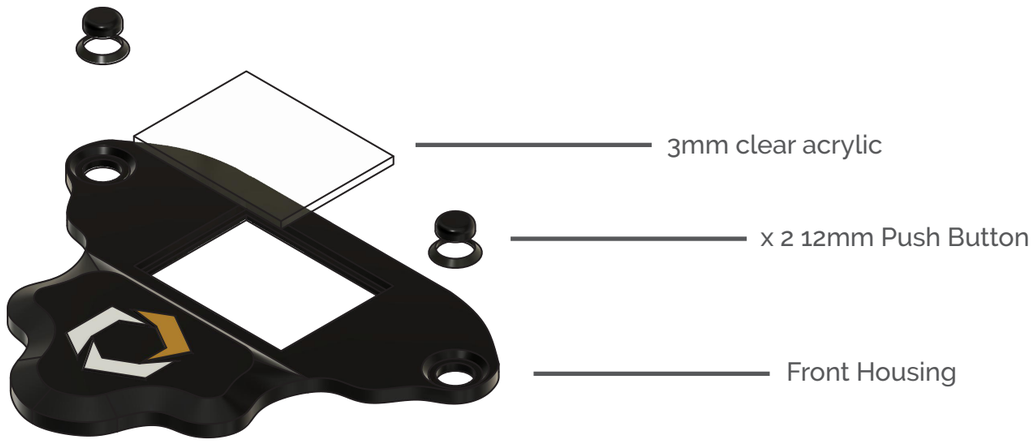
Technical Analysis:
A clear 3mm piece of acrylic was positioned directly in front of the LCD display to remove any direct environmental impacts that could damage the display.

A liquid silicone sealant was placed around the resting groove for the acrylic, acting as both an adhesive and watertight feature.

Two push buttons were introduced into the design. Requirements for the buttons included: suitable tactile feedback for the driver, they must be waterproof, anti-vandal resistant and have two prongs for wire connections.



The central 3D element of the front housing was introduced to provide more ease when actuating the quick release.



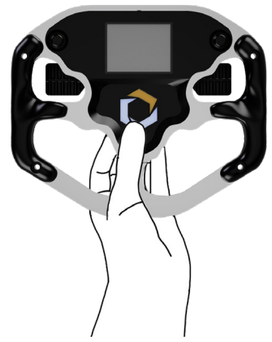
Technical Analysis:
The quick release is a critical safety component and is a required component for racing. As a standard pre-bought part, the Aluminium quick release connects the steering wheel to the steel steering column, which then allows the steering wheel to operate the front wheels of the car.

Referring to rule T 4.11.1, driver egress is a critical safety test within the scrutineering stage at the FSUK competition. It ensures the driver can switch the engine off, disconnect their seatbelt, remove the wheel, and exit the car within 5 seconds.

Within the design of base plate, the way a driver accesses the quick release became a very important consideration. Comparing the 5th female percentile alongside the 99th male percentile the hand size varies by approximately 6cm. Therefore, the design of the base plate offers three options for how to access the quick release.

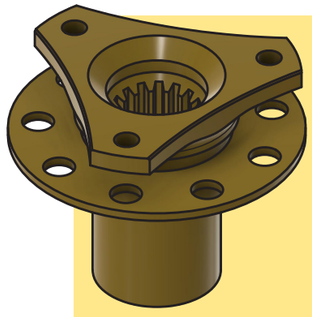
Possible ways for the Driver to access the Quick Release:

Two-handed around the outside of the base plate



One-handed access from the bottom of the base plate

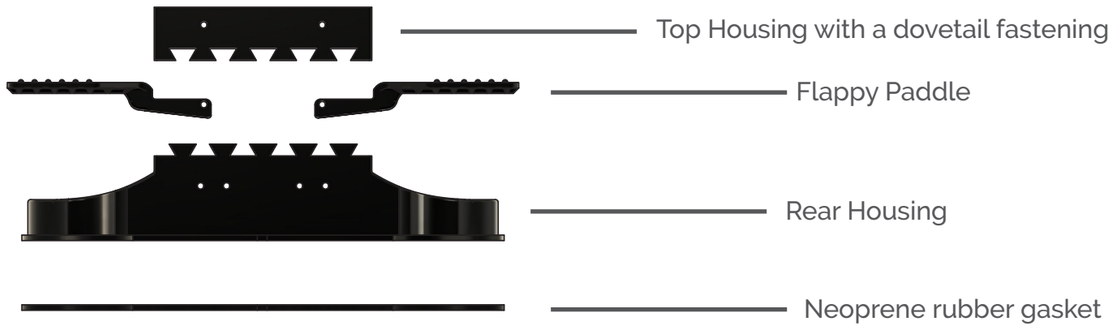
Two-handed access through the inner hand spacing in the base plate



Quick Release: 4

1. Critical safety component
2. It is a required component set by FSUK
3. The quick release is fastened to the base plate, then slides and attaches to the steel steering column

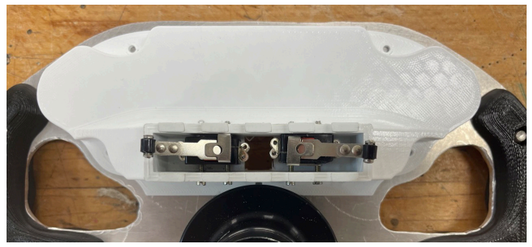
COMPONENT DETAILS



Technical Analysis:
A 2mm neoprene rubber gasket was chosen and positioned around the edge of the rear housing to seal the gap between the housing and the base plate. Neoprene rubber was chosen for its excellent water-resistant properties and its resistance to tearing and twisting.

Four M3 bolts will be used to fasten the housing tightly to the base plate, generating enough compression to tightly seal the gasket.

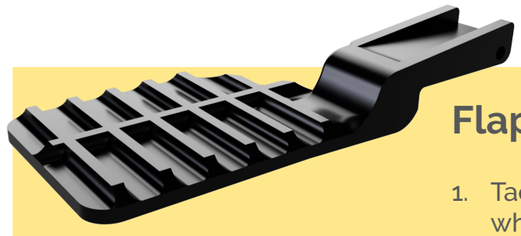
Microswitch:
Two microswitches were positioned within the housing. To cover and contain the microswitches within the housing, a top housing piece was connected using a dovetail joint. The main benefit of having these two separate housing pieces was to allow quick and easy access to the microswitches for maintenance.



Material: Black PLA
Manufacture: 3D Printing
Purpose: The purpose of the rear housing was to house and protect all the electronic components and cabling.

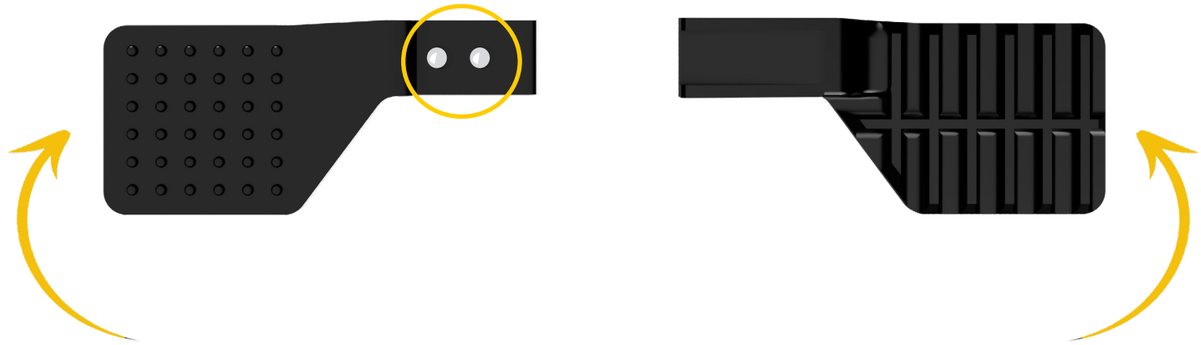
Rear Housing 5

1. Neoprene gasket was chosen as the main waterproofing measure to protect the electronics.
2. x4 screws were required to compress the gasket to ensure it works effectively.
3. Dovetail top housing components was designed to be removed to give quick access to the microswitches for maintenance.
4. The housing was primarily designed to house all the electronics and allow for easy maintenance access.



Flappy Paddles 6

1. Tactile dotting was used to improve grip for the driver when changing gear.
2. Structural ribs were added to provide more strength to the paddle to prevent them from snapping.
3. Magnets were used to keep the paddle in a horizontal position to prevent accidental actuation of the microswitches.
4. The paddles were positioned just above the half way point to avoid contact with the clutch assembly.
5. The sizing and location of the paddles was optimised based on anthropometric data sources and physical testing.



Tactile dotting:
For additional grip when driving in poor weather conditions.

Rib Strengthening:
Ribs were added to the flappy paddle to improve the strength and rigidity to prevent the paddle from failing during actuation.

Magnets:
The purpose of the magnets is to keep the flappy paddles in a horizontal position when not in use to prevent accidental actuation.

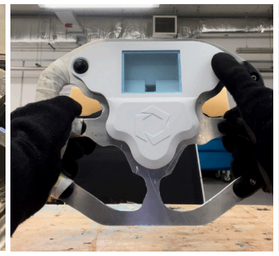
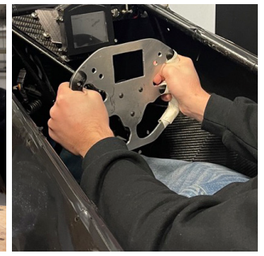
Material: Black PLA
Manufacture: 3D Printing
Purpose: To actuate the microswitches to change gear in the car.

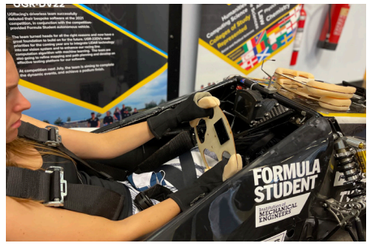
FINAL PRODUCTION COST: £273.86
FINAL PRODUCT WEIGHT: 593 GRAMS

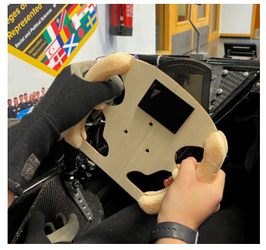
USER TESTING | USER FEEDBACK

First Metal & 3D printed Prototype: January 2022
First hand cut Aluminium base plate, with 2 designs of 3D printed handles and front housing. The introduction of grip tape to the handles for testing.

Key Findings:
The Aluminium provided a much better experience, due to realistic weight and handling. UGR were given the option to decide the designs they preferred, and all drivers agreed grip tape was a useful addition.





First Prototypes: October 2021
Initial prototypes were made from 3mm plywood and foam. 3 base plate designs were made to help decide the suitable dimensions, hand positioning and hand spacing within the plate.

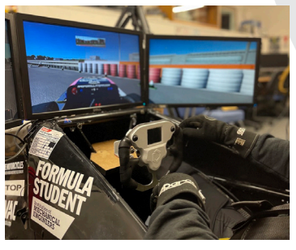
Key Findings:
A smaller base plate was preferred with a suitable ledge for the thumb to hold. Maintaining suitable hand spacing within the plate will be a good feature for those with smaller hands, as it will provide those with room to access the quick release and the back of the plate.

Flappy Paddle testing: February 2022
The rear housing was fully assembled including the microswitches. Initial foam handles were used to decide the optimum sizing. Once decided the paddles were 3D printed for the final model.

Key Findings:
Tactile dotting on the paddles provided excellent grip when gloves were worn. The actuation of the paddles was easy although stronger magnets for feedback would be preferred. The paddles were described as weak, and would require strengthening before racing.


Back side of wheel Prototyping: February 2022
Foam models were made to help decide the size of the rear housing and the positioning of the flappy paddles. The flappy paddles were made with 2 options: as one single paddle or 2 individual paddles.

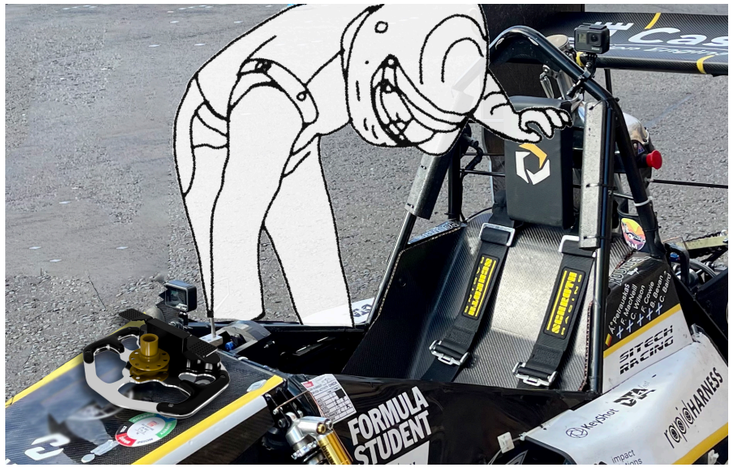
Key Findings:
Drivers preferred the 2 separate paddles as they provided better feedback when pressed. UGR decided that 2 paddles were better than one as it would require a less complex mechanism.

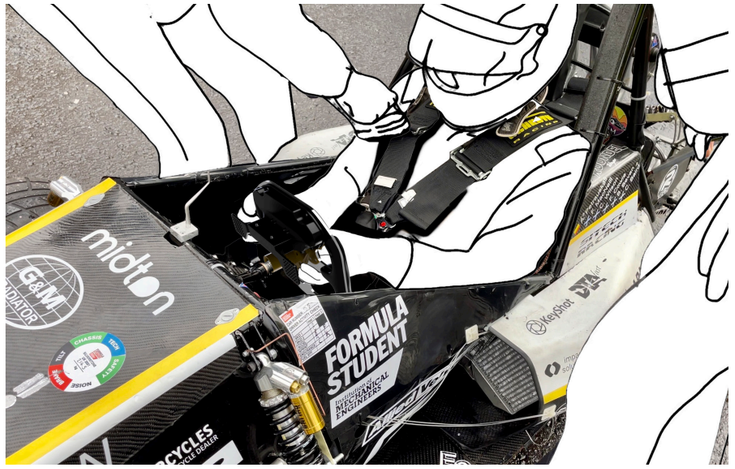
Final Prototype: March 2022
A final working prototype was made and then tested using the UGR simulator. This allowed the drivers to test the functions of the wheel against a realistic racing circuit.

Key Findings:
All drivers gave positive feedback and liked all of the new features compared with the old wheel from 2021. The magnets within the flappy paddles were well liked and provided good tactile feedback when attempting to change gear. The addition of grip tape provided significant comfort when handling the wheel and was a sensible feature for adding customisability for each individual driver.

USER JOURNEY

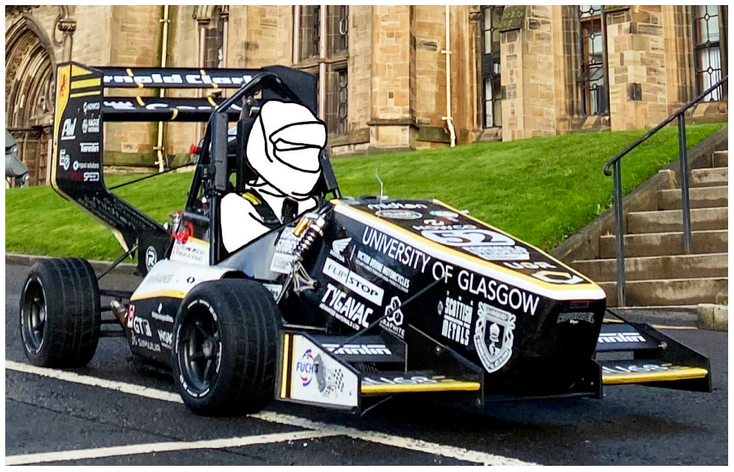


1. Driver enters the car

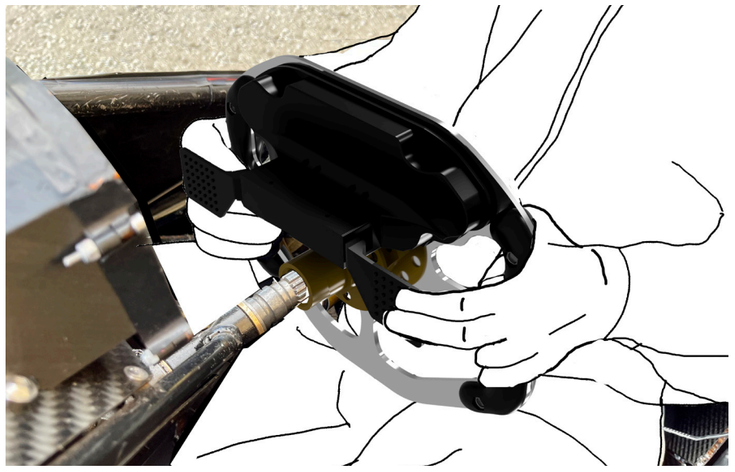


2. Driver is tightly fastened into the harness

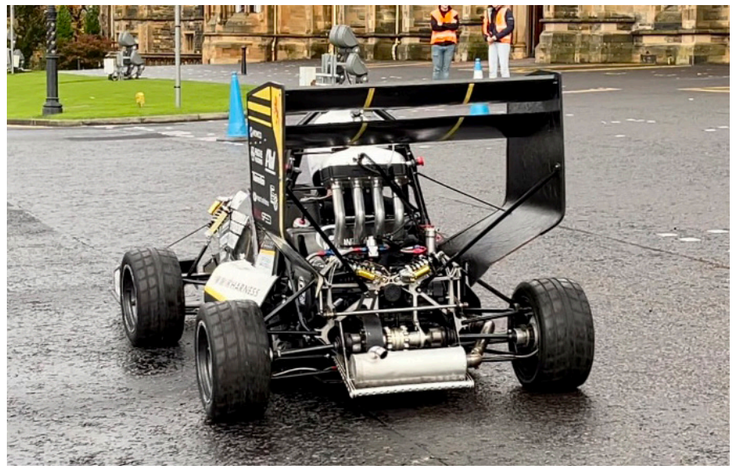
3. Driver initiates start up of car



4. Driver begins race event

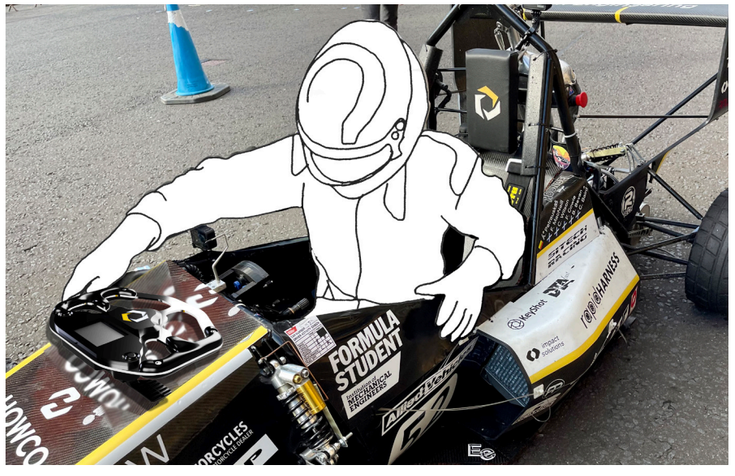


5. Driver changes gear by pressing paddle

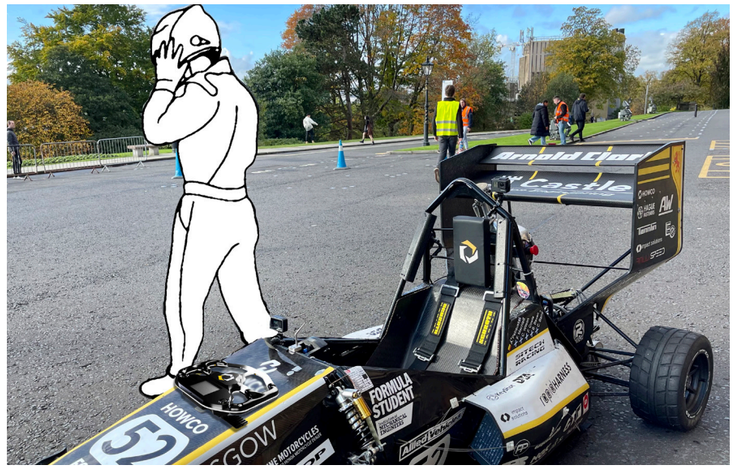


6. Driver returns to paddock

7. Driver turns off the engine and disconnects the quick release



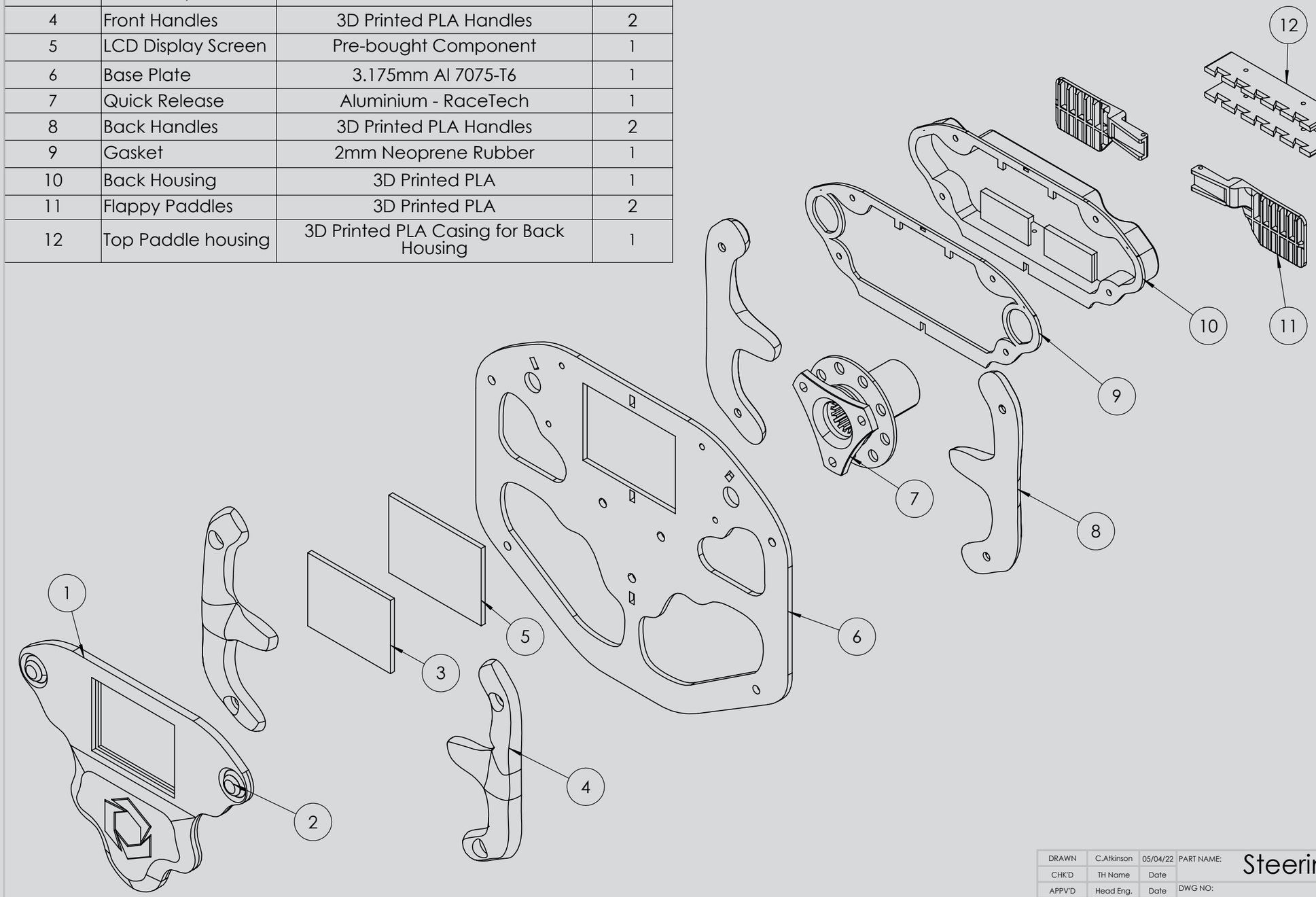
8. Driver unfastens seat belt and places wheel onto the nose cone



9. Driver exits the car

FINAL MODEL | EXPLODED VIEW

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Front Housing	3D Printed PLA	1
2	Push Button	12mm diameter - RS Components	2
3	Clear Acrylic	3mm - Laser Cut	1
4	Front Handles	3D Printed PLA Handles	2
5	LCD Display Screen	Pre-bought Component	1
6	Base Plate	3.175mm Al 7075-T6	1
7	Quick Release	Aluminium - RaceTech	1
8	Back Handles	3D Printed PLA Handles	2
9	Gasket	2mm Neoprene Rubber	1
10	Back Housing	3D Printed PLA	1
11	Flappy Paddles	3D Printed PLA	2
12	Top Paddle housing	3D Printed PLA Casing for Back Housing	1



University of Glasgow RACING
University of Glasgow
James Watt Building (South)
University Avenue
Glasgow
G12 8QQ

GENERAL M/C TOLERANCE:

ANGULAR: +/- 5°
0-50mm: +/- 0.1
50-100 mm: +/- 0.15
100-250mm: +/- 0.2
>250 mm: +/- 0.4
THREAD TOL: INT 6H/EXT6g
GENERAL PROFILE: 0.5

GENERAL SURFACE FINISH Ra 1.2 ON MACHINED SURFACES

DEBUR AND BREAK SHARP EDGES TO R0.3 MAX OR 0.3 X 45°

IF IN DOUBT - CONTACT:

Callum Wilson
Head Engineer

technical@ugracing.co.uk

07402354034

ISSUE	DATE	MODIFICATION
01A	01/03/21	FIRST RELEASE

DRAWN	C.Atkinson	05/04/22	PART NAME: Steering Wheel	
CHK'D	TH Name	Date		
APPV'D	Head Eng.	Date	DWG NO: 1	A3
MFG	x	x		SHEET 1 OF 1
QA	x	x	MATERIAL: Al-7075-T6, PLA & Neoprene	WEIGHT: 593g / SCALE: 1:2