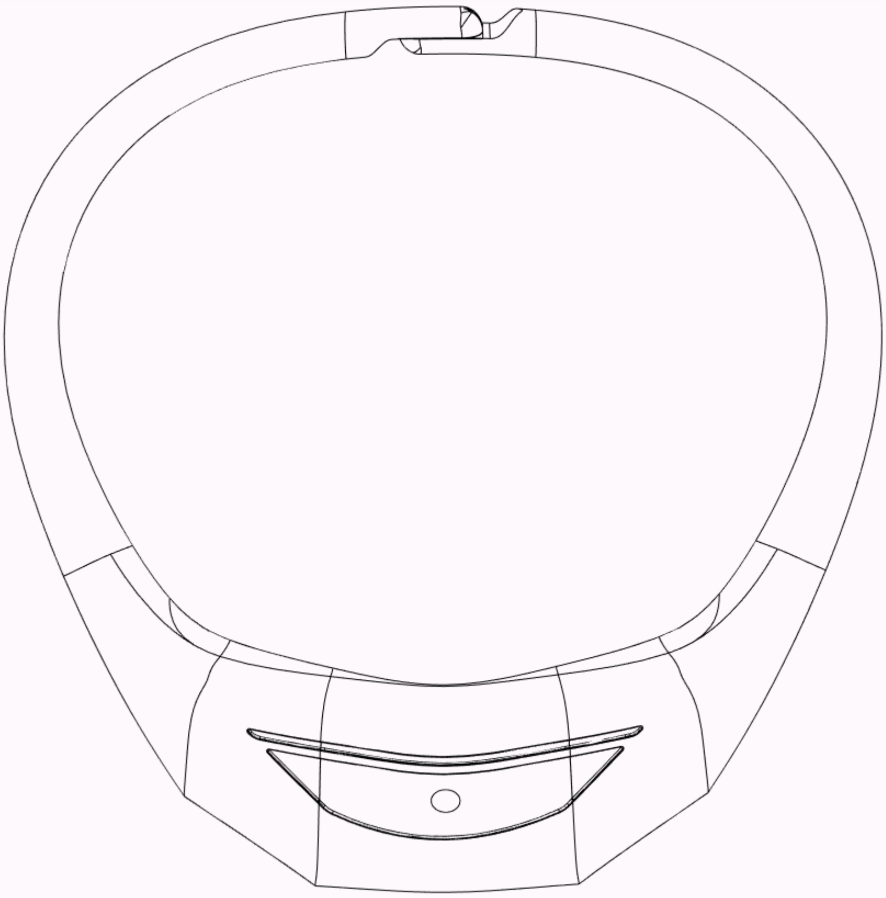
GARMIN®



Venio™

Product Report

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THE TEAM

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REPORT/FOLIO STRUCTURE

The two documents should be read together, but can be standalone. Portfolio pages are referenced when relevant in the report, and the caption of each portfolio page indicates the corresponding report page(s).

LINK TO VIDEO

https://imperialcollegelondon.app.box.com/file/975142662863

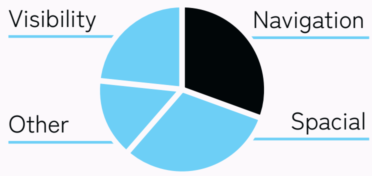
METHODS RESEARCH

SELECTION RATIONALE

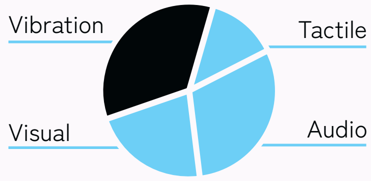
To decide which concept to take forward, we asked users about our four ideas and also considered feasibility for each one. 86% preferred Routec, because favourite features were navigation and vibration, so we decided to take this product forward.

We took this concept of communicating navigational instructions through vibrations, but wanted to improve form factor to develop the most comfortable, safe and intuitive product.

PREFERRED FUNCTIONS OF A CYCLING DEVICE



PREFERRED METHOD OF DEVICE FEEDBACK



METHODS RESEARCH

Over this project we used an iterative testing approach to develop our concept. First, we brainstormed as a group, and chose the most feasible concepts to carry forward. To evaluate viability, we asked inexperienced cyclists for opinions regarding form, function and fit, and used in-action tests to check the concept was feasible while riding a bike. The time line below outlines the methods used, and what we aimed to find out.

Development 1: Comfort + Convenience
Form ideation on different body parts including wrists, ears, ankles and head, testing for recognisability and comfort.

Test 1: Noticeability
Placing vibration motors on different parts of the body and rating each in terms noticeability and comfort. Neck proved best.

Development 2: Placement of Motors
Developed ideas around the chest and neck, exploring forms and locations for the electronics and the motors.

In-action Test 2: Recognisability
Testing if users were able to differentiate vibrations on the left and right while cycling on busy urban roads.

Development 3: Security
3D form prototyping with foam and fabric to develop the best way to keep motors in contact with the skin.

Test 3: Resonance
Use computational simulation to check device resonance when vibration motors are active, and analyse manufacturability.

USER FEEDBACK

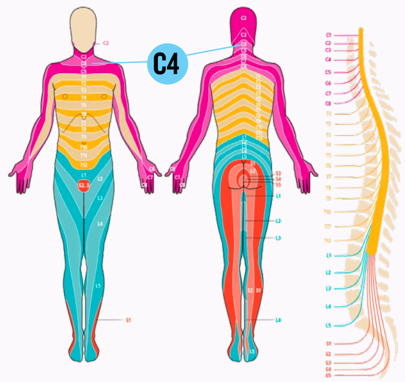
Through the process we asked inexperienced cyclists to give feedback. At early stages, before access to physical prototypes, we used renders to convey ideas, and surveys to gauge responses. While prototyping, we approached users for direct testing, and got verbal feedback. When it came to specific features such as vibration patterns, we designed special experiments.

This rigorous user testing approach revealed that though locating the product on the neck had connotations for some, lower on the neck achieved both comfort, and distinctive vibrations while cycling.

PRODUCT REQUIREMENTS

DERMATOME RESEARCH

A dermatome is an area of skin that gets its sensation from a specific spinal nerve root[1]. These nerves send signals for things like pressure, pain, temperature, and specifically to our project, vibrations. We will focus on areas C4 and above, which are connected to the neck spinal nerve. The neck has higher tactile sensitivity due to an increased number of receptors, and, because of the short distance to the brain stem, reflex signals take less time to register[2]. This means cyclists would be more sensitive to the vibrations and be able to react faster to the instructions.



WHY THE NECK?

Although wearables are not often located on the neck, there are several reasons why it is more suitable than other body parts for this device. Conventional locations such as the hands or the bike itself were unsuitable as a small bump transmits unwanted vibrations to the rider's hands[3, 4] making it difficult to receive instructions.

REDUCED PARTS

- Vibrations must be felt on both sides to indicate which direction to turn. Wrists would require two devices, which would increase cost and assembly time, and the user would have to carry and charge two devices.

EASE OF USE

- The neck does not require the user to take off or change clothes, and does not prevent the user from wearing other accessories (for example, if the user is wearing gloves).
- A single attachment allows for easy use and does not interfere with the user's routine by taking time.
- Does not rely on existing equipment, so it is suitable for hire bikes and does not require a helmet.

OPTIMAL CONTACT

- Electronics weigh down the front of the wearable and allow good contact between the skin and the vibration motors.
- Wide enough for motors to be separated so users can tell which side is which.
- Far enough away from bike to avoid transmission of road vibrations.

REQUIREMENTS	PERFORMANCE METRICS
Natural frequency of the device must be different to the road and motors.	FEA analysis conducted to measure the amplitude of vibrations which must be different to bike vibrations (p07).
Vibration patterns (sides, straight and roundabouts) must be intuitive.	Users must be able to recognise the correct pattern and perform the associated move while on the bike (p04).
GPS module must be able to operate without relying on a phone.	The prototype must work when the user's phone cannot communicate (p06).
Wearable must be easy to put on and held securely in place while cycling.	The device must take less than 5s to put on, and must remain in place for the whole journey, even on bumpy roads (p03)
The battery life should last for over one day's cycling (there and back).	Calculations performed to ensure that it will last, and testing by leaving it on for extended periods of time (p07).

PROTOTYPING

CLASP

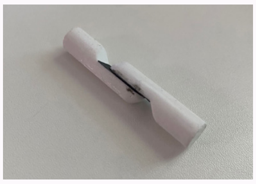
Putting on the device has to be quick and easy. It had to be out on behind the head due to the location. A variety of fasteners were tested, both existing ones and new 3D printed mechanisms.

PUSH IN
- Fairly easy to put on, requiring one movement - pushing. Very secure and did not separate while cycling.
- Mechanism was large ad heavy, and would require complex mechanics that would not be convenient to fit in the strap. Locating the place to push in was also slightly difficult.

HOOK
- Very simple and easy to manufacture.
- Was difficult to locate and gets caught in hair. Stays on while cycling but feels less reliable.

HOOK-SHAFT
- A magnet aids with location. It was secure while cycling, and though a complex mechanism would not be too difficult to manufacture.
- Was too fiddly to fasten when it was behind the head, and got caught in long hair.

MAGNET
- Easy to locate, didn’t get caught in hair. Looks best, is integrated into the strap.
- Feels the weakest, given the lack of mechanical fasteners.



Magnets were best, so more were tested. Square magnets were stronger, so we made a custom 3D printed case. This was tested for speed and security, and passed both.

BUTTONS

For a seamless finish, capacitive touch was chosen. For this, a conductive material had to be used. Foil and conductive paint were tested, and foil was found to be more responsive.

As the button is activated by skin, it cannot be in contact with the body. While cycling, people were asked to touch the prototype where it was easiest. Almost all participants, both left and right handed, chose the centre. The area is large enough to be easy to press, so doesn’t take hands away from the handlebars for long.

VIBRATION PATTERNS

Intuitive direction is at the core of the product. Users were shown a video from the point of view of a cyclist who was carrying out three manoeuvres. They held two motors to their neck, and various vibration sequences were played - refer to p05 folio for specific sequences. They were then asked to rate them.

Side turns had a clear favourite - two sets of “intro bursts” to warn something is coming, then a long buzz indicating when to carry out the manoeuvre. Straight turns were more divisive: between a short “intro bursts” and no vibration at all. Users stated that as they are travelling past many places where they may turn off, having so many “intro bursts” would be distracting. Therefore the chosen pattern would only play at crossroads.

Roundabouts required more information. Users preferred knowing which exit to take rather than when to leave. After feedback, a new pattern was created: three intro bursts, then longer buzzes to count out the exit number, followed by a long buzz when you reach the exit (similar to side turns).

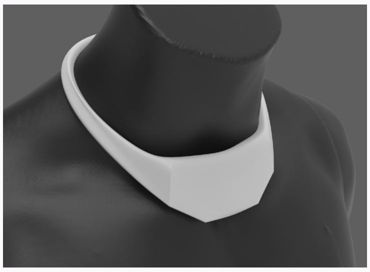
The short series of three vibrations - “intro bursts” - added consistency to the communication and was used on all manoeuvres, reducing learning, and simplifying use.

DIGITAL PROTOTYPING

Once we had finalised on a workable form through physical prototyping, the shape was refined in CAD (folio p06) making sure all components would fit inside the casing.

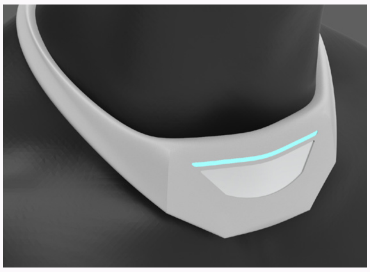
THE FORM

After several iterations of form, the final casing shape was chosen. At this stage, measurements were taken to ensure all components would fit inside. Using forms modelled around an average human torso ensured that sizes looked appropriate.



THE CONTROL

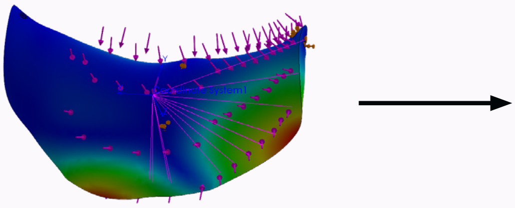
The device also includes a capacitive-touch button and an indicator LED. Various different locations were tried for these, see folio p06. The final version, had an appropriate visual hierarchy for ease of use as well as aligning with the Garmin branding (further explored in branding pages).



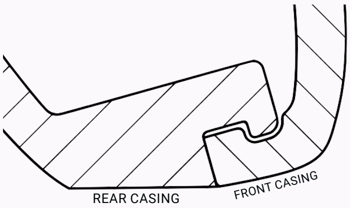
DETAIL AND ANALYSIS

The form was hollowed out to give space for internal features. 1.5 mm ribs were added to stiffen the casing, and provide support for the electronics. 2 mm wall thickness provided a compromise between strength and internal space

Finite element methods were used to analyse this first prototype, informing refinements to improve performance. One particular study simulated an emergency stop on a bicycle, showing the rear casing was not stiff enough, and would bend away from the front casing. In response, a reinforcing rib was added to the back panel, and a non-permanent locking mechanism was used to help the bottom of the casing stay in place.



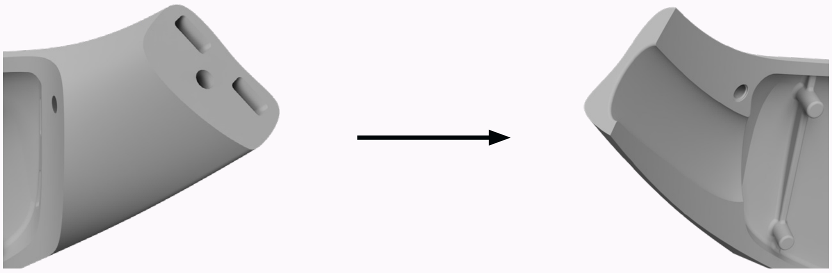
EMERGENCY STOP SIMULATION (DISPLACEMENT)



NON-PERMANENT LOCK

MOULDING CONSIDERATIONS

Modifications were made to the location of the split-line in the casing. Mould flow simulations showed that the original split with thick areas at the sides led to shrinkage. The split line was modified to keep features as close to the nominal 2 mm thickness as possible.



ELECTRONIC FUNCTIONALITY

THE APP

The app (folio p04) allows users to set their route and preferences, then sends the exported route data to the device. All processing is then done in the microprocessor, so that navigation is not dependent on the user's phone battery.

THE PROCESS

Though the outcome is fairly simple, the process requires several complex steps. On boot, the microprocessor initialises the bluetooth connection with the phone and tries go get a GPS location. This can take time, so continues in the background while the rest of the program runs.

Once bluetooth is initialised, Venio alerts the user that it is ready to receive data. This will be passed on to the device via the app. Route data are sent as an array of waypoints, which are stored on the device. At this point the device is no longer reliant on the phone, which is important for safety. The processor reads the first direction and waits for the user to begin route guidance by tapping the capacitive start button.

At this point, the unit is set up: as the user reaches subsequent waypoints, specific vibration patterns are used to explain the route ahead (folio p04).

In the prototyping stages, a dummy GPS mode was used instead of an app: a pre-determined set of route data were uploaded to the device, and the Adafruit IO IoT platform was used to control the device by passing in simulated GPS points. This approach was used so that functionality could be tested indoors, without having to follow the selected route - although it was also verified that the GPS module worked correctly with the navigation program.

THE COMPONENTS

After research, the following components were selected:
- Processor - FireBeetle ESP32[5]
- GPS module - L76X[6]
- Vibration motors - 1027-type[7]
- Battery - 3.7 V, 500 mAh Li-Ion cell[8]

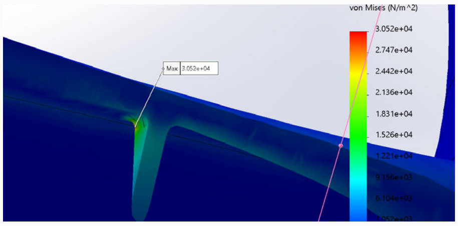
The ESP32 Development Board selected has a built-in battery charge controller, so an external board was not needed for the prototype. In the final product, the raw ESP32 chip will be used, along with a 3.7 V charge controller (for compactness). The GPS module, while the bulkiest component (nearly 20mm thick), provides a good compromise between size and speed of GPS locating, and will still fit in a sleek wearable. 1027-type vibration motors are extremely common, so sourcing them was easy, and in a commercial product would not cause a bottleneck in manufacturing.

The ESP32 Development Board uses 80 mA, the GPS module 11 mA, and the vibration motors up to 80 mA each - however, as the motors are only on one at a time, and even then only a fraction of the time, an average motor power consumption of 20 mA is reasonable (one motor is on, 1/4 of the time). This gives an average power consumption of 111 mA. In order to achieve a three-hour battery life, minimum 333 mAh at 3.7 V is needed. The next common size up, 500 mAh, was therefore chosen. The battery selected had a convenient pencil shape, to allow it to fit into a lightweight, small device.

POWER AND LOAD CALCULATIONS

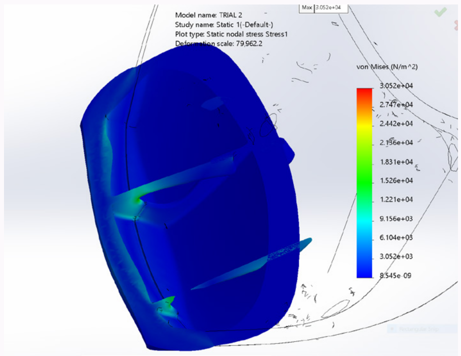
FINITE ELEMENT ANALYSIS

Digital testing was done on the whole product and for each part of the casing. This was to identify stress concentrators that could be minimised in further iterations. The forces applied were weight (1.96 N including the electronics) at the centre of mass, emergency brake deceleration of 2.6 m/s^2 (0.52 N) to the front of the casing, and 0.6 G force from each motor (1.17 N) applied to the band.



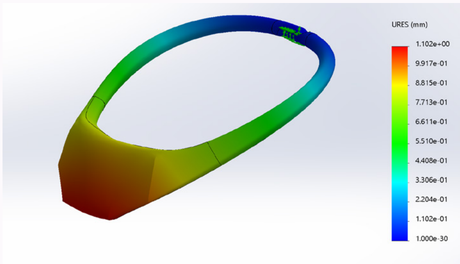
STATIC STUDIES

The areas of maximum stress were where ribs joined the main casing. These were potential areas of failure. Fillets were used to decrease stress concentrators and the rib depth was increased for rigidity. The maximum stress from the new model was 27 MPa, below the yield strength of ABS[9] (average value of 40.7 MPa). For a higher safety factor, a high impact ABS composition will be chosen.



FREQUENCY STUDIES

The vibration motors have a frequency of 200 Hz, significantly below the natural frequency of the product, 34.77 Hz. Therefore the user will be able to feel the vibration without resonance. In addition, the maximum displacement due to vibration forces is 1.102 mm, indicating the device will not move significantly.



HAND CALCULATIONS

ω (angular velocity) - 1256.6 rads^{-1}
g (gravity) - 9.81ms^{-1}
M (mass of full product) - 159 g
c (damping coefficient, calculated from FEA) - 111.5
k (stiffness of product, calculated from FEA) - 19,565
M_v (mass of vibration motor) - 0.9 g

M_e (mass of rotating mass) - 0.2 g
e (eccentricity) - 2 mm
S (design stress) - 450,000 Pa
D (screw pitch diameter) - 2.5 mm
L (length of screw) - 10 mm

AMPLITUDE

$$A = \frac{m_v e \omega^2}{\sqrt{M^2\left(\frac{k}{M} - \omega^2\right)^2 + c^2\omega^2}}$$

$$A = \frac{0.9\times10^{-3} \times 2\times10^{-3} \times 1256.6^2}{\sqrt{(159\times10^{-3})^2\left(\frac{19565}{159\times10^{-3}} - 1256.6^2\right)^2 + 111.5^2 \times 1256.6}}$$

$$A = 0.0007\ m$$

$$A = 0.7mm$$

The amplitude of the vibration through the casing is 0.7 mm - easily large enough to be felt by human skin[10].

MOTOR ACCELERATION

$$a = \frac{2E\omega^2}{g \cdot M}$$

$$a = \frac{2 \times M_e \times e \times \omega^2}{g \cdot M}$$

$$a = \frac{2 \times 2\times10^{-3} \times 0.2\times10^{-3} \times 1256.6^2}{9.81 \times 159 \times10^{-3}}$$

$$= 0.8G$$

The acceleration detectable by bare human skin is 0.04 G. 0.8 G is enough to be detectable[10], even through clothes.

PULL-OUT FORCE

$$F = \left(\frac{S}{\sqrt{3}}\right) DL\pi$$

$$F = \left(\frac{450{,}000}{\sqrt{3}}\right) \times 2.5\times10^{-3} \times 10\times10^{-3} \times \pi$$

$$F = 20.41N$$

The pull out force of the screws is 20.41 N each. Even including foreseeable misuse, the device should not experience this force.

GARMIN

ASSEMBLY CONSIDERATIONS

THICKNESS, CORNERS AND RIBS

The model casing has walls that are 2 mm thick, fitting the 0.5 - 5 mm unreinforced feature thickness guidance. Feature thickness is even to avoid shrinkage and to speed up the cooling process. Areas that do reduce down to a 1 mm thickness do so though a gradual transition.

There are no sharp corners. Fillets are 0.6 mm at the base of features, while tops have fillets of 0.4 mm in radius - within the 60 - 75% wall thickness recommendations. Top fillets are smaller so as not to interfere with each other, while still helping guide electronics in. Fillets also reduce stress concentrators and allow for plastic to flow more easily into the mould due to reduced pressure drop and flow-front breakup.

Ribs are 1.5 mm thick, and have a depth at a maximum of 5 times the rib thickness, i.e. 7.5 mm. This is to maximise efficiency as deep ribs are more structurally efficient than thick ribs. They also have a one-degree draft angle on each side to allow for release from the mould. Bosses are supported by two ribs.

DESIGN FOR ASSEMBLY

Assembly is carried out from one orientation, with a “drop in” assembly approach ensuring simplicity and speed. There are locating features where needed, and the casing is asymmetrical so is very difficult to assemble incorrectly. The pins that hold the microcontroller also serve another purpose, mating with bosses on the other half of the casing to reinforce location and hold components in the correct place. The ribs also aid with location and give guidance on where the electronics go. The fillets allow for components to slide in, as a version of lead-in chamfers.

The product needs to be easy to repair and take apart, so is built for disassembly: non permanent fasteners were preferred. A locking mechanism along the lower rim of the casing holds the parts in place, allowing for two M2.5 screws to be screwed in without the components moving around. Though this increases assembly time, it is more sustainable than permanent fasteners as it allows for repair and recycling. Fasteners have been kept to a minimum, so only one tool is needed - an allen key.

The two parts of the neck clasp need to have slightly different curvature. Therefore, to differentiate one from the other, one has an extra semicircular marking on a face that becomes hidden once the neck bands are installed.

Though wires are used, these are kept to a minimum. This is to prevent parts tangling. Electronics are arranged as compactly as possible, with the two motors being the only parts requiring extended wires. The neck band has an aluminium wire core to allow for flexibility, and this is overmoulded with silicone immediately after installation to avoid tangling.

MANUFACTURE CONSIDERATIONS

INJECTION MOULDING CONSIDERATIONS

Simulations were carried out to validate the casing design and to test optimal injection sites. The back section can be injection moulded in 2.0507 seconds, and has minimised sink marks that reach 0.0618 mm. This is negligible, and can be reduced through packing. Shrinkage is around 5%, and rarely reaches over 8%. This part can successfully be filled with an injection pressure of 27.9 MPa, 66% of the maximum. Injection sites are from either side, which minimises the number of air traps (which may be subsequently reduced though tooling design). The weld line for this would be in the centre, but increasing the melt and mould temperature and the ram speed would mask this less visible. The entirety of this part was marked as “easy” to injection mould.

The front section also can be moulded, in 1.9502 seconds. Injection is from each side, reducing shrinkage coverage compared to the injection site being in the centre. Shrinkage is around 6%, reaching 9% in small areas. In practice this can be reduced to near zero by packing. Compared to the first CAD versions, the way the front and rear casing sections are split was changed to make the front and back sections more even, and to reduce the thickness of the section that links onto the neck band, again reducing shrinkage.

All parts have draft angles of 1 degree to ensure they can be removed from the mould, and each part has been designed to have a consistent pull direction so the tooling does not require complex moving parts. This reduces tooling costs.

MATERIAL FOR MANUFACTURE

Lightweight ABS was chosen as the material for the casing. It has a high strength to weight ratio, high tensile strength and most importantly is suitable and inexpensive to injection mould. It is highly resistant to chemical corrosion and physical impacts[9], making it durable and suitable for use outdoor and potential contact with the body. It is also recyclable, complying with regulations and increasing Garmin’s positive reputation of being a socially and environmentally responsible brand - Garmin has a focus on those who love the outdoors, so actively harming it would be detrimental to their brand image[11].

There is a waterproof gasket made with silicone paste between the two casing halves, protecting the electronics from rain.

Silicone over-moulded on wire armatures is used for the neck band for its smooth feeling against skin. It too can be injection moulded, and the regular cylindrical shape of the neck band is suitable. Silicone is often used in Garmin products (for example, watch straps), making it consistent with their brand, and already accepted by their current customer base. The back of the casing will have an overmoulded antimicrobial, sweat resistant silicone layer. This will add extra padding against the chest, prevent slipping and be more hygienic and comfortable.

TIMING AND COST ESTIMATES

The product should be assembled in less than 5 minutes, excluding plastic moulding processes (see above). Assembly time will be measured both with the prototype and based upon the CAD.

We aim for out product to be able to retail for under £100 and with a 50% profit margin, meaning production should cost under £50. We will use SOLIDWORKS costing tool and supplier prices to calculate the costing.

BRAND COMPARISON

When considering a brand that would fit Venio we considered their values, aesthetic, existing products and opportunities we would provide for the brand.

NIKE

Leading brand in sports apparel, footwear and accessories, with a mission "to do everything possible to expand human potential"[12]. They already have indoor cycling products, including clothing and footwear, and this would be an opportunity to expand to the outdoors. However, their main focus is on fitness[13], where ours is on the navigation experience.

FITBIT

Digital health and fitness brand, focusing on wearable technology worn around the wrist or clipped on clothing. Their devices include GPS navigation. However, since they are mostly known for devices around the wrist[14], and their target audience is people who want to track their fitness, not aligning with our goals.

APPLE FITNESS+

Apple is expanding their consumer electronics to take in fitness and exercise, through the Apple Watch. Our product would be another opportunity to develop wearable technology but with a focus on cycling navigation[15]. This would fit with our product as our goal is to optimise the experience of cyclists. Our product however, is likely too niche for Apple's mass market approach.

GARMIN

Technology company focusing on durable sports equipment. Their goal is tracking and enhancing performance, with a focus on utility and usability to enhance the user experience[16]. This aligns with our goal to provide the best navigation experience for new cyclists. Since Garmin already has a market for cyclists, they would be able to use their existing navigation technology in a new wearable.

WHY GARMIN?

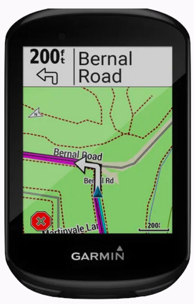
We chose Garmin as their product portfolio[17] closely aligns with that of out proposed device. Though they already have both wearables and cycling products, this would be their first combination of the two. We would target a new demographic - Garmin's customers are often semi-professionals or professionals, where Venio aims to appeal to new cyclists.

Our goal is to make Venio simple and intuitive to use. It will help inspire confidence, encouraging new cyclists to be adventurous and try new routes and allowing attention to be on the road instead of the route.

EXISTING FEATURES

Garmin has existing cycle computers, with many features transferable to our product[18].

- Option to select bike friendly routes
- Turn by turn directions and alerts
- Displaying popular routes among other cyclists
- App integration to track workouts and routes



[19]

Our aim is to use similar features, but without any visual or audio cues.

BUSINESS PROPOSITION

Garmin caters to a focus-segmented market, as the wearables are targeted to specific sports, and suit a more professional user group. It does not rely on cost leadership, and instead the focus is on performance.

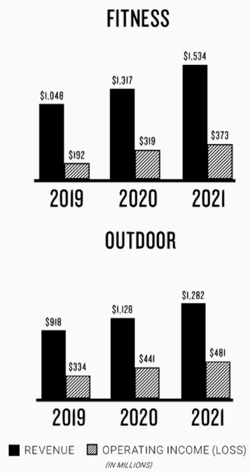
TARGET MARKET

Our product is not aimed towards users who want to track exercise. Instead, it is for inexperienced cyclists, such as users who have started cycling recently, are cycling in an unfamiliar location or are transitioning from rural to urban cycling.

BENEFITS FOR GARMIN

Garmin's Fitness and Outdoor sectors are rapidly growing. 31% of all net sales were in the fitness sector, and, according to the Garmin Annual Report:

> THE FITNESS REVENUE INCREASE WAS PRIMARILY DRIVEN BY A STRONG DEMAND FOR ADVANCED WEARABLES AND CYCLING PRODUCTS.



By introducing Venio to the market, Garmin would be able to combine both market needs into one device. By investing heavily in R&D and with vertical integration (as much as possible done in-house), Garmin would be able to develop the product faster and better than its competitors.

Garmin is a leading brand in personal navigation devices. In the early 2000s, they were the pioneers of GPS systems and automotive navigation. Their mission was to create "GPS-enabled hardware, as well as customer-facing navigation software"[16]. However, with the rise of smartphones, their stock plunged by more than 80% in 12 months[20]. Garmin was able to survive the smartphone revolution because of its diverse portfolio and having their own GPS system. They are still developing innovative ways of integrating navigation systems, such as wearables or cycling computers. They can have a longer battery life without compromising on navigation, a feat their competitors struggle with.

Garmin has recently focused on wearables targeted to different sports to track and enhance an active lifestyle. The smartwatch market has grown by 24% in 2021, but Garmin only represents 4.6% of it[21]. Venio has a specific purpose, navigation, is not a tracker and does not go around the wrist, thus avoiding launching a product into a saturated market.

BUSINESS FEASIBILITY

Garmin products are available all over the world, but have a focus on US markets. It would be advertised mainly through social media, as they are a digitally orientated company and rely on customer loyalty[22]. Garmin is able to offer devices at an elevated price due to the high quality and long lasting technology, but Venio aims to be more affordable for less committed users, and will be sold at a lower price point, as the electronics do not need to be as compact.

PRODUCT ASSEMBLY

NOTE

It is important to note this assembly process is for the prototype, and a commercially produced product would implement custom PCBs and overmoulding processes that we could not carry out. This changes would reduce the size and weight of the overall product, make assembly easier and have a sleeker, more finished, look. Refer to folio p13 for images relating to each step.

ASSEMBLY STEPS

STEP 1: Casings are 3D printed (or, for a commercially produced product, injection moulded), and laid out in preparation for assembly. Pliers, wire cutters, a knife, soldering iron and allen key required.

STEP 2: Apply the conductive tape to the button area. Use the knife to cut it to shape. In a commercial product this would be a solid piece of anodised aluminium with a wire attached that could be simply placed in.

STEP 3: Place in the electronic components, using the party features guide them into place Feed the wire through the hole in the front casing to prepare it for attachment with the foil button. In a commercially produced product, this subassembly would be smaller as a custom PCB would be created.

STEP 4: Use the locking feature to attach the casing together, and the allen key to screw everything in place.

STEP 5: Flip the assembly over. Use the solder to connect the foil to the capacitive touch wire. In a commercial product, the pre-attached wire would be connected to the PCB using a snap connector during step 3, eliminating this step, and reducing the tools and time.

STEP 6: Use the pliers to push in the aluminium wires into each side of the casing.

STEP 7: To recreate the overall shape of an actual product, structural ribs were printed and glued onto the wires. Padding was wrapped around to give it structure and the whole thing was wrapped in cloth to give it a cohesive finish. In a commercially produced product, silicone would be overmoulded onto the wire to create each arm, and these then attached, instead of this step.

ASSEMBLY ANALYSIS

Assembling the prototype took 4 minutes 26 seconds, but in an industrial assembly process, this could be reduced to 51 seconds. This assumes that the average assembly time for a part presenting no assembly difficulty is about three seconds, and three of the components (two screws and the capacitive touch button) would require a few extra seconds each.

The assembly efficiency of our prototype was 25% when the formula is applied (22 components, 3 seconds each), but a commercially viable process would considerably streamline this, resulting in far greater efficiency.

In addition, the electronics can be reduced to be less than 50% of their current size (as evidenced by current Garmin wearables) through the use of a custom-made, integrated PCB - this means a commercially produced product could be more sleek, lightweight and discreet.

COST ANALYSIS

COMPONENT COST ESTIMATE

The table below presents the bill of materials for all bought-in components and manufactured parts. Prices of electronic components vary significantly based on how many are purchased, but the below estimates were found to be accurate over the widest range of quantities. Due to economies of scale, it would in reality be possible to bring the overall price for bought components well below than $12. The manufacturing costs for injection moulded parts were calculated using the SOLIDWORKS costing tool, assuming a volume of 100,000 units, and a moulding cost of US$5000. Some materials would be purchased in stock form to eliminate the need for in-house processing, and the only operations required would be cutting, bending and soldering. The price per unit includes both the price of raw materials and the price of manufacture.

ASSEMBLY COST ESTIMATE

Assuming assembly cost estimates of US$7/hr, our product would cost US$0.52 to assemble, which is 2.11% of the total cost. This results in a total production cost of US$24.59, currently equivalent to £20.11. However, this estimate does not include labour costs, production supplies or factory overhead, and cost could therefore vary.

PURCHASED COMPONENTS

PART	UNIT COST (USD)
ESP32	3.60
Li-ion battery	3.80
GPS module	2.49
LED strip	0.01
Charging port	0.15
Vibration motors	0.48
Magnets	0.02
Screws	0.01
Charging cable	1.34
Wires	0.01

Total Cost: US$12.00

MANUFACTURED COMPONENTS

PART AND MATERIAL	MATERIAL PRICE (USD/KG)	MANUFACTURING PROCESS	PRICE PER UNIT (USD)
Front casing (ABS)	2.54	Injection moulding	2.74
Back casing (ABS)	2.54	Injection moulding	2.6
Neck bands (silicone)	15.04	Moulding	0.99
Button (anodised aluminium)	5.59	Cutting, forming, soldering	0.56
Support wires (aluminium)	2.95	Cutting	0.06
Magnet holders (ABS)	2.54	Injection moulding	5.10
Separating strips (grip tape)	1.84/meter	Cutting	0.02

Material Cost: US$12.07
Assembly Cost: US$0.52

Sum of all costs: US$24.59

TARGET MARKET

Garmin's products are sold at a range of prices, from £70 (children's smart watch without GPS[23]) to £1,400 (professional ballistics smart watch[24]). Our goal for the product was less than £100, as the cheapest Garmin product with GPS is £150, but our product does not include other features such as counting steps, calories and sleep tracking. The £20.11 price makes this feasible for Garmin to manufacture and then to add a profit margin of 50% or more, and still sell the product to inexperienced cyclists for less than the target price.

The price point is low, meaning it is more likely to be bought by inexperienced cyclists. The streamlined functionality focusing solely on navigation and comfort increase appeals to users who do not need excess features. It has mass market appeal, and other cyclists would benefit from this, along with anyone who needs help with navigation - whether that's people who are bad with maps, or the visually impaired.

* price for the stock form instead of raw material (sheet and wire respectively)

UK AND EU COMPLIANCE

Garmin operates in three main markets: the US, EU, and UK[22]. Thus, the product and its packaging must comply with the legislation of each area to allow it to be sold. This is a vital part of releasing any consumer product, and we have taken care to ensure that the necessary regulations have been met.

The UKCA mark applies to goods previously subject to the CE marking. Requirements are "largely the same as they were." It must be used in the UK from Jan. 2023[25].

The CE mark indicates conformity with European requirements for product safety. This is an essential mark to include for regulation and customer reassurance purposes[26].

LEGISLATION AND STANDARDS

Despite the introduction of the UKCA mark post-Brexit, UK and EU legislation is still largely the same. The below outlines regulations, directives and standards that are applicable to our product. A conformity assessment for these regulations has not been carried out, but this would be necessary if formally releasing the product.

RADIO EQUIPMENT REGULATION 2017[27]

- Implements Directive (2014/53/EU) for the safety and electromagnetic compatibility of radio equipment and promotes protection of the radio spectrum — relevant to GPS module.
- EN 301 489-1 — Common technical requirements relating to electromagnetic compatibility, standard for radio equipment and services[28].

ELECTRICAL EQUIPMENT (SAFETY) REGULATIONS 2016[29]

- Implements Directive (2014/35/EU) on electrical equipment designed for use within certain voltage limits.
- EN 62 061 — Methodology for the safety of electronic systems including equipment with regard to electromagnetic phenomena[30].

ELECTROMAGNETIC COMPATIBILITY REGULATIONS 2016[31]

- Applies to all electrical equipment which is liable to create electromagnetic disturbance, like Bluetooth.
- EN 300 328 — For data transmission equipment operating in the 2.4 GHz ISM band (typical frequency of Bluetooth[32]).

RoHS IN ELECTRICAL AND ELECTRONIC EQUIPMENT REGULATIONS 2012[33]

- Guidance for EEE products, restricting the use of certain hazardous substances. These include but are not restricted to: lead, mercury & cadmium.
- EN IEC 63000:2018 — Technical documentation for the assessment of electrical and electronic products with respect to the restriction of hazardous substances[34].

TRACEABILITY

According to UK and EU legislation, a product must be traceable to its manufacturer to allow for effective product recall. To enforce this, the product or packaging must include a registered trade name, country of origin, a postal address, and a unique serial number. Including these in will also comply with US legislation.

INFORMING THE USER

The user must be informed about a product's associated risks and must be provided with guidance on the intended use as well as any foreseeable misuses. We will provide this information in the form of a short user guide and user safety leaflet.

US AND CANADA COMPLIANCE

The North American market can be divided into two areas: the US and Canada. Much like the UK and EU, legislation in these two countries is similar. Notably, traceability requirements for both of these markets includes a statement on the product of the country of origin.

The FCC mark is voluntary, placed on electronic products sold in the US. IT indicates that the electromagnetic radiation is below the limits specified by the Federal Communications Commission[35].

The CSA mark means product has been tested for North American standards written by the ANSI, UL, CSA Group, NSF International, and other North American and global organizations[36].

FCC SUPPLIERS DECLARATION OF CONFORMITY LABELLING REQUIREMENTS[36]:
Issuing company, address, phone, product name, country of origin, model number, applicable standards.

Much of Canadian legislation uses harmonised ANSI standards in their regulations, meaning in general, if a product is certified for use in the US, it will be accepted by CSA too. Relevant regulations and standards in both the US and Canada are listed below.

LEGISLATION AND STANDARDS

US: FCC - 47 CFR PART 15[38]
CANADA: RSS-102, RSS-310[39, 40]

- Covers regulations for class B radio frequency devices. Our product is in the class B category as an intentional radiator (communicates with radio waves at low power). Canada, does not require a technical acceptance certificate (TAC),
- ANSI C63.4 — American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz[41].
- ANSI C63.10 — American National Standard for Testing Unlicensed Wireless Devices[42].
- CSA C22.2 NO. 0.23-15 — General requirements for battery-powered appliances[43].

If the product were to be released onto these four markets, it must meet the requirements of these regions as listed above.

CE AND UKCA MARKS

- Our product will fulfil the requirements of the applicable directives and, as it is in the appropriate product category, it may be self-declared as compliant.

FCC DECLARATION OF CONFORMITY

- There are three verification procedures in FCC certification: prior inspection, obtaining a declaration of conformity, and certification. According to FCC part 15, radio frequency devices shall be authorized prior to placement in the market[44].

USER GUIDE DESIGN

To align with Garmin, the Owner's Manuals of various products were analysed to allow us to maintain a consistent use of image styling and overall tone.

USER GUIDE ANALYSIS

- Simple, clear images that communicate relevant details, often via thumbnails or arrows. Images are renders of the product to allow for simple instruction.
- Illustrations and images are followed by bullet-pointed instructions to outline the order of each operation. Any text is simple and clearly worded, with no more than two sentences per step.
- Garmin addresses the user directly in the second person ("your device", "you can replace...") to make users feel like Garmin is talking with, not at them.

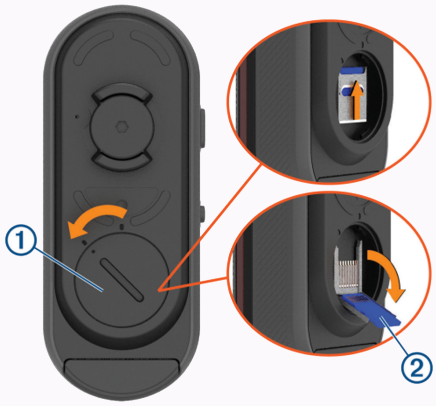
[45]

Replacing the Memory Card

You can replace the memory card to increase the storage capacity or to replace a card that has reached the end of its useful life. The device requires an 8 to 128 GB microSD® memory card with a speed rating of Class 10 or higher.

NOTE: A memory card is included so your device is ready to use out of the box. All memory cards have a limited life and must be replaced periodically.

1 Open the cover ①.



2 Slide the card holder toward the mount, and lift up.
3 Pull open the card holder ②.
4 Insert the memory card into the memory card slot with the contacts facing the device.

SAFETY INFORMATION

Users must be given proper guidance and warnings about any associated risks with a product's use and foreseeable misuse. Typical Garmin product safety information has been analysed, and the following safety[46] information has been complied with the relevant information about our product.

IMPORTANT SAFETY AND PRODUCT INFORMATION

The product should only be used as described in the user guide. Failure to follow the following warnings could result in an accident or medical event resulting in death or serious injury.

BATTERY WARNINGS

A lithium-ion battery is used in this device. If these guidelines are not followed, batteries may experience a shortened life span or present a risk of damage to the device, fire, chemical burn, electrolyte leak, and/or injury.

- Do not expose the device or batteries to fire, heat, or other hazard.
- Do not disassemble, modify, puncture or damage the device or batteries.
- Do not remove or attempt to remove the non-user-replaceable battery.

DISPOSAL NOTICE

- Contact your local waste disposal department to dispose of the device in accordance with applicable local laws and regulations.

DEVICE WARNINGS

- Do not leave the device exposed to a heat source or in a high-temperature location, such as in the sun or in an unattended vehicle.
- Do not operate the device in extremely high or low temperatures.
- Remove your Garmin product immediately if it feels warm or hot.
- When storing the device for an extended period, store within the temperature ranges specified in the printed manual in the product packaging.
- Do not use a power cable, data cable and/or power adapter that is not approved or supplied by Garmin.

BICYCLE WARNINGS

- Always use your best judgement, and operate the bicycle in a safe manner.
- Make sure your bicycle and hardware are properly maintained and that all parts are correctly installed.

APP USAGE WARNINGS

- Setting up the route on the Garmin App should be done before departure, not on the road. Always be aware of your surroundings when using Garmin's products.

NAVIGATION WARNINGS

- Always carefully compare information from the device to all available navigation sources, including information from visual cues, local rules and restrictions and maps. For safety, always resolve any discrepancies or questions before continuing navigation, and defer to signs and road conditions. Use this device only as a navigational aid.
- Do not attempt to use the device for any purpose requiring precise measurement of direction, distance, location, or topography.

GPS NOTICES

- The navigation device may experience degraded performance if you use it in proximity to any device that uses a terrestrial broadband network operating close to the frequencies used by any Global Navigation Satellite System (GNSS), such as the Global Positioning System (GPS). Use of such devices may impair reception of GNSS signals.
- This product uses the Google Maps API as a data source. It may contain some inaccurate or incomplete data.

PRODUCT PACKAGING

GARMIN'S ADVERTISING PHILOSOPHY

Garmin's advertising strategy changes based on user touchpoint. At first contact with the product (e.g. in ads) they are emotional, then at the point of purchase (e.g. packaging) they are rational, sticking with the necessary facts. Packaging should be "light on emotion and dominated by product features and other factual information': functionality is more important than aesthetics for the packaging.

"PURCHASE DECISIONS ARE BASED ON EMOTION THEN RATIONALISED BY LOGIC[46]"

SPECIFICATION OF MATERIALS AND PRODUCTION PROCESSES

Garmin strives for sustainability by using eco-friendly materials: the majority of their products are shipped in cardboard packaging made with over 80% recycled paper. Since 2017, they've completely eliminated the use of plastic windows, clamshells or blister packs[11].

The sleeve (see folio p18) is made of 100% recycled 200 gsm paper, and the main box will be matboard. The insert is made of moulded fibre, which is recyclable and biodegradable, instead of the plastic used by many companies. A pouch (also 200 gsm paper) containing the user guide and a charging cable is located under the insert, accessed by lifting the insert with the cutout (in the shape of the Garmin delta).

To produce a high quality print finish that is suitable for mass production, flexography will be used. The recycled cardboard is fed through flexible plastic plates which allow for high quality imaging on uneven surfaces - common in heavier/recycled cardboard. The cardboard will be die cut and scored to produce nets that can be folded. Spot UV curing will then be used to create the shiny Garmin logo. All of the packaging can be made out of 100% recycled materials, and the printing/curing processes do not affect recyclability.

GRAPHICS AND BRANDING

Since Garmin's main focus for packaging is on factual information rather than emotion, the style is very simple and clearly shows all required information[47].

The grey sleeve is standard for all of their products, and shows the product itself for easy identification. The product name and description then follow in the typography hierarchy. Other text, such as safety, components, warnings and location of manufacture, are on a different face of the packaging. The main shape is a cuboid to facilitate storage and transportation, increasing efficiency and reducing cost. Underneath the sleeve, the minimalistic box is thick and gives the sense of quality. It can be kept and reused, adding sentimental value to the device and solidifying a relationship with the company. Opening the box reveals the product itself and an introductory sentence, as well as icons highlighting main functions. Everything is in Garmin's characteristic colours.

COMPLIANCE MARKING - PACKAGING

ELECTRONICS: Garmin supports the WEEE takeback initiative for electronics: the symbol must be placed on the packaging to continue this initiative[11].

TRACEABILITY: The batch and serial number must both be included, as well as a barcode to ensure it can be traced back to the manufacturer and recalled if necessary.

SUSTAINABILITY: Mobius loop[48] to encourage recycling, green dot [49] to signify the manufacturer has made a financial contribution towards packaging recovery, and FSC indicates 100% recycled material[50].

PROJECT PLAN

This page details our plan to achieve the required targets for phase 2 of the project. With four key deliverables: portfolio, report, video, and presentation, it was of vital importance that workload was managed appropriately.

DIVISON OF WORK

Workload was divided as fairly as possible between team members, using our chosen roles as a guide for leader allocation for each topic covered:

CTO, JAMES HOWELLS
- Led and coordinated the hardware and software developments for physical prototype and CAD model generation.

COO, LAURA BASTOS
- Coordinated, logistics and timetabling, DFMA research, budget management, and led video production.

CIO, AMELIA BRYANT
- Synthesised insights and validation from user feedback, led digital testing (FEA simulations) and page collation.

CCO, AMY SMITH
- Led brand analysis, development and implementation, CMF, graphical communications, and overall narrative.

1. COLLECT USER FEEDBACK ON CONCEPTS
Lead by Amelia, user feedback via surveys and interviews informed which of the four concepts from phase 1 would be developed.

The brief from phase 1 to design product to create a “natural separation” between cyclists and other road users, however, after user feedback, focus shifted to improvement of navigational instructions.

2. DESIGN ITERATION AND PROTOTYPING
We then began prototyping to test the feasibility of the product. This was done via physical and digital testing.

Extra time was allocated for the prototyping and testing phase of the project to ensure all features would be running smoothly prior to demonstration.

3. BRAND IMPLEMENTATION
After thorough review, we decided on a brand we aligned with and researched their visual language, values, and overall style.

4. PRODUCT COMPLIANCE AND LABELLING
Product compliance research was undertaken so the product met the standards and requirements needed to be market viable.

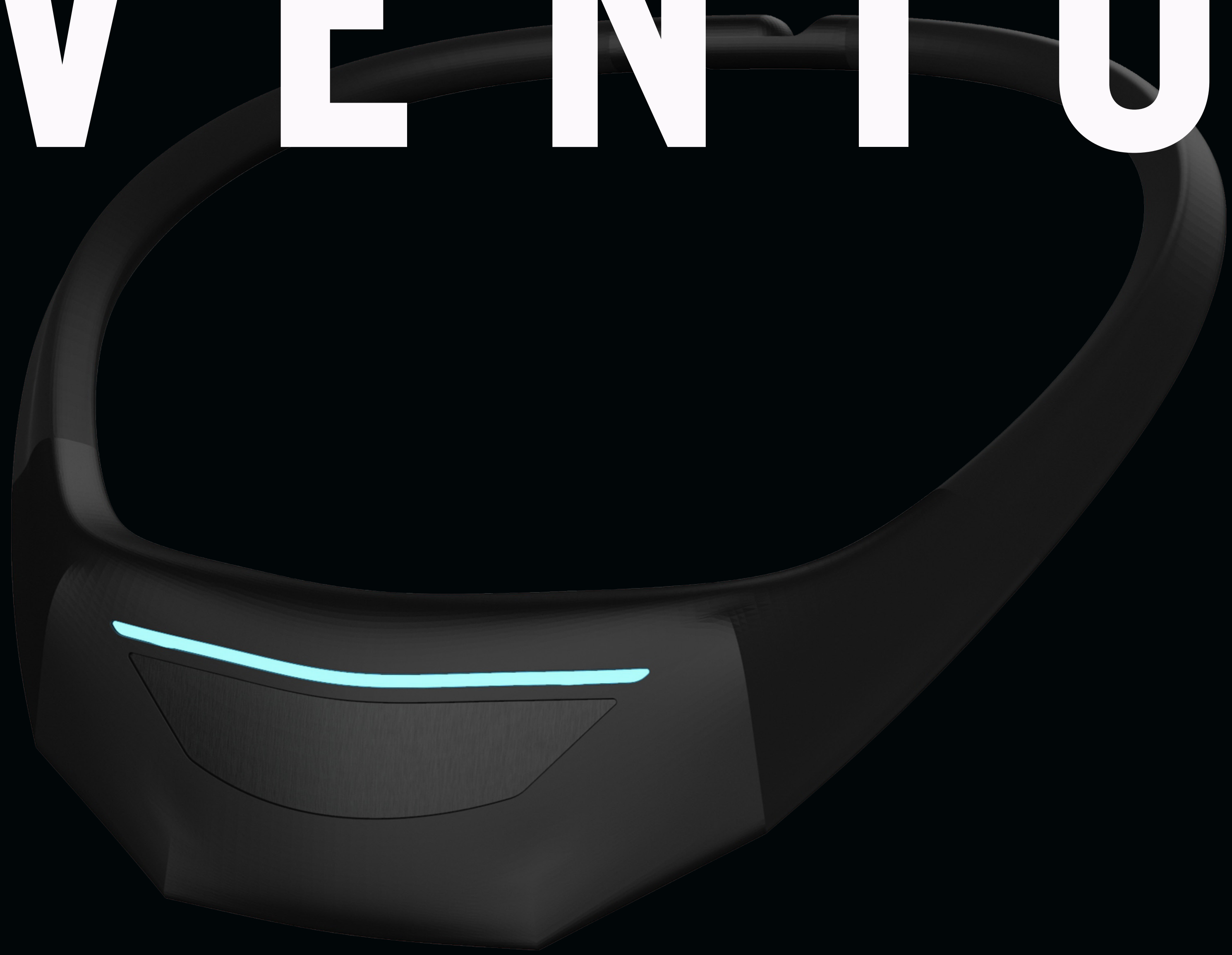
5. DFMA, COSTINGS AND TIMINGS
Laura coordinated the calculation of costings and timings. James focused on production of part drawings, fits, and tolerances.

6. PAGE COLLATION, VIDEO, PRESENTATION
The whole project journey was collated into two concise documents. We will deliver a 12 minute presentation and a short video.

PROJECT BUDGET
- The team had a £200 budget to spend.
- For phase 2, this was primarily used to purchase prototyping materials (e.g. 3D printer filament), electronic components, and specific tools for manufacture.
- Additionally, product renders and animations were made using commercial render farms.

GARMIN

VENIO



LAURA **BASTOS**

AMELIA **BRYANT**

JAMES **HOWELLS**

AMY **SMITH**

01 | PRODUCT OPPORTUNITY

VIBRATIONAL NAVIGATION

THE PROBLEM

10.7 million people in the UK cycle at least once a week[1], and cycling in central London is steadily increasing: it jumped by 35% in February 2021[2]. Though it is good that this eco-friendly transport is popular, cycling conditions are still perceived as impractical and unsafe. COVID-19 reduced the number of cars on the roads, encouraging people to try cycling, and many inexperienced cyclists still brave the roads daily.

A central reason we identified for insecurity on the road is navigation. Inexperienced cycling requires constant focus, on traffic, stability, and basic bicycle skills. When listening to instructions, processing for other auditory cues (such as approaching cars) is slowed. Visual aids divert cyclists' attention from the road, as well as making them less good at controlling the bike[3], decreasing stability and increasing risk of crashes.

Inexperienced cyclists need to be reassured that they are going in the right direction, while being able to maintain full focus on their own skills. Garmin creates a variety of cycling navigation devices, all of which rely upon the rider looking at a screen or listening out for beeps. Garmin would benefit from another intuitive device that communicates direction in a new way - increasing accessibility and improving safety for the inexperienced.

OUR AIM

We are going to develop Routec into a complete wearable navigation system that communicates direction intuitively, through vibration alone. We want to make cycling on new roads approachable. We want to increase safety and reduce fear while increasing confidence.

OUR USERS

We were in correspondence with our users at every step of testing to make sure the product would be accessible for all. Though inexperienced cyclists were the main test subjects, we sought the feedback of cyclists of all abilities to ensure mass market appeal. Our updated product opportunity is:

HOW MIGHT WE COMMUNICATE NAVIGATIONAL INSTRUCTION TO INEXPERIENCED CYCLISTS WITHOUT RELIANCE ON VISUAL AND AUDITORY CUES?

OPPORTUNITIES TO EXPLORE

Further areas for exploration can be divided into three sections that will be prototyped thoroughly:

FORM
- Materials - comfort, waterproofing, product stiffness and button location
- Location on the body - where is receptive to vibration but won't be a distraction?
- Ergonomics - how does the product feel, and can it be stored/transported?
- Assembly - how many parts does it contain, and how long does it take to manufacture and assemble?

FUNCTION
- How will the users interact with the product and app?
- Vibrations - what is intuitive? How strong, how many motors?
- Will the product be fully reliant on the app? What effect does this have on safety and reliability?
- Number of products - will the technology be separated into multiple devices?

INTERACTION
- Buttons - how will users change settings, what options will we give them and with what interface?
- What can we do to reduce errors, fix routing mistakes and make it as intuitive as possible?
- How do we make it simple and quick to put on, to increase frequency of use?

UNFAMILIAR ROUTES ARE UNNERVING FOR NEW CYCLISTS

LOOKING AT YOUR PHONE TAKES EYES OFF THE ROAD

GETTING OFF BIKE TO CHECK ROUTE SLOWS YOU DOWN

AUDIO REDUCES AWARENESS OF SURROUNDINGS

CURRENT NAVIGATION DEVICES RELY ON LOOKING DOWN

LOCATION AND SHAPE

FINDING THE BEST LOCATION FOR THE VIBRATION MOTORS, AND EXPLORING FORM FACTOR | REPORT P01-2

TEST 1: VIBRATION MOTOR

EAR (ORIGINAL CONCEPT)

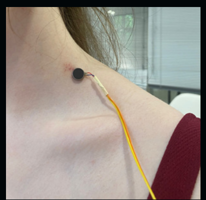
"Very noticeable, but too much resonance, it's uncomfortable"

WRIST

"When handlebars were vibrating, I couldn't feel it"

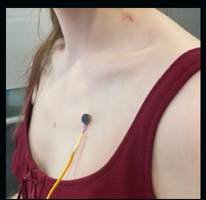
BACK OF HAND

"Too sensitive, was a bit painful"



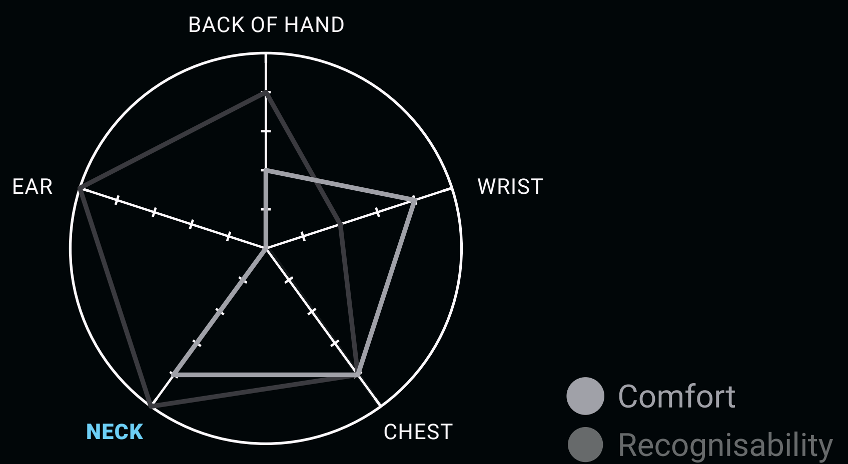
NECK

"The best as long as it's not too high up"



CHEST

"Similar vibration level to neck, it's comfortable"



Testing shows the neck scores highest in comfort and recognisability.

TEST 2: ON THE BIKE

CYCLISTS LEAN FORWARDS

Restrict how far down the motors are to ensure proximity to the skin.

SEPARATION OF MOTORS

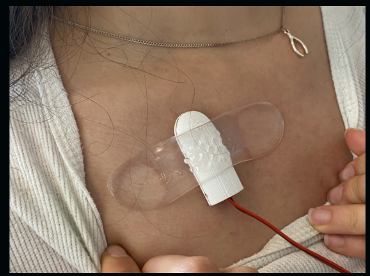
Vibrations have to be on opposite sides to make them distinguishable.

STRENGTH OF VIBRATION

Needs to be maximum strength so you don't miss directions.

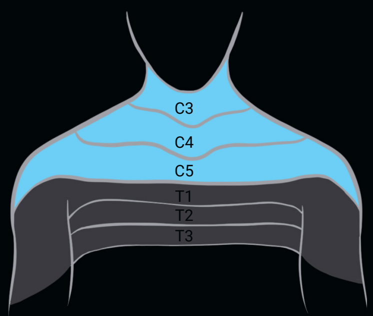
CONTACT OVER LOCATION

Firm, constant contact is more key than the location of the vibration.



ADHESION PADS ARE NOT EFFECTIVE

Sweat loosens adhesive. Instead the device must be rigid to stay in place.



THE SCIENCE: DERMATOMES

WHAT: Area of skin that gets sensation from a specific spinal root[4].

HOW: By using nerves in the C1-4 range, reaction time will be faster as nerves are closer to the brain. This reinforces why, biologically, the neck is a good choice.

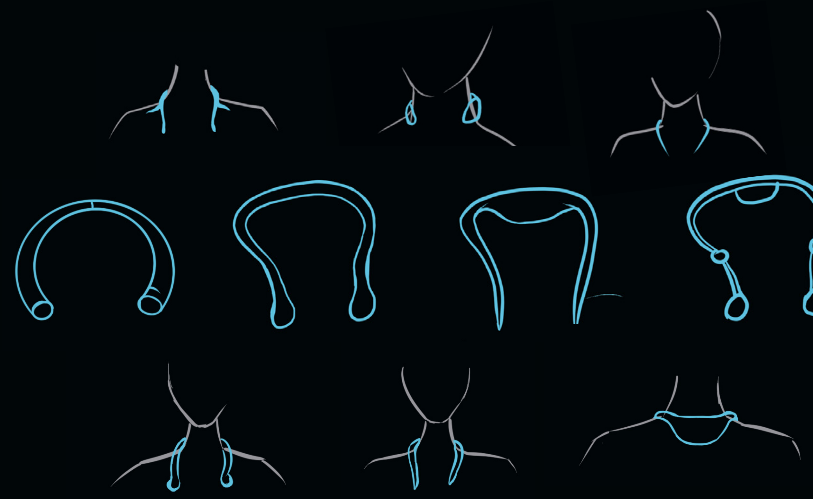
FURTHER RESEARCH: ANTHROPOMETRICS

We aim to fit male and female adults to the 90% percentile, and researched the relevant neck sizes[5] to create an ergonomic product.

SOLUTION

A WEARABLE THAT HAS TWO SETS OF VIBRATION MOTORS ON EITHER SIDE OF THE NECK. THESE CORRESPOND TO DIRECTION.

The neck is the optimum choice in terms of both user comfort and recognisability of vibration when riding.



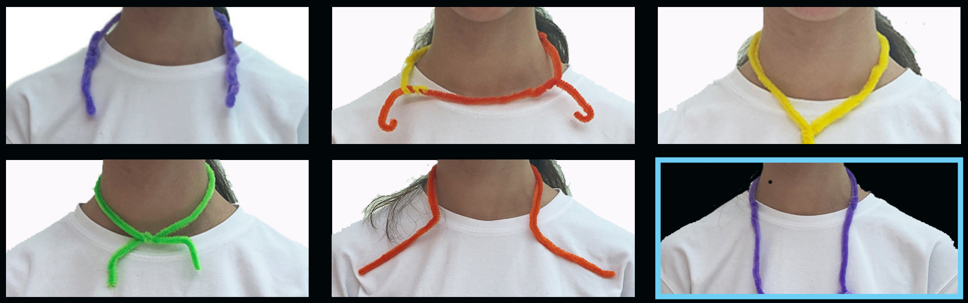
GROUP IDEATION OF NECK FORMS

03 | CONCEPT DEVELOPMENT

REFINING THE SHAPE

DEVELOPMENT OF PRODUCT FORM TO ENSURE COMFORT AND GOOD CONTACT WITH THE NECK | REPORT P02-3

PROTOTYPES 1.1-6: FORM VARIATIONS



INITIAL PROTOTYPES TO TEST SHAPES AROUND THE NECK

PROBLEM →

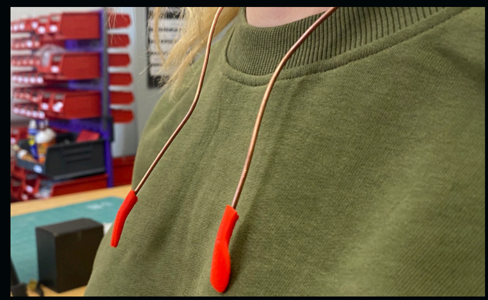
The highlighted form was chosen. Due to the lack of attachment, limited contact with the user and uneven weight, this was refined.

REQUIREMENTS

- Comfort
- Fit
- Stability
- Contact

PROTOTYPE 2: BACK WEIGHT

ELECTRONICS AT THE BACK



DOES NOT REMAIN IN CONTACT WITH SKIN

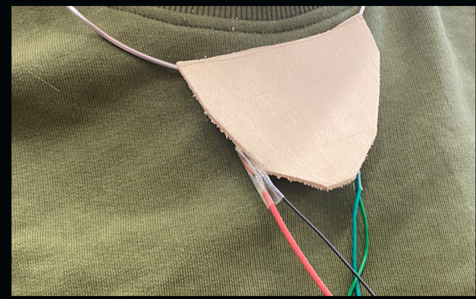
PROBLEM →

WEIGHT: Electronics at back cause device to fall backwards.
OPEN LOOP: Less secure and more likely to fall.

SOLUTION

- Bulk of it's weight should be at the front.
- Close the loop with a clasp.

PROTOTYPE 3: FRONT WEIGHT



ELECTRONICS WEIGH DOWN

THIS RESULTS IN BETTER CONTACT

PROBLEM →

RESONANCE: Feeling which side motor was on was difficult.
CONTACT: The front leaves the chest when leaning forward.

SOLUTION

- Move motors to top of neck to fully separate vibration.
- Ensures constant contact.

PROTOTYPE 4: LOCATION OF MOTORS

FLATTER SHAPE ALLOWS GREATER CONTACT AREA

MINIMUM SIZE ALL COMPONENTS WILL FIT INTO

PROBLEM →

BULKY: Wearable is too large, would attract attention and not fit under clothes.

SOLUTION

- Reduce size of electronics

FINAL FORM

CENTRAL BUTTON FOR HIGH LEVEL CONTROL

SECURE BACK-OF-NECK ATTACHMENT

MOTORS ON THE SIDES OF THE NECK

LED INDICATES PAIRING

FRONT-FOCUSED WEIGHT DISTRIBUTION

04 | CONCEPT DEVELOPMENT
USER FLOW

PAIR DEVICE — Press and hold button
- ESP32 initialises GPS
- App pairs with ESP32
- A light on device indicates successful pairing

CHOOSE DESTINATION — Select Destination
- GPS finds current location
- App finds destination coordinates

OPTIMISE ROUTE — Select Route Parameters
- Google maps API sends calculated route as array of latitude and longitudes
- ESP32 receives route, converts to vibration

CYCLING — User Cycles
- GPS updates current location
- ESP32 checks for next direction
- Vibration motors activate

END ROUTE — Double Tap to Stop | ESP Senses End
- "End route" buzzes
- Rate how you found the route

Charge Device

- User Actions
- Wearable
- App

PHYSICAL PROTOTYPING

TESTING INDIVIDUAL ELEMENTS OF PRODUCT | REPORT P03

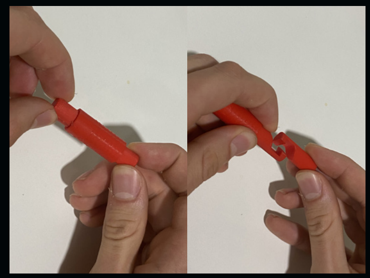
CLASP

LOCK IN

Simple but requires force and precision.

HOOK

Difficult movement, wasn't as reliable.



HOOK-SHAFT

Easy to locate, but was fiddly to put on.

MAGNET

Self-locating, didn't require much movement.

STRIP MAGNET

Wasn't strong enough, but good contact area.

BUTTON

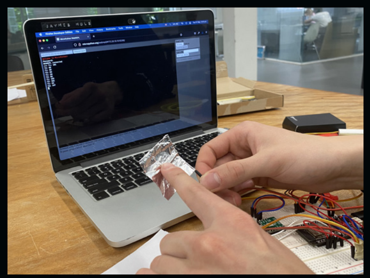
Strong but too small and trapped hair.

FINAL CLASP

A strong magnet casing was created that would contain block magnets, with a rough tactile surface to increase friction.

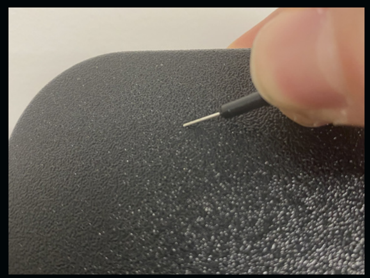
This was tested: it stayed on throughout cycling and was easy to put on blind.

BUTTONS



FOIL

Bulkier but more reliable in registering touch.



CONDUCTIVE PAINT

Less reliable, curing time slows manufacture.

LOCATION

As it works though capacitive discharge, it needs to be away from the skin.

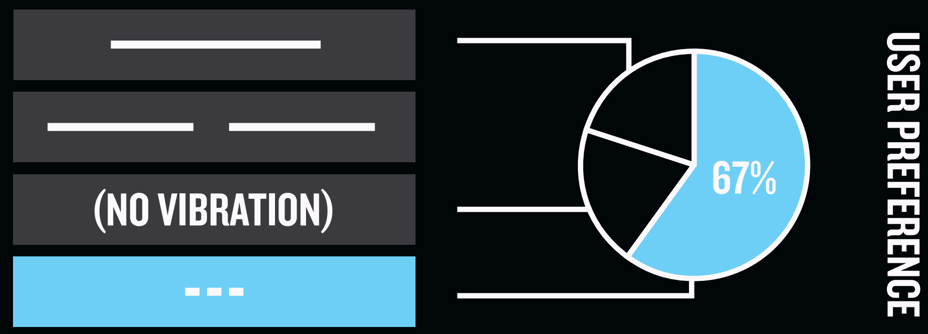
For easy access while cycling, the button should be at the front.

VIBRATION PATTERN

EXPERIMENTAL SETUP - USERS WATCHED GOPRO FOOTAGE AS VIBRATIONS WERE PLAYED.
REFER TO REPORT p03 FOR DETAIL ON PATTERN MEANINGS

SIDE TURN

STRAIGHT ON

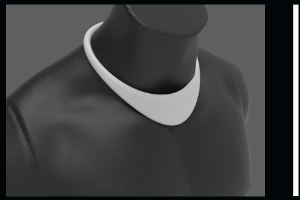


ROUNDABOUT

DIGITAL PROTOTYPING

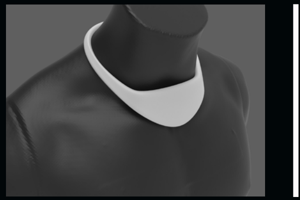
DETAILS HOW THE FORM OF THE DEVICE AND SIMULATIONS INFORMED DEVELOPMENT | REPORT P04

THE FORM



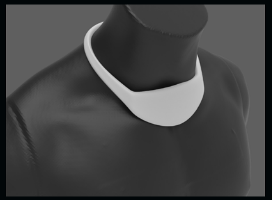
SMOOTH

- Sleek but too small to fit the required electronics.
- Less aligned with Garmin brand style.



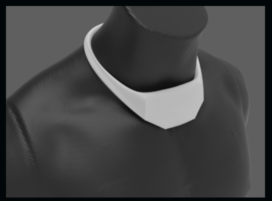
WIDER

- Too small for electronics.
- Too thin and not high enough at sides.



LARGER

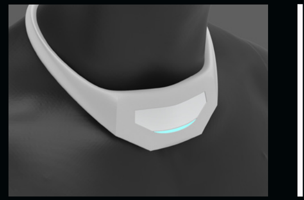
- Components would fit.
- Less aligned with Garmin style.



ANGULAR

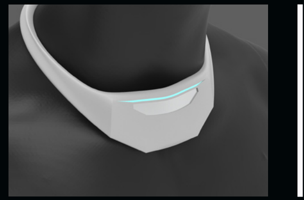
- Fits Garmin's design language.
- May not conform to neck shape.

THE CAPACITIVE BUTTON AND LED



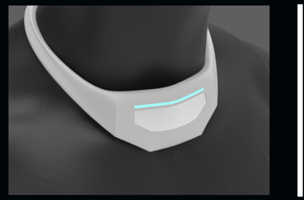
SLIP WITH LOWER LED

- Button is above the LED, giving the LED less priority.



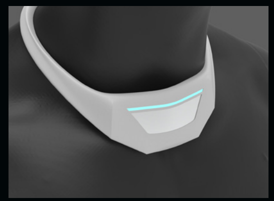
TOP LINE LED

- Hierarchy of features is more intuitive but button feels cramped against the top.



TALL BUTTON

- Placement looks better, however the button shape disrupts overall form.

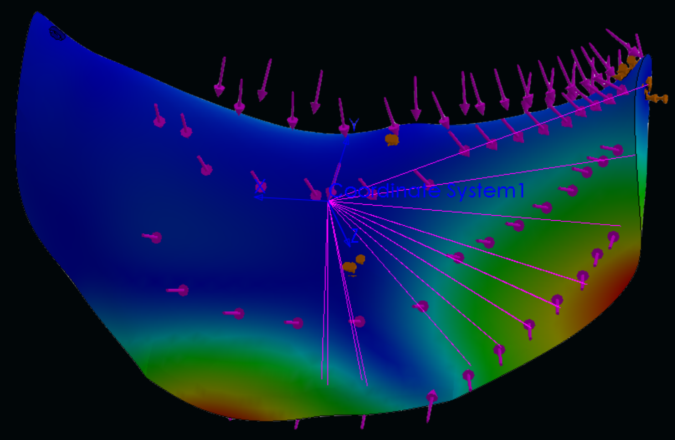


STRAIGHT TAPER

- Button matches the casing better, but is too angular.

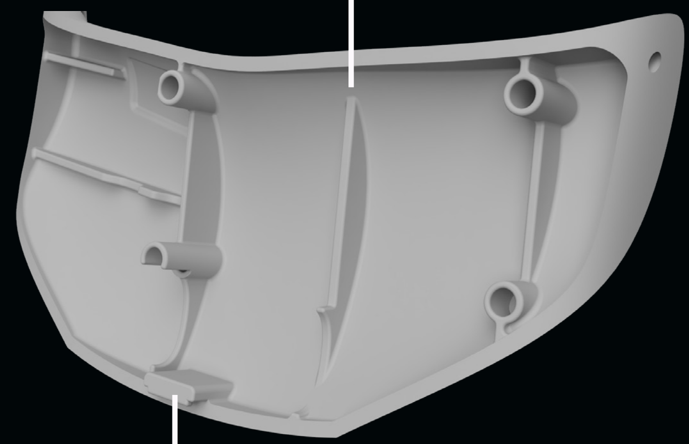
SIMULATIONS AND ANALYSIS

We used simulations to validate each model and make refinements.

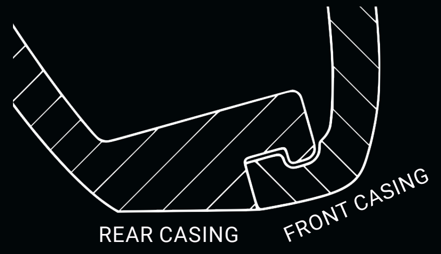


FEA SHOWED SEVERE DEFORMATION IN THE BACK CASING

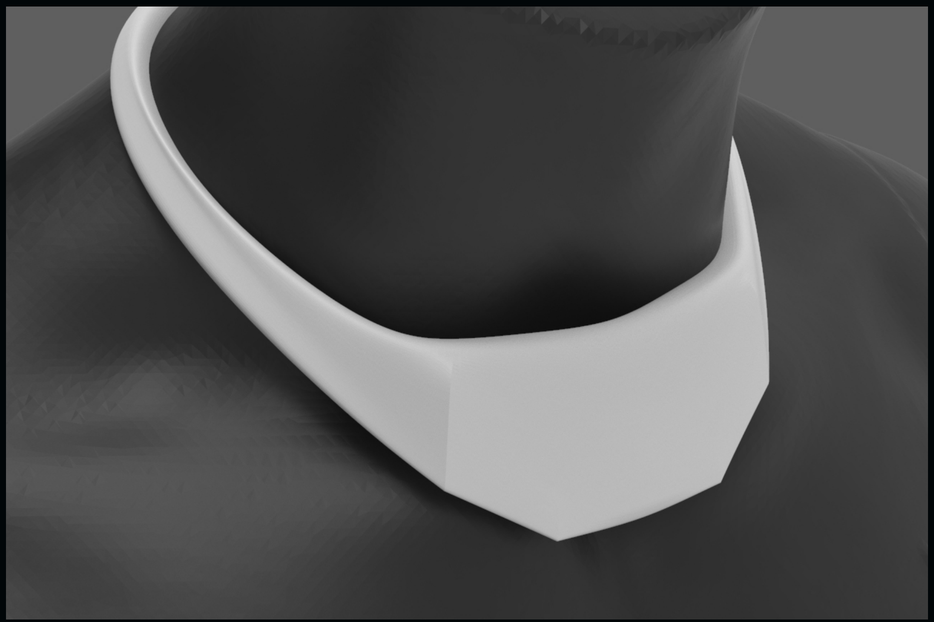
New rib added for strength



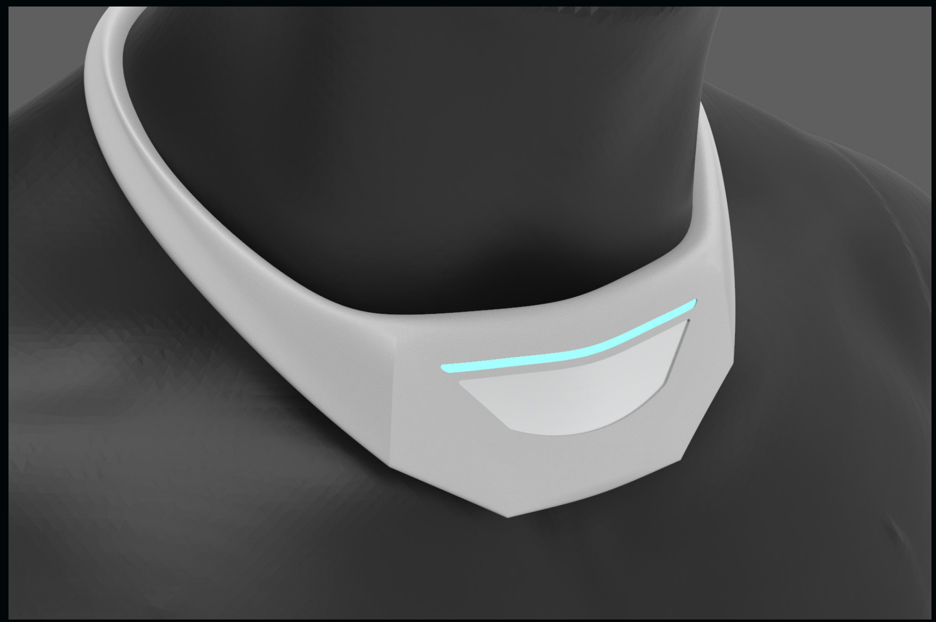
Additional locking feature created



FINAL FORM: CASING



FINAL FORM: BUTTON AND LED

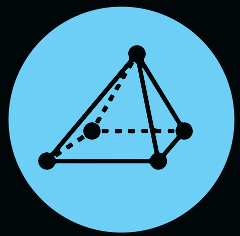


07 | POWER AND LOAD
COMPONENTS

SUMMARY OF CALCULATIONS AND SIMULATION DATA TO SHOW VIABILITY, AND CODE OVERVIEW | REPORT P05-6

CALCULATIONS

Finite Element Analysis



27 MPA MAXIMUM STRESS

Yield strength of ABS[6] is 40.7 MPa on average, and maximum stress is below this: no plastic deformation occurs.

34.72 HZ NAT. FREQUENCY

Significantly below the 200Hz frequency of the vibration motors[7], therefore resonance will not occur.

1.102 MM DISPLACEMENT

When constrained at the clasp and an emergency brake force was applied, it had a very small displacement

Hand Calculations

0.7 MM AMPLITUDE

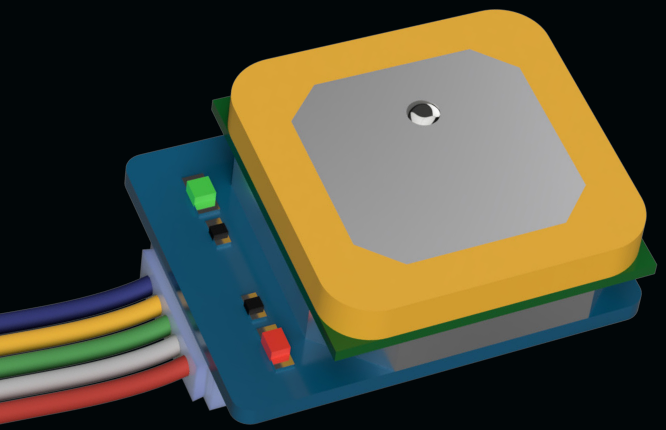
Vibration amplitude is large enough for skin to recognise[8].

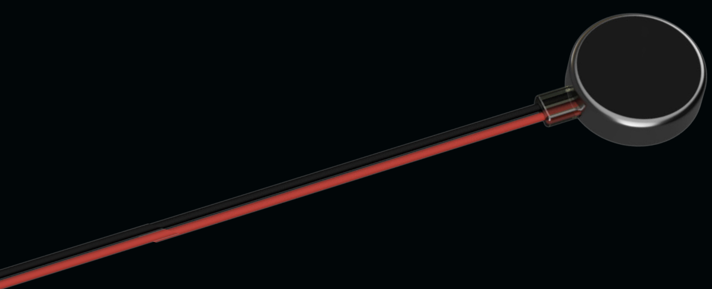
0.8 G ERM ACCELERATION

Humans can perceive min. 0.04 G, so this is perceptible[8].

20.41 N PULL OUT FORCE

Pull-out force is more than what screws will be subjected to.





FIREBEETLE ESP32[9] - 80 mA

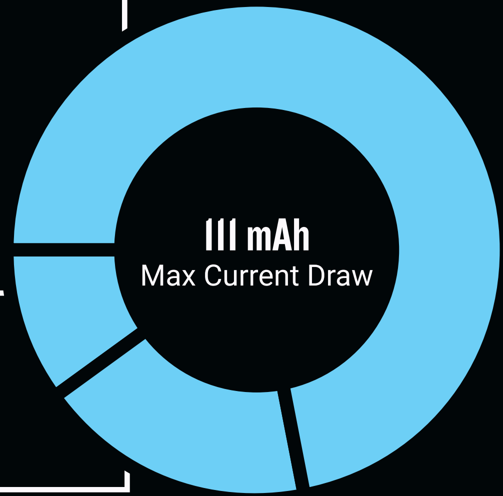
- Built-in charge controller
- Charging port
- Capacitive touch pins (for use as buttons)

L76X GPS MODULE[10] - 11 mA

- 15 s boot time
- 1 s GPS fix time
- 2.5 m accuracy
- 1-10 Hz report frequency

1027 VIBRATION MOTORS[7] - 20 mA

- Best for size and power
- Run off 3 V
- Spin at 12,000 RPM
- Very common



Battery life must be over three hours, requiring a minimum of 333 mAh capacity. The closest readily available battery size, 500 mAh, represents improved performance at nearly five hours.

PSEUDO-CODE

The processing of a route, from start to finish, follows the below flow. The ESP32 runs MicroPython and interfaces with a phone through bluetooth.

```
boot system{
      initialise_bluetooth()
      initialise_GPS()
};

USER.alert{'system_ready'};

receive_route_data{
      GPX()
      waypoint_information()
};

analyse_route_data{};

USER.alert{'ready to navigate!'};

USER.wait{start_button pressed?};

DIRECTIONS.read{first_command};

while (journey is not finished){
      USER.wait{reached next
      waypoint?};

      DIRECTIONS.read{next};
};

end();
```

08 | DFMA

FEATURES

SUMMARY OF DESIGN CONSIDERATIONS FOR MANUFACTURE AND ASSEMBLY | REPORT P07-8

RIB SPACING

Ribs spaced by more than 3x nominal wall thickness (=2mm) to ensure shrinkage doesn't cause mould to bind.

DRAFT ANGLES

All features have 1° draft so they can easily be removed from the mould.

COUNTERBORE

Reduces stress concentrators at the screw holes to decrease the chance of splitting.

M2.5 SCREWS

Non permanent fixing facilitates recycling and disposal of electronics in the correct facility (WEEE regulation) and allows the product to be repaired.

THREAD FORMING SCREW

Thread forming screws reduce likelihood of pull-out in thermoplastics as their coarse threads reduce the likelihood of thread stripping.

EXAGGERATED ASYMMETRY

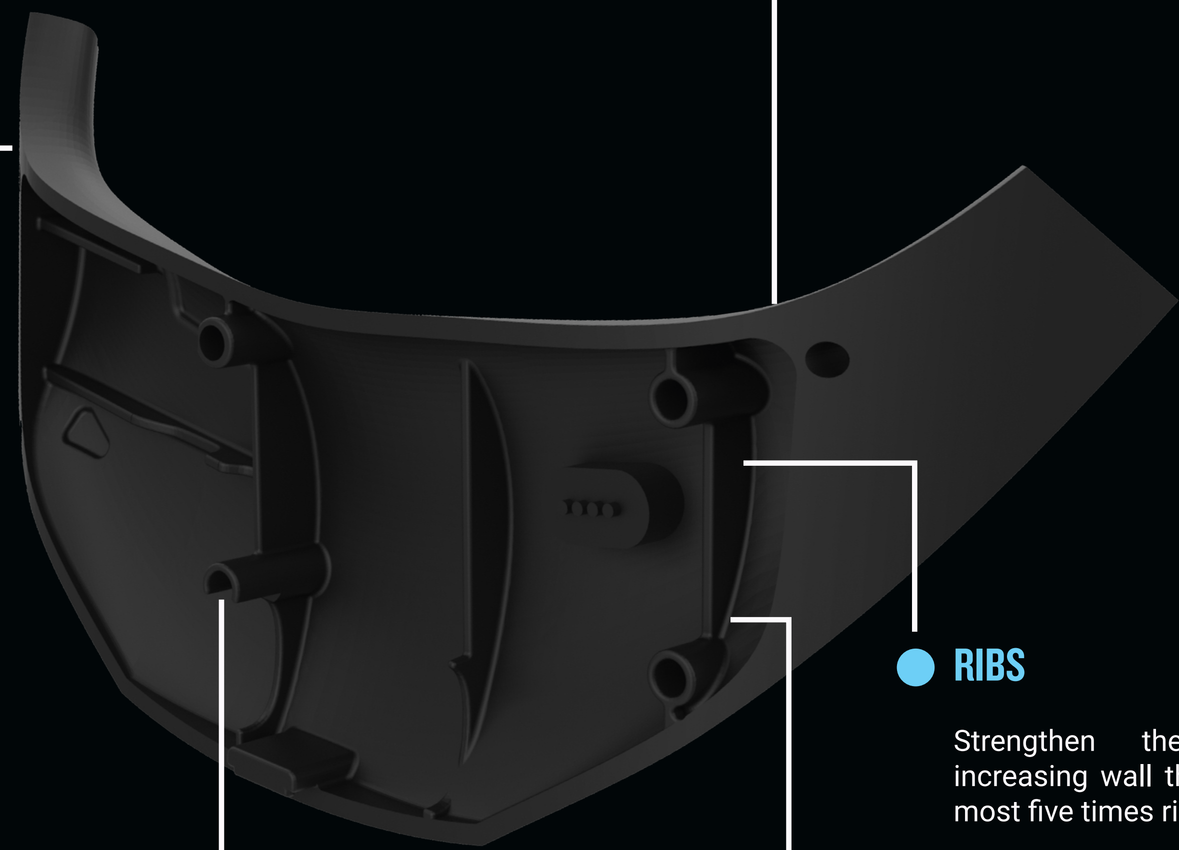
Cases are asymmetrical to avoid errors in assembly - they only fit together in one orientation.

2MM WALL THICKNESS

Thin walls allow for even and fast cooling. Where there has to be variation in thickness there is a gradual transition.

NON-PERMANENT FIXING

Supports the bottom of the casing, which is furthest from the screws, and prevents it from popping open. Also helps position the casing in assembly and better allows for disassembly when compared to snap fits.



RIBS

Strengthen the casing without increasing wall thickness. Depth is at most five times rib thickness.

KEY PRINCIPLES

DESIGN FOR ASSEMBLY

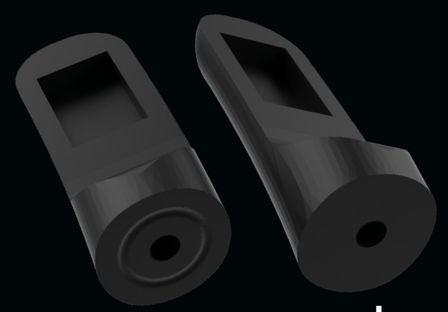
- Minimise number of parts to reduce costs and assembly time
- Minimise and standardise fixings
- Assemble from the same direction

DESIGN FOR MANUFACTURE

- Reduce complexity to facilitate injection moulding and reduce tooling costs
- Use ribs to add rigidity without adding extra wall thickness

DESIGN FOR DISASSEMBLY

- Use screws instead of snap fits or adhesives
- All electronics can be removed and disposed of and parts can be recycled at end of life



DIFFERENTIATING FEATURES

Clasps are similar but not identical, so a differentiating feature was added so they are installed correctly. Feature is then hidden by overmoulded silicone.

BOSSES

Aligned to support electronics and allow mould release, pins and bosses are paired with ribs for extra rigidity.

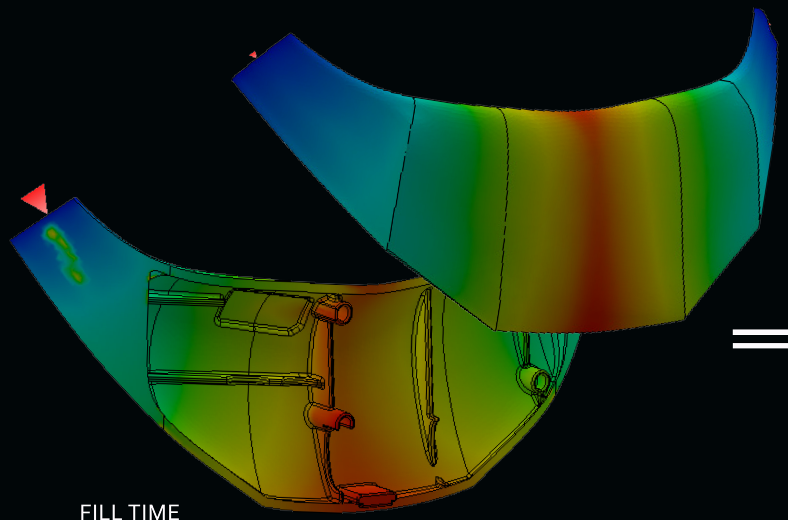
ROUNDED CORNERS

Fillets reduce stress concentrators and help with mould flow. They also avoid pressure drops and flow-front breakup.

INJECTION MOULDING + EXPLODED VIEW

FURTHER ANALYSIS OF SPECIFIC MANUFACTURING PROCESSES AND ASSEMBLY | REPORT P07-8

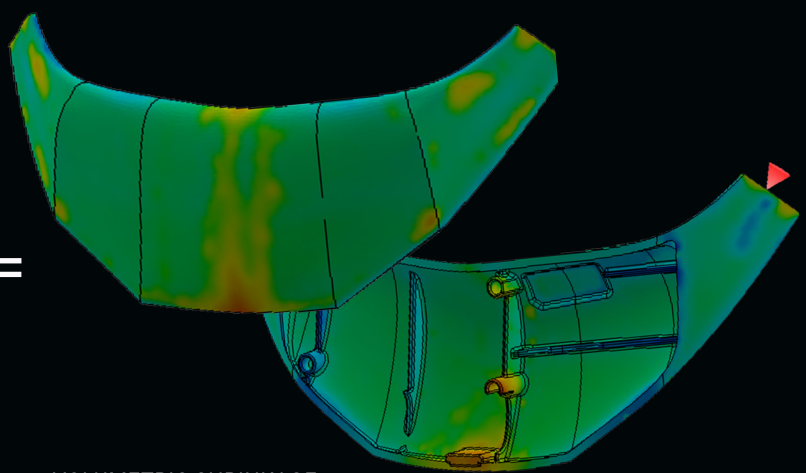
INJECTION MOULDING CONSIDERATIONS



FILL TIME

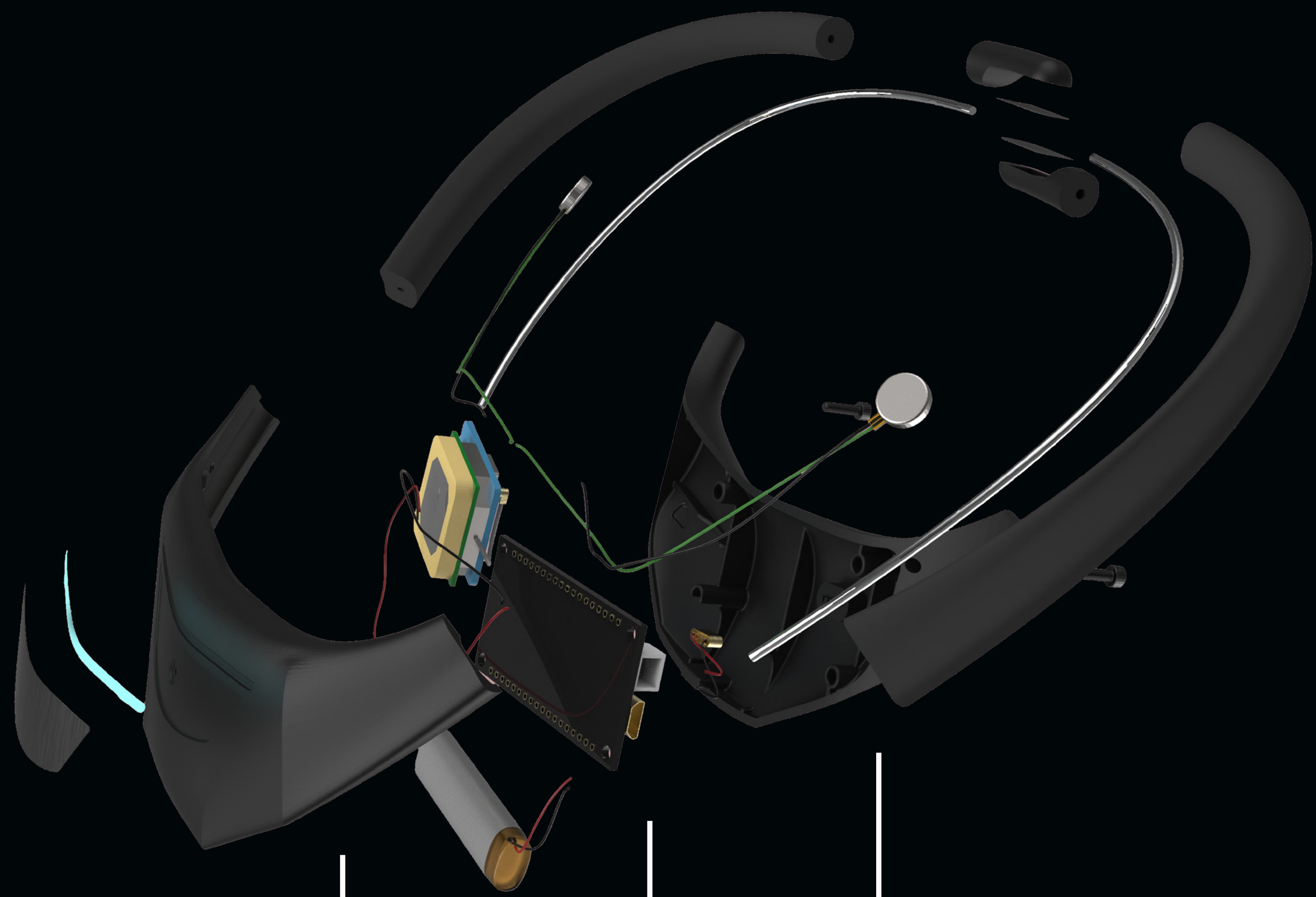
- 1° DRAFT ANGLES
- GENERALLY CONSTANT THICKNESS
- CENTRAL WELD LINES MINIMISED BY HIGH TEMPERATURES
- EFFICIENT, DEEP RIBS

- NO SHARP CORNERS
- SUPPORTED BOSSES
- GATES ON THE SIDE
- MAX 9% SHRINKGE, REDUCED TO NEAR ZERO BY PACKING
- ABS MATERIAL



VOLUMETRIC SHRINKAGE

ASSEMBLY CONSIDERATIONS



LOCATING FEATURES

Lock in hook mechanism facilitates installing the back of the casing.

AUTOMATIC ALIGNMENT

Lead in chamfers and holes provide guidance for location of electronics and fasteners.

ONE BY ONE

There is a clear order of assembly, with no simultaneous operations necessary.

PYRAMID ASSEMBLY

Device is assembled top-down, in the z-direction, easing the assembly process.

EXAGGERATE ASYMMETRY

All parts are clearly different to minimise possibility of incorrect installation.

COMPETITORS AND BRAND ANALYSIS

HOW WE CAME TO CHOOSE GARMIN, AND SWAPPED THE NAME ROUTEC FOR VENIO | REPORT P09-10

NIKE

"IF YOU HAVE A BODY, YOU ARE AN ATHLETE"

Nike has clothing and footwear suitable for indoor cycling, and this would be an opportunity to expand their cycling accessories into the wearable sector[11].

GARMIN

"ENGINEERED ON THE INSIDE FOR LIFE ON THE OUTSIDE"

Garmin has a range of cycling accessories, including navigation devices and tracking watches. This would be an opportunity to use their existing maps technology to develop a new wearable[12].

fitbit

"A PERSONAL APPROACH TO FITNESS"

Fitbit aims is to inspire people to live a healthier life. This would present an opportunity for them to expand into non-wrist-based wearables[13].

Fitness+

"WALK. RUN. AND BE INSPIRED."

Apple Fitness is the workout software that powers the Apple Watch. With our product, they could integrate this and their mapping software into an entirely new device type[14].

GARMIN

WHY GARMIN?

Garmin's existing products align best with Venio. They are expanding their cycling collection, and, previously catering only to high-end consumers, Venio will cater to less experienced users.

STRATEGY

Garmin is a leader in aviation, marine, automotive, outdoor and fitness markets due to the variety of products they offer.

They focus on utility, functionality and ease of use.

VISION

"We will be the global leader in every market we serve, and our products will be sought after for their compelling design, superior quality, and best value."

VISUAL IDENTITY

- "Delta" logo points North: success, growth and development.
- Dynamic and active imagery used in promo material.

CORE VALUES

- Innovation
- Enhancing active lifestyles
- Engineered for longevity

SOCIAL PRESENCE

Recognised for durable and reliable products for sports including running, swimming, cycling and diving.

Garmin is known for their adventurous, outdoor spirit and athletic nature.

HEALTHY PRODUCT ECOSYSTEM + INSPIRING DESIGN + QUALITY + SUPERIOR RELIABILITY = EXCELLENT USER EXPERIENCE[15]

11 | BRANDING

WHY GARMIN?

WHAT VENIO CAN OFFER TO USERS AND GARMIN | REPORT P09-10

VALUE MAP

GAIN CREATORS

- Assist navigation through intuitive vibrations that indicate directions
- Discreet wearable that does not attract attention, designed for everyday use
- Reduce uncertainty in navigation and allow for focus to be on the road
- User can tailor their route (e.g. time, safety, traffic)

PRODUCTS AND SERVICES

- App provides the best route based on chosen parameters
- Algorithm optimises route based on your preferences
- Wearable navigation device that communicates instructions via vibrations

PAIN RELIEVERS

- Optimised route allows you to stay away from busy roads
- Many devices are difficult to integrate into daily routines - Venio is easy to wear and carry around
- No auditory or visual distractions means users can both hear and look for incoming cars and react to possible dangers

CUSTOMER PROFILE

GAINS

- Cycle safely by reducing distractions
- Gain confidence while cycling unfamiliar routes
- Less anxiety about missing turns

CUSTOMER JOBS

- Commute safely, avoiding busy roads
- Focus on the road without being distracted
- Follow new routes with ease

PAINS

- Visual and audio navigation devices are distracting
- Higher risk of accidents when uncertain of route/distracted
- Unsure how to cycle on difficult road features, i.e. roundabouts

PRACTICAL. DURABLE. RELIABLE.

Garmin stands out from its competitors through its three core values: practicality, durability, and reliability. Our product must be trusted by users, so instilling these values will be vital for its success.

EXISTING PRODUCTS

Garmin provides products designed to relieve pain points - e.g. Varia Radar, to help customers “ride with confidence”. Venio aims to achieve the same, boosting the confidence of inexperienced cyclists.

NEW TERRITORY

Our product targets an untapped customer base, and would be affordable, thus attractive, to users. This would allow Garmin, known as an innovative company, to push the boundaries of wearable technology.

BRANDED ELEMENTS

EXPLORATION OF GARMIN'S CMF FOR APPROPRIATE PRODUCT ALIGNMENT

When designing the Venio, we investigated Garmin's distinctive visual language in terms of CMF by analysing their current products. In our implementation of CMF, we paid close attention to the wants of the everyday consumers that the Venio should appeal to.

GARMIN INSTINCT: GRAPHITE

STEALTH, TACTICAL AESTHETIC

Crimson Accents: strength, dynamic, excitement

Graphite Base: timeless, neutral, dependable

Powder coat surface finish

Fibre reinforced polymer casing in graphite

Textured on straps for grip

[16]

GARMIN VENU: SLATE

SLEEK, CLEAN AESTHETIC

[17]

Knurled texture on straps for grip

Sky Blue Accents: calm, confidence, trust

Brushed stainless steel bezel

Slate Base: timeless, neutral, dependable

TARGET CONSUMERS

- The Venio should instil feelings of reassurance, calm, and trust - thus sky blue (see Garmin Venu) will be our accent colour.
- Our product should be unisex, balancing inspiration from more rugged, masculine Garmin designs such as the Instinct and cleaner, more feminine designs like the Garmin Venu.
- We will align with Garmin's material finishing language to maintain their aura of quality and practicality.
- It should be subtle, not flashy, as our target group does not want to stand out.

GARMIN VENIO

UNIVERSAL, DISCREET, TRUSTED

Carbon grey silicone straps

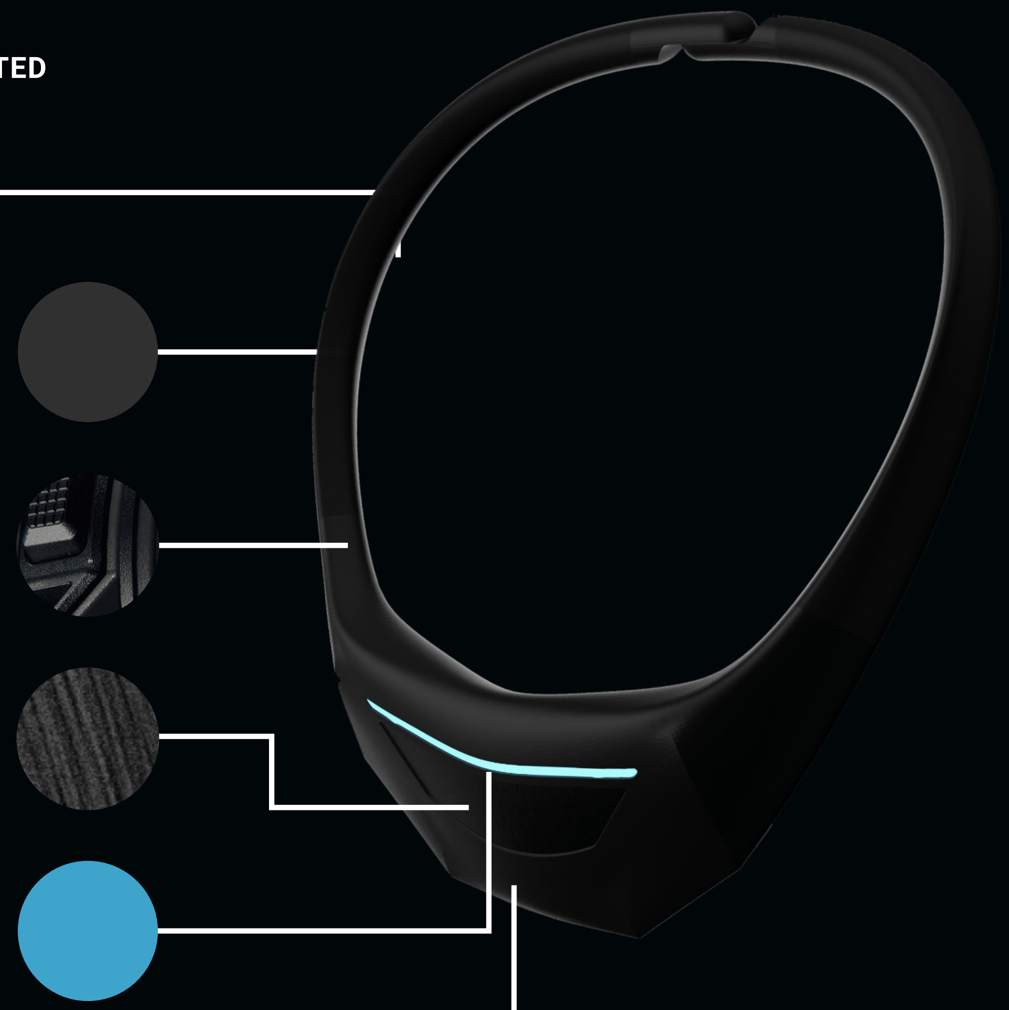
Graphite Base: timeless, neutral, dependable

Powder coat finish for quality feel

Black anodised aluminium, brushed for button tactility.

Sky Blue Accents: calm, confidence, trust

Anti-microbial, sweat-resistant, easy-clean, soft-touch silicone

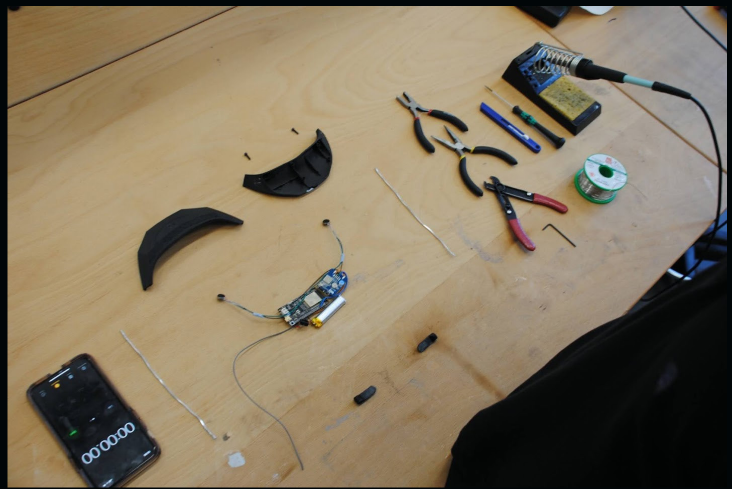


CMF EVOKES:

- Sense of dependability
- Sleek and calming form
- Practicality and functionality

PRODUCTION ASSEMBLY

OUR ASSEMBLY PROCESS FOR THE PROTOTYPE | REPORT P11

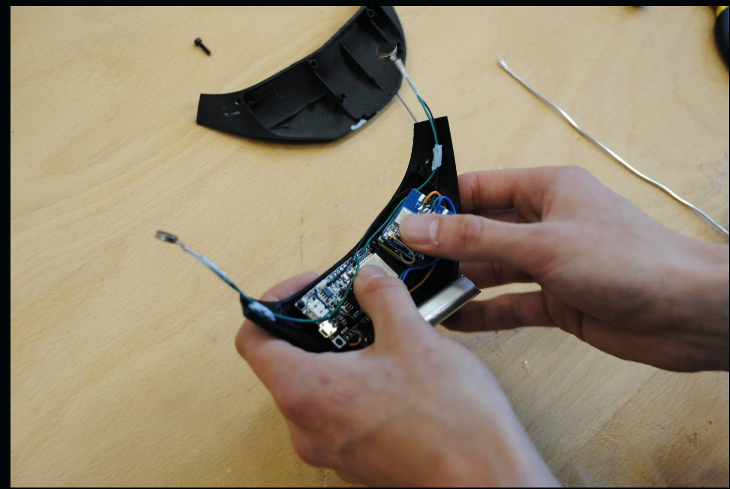


STEP 1

3D print all the parts, and prepare all the parts for assembly.

STEP 2

Apply conductive tape to the button area and cut it to fit.



STEP 3

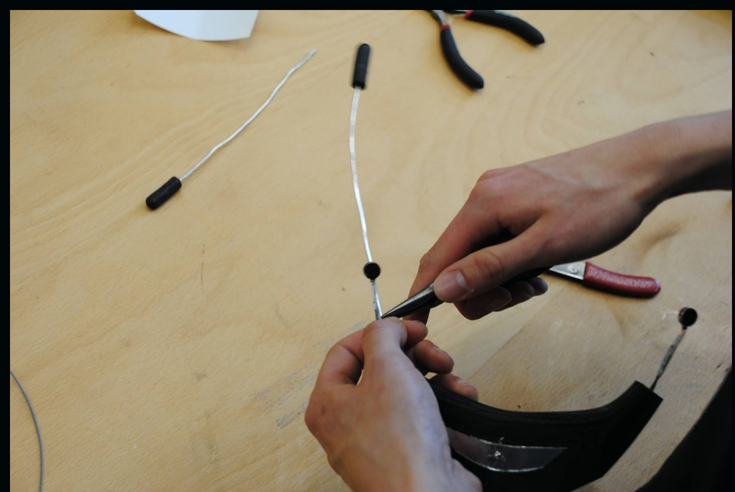
Place in the electronics into their mounts, helped by aligning features.

STEP 4

Place the back casing on top, and use the allen key to screw the cases together.

STEP 5

Solder the wire that connects to the capacitive touch to the foil button.



STEP 6

Use pliers to insert the metal wires to each side. These are attached to the clasp.

STEP 7

Slide on structural ribs, reinforce with padded wires and wrap in cloth.

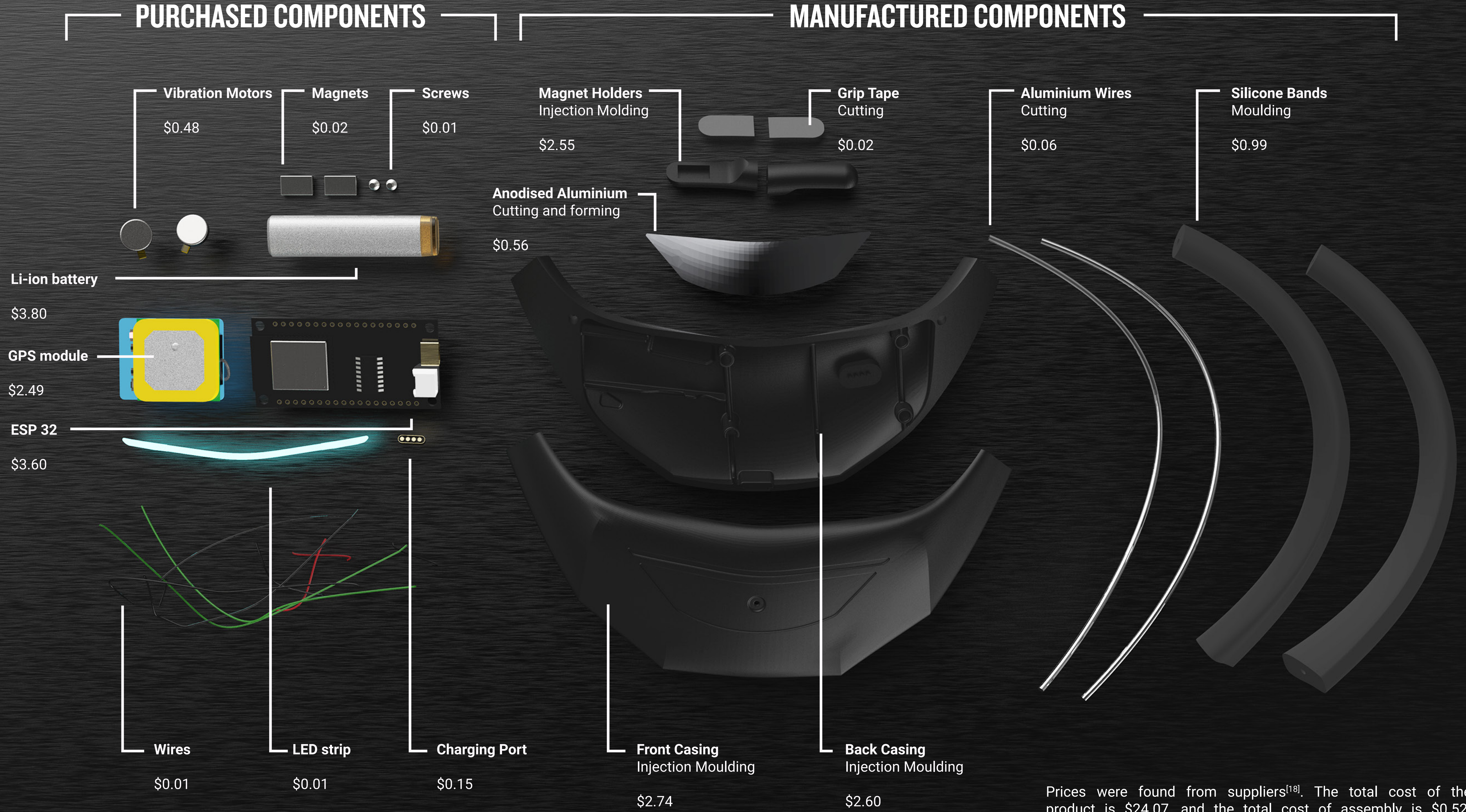
IN A COMMERCIAL PRODUCT:

- ASSEMBLY TIME REDUCED TO 51 SECONDS
- SIZE OF ELECTRONICS REDUCED BY OVER 50%

14 | ASSEMBLY

COST ANALYSIS

A BREAKDOWN OF COMPONENTS, BOTH MANUFACTURED AND PURCHASED, BY COST | REPORT P12



Prices were found from suppliers[18]. The total cost of the product is $24.07, and the total cost of assembly is $0.52. Our target being able to retail for under £100 with a 50% profit margin was met, therefore it will be affordable to inexperienced cyclists who don't want to invest heavily in new equipment.

LAWS AND REGULATIONS

GARMIN'S MAIN MARKETS ARE: THE EU, UK, US, AND CANADA: EACH HAS THEIR OWN REGULATIONS AND SAFETY LEGISLATION OUR PRODUCT MUST SATISFY | **REPORT P13-14**

UNITED STATES

FCC - 47 CFR PART 15

Covers regulations for class B radio frequency devices. Our product is in the class B category as an intentional radiator (communicates with radio waves at low power) [19].

RELEVANT LAWS

- ANSI C63.4 - radio noise emissions from low-voltage electrical equipment[20]
- ANSI C63.10 - testing unlicensed wireless devices[21]

The FCC also requires labelling for traceability:

- Issuing company
- Address
- Phone number
- Country of Origin
- Product name
- Model number
- Applicable standard (e.g. for our product: FCC Part 15, Subpart B, Intentional Radiators)

UK & EU

REQUIRED ON PRODUCTS SOLD IN THE UK FROM JAN 2023

ELECTROMAGNETIC COMPATIBILITY REGULATIONS 2016 & RADIO EQUIPMENT REGULATION 2017

- Implements Directive 2014/53/EU promoting protection of the electromagnetic spectrum and the safety of radio equipment, relevant to the Bluetooth and GPS modules in the product[22].
- **EN 300 328** standard for data transmission equipment in the 2.4GHz ISM band[23]. **EN 301 489-1** standard for common technical requirements related to electromagnetic compatibility radio equipment and services[24].

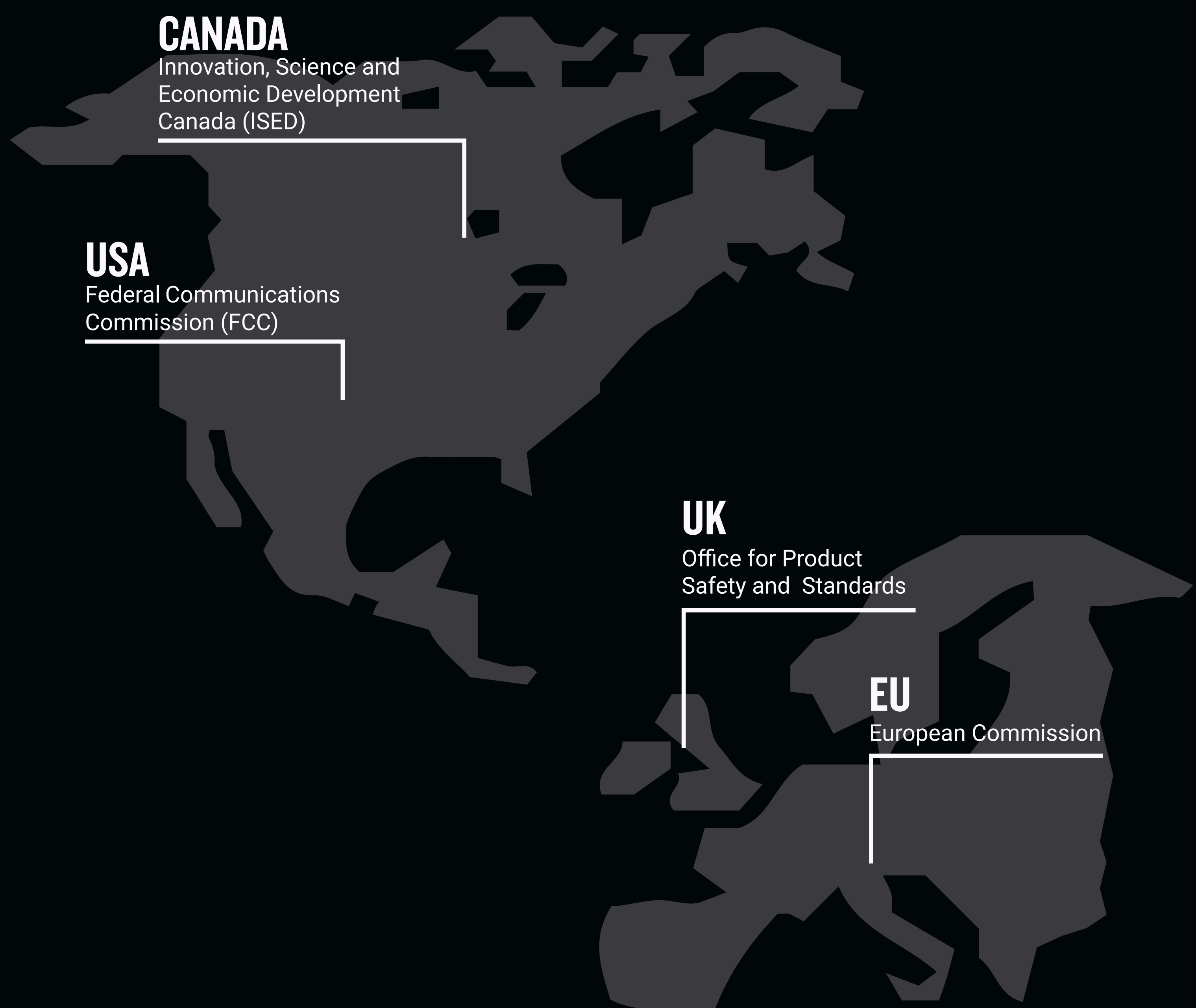
ELECTRICAL EQUIPMENT SAFETY REGULATIONS 2016

- Implements Low Voltage Directive (2014/35/EU) on electrical equipment designed for use within certain voltage limits[25].

ROHS IN ELECTRICAL AND ELECTRONIC EQUIPMENT 2012

- Guidance for EEE products, Restricting the use of certain Hazardous Substances. This is relevant mostly in the battery component.
- **EN IEC 63000:2018** standard for restriction of hazardous substances[26].

REGULATORY AUTHORITIES



CANADA

Canada's regulating body is Innovation, Science and Economic Development Canada (ISED). Products sold in Canada may have the FCC declaration and/or the CE declaration, however, neither declaration has any legal significance in Canada. Instead, the CSA mark is used.

Much of Canadian legislation often uses harmonised ANSI standards in their regulations meaning that, in general, if a product is certified for use in the US, it will also comply in Canada [27].

LABELLING

SUMMARY OF PRODUCT COMPLIANCE AND LABELLING FOR PRODUCTS SOLD IN THE UK | REPORT P13-4

PRODUCT

WEEE

Due to the electronics, the product should not be discarded in general waste, and must be sent to a separate collection facility[28].

CE AND UKCA

The CE mark indicates the product can be sold in the EU, and the UKCA indicates it can be sold in Great Britain. The product must conform to both requirements. The letters must have the same vertical dimensions and be no smaller than 5mm[29].

PACKAGING

GREEN DOT

Indicates the producer has made a financial contribution to packaging recovery, sorting and recycling[30].

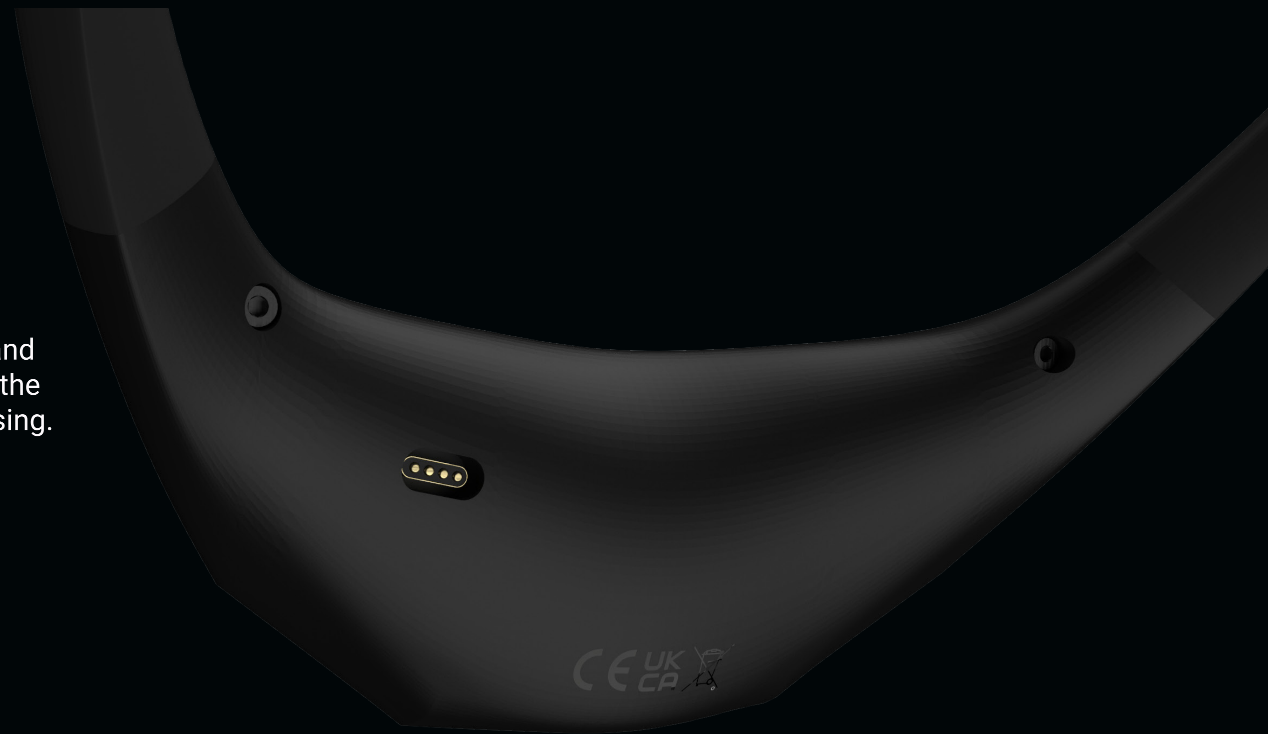
MOBIUS LOOP

Packaging is recyclable and meets the requirements of the Packaging Directive, although it may not be accepted in every recycling centre[31].

FSC CERTIFIED

All the forest-based materials are verified as 100% recycled and have a Forest Stewardship Council label[32].

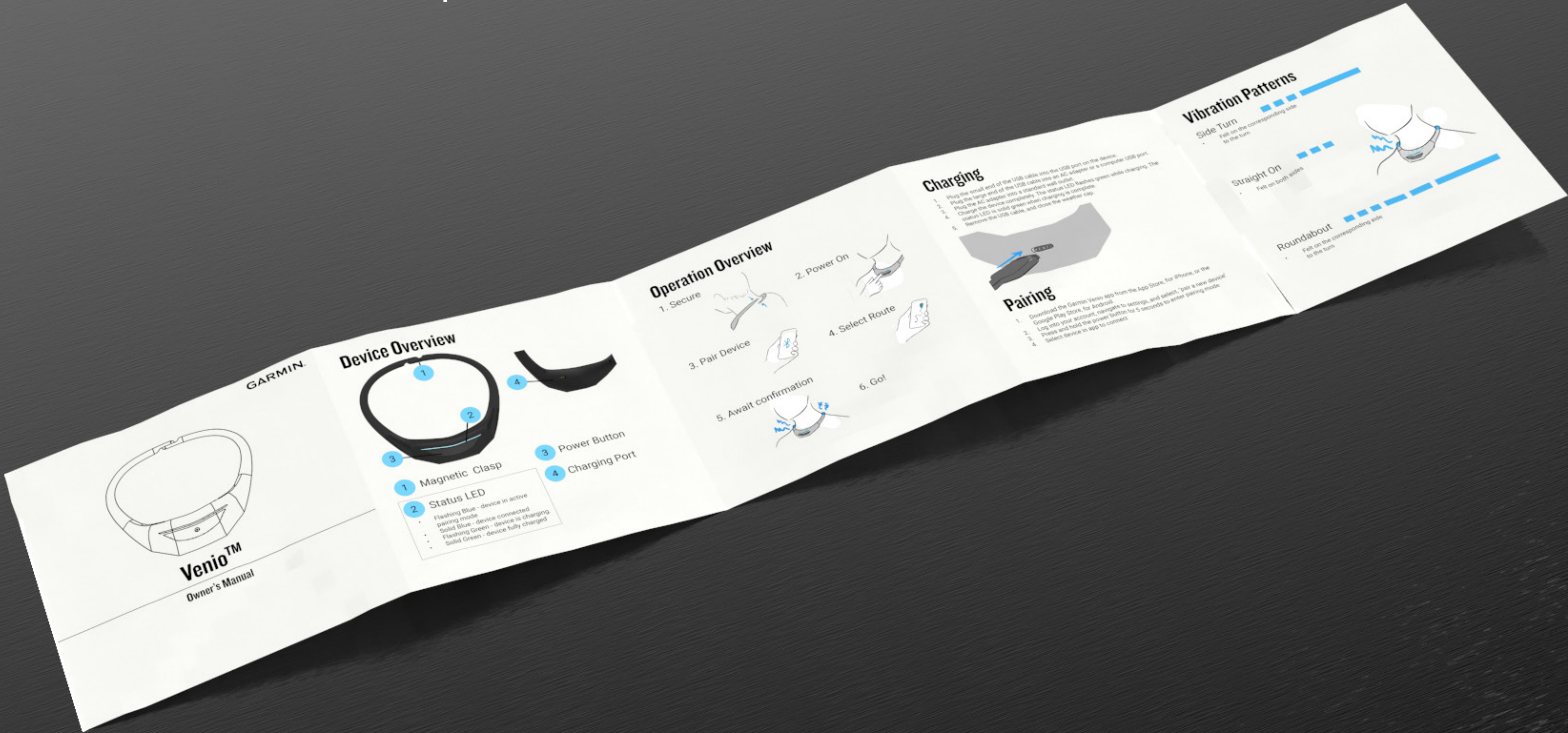
Labels present on the product will also be present in the packaging. It will also have a bar code, serial number, name of manufacturer and address. Safety information will be displayed on the box and on the instruction manual, including warnings and maximum voltage.



All labels must be clearly visible and legible, and so will be placed on the back of the casing.

USER GUIDE DESIGN

RENDERED IMAGE OF THE USER GUIDE IN GARMIN'S STYLING | REPORT P15



DEVICE OVERVIEW

This page details touchpoints and their location on the device, outlining each function. Additional details are provided on colour language of the status LED.

OPERATION INSTRUCTIONS

Visual communication of how to use the product, including how to wear, turn on, pair, and select route. Information regarding the app is also provided.

CHARGING AND PAIRING

This section walks through how to charge the device and pair it with the Garmin Venio app.

VIBRATION PATTERNS

Users must understand what the vibrations mean. A visual representation of this is provided.

PRODUCT PACKAGING

TESTING INDIVIDUAL ELEMENTS OF PRODUCT | REPORT P16

EXISTING PACKAGING

Garmin focuses on giving the consumer all the practical information in clear and minimal packaging. We will be using grey, and similar render styles for easy recognition on the shelf.

The high quality of the product should be reflected on the packaging, as it strengthens the sense of well-spent money. This is achieved through the sleek dark and glossy finish.

Minimal inserts are used to hold the product. This reduces production costs and weight. No plastic is used. All Garmin products are sold in cuboidal boxes to facilitate stacking and transportation.

To keep the information concise, Garmin uses symbols to explain the function of the product. In Venio, this will be on the inner part of the box to inform the consumer of the main features of the product.

VENIO PACKAGING

SLEEVE

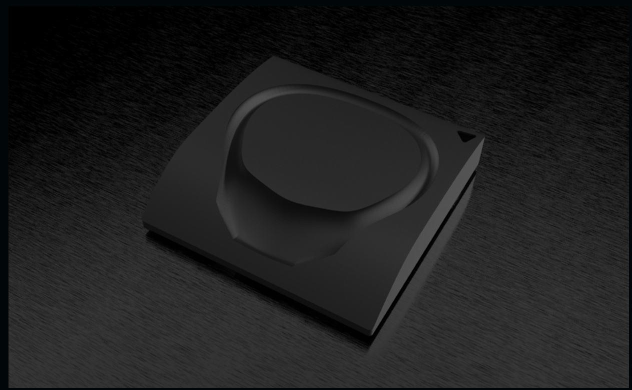
FUNCTION: Convey function to the buyer, fit in with Garmin's packaging convention.

MATERIAL: 100% recycled paper (200 gsm), flexography printing.

BOX

FUNCTION: Contain the device.

MATERIAL: embossed matboard, flexography printing, spot UV varnish.



INSERT

FUNCTION: Protect and hold the device. Features a cutout that can be used to pull it up and reveal the pouch underneath.

MATERIAL: Moulded fibre.

POUCH

FUNCTION: Hold user guide and charger in a sleek way.

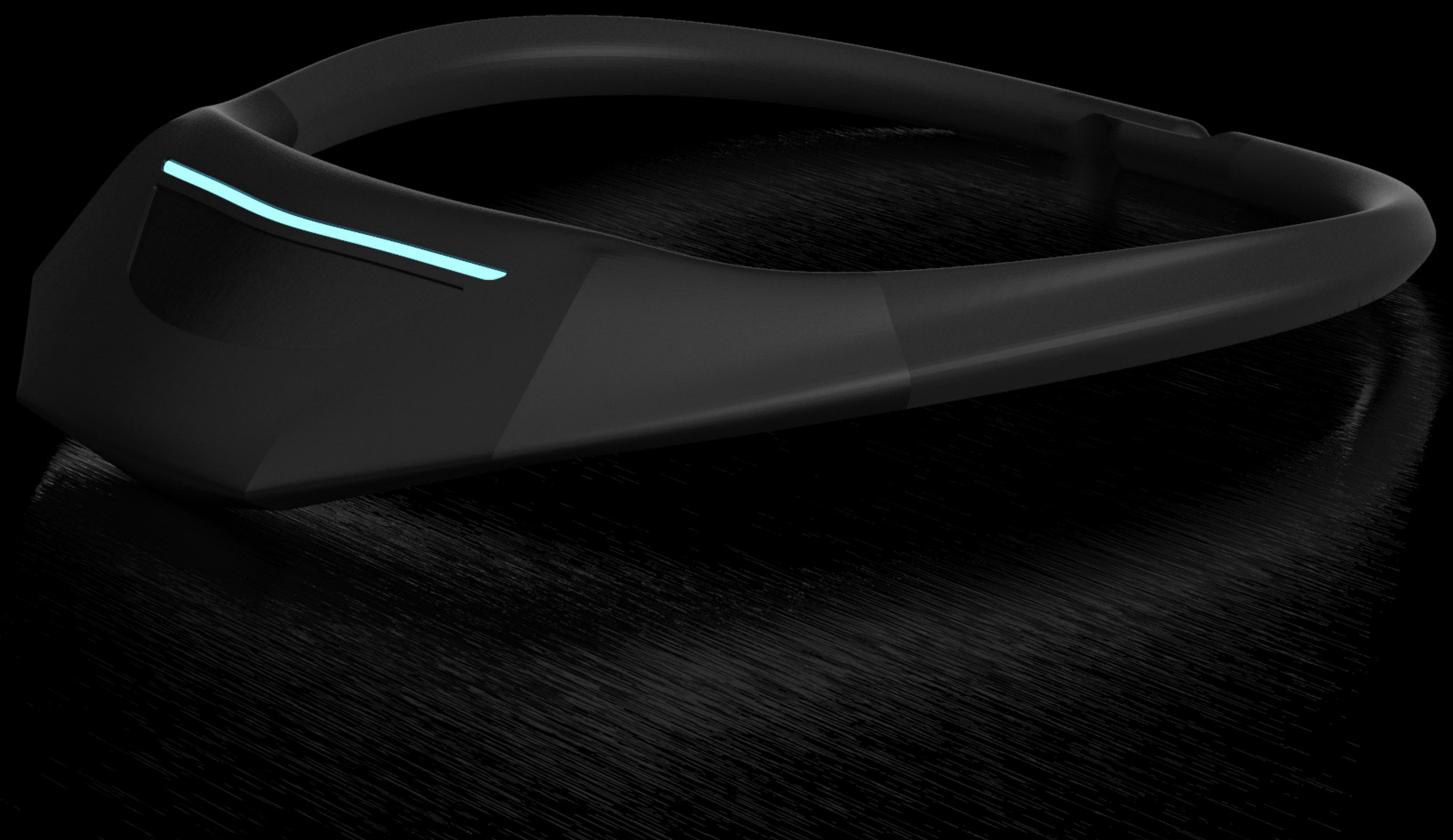
MATERIAL: 100% recycled paper (200 gsm), flexography printing.

19 | FINAL PRODUCT

PACKAGING RENDER

GARMIN VENIO

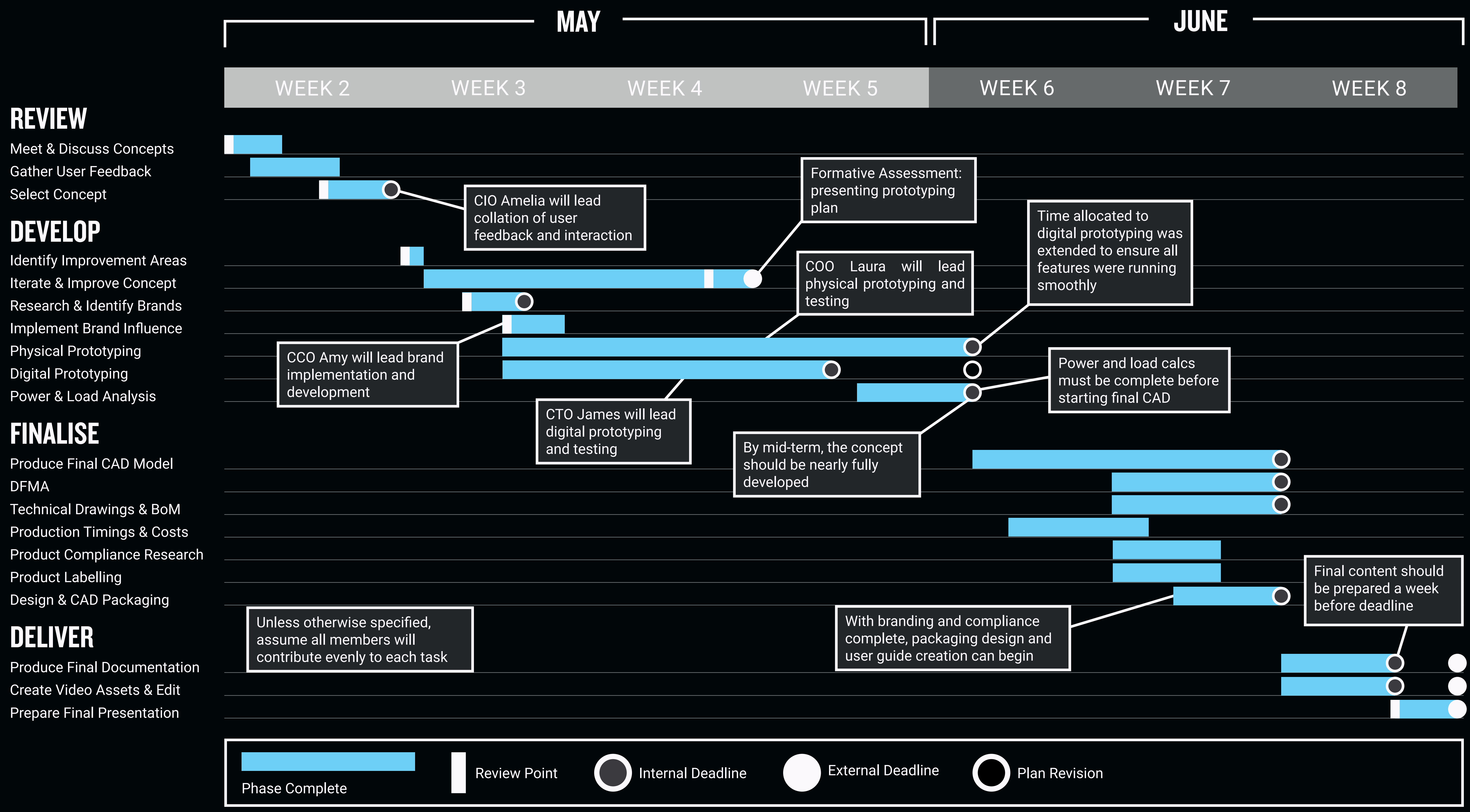
GARMIN VENIO

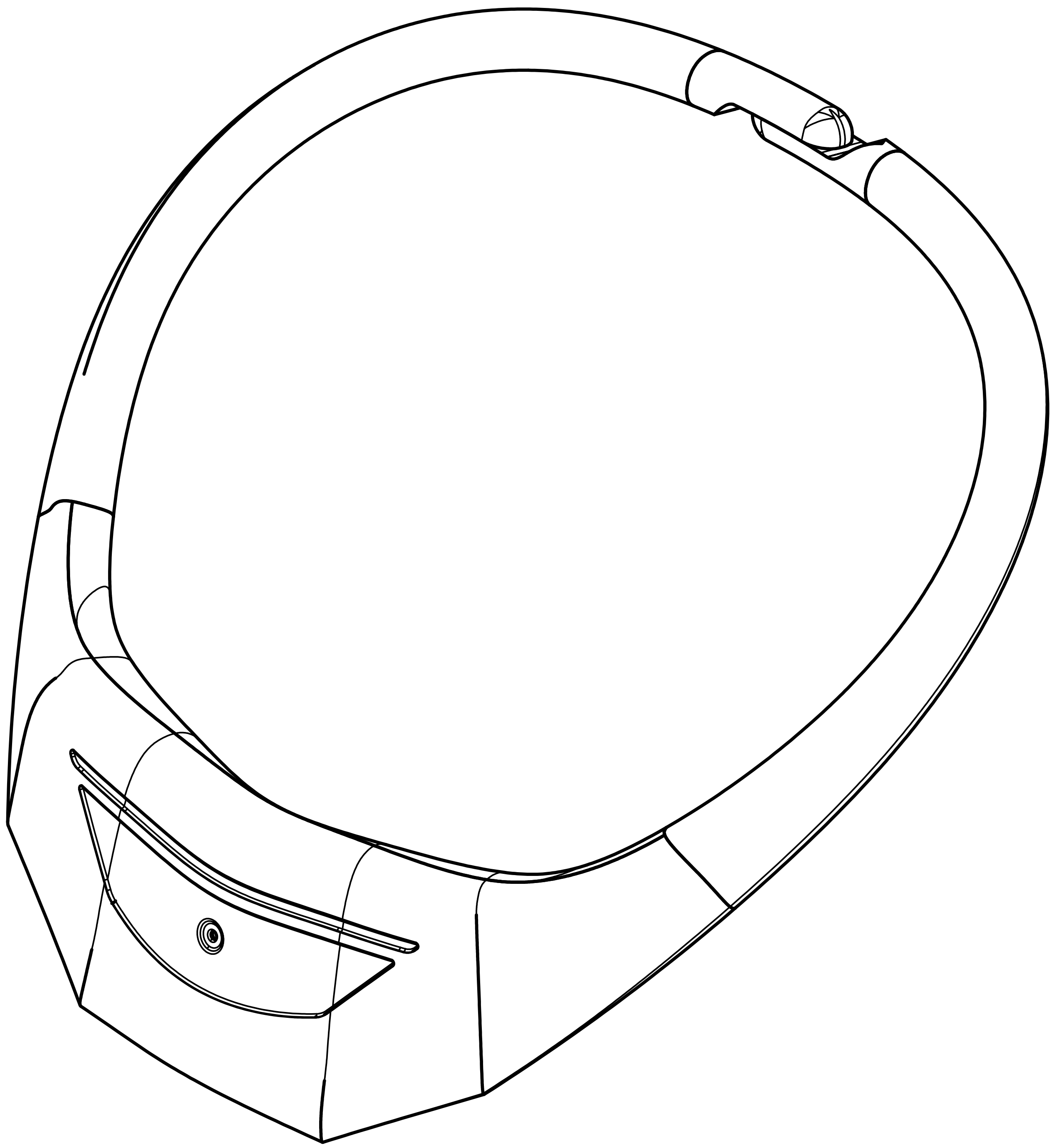


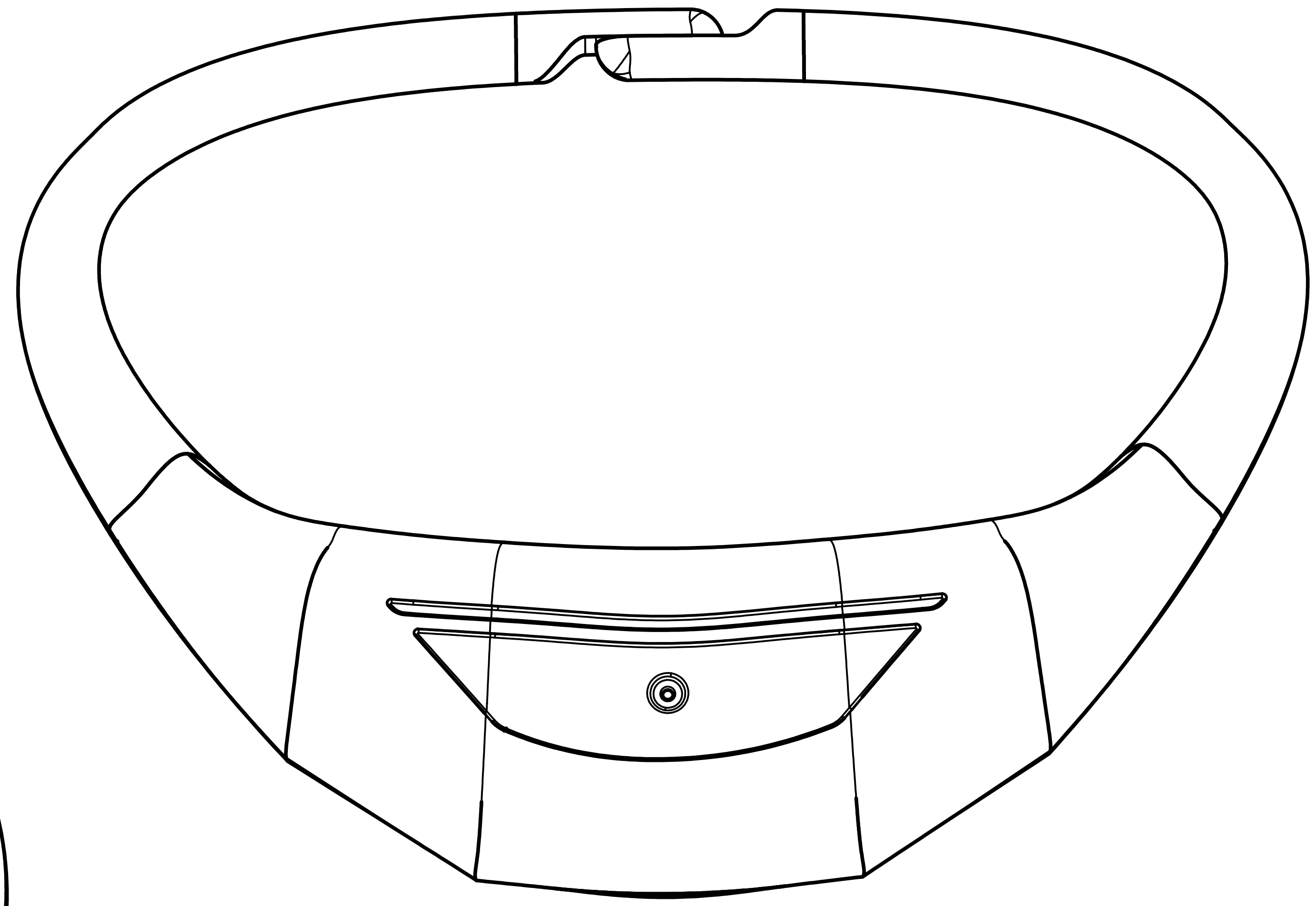
GARMIN

GANTT CHART

PROJECT PLAN WITH REVISIONS AND MILESTONES | REPORT P17







UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILIMETRES SURFACE FINISH: SPI B2 TOLERANCES: LINEAR: ±0.5 ANGULAR: ±0.15	SURFACE FINISH: MATTE FINISH	DEBURR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

GARMIN VENIO

	NAME	DATE
DRAWN	James Howells	6/15/2022
CHECK'D	Amelia Bryant	22/06/2022
APPV'D		

TITLE:

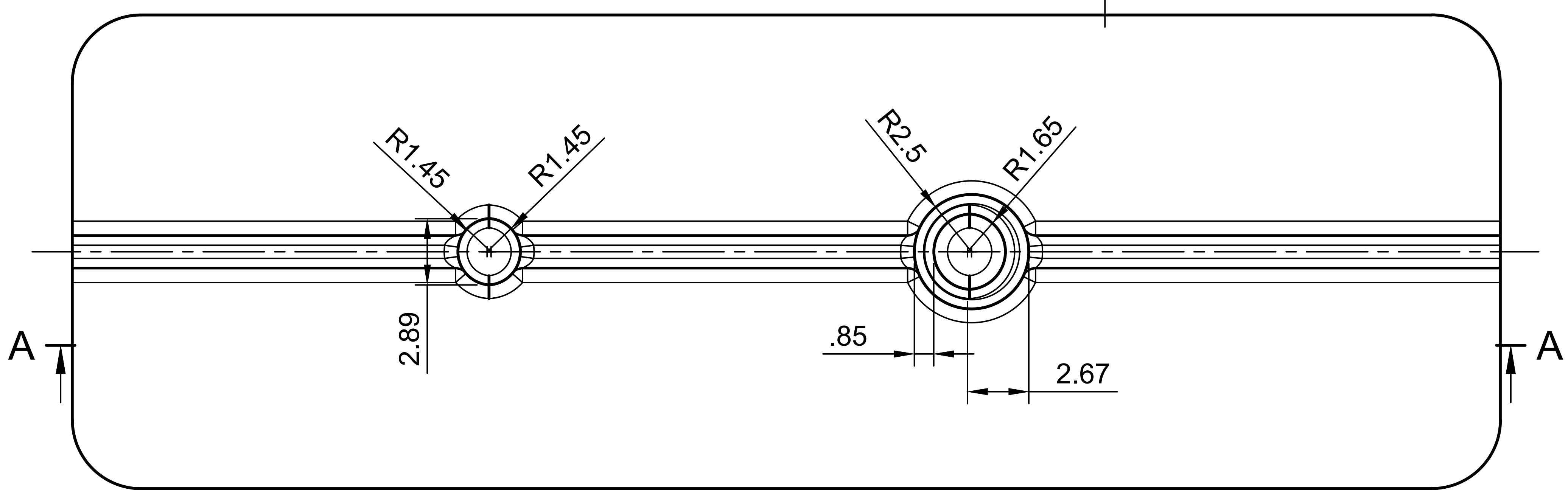
OVERVIEW

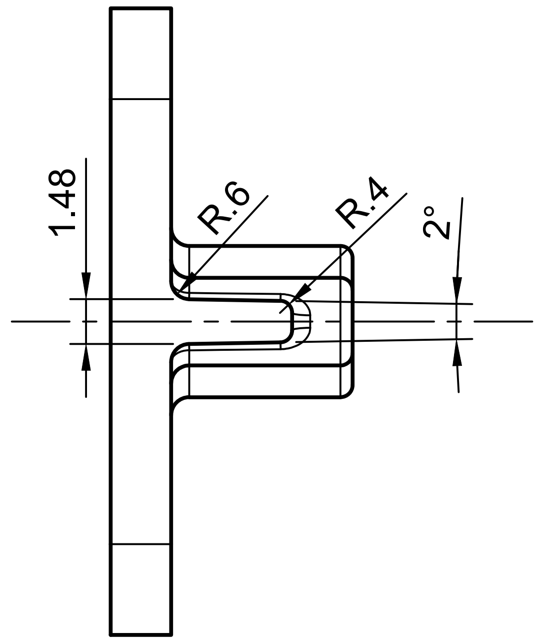
FIRST-ANGLE PROJECTION

DWG No.: VEN-001

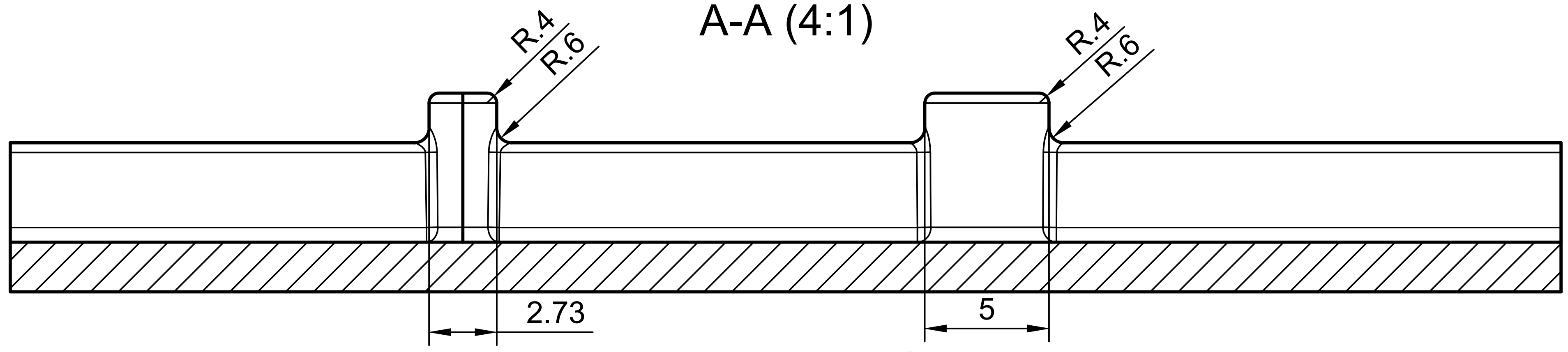
SIZE: A3

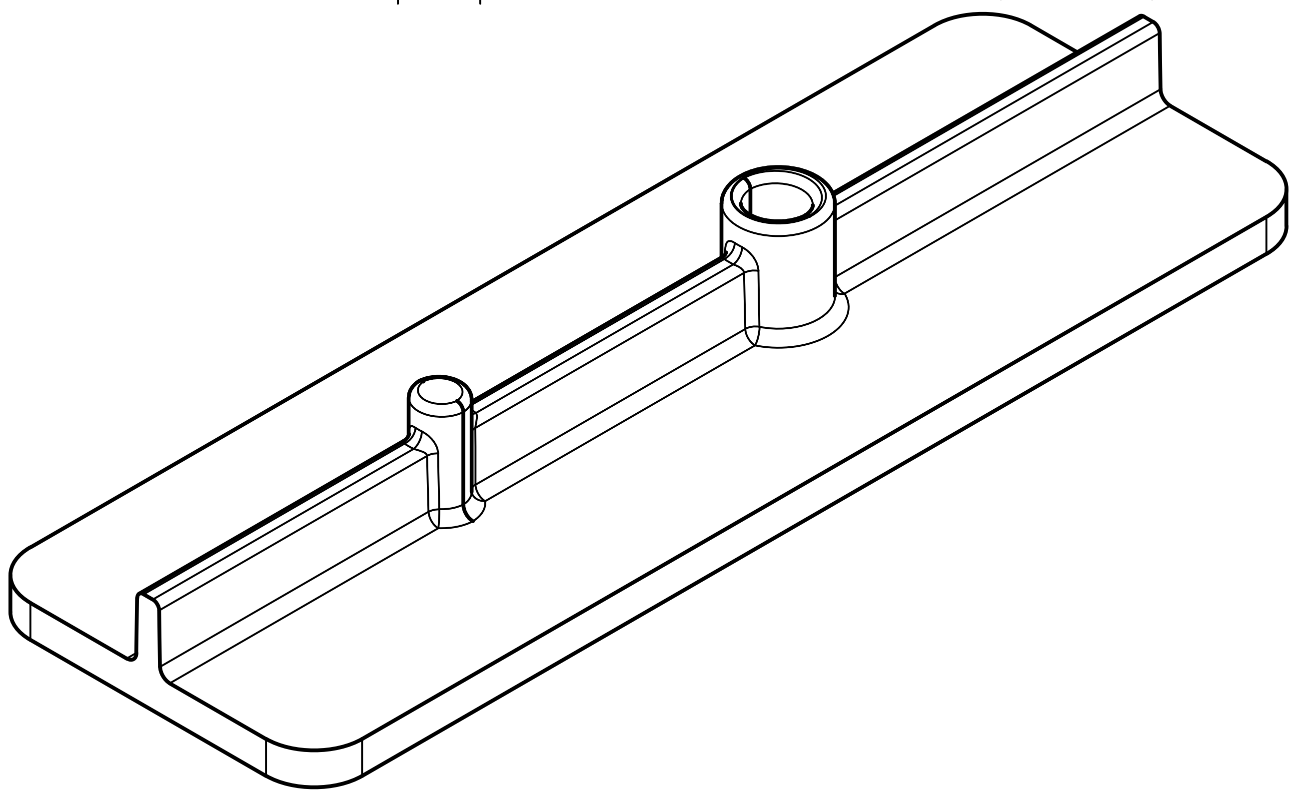
SCALE: 1:1





A-A (4:1)



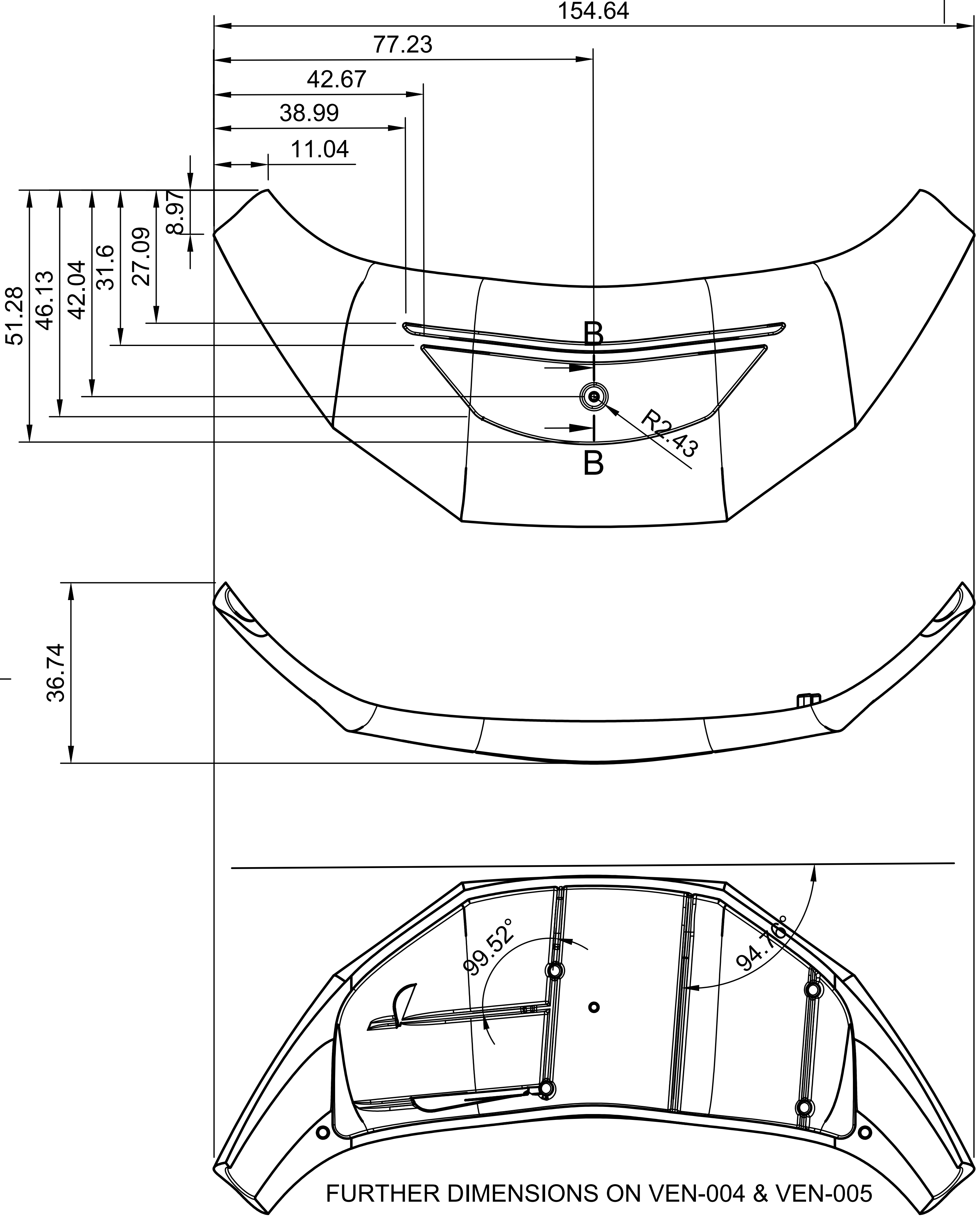


THIS SHEET PROVIDES GENERAL DIMENSIONS FOR RIBS, PINS AND BOSSES. FEATURE HEIGHTS ARE PROVIDED AS AND WHEN FEATURES ARE USED. DIMENSIONS SPECIFIED HERE WILL NOT BE SPECIFIED ON EACH FEATURE UNLESS THEY ARE DIFFERENT. FEATURES WILL BE LABELLED AS RIBS, PINS OR BOSSES.

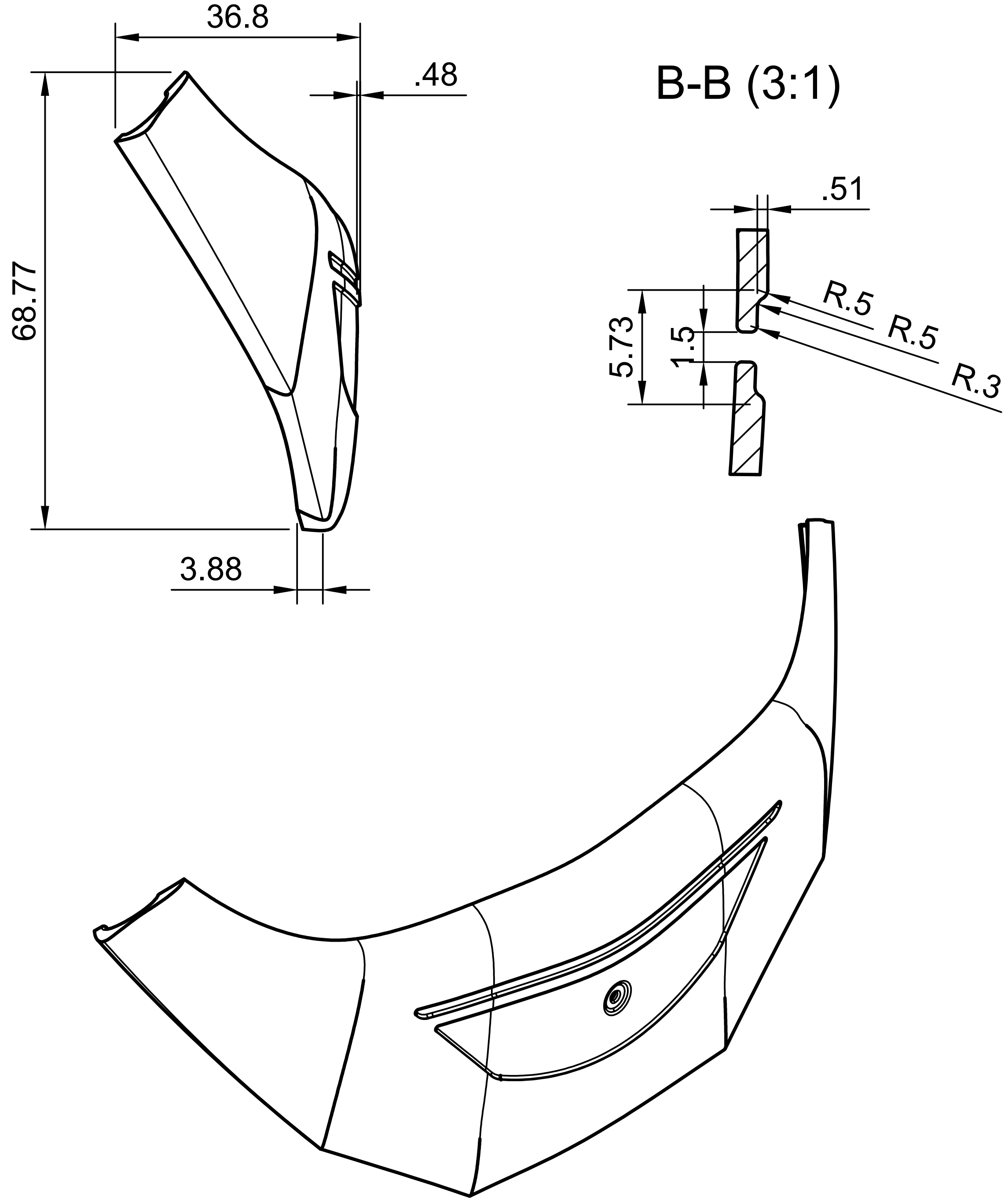
FILLETS AT BASE OF A FEATURE ARE ALWAYS .6 RADIUS, AT THE TOP ALWAYS .4 RADIUS.

THIS IS A SAMPLE PART TO DEMONSTRATE RIBS, PINS AND BOSSES.
IT IS NOT TO BE MANUFACTURED.

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILIMETRES SURFACE FINISH: SPI B2 TOLERANCES: LINEAR: ±0.5 ANGULAR: ±0.15	SURFACE FINISH: MATTE FINISH	DEBURR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING GARMIN VENIO
	NAME	DATE	TITLE:
DRAWN	James Howells	6/15/2022	RIBS AND BOSSES
CHECK'D	Amelia Bryant	22/06/2022	
APPV'D			
FIRST-ANGLE PROJECTION			DWG No.: VEN-002
			SIZE: A3
			SCALE: 1:1



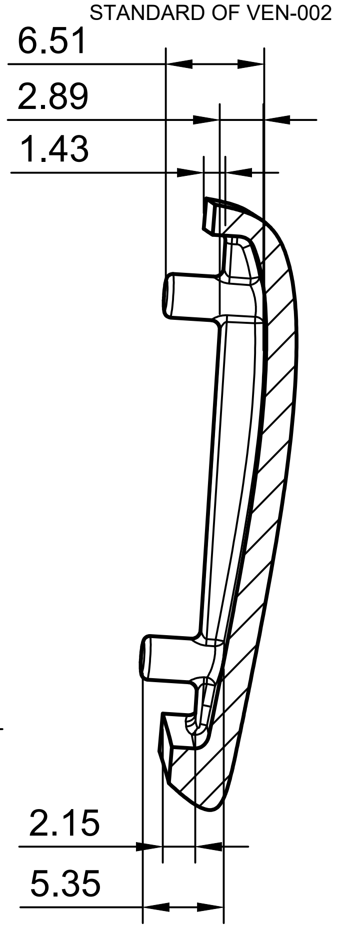
FURTHER DIMENSIONS ON VEN-004 & VEN-005

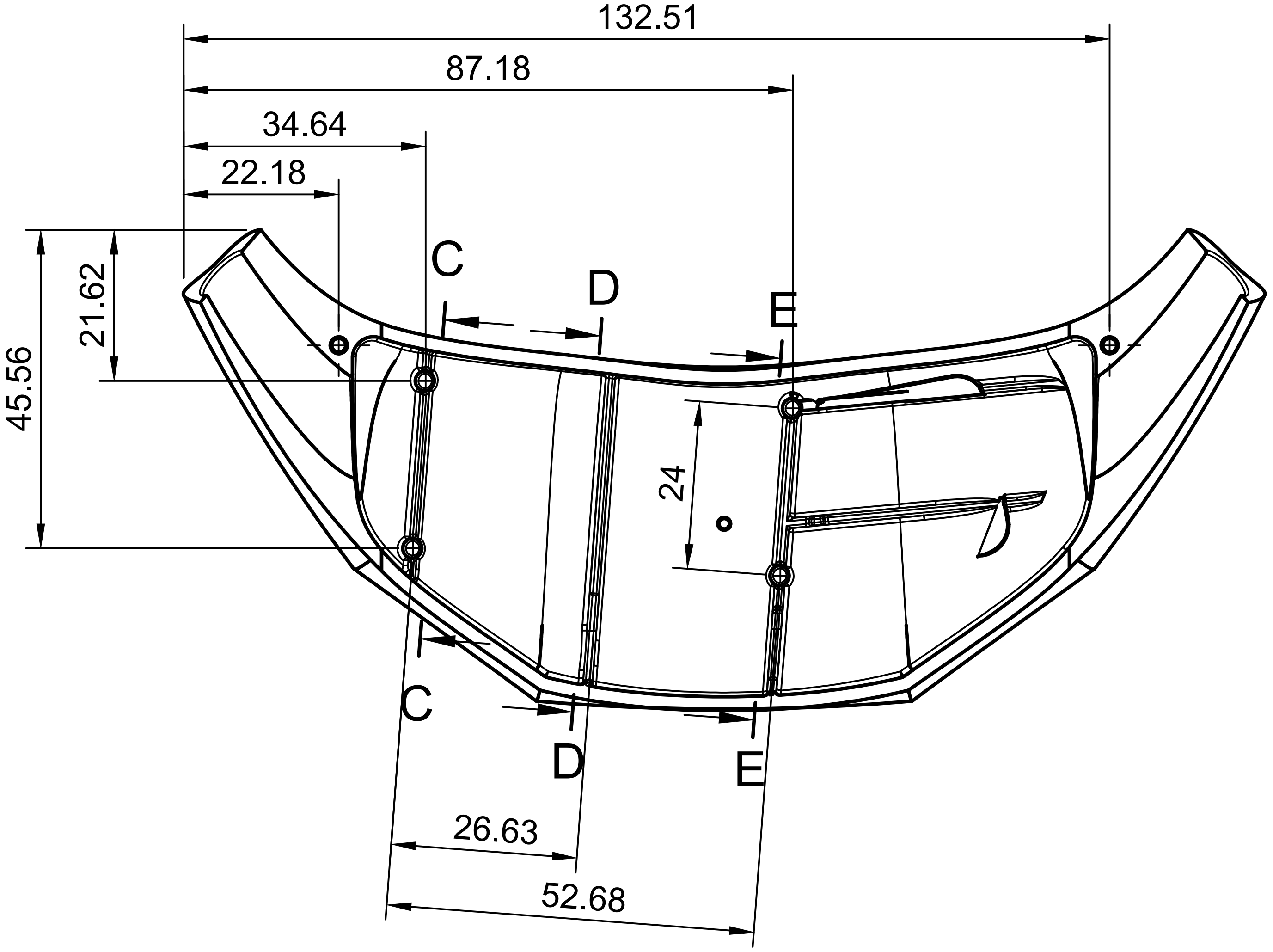


UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILIMETRES SURFACE FINISH: SPI B2 TOLERANCES: LINEAR: ±0.5 ANGULAR: ±0.15	SURFACE FINISH: MATTE FINISH	DEBURR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING GARMIN VENIO
	NAME	DATE	TITLE:
DRAWN	James Howells	6/15/2022	FRONT CASING 01 - OVERVIEW
CHECK'D	Amelia Bryant	22/06/2022	
APPV'D			
FIRST-ANGLE PROJECTION			DWG No.: VEN-003
			SIZE: A3
			SCALE: 1:1

C-C (2:1)

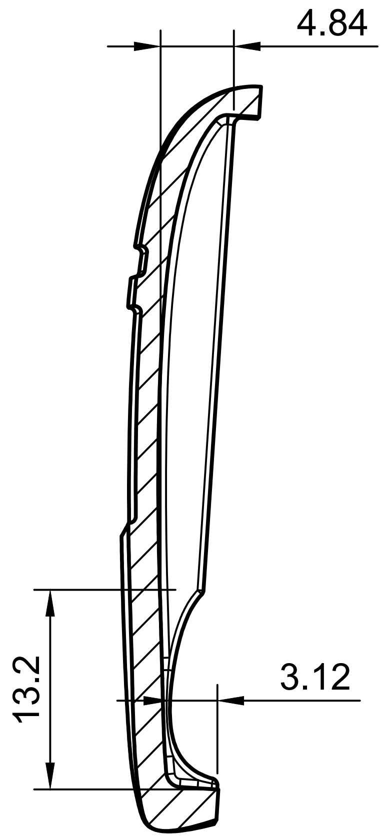
RIB AND PINS TO STANDARD OF VEN-002





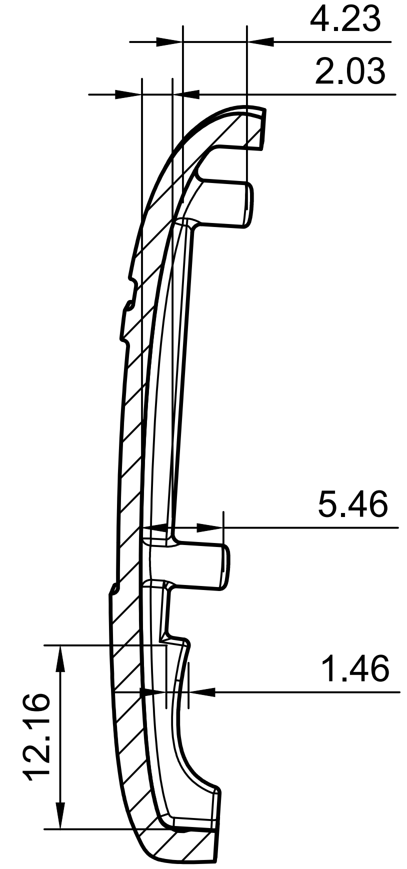
D-D (2:1)

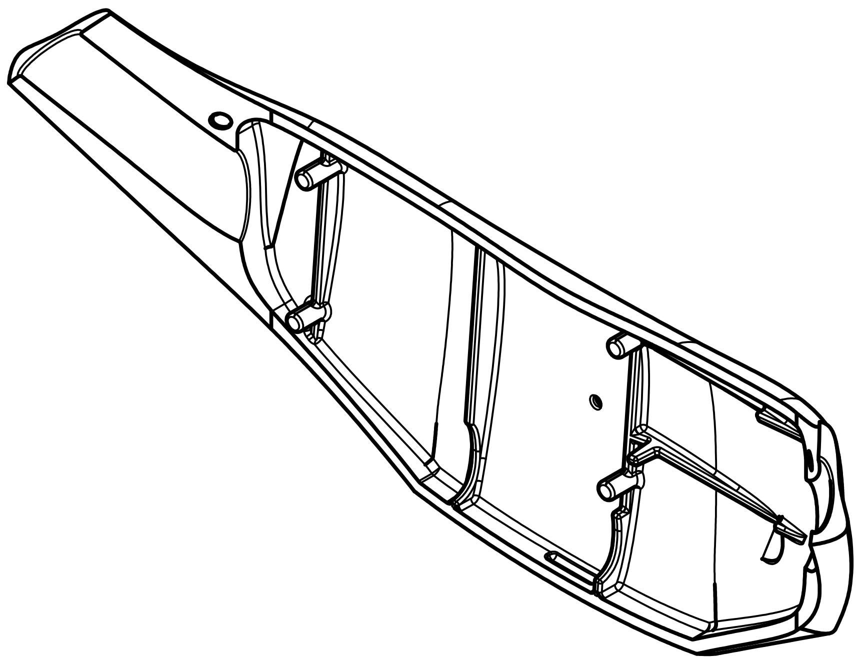
RIB TO STANDARD OF VEN-002



E-E (2:1)

RIB AND PINS TO STANDARD OF VEN-002





UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILIMETRES
SURFACE FINISH: SPI B2
TOLERANCES:
LINEAR: ±0.5
ANGULAR: ±0.15

SURFACE FINISH: MATTE FINISH

DEBURR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

GARMIN VENIO

	NAME	DATE
DRAWN	James Howells	6/15/2022
CHECK'D	Amelia Bryant	22/06/2022
APPV'D		

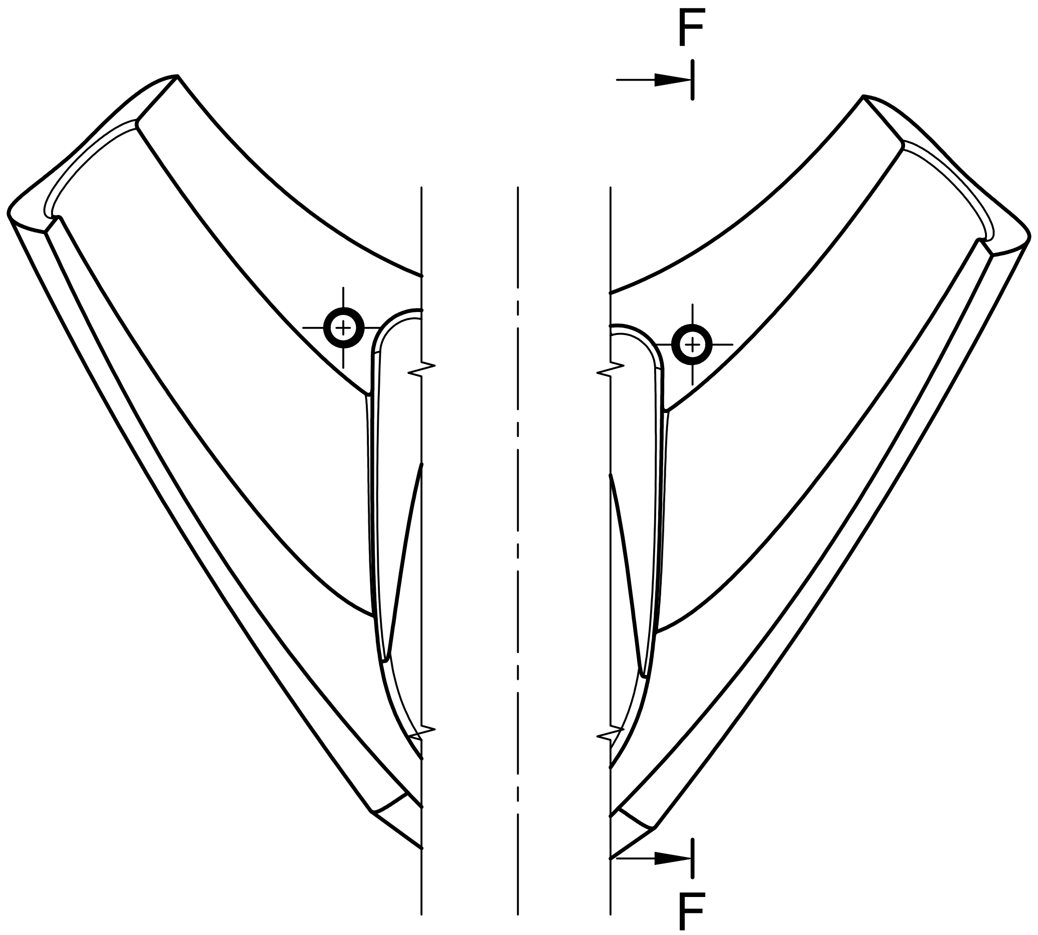
FIRST-ANGLE PROJECTION

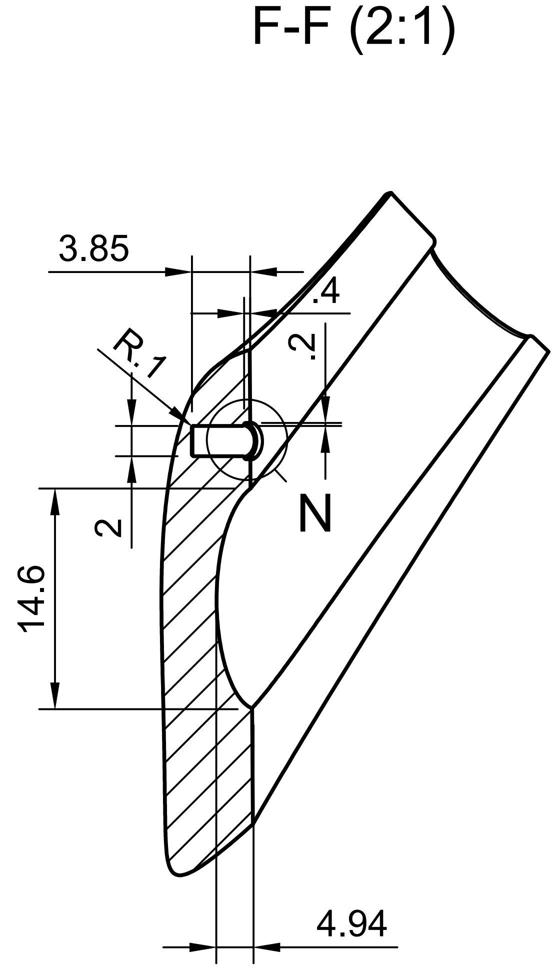
TITLE: FRONT CASING 02 - RIBS

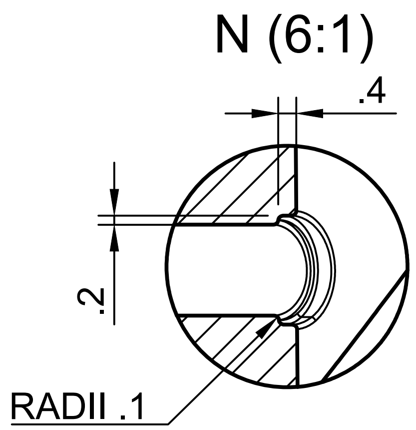
DWG No.: VEN-004

SIZE: A3

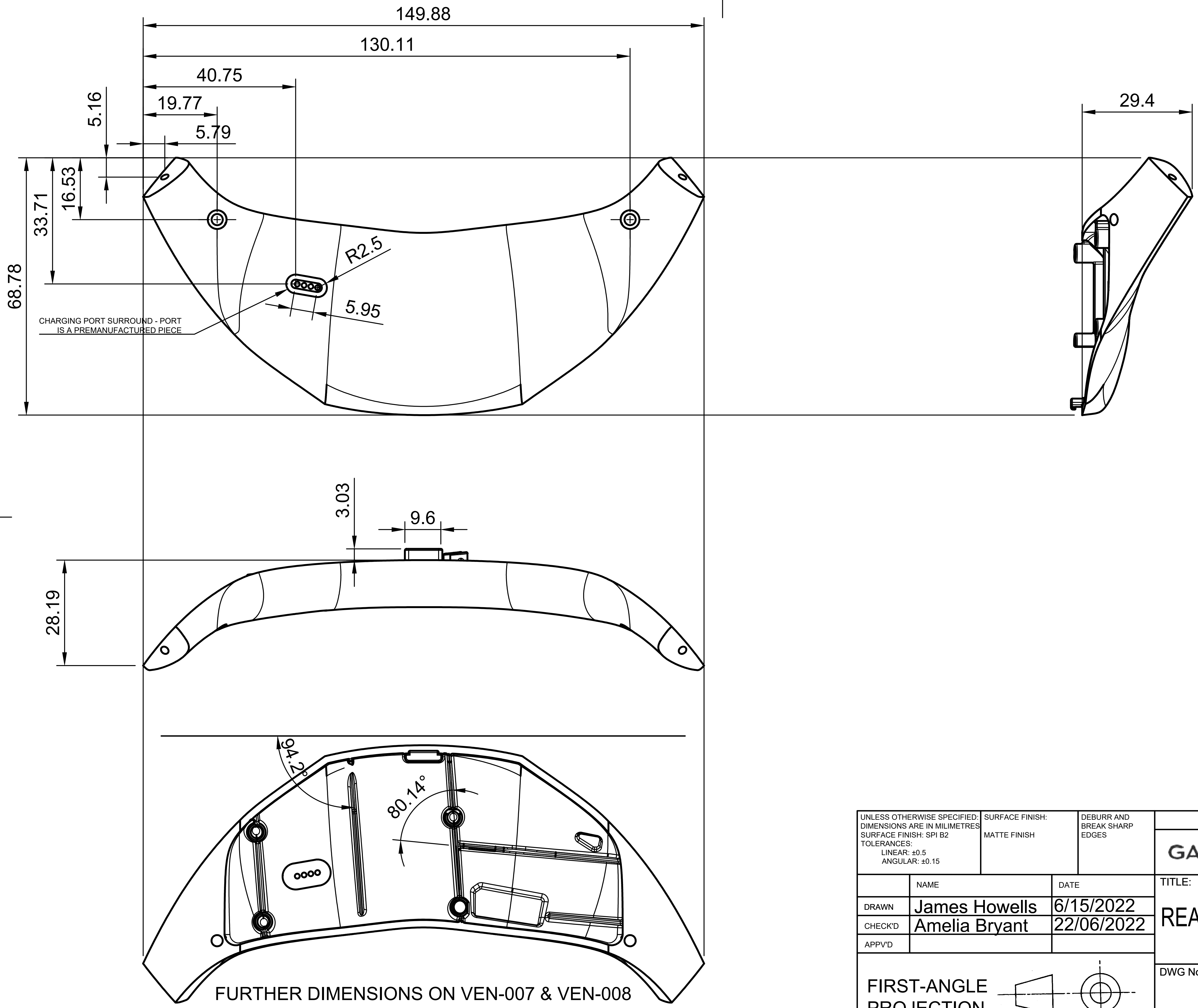
SCALE: 1:1







UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILIMETRES SURFACE FINISH: SPI B2 TOLERANCES: LINEAR: ±0.5 ANGULAR: ±0.15	SURFACE FINISH: MATTE FINISH	DEBURR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	GARMIN VENIO
	NAME	DATE	TITLE:	
DRAWN	James Howells	6/15/2022	FRONT CASING 03 - WINGS	
CHECK'D	Amelia Bryant	22/06/2022		
APPV'D				
FIRST-ANGLE PROJECTION			DWG No.: VEN-005	SIZE: A3 SCALE: 2:1



UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILIMETRES SURFACE FINISH: SPI B2 TOLERANCES: LINEAR: ±0.5 ANGULAR: ±0.15	SURFACE FINISH: MATTE FINISH	DEBURR AND BREAK SHARP EDGES

	NAME	DATE
DRAWN	James Howells	6/15/2022
CHECK'D	Amelia Bryant	22/06/2022
APPV'D		

FIRST-ANGLE PROJECTION

DO NOT SCALE DRAWING

GARMIN VENIO

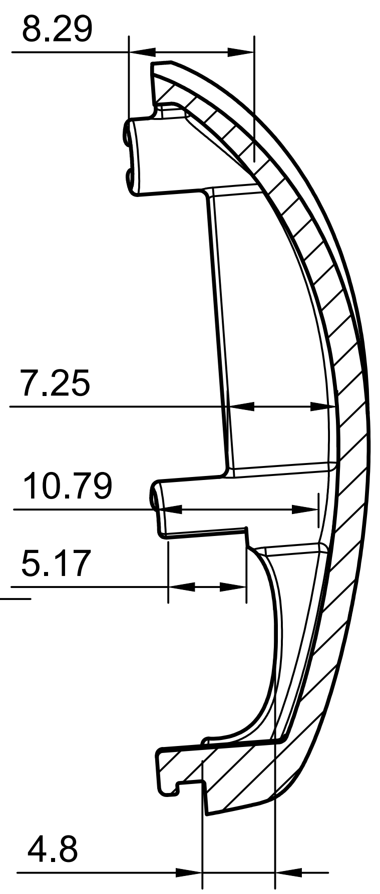
TITLE:

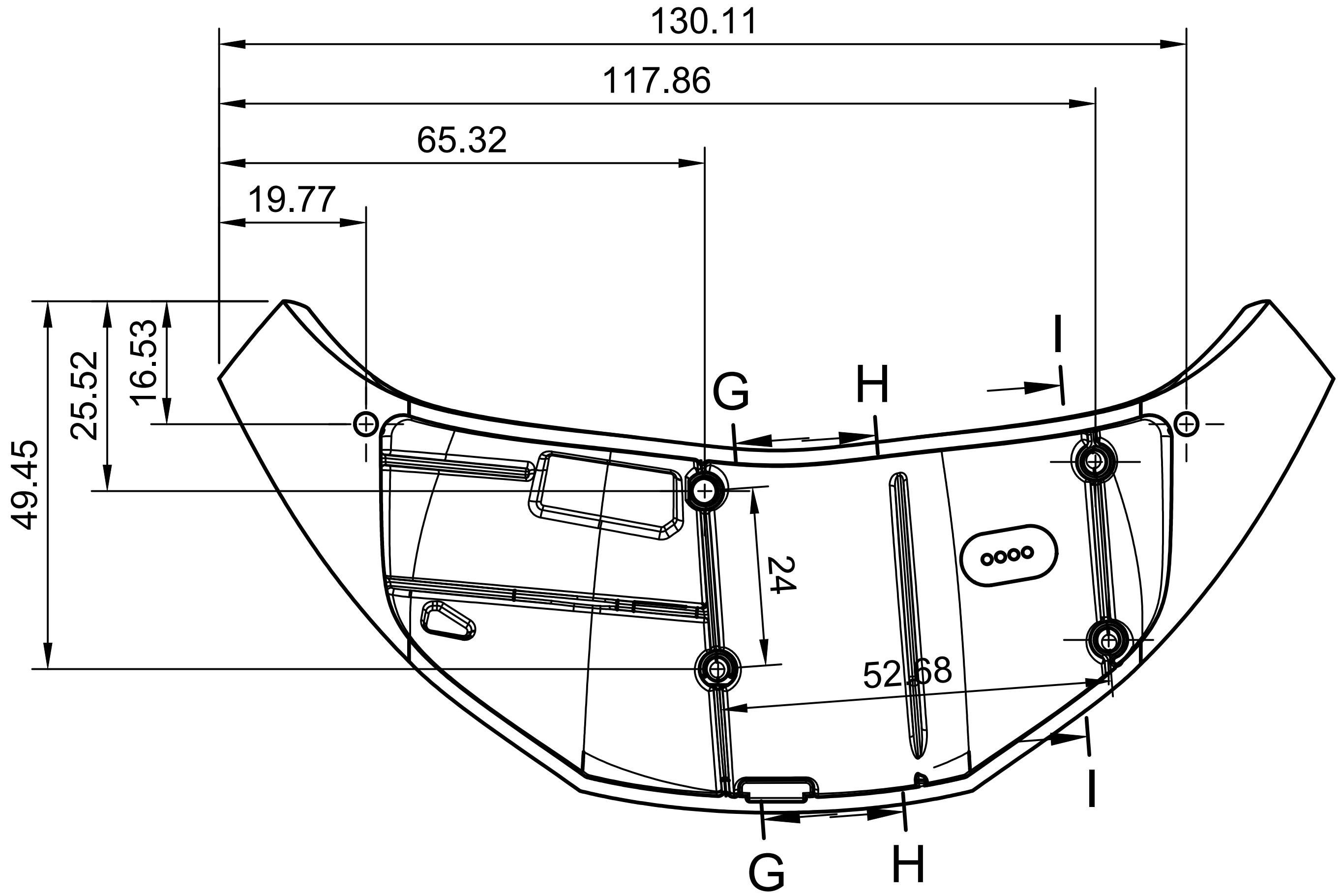
REAR CASING 01 - OVERVIEW

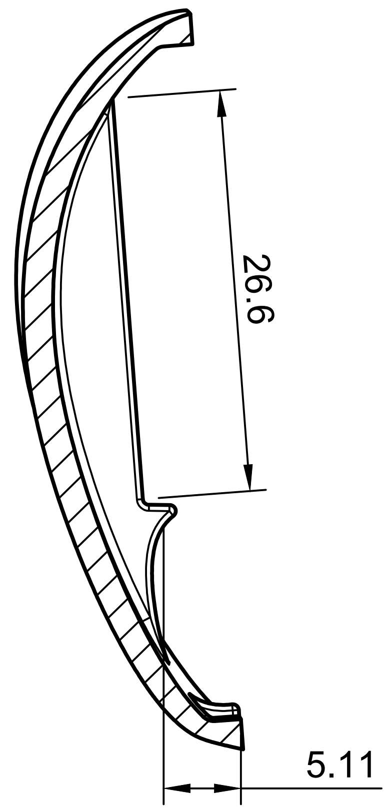
DWG No.: VEN-006

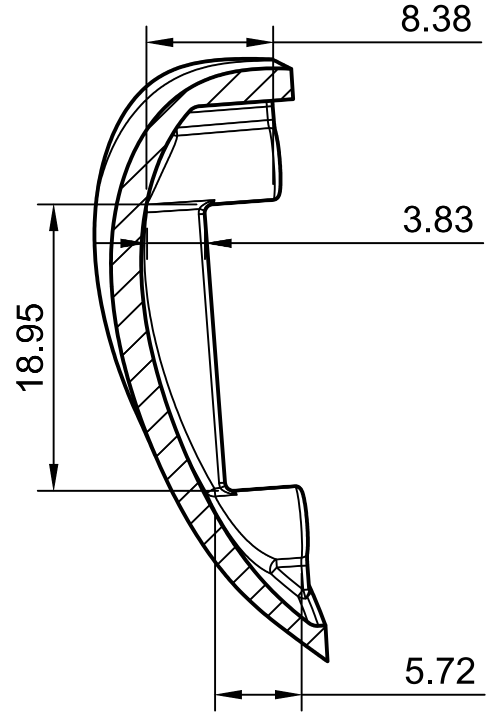
SIZE: A3

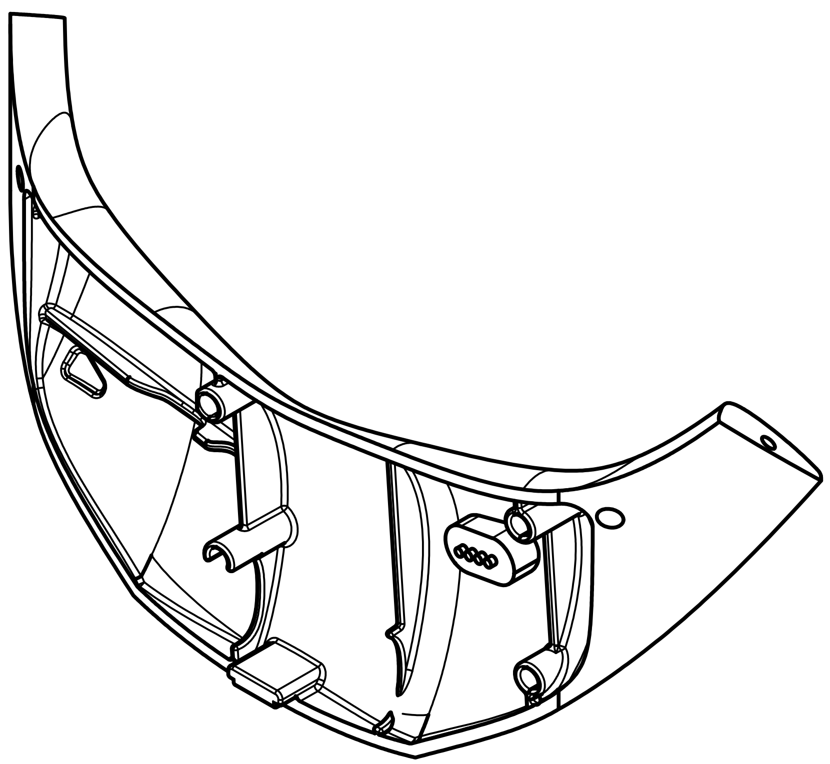
SCALE: 2:1



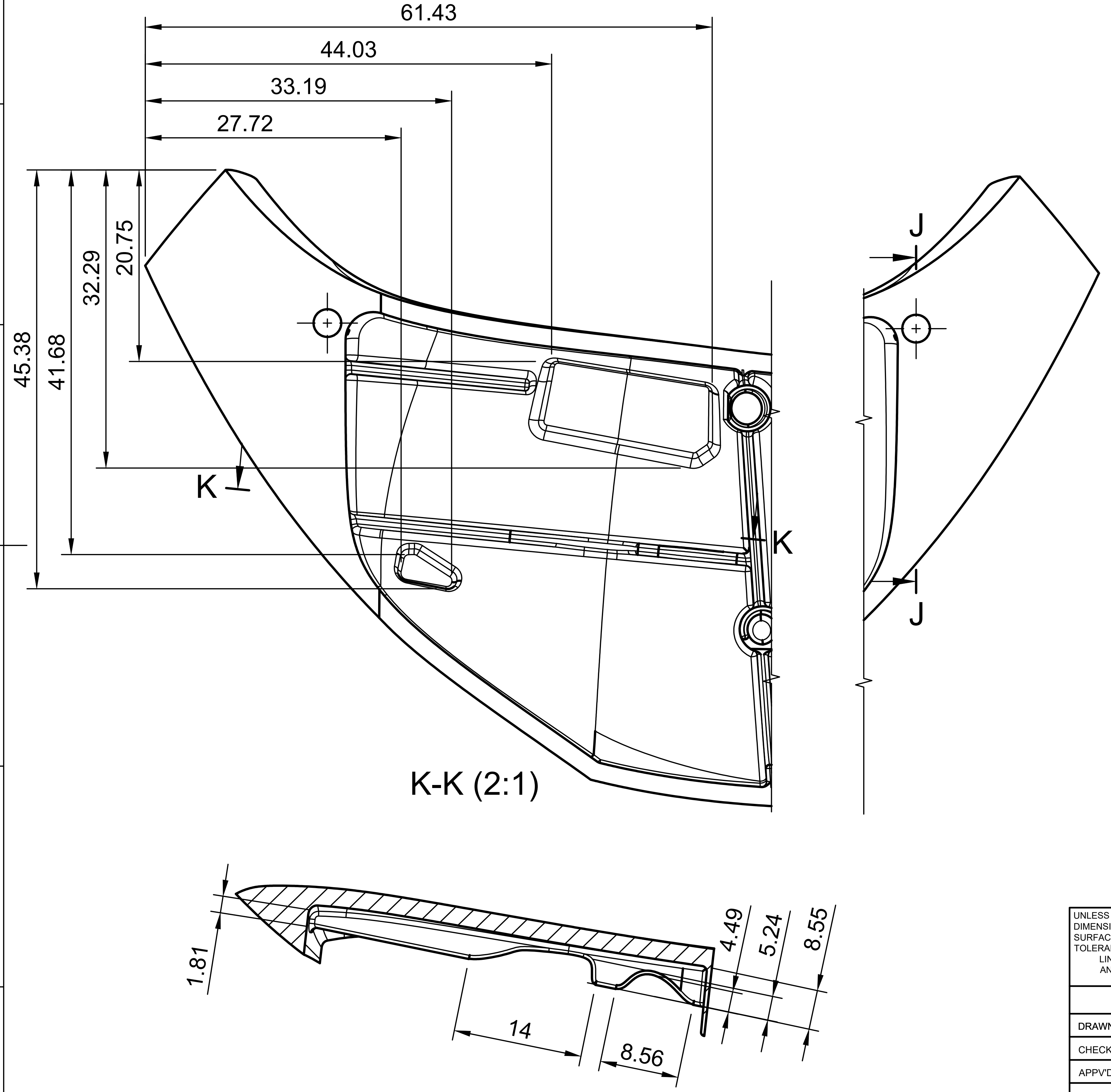






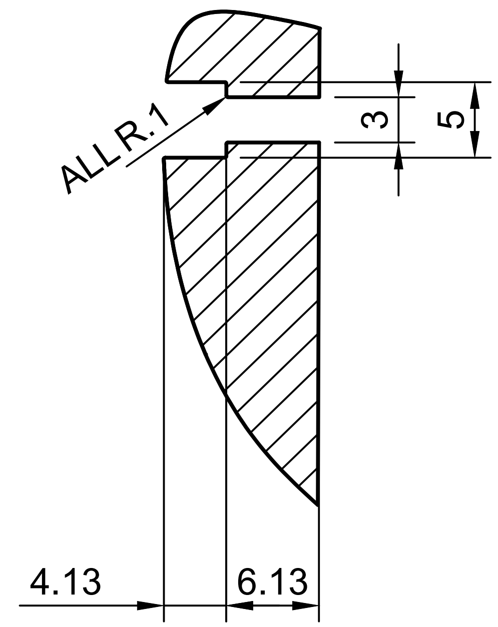


UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILIMETRES SURFACE FINISH: SPI B2 TOLERANCES: LINEAR: ±0.5 ANGULAR: ±0.15	SURFACE FINISH: MATTE FINISH	DEBURR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING GARMIN VENIO
	NAME	DATE	TITLE:
DRAWN	James Howells	6/15/2022	REAR CASING 02 - RIBS
CHECK'D	Amelia Bryant	22/06/2022	
APPV'D			
FIRST-ANGLE PROJECTION			DWG No.: VEN-007
			SIZE: A3
			SCALE: 1:1



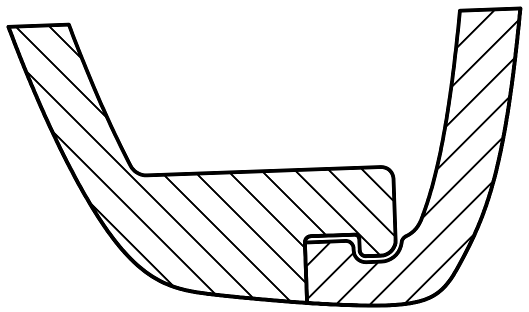
K-K (2:1)

J-J (2:1)

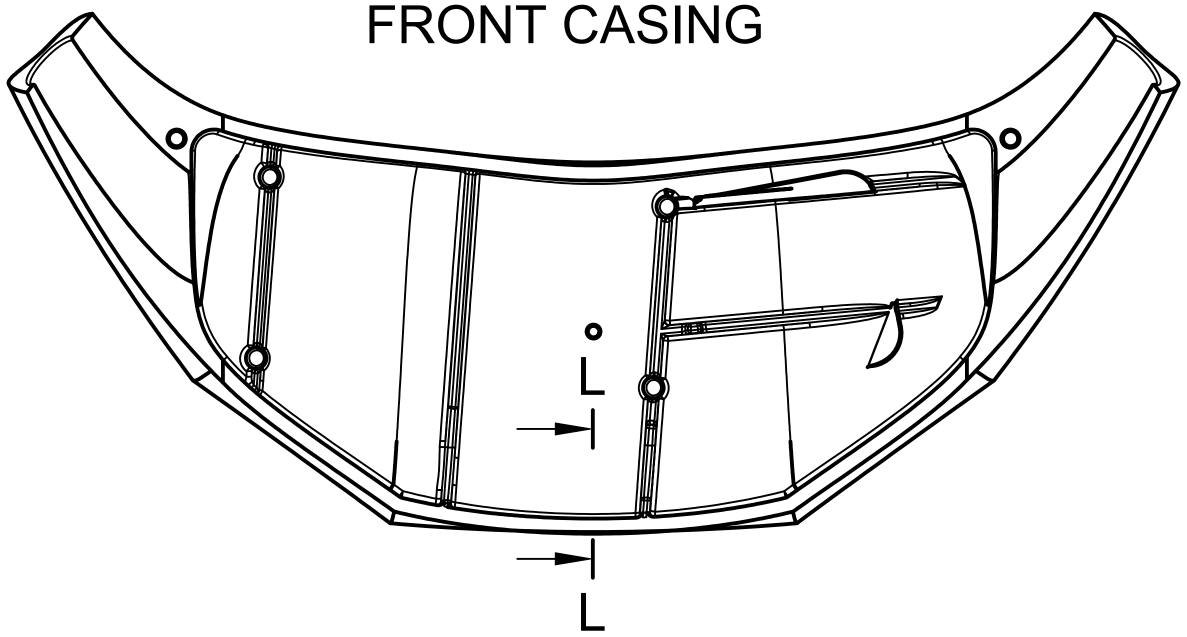


UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILIMETRES SURFACE FINISH: SPI B2 TOLERANCES: LINEAR: ±0.5 ANGULAR: ±0.15	SURFACE FINISH: MATTE FINISH	DEBURR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING GARMIN VENIO
	NAME	DATE	TITLE:
DRAWN	James Howells	6/15/2022	REAR CASING 03 - WINGS
CHECK'D	Amelia Bryant	22/06/2022	
APPV'D			
FIRST-ANGLE PROJECTION			DWG No.: VEN-008
			SIZE: A3
			SCALE: 2:1

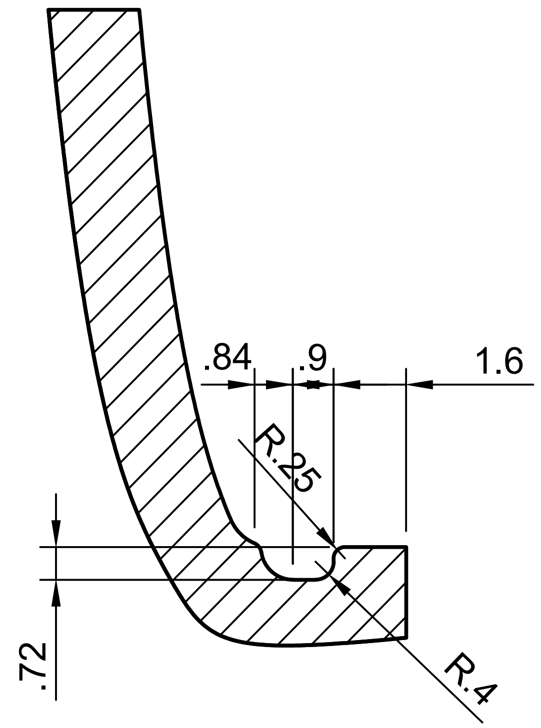
CLASP (4:1)



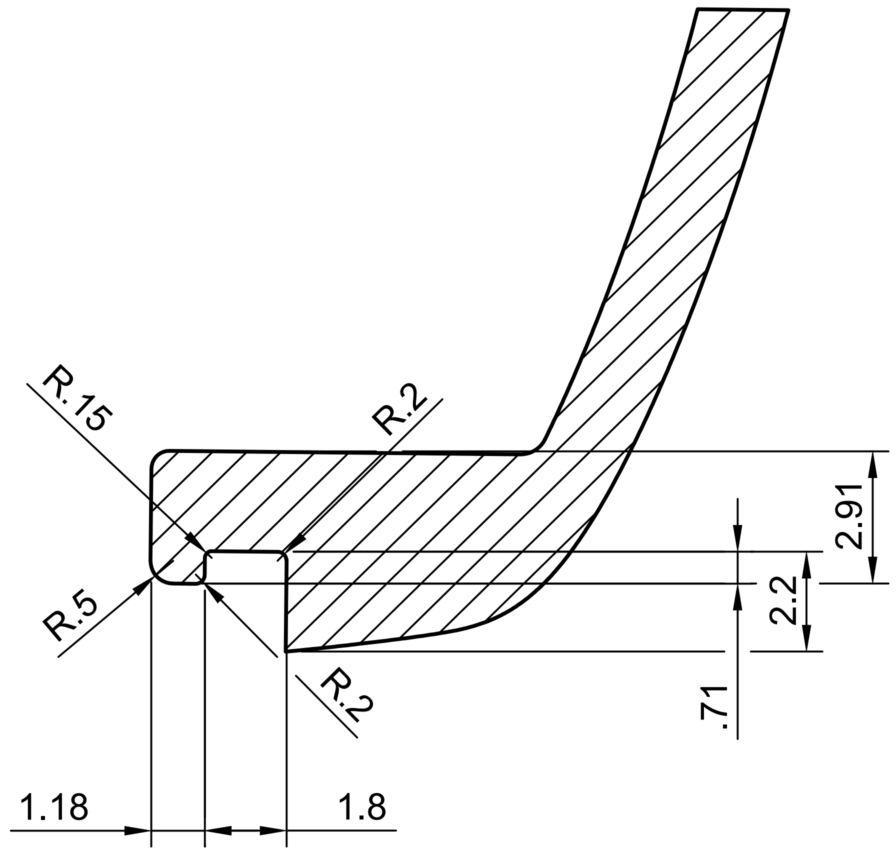
FRONT CASING



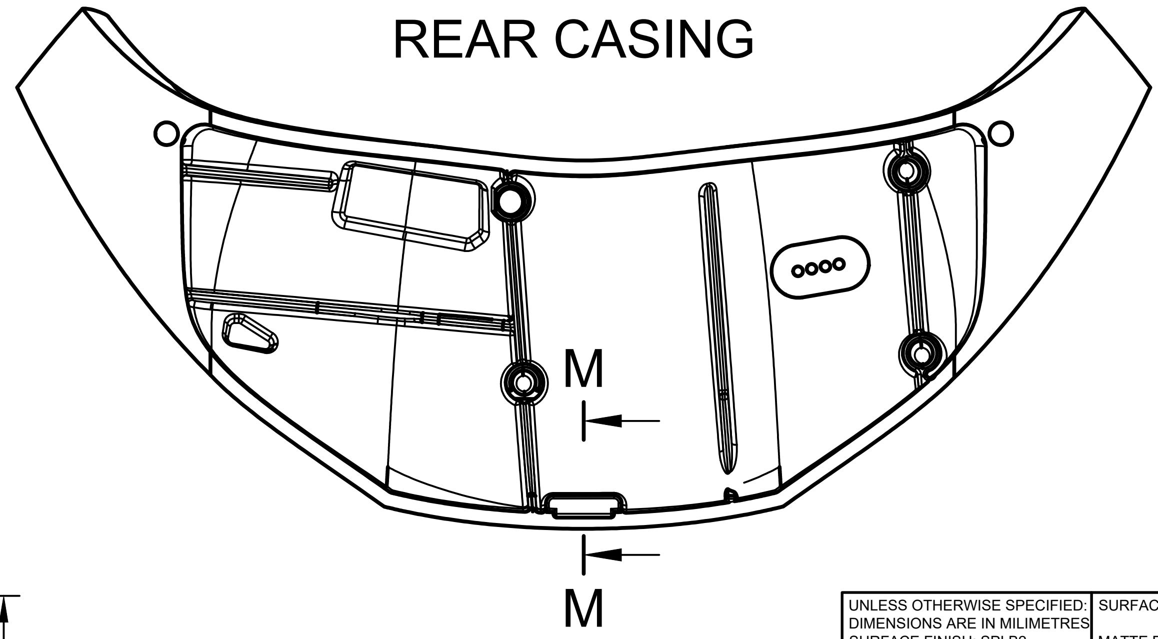
L-L (6:1)



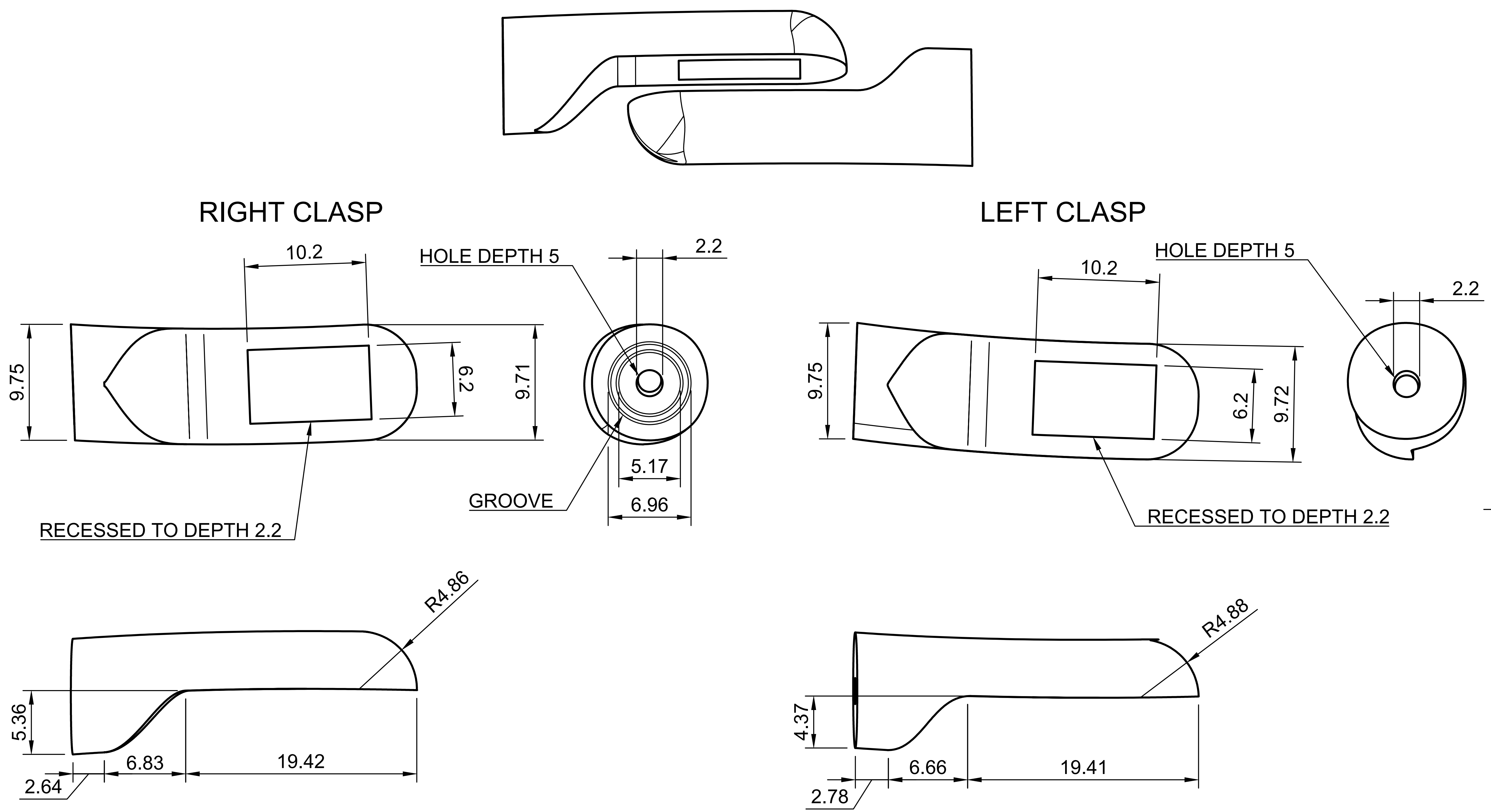
M-M (6:1)



REAR CASING

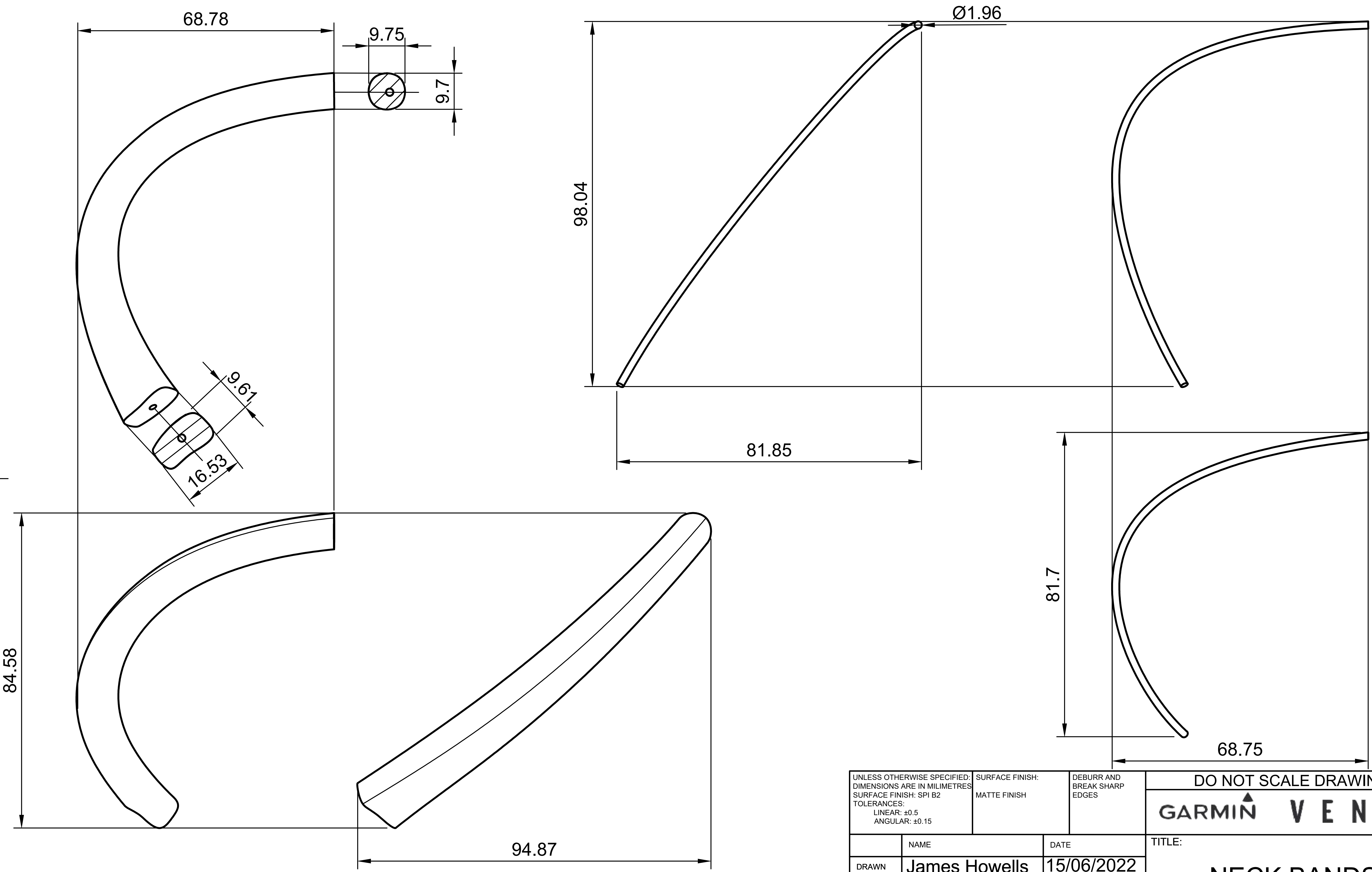


UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILIMETRES SURFACE FINISH: SPI B2 TOLERANCES: LINEAR: ±0.5 ANGULAR: ±0.15	SURFACE FINISH: MATTE FINISH	DEBURR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING GARMIN VENIO
	NAME	DATE	TITLE:
DRAWN	James Howells	15/06/2022	LOCKING MECHANISM
CHECK'D	Amelia Bryant	22/06/2022	
APPV'D			
FIRST-ANGLE PROJECTION			DWG No.: VEN-009
			SIZE: A3
			SCALE: 1:1



DUE TO GEOMETRY OF HUMAN NECK CLASPS ARE NOT SYMMETRICAL, AND LEFT AND RIGHT CLASP ARE DIFFERENT. RIGHT CLASP IS MARKED WITH AN EXTRA RING-SHAPED FEATURE.

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILIMETRES SURFACE FINISH: SPI B2 TOLERANCES: LINEAR: ±0.5 ANGULAR: ±0.15	SURFACE FINISH: MATTE FINISH	DEBURR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING GARMIN VENIO
	NAME	DATE	TITLE:
DRAWN	James Howells	15/06/2022	CLASPS
CHECK'D	Amelia Bryant	22/06/2022	
APPV'D			
FIRST-ANGLE PROJECTION			DWG No.: VEN-010
			SIZE: A3
			SCALE: 3:1



SHOWING RIGHT NECK BAND. LEFT BAND IS A MIRROR IMAGE. SILICONE BAND (LEFT) IS OVERMOULDED ONTO WIRE (RIGHT) AND VIBRATION MOTORS. SEE VEN-012 FOR MOTOR POSITIONING.

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILIMETRES SURFACE FINISH: SPI B2 TOLERANCES: LINEAR: ±0.5 ANGULAR: ±0.15	SURFACE FINISH: MATTE FINISH	DEBURR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

GARMIN VENIO

	NAME	DATE
DRAWN	James Howells	15/06/2022
CHECK'D	Amelia Bryant	22/06/2022
APPV'D		

FIRST-ANGLE PROJECTION

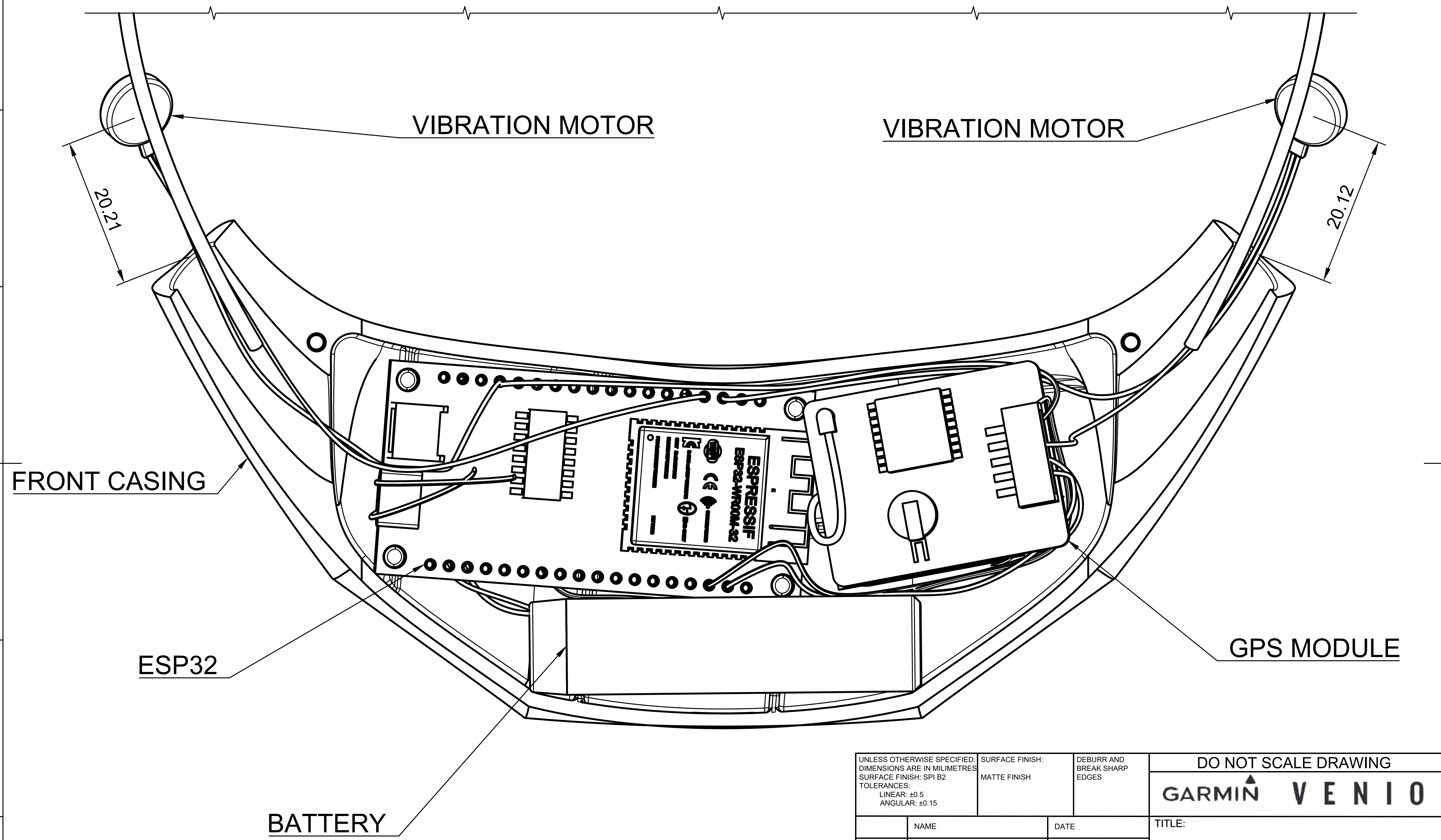
TITLE:

NECK BANDS

DWG No.: VEN-011

SIZE: A3

SCALE: 1:1



UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILIMETRES SURFACE FINISH: SPI B2 TOLERANCES: LINEAR: ±0.5 ANGULAR: ±0.15	SURFACE FINISH: MATTE FINISH	DEBURR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

GARMIN VENIO

	NAME	DATE
DRAWN	James Howells	15/06/2022
CHECK'D	Amelia Bryant	22/06/2022
APPV'D		

FIRST-ANGLE PROJECTION

TITLE:

ELECTRONICS POSITIONS

DWG No.: VEN-012

SIZE: A3

SCALE: 1:1

REPORT REFERENCES

1. Dueñas L, Zamora T, Lluch E, Artacho-Ramírez M, Mayoral O, Balasch S et al. The effect of vibration therapy on neck myofascial trigger points: A randomized controlled pilot study. Clinical Biomechanics [Internet]. 2020 [cited 10 May 2022];78:105071. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0268003320301893#:~:text=Highlights&text=Mechanical%20vibration%20could%20be%20used,method%20to%20reduce%20neck%20pain.&text=Self%2Dapplied%20mechanical%20vibration%20increases%20sensitivity%20at%20cervical%20muscles.&text=Self%2Dapplied%20mechanical%20vibration%20reduces%20neck%20pain%20and%20disability

2. Dermatomes [Internet]. Physiopedia. 2022 [cited 10 May 2022]. Available from: https://www.physio-pedia.com/Dermatomes

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4. The science of bike building: What is 'ride quality' and what factors affect it? - CyclingTips [Internet]. CyclingTips. 2022 [cited 11 May 2022]. Available from: https://cyclingtips.com/2016/06/the-science-of-bike-building-what-factors-affect-ride-quality-and-what-even-is-it/

5. FireBeetle ESP32-E IoT Microcontroller [Internet]. The Pi Hut. 2022 [cited 16 May 2022]. Available from: https://thepihut.com/products/firebeetle-esp32-e-iot-microcontroller-supports-wi-fi-bluetooth

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