Beobridge Connect

Industrial Design Engineering

Designed to bridge distances

BEOBRIDGE CONNECT facilitates long-distance caregiving, forging strong **connections** between carers and the elderly, uniting families, and seamlessly introducing seniors into the world of technology.

The device **bridges** the gap that elderly people can experience with technology with a user-friendly interface and simple dial based input method,

The onboard camera offers the option for carers to provide discrete wellbeing checks, interacting remotely with those under their care.

BEOSOUND BRIDGE - more than a device, it is a gateway to the world of smart home devices designed with the elderly and their carers in mind.

Accessibility Technology Communication

Echoing excellence and elegance

Founded in 1925, Bang and Olufsen, (B&O) produce high-end audio and video products.

Initially they produced tape recorder and portable radios.

In the 1990s, B&O expanded into the home theatre market.

By the 2000s they were integrating smart technology into their products.

They focus on collaboration with designers and architects to create visually stunning products.

"Acoustic Works Of Art"

BEOSOUND Explore

£169

8.1 W x 12.4 H x 8.1 D cm

Compact — **Utilitarian**

Aluminium

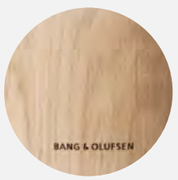
Textiles

BEOSOUND Balance

£2,399

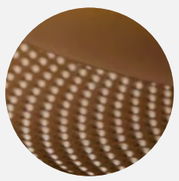
20 W x 38 H x 20 D cm

Muted — **Natural** — **Sculpted**



Wood

Textiles



Aluminium

Base products are generally smaller or even portable.

BEOLAB 90

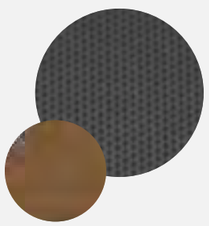
£93,250

73.5 W x 125.3 H x 74.7 D cm

Organic — **Dramatic**

Textiles

Wood



High end products use wood and textiles to radiate quality.

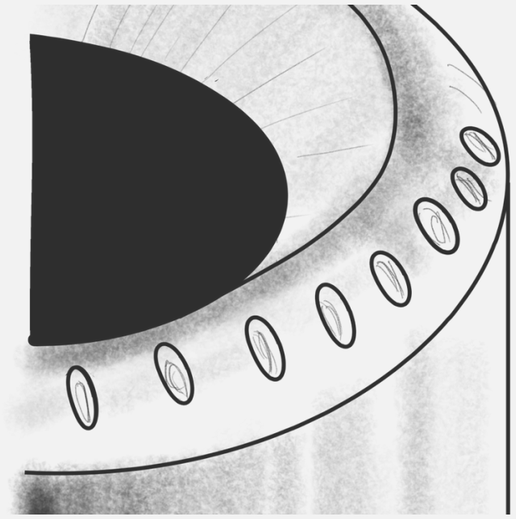
Informed design, inspired solutions

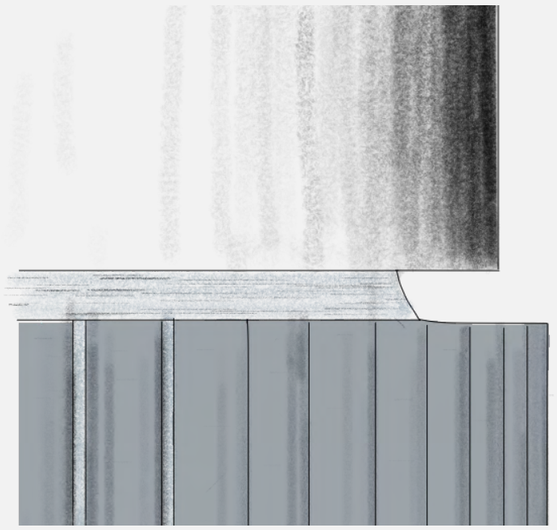
BEOBRIDGE CONNECT's design is rooted in the understanding of users' needs, achieved through hands-on interaction and collaboration with Age UK charity [1].

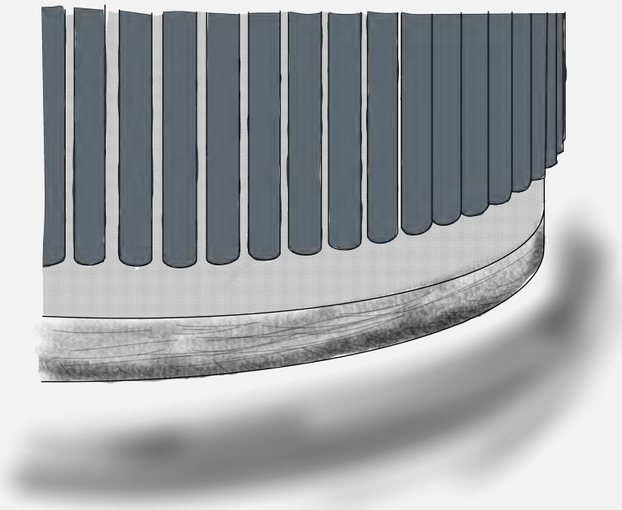
We applied our previous research conclusions to generate sketches shaping the form and function of the product.

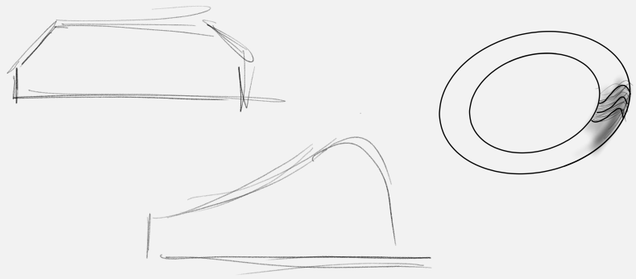
Rapid prototyping was essential in designing the product, assessing size and component fit., particularly balancing the dial, screen adn overall product dimensions.

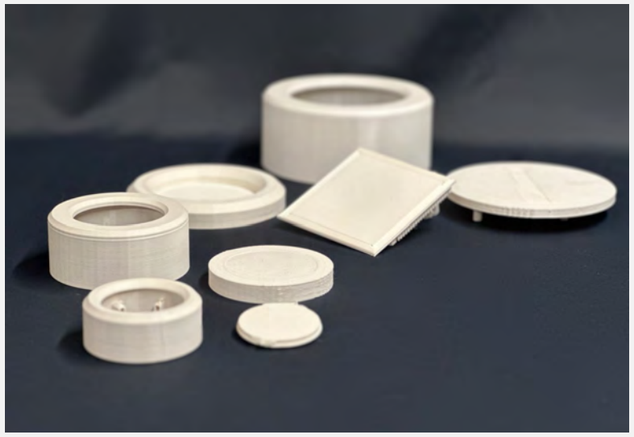
Additionally, 3D CAD and rendering enabled visualization of our ideas and concepts which we could then iterate over, repeating the [process until we had a final product form..

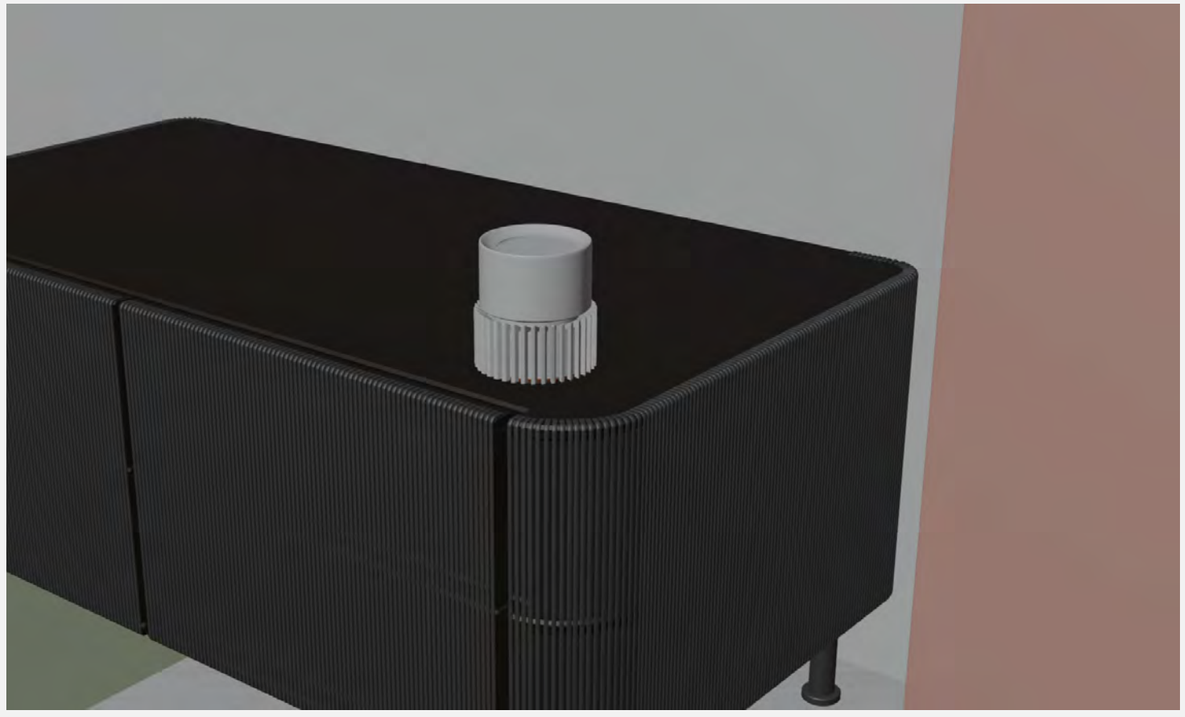












Timeless materials with innovation

Aluminium, wood, and fabric are a defining feature of a B&O product. We ordered several samples to find combinations that complemented one another other well.

Visits to a B&O's store, gave insight on their design, packaging and general aesthetics in a hands on way.

Seeing their materials in person gave us a understanding of the finishes we needed to strive for.

AI-powered Mid-journey visualization offers rapid, high quality and immersive views of CAD models . This allowed us to place our product concepts in many environments in a short amount of time to compare the designs.

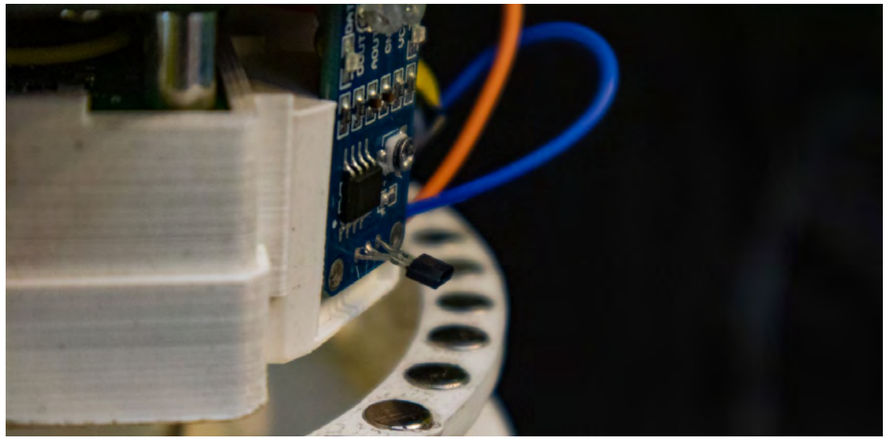
* Original image by Industrial Design Engineering Project

Informed design, inspired solutions

Electronics/Programming
One of the key issues we faced with constructing the device was getting the electronics to communicate with each other a variety of methods were tried including UART, serial communication, Wi-Fi before finally settling on USB serial.

Machining
During the machining process we ran into issues when the HAAS CNC mill broke in Hackspace which meant we were unable to form the metal bezel into the curved form we desired. We simplified the design exchanging the curved edge for a straight chamfer which allowed us to cut it using the lathe.

Minturisation
Bang and Olufsen products are designed to be the perfect form for their function, therefor after user testing to find the optimal dimensions, many design iterations were developed to fit the internal components into an ever smaller form.



Mahogany Slats

The hardwood slats ground the product and giving it presence. The floating undercut raises the product, making it stand out. Together they make the product a statement piece in the home.

Polished Aluminium

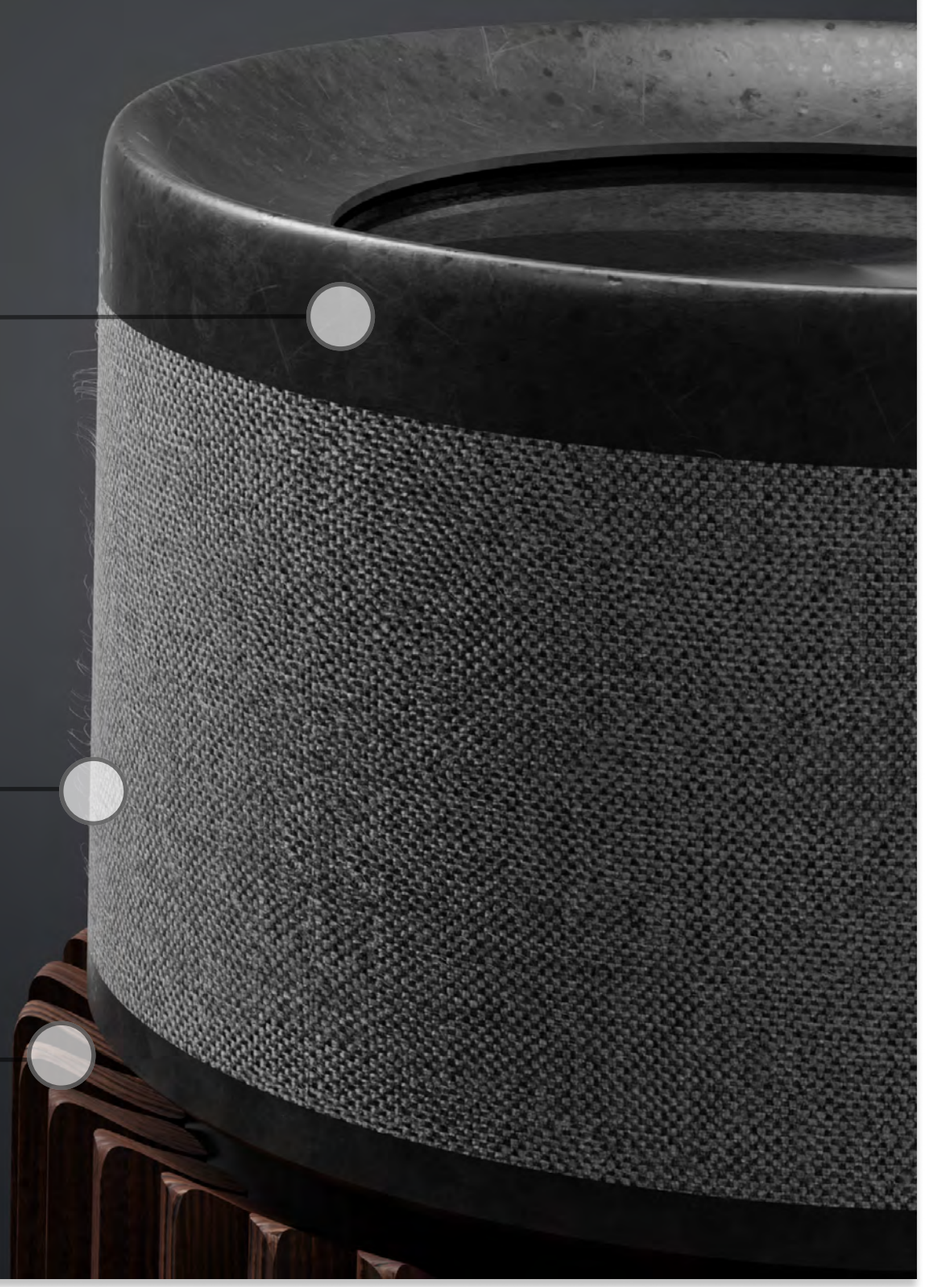
The metal bezel seamlessly extends the screen like a frame that enhances the picture. The subtle cool to the touch, smooth and sleek metal connotes elegance. It mirrors B&O's commitment to quality and design.

Premium Textiles

Distinction from the aluminium retains the products homely ambience

Mahogany Base

Implementing classically premium materials grounds the product in B&Os product line-up



DETAILED DESIGN

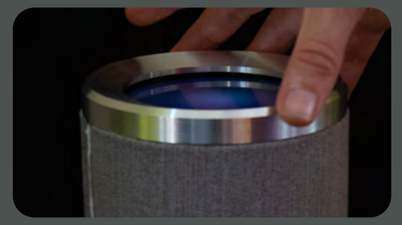
KEY DESIGN FEATURES

Ergonomic Concave Bezel

Designed with anthropometrics, the bezel cradles the index finger in the groove, inviting further interactions with the product.

Seamless

By incorporating grooves within the product, it allows the material to be hidden-out of sight. This seamless design blends the components into a single product.



Harmonised Contours

Mimics the interaction of pressing the dial unification of wood and metal sections, compels the user the to unify the product.

Guiding Fins

Tapered horizontal fins guide the user's gaze horizontally around the product providing the illusion of motion around the upper dial.

Elevated

The floating bottom coupled with diffused lightning elevated the design, providing greater space for internal components whilst reducing the visual vertical real-estate.

The product is designed with 4 distinct subassembly's which simplifies the assembly process and allows for relatively simple deconstruction for repair or maintenance.

Upper Casing Assembly

The upper casing is the main interaction point for the user, so a high quality finish is crucial. The aluminium dial and lower metal cap are press fit onto the central plastic sleeve which is wrapped in fabric. The aluminium facier plate is then joined with adhesive to cover the seam line.

Upper Electronics Assembly

The majority of the electronics are housed within the top casing. They are supported by a 5mm stainless steel tube via a press fit which allows for the screen to stay stationary while the casing rotates.

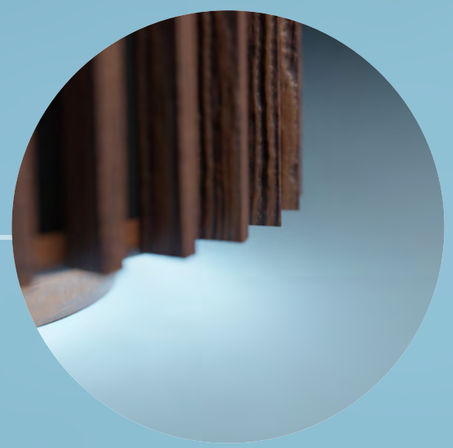
Fasteners are used to secure the electronics hardware which allow for disassembly. Power cables pass through the centre of the brushless motor which acts as the main bearing for the assembly as well as controlling the products feel and motion.

Spring Assembly

The spring assembly allows for the top section of the dial to be pressed down to enable the user to select item on the interface. The springs are held in compression to give the perfect amount of travel and tactile feel to the user.

Base Assembly

The base assembly contains the electrical distribution system, Alexa voice control module, the LED's and the 3D touch hall effect sensor. During assembly wiring was left with slack so that the base could be wired and then press fitted on.



After rendering our final product we placed it in a sccene with many of the other B&O product ranges such as:

BEO

Sound

Vision

Link

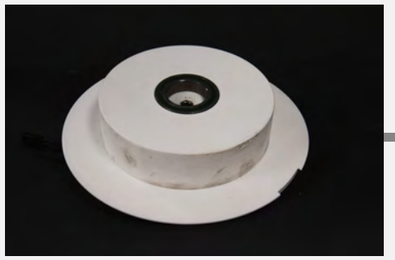
Explore

Balance

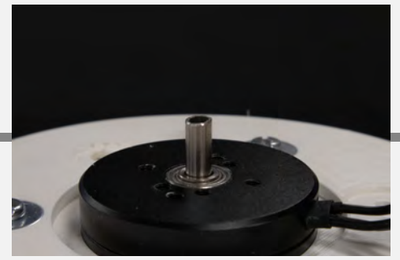
PRODUCT ASSEMBLY PROCESS

TIMINGS AND COST ESTIMATE

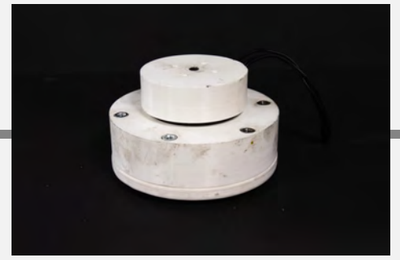
Upper Subassembly



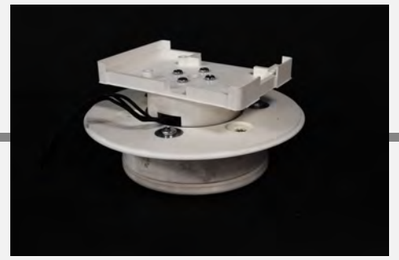
Main Bearing
Press Fit 10 Seconds



Hollow Motor Shaft
Slip Fit 5 Seconds

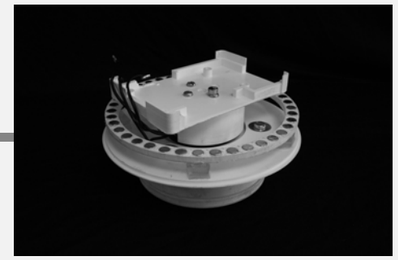


Motor Mount
Press Fit 10 Seconds



Casing Supports
M3 Bolts 2 Minutes

Magnets
Bonded 5 Minutes

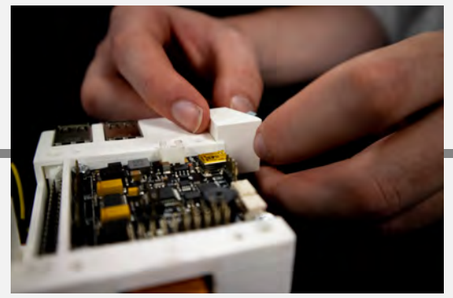


Encoder Ring
Bonded 1 Minute

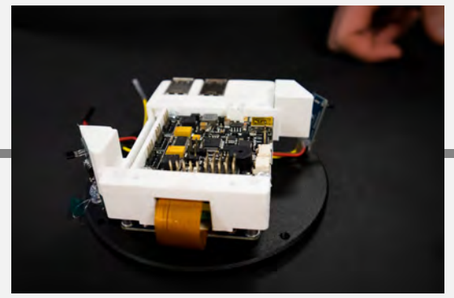
Electronics Subassembly

Raspberry Pi Casing
M2.5 Bolts 1 Minute

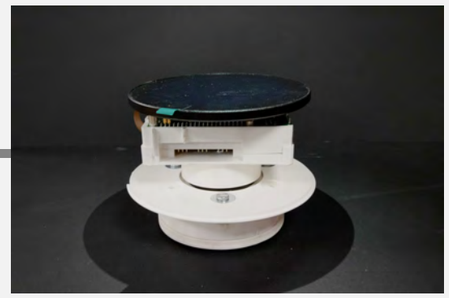
Second Raspberry Pi Case
Snap Fit 5 Seconds



Hall Effect Sensors
Bonded 1 Minute

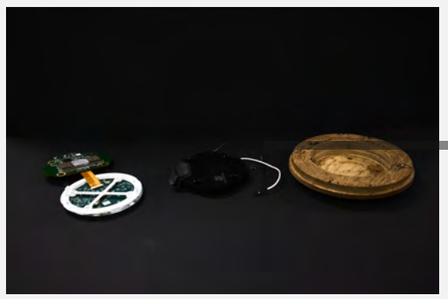


Hall Effect Sensors
Soldered 2 Minutes

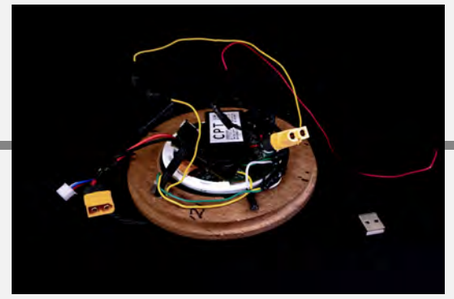


Assemblies Combined
Snap Fit 10 Seconds

Lower Subassembly



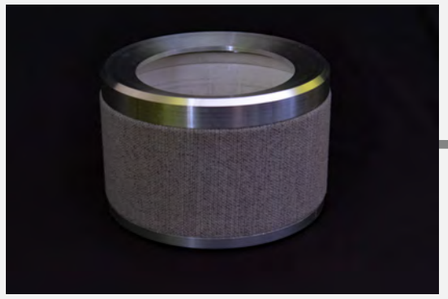
PCB Speaker Stack
M4 Bolts 1 Minute



Power Delivery Connections
Soldered 3 Minutes

Fabric and Trim Pieces
Bonded 6 Minutes

Final Assembly



Fabric and Trim Pieces
Adhesive 3 Minutes

Combining Sub Assemblies
Variety 3 Minutes

Total Assembly Time: **28 Minutes 40 Seconds**

Total Assembly Cost: **~$3.50**

2 Operation Control

The key design feature of the UI is that it can be navigated completely with only 2 interactions, the rotation and pressing of the dial.

Simplicity

The UI is very simple and clean, which prevents overwhelming of the elderly user . We found icons to be much clearer than text int this application

Companion in & out the home

Enhancing the user experience our customer expect from B&O, our app builds on features of the product, allowing careers and more proficient users to customise their interaction methods. This ranges from fine increments to the maximum load .

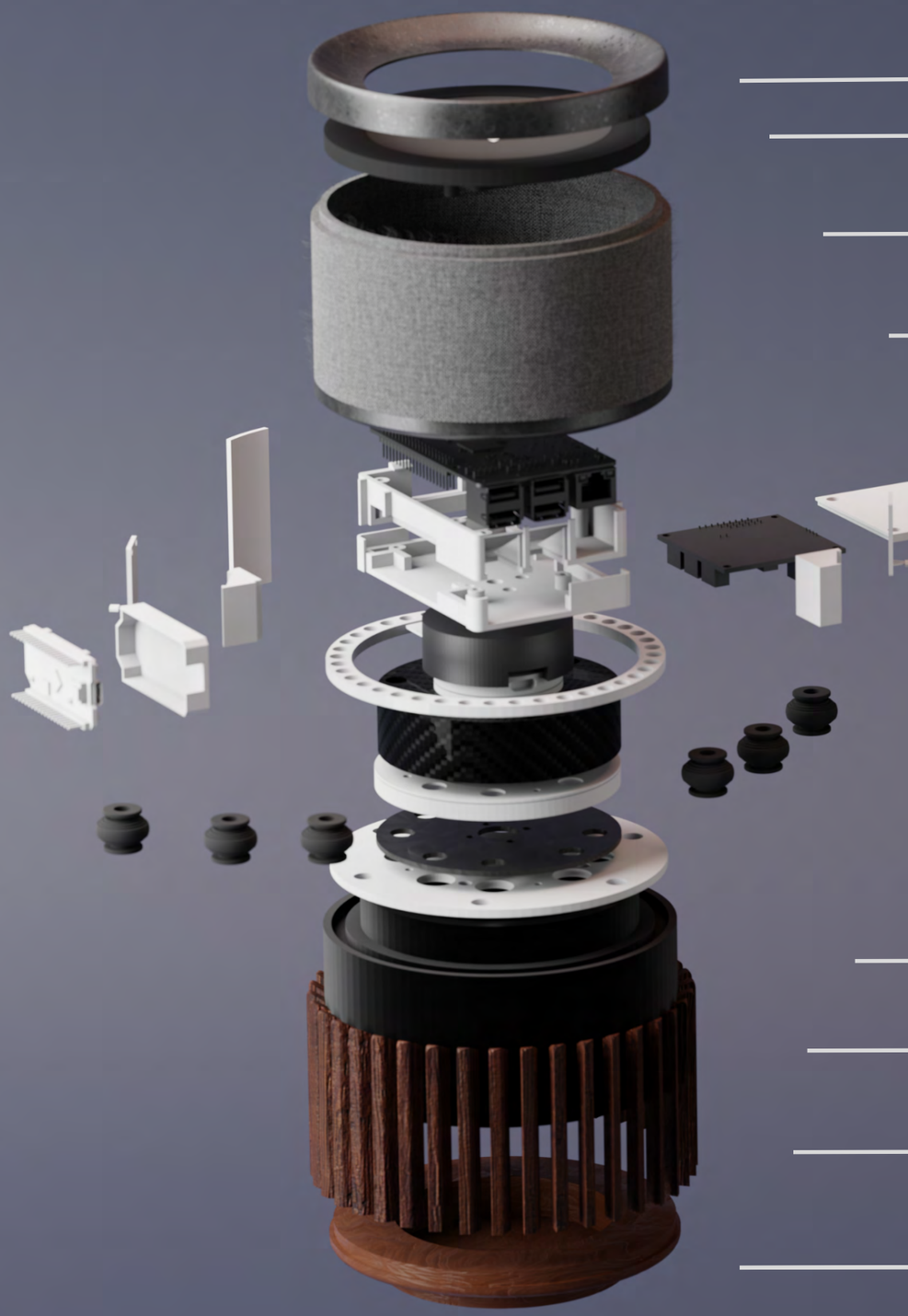
The app integrates with Alexa and other smart-home systems like B&O. Th app acts as a central but portable hub for not only Connect but the entire smart-home becoming an extension of the product and not just a standalone app.

its important to recognise security and safety of all stakeholders which is why the app echos the security measures in place on Connect.

The companion acts a s a portal for the carers, being notified of any potential emergency events or the ability to wellbeing check on the person they are caring for through the remote camera after it goes through its safety timeout.

EXPLODED VIEW

VISUAL RENDER



Aluminium Top Ring

HD Display

Fabric Upper Casing

Upper Chassis

Raspberry Pi & Protective Case

Hall Effect Sensor

ESP32

Motor & Casing

Rubber Spring

Carbon Fibre Plate

Aluminium Bottom Ring

Fabric Lower Casing

Battery & Power Distribution

Decorative Wooden Slots

Wooden Base

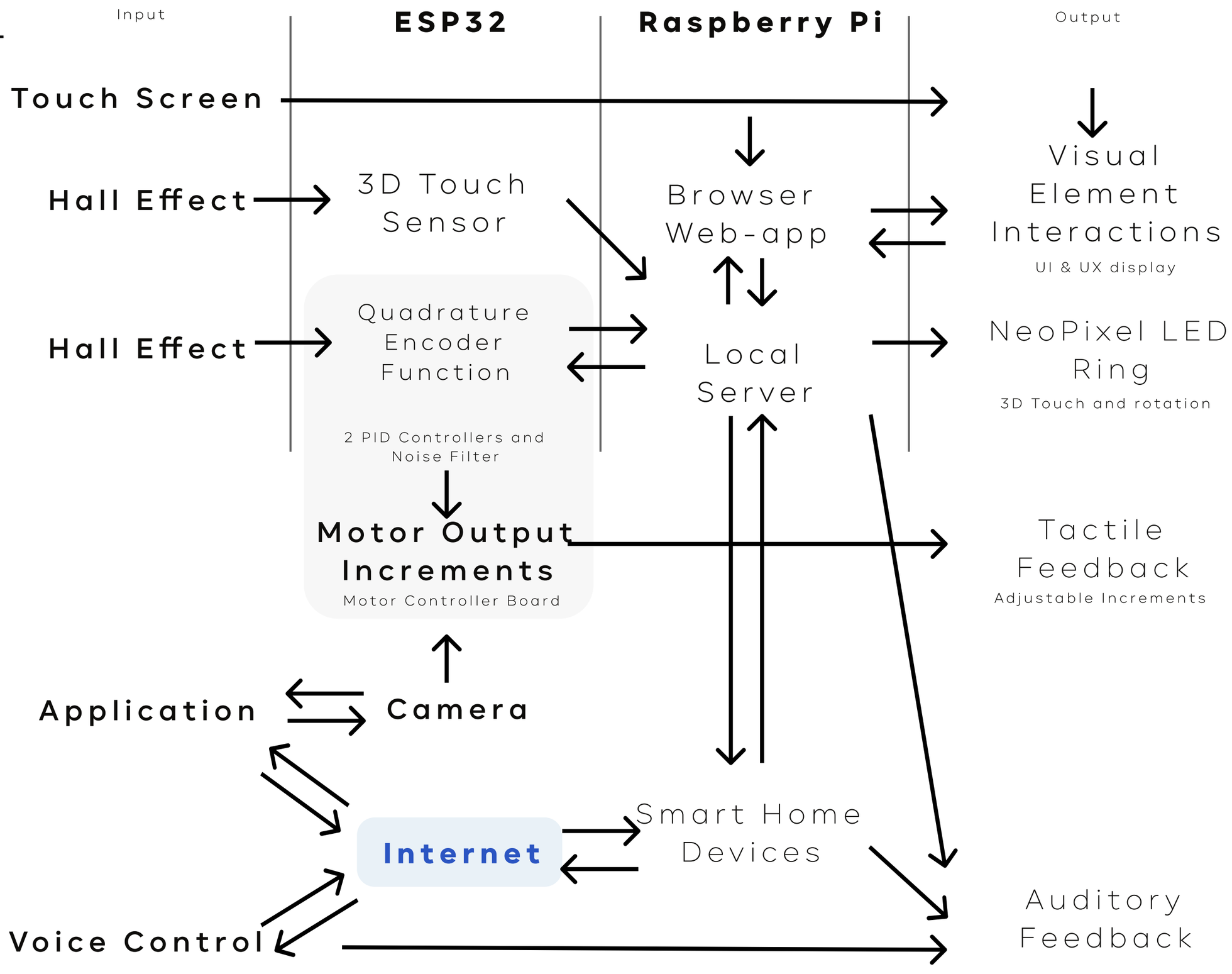
SYSTEM ARCHITECTURE

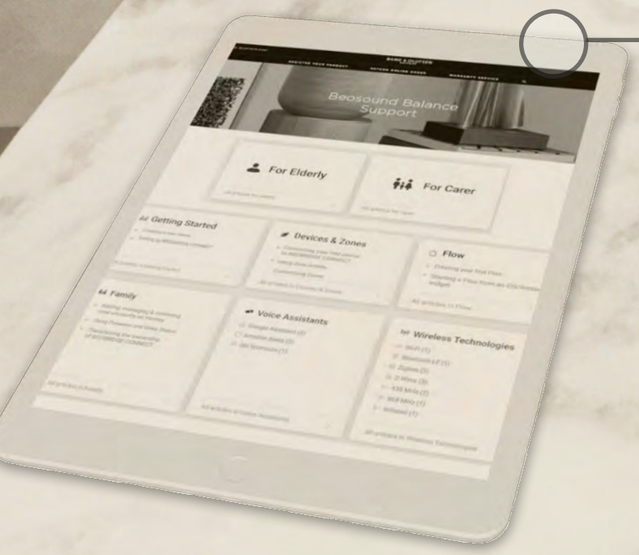
TIMELINE AND CONTRIBUTION

The System Architecture of the product consists of a central local server on the Raspberry Pi which offloads computation to more specialised processors or threads within the PI.

The main functionality of the product hinges on the Manual Quadrature Encoder which sends its values to the main hub and to the motor which allows for infinite range of adjustment on the motor from increments to power, tailoring the experience to the user and current functionality.

Other processes consist of camera control for wellbeing checks on the elderly. By connecting the device to the internet it not only allows for more rapid responses of voice requests but allows the user to communicate with other devices and phones. This in-turn improves their independence and accessibility to social networks.





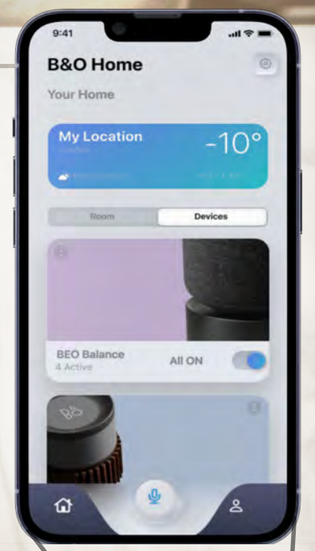
Detailed User Guide

Online user guide provides more detail troubleshooting
Can be accessed via a URL or QR code on packaging

Mobile Application

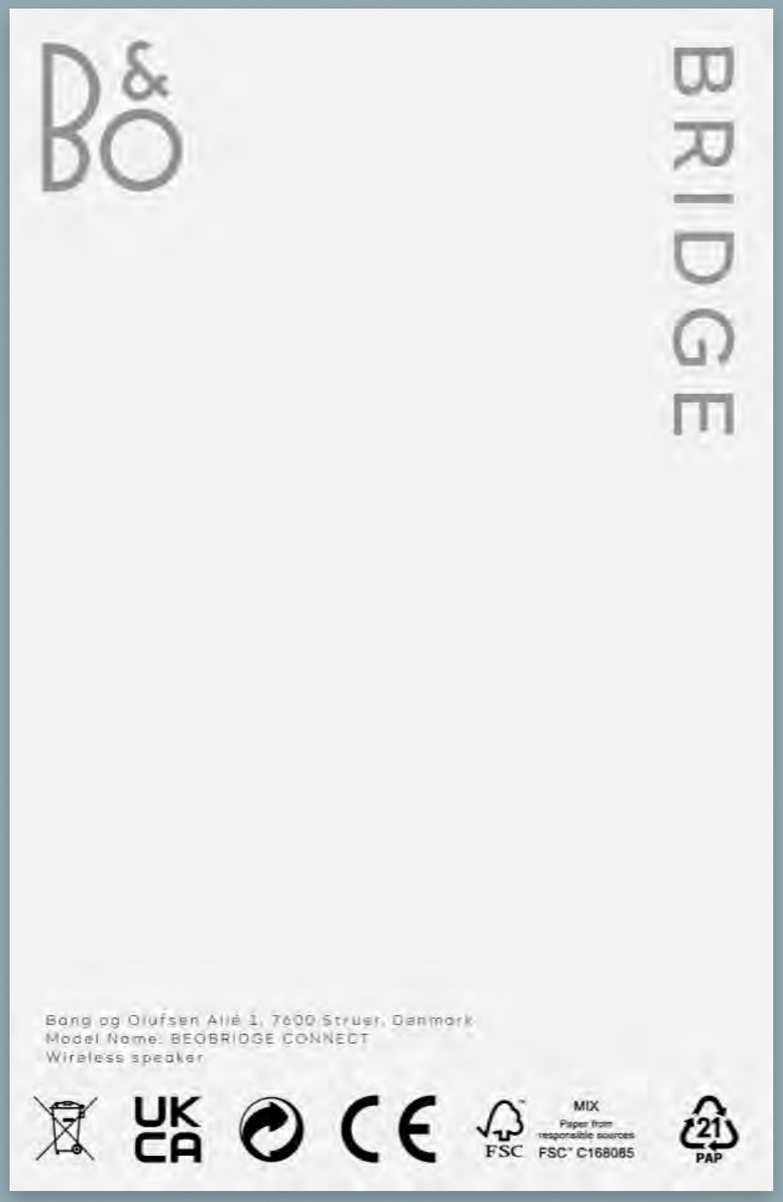
Mobile app provides tips and technical support to the carer

Quick access to a B&O operator to help with any problems



Integrated User Guide

Internals of packaging displays the quick start guide
The packaging can be rotated to view each step



Packaging compliance

We add relevant standards to the packaging

Safety Guide

Beosound Bridge

Important

For additional information, see:
https://www.bang-olufsen.com/support

Scan the QR code below for a larger, more readable version of this guide.

CAUTION

Do not put heavy items on top of your Beosound Bridge.

It may cause damage to the touch screen.

Important safety instructions

- Read these instructions.
- Keep these instructions.
- Heed all warnings.
- Follow all instructions.
- Do not use this apparatus near water.
- Clean only with dry cloth.
- Do not block any ventilation openings. Install in accordance with the manufacturer's instructions.
- Do not install near any heat sources such as radiators, heat registers, stoves, or other apparatus (including amplifiers) that produce heat.
- Do not defeat the safety purpose of the polarized or grounding- type plug. A polarized plug has two blades with one wider than the other. A grounding type plug has two blades and a third grounding prong. The wide blade or the third prong are provided for your safety. If the provided plug does not fit into your outlet, consult an electrician for replacement of the obsolete outlet.
- Protect the power cord from being walked on or pinched particularly at plugs, convenience receptacles, and the point where they exit from the apparatus.

- Only use attachments/accessories specified by the manufacturer.
- Use only with the cart, stand, tripod, bracket, or table specified by the manufacturer, or sold with the apparatus. When a cart is used, use caution when moving the cart/ apparatus combination to avoid injury from tip-over.
- Unplug this apparatus during lightning storms or when unused for long periods of time.
- Refer all servicing to qualified service personnel. Servicing is required when the apparatus has been damaged in any way, such as power-supply cord or plug is damaged, liquid has been spilled or objects have fallen into the apparatus, the apparatus has been exposed to rain or moisture, does not operate normally, or has been dropped.
- WARNING: To reduce the risk of fire or electric shock, do not expose this appliance to rain or moisture. Do not expose this equipment to dripping or splashing and ensure that no objects filled with liquids, such as vases, are placed on the equipment.

The lightning flash with arrowhead symbol within an equilateral triangle, is intended to alert the user to the presence of uninsulated "dangerous voltage" within the product's enclosure that may be of sufficient magnitude to constitute a risk of electric shock to persons.
The exclamation point within an equilateral triangle is intended to alert the user to the presence of important operating and maintenance (servicing) instructions in the literature accompanying the product.

The product can only be switched off completely by disconnecting it from the mains socket. The mains socket must always be accessible.
No naked flame sources, such as lighted candles should be placed on the product.
Make sure the cable connection between the product and the router does not exit the building to avoid contact with high voltage.

To prevent electric shock hazard, do not connect to mains power supply while grille is removed.

CAUTION

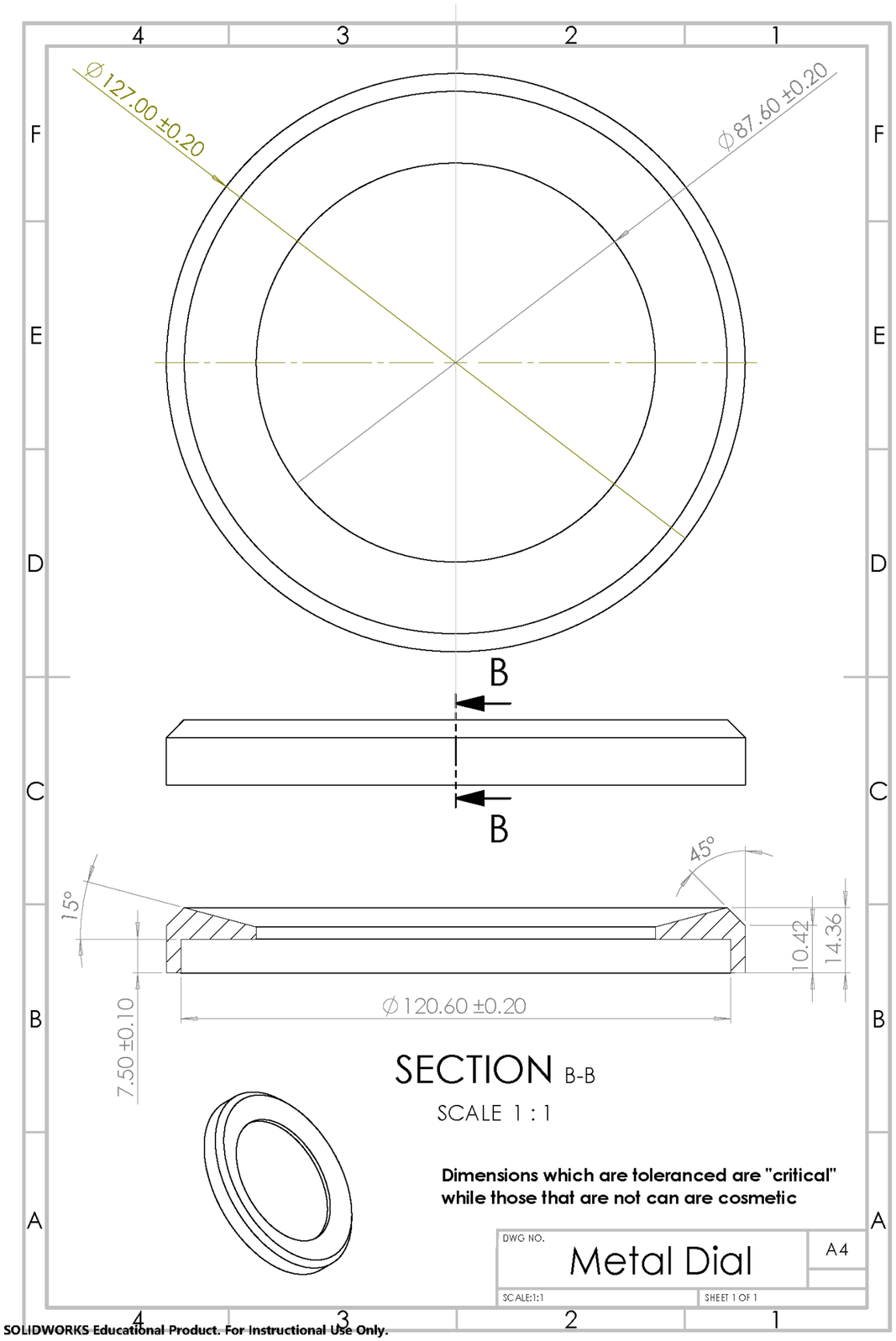
Electrical and electronic equipment, parts and batteries marked with this symbol must not be disposed of with normal household wastage, it must be collected and disposed of separately to protect the environment.
Your Bang & Olufsen retailer will advise you of the correct way of disposal in your country.

WEEE English

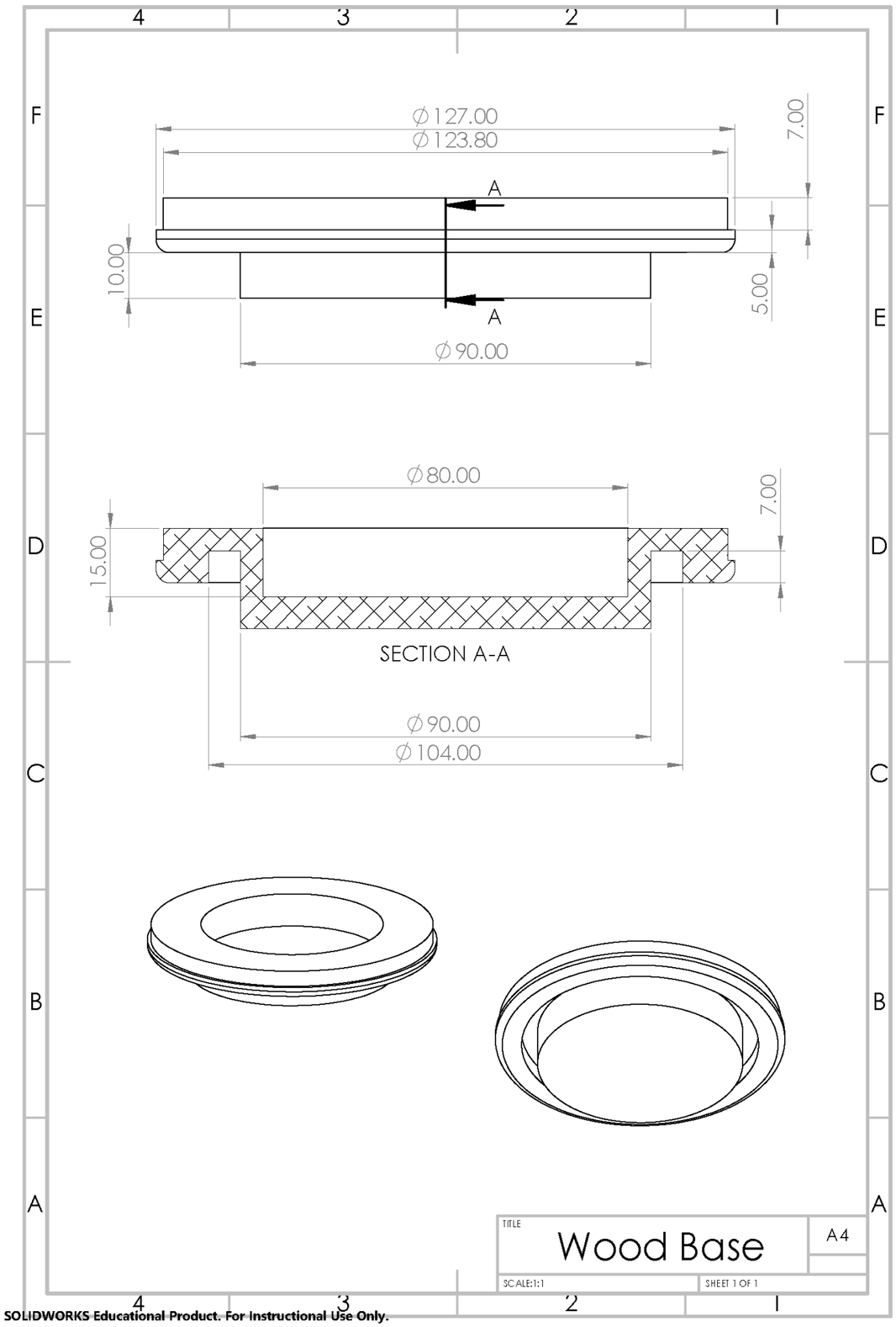
Important!

- Avoid placing the product in direct sunlight or direct artificial light, such as a spotlight.
- Make sure that the product is set up, placed and connected in accordance with the instructions.
- Place your product on a firm surface or stand where you want it placed permanently. Use Bang & Olufsen approved stands and wall brackets only!
- Do not place any items on top of your product.
- Do not subject the product to high humidity, rain or sources of heat.
- The product is intended for indoor use in dry, domestic environments only. Use within a temperature range of 10– 40°C (50–105°F).
- Leave enough space around the product for adequate ventilation.
- WARNING: To reduce the risk of fire or electric shock, do not expose this appliance to rain or moisture. Do not expose this product to dripping or splashing and ensure that no objects filled with liquids, such as vases, are placed on the equipment. To completely disconnect this equipment from the AC Mains, disconnect the mains plug from the wall socket. The wall socket must always be easily accessible.

Product labelling



SOLIDWORKS Educational Product. For Instructional Use Only.



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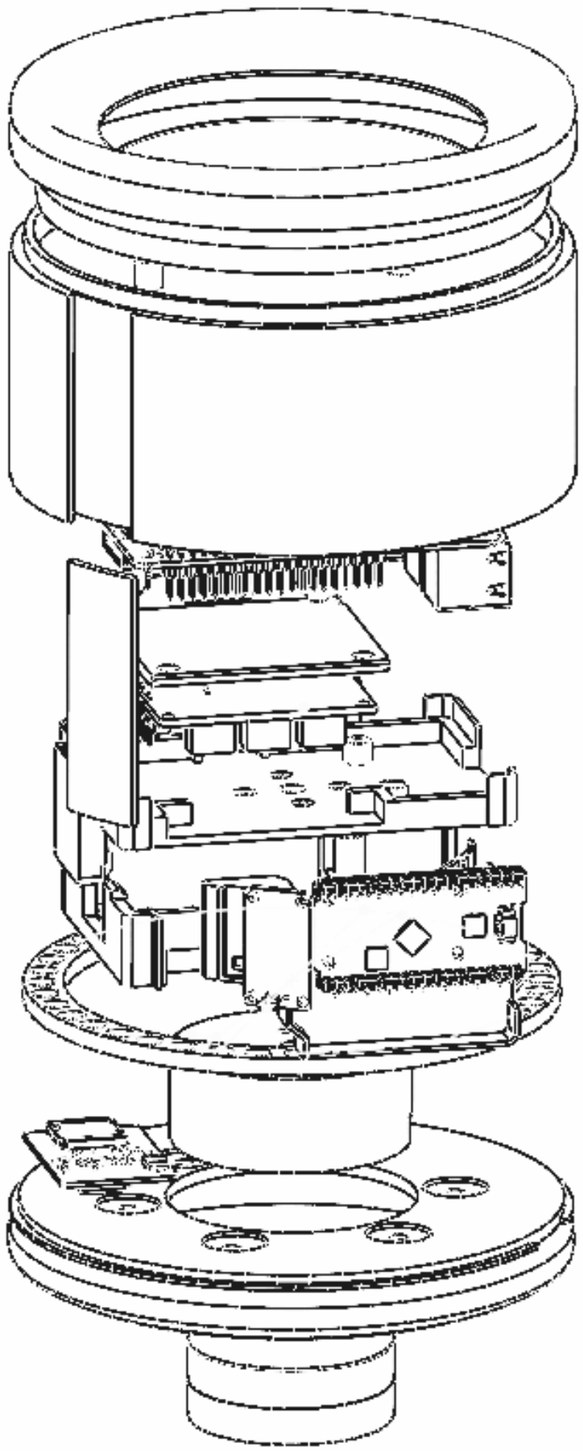
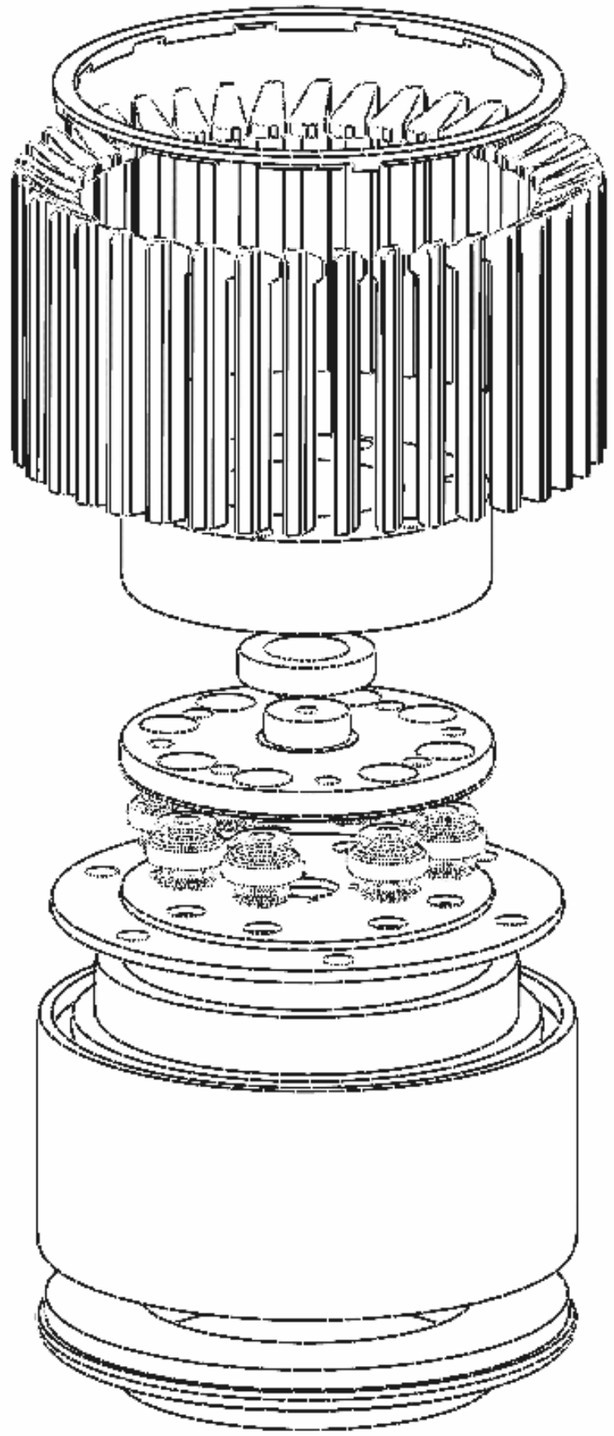
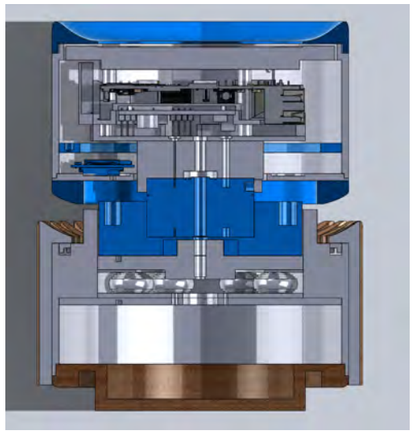
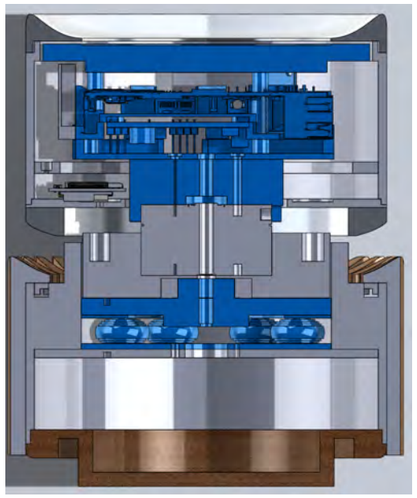
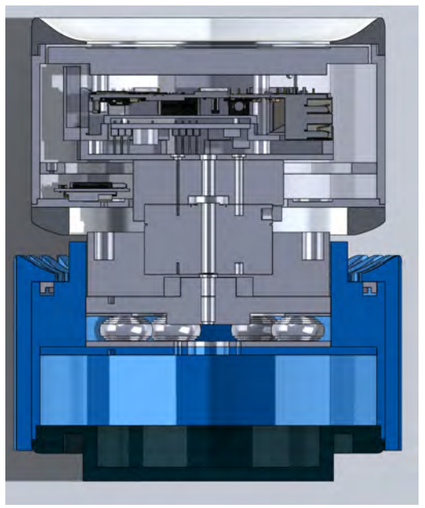






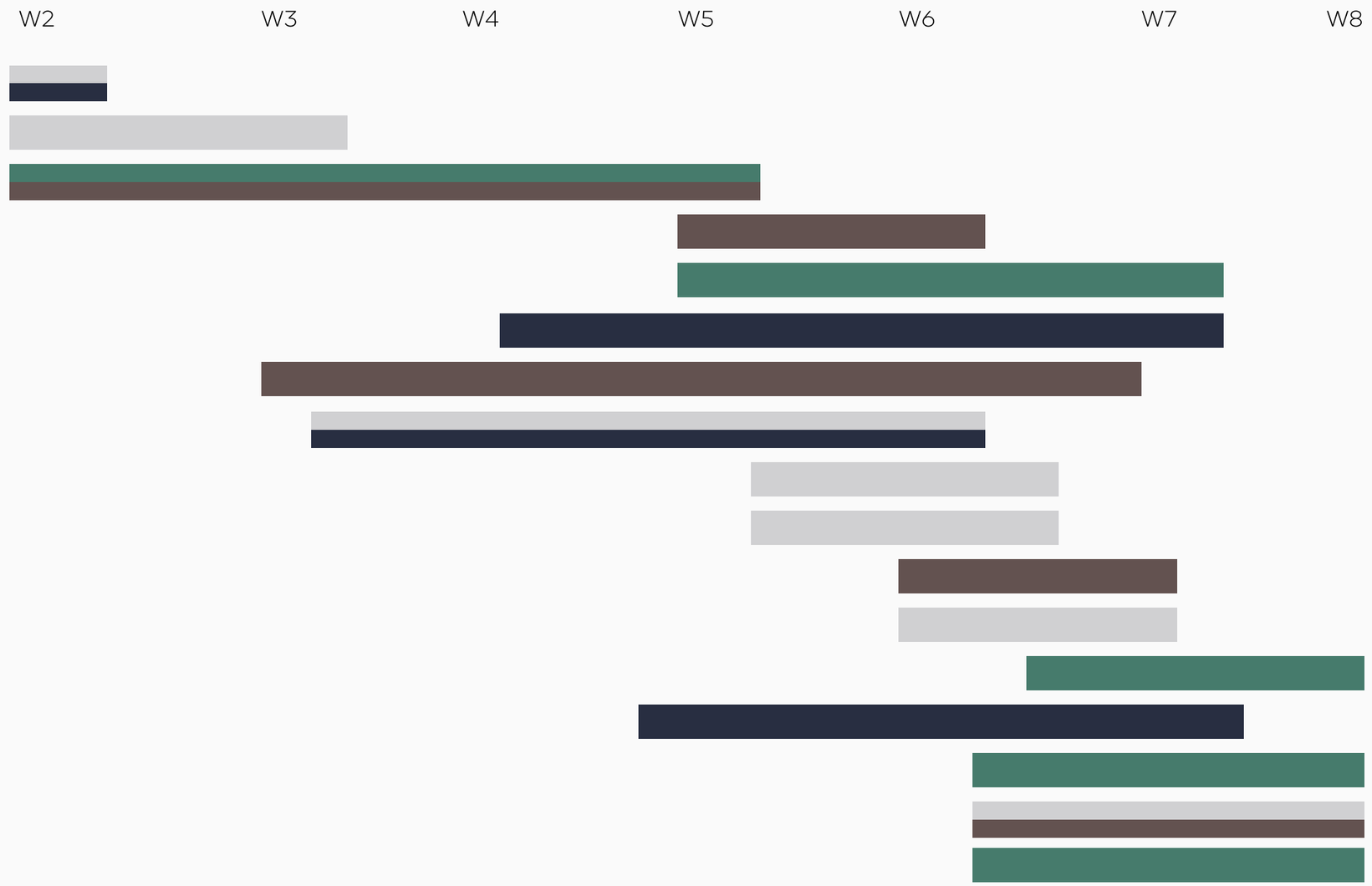




PROJECT PLAN

TIMELINE AND CONTRIBUTION

Gantt Chart



Henry

Chief Technical Officer

Managed CAD and product visualization

Liam

Chief Information Officer

Enhanced media and interface components.

Ross

Chief Operation Officer

Prepared materials and prototypes for production.

Jackson

Chief Creative Officer

Conducted research and developed branded reports.

Reference

1. Project, I. D. E. (n.d.). Concept Booklet. Retrieved from https://drive.google.com/file/d/1_o58P29r7O6EgeIr6NIfElc66G1KGXia/view?usp=sharing.

ohnson, M. (2020). The impact of technology on mental health. Journal of Psychological Studies, 8(3), 120-135. https://doi.org/10.1016/j.jpsych.2020.05.002

Smith, A. (2019). Environmental sustainability in the 21st century. Green Earth Press.

Davis, R., & Thompson, L. (2018). The role of social media in modern politics. Political Analysis, 26(4), 233-248. https://doi.org/10.1093/polana/asy017

Williams, J. (2021). Virtual reality in education: A new horizon. Journal of Educational Technology, 19(1), 15-30. https://doi.org/10.1080/09556780.2021.1879863

National Institute of Health. (2022). The importance of sleep for good health. Retrieved from https://www.nih.gov/health/sleep/

Rodriguez, P. (2017). The history and evolution of jazz music. Musicology Quarterly, 13(2), 45-60.

Patel, S. (2022, February 23). Renewable energy and its impact on the economy. The Economic Times. https://www.economictimes.indiatimes.com/renewable-energy-impact

Compliance related reference
(N.d.-a). Retrieved from https://www.bang-olufsen.com/en/gb
(N.d.-a). Retrieved from https://www.gov.uk/guidance/product-safety-for-businesses-a-to-z-of-industry-guidance
(N.d.-a). Retrieved from https://www.legislation.gov.uk/uksi/2005/1803/made
(N.d.-a). Retrieved from https://www.legislation.gov.uk/uksi/2005/1803/pdfs/uksi_20051803_en.pdf
(N.d.-a). Retrieved from https://single-market-economy.ec.europa.eu/single-market/european-standards/harmonised-standards_en
(N.d.-a). Retrieved from https://www.gov.uk/guidance/designated-standards#the-designation-process
(N.d.-a). Retrieved from https://www.gov.uk/guidance/ce-marking
(N.d.-a). Retrieved from https://www.gov.uk/guidance/using-the-ukca-marking
(N.d.-a). Retrieved from https://single-market-economy.ec.europa.eu/single-market/goods/new-legislative-framework_en

Industrial Design Engineering

Ross Davenport, Kang Yang, Henry Adams, Liam Jones

June 22, 2023

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1 Overview

The **Beobridge** Connect is an innovative smart home product that caters to the needs of long-distance caregiving and seeks to address the challenge of modern technology being inaccessible for elderly individuals. Designed with inclusively in mind, the device bridges the gap between elderly users and smart homes. By shaping its interface devices from scratch, **Beobridge** Connect ensures a user-centric design that accommodates the diverse needs of seniors. It facilitates seamless communication between seniors and caregivers across geographical barriers, fostering meaningful connections and empowering the elderly to be more independent.

2 Objectives:

The objectives outlined for the **Beobridge** Connect aim to ensure a user-centric design, universal compatibility, effective communication features, robust safety measures, seamless setup process, strong security, and continuous improvement based on user feedback. By consistently referencing these quantifiable goals, we created a product that empowers the elderly for independent living and direct and reliable connection with caregivers.

2.1 Usability and User Interface

1. Achieve a minimum score of 4 out of 5 on a user satisfaction survey regarding the intuitiveness, quick setup and accessibility of the interface.
2. Ensure at least 90% of users can successfully customize the dial sensitivity and controls within the first use.
3. Comply with WCAG 2.1 Level AA standards and achieve a minimum score of 4 out of 5 in user satisfaction regarding accessibility features.

2.2 Integration and Compatibility

Ensure compatibility with at least 95% of smart home systems in the market.

2.3 Safety and Emergency Response

1. Ensure emergency calls are initiated within 3 seconds and contacts are notified within 10 seconds
2. Ensure that the camera feed is accessible by caregivers within 5 seconds of request initiation, with encrypted transmission.

2.4 Setup and User Education

1. Ensure that 80% of users can complete the setup process unaided within 5 minutes.
2. Achieve a minimum score of 4.5 out of 5 on user feedback regarding the effectiveness and clarity of user guide.

2.5 Security and Privacy

1. Comply with GDPR and other relevant data protection laws, and achieve an 'A' rating on a security assessment.
2. 100% of the time, users will receive a notification that the camera is turning on, with a 5-second delay before the camera actually activates.

3 Concept Development Approach

3.1 Methods research & Selection Rationale

3.1.1 Exploring Diverse Avenues

As a team, we launched our project with a comprehensive vision: evolving the elderly healthcare network to address the multifaceted challenges faced by seniors and their caregivers. We worked together and came up with different solutions[1]. Our early ideas included:

1. **Smart Dial:** A user-friendly interface bridging the communication gap for the elderly with caregivers and technology.
2. **SOS Fly Drone:** A rapid-response drone equipped with medical supplies, ensuring timely assistance to seniors in emergencies.
3. **Remote Consultation:** A smart device that can live stream video and measure key healthcare metrics remotely.
4. **Self-Balancing Walking Stick:** A stabilizing walking aid that auto-adjusts to prevent falls and support mobility.

Figure 1: Early product ideas

3.1.2 Focused Development

After considering various ideas, we found that Smart Dial has significant potential to improve elderly lives. The need for this product became clear from UK data showing that 69% of people over 65 are competent with using smart devices; leaving a third of elderly people with no access to technology, which has the potential to improve their level of independence.

Furthermore, 15% of caregivers live an hour away from those they care for, with long-distance caregivers reporting higher emotional distress compared to those living with their care recipient or nearby [2]. The Smart Dial concept emerged as the most promising option by overcoming communication barriers and making technology accessible.

As we sought to improve the Smart Dial, market leaders provided valuable insights.

1. **Amazon Echo Dot:** revealed the potential for intuitive device management, while also highlighting the need for an interface that goes beyond voice control - especially for elderly users.
2. **Google Nest Thermostat:** Leverages the ergonomics of a physical interface, enabling users to easily understand and interact with the device's features.
3. **The GrandPad Tablet:** Presented an elder-friendly UI and symbols, offering an excellent example of what our interface should look like.

With these observations in mind, we made informed decisions to enhance Smart Dial's accessibility and functionality.

Figure 2: Amazon Eco, Google Nest and GrandPad

3.2 Branding Consideration

As we continued developing various concepts to tackle the obstacles faced by both elderly individuals and their caregivers, it became increasingly clear that branding played a vital role in guaranteeing product effectiveness. The connection between a brand and its products can significantly enhance market position while also ensuring design language and ethos that resonate with our intended audience.

3.2.1 Selection of Brand Partner

After selecting the Smart Dial concept, we realized that the product's identity must reflect simplicity and timeless design. Therefore, we decided to collaborate with a brand known for its iconic design and quality. Bang & Olufsen (B&O) has served as an excellent source of inspiration for our product. The minimalist elegance, exceptional finish and interaction focused design defines a B&O product.

All of Bang and Olufsen's current market products are digitally connected and boast a seamless ecosystem to give the best auditory experience possible in which all of their products can be controlled through their app. The issue with this is that other external systems are unable to be integrated in and it makes many features unavailable to those who are unable to use the app. This is where our product would fit in bringing the B&O ecosystem to the rest of the home in an simple and accessible way.

3.2.2 Naming Significance

The device is called **Beobridge** Connect, following the category then device naming convention that B&O have established.The name is also symbolic, representing the essence of our mission. The product bridges accessibility and technology barriers that stand between elderly people's access to useful smart home products, that could improve their level of independence and communication to carers and relatives.

3.2.3 Aligning with Brand Values

By incorporating the B&O branding, our product aims to encapsulate the following key values that are integral to the brand's identity:

1. **Design:** Honest, innovative and human-centric. The spotlight is on user focused design and minimalism.
2. **Technology:** Integration of industry leading and innovative technologies into their products.
3. **Craft:** Pairing of premium materials with seamless design.

4 Product Opportunity

The key function of the device is to give an elderly person as much control over what goes on in their home as possible, from a central location, in a way that is easy to understand and use.

4.1 Fully Connected

The device should be able to control and operate as many devices as possible to extend its reach and capabilities, to provide the highest level of aid.

4.2 Limiting Input Types

Controls should be accessible through the fewest number of input types, this means minimising the amount of buttons, switches, etc as this makes it more difficult to learn how to operate.

4.3 Limiting Inputs

The number of inputs the user must carry out to perform an action increases the difficulty. It is important to reduce this and avoid hiding actions deep within menus while having as few different screens as possible.

4.4 Visually Simple

Having fewer things to look at allows the user to focus on what they want to do, making operation easier and less stressful. To achieve intuitive design in the user interface, color and contrast are harnessed to distinguish screen elements. Furthermore, users with visual impairments benefit from large and legible text while consistent icons minimize the learning curve and make navigation easier for all.

4.5 Variable Ability

From our previous research we identified that there was a wide variety of abilities and technology competence which not only vary between people but also could vary over a short space of time. Therefore the device needs to be adaptable and easily adjustable to accommodate for changing needs and abilities. In order to address this, the device includes an adaptive design with adjustable feedback that guarantees usability even for people with hand control impairments.

5 Initial Prototyping

5.1 Sketch Development

We began the prototyping process by developing sketches of the general form and aesthetic design of the product. This focused on aligning the device within the B&O product range as well as iterating on key features of the device such as the shape of the dial.

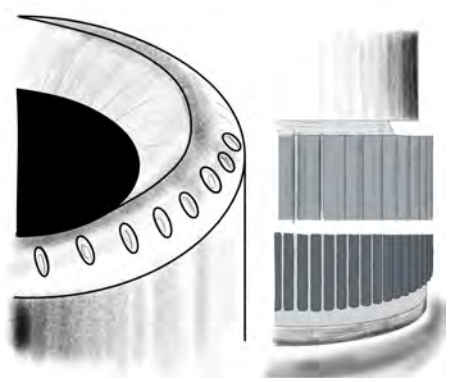

Figure 3: Initial sketching of key features

5.2 AI Prompt Engineering

After we had completed our initial sketches of the form and key features of our product we chose to use AI tools to enhance them. The method for this involved taking our sketches and ideas and rapidly producing draft CAD models which we rendered quickly and in relatively low quality. This allowed us to quickly iterate over several designs.

Figure 4: Concept development through Midjourney visualization

We then used Midjourney, an AI image generation tool as shown in in Figure 5. Feeding our own renders into the tool meant that we could generate 4 new concepts at a time, while directing the AI towards our end goal by adding more and more detail to the prompts.

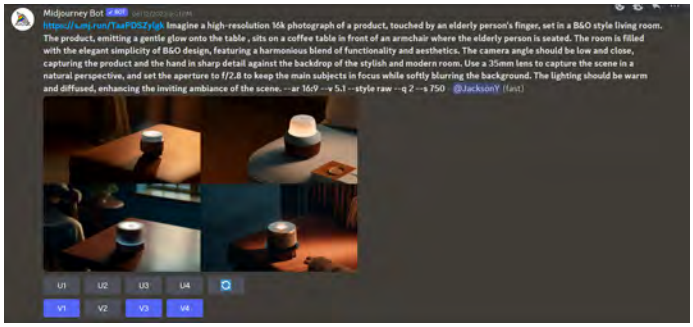

Figure 5: Midjourney prompt input example

5.3 Colour, Finish and Material Selection

Since B&O's brand image is driven by the premium feel and finish of their products we integrated the same ethos into our design. Initially we ordered sample materials to select a combination of wood, fabric and metal that complemented each other well. Since we had physical samples it was easy to compare surface finishes and textures.

The dial is the main touch point of the product so achieving an excellent feel was crucial. Aluminium was chosen as it was durable while having a high level of machinability, ensuring the surface finish would be very smooth. It's thermal conductivity is high, meaning that the dial should feel cool to the touch. This will juxtapose the other materials such as wood and fabric that we selected, which are generally rougher and warmer. Ideally we would have anodized the aluminum to add a level of protection and colour , however we did not have access to these facilities.

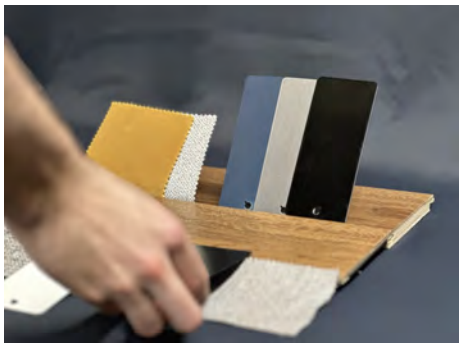

Figure 6: Different material selection

5.4 Rapid Prototyping

In order to determine the overall size and test how the internal components fitted together. We 3D printed different sizes of dial that could be used and the different displays that could go with them. This was a key aspect of the design as the display had to be large enough to aid in readability while being small enough to be easily controlled.

We selected a 3.4" display with HD resolution, paired with as thin as possible bezel to minimize the dimensions of the product. This dictated the outer diameter of 127 mm.

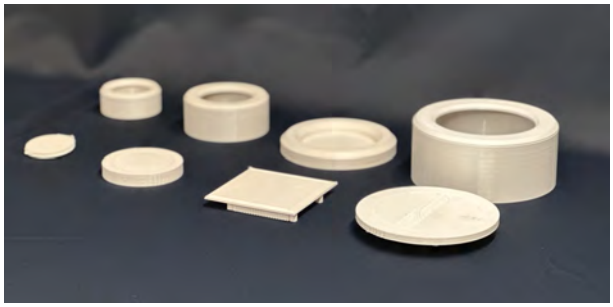

Figure 7: Prototyping via 3D printing of various sizes of bezels and displays

6 Electronic Component Selection

6.1 Motor Requirements

In terms of motor selection, the overarching requirement was that the shaft had to be hollow, in order to allow the wires to pass between the rotating and stationary sections without tangling. A brushless (BLDC) motor was also preferable due to the increased efficiency and durability which would lead to increased battery life and lengthen the product's life cycle.

The first requirement for the motor was its maximum angular velocity, in relation to rotate the camera to be able to effectively check up on the elderly individual. To calculate this we made some assumptions. Firstly,

taking an average living room size of 3.7 x 5.5 m and the average walking speed of 1.2 m/s [3] it can be deduced that the fastest time to cross the shortest side of the room would be around 3 seconds. Assuming a somewhat worst case for the positioning of the device in the mock living room shown in Figure 8, the camera would need to turn 120 degrees in the 3 second period. This gives an angular velocity of 0.6981 rad/s or 6.67 rpm. Applying a safety factor of 1.5 results in a requirement of around 10 rpm.

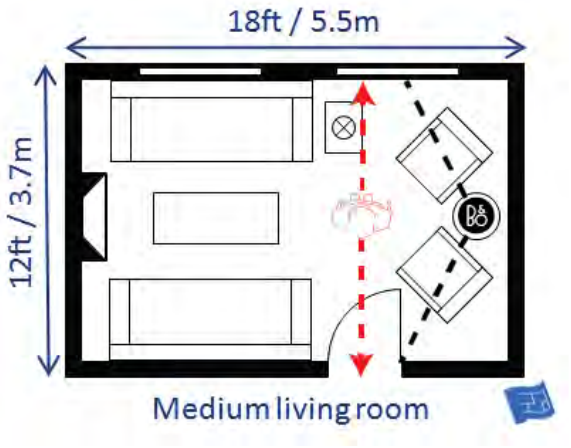

Figure 8: Person moving in average living room

The second requirement for the motor is to have sufficient torque to accelerate at a desirable rate. This can be calculated using the moment of inertia and angular acceleration of the rotating parts. Using the CAD model of the upper device section it was found that the moment of inertia is 0.002997835 $kg * m^2$.

As a worse case scenario for acceleration, we specified that if the camera is moving in one direction at maximum velocity then it should be able to reverse to the opposite direction at maximum velocity within a second. Using Equation 1, a change from 10 rpm to -10 rpm in 1 second results in an angular acceleration of around 2.1 rad/s^2 .

$$\alpha = \frac{\omega_1 - \omega_2}{t} \tag{1}$$

Therefore using Equatioon 2 the required torque is 1.01 kg-cm, equal to the product of the moment of inertia and acceleration. Again applying a safety factor to account for additional friction the required torque is 1.5 kg-cm

$$\tau = I\alpha \tag{2}$$

Budget considerations were also taken into account, which led to us selecting the iPower GBM4108H-120T. The hollow shaft diameter of 5.5mm is adequate for the wires to pass through and the torque rating of 1.8 kg/cm is in excess of our requirements.

6.2 Battery Calculations

To calculate the battery requirements the power draw for each component was found. This assumes a worst case where all the components are simultaneously being used at their maximum rating. Although this is unlikely it is required to ensure that the selected battery can meet the maximum required current draw. Power was used instead of current since different voltage levels are required for various components.

Table 1: Power consumption of various components

Component	**Power Draw (W)**
Raspberry Pi 3B Board	1
3.4” Display	1
32 LED Ring	3
BLDC Motor	3
Alexa Module	1
ESP32	1
ESP32 Camera	1
Hall sensor	1
Total	12

Selecting the battery voltage was simple since the BLDC motor requires 12 V to operate optimally. Table 1 shows that the total power draw is around 12 W, which equates to drawing 1 A from the 12 V battery.

$$Battery\ Life\ (Hrs) = \frac{Battery\ Capacity\ (mAh)}{Load\ Current\ (mA)} \tag{3}$$

Since the product is mainly designed to be plugged in with the battery acting as a backup in the event of a power cut, a relatively short 2 hour target for battery life was set. Using Equation: 3 and setting the load current to 1 A it can be found that a 2000 mAh battery is required. We therefore selected a 2000 mAh 3S Li-Po battery for its high energy density to maximise spacial efficiency. The battery has a discharge rate of 30C meaning it can deliver 67 A continuously, which will not be an issue for our 1A current draw.

6.3 Quadrature Encoder

In order to control the motor’s speed and direction accurately its position had to be calculated. The solution preferably would not have contact between the upper and lower sections of the device since communication between the relative movement of each section cannot be via physical wires. We settled on using a magnetic encoder which would allow for a high resolution of angle reading, as well as direction sensing.

The position of the motor is determined by passing a ring of magnets over a pair of analog hall effect sensors which are out of phase with one another. The change

in flux of the north and south poles of each magnet are mapped onto sine waves during rotation. This allows the rate at which the magnet passes over the the sensor to be determined. We did have some issues, since if the rate at which the sensor is polled is too slow it may miss some of the peaks, leading to aliasing and ultimately the motor skipping positions.

Theory dictates that the minimum sampling frequency (Nyquist Theorem) should be at least twice the maximum frequency that is being sampled. Despite our sensors polling at 1Mhz we would not be able to interrupt at that speed due to the clock speed of our microprocessor. Through experimentation, we determined that the fastest rotation speed of the dial and therefore worst case for sampling frequency would be around 3 full rotations of the dial per second when turned by hand. The frequency at which the magnetic pulses alternates is proportional to the number of magnets on the encoder ring, which we set to be 32, as shown in Figure 9. Therefore the worst case is 96 triggers per second.

Figure 9: Magnets fitted to encoder ring

To further increase the resolution of the encoder from 32 positions, the analog output of the hall effect sensors can be sampled in order to interpolate between distinct peak magnet positions. Two offset sensors were required to calculate a gradient between them a ninety degree phase relationship between them allows for both the magnitude and direction of rotation forming a quadrature encoder. This requires a much higher sampling frequency. At higher frequencies the Raspberry Pi sampling becomes less accurate as shown by Figure 10. This frequency is too high for the raspberry pi to sample at over PWM communication using python (the required language due to the display) therefore, an ESP32 is required as it can run C++ to handle the increased sampling rate, process that data and then feed it to the Raspberry Pi at a slower rate but within our tolerance.

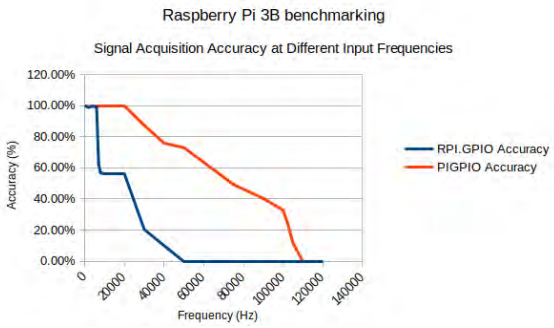

Figure 10: Raspberry Pi sample frequency [4]

6.4 Hall Effect Sensors

To determine which hall effect sensors to use, the field strength the magnet is required to produce needed to be calculated to avoid saturation of the output at the fixed separation of the magnet and encoder. We chose the magnets first due to space requirements with cylindrical magnets of 6 mm diameter and 3 mm height being used. Equation 4 shows the field strength for a cylindrical magnet.

$$B = \frac{B_r}{2}\left(\frac{D+z}{\sqrt{R^2+(D+z)^2}} - \frac{z}{\sqrt{R^2+z^2}}\right) \quad (4)$$

Where [5]:
Br: Remanence field z: Separation
D: Magnet Thickness R: Magnet Radius

From the CAD, the maximum separation of the hall effect sensor and magnets was 15mm. When substituted into Equation 4 this gives a value of 37 Gauss. A readily available hall effect sensor is the Waveshare AH49E [6] which claim a magnetic field range of ±1000GS. Substituting the required 1000 Gs range into 4 reveals an optimum separation of around 3.5mm without saturation. This made the AH49E sensors suitable for our application.

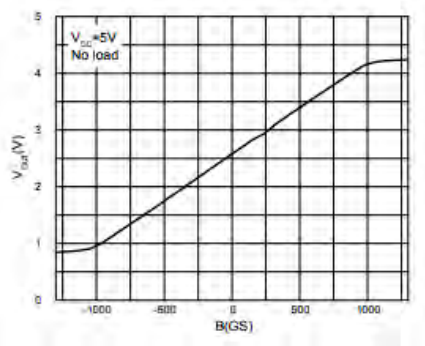

Figure 11: AH49E Output [4]

7 Design for Manufacture

7.1 Dial Machining

6082 T6 aluminum alloy was selected for the dial since it has excellent corrosion resistance and is also highly machinable. Since the dial contained complex curves, CNC machining was the only viable option. We did not have access to a CNC lathe which would have been the optimum process, so instead a HAAS 3 Axis CNC Mill was used. We therefore optimized our design to suit this tool.

To do this we ensured that tool access was possible at all times as show in in Figure 12 by avoiding overhangs and very small features. Unfortunately since our part required machining on both sides, an operation was required to flip between passes on either side. Wall thickness was kept to a minimum of 1mm which avoided distortion from tool pressure when machining. The dial was toleranced to ISO 2768 fine standards for critical dimensions and medium for all aesthetic features.

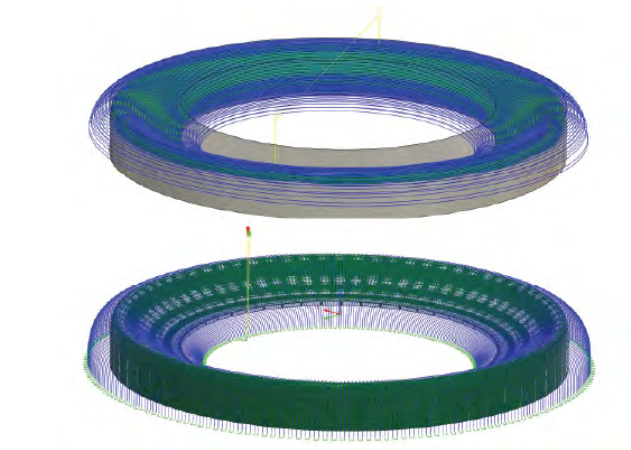

Figure 12: Tool paths for machining dial faces

7.2 Wooden Slats

Although the wooden slats around the base appear to be a complex they are designed take a minimal number of processes to make.They are made from long stock, meaning mass or batch production within B&O would be possible. Initially each of the faces of the stock material is sanded to the cross section required, which can be fed in a jig. A work-piece stop is used to rapidly cut the long stock into individual identical lengths. Then another jig is used in order to created the cutout on a band saw. Finally to add the chamfer a disc sander is used with an angled jig. Total process time for each piece was around 20 seconds, which equates to 10 minutes per device.

7.3 Casings

Although for this project the casings were 3D printed, they were still designed with manufacture in mind for a production environment with injection moulding capabilities. For this reason the complexity is minimized and modularity is used via snap fitting or bonding of additional features which would otherwise prove difficult to mould.

For example, Figure 13 shows the cross section of the upper casing, which has a inner bore and outer face without any overhanging features that would prevent a mould from being retracted. Furthermore, split lines and general surface finish on this section of the mould are not critical since it will be covered in fabric for the final product, meaning a lower quality mould could be used to reduce manufacturing costs.

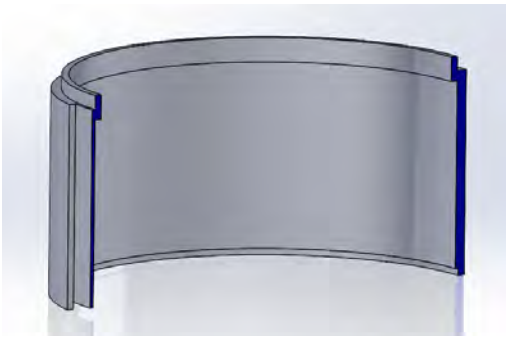

Figure 13: Main casing cross section

For smaller casings, the wall thickness was carefully monitored to ensure that parts do not become too thin to manufacture, avoiding warping and sinkage. Figure 18 shows the Raspberry Pi casing, where no wall thicknesses are less than 1 mm. For thin areas of the part such as on the left hand side, supportive ribs are added to increase rigidity. Since the part is internal, ejector pins could be placed on any of the surfaces without visual impact.

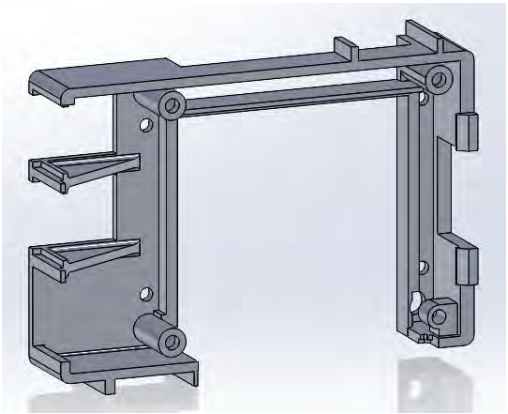

Figure 14: Small casing section with ribs

8 Design for Assembly

8.1 Z Axis and Modular Assemblies

When designing the components within our product we aimed to build vertically upwards, which saves time when assembling the product and also optimizes it for mass production. The design is split into smaller discrete sub assemblies which can can be separately put together and then combined. For example, Figure 15 shows the screen, Raspberry Pi and motor control board fully assembled, ready to be snap fit to the motor and casing sub assembly. The modular elements allowed for quicker disassembly, redesign and repair.

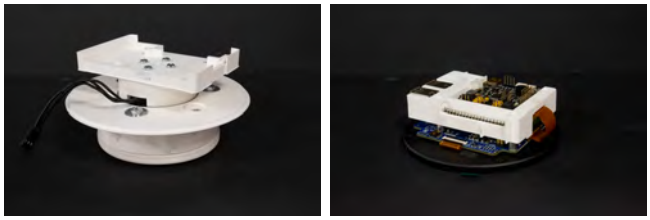

Figure 15: Sub-assemblies to vertically stack.

8.2 Snap Fits

To simplify and speed up the assembly process as much as possible snap fits are used. One key example is the screen assembly mounting as shown in Figure 18. During normal operation the screen will only take downwards force so could not be accidentally removed by the user, so a snap fit is ideal. But once the internal components are accessed it provides easy disassembly.

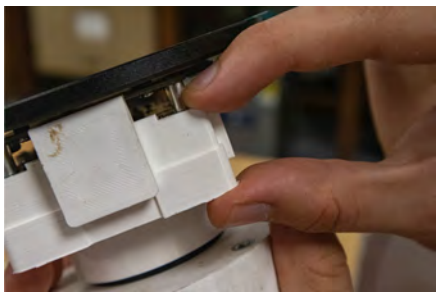

Figure 16: Snap fit assembly of Raspberry Pi casing

Snap fits are also integrated where using fasteners would not be feasible. An example is the ring that hides the seam between the two pieces of fabric on the lower casing. Removable fasteners in this case would likely be small, inaccessible or overly visible from the exterior breaking away from the clean and simple design of B&O.

8.3 Standard Fasteners

There are a variety of fasteners used in the device; the majority being nuts and bolts. This allows for disassembly but also for a stronger connection between parts than a snap fit can generally offer. Since these fasteners are slower to assemble we designed features to streamline the assembly process, such as recesses to hold washers and locating features for bolt heads, as shown in Figure 17.

Figure 17: Recesses for washers

Using standard fasteners aids in the repairability of the product, which is crucial for a B&O device since they design for the ability to swap internal hardware once new technology is released or the electronics degrade. It also made it simpler to prototype the product since it can be disassembled in order to troubleshoot issues.

8.4 Symmetry and Asymmetry

Many of the parts in the assembly are symmetrical which results in faster assembly as they can be inserted in any direction by the production line operator. This is the optimum solution, but when the parts are asymmetric it was important to design them to be instantly obvious which orientation they must go in.

One example is the main bearing holder and upper casing as shown in Figure 18. This split line is where the upper casing is sealed off by this part and attaches to the bottom casing. We placed a notch on the outer diameter shows where alignment with the upper casing is needed.

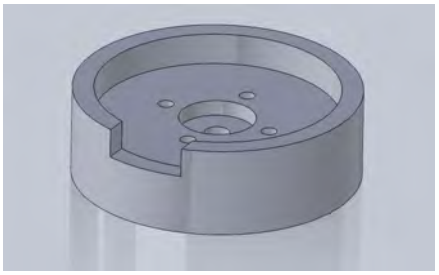

Figure 18: Asymmetric feature on casing

9 Product Assembly Process

9.1 Step by Step

A full breakdown of the step-by-step assembly process can be found on Portfolio Page 10.

9.2 Timing and Cost Estimate

Upper and lower section assembly take around 8 minutes and 25 seconds and 10 minutes respectively. Electronics sub assembly takes 4 minutes and 15 seconds. The final assembly takes 6 minutes, meaning the total time is 28 minutes and 40 seconds. With some transition time between assembly stations and packaging, around 30 minutes can be expected, making cost approximately $3.50 for a $7/hour salary. The tools we need: a vice, hex key set, adhesive, flat head screw driver and soldering iron.

10 Issues Arising & Resolution

10.1 Obstruction of Screen View due to Dial Rotation

During the prototyping process, it was discovered that users often obstructed their view of the screen while rotating the dial with their hand. This usability issue hindered their experience. We resolved the issue by implementing skeuomorphic design of rotary telephones into our design. The curved inner face of the ring enables users to rotate with a single finger, while the main body can also be rotated for coarser movements. This dual-method of interaction ensures an unobstructed screen view. Ideally a dimple would have been added to prompt the use of a finger for rotation, however manufacturing this feature was limited by the CNC mill failing.

10.2 Covering the Fabric Seams

Our design incorporated fabric around the product in the style of B&O. However, attaching fabric seamlessly was a challenge. We devised a seam in the shape of a ring within the device, using a snap fit to secure the fabric. The seams running vertically up the product were then hidden behind one of the wooden slats for the bottom portion and an aluminium facial plate for the top.

Figure 19: Focus shot of the fabric seam

10.3 Insufficient Processing Power

10.3.1 Raspberry Pi

The Pi does not have enough computational power to process the resolution of the display output in parallel with running server side hosting and voice recognition algorithms. We overcame this by outsourcing the computation to support processors.

10.3.2 ESP32

During our development phase, we observed that the processing requirements of our device exceeded the capabilities of Raspberry Pi's processing speed in terms of sampling the hall effect signal. An ESP32 was needed to process the encoder value data from the pair of hall-effect sensors. It needed to run two PID control algorithms as well as mapping position values on to boundary constraints. As the ESP needs to read and write at such high speed, it was not able to meet the requirement as the clock speed was too low. To combat this, overclocking was applied to gain additional performance.

10.4 Hall Effect Sensor Positioning

We utilized a hall effect sensor to determine the position of the motor as the user rotates the dial. The initial hall effect sensor we used required a diametric magnet to be so close that it didn't allow wires to pass through its centre which was a necessity in the design. Additionally, the second hall sensor we tried only provided a digital read, resulting in too low resolution. We resolved the issue by choosing linear hall effect sensors. These sensors better suited our design because they allowed for much higher resolution by interpolating between the peak outputs from the sensors. As a result, we can accurately detect the motor's position when the dial is rotated with over 20000 increments.

Figure 20: Hall effect sensor positioning relative to magnetic encoder ring.

10.5 Overall Height

After user feedback we found that the device's height exceeded what would be practical, hindering usability and detracting from its aesthetic appeal. To address this we focused on reducing the vertical spacing of the internals as much as possible.

Firstly, we modified the wooden base, reducing the wall thickness of the hollow section to allow for placement of components deeper within the base instead of on top, resulting in a reduced height. In addition to this, the travel of rubber squeeze structure that provides tactile feedback to the user was reduced, using bolts which could vary this distance.

Another change we made was to move from sliding plates to a bearing in order to support the rotation of the dial. This saved around 1 cm off the total height and also substantially reduced the friction to overcome in order to to rotate the device. Finally we reduced clearances between many of the parts by transitioning from using breadboard pins to directly soldering the electrical connections.

Figure 21 shows the progression of our casing design, with the shortest final version reducing the total product height compared our initial version by around 10%. Combining several of these modifications brought the height back into proportion.

Figure 21: Design adjustments for height optimization

10.6 CNC Machining

Our initial designs for the top and bottom metal ring contained contours which could not easily be machined on a manual lathe, and without access to a CNC lathe the best option was to use a CNC milling machine. Unfortunately, while setting up our parts, the machine broke, leaving no time to manufacture the parts in this way. To ensure the project was still delivered, the design was simplified, substituting the complex curves for chamfers of various angles.

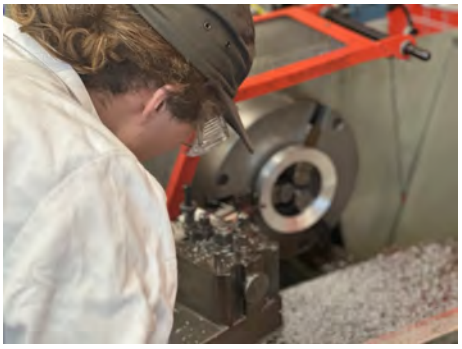

Figure 22: Manual machining of the simplified dial

11 Product Compliance Research

It's crucial we adhere to compliance standards when developing our product. These requirements aren't just legally necessary but also reassure customers of the product's quality and safety. B&O, an international company, places a high priority on meeting product regulations in all markets where they are sold. In particular, complying with EU and UK standards is critical because a significant portion of their customer base resides in those regions.

11.1 CE Marking

For products to be sold in the European Economic Area, they must comply with EU safety, health, and environmental protection standards. This is indicated through the CE marking, which is mandatory for products like those of B&O. To attain the CE marking, B&O must:

- Ensure the product complies with specific EU requirements.
- Conduct or have a third party conduct an assessment of conformity.
- Maintain technical documentation.
- Complete an EU Declaration of Conformity.

- Affix the CE marking to the product or the packaging.

11.2 UK Conformity Assessed (UKCA) Marking

Following the UK's exit from the European Union, the UK Conformity Assessed (UKCA) marking has been introduced as a replacement for the CE marking for products sold in Great Britain. This marking signifies that the product complies with UK regulatory requirements.To obtain the UKCA marking, B&O must:

- Carry out a conformity assessment.
- Maintain a technical file that includes how the product is designed, manufactured, and complies with relevant requirements.
- Have a UK Declaration of Conformity.
- Affix the UKCA marking to the product or the packaging.

The technical file must be retained for 10 years and must be presented upon request by market surveillance or enforcement authorities.

11.3 Global Compliance Considerations

B&O are a global brand which operates in different countries which have unique regulations and standards. Although this document emphasizes UK and EU compliance, we also know the significance of following international standards to maintain product quality and customer satisfaction worldwide. Meeting necessary requirements is our commitment to all markets where we operate.

11.4 General Legislations

Since B&O is a European company and its primary markets are in Europe, it's essential to focus on EU legislation compliance. Here are the general legislation that are relevant for our product.

Radio Equipment Directive (RED) 2014/53/EU:
This directive ensures that radio equipment, including our product, adheres to standards related to the efficient use of radio spectrum in order to avoid harmful interference. As our product employs wireless communication, complying with the RED is crucial for it to be marketed in the EU.

Electromagnetic Compatibility Directive (EMCD) 2014/30/EU:
This directive ensures that electrical and electronic equipment doesn't generate, or is not affected by, electromagnetic disturbance.

Waste Electrical and Electronic Equipment (WEEE) Directive 2012/19/EU:
This directive is for the proper disposal and recycling of electronic products and aims to minimize the environmental impact of E-waste.

Eco-design Directive 2009/125/EC:
This directive focuses on the ecological design of energy-related products, aiming to improve the environmental performance throughout the product's lifecycle.

Battery directive 2006/66/EC:
Our aim is to minimize the negative impact of batteries on the environment through this directive. The directive includes provisions that restrict hazardous substances in batteries and require proper labeling, removal, and recycling of used batteries.

Regulation of hazardous substances and chemicals in electronics:
Our product complies with the RoHS Directive 2011/65/EU and REACH Regulation (EC) No. 1907/2006. RoHS limits hazardous materials in electronics, while REACH oversees the safe use of chemicals. Together, they ensure our product is environmentally sustainable and safeguard human health.

11.5 Incorporating Industry Standards

We adhere to key industry standards to ensure the highest quality and safety for our product. These standards provide technical guidelines that meet regulatory and consumer expectations, fulfilling legislative requirements.
Radio Equipment Directive (RED) 2014/53/EU:

- Standard: ETSI EN 300 328 (For wideband transmission systems)
- Standard: ETSI EN 301 893 (For 5 GHz high-performance RLAN)
- Standard: ETSI EN 300 440 (For short-range devices)

Electromagnetic Compatibility Directive (EMCD) 2014/30/EU:

- Standard: EN 55032 (Electromagnetic compatibility of multimedia equipment - Emission Requirements)
- Standard: EN 61000-3-2 (Electromagnetic compatibility (EMC) - Limits for harmonic current emissions)
- Standard: EN 61000-3-3 (Electromagnetic compatibility (EMC) - Limitation of voltage changes, voltage fluctuations and flicker)

Waste Electrical and Electronic Equipment (WEEE) Directive 2012/19/EU:

- Standard: EN 50625 (Collection, logistics & treatment requirements for WEEE)

Eco-design Directive 2009/125/EC:

- Standard: EN 50564 (Electrical and electronic household and office equipment - Measurement of low power consumption)
- Standard: EN 60960-1 (Requirements for the reduction of hazardous substances in multimedia equipment)

Battery Directive 2006/66/EC:

- Standard: EN 62133 (Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for portable sealed secondary cells, and for batteries made from them, for use in portable applications)
- Standard: IEC 60086-4 (Primary batteries - Safety of lithium batteries)

Regulation of Hazardous Substances and Chemicals in Electronics (RoHS Directive 2011/65/EU and REACH Regulation (EC) No. 1907/2006):

- Standard: EN 50581 (Technical documentation for the assessment of electrical and electronic products with respect to the restriction of hazardous substances)
- Standard: EN ISO 14021 (Environmental labels and declarations - Self-declared environmental claims)

11.6 EU Declaration of Conformity

As part of this report's appendix, we have included the comprehensive EU Declaration of Conformity for those interested in a detailed overview of our product's adherence to relevant European Union regulations. The document confirms that our product satisfies the essential standards outlined in applicable EU Directives and Standards. To locate the EU Declaration of Conformity quickly, flip to page 20 within the appendix.

12 User Guide

To ensure a smooth experience for our users, it was crucial to develop a comprehensive and user-friendly guide. Our product boasts multiple features that users need to be educated on effectively.

12.1 Key Considerations:

- **Accessibility:** The guide had to be easily understandable and accessible.
- **Clarity:** Clear instructions on the setup and use of all the features.
- **Troubleshooting:** Including a section for common issues and their solutions.
- **Safety and Maintenance:** Information on how to safely use and maintain the device.
- **Customer Support:** Providing contact information for further assistance.

As developers of **Beobridge** Connect we understood that our guide should be user-friendly to seniors. They may not be familiar with technology jargon; thus, it's important for them to easily and quickly start using the product without any hassle or confusion.

12.2 Quick Start Guide:

To enhance convenience and reduce material usage, we have incorporated a Quick Start Guide within the packaging's inner section. This concise guide will walk users through the basic steps to get the device up and running smoothly. We utilized standardised B&O icons to guide the user through setup, with their location in the packaging corresponding directly to the relevant features of the product, such as the charging port.

12.3 Online Detailed User Guide:

We have also developed an online version of the user guide, containing more detailed information, additional resources for troubleshooting, advanced features, and customer support. Scanning a QR code

printed next to the Quick Start Guide gives easy access. This ensures that all necessary information is conveniently available to both elderly users and their caregivers.

12.4 Product Labelling

12.4.1 Brand Identity and Manufacturer Information

The B&O logo and "**Beobridge** Connect" product name are displayed on the packaging to establish a robust brand identity. The product code and serial number are included for easy identification that's crucial for customer support and warranty claims. We also comply with regulatory requirements by clearly stating the manufacturer's name and address on the product/packaging.

12.4.2 Regulatory Compliance and Environmental Marks

Both the product and packaging display regulatory compliance marks, like CE and UKCA. The environmental symbols like the Mobius Loop on the packaging communicate its recyclability to consumers. These markers indicate that the product is adhering to necessary standards of regulation and committing to eco-friendliness.

12.4.3 User Guide and Safety Information

Finally the packaging contains a leaflet with important safety information, ensuring that users handle and use the product properly. It outlines key points such as environmental conditions that could be damaging to the product as well as disposal information.

13 Product Packaging

13.1 Branding and Visual Identity

Since the packaging is the first touch point that the buyer will have with the product it is important that it reflects the premium and unique brand identity of B&O.

Visually the design should be simple and minimalist to be in line with the existing B&O packaging coloured with the hex code #F2F2F2, a light grey. Wire-frame outlines of their products are also common so we continued this trend, creating a stylized outline of the product from both the top and side views. The B&O logo is present on the packaging but is generally quite understated, with the product outline and photos being more dominant.

13.2 Target Audience

Designed for the elderly and carers, the packaging should clearly show the required steps as soon as it has been opened. Text should also be simple and easy to read, so we increased the text size to a minimum of 14pt, and icons were used throughout to add a visual way to understand the product set up process. A key consideration was that the product should be easy to remove from the packaging since an elderly person could struggle with the grip strength of holding onto the product while lifting it. The design to accommodate this is discussed below.

13.3 Functionality and Design

Besides attracting the user to buy the product, the packaging also serves the purpose of protecting the product in transit and when on display. Often this can introduce waste into the design with excess packaging such as packing peanuts or pillows. Therefore, we designed packaging which removed the need for additional packing materials by integrating protection for the product into the packaging itself.

Prototyping began with recycled cardboard at a reduced scale to validate our net design. An Amazon Alexa was used for testing since it has a round exterior face, while the smaller scale sped up the prototyping process before we up scaled the packaging size to one that would fit our larger product.

Figure 23a shows the unique feature of our packaging design: the integration of internal protective corners. Folding the net in this way allows for the device to be held securely and safely without the need for excess packaging. Furthermore, Figure 23b shows how the packaging folds completely flat. This enables 2 more design features. Firstly, the product is now far easier to remove from the packaging since it can be accessed from all sides and does not need to be lifted, with the packaging instead being slid out from underneath. In addition there is also free space on the inside of the packaging that we decided to use to place our quick start user guide, which can be rotated to view the

(a) Protective Corners & Sealed Box

(b) Net Unfolded Flat

Figure 23: Packaging prototyping using cardboard

13.4 Production Process

To produce the packaging we first designed the net as shown in Figure 24. Adobe Illustrator was used to generate a DXF file which could be sent to the laser cutter. Each panel was split up into sections since we did not have access to a suitably large laser cutter to cut a complete net. The square panels are 150 mm wide to fit the 127mm outer diameter with some excess room, while the rectangular panels are 250mm tall to account for the height of the product. The connecting flaps can be altered to adjust the fit around the product once they have been folded inwards.

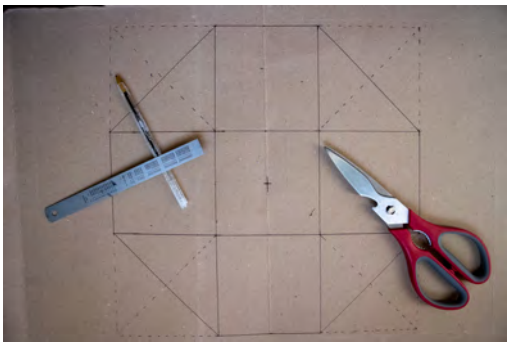

Figure 24: Net Design

Figma was used to design the graphics since it is vector based, allowing for scaling to various packaging sizes without resolution loss. In total 10 panels were designed before being printed on photo paper and bonded to the cardboard panels. In a production environment of the final product the process would be significantly more streamlined as the graphics could be directly printed to the material before cutting.

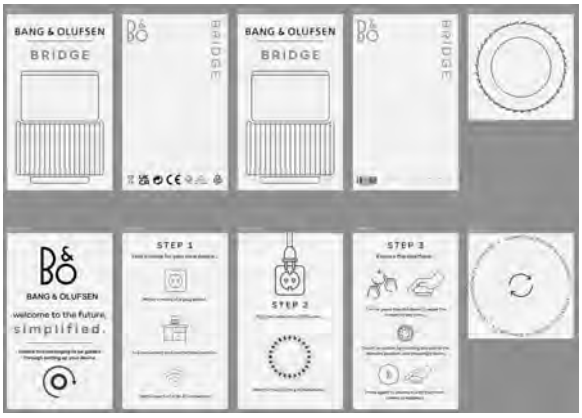

Figure 25: Packaging exterior and interior

13.5 Material Selection

Sustainability is a key element of the packaging design that B&O use, as they target using only FSC sourced materials. The packaging is generally a simple cardboard box while a separate piece of cardboard is moulded to the product to hold it securely within the box.

Construction card was used for the panels as it is fairly stiff yet can be easily recycled everywhere in the UK. To further reduce paper usage the user guide was printed on the inside of the packaging rather than as a separate booklet. An adhesive sticker acts as a seal of authenticity while also securely joining the top and bottom sections. This prevents them from sliding apart while removing the need for a non-recyclable plastic wrap as seen on many other products.

13.6 Packaging Compliance

Several labels are added to the packaging to convey the standards and directives that the product and packaging conform to.

FSC Label: We utilize a combination of forest-based materials sourced sustainably and recycled paper for our packaging. This approach has earned us the Forest Stewardship Council (FSC) label, which certifies that all materials have been responsibly sourced from carefully managed forests.

Green Dot Symbol: The Green Dot symbol on our packaging indicates that we have contributed financially towards the recovery and recycling of packaging

materials in Europe. This enables us to be environmentally responsible and prevent pollution caused by our packaging.

Mobius Loop: We display the Mobius Loop symbol on our packaging, an internationally recognized icon indicating that it is recyclable. By recycling our packaging, consumers can contribute to environmental sustainability, and this icon serves as a clear message of that opportunity.

WEEE Label: As per the Waste Electrical and Electronic Equipment Directive, our product features the WEEE Label. This label serves as a gentle warning to customers that the product should not be disposed of like regular waste but rather directed towards special collection points for responsible recovery and recycling procedures.

14 Final Design

14.1 Features

Smart Home Control - The primary function of the product is to integrate with and control many of the smart home devices such as light and heating that are already on the market. Currently Amazon Alexa integration is the only form of communication available on the device due to it's simplicity, off-device processing and inbuilt encryption, but expansion to Apple HomeKit and the internet of things would be possible with more time requiring licensing and on-device computation, local network communication and network hopping.

Tactile Rotary Feedback - Our main focus was on developing a reliable, accurate and flexible way for the user to control the device, complementing existing interaction methods such as voice and touch control. The dial which can be only turned and pressed enables complete navigation of the UI with only 2 actions. Resistance applied by the BLDC motor allows an adjustable level of force feedback to be given to the user, catering to various grip strengths and dexterity. This adaptability grows with the user catering for their needs even if their dexterity reduces. The ability to virtually adjust increments allows us to reflect the functionality of the UI in the physical interaction from emulating a rotary phone dial to physically communicating discrete temperature values on a thermostat. Limiting increments to a switch, on or off for a lightbulb or someone with very limited dexterity, means a interaction has to be very intended in order to change a something in the smarthome and reduces the chances of accidental home commands.

Built-in Camera - One of our key aims was to help carers carry out well being checks remotely. The camera on the device utilizes the motor controlling the dial to rotate around the room, ensuring that the elderly person can always be seen. Privacy concerns are mitigated by wiring the LED ring to the camera in order to offer a visual indication that it is operating. A buffer time has been implemented between the carer's request for video and the streaming of video, allowing the elderly to respond to the request in ample time from both auditory and visual feedback.

Voice control - To further increase simplicity and accessibility voice control was added to give an extra level of potential interaction to allow any user to access the technology in the simplest way for them. Voice detection software is achieved through an Amazon Alexa module which is integrated into the bottom.

Speaker - Giving sensory feedback in as many ways as possible will ensure that the user is clear on how the device is responding to their interactions. Auditory confirmation is available through the speaker when operating the menus. As a B&O product it also doubles as playing music, although sourcing high quality audio components assets was out of scope for this project so the sound clarity is somewhat low. As it is designed to connect devices together the audio quality isn't as important as the user would be expected to use their other B&O products to play music.

15 Business Case

The **Beobridge** Connect is an innovative product developed by B&O that elegantly integrates a touchscreen interface with a speaker and dial. Priced at £1,499, it has been meticulously designed for the elderly, offering them an easy-to-use device that doesn't compromise on modern functionalities. Its sleek design, high-end finish, and intuitive interface make it an attractive and practical choice for consumers.

15.1 Market Analysis

15.1.1 Target Market

The primary target market for **Beobridge** Connect includes the elderly and their caregivers, particularly within the high-end consumer segment. There is a growing need among the elderly population for simple yet functional device that enhance their daily lives and allow them to maintain a level of independence.

15.1.2 Market Size

With an aging population in many developed countries, the market for devices catering to the elderly is substantial. There are almost 11 million people aged 65 and over in the UK. This equates to around 19% of the UK population [7]. Although our product is at the high end of the market, Figure 26 shows that there is a niche for it, with income peaking around 50 years of age. This coincides with when a person is likely to start caring for their parents making them a key consumer of the **Beobridge** Connect, purchasing on behalf of the elderly user.

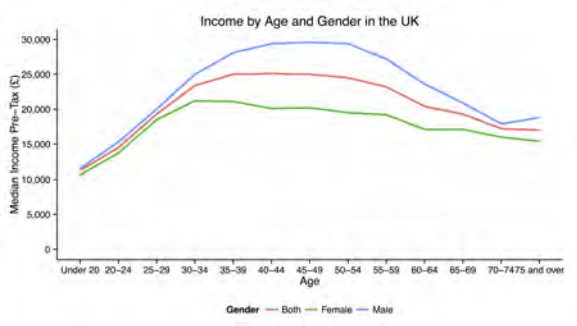

Figure 26: Income vs Age in the UK

15.1.3 Competitive Analysis

With B&O's expertise in high-end audio, multimedia products, and integrated ecosystem design, B**Beobridge** Connect is technologically feasible.

15.2 Product Feasibility, Desirability, and Viability

Feasibility: Given B&O's expertise in creating high-end audio, multimedia products and integrated ecosystem design, the **Beobridge** Connect is technologically feasible.

Desirability: There is a high demand for smart home devices among the elderly, especially those that are easy to use and help in enhancing their quality of life. With almost every aspect of the home having a specific smart device to provide control a desire for a simple way to control everthing is created.

Viability: The pricing of £1,499 is reflective of the premium nature of the product and the B&O brand. With the substantial market size and limited competition in this niche, there is an opportunity for profitable sales.

15.3 Revenue Model

The primary revenue for **Beobridge** Connect will be generated through product sales, and the premium pricing strategy is expected to yield healthy profit margins. Exploring partnerships with healthcare or senior living facilities for bulk orders could also be a lucrative avenue.
A comprehensive marketing strategy that encompasses both online and offline channels will be pivotal. Online efforts could focus on social media campaigns specifically targeting caregivers, while offline strategies could involve collaborations with senior living communities. Moreover, establishing partnerships with healthcare providers and retail outlets that specialize in products for the elderly can further extend the product's reach and bolster sales.

16 Software

16.1 System architecture

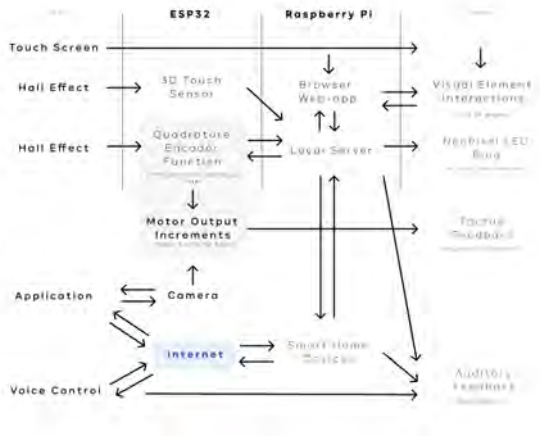

Figure 27: System architecture diagram

16.2 User interface

Designed to be simple and clean the user interface aims to provide as much information as possible without overloading or confusing the user. Out of the box the UI provides a selection of pre-setup interfaces adapted to different possible circumstances which the user can select from. Furthering this, to make the display as accessible as possible the carer is able to completely customise the display so that they can adapt it to the users specific requirements allowing them to change icons, layout, colours, text and touch screen capabilities.

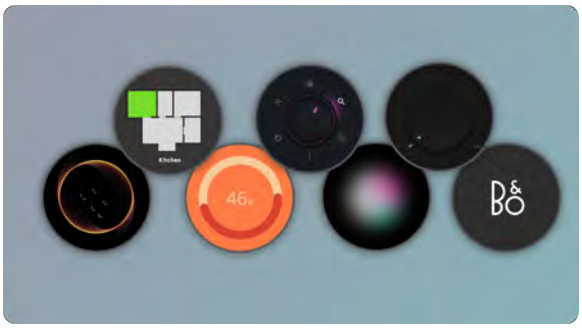

Figure 28: User interface design

16.3 Accompanying App

The **Beobridge** Connect has an accompanying app to allow users to fully customise their device to best suit their needs. The layout is clean and simple amplifying B&O design and while it is designed to be as intuitive as possible to use it is expected that it would be mostly used by the carers of the elderly person to control what and features of the home could be controlled along with the responsiveness, text size, icons, motor power and other accessibility features. The app is also designed to control the monitoring feature of the device.

Figure 29: App design

17 Objective Validation

In this section, we evaluate the objectives laid out at the start using project data. We conducted user validation with three seniors above 65. We could substantiate some objectives but not all. The limited timeframe and small sample size necessitate further testing with a larger user group for thorough validation.

17.1 Usability and User Interface

1. **Intuitive Interface Design:** Our user satisfaction survey indicated an average score of 4 out of 5 regarding the intuitiveness of the interface, exceeding the objective target of 3.
2. **Customise Controls:** All users were able to successfully customize the dial sensitivity and controls within the first use.
3. **Accessibility Standards Compliance:** The product has been designed with compliance to WCAG 2.1 Level AA standards in mind. However, official certification and user satisfaction regarding accessibility features are yet to be assessed.

17.2 Integration and Compatibility

Universal Compatibility: Beobridge CONNECT demonstrated compatibility with all smart home systems tested among the users. Further validation needs to be done to reach fully the objective.

17.3 Safety and Emergency Response

1. **Emergency Call Trigger:** Time limitations restricted our ability to fully assess this objective.
2. **Camera Feed Access:** The camera feed is accessible within 4 seconds of request initiation, with encrypted transmission, meeting the objective target.

17.4 Setup and User Education

1. **Setup Process:** All users were able to complete the setup process unaided within 5 minutes.
2. **Clarity of Educational Materials:** The educational materials received an average score of 5 out of 5 on user feedback.

17.5 Security and Privacy

1. **Compliance with Data Protection Laws:** We are in the process of evaluating the compliance with GDPR and other data protection laws. The security assessment is ongoing, and an 'A' rating is targeted.
2. **Camera privacy:** 100% of the time, users receive a notification that the camera is turning on, and there's a 5-second delay before it actually activates.

18 Project Plan

18.1 Project Milestones

i. Milestone 1: Kickoff & Ideation
Date achieved: January 10, 2023

Description: The project was launched with goal setting and brainstorming for concept generation.
Updates: Ideas underwent refinements based on collaboration and research.
Learnings: Importance of early-stage adaptability.

iii. Milestone 3: Market Research & Branding
Date achieved: May 19, 2023
Description: Market research conducted to identify target audience and branding elements developed.
Updates: Branding elements refined for better alignment with market insights.
Learnings: The critical nature of market alignment in branding and design was learned.

ii. Milestone 2: CAD Models & Prototyping
Date achieved: June 2, 2023
Description: Development of CAD models, and creation of initial prototypes for concept testing.
Updates: Prototypes and models iteratively improved through feedback.
Learnings: Early evaluation and iteration are crucial.

iv. Milestone 4: Software Development & Integration
Date achieved: June 14, 2023
Description: Development of software and effective integration of various electronic components.
Updates: Software optimized based on testing and integration needs.
Learnings: Integration complexity; thorough testing necessary.

v. Milestone 5: Final Assembly & Testing
Date achieved: June 16, 2023
Description: Guided the final assembly and carried out comprehensive testing of the product.
Updates: Adjustments made to hardware and software based on testing results.
Learnings: Meticulous testing crucial for quality assurance.

vi. Milestone 6: Documentation Compilation
Date achieved: June 21, 2023
Description: Compiled the final project report and portfolio, incorporating all project elements.
Updates: Multiple revisions for accuracy and completeness.
Learnings: Importance of detailed, reflective documentation.

18.2 Team Roles and Contributions

Henry - Chief Technical Officer (CTO)

Role and Responsibilities: Henry, the CTO, was tasked with the technical development and design of the product through CAD modeling, prototyping, product visualisation to final design.

CAD Modeling: Henry created intricate CAD models using SolidWorks for rapid iterations, essential for product design conceptualization.

Prototyping: He developed physical prototypes from CAD models, testing the product's design and functionality.

Rendering and Visualization: Henry set up renders, photos & videos for marketing, video and portfolio.

Ross - Chief Operations Officer (COO)

Role and Responsibilities: Ross played a key role in the hands-on manufacturing and assembly of the product.

Material Fabrication: Skilled in using machinery and tools, Ross crafted materials such as wood and aluminum, ensuring seamless component integration.

Electronic Assembly: His expertise in soldering and wiring contributed to the accurate assembly and functioning of electronic components.

Liam - Chief Information Officer (CIO)

Role and Responsibilities: As CIO, Liam handled programming, video rendering, and electronics integration for the product.

Programming and User Interface: He developed intuitive interfaces through coding.

Rendering and Visualization: Liam produced quality renders, photos & videos for marketing, video and portfolio.

Component Understanding: He researched integrating electronic components such as encoders and motors.

Jackson - Chief Creative Officer (CCO)

Role and Responsibilities: As CCO, Kang was responsible for the project's presentation, documentation, market research, and branding.

Project Report and Portfolio: Kang developed a comprehensive project report and portfolio.

Market and User Research: He conducted research to identify the target audience and analyze market potential.

Branding: Kang crafted branding elements, including the product name and logo, aligning with B&O's style.

A Appendix (MOCK DECLARATION)

Bang & Olufsen A/S
Bang og Olufsen Allé 1, 7600 Struer, Denmark

EU DECLARATION OF CONFORMITY

Equipment:	**Wireless Speaker**
Brand:	**Bang & Olufsen**
Model name:	**Beobridge Connect**
Object of equipment:	

Figure 1: Example photo, colours may vary

Accessories: Beobridge Connect unit, User Guide, Safety guide, Power Cable.

We, the offeror, Bang & Olufsen A/S, declare under our sole responsibility that the abovementioned product is in conformity with the relevant Union harmonisation legislation:

- Radio Equipment Directive (RED) 2014/53/EU
- Electromagnetic Compatibility Directive (EMCD) 2014/30/EU
- Waste Electrical and Electronic Equipment (WEEE) Directive 2012/19/EU
- Eco-design Directive 2009/125/EC
- Battery directive 2006/66/EC
- RoHS 2 Directive 2011/65/EU with Directive (EU) 2015/863
- REACH SVHC Regulation (EC) No. 1907/2006

The following harmonized standards and technical specifications have been applied:

Safety	**EN 62133**
	IEC 60086-4
EMC	**EN 55032**
	EN 61000-3-2
	EN 61000-3-3
	EN 50581
	EN ISO 14021
	EN 50625
	EN 50564
	EN 60960-1
Radio	**ETSI EN 300 328**
	ETSI EN 301 893
	ETSI EN 300 440
Packaging Compliance	**FSC Label**
	Green Dot Symbol
	Mobius Loop
	WEEE Label

References

(1) Project, I. D. E. Concept Booklet. Available at `https://drive.google.com/file/d/1_o58P29r7O6EgeIr6NIfElc66G1KGXia/view?usp=sharing`.

(2) Mylife The Challenge of Long-Distance Caregiving. *https://mylifesite.net/blog/post/challenge-of-long-distance-caregiving/*.

(3) Bohannon, R.; Andrews, A. Normal walking speed: A descriptive meta-analysis. *Physiotherapy* **2011**, *97*, 182–9.

(4) Khoury, K. Can the Raspberry pi acquire high frequency signals? *https://atman-iot.com/blog/raspberry-pi-benchmark/*.

(5) How do you calculate the magnetic flux density? *https://www.supermagnete.de/eng/faq/ How-do-you-calculate-the-magnetic-flux-density*.

(6) Waveshare AH49E Data sheet. *https://www.waveshare.com/w/upload/b/b0/AH49E.pdf*.

(7) Ageing and older population UK statistics for 2022. *https://www.ageukmobility.co.uk/ -news/article/ageing-and-older-population-uk-statistics-for-2022*.