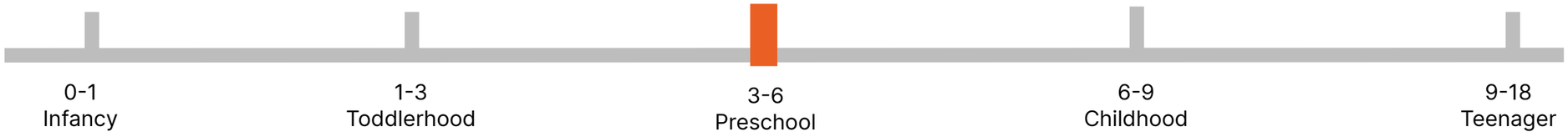
Nature Kit

Final Product Oppertunity



Children in this age group are eager to explore, have a strong sense of **imitation** and **curiosity**, and are easily distracted. They have a certain degree of **task performance** and are at a critical stage of active cognitive brain development, establishing basic habits and an interest in learning.

What's the problems?

Addicted to electronic devices

Boring book knowledge

Limited sensory engagement

How Might We

make learning more engaging by grounding it in children's real-world explorations?

A Product With...

Durable
Non-toxic
Easy to clean
Rich sensory experiences
Easy to use
elimination of small parts

Concept Development - Rationale

Prior to making final design choices, our team conducted a comprehensive reevaluation of the four initial concepts developed by each member of the team. This evaluation not only reviewed each concept's feasibility, appeal, and fit with user needs, but also incorporated key insights gleaned from parents and children ages 3-6.

Smart Hanger

The smart drying rack helps children choose appropriate clothing based on temperature and weather conditions.

Feasibility
Desirability
Innovtative
Effectiveness
Inclusivity

Smart Laundry Baske

The Smart Laundry Basket helps children turn the otherwise boring task of organizing dirty laundry into a fun and interactive experience through projection.

Feasibility
Desirability
Innovtative
Effectiveness
Inclusivity

Play-Stack

Play-Stack making tidying up a fun and effortless experience for both kids and parents.

Feasibility
Desirability
Innovtative
Effectiveness
Inclusivity

Nature Kit

Nature-Kit combines a plant identification camera and digital nature journal in one kit. helps children capture and identify plants during outdoor adventures

Feasibility
Desirability
Innovtative
Effectiveness
Inclusivity

Method Of Research

Nature Kit allows children to capturing photos of plants and insert the module into the base station which then provides interactive audio and visual information about the plant

We are currently iterating on: Child-friendly ergonomics & Engaging interaction methods

Benchmarking

- Refinement of its interaction mode, physical structure safety standards.
- Analyze the feasibility of voice playback module and picture recognition technology at the technical level.

Research

- Realise what is the common holding styles for children

Co-design

- parents and children were invited to participate in our prototype discussions and evaluation feedback.

Concept Development - Sketching

Deconstrction

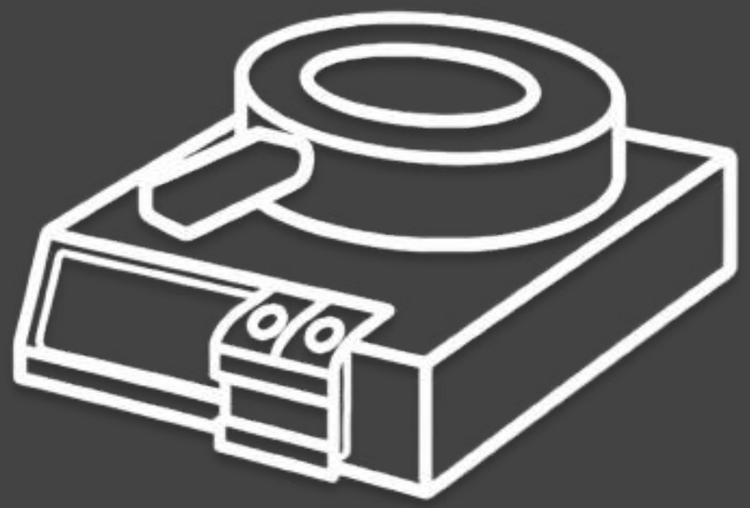
We have rethought the structure of a nature kit, in order to minimize the amount of time children spend using the screen, we have made it possible to turn the handle to control the functions.

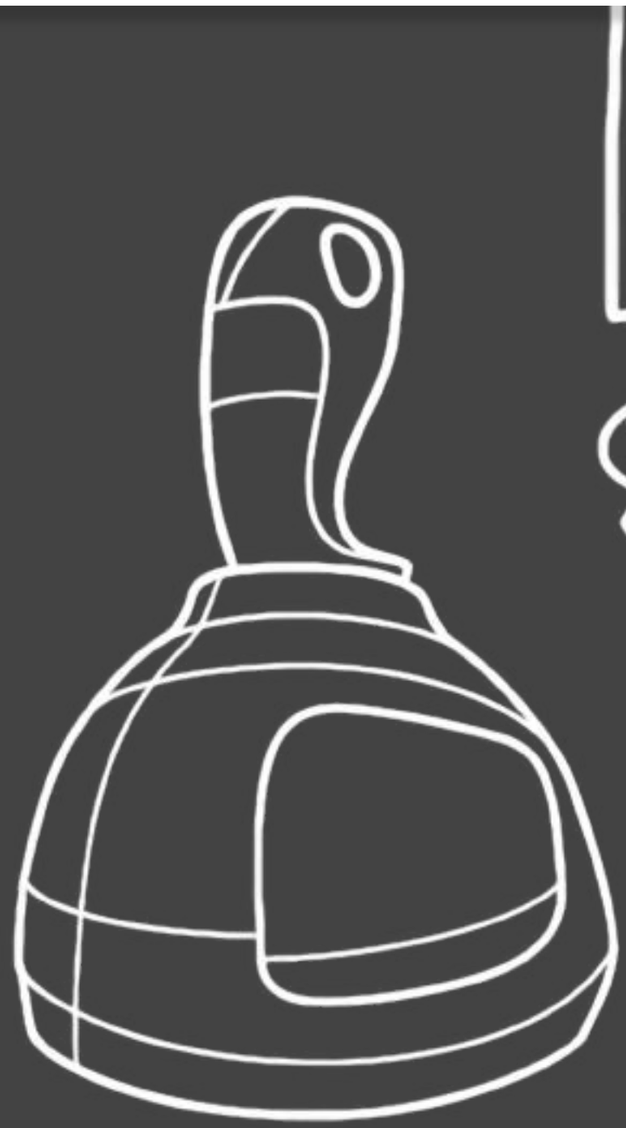
colour

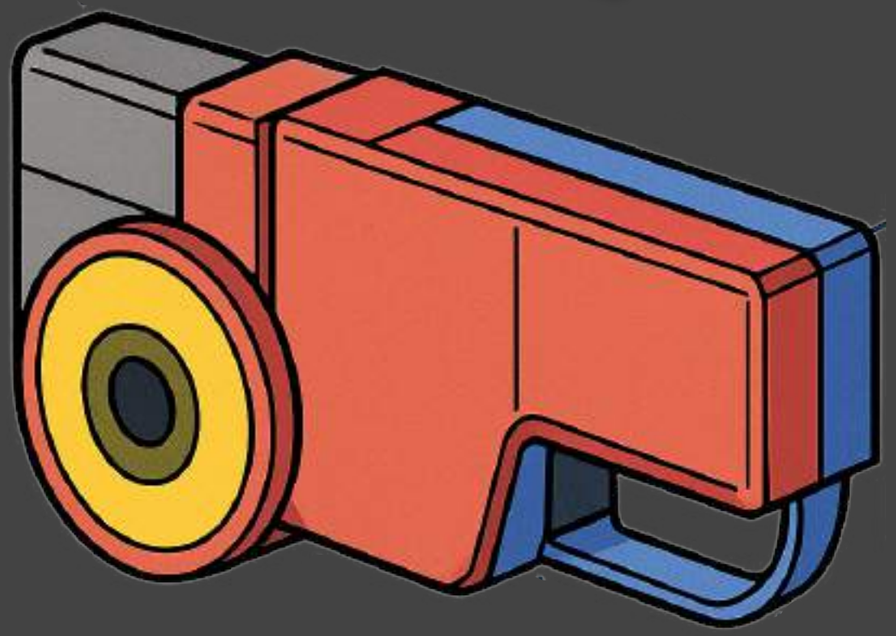
In early childhood the visual system is still developing and high contrast + saturated colors attract more attention, we drew a high saturation, high contrast red, yellow and blue color scheme.

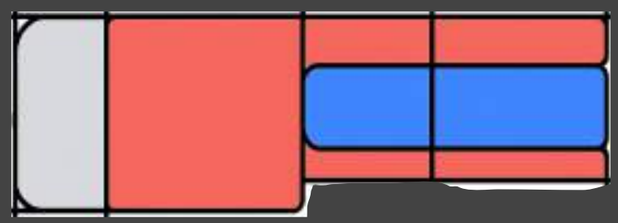
Appearance

We sketched out various designs for the nature kit, and the concept we finally decided on borrows from the styling of vintage phonographs. It creates a warm nostalgic feeling and also provides a stable operating platform.



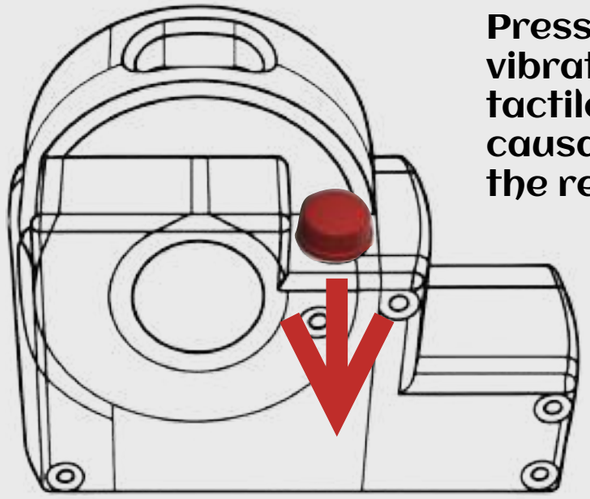




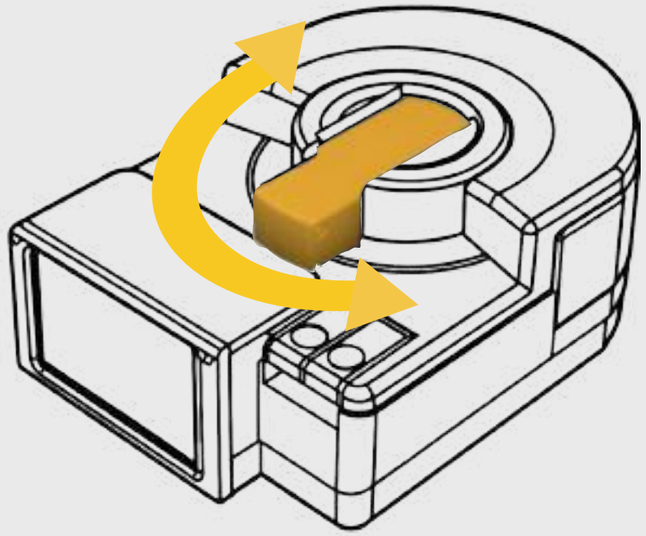


Concept Development - Interaction

Completely screen-free interaction logic encourages children to engage in play through body movement and multi-sensory feedback.



Press the shutter button and the vibration motor provides brief tactile feedback to help establish a causal link between the action and the result.



When the handle is inserted into the base, it acts as a physical controller. The child can rotate the handle left or right to toggle through the photos that have been taken.

When pressed, the product screen displays the selected photo and plays information and knowledge about the plant.

Charging method optimization

Improve safety &convenience

we have adopted a magnetic charging port on the handle instead of the traditional jack structure. Magnetic charging is not only easy for children to operate, but also effectively prevents food debris from getting stuck inside the interface.

Ergonomics and Safety

- All interactive components are designed to fit children's hand size and usage habits
- Materials and feedback methods are safe

Multi-sensory feedback

We combine

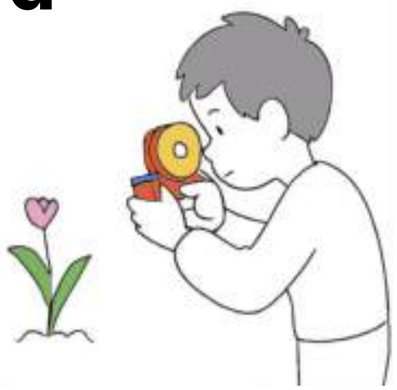
tactile (vibration)	visual (screen)
sound (speaker)	motion (rotation)

feedback mechanisms

Concept Development - Story Boared

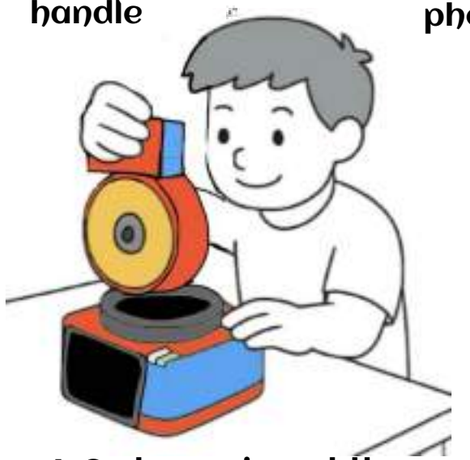
Story Board

1. Children go out with handle

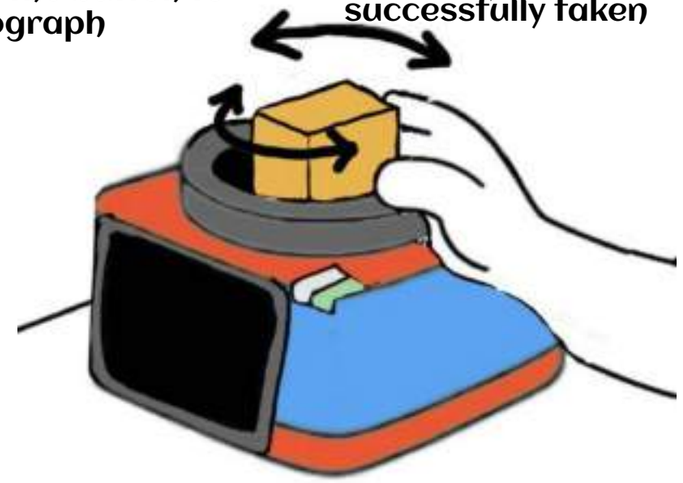


2. Explore and discover plants of interest, and press the button to photograph

3. The handle vibrates to alert the child that the photo has been successfully taken



4. Go home, insert the handle into the base, the base reads the data and the handle charges up

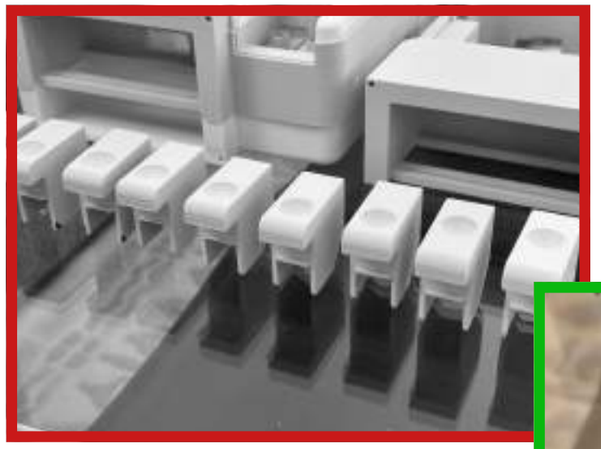


5. Turn the handle clockwise or counterclockwise to switch between left and right to browse the photos you have taken.

6. Presses base button to select plant photo

7. The speaker starts to explain the plant information, and the screen plays the photo at the same time.

Issue arising & Resolutions



When we were prototyping, we realized that the support posts for the base buttons didn't fit properly, which would prevent access to the microswitches

Through constant iterations of constant testing and feedback, we figured out the perfect height

we used a standard 18650 lithium-ion battery to power the handle. but large diameter and length of the cylindrical cell made the handle too bulky and heavy for a child's grip

we replacedwith a compact rectangular lithium-ion battery (3.7V, 1000mAh) which still providing sufficient power for the product's functions

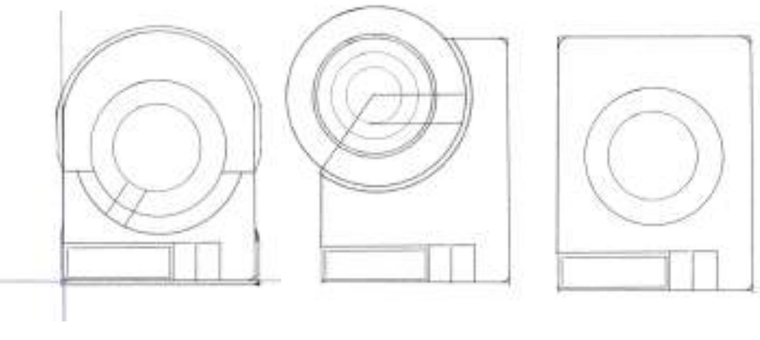
We have found that the long posts used for screw mounting are very prone to breakage during assembly or handling.

We added a ring of rectangles at the base of the columns for structural stability.

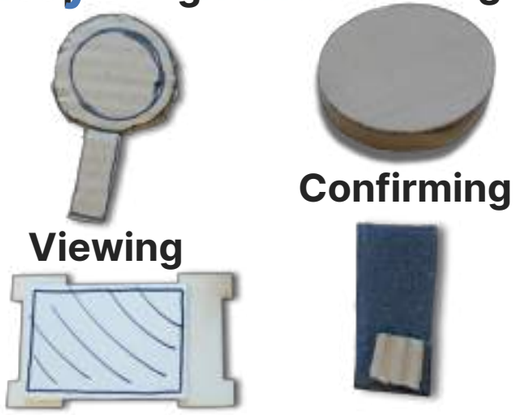
Lo-Fi Prototyping

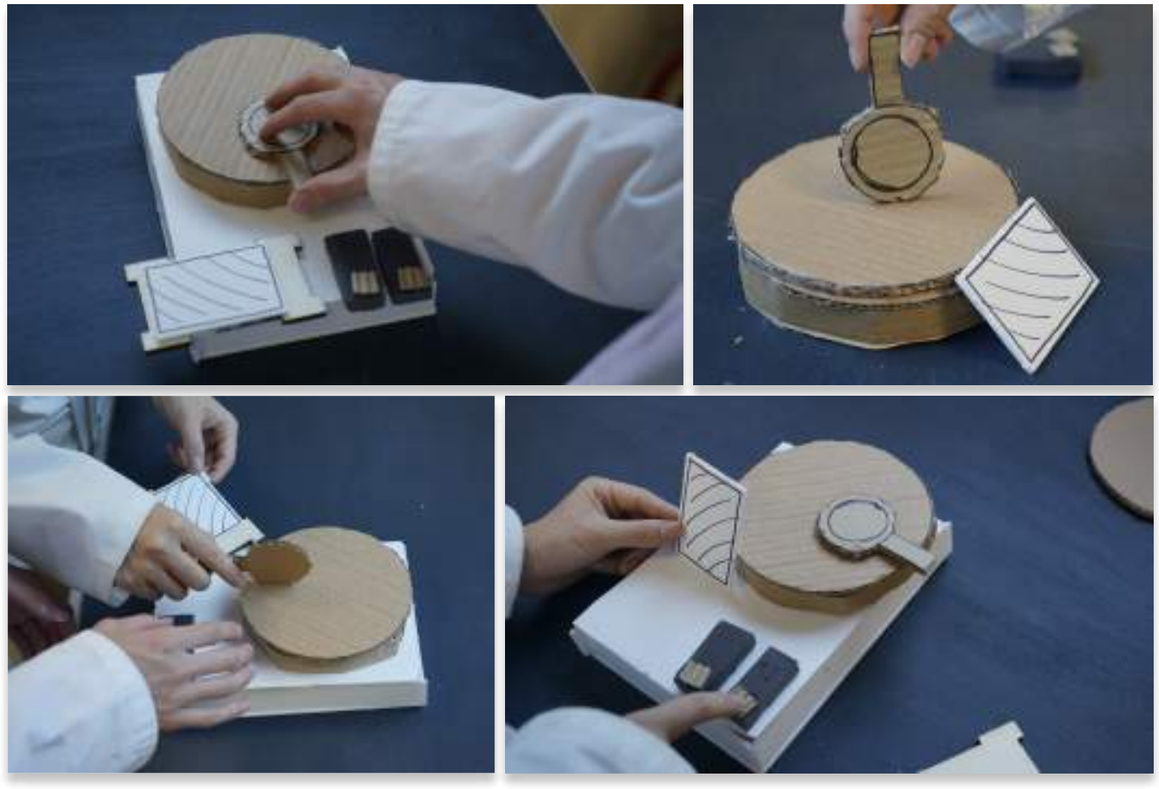
Lo-Fi prototyping explore the different arrangement and combintation of the interation elements including buttons,selecting mechanism and screen to help find the best interacting way for children.

Sketching



Key Elements





Hi-Fi Prototyping

Digital Testing

We tested our OLED display with various interface we designed including main interface, collection library, and display with AI story telling.

Physical Testing

We tested our buttons and the rotating mechanism. We found there is high friction between the wall and the moving parts. So the tolerance need to be adjust to allow the moving parts move freely.

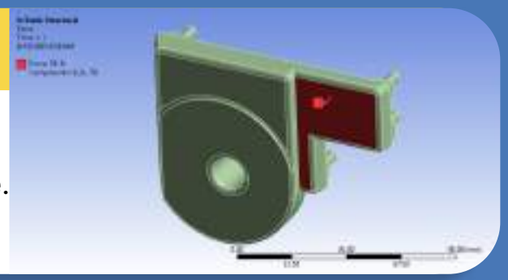
CONCPET DEVELOPMENT

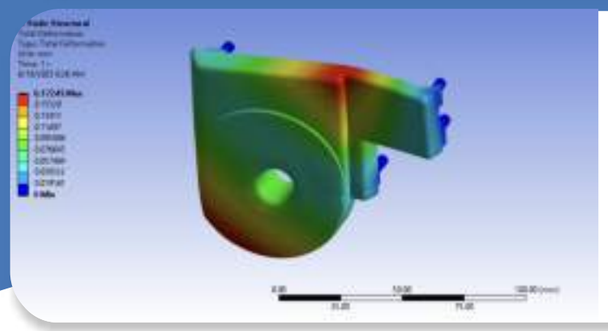
Power & Load

Camerae Handle Load Analysis

Assumptions

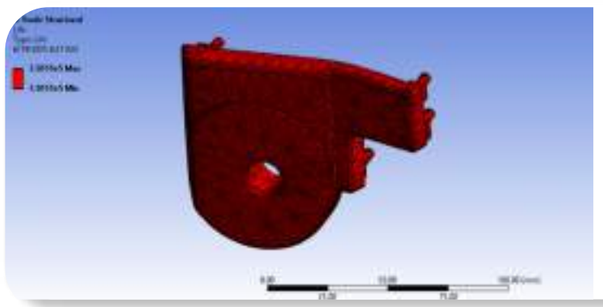
- No safety factor included.
- A 70 N static load is applied at the gripping surface to simulate a child's maximum hand force.
- The handle is fixed.





Total Deformation

Requirement: The casing should experience small deformation under kids' gripping.
Results: The FEA results show the maximum deformation is about 0.172 mm which is in a acceptable range.

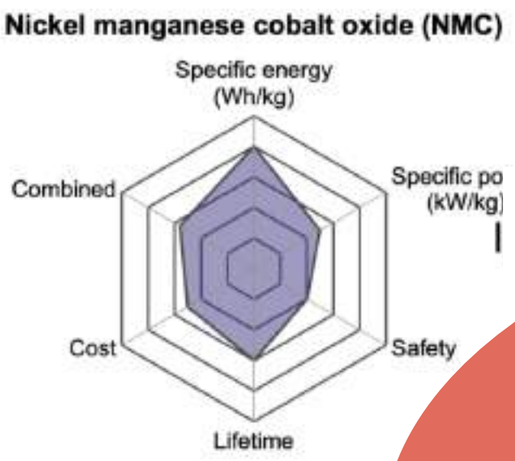


Fatigue Analysis

Requirement: The casing should last for years for sustainability requirement.
Results: The FEA results show a high maximum life which is equal to minimum life, means it is able to withstand 750000 usage.

Battery Selection

3.7v 500mAh Lithum battery is chosen for the balance between saftety, cost and battery life.



Components Calculation

Assumptions

- The base station is pluged to the socket all the time.
- User use camera to take photos 1 minutes a day.
- The machine is in active mode only when user is taking photos, otherwise it is in standby mode.

Power calculation formula: P = VI

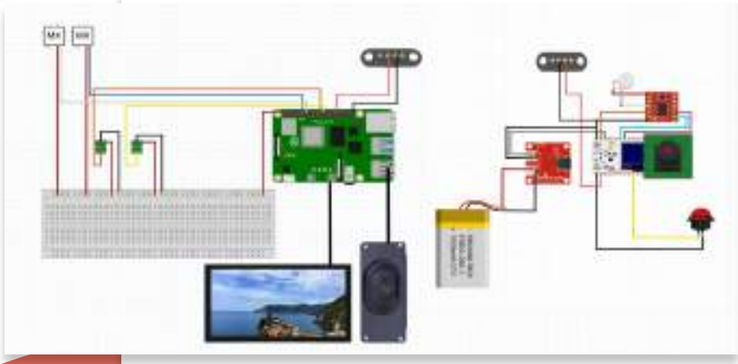
Mini Vibrating Disk

Working Voltage: 3V
Current 80mA
P_{disk} = 3 * 0.08 = 0.24W

ESP32 Camera

Woking Voltage: 3.7V
Working Current: 200mA Standby Current: 5mA
active $P_{cameraA}$ = 3.7 * 0.2 = 0.74W
standby $P_{cameraS}$ = 3.7 * 0.005 = 0.0185W

Fritzing



Total Power Consumption

$P_{Working}$ = Pdisk + PcameraA +
= 0.24W + 0.74W = 0.98W

$P_{Standby}$ = PcameraS = 0.0185W

$E = P_{working} * T_{working} + P_{standby} * T_{standby}$
= 0.98 × 1/60 + 0.0185 × 1439/60
= 0.4604Wh

There is one lithum battery in the handle wich is 1.85Wh, so the handle only needs to be recharged once every 4 days approximately.

3 Selected Brands

Three brands that shares similar value to our concept were selected with their most presentative products. Sony is selected as the chosen brand to be implemented.

Nintendo

Nintendo Sound Clock Alarmo

Nintendo's Alarmo transforms the dull routine of waking up into a **joyful, game-inspired experience**— engaging **multiple senses** and offering **playful**, **interactive ways** to start the day.

Brand Value

"Creating smiles for generations."

Osmo

Coding/ Genius Starter Kit

Osmo's hands-on kits help kids gain confidence in coding, math, and art—through the power of **real play**. By combining **physical pieces** with **interactive** digital experiences, Osmo turns learning into an engaging, magical adventure.

Brand Value

"Learning is best when it's called play."

my first Sony

My First Sony Siries

My first sony siries is a subbrand (1988) of sony whoes mission is to **spark** the **interest** of **science and tehcnology**. The products were built to **arise** children's **curiosity** by revealing its internal structure and mechanism.

Brand Value

"Simplified Controls"
"Easy Learning"
"Playful Design"

+

Our Value

"Explore Nature"
"Interactive"
"Joyful learning"
"Suppor Early Observation"

+

Shared Value

"Save to play with"
"Hands on discovery"
"Curiosity"

=

Creates **playful tools** that help children to **explore the natural world**. By combining **intuitive design** with **sensory interaction**, the collaboration supports **joyful**, **independent discovery** and **early scientific thinking** through **safe, hands-on experiences**.

Mood Board

The mood board tried to explore the design language of my first sony series products in terms of colour theme, materials, we also got inspired by some products designed by Dieter Rams. So the square and circle shape design is brought to our product.

Colour Platte

The colour theme is alied with My First Sony Siries which features bold colour combination and round design. The speaker is yellow, the and other basic parts were red or otherwise organized based on their fundamental structure.

Cream #E1DECD

Green #47986B

Grey #352D3D

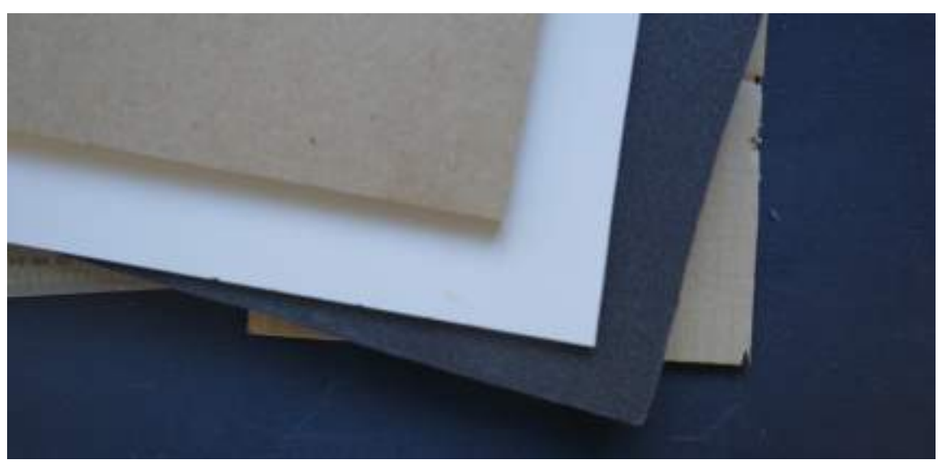
Yellow #F4C647

Navy #22317C

Red #A52B25

Material Selection

The ABS and acrylic is selected as the selected material due to its smooth textured and shine surface.



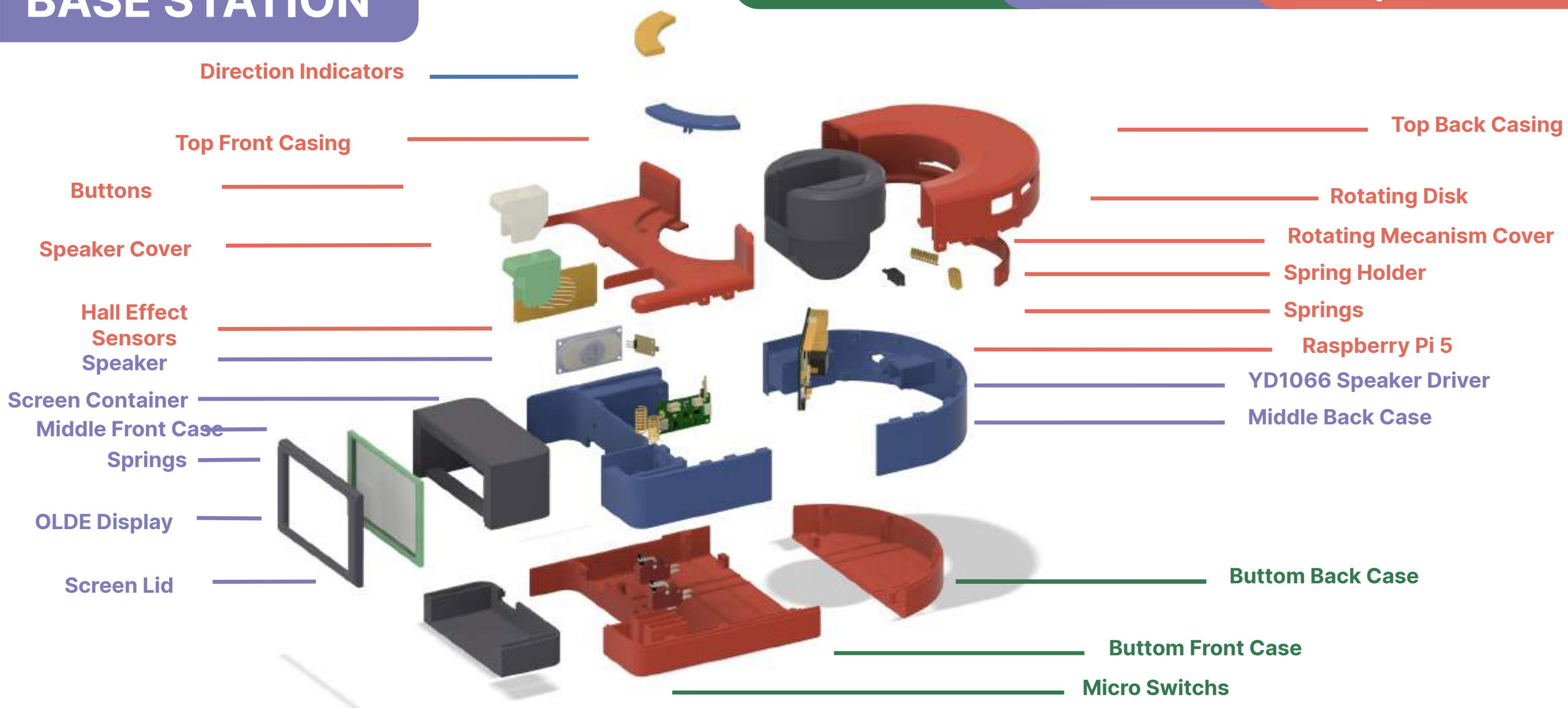
CONCPET DEVELOPMENT

Exploded View

CAMERA

BASE STATION

Buttom | Middle | Top



Ribs & Webs

Ribs and webs are added to certain part of structurei to ncrease structural rigidity and reduce material usage. Those features helps resist bending and deformation for thin components.

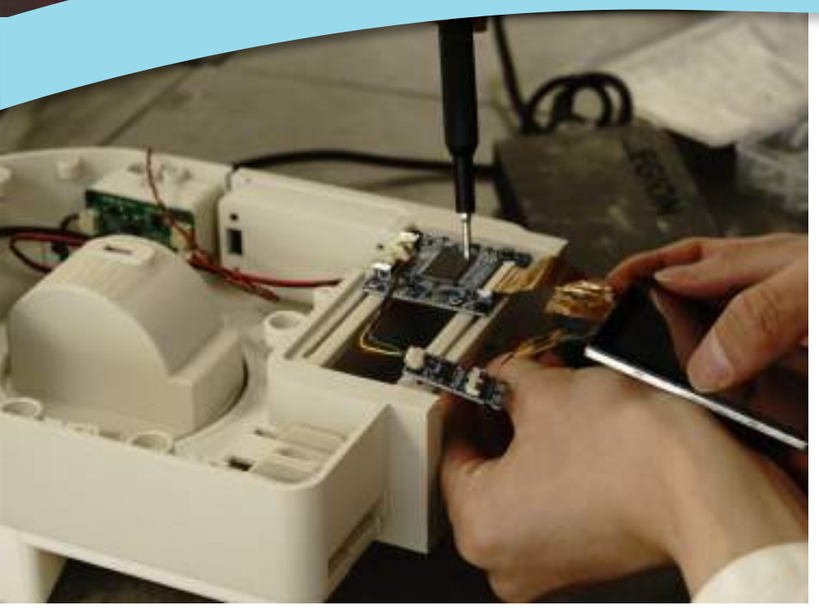
Design for Manufacturing (DFM)

Fillet Edges

All outer casing edges are filleted to create smooth, rounded corners. This improves both user safety by eliminating sharp edges and enhances product aesthetics.

Tolerance

Structure is designed with tolerance to accomodate 3D printing inaccuracies. ISO 2768-m was reference for the dimensions.

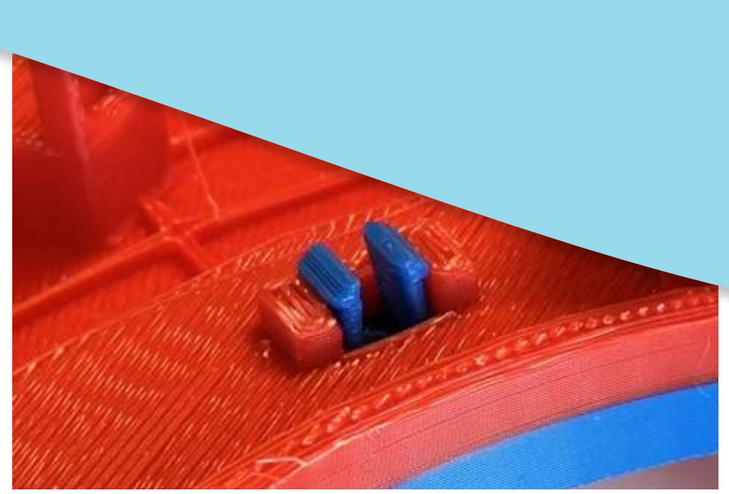


Fastening

The casing and internal electronic components are secured using screws, while critical structural parts are reinforced with bolts to ensure a stable and reliable assembly.

Assembly Acess

The casing is designed with access holes aligned to screw positions, allowing screwdrivers to reach fasteners easily and reducing assembly time and complexity.



Snap Fit

Some major modules, such as the OLED display container, are secured using snap-fit features to allow for quick disassembly and easy maintenance without using tools.

Design for Assembly & Disassembly (DFA & DFDA)

Product Assembly Process

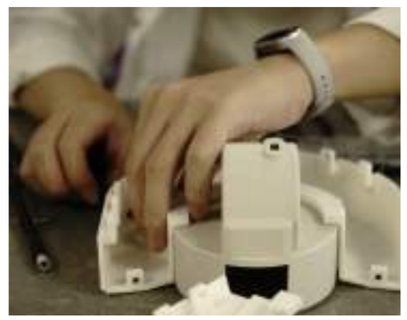
Base

2x M3 6mm

2. Hall senser x2
M2.5四颗

4.旋转弹性的，M3 8mm一颗

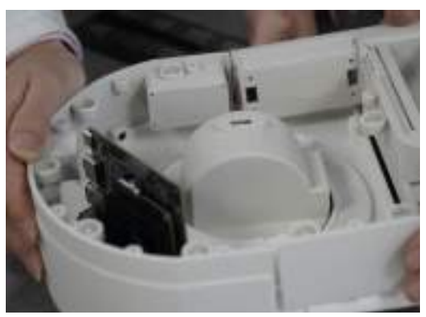
5.两个3.5×38mm的弹簧 塞进去



2x M2.5×6mm screws

4xM3×4 screws

2xM3×6mm Screws



8x m3×6 screws

4x M2.5 screws

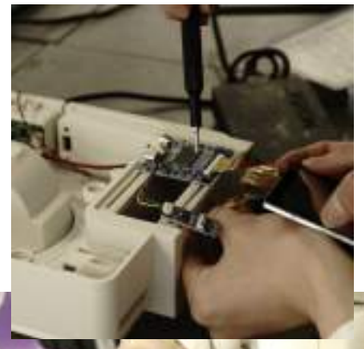
4x M3×20 screws

insert

9x m3×30 9颗

put spring 9.5×19

insert



6x m3×10 screws

2x m3×6mm

Assembly Time:1h20min

Cost:199POunds

21.按钮 用按钮自带的固定方式固定

Product Compliance Research

General Product Safety

The selected materials are all non-toxic, harmless and comply with EN 71 (toy safety standard).
The toys have no sharp edges and are structurally stable to prevent the risk of accidental swallowing and mishandling.
If non-compliance is detected, the manufacturer must take corrective action in a timely manner.

Battery & Charging Compliance

The built-in battery complies with the RoHS directive and does not contain hazardous substances (such as lead, mercury and cadmium) that exceed the limits.
Magnetic charging connector prevents food debris, water or dust from getting stuck in the socket and improves the safety of children's use.
The battery system is protected against short circuit and overheating to avoid electrical accidents during use.

Electrical Device Compliance

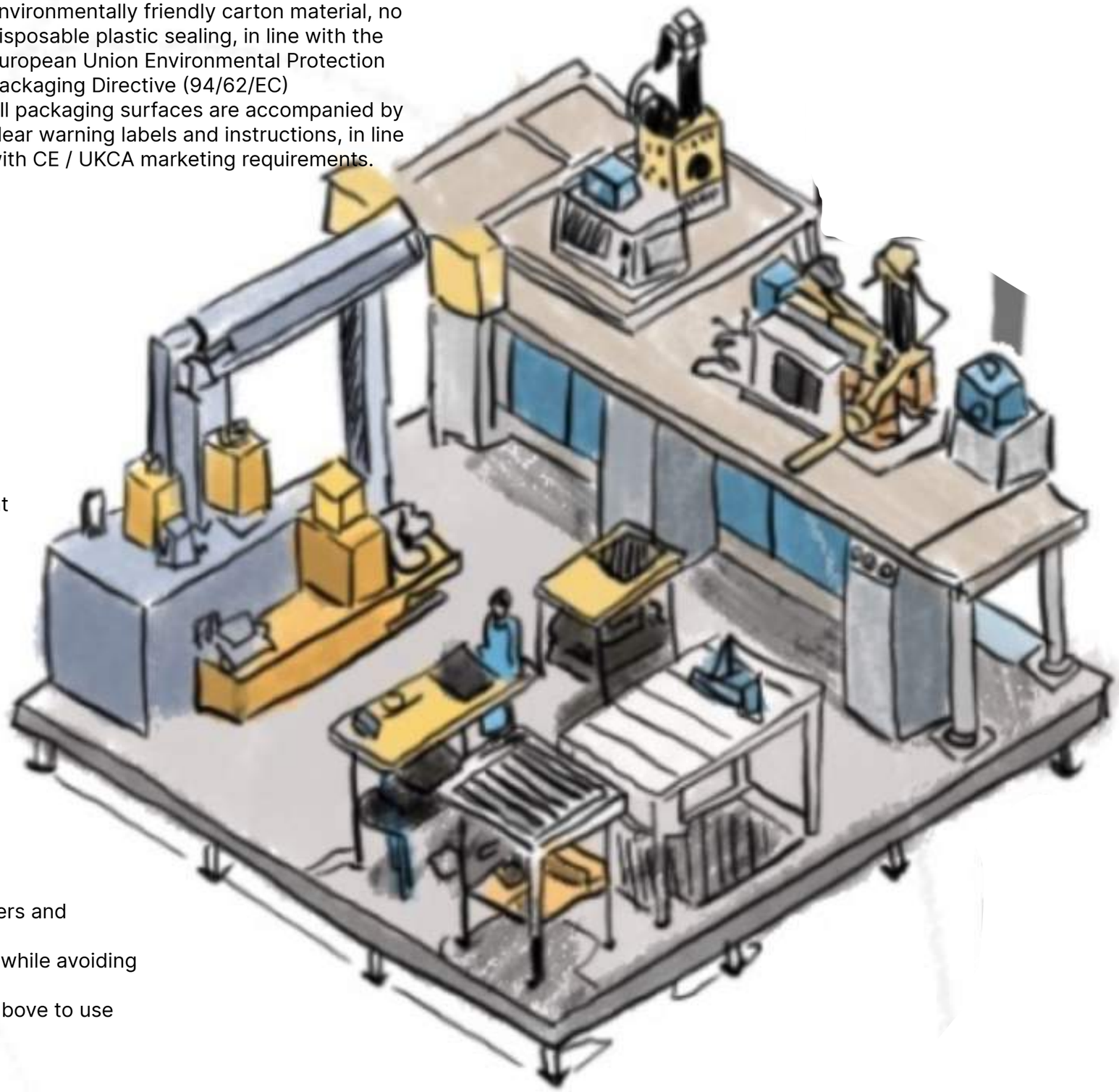
The ESP32 main control, screen and motor have been tested for low voltage safety in accordance with IEC 62115.
The toy has good anti-electromagnetic interference capability and will not interfere with other home electronic devices.
All electrical modules are insulated during the packaging process to

Assembly & Handling

All buttons and swivels are of large anti-pinch design with rounded corners and ergonomics.
The plug-and-play structure can be operated by children independently while avoiding jamming or accidental disassembly.
The buttons are of moderate strength, suitable for children aged 3 and above to use independently or under adult guidance.

Packaging Compliance

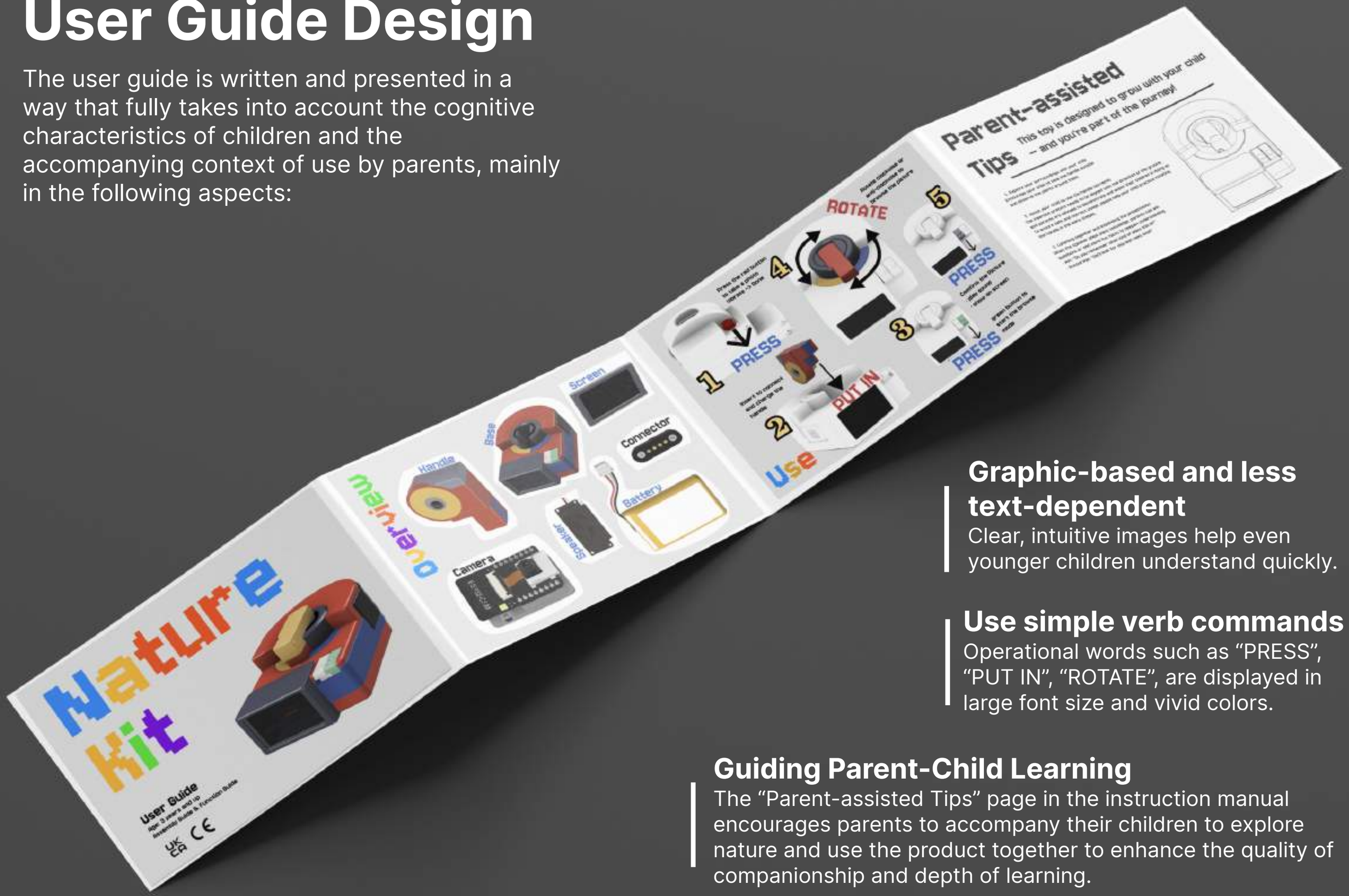
Packaging is made of recyclable and environmentally friendly carton material, no disposable plastic sealing, in line with the European Union Environmental Protection Packaging Directive (94/62/EC)
All packaging surfaces are accompanied by clear warning labels and instructions, in line with CE / UKCA marketing requirements.



Product Labeling

User Guide Design

The user guide is written and presented in a way that fully takes into account the cognitive characteristics of children and the accompanying context of use by parents, mainly in the following aspects:



Graphic-based and less text-dependent

Clear, intuitive images help even younger children understand quickly.

Use simple verb commands

Operational words such as “PRESS”, “PUT IN”, “ROTATE”, are displayed in large font size and vivid colors.

Guiding Parent-Child Learning

The “Parent-assisted Tips” page in the instruction manual encourages parents to accompany their children to explore nature and use the product together to enhance the quality of companionship and depth of learning.

PACKAGING DESIGN

Specification

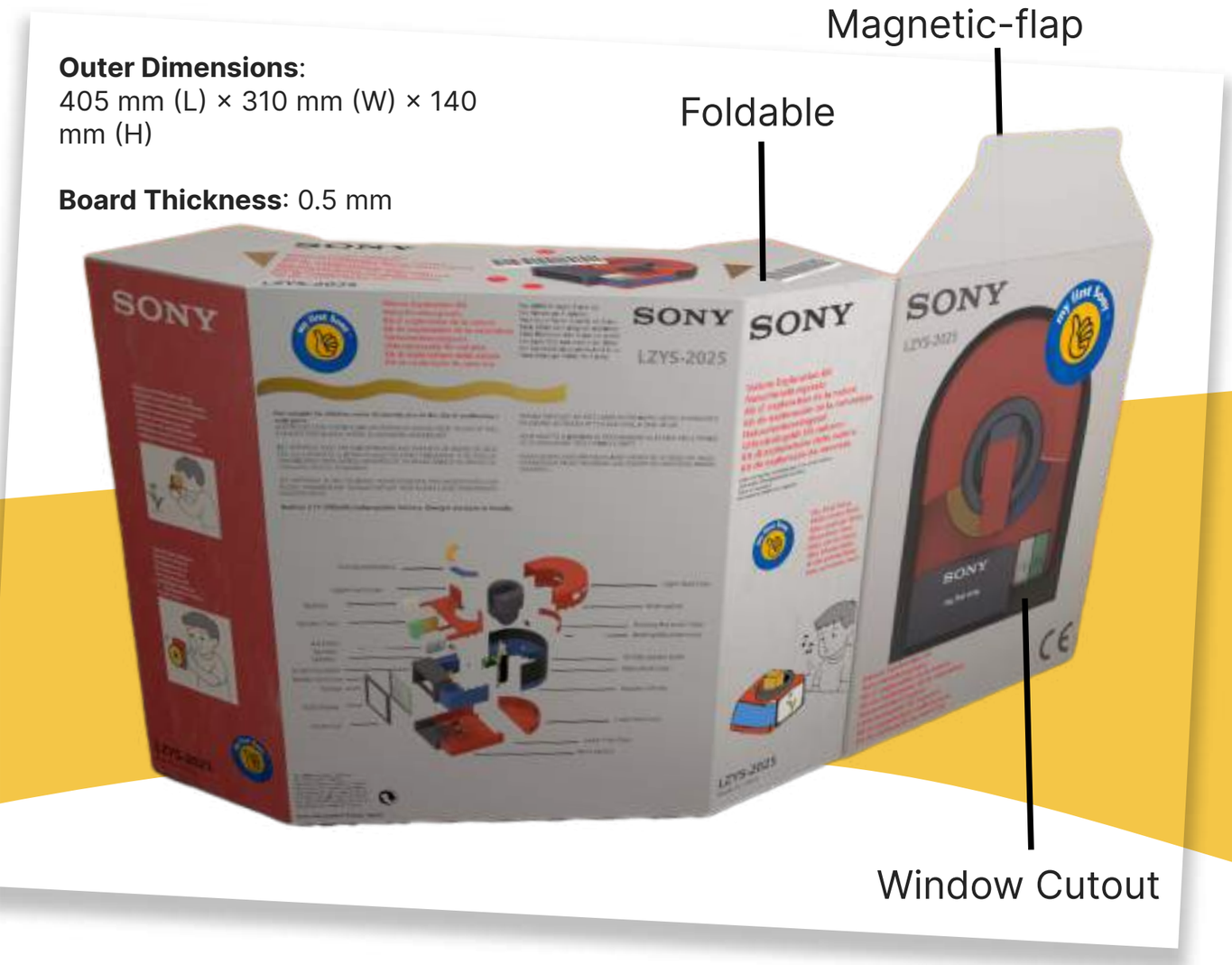
Book-Style Magnetic Flap Box

Inspired by Sony's My First Sony line, this retro magnetic-flap box creates a sense of ceremony—like unwrapping a gift, designed to spark curiosity in kids.

Unboxing Mechanism

Outer Dimensions:
405 mm (L) × 310 mm (W) × 140 mm (H)

Board Thickness: 0.5 mm



Branding

The packaging design pays homage to Sony's iconic ***My First Sony*** product line, characterized by its playful geometric forms, and high visual contrast.
Brand assets such as the **official Sony logo** and the **classic multi-language** product labeling is printed in each side of the package.

Target Audience

Aimed at children aged 4 and up, the packaging is also designed to appeal to parents—the key decision makers—by highlighting safety, exploration, and interactive features. Its retro charm may further attract vintage toy enthusiasts.

Material

Inspired by Sony's My First Sony line, this retro magnetic-flap box creates a sense of ceremony—like

Die-Cut Template

PACKAGING DESIGN

Final Render

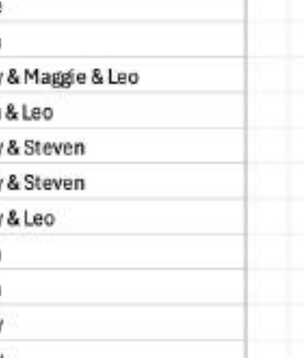
Project Start Date: 10-May-25

Project Name: IDE

#	Activity	Assigned To
1	CAD Modeling - Base Station	Tommy
2	CAD Modeling - Camera	Maggie
3	Buy Components	Steven
4	Portfolio	Tommy & Maggie & Leo
5	Report	Steven & Leo
6	3D Printing & Iteration - Camera	Tommy & Steven
7	3D Printing & Iteration - Base Station	Tommy & Steven
8	Prototyping - Lo Fi	Tommy & Leo
9	Prototyping - Hi Fi	Steven
10	Coding	Steven
11	Branding Consideration	Tommy
12	Branding Implement	Tommy
13	Power & Load Calculation	Tommy
14	Product Assembly	Tommy & Maggie & Leo & Steven
15	Exploded View - Camera	Maggie
16	Exploded View - Base Station	Tommy
17	Labeling Design	Maggie
18	User Guide Design	Maggie
19	Packaging Design	Leo
20	Pakcaging Render	Leo
21	Programming	Steven
22	Final Project Rendering	Maggie
23	Slides	Steven
24	Filming	Leo
25	Video	Leo & Maggie
26	Project Plan	Tommy

Tommy

Chief Organisation Officer



Maggie Zhou

Chief Creative Officer

Leo Liu

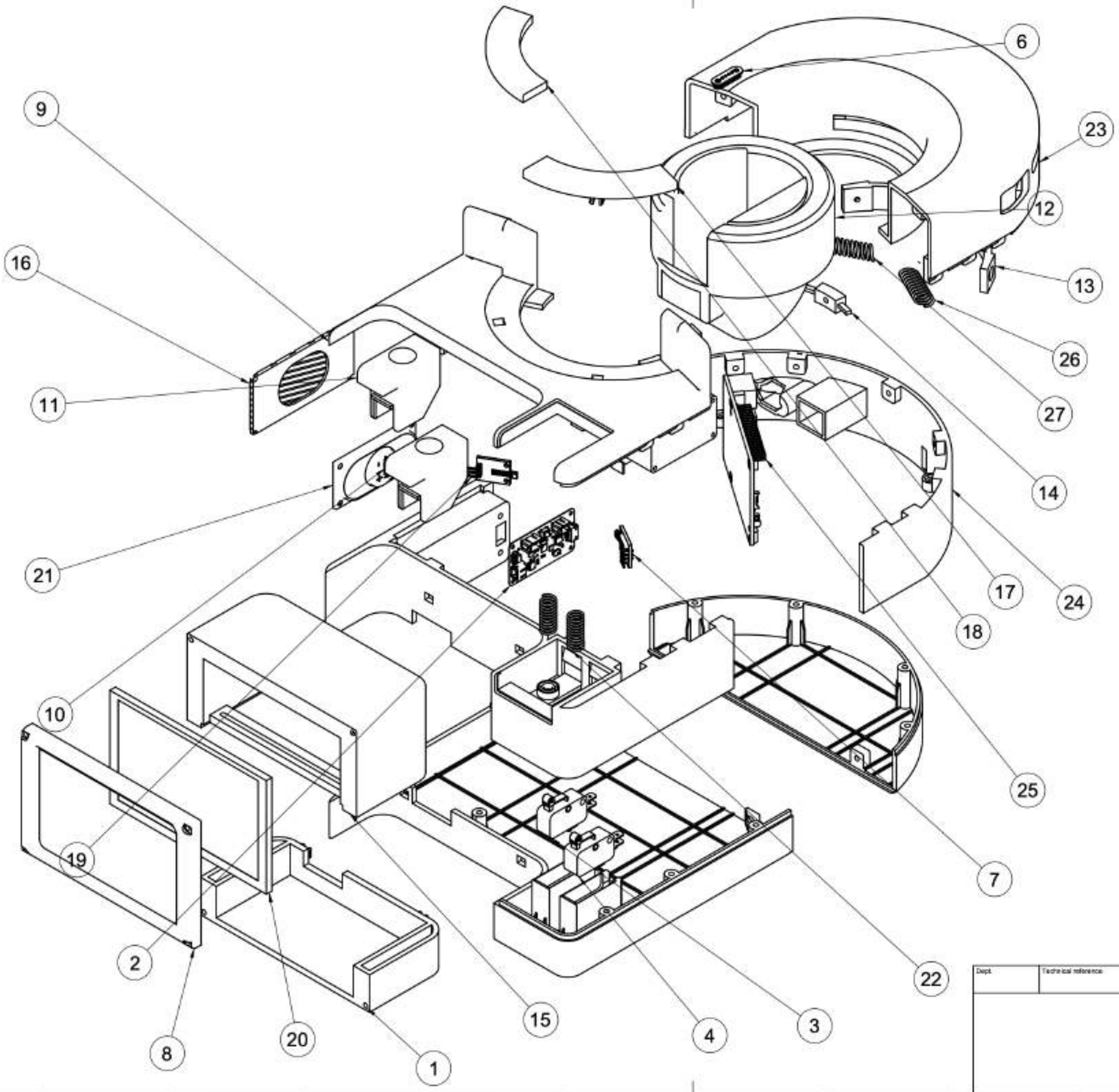
Chief Information Officer

Steven Ye

Chief Techincal Officer

Project Plan

Please notice that tasks assigned to multiple team members are carried out collaboratively within the same time frame, not in sequential handover.



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2	1	PCB
3	1	Omron V-155-1C25_Mirco Switch v1 (1)
4	1	Omron V-155-1C25_Mirco Switch v1
5	1	Handle3.0 v3 v3
6	1	Magnetic Pogo Connector 4 Pin (Type 2)
7	1	Limit Hall Sensor
8	1	Lid
9	1	TBody
10	1	GreenButton
11	1	WhiteButton
12	1	RotateDisk
13	1	RotateCover
14	1	SpringHolder
15	1	MFront
16	1	SpeakerCover
17	1	BlueDecoration
18	1	YellowDecoration
19	1	Limit Hall Sensor v1(Mirror) (1)
20	1	Screen
21	1	Speaker 4 Om 2 W
22	1	Spring
23	1	TBody (2) v1
24	1	MBack v1
25	1	Raspberry Pi 5
26	1	SpringRotate1
27	1	SpringRotate2

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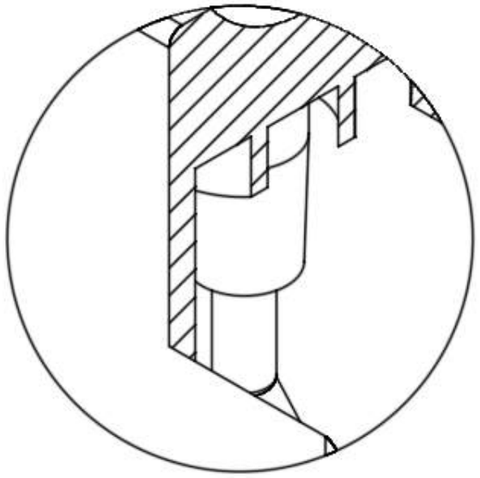

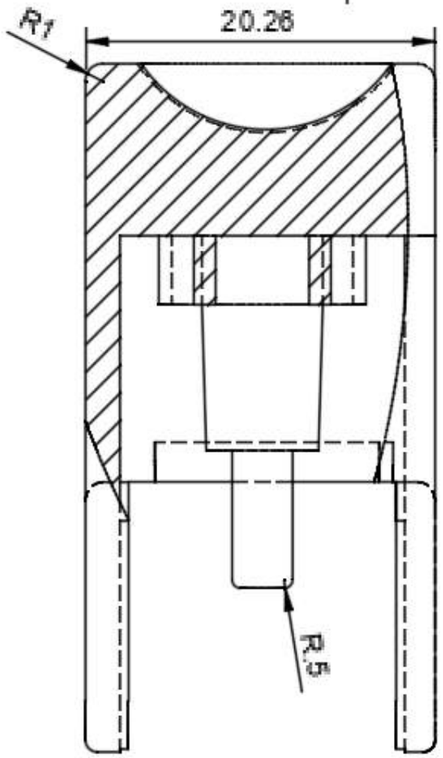

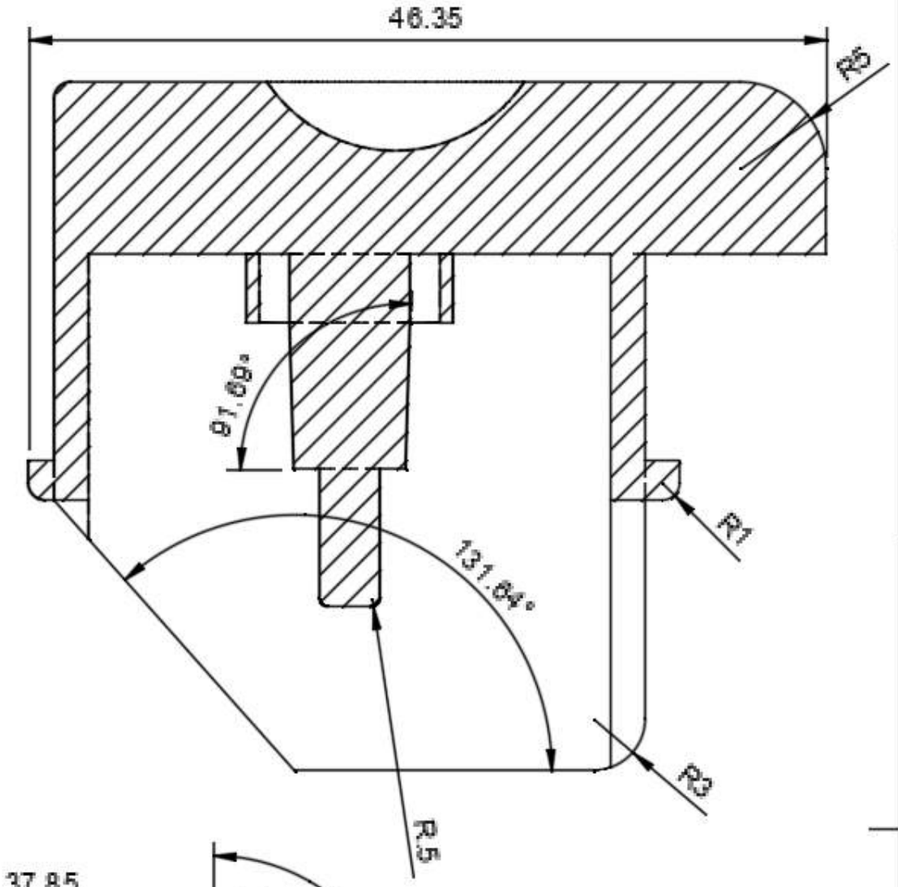

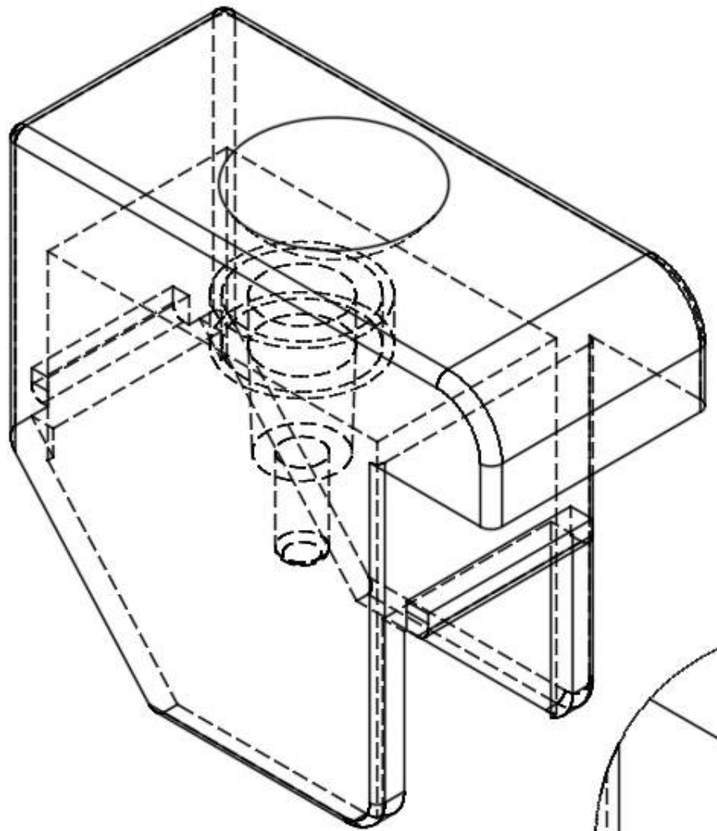

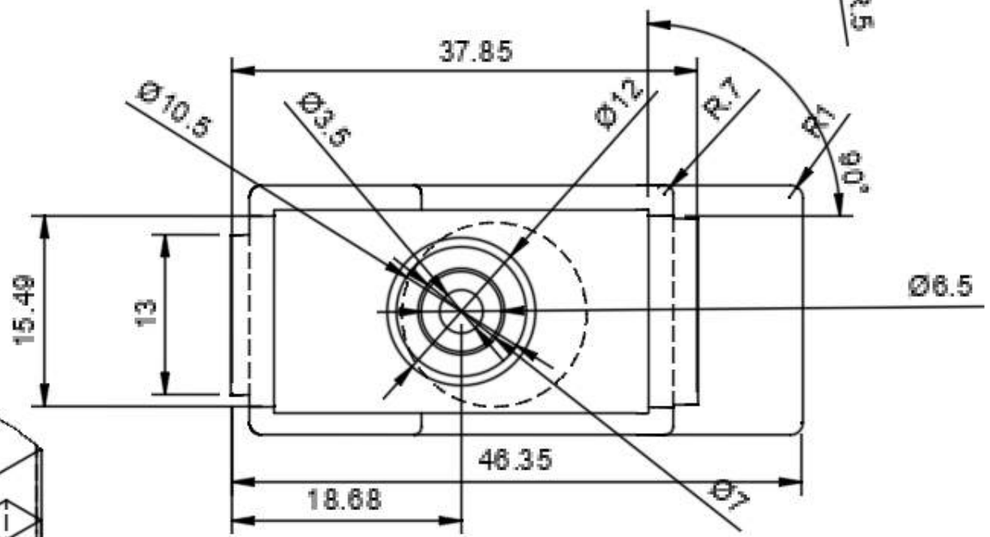

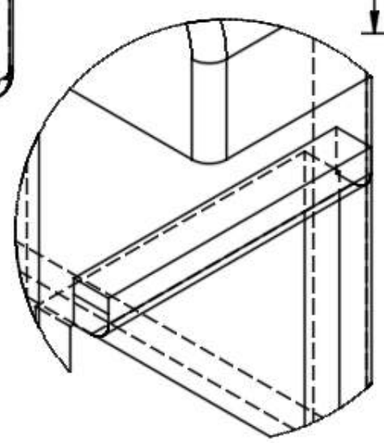

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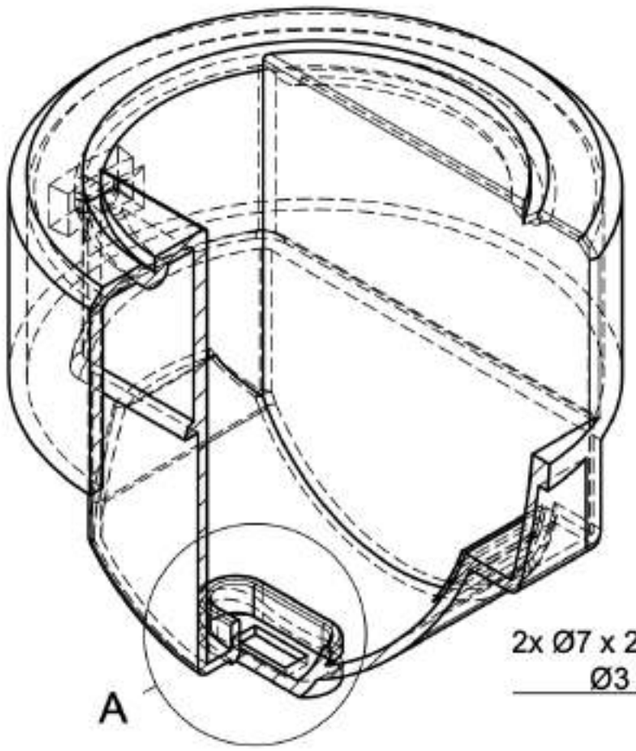

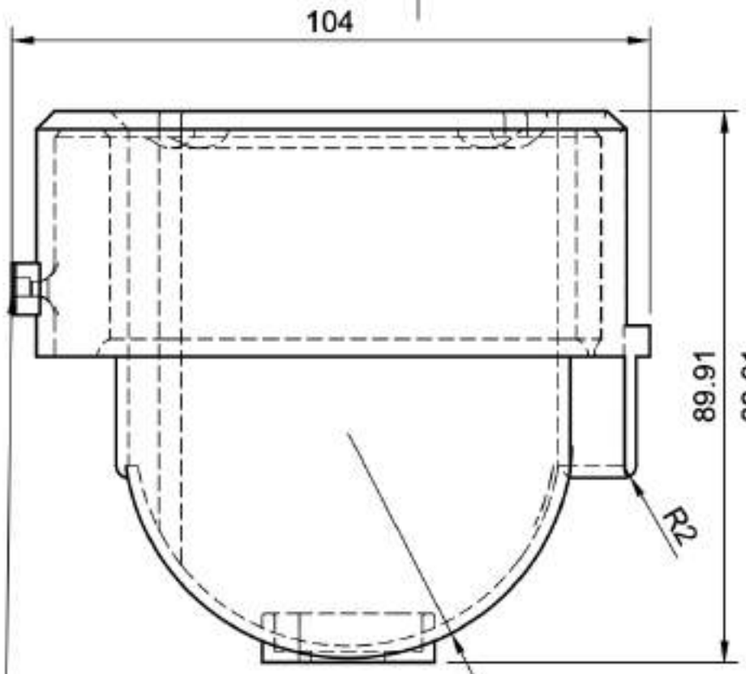

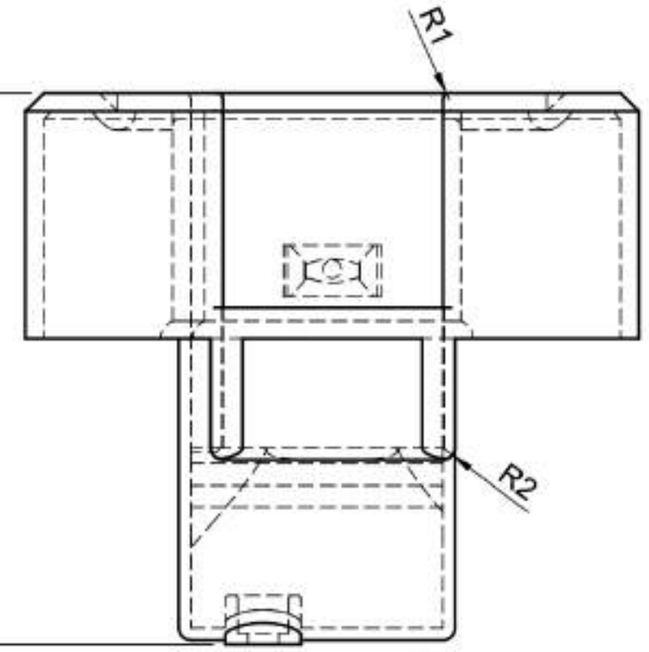

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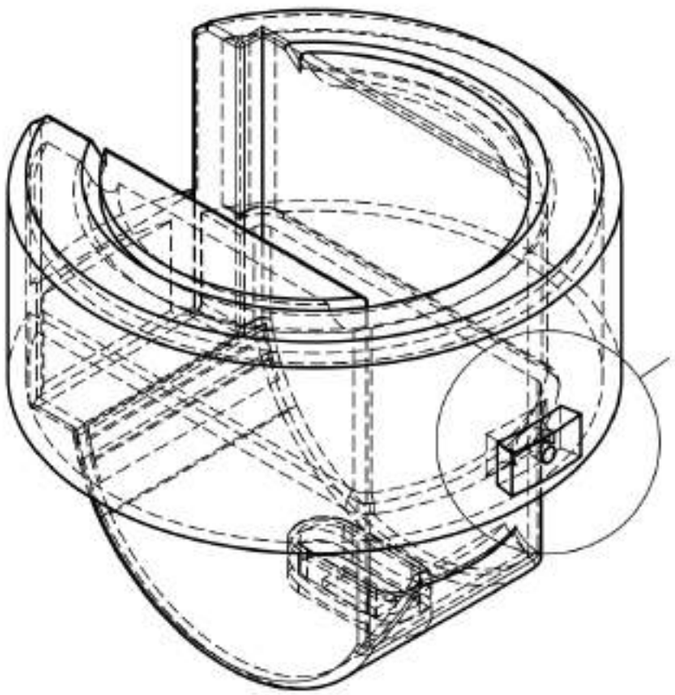

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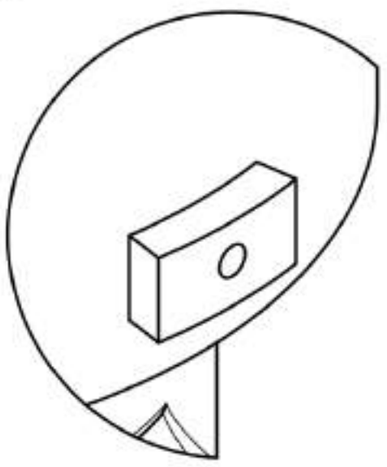

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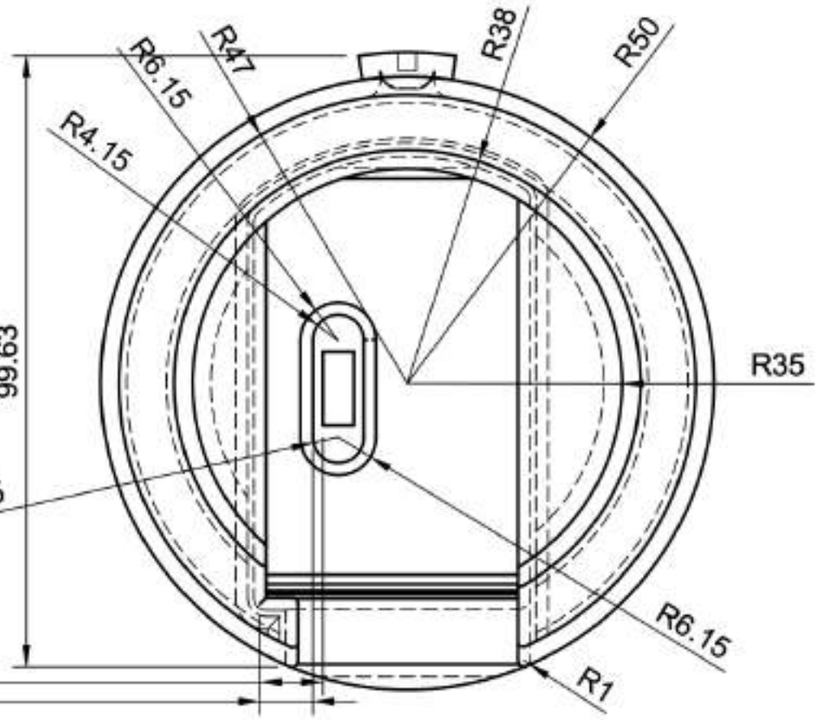

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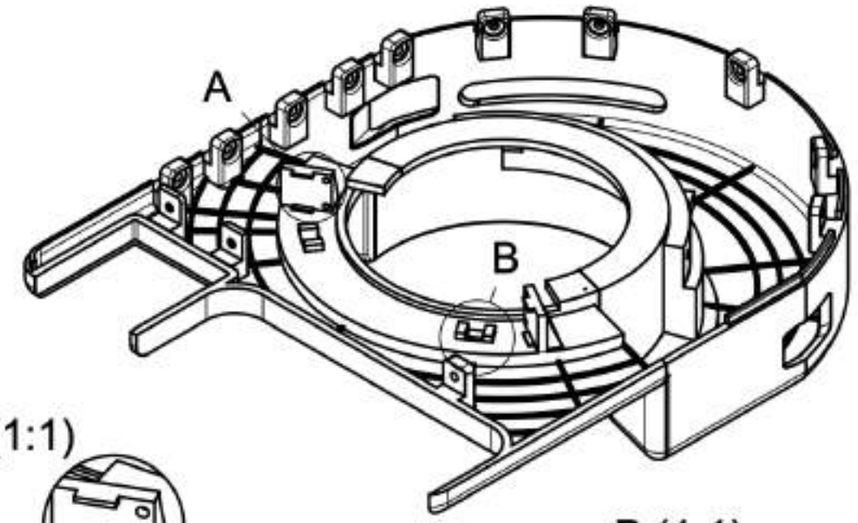

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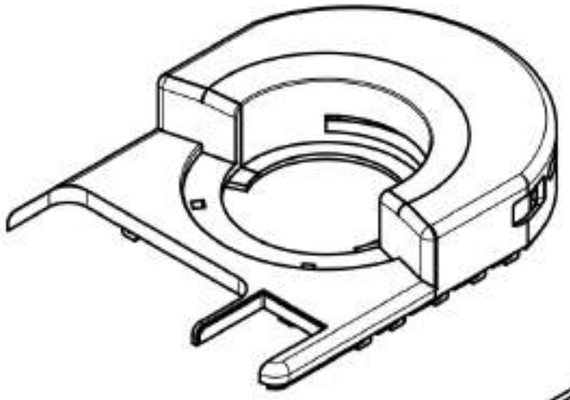

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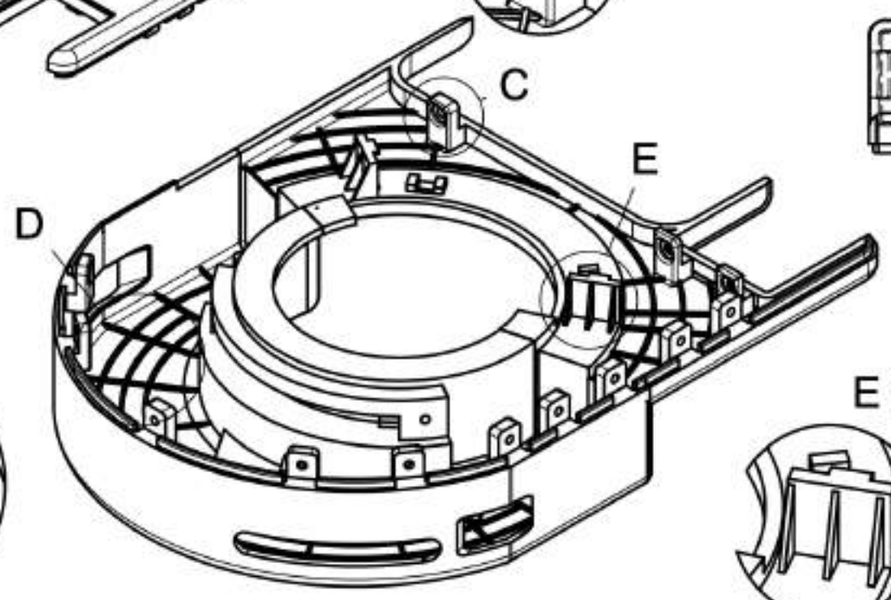

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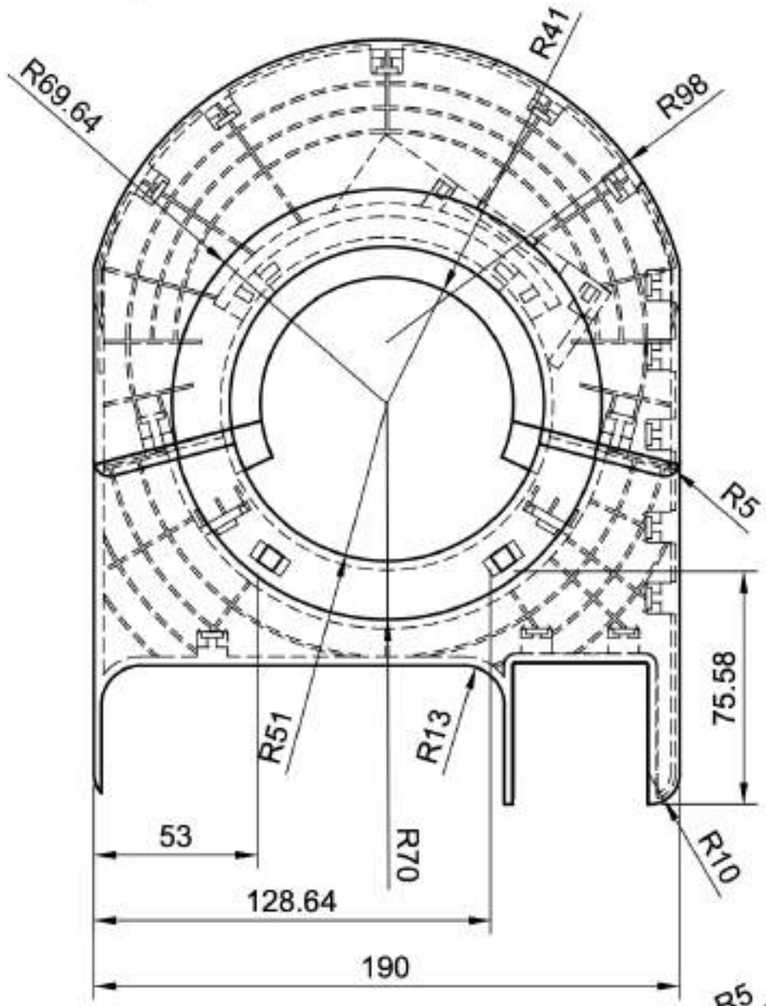

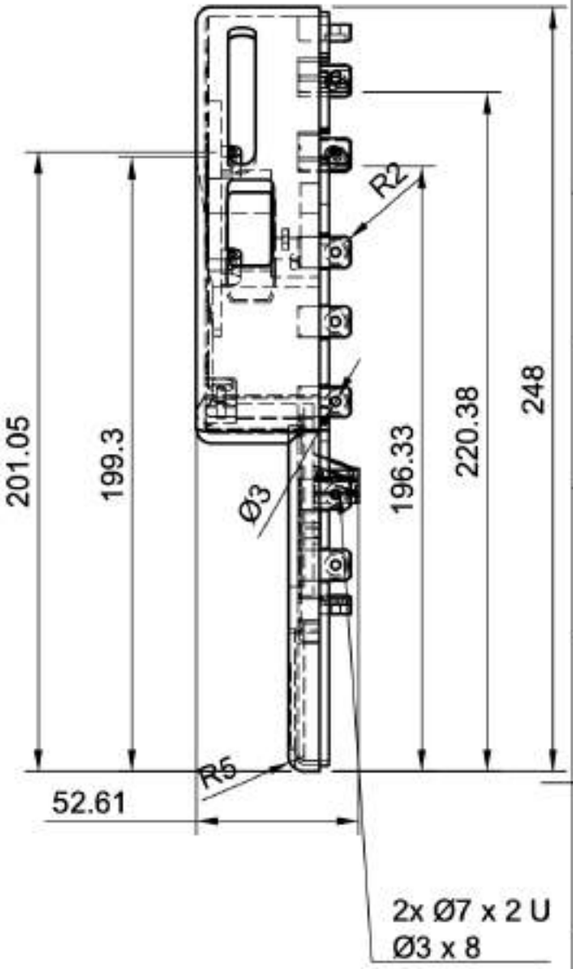

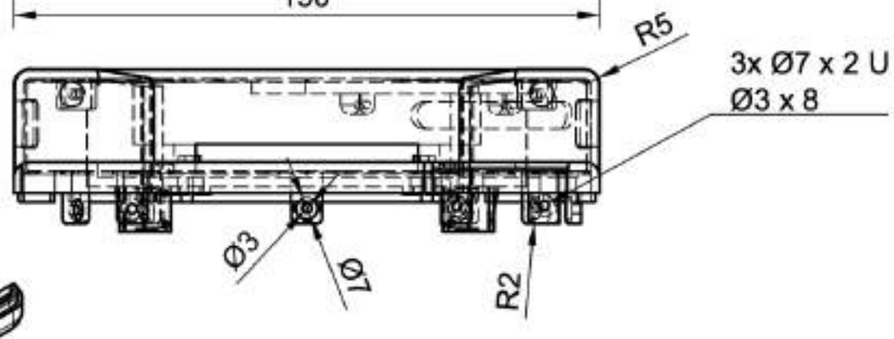

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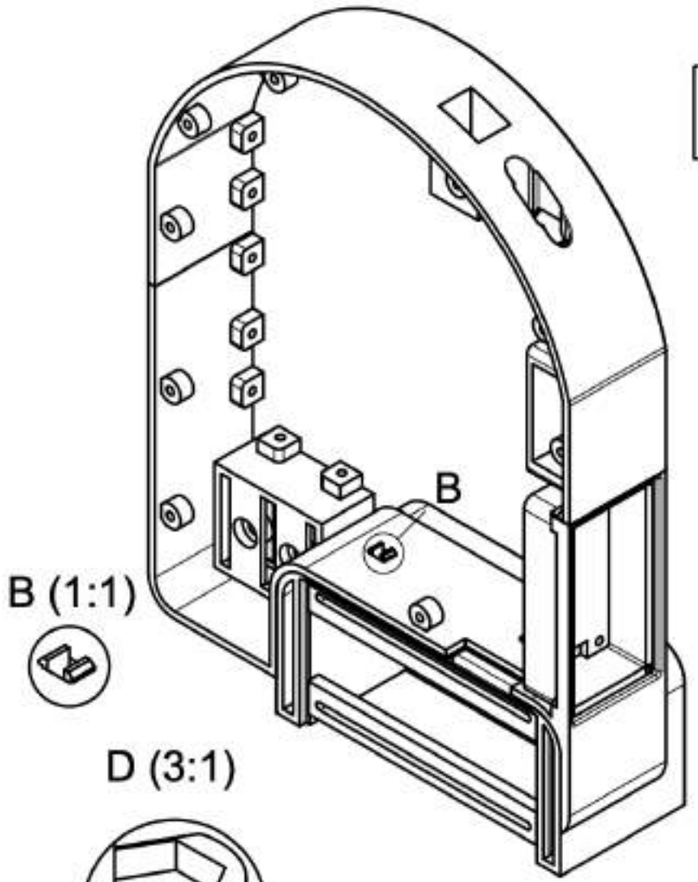

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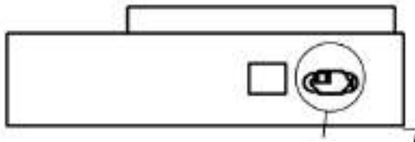

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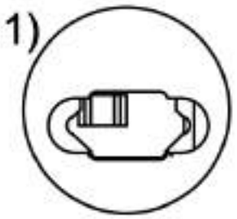

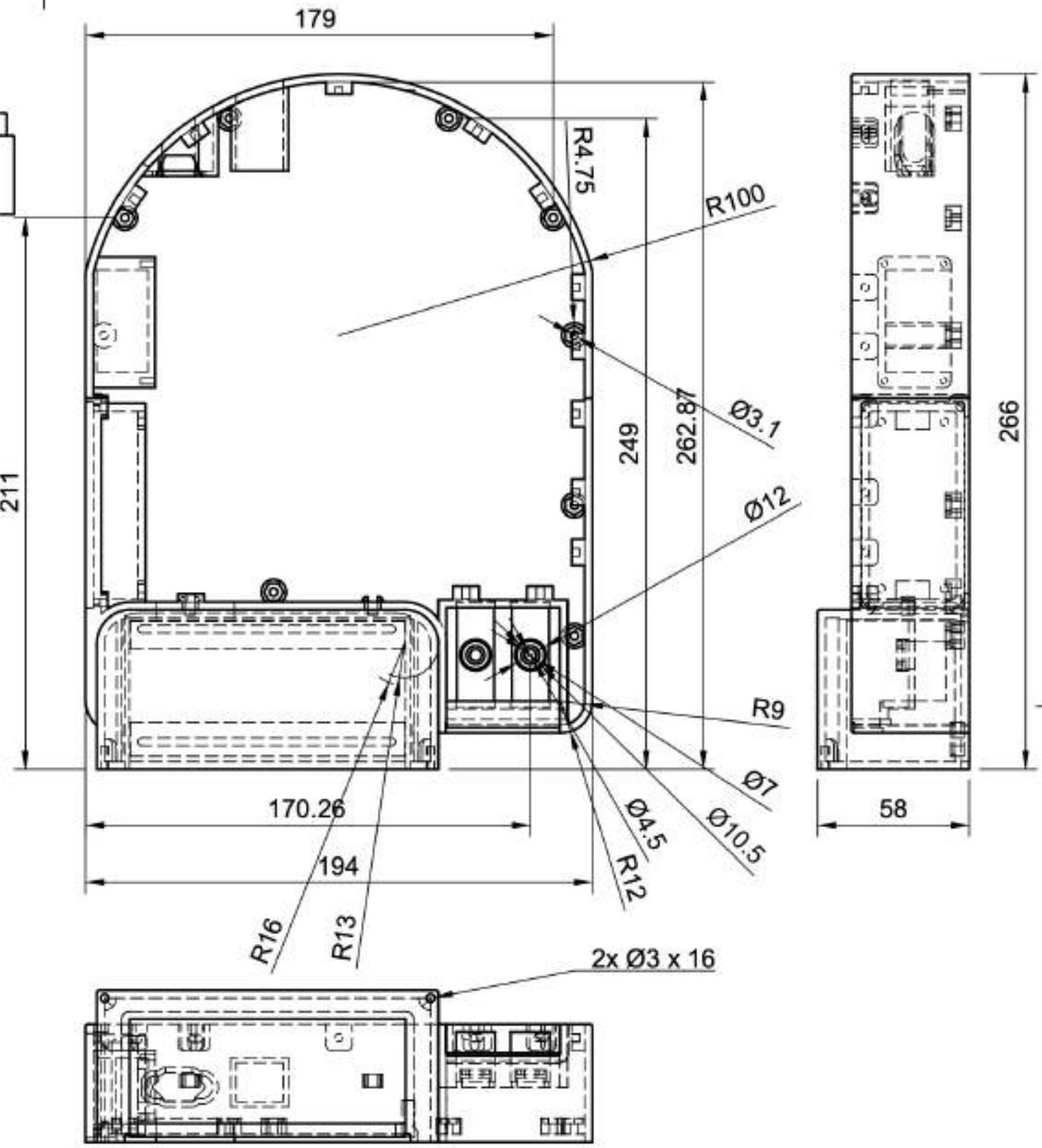

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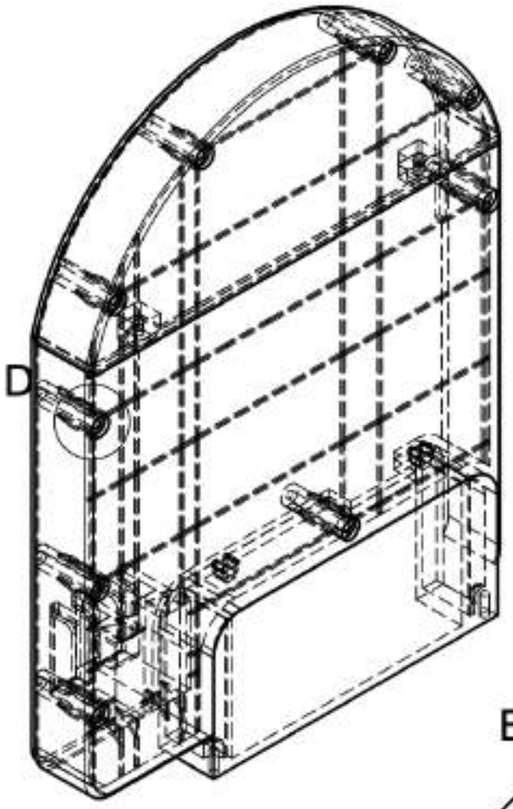

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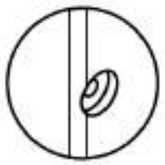

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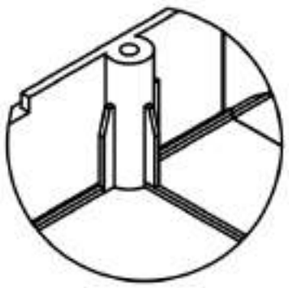

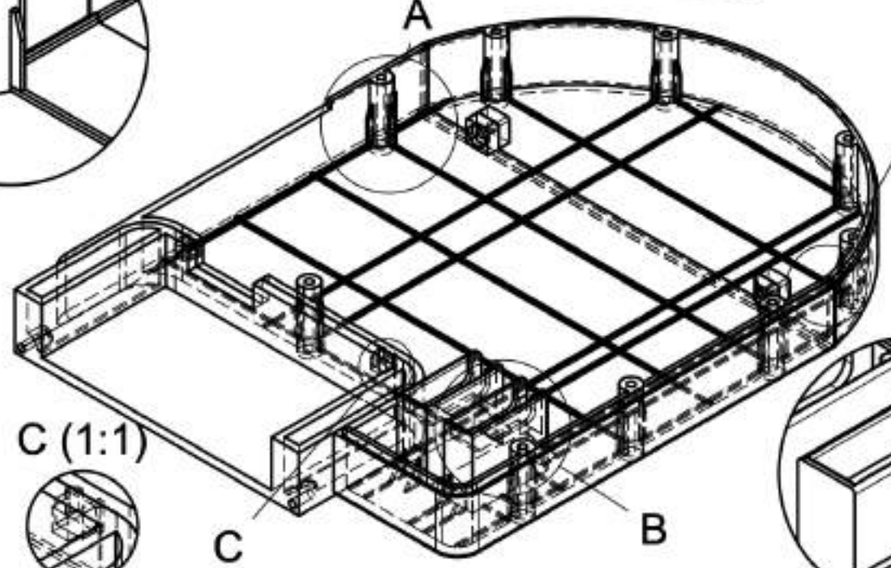

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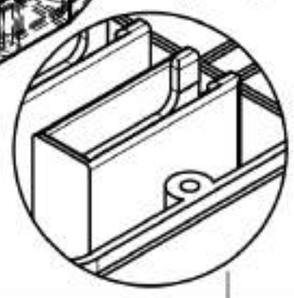

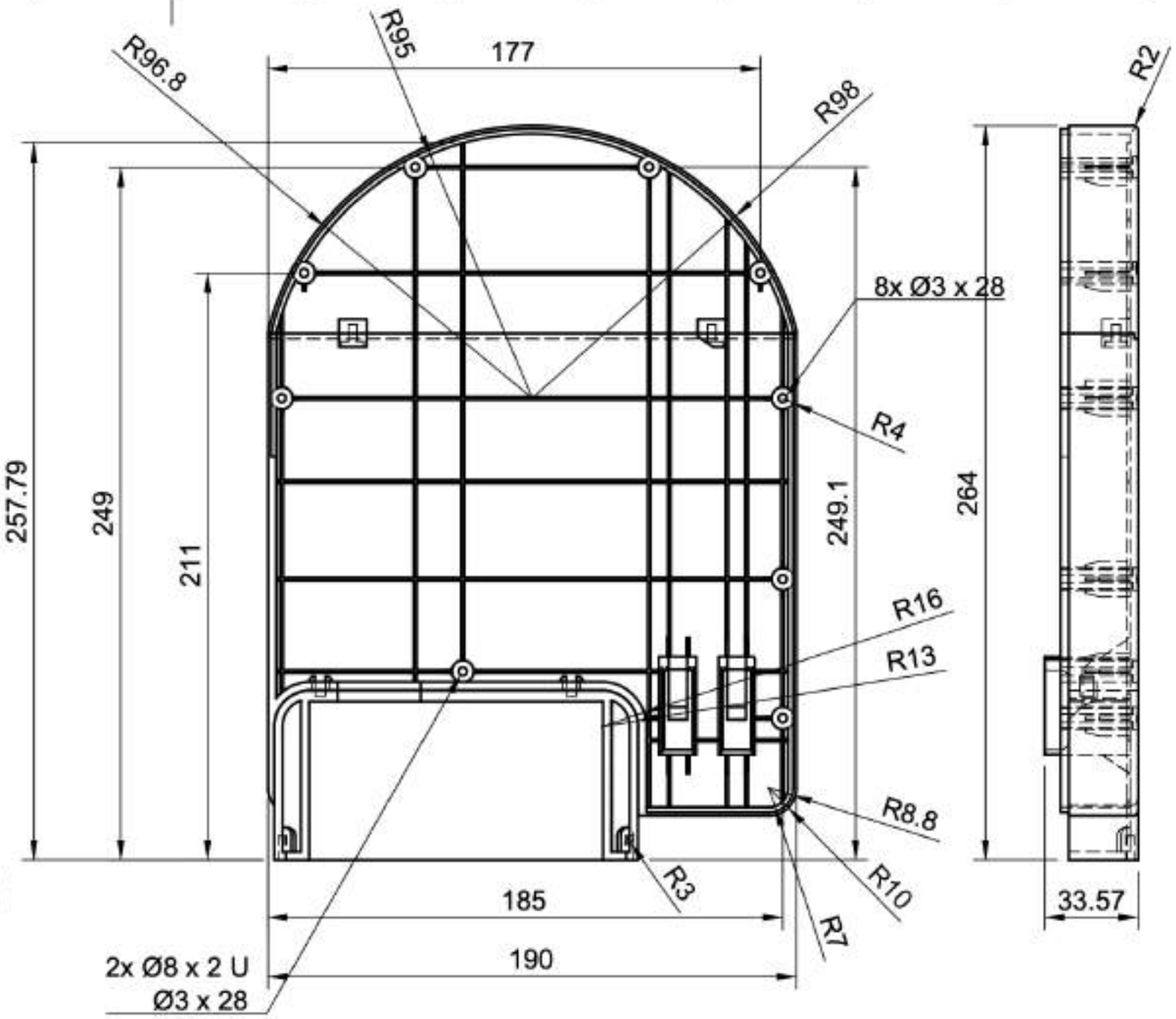

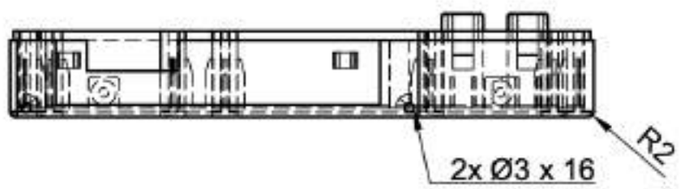

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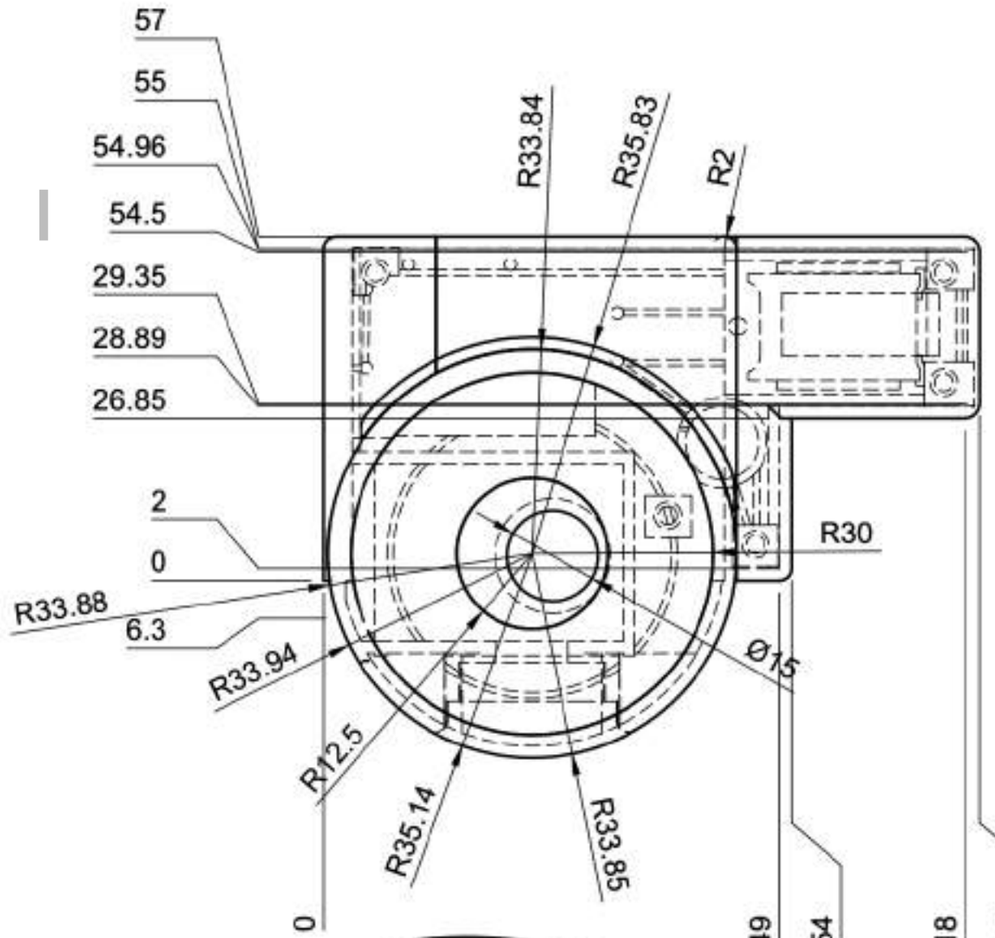

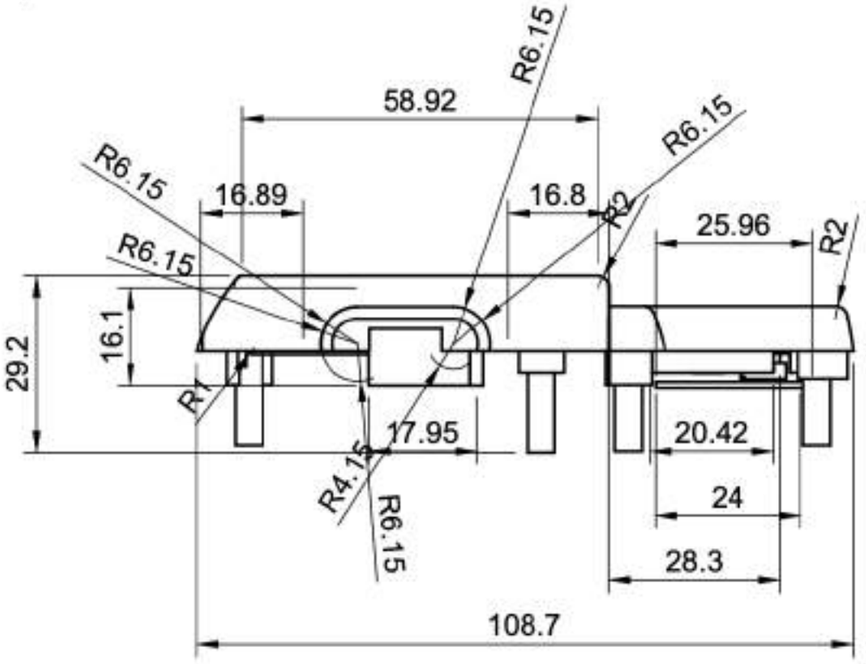

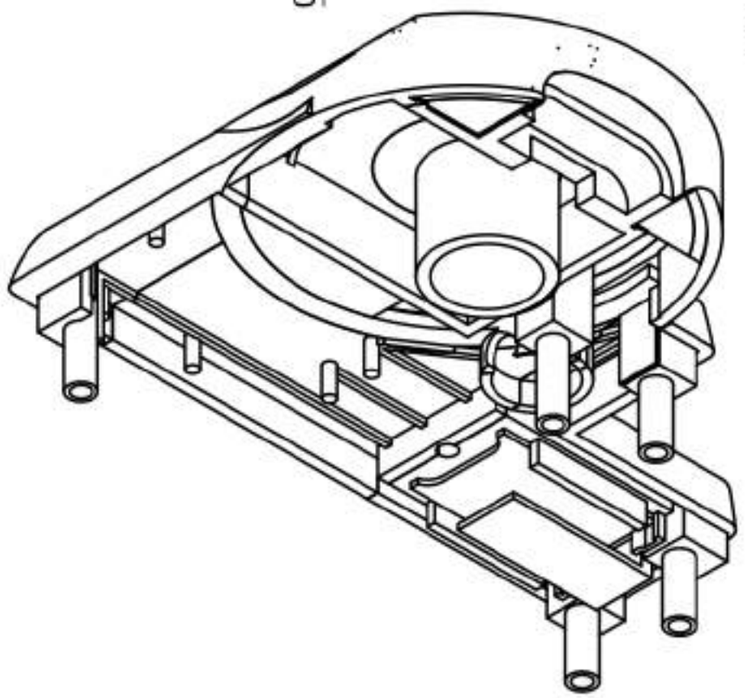

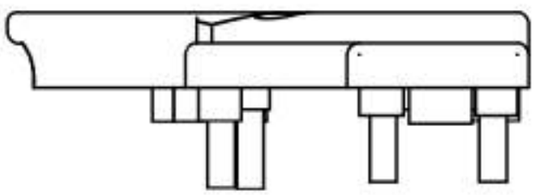

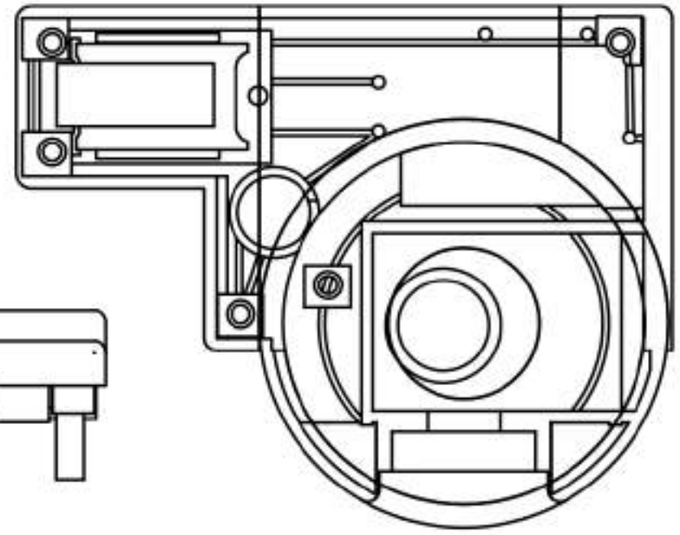

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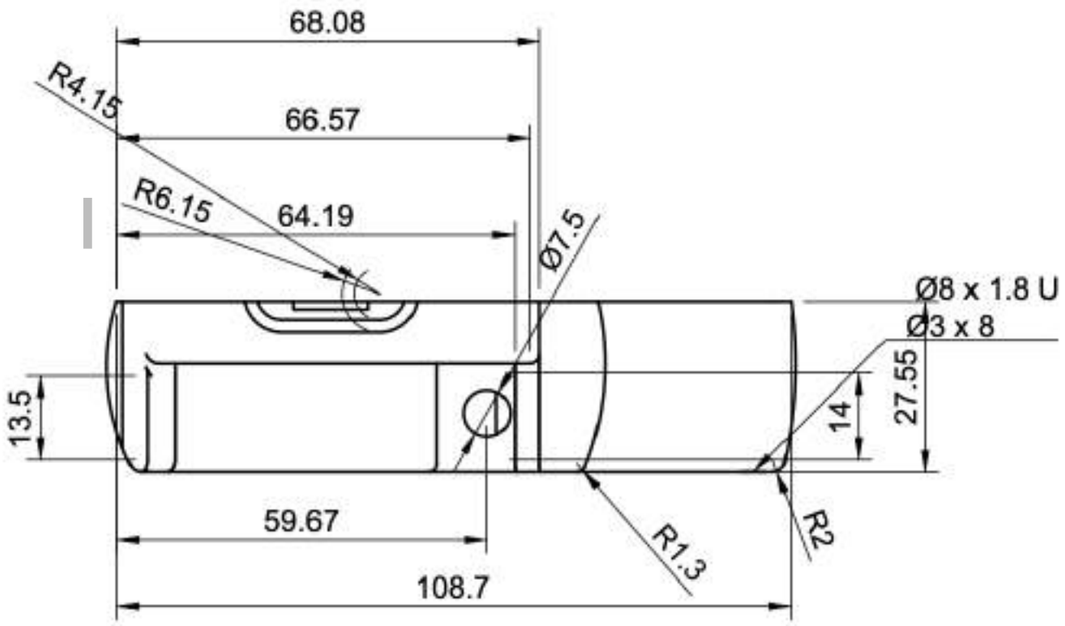

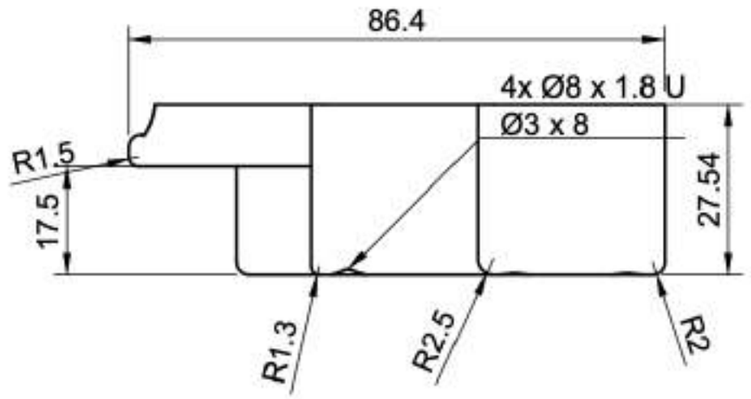

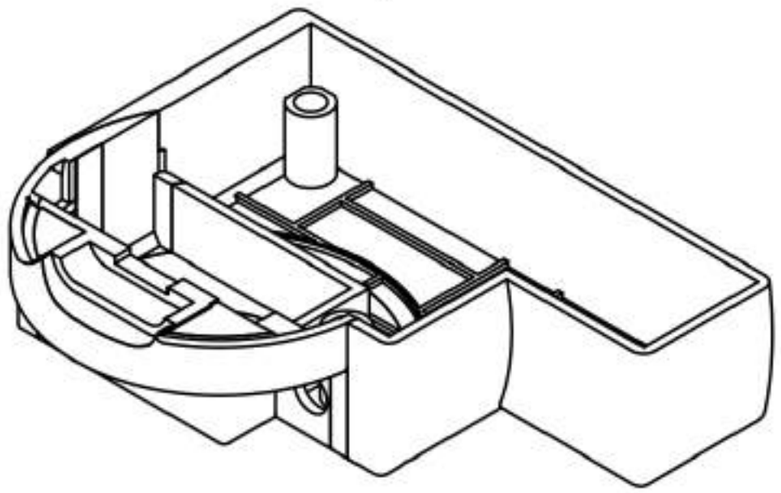

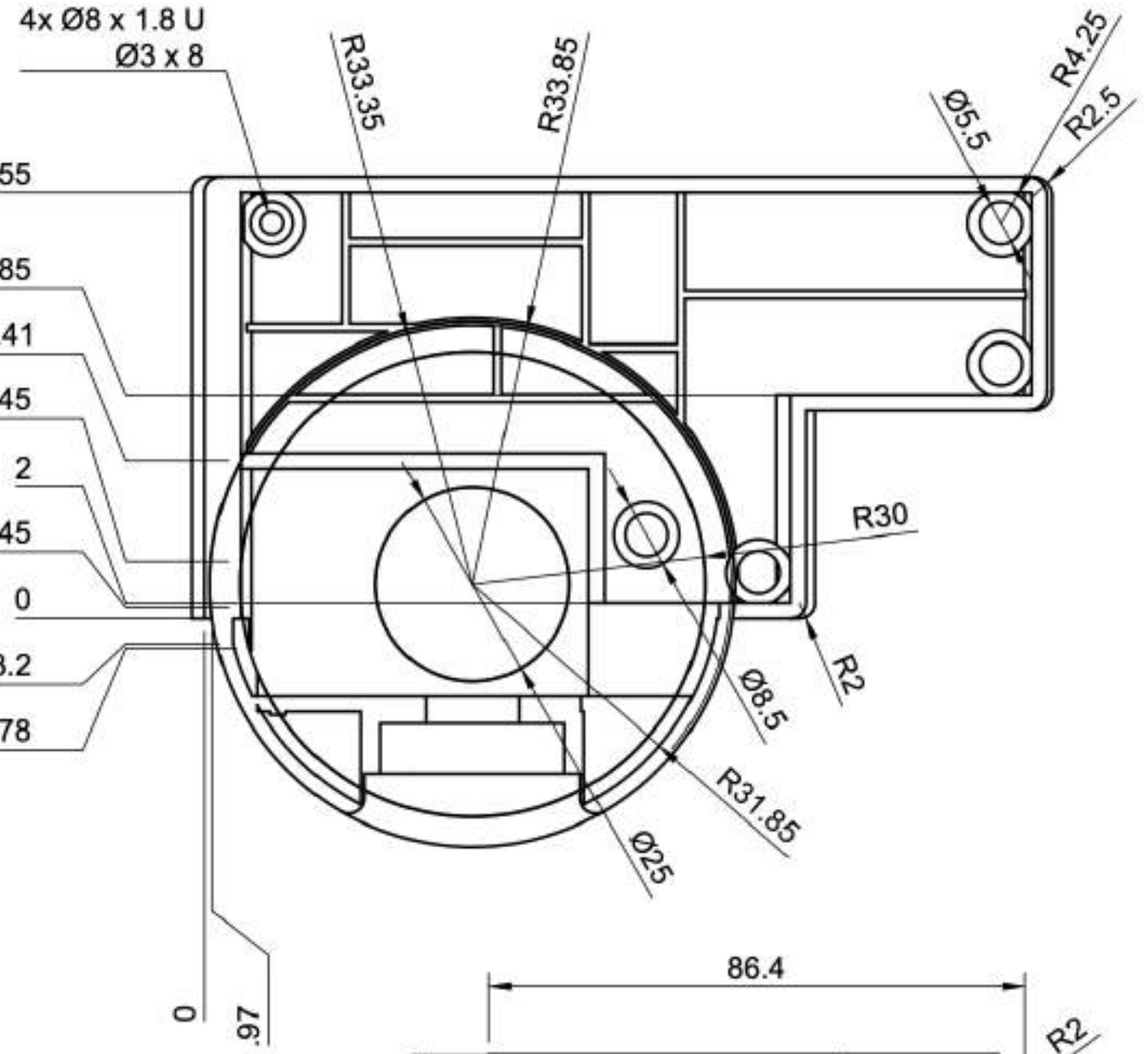

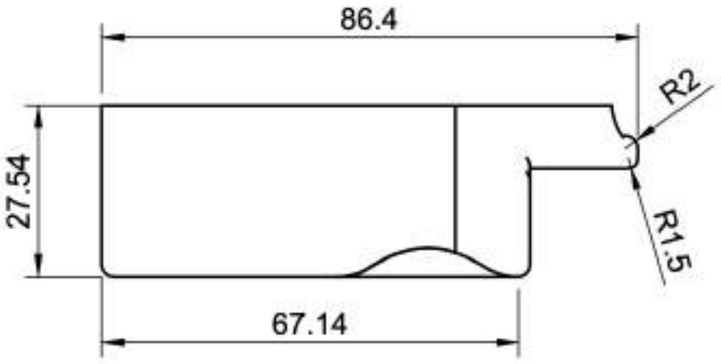

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A Nature Exploration Toy for Children

Design Technical Report

by

Ziheng Liu, Boxuan Ye

DYSON SCHOOL OF DESIGN ENGINEERING

IMPERIAL COLLEGE LONDON

JULY 2025

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Chapter 1

Overview

The Nature Kit is an innovative two-component educational toy designed to engage children aged 3-6 in hands-on nature exploration while fostering meaningful parent-child interactions. This interactive toy consists of a base station and a handheld camera that work together to transform outdoor discovery into learning experiences.

The handheld camera allows children to examine plants, leaves, and flowers in detail during outdoor exploration. When the photo of specimens are collected and the handheld camera is inserted into the smart base station, advanced plant recognition identifies the specimen and generates personalized, AI-created stories about the discovered plant.

The smart base station can also act as a night lamp when it's not in use.

This approach seamlessly combines hands-on discovery with intelligent feedback, satisfying children's natural curiosity with immediate responses, and helping parents to create structured, educational outdoor experiences.

The entire product development of the Nature Kit followed a user-centric approach. User interviews, surveys, and observational studies were conducted to validate every major design decision, ensuring that the final product reflects not only the team's vision but also the real desires and needs of both children and parents.

Chapter 2

Product Opportunity

Extensive research and user studies have identified a significant disconnect between children and natural environments, commonly referred to as "Nature Deficit Disorder" in educational literature [1].This phenomenon, amplified by increasing urbanisation and digital entertainment prevalence, significantly limits children's opportunities for outdoor exploration and discovery. Our research revealed that modern children face substantial barriers to nature engagement, with many parents reporting that their children "rarely get to experience nature since we live in the city." The consequences of this separation extend beyond missed learning opportunities, correlating with diminished sensory development, reduced environmental awareness, and difficulty forming lasting memories from outdoor discoveries.

The challenge is particularly acute for children aged 3-6, who are at a critical developmental stage where environmental attitudes and knowledge foundations are established. While children naturally exhibit high curiosity about plants and natural specimens, they struggle to transition outdoor discoveries into sustained learning experiences. Current solutions inadequately bridge this gap, with existing nature exploration tools predominantly designed for older children, leaving younger learners with limited options for active participation in botanical discovery activities.

2.1 User Definition

Defining a clear user scope helps us properly identify the operating logic of our product and how it should be crafted. We have identified children aged 3-6 years as our primary target users, representing a developmental stage where natural curiosity and learning capacity are at their peak. This age group is characterized by high engagement with hands-on activities, strong visual learning preferences, and an innate fascination with the natural world.

Secondary users include parents and caregivers who serve as facilitators and supervisors during outdoor exploration activities. These adults play essential roles in ensuring safe usage, providing guidance, and enhancing the educational value of the Nature Kit.

2.2 Product Objectives

Child-Friendly Design: The interface should be intuitive and age-appropriate, with simple operations manageable by children aged 3-6 independently. The handheld camera features ergonomic design suitable for small hands, while the smart base station provides clear visual feedback that children can easily understand. The system complies with and exceeds required safety standards for children's toys, ensuring durability and non-toxic materials.

Nature Connection and Learning: The Nature Kit aims to bridge the gap between children and the natural world by making plant discovery engaging and educational. Through AI-generated stories and plant identification features, the product transforms outdoor exploration into structured learning experiences that develop botanical knowledge and environmental awareness.

Parental Involvement and Support: Parents play a crucial role in our product ecosystem. They make purchasing decisions and facilitate and enhance the educational experience. The system encourages collaborative exploration, where parents and children can discover nature together.

Chapter 3

Concept Development

3.1 Methods of Research and Selection Rationale

The project was started with a comprehensive vision to provide children aged 3 to 6 years with educational products that improve their learning and development. Each proposed concept was investigated by an individual user to understand specific needs and validate design directions. Various solutions are conceived, including:

1. **Nature Explorer Kit:** A portable outdoor discovery set with a digital stamp and interactive palette that enables young children to capture, organise and review plant collections through hands-on interaction and AI-based identification.
2. **Smart Laundry Basket:** A gamified laundry basket that encourages children to sort and throw clothes using interactive features such as voice reminders, app connectivity and LED scoring.
3. **Smart Hanger**: An interactive clothing hanger that teaches children proper clothing organization through sensors, LED cues, and app-based tracking.
4. **Play-Stack**: A modular soft-storage system that helps young children learn tidying habits through playful stacking, sorting, and colour-coded compartments.

Nature Explorer Kit *Smart Laundry Basket* *Smart Hanger* *Play-Stack*

Figure 3.1: **Four early product ideas**

Following a thorough discussion and careful consideration of all the ideas put forward, we concluded that the Nature Explorer Kit offers the greatest potential for development and best

aligns with our goal of creating an educational product for children. It is also highly feasible and appeals to families seeking alternatives to screen-based entertainment. Research shows that 81% of parents believe their children need more exposure to nature and 72% are concerned about excessive screen time on devices such as iPads.

3.2 Development and Integrations

The initial concept was to build a nature collection system for kids with a portable camera that captures plant specimen photos when they explore outdoors and a rounded interactive palette that displays their collected discoveries. The kids can attach the stamp to the center of the palette and rotate it to select and view the plants they collected.

3.2.1 Selection of Base forms

The initial base design adopted a circular shape, with the camera stamp docked at the center and an outer ring-shaped display showing collected plant photos. Children could rotate the stamp to browse through their discoveries. This minimal screen set-up was intentionally chosen to reduce children's exposure to electronic devices: **avoiding touchscreens** and relying instead on **physical interaction** through rotation and pressing.

However, this form proved limiting once we introduced AI-driven features such as plant explanations and personalized story generation. These additions required higher display resolution, better integration, and more interaction controls than the original design could support.

As a result, the simple rotating ring screen and base geometry was no longer sufficient. To address this, two layouts were explored to accommodate a **higher-function display** and **AI interaction buttons** suitable for children.

To reduce screen time, we prioritized physical interaction enabling children to explore content by rotating and pressing rather than swiping—aligning with our core value of multi-sensory exploration.

Considering that young children's visual systems are still developing, we selected a **high-contrast, high-saturation** colour palette. The use of bright red, yellow, and blue enhances visual attention and stimulates right-brain perception.

To resolve the layout challenge, two design directions were proposed:

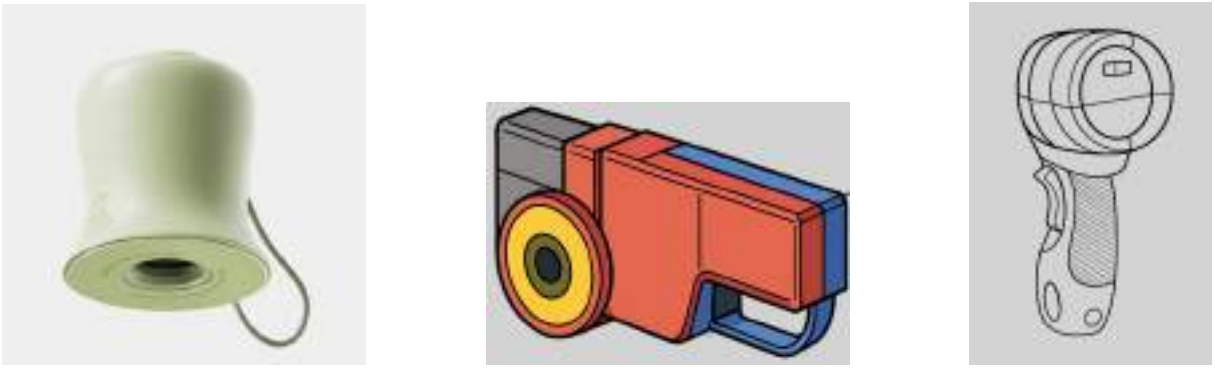
1. Retain the circular ring display for browsing collected plants, while introducing a thicker base with an extended curved side screen. This additional display layer, wrapped around the base, would be used to show AI-generated explanations and stories without disrupting the original interaction.

2. Replace the ring display with an integrated rectangular screen interface that could handle plant albums and AI-based educational output, while incorporating physical buttons and maintaining the rotating mechanism as part of an interactive toy experience. The concept was inspired by vintage gramophones - a warm, circular form that provides both nostalgic appeal and physical stability for interaction.

User feedback revealed that the curved side screen in the first concept was visually ambiguous and harder for children to focus on. In contrast, the integrated rectangular screen was found to be more intuitive, when paired with physical buttons and rotation. Young children respond well to clear, cause-and-effect feedback when digital content is supported by tactile actions. Based on this, the second concept was selected.

3.2.2 Selection of Camera Forms

Early-stage exploration included a variety of form concepts for the camera module, such as stamp-like structures, magnifier, and detector shapes. Regardless of the external form, the camera handle needed to serve a dual function when docked into the base: enabling **physical interaction** and acting as a conduit for **data transmission**. This requirement informed both the structural geometry and the interface design, ensuring that the camera could reliably transfer captured content while maintaining interaction with the base.



(a) Stamp Concept (b) Magnifier-Inspired Form (c) Detector Form

Figure 3.2: **Early Camera Form Explorations**

After comparative evaluation, the magnifier-inspired form was selected for further development. This choice was supported by the following considerations:

- **Ease of handling:** The form can be held and operated with one hand, making it suitable for children aged 3–6 with limited grip strength and coordination.
- **Symbolic association:** The magnifier shape naturally evokes a sense of exploration, aligning closely with the activity of observing plants in outdoor environments.
- **Aesthetic alignment:** The rounded geometry offers a soft, toy-like appearance that fits within a playful product language while avoiding visual cues associated with digital devices.

- **Technical feasibility:** The continuous cylindrical form allows stable data transmission when docked into the base, ensuring physical alignment without requiring **precise adjustment**. It minimizes the chance of disconnection or breakage.

3.2.3 Interaction Mechanism

To achieve a physically engaging interaction experience, the magnifier-shaped camera was designed to dock vertically into a circular notch at the centre of the base. This upright configuration enables stable rotational movement and ensures the embedded pin connectors **align precisely** for reliable data transfer. It also **prevents accidental misalignment**.

Once inserted, the camera acts as a physical controller. Children can rotate the handle left or right to browse through their collected photos.

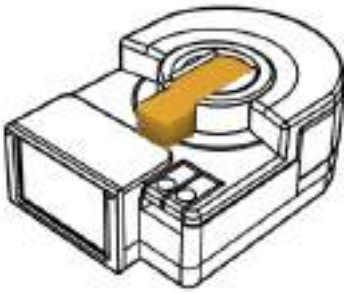


Figure 3.3: **(a) Camera inserted into base for physical alignment and data transfer**

The camera's shutter button allows for photo capture and is equipped with a **vibration motor** that provides haptic feedback, establishing a sensory link between child's action and the image capture.

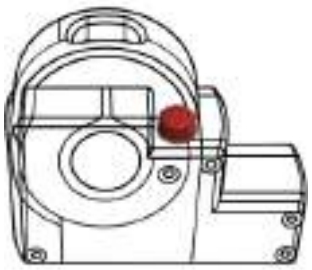


Figure 3.4: **Tactile shutter button provides vibration feedback upon capture**

In addition to the camera, two dedicated buttons are integrated into the base to extend functionality:

- One button enables zooming in to inspect image details.

- The other button activates the AI-based explanation and story generation function.

3.2.4 ?Interface Design?

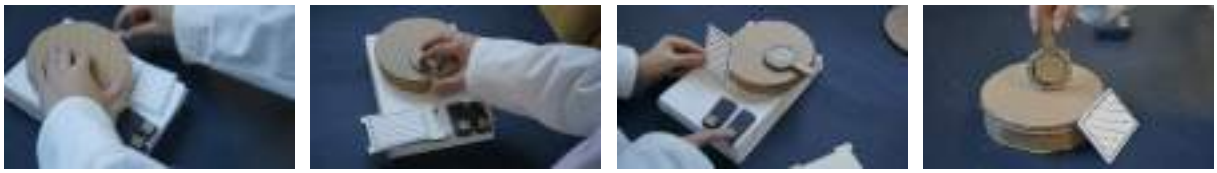
Chapter 4

Prototyping, Experiment, and Iteration

4.1 Low-fi Prototype

To explore the arrangement and basic interaction logic of the product, a series of low-fidelity prototypes were created using cardboard, foam, and laser-cut boards. After the overall concept was defined, our focus shifted to testing how different elements, such as the rotating camera module, screen position, and button layout.

Several key questions guided our prototyping: Should the camera be inserted vertically like a sword, or laid flat into a fitted slot? Where should the rotating mechanism be placed to ensure usability? How should the buttons be arranged so that they are accessible for children?



(a) Testing the alignment and rotation (b) Evaluating rotating interaction (c) Button position testing (d) Exploring vertical insertion

Figure 4.1: **Low-fi prototyping**

4.2 Hardware for High-fidelity Prototype

4.2.1 CAD Design and Structural Iterations

To ensure the shell met both functional and ergonomic requirements, several iterative improvements were made during the CAD design phase. Initially, the outer casing was too thick, which was noted by the supervisor **excessive wall thickness** in **injection moulding** can significantly increase **cooling time** and risk of deformation,making it unsuitable for mass

production. This observation prompted a redesign to optimize wall dimensions.

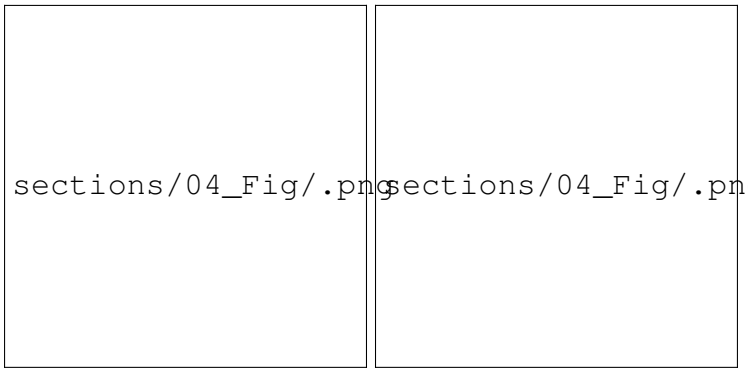


Figure 4.2: Shell thickness iteration: original (left) vs. revised (right)

Additional support ribs were added to critical areas of the structure to prevent deformation during use. Moreover, several dedicated cutouts were designed into the shell for component integration: a recessed slot for the microswitch that fits precisely (see Figure 4.4), and a grille slot to accommodate the speaker component (see Figure 4.4).

Figure 4.3: Left: Internal support ribs and microswitch slot; Right: speaker cutout;

The rear side of the screen housing was also designed with a **long recessed screw slot** to flexibly accommodate electronic boards.(see Figure 4.4).

Figure 4.4: Elongated screw slot for screen PCB

Finally, the structure was iterated with fitting geometries and fastening points. The exploded view shows internal component layout, while the top-bottom assembly highlights casing alignment and microswitch positioning (see Figure 4.5).

Figure 4.5: Left: Exploded view of internal layout; Right: Top-bottom casing assembly

4.2.2 Interactive Mechanism Testing

To validate the feasibility and ergonomics of mechanical interaction, two subsystems were prototyped and tested in their high-fidelity forms: button mechanisms and the rotating camera handle.

The base button mechanism was developed to **interact precisely** with an internal microswitch via a **vertically aligned shaft**. The cylindrical shaft was designed to pass through a dedicated guide hole and make contact with the microswitch below upon pressing (Figure 4.6).

In the initial prototype, the shaft was too thin and frequently broke under normal use. This compromised structural stability and raised safety concerns, particularly for children. In response, the design was revised with **a widened base for reinforcement**, enhancing durability without affecting the function.

Figure 4.6: Button prototype showing reinforced vertical shaft

The button module in both base and camera were designed with **a pressable geometry**. The surface was shaped to provide haptic feedback while fitting seamlessly within the outer casing. (Figure 4.7).

Figure 4.7: Button interaction test

For the rotating mechanism, **a cylindrical guide and slot system** was developed to allow secure yet **smooth axial rotation**. Spring components were integrated into the grooves to achieve repeatable left-and-right movement. Iterative tests (shown in Figure 4.8) helped refine tolerances and user grip.

Figure 4.8: Testing of rotating camera handle structure

A comprehensive image of all components, including hardware-ready shell parts and key internal electronics, is shown in Figure 4.9, providing a full overview of the high-fidelity build state.

Figure 4.9: All printed components and key circuit modules

4.2.3 Electrical Components Selection and Comparative Analysis

This subsection justifies the final bill of materials[1] for the high-fidelity prototype and contrasts each chosen part with at least one credible alternative. Table **??** summarises the key metrics; the following paragraphs expand on the rationale.

4.2.3.1 Display: 5-inch IPS TFT (800×480)

The selected model (part no. E5001I-DCT) is supplied as an all-in-one "Package 8" kit comprising the LCD panel, an HDMI driver board, a capacitive-touch controller, and the required HDMI and USB-C cables (Fig. 4.10). Compared with DSI or DPI solutions, the HDMI interface offers true *plug-and-play* compatibility across Raspberry Pi, Jetson, and even desktop PCs; no kernel overlays or customised ribbons are needed. At 800×480 resolution the 5-inch form factor still renders a full photograph plus two caption lines while keeping weight under 120g. Power consumption rises slightly (about 2.1W) because of the external driver board, yet remains below that of most 7-inch HDMI panels. The bundled FT5xxx capacitive controller exposes an I^2C interface, preserved for future gesture-based UI but left disabled in the current firmware. Comparable 5-inch HDMI displays from Waveshare advertise identical resolution and multi-platform support, confirming the kit's suitability.

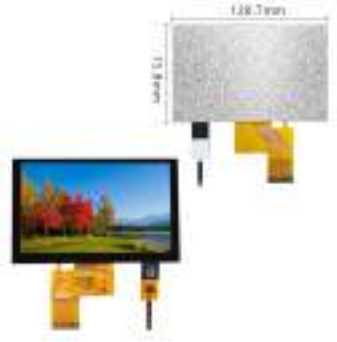


Figure 4.10: "Package 8" 5-inch display kit: (1) LCD panel, (2) HDMI driver, (3) touch board, (4) HDMI lead, (5) USB-C power lead.

4.2.3.2 Camera: ESP32-CAM (Slave Node)

Two camera architectures were evaluated:

- **Raspberry Pi Camera Module V3** connected via the CSI ribbon cable.
- **ESP32-CAM** streaming still images over Bluetooth Low Energy (BLE).

Solution (a) provides up to 12-megapixel stills and on-board ISP tuning, but it monopolises the Pi's CSI port and needs a wide, fragile ribbon—hard to protect inside a child-proof enclosure.

[1] A complete parts list with vendor links is provided in Appendix 4.1.

Solution (b), chosen for the prototype, combines a 2-megapixel OV3660 sensor, BLE 5.0 radio and SD-card slot on a 27 mm × 40 mm board costing under £5. Thanks to 8 MB of on-board PSRAM the module can capture at 1600 × 1200 and compress to JPEG locally. With a 247-byte MTU on the 2 Mbit s^{-1} BLE PHY, a typical 60 kB JPEG transfers in about 1.8 s while drawing roughly 25 mW—an order of magnitude less than Wi-Fi streaming.

4.2.3.3 Processing Unit: Raspberry Pi 5 (Master)

Migrating from an early Jetson Nano prototype (Cortex-A57, 1.4 GHz) to Raspberry Pi 5 (Cortex-A76, 2.4 GHz) cut Whisper-base ASR inference time from 730 ms to 280 ms and reduced the idle power budget from 2.9 W to 1.6 W.

- 8 GB LPDDR4X for conversational context
- dual-lane DSI/DPI for high-refresh graphics
- on-board BCM4387 Bluetooth 5.2, so no external dongle is required

4.2.3.4 Audio Output: YD1066 USB Speaker

A plug-and-play YD1066 USB speaker (UAC 1.0 compliant) was favoured over I^2S plus Class-D HATs. Both options deliver roughly 3 W × 2 RMS, but the YD1066

1. avoids kernel-level ALSA overlays,
2. reduces PCB area by about 20 %, and
3. isolates audio ground from the Pi, mitigating hum when powered from battery packs.

4.2.4 Circuit Design

4.3 Software

4.3.1 System Architecture

4.3.1.1 Overview

The prototype is organised as a *two-tier* system (Fig. 4.11). The **edge tier** comprises an ESP32-CAM, a Raspberry Pi 5, a 5-inch HDMI display, a YD1066 USB speaker and four GPIO buttons. The **cloud tier** supplements the edge tier with GPT-4o for story generation whenever Internet connectivity is available.

Table 4.1: Chosen components compared with representative alternatives.

Category	Item	Spec./Resolution	Power	Cost	Key Rationale
Display	5 IPS HDMI (chosen)	800×480 @60 Hz	2.1 W	$32	Plug-and-play, no ribbon
Display	5 IPS DSI	800×480 @60 Hz	1.6 W	$41	Neat cabling, Pi-only
Camera	ESP32-CAM (chosen)	2 MP OV3660	25 mW	$5	Wireless, ultra-compact
Camera	Pi Camera V3	12 MP IMX708	200 mW	$25	Higher res.; ribbon cable
Compute	Raspberry Pi 5 (chosen)	4×A76, 8 GB RAM	1.6 W idle	$80	Faster CPU, on-board BT
Compute	Jetson Nano	4×A57, 4 GB RAM	2.9 W idle	$99	Better GPU, heavier PSU
Speaker	YD1066 USB (chosen)	2×3 W RMS	2.5 W	$9	Driver-less, EMC-friendly
Speaker	I^2S HAT	2×3 W RMS	2.5 W	$14	Needs overlay, extra PCB

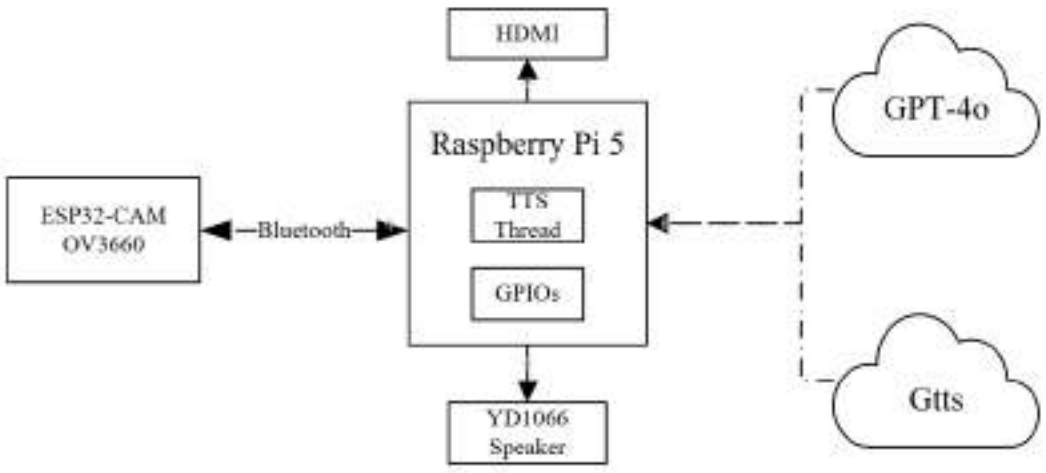


Figure 4.11: Two-tier system architecture. Solid arrows denote local links; dashed arrows denote optional cloud links.

Images are captured on the ESP32-CAM and forwarded to the Pi via Bluetooth Low Energy (BLE, 2 Mbit/s). Once received, they are sent to the cloud for text generation, converted to speech in a multithreaded, quasi-real-time text-to-speech (TTS) pipeline, and finally rendered on the local display and speaker. All essential functions on the *slave* (ESP32-CAM) operate offline, while the *master* (Raspberry Pi 5) can fall back to Wi-Fi or Ethernet whenever cloud access is required.

4.3.1.2 Multi-threaded TTS pipeline

Upon image arrival, the *Story Thread* submits the picture to GPT-4o and receives a JSON story segmented into sentences. Each sentence is enqueued in a thread-safe queue shared with a dedicated *TTS Thread*. While the Story Thread waits for the next network round-trip, the TTS Thread converts the current sentence to raw PCM—using `gTTS`—and streams it asynchronously to the YD1066 speaker. This overlap hides cloud latency; empirical measurements show an average gap of ≈ 350 ms between sentences, which is imperceptible during bedtime storytelling.

4.3.2 BT-SPP Data Transition

To decouple image acquisition from downstream processing, the ESP32-CAM pushes every captured JPEG to the Raspberry Pi over a lightweight, "UART-style" Bluetooth SPP link. Listing 4.1 shows the trimmed source, and the resulting wire-protocol is summarised below.

4.3.2.1 Memory-first start-up.

Because the camera driver consumes the largest contiguous DRAM block, it is initialised *before* the Bluetooth stack. Immediately afterwards the BLE controller RAM (50 kB) is released with `esp_bt_controller_mem_release(ESP_BT_MODE_BLE)`, and only Classic BT-SPP is kept—saving enough heap for the camera framebuffer and a 256-byte TX buffer.

4.3.2.2 Capture & store.

Pulling `GPIO 3` low snaps a 320×240 JPEG (≈ 45 kB, quality 18) and writes it to micro SD as `/img_<millis>.jpg`. The file remains on the card until the Pi explicitly requests a sync.

4.3.2.3 Pi-initiated synchronisation.

When the Raspberry Pi sends `SYNC\n`, the ESP32 enumerates every `*.jpg` that is *not* yet marked with the `.ok` extension and streams them in FIFO order.

Stage	→	Payload (ASCII unless noted)
1. File name		`/img_168523.jpg\n`
2. Hand-shake		`sent\n`
3. Length (little-endian U32)		`0x0000B3F4`
4. JPEG data		len bytes
repeat 1–4 for every pending file		
5. Sync terminator		`SYNC_DONE\n`

4.3.2.4 Idempotence and Time Stamping

Once an image has been transferred without error, the file is *atomically* renamed from `*.jpg` to `*.jpg.ok` on the SD card. This single-step operation provides *at-most-once* semantics: if the Raspberry Pi loses power in the middle of a transfer the file remains unmarked and will be retransmitted during the next synchronisation cycle.

The same mechanism doubles as an offline time-stamping aid. When the ESP32-CAM boots it records a start-up tick $t_0 = \texttt{millis()}$. For every photo we log the capture tick t_i and the completion tick t_{send}. Because the Pi is continuously on-line, it can reconstruct the absolute shooting time via

$$T_{\text{capture}} = \texttt{time.time()} - \frac{t_{\text{send}} - t_i}{1000},$$

thereby assigning each image a reliable UTC time-stamp even when the camera itself was disconnected from the Internet.

4.3.2.5 Throughput & latency

With SPP's raw throughput of 115 kb/s,$^{-1}$ the 45 kB payload reaches the Pi in 3.5 s, comfortably hidden underneath the TTS pipeline's network round-trips (Sec. **??**).

```
bool sendFileBT(const String& path) {
  File f = SD_MMC.open(path, FILE_READ);
  uint32_t len32 = f.size();
  BT.println(path);           //     filename
  BT.println("sent");         //     handshake
  BT.write((uint8_t*)&len32, 4); //     length
  ...
  BT.write(buf, r);           //     JPEG bytes
  ...
  BT.println("SYNC_DONE");    // terminator
}
```

Listing 4.1: ESP32-CAM Bluetooth SPP image-push (excerpt)

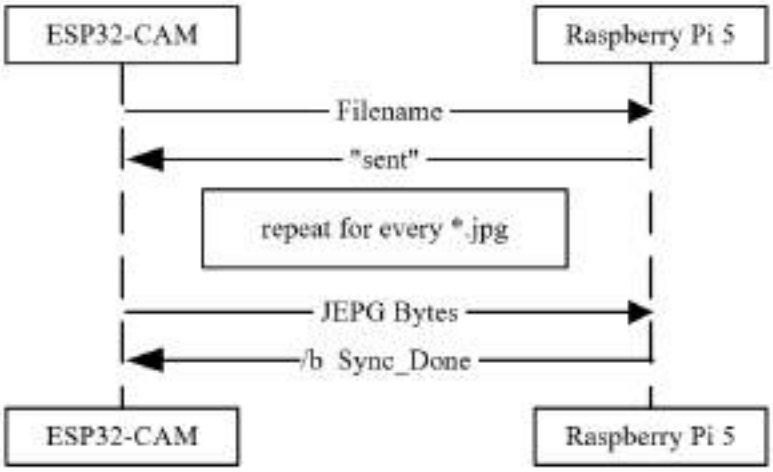


Figure 4.12: Bluetooth SPP push protocol between ESP32-CAM and Raspberry Pi.

4.3.3 User Interface

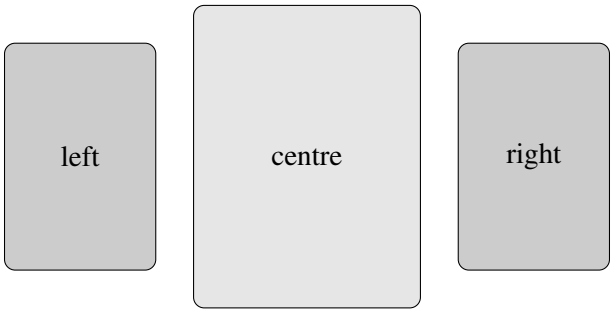
The front-end runs inside an `index.html` page served by `Flask`. All elements are absolutely positioned on an 800×480 canvas to match the five-inch HDMI panel on the Raspberry Pi 5 [**stylecss˙layout**].

4.3.3.1 Idle (slideshow) mode.

- A full-screen `.slideshow-container` hosts two overlapping `<img>` tags (`#img1`, `#img2`). Cross-fading is achieved by toggling the CSS class `.visible`, which ramps `opacity` from 0 to 1 over 1.5 s and restarts a gentle `zoomIn` key-frame animation every 20 s 5 [**stylecss˙slideshow**].
- A digital clock (`#clock`, 70 px) is fixed to the top-right corner; the date (`#date`, 30 px) occupies the bottom-right. Both are updated once per second by `updateClock()` in `main.js` [**mainjs˙clock**].
- The lower third contains an initially empty `#story-text` element. When the user presses C, the Pi requests GPT-4o to create a bedtime story for the currently displayed image; each sentence is spoken by the TTS thread and simultaneously appended to this textbox [**mainjs˙story**].

4.3.3.2 Card (gallery) mode.

Pressing P pauses the slideshow and slides a dark `.card-switcher` overlay above the images [**stylecss˙card**]. Three thumbnails are shown at a time:



Keyboard focus is captured by `handleKeyPress()` so that A/D shift the selection left or right, while P (or Esc) exits the overlay with a smooth zoom-out transition (`.card-exit`)[**mainjs˙card**]. The selected image then fills the screen and the slideshow timer resumes.

4.3.3.3 Accessibility.

The UI avoids small touch targets: all interactive areas are either full-screen or mapped to the four physical GPIO buttons on the picture frame (Sec. **??**). High-contrast white text over a dimmed photo background maximises legibility in a dark bedroom environment.

4.3.3.4 Assets.

System fonts are loaded locally; only the Google *Inter* family ($300\,\mathrm{wght}$ to $500\,\mathrm{wght}$) is fetched once at start-up (`<link>` tag in the document head).

4.3.3.5 Further work.

Planned improvements include:

- swipe gestures for left/right navigation on a touch panel,
- an on-screen progress indicator during TTS playback, and
- dynamic font scaling for longer stories.

Chapter 5

Design Considerations

5.0.1 Rounded Edges

All exterior edges of the product casing were **filleted** to enhance child safety and improve tactile comfort. Rounded corners help reduce the risk of accidental injuries and visually communicate friendliness. This also contributes to a more refined appearance and aligns with child-focused design language.

5.0.2 Design for Manufacturing

Although 3D printing was used for early-stage prototyping, injection moulding was considered for mass production. The casing components were designed with uniform wall thicknesses (typically 2–2.5 mm) and draft angles (1°) to ensure smooth demoulding. Tolerances followed ISO 2768 standards to accommodate slight deviations in FDM-printed parts and ensure compatibility with moulded production.

5.0.3 Design for Assembly & Disassembly

The internal structure was modularised to improve maintenance. Tight-fit features were applied to microswitches enabling tool-free disassembly for repair or recycling. Access holes were added near screw locations to allow easy reach with screwdrivers.

5.0.4 Detailed Design

Ribs and webs were integrated into thin-wall regions of the casing to improve rigidity and prevent bending. Fastening relied on a mix of machine screws and bolts to secure both electronics and load-bearing joints. Silicone covers were added to conceal screw heads, improve

child safety, and increase table friction. Internal wiring and ports were carefully routed to avoid interference with assembly and to ensure durability during repeated docking actions.

Chapter 6

Branding

Five leading brands specialising in children's educational technology were selected as potential partners for incorporating the Nature Kit into their product portfolios. A comprehensive review of these brands and their design approaches was conducted.

6.1 Brand Consideration

Figure 6.1: **Example products - Fisher Price**

Fisher-Price: As a subsidiary of Mattel, Fisher-Price specializes in offering a diverse range of products for infants and children under the age of five. Their product lineup includes baby care items, non-electronic toys, and educational toys with electronic features [1].

Figure 6.2: **Example products - Hasbro**

Hasbro: An American multinational toy and entertainment company which creates joy and community through play experiences for children and families worldwide.Their diverse portfolio includes iconic brands such as Transformers, Nerf, Play-Doh, My Little Pony, and Monopoly.

The **Play-Doh** product line includes nature-themed sets such as Blooming Flowers, which allows children to create botanical designs while developing **fine motor skills** and creativity[07hasbro1] [07hasbro2].

Figure 6.3: **Example products - Sony**

My First Sony: Sony's pioneering children's electronics brand launched in 1987 focuses on creating lifelong technology literacy through *full-fledged electronics* rather than toys. My First Sony's product line is specifically designed for children, offering radio cassette recorders, tape players, and Walkman models that incorporate Sony's groundbreaking **Automatic Volume Limiter System (AVLS)** for hearing protection [07sony1]. This product line primarily features durable electronics with rounded shapes, big buttons, and chunky materials that emphasize *simplicity through sophistication*, fostering cognitive development, hand-eye coordination while ensuring safety and durability. The educational philosophy focuses on developing problem-solving abilities, creativity, and critical thinking skills. [07sony2].

Figure 6.4: **Example products - Osmo**

Osmo: Founded in 2013, Osmo is an award-winning interactive learning system that bridges physical and digital play through *Reflective Artificial Intelligence* technology [07osmo1]. The brand's product line is specifically designed for children ages 3-12, offering hands-on educational games that combine **tangible manipulatives** with iPad technology to teach math, reading, coding, creativity, and problem-solving skills [07osmo2]. Osmo's educational philosophy centers on *"learning is best when it's called play,"* fostering social intelligence and creative thinking through experiential learning [07osmo3]. The system enables real-time feedback and stress-free experimentation, allowing children to develop logical thinking, spatial awareness, fine motor skills, and STEM competencies.[07osmo4].

Figure 6.5: **Example products - Nintendo**

Nintendo: Nintendo is a leading family-friendly gaming company with a mission to *"put smiles on the faces of everyone we touch"* through **inclusive and safe gaming environments** for all ages [07nin1]. The product line specifically targets **children ages 3-18+** with comprehensive educational games that teach **math, reading, logic, reflexes, memory, and STEM skills** through interactive gameplay experiences [07nin2]. Nintendo's educational philosophy emphasizes **hands-on learning through play**, featuring specialized titles like **Nintendo Labo for STEM education**, Game Builder Garage for programming concepts, and Brain Training games. [07nin3].

6.2 Brand Selection

Upon evaluating our product, we identified technological characteristics, educational value as the most important aspects. Therefore, these factors will play an important role in determining which brands we choose to collaborate with.

6.2.1 Positioning Analysis

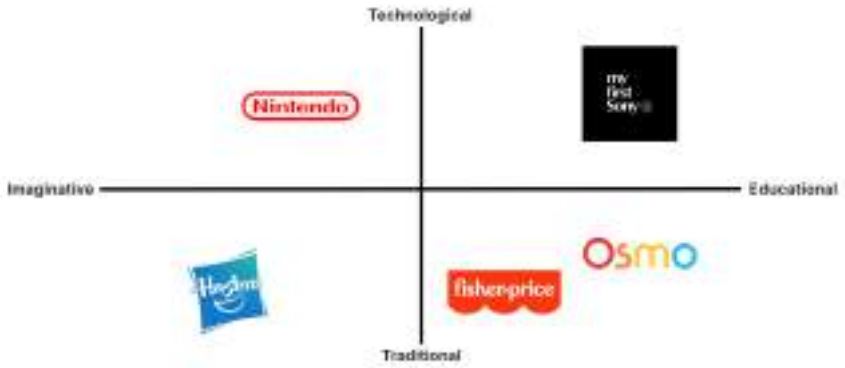


Figure 6.6: **Brand Positioning Analysis**

Upon evaluating our product, we identified technological characteristics and education as the most important aspects. Therefore, these factors will play an important role in determining which brands we choose to collaborate with.

- **Value Alignment:** Sony's "My First Sony" philosophy demonstrates alignment with our nature kit's mission through its emphasis on introducing children to technology as *"full-fledged electronics"* rather than toys, prioritizing hands-on exploration and real-world engagement [07sony1].
- **Chosen Brand:** We chose Sony (My First Sony) due to its technological expertise in children's electronics, established educational product portfolio and emphasis on hands-on learning experiences.[07sony2].

6.3 Branding Implementation

6.3.1 Software Integration

Sony has established a mature educational ecosystem including the KOOV programming platform and Sony Ci Media Cloud system [07imp1]. The Sony Nature Kit can be directly integrated into the existing KOOV platform, utilizing its visual drag-and-drop programming interface that enables students to program sensors for environmental monitoring. The platform's modular approach with 7 types of translucent blocks can easily accommodate nature-specific sensors for measuring soil pH, air quality, and light levels [07nin2].

Additionally, Sony Ci Media Cloud provides unlimited user scaling and REST API integration, allowing students to directly upload field observations, photos, and videos from mobile devices to create nature documentaries as educational outcomes [07nin3]. This unified system minimizes the learning curve for users, as the platform is already familiar to educators worldwide, enhancing user experience and reducing additional training costs.

6.3.2 Sub-brand Development Strategy

Sony Global Education operates as an independent subsidiary established in 2015, following a three-tier brand architecture: Sony Global Education serves as the master brand, with flagship products like KOOV representing comprehensive learning platforms.[07nin6].

Our nature kit will be integrated as a **thematic learning module** within Sony Global Education rather than a standalone product. This positioning leverages Sony's broader technological ecosystem, including camera technology for nature photography, audio equipment for soundscape recording, and sensor capabilities for environmental data collection. Sony's educational philosophy centers on "creating the future" through individual creativity and STEAM integration, aligning with our nature kit that combines hands-on environmental exploration with digital analysis capabilities.[07nin7].

Chapter 7

Product Compliance

7.1 Product Compliance

Products sold in the UK and EU must adhere to various standards before entering the market. Since our product is designed for children and will be marketed in both the UK and EU regions, it is crucial to ensure full compliance with relevant safety directives. We aim to exceed the minimum legal requirements to provide a high-quality and safe product experience.

7.1.1 CE Marking

CE marking (European Conformity) certifies that a product meets the essential health, safety, and environmental requirements set out in EU legislation. The following steps outline the compliance procedure [8CE] [8.2CE]:

1. Address safety, health, and environmental compliance during the design and manufacturing stages.
2. Engage certified third-party testing bodies to perform conformity assessments.
3. Prepare technical documentation that includes all relevant product information.
4. Draft and sign the EU Declaration of Conformity (EU DoC).
5. Affix the CE marking visibly on the product, packaging, or documentation.
6. Update documentation and repeat conformity checks if the design or standards change.

7.1.2 UKCA Marking

UKCA marking (UK Conformity Assessed) certifies that a product complies with the relevant safety, health, and environmental regulations set by UK law. This certification is required for products sold in Great Britain and ensures unrestricted market access. [8.3ce] [8.4CE]:

The UKCA process follows similar steps to CE marking but is adapted to UK-specific legislative frameworks. These include:

1. Ensuring regulatory compliance is addressed during product design and manufacturing.
2. Performing conformity assessments in line with UK standards.
3. Compiling technical documentation for review.
4. Drafting the UK Declaration of Conformity.
5. Affixing the UKCA mark clearly on the product or packaging.
6. Revising the documentation and reassessing conformity if the product design or regulations change.

7.1.3 CE & UKCA Shared Legislations and Standards

Product Safety Legislations:

- Toy Safety Directive (2009/48/EC) and UK Toy Safety Regulations (2011), which ensure that products for children are mechanically safe, flammability-tested, and free of chemical risks [15].
- Low Voltage Directive (2014/35/EU) and Electrical Equipment (Safety) Regulations (2016), covering electronic safety compliance for powered components [16].

Environmental Legislations:

- RoHS Directive (2011/65/EU) limits hazardous substances in electronics and aligns with EN 50581 [17].
- WEEE Directive (2012/19/EU) mandates proper disposal and recycling of electrical products [18].
- Battery Directive (2006/66/EC) requires safe and traceable battery usage, referring to EN 62133 [19].

Data Protection: Our product does not collect personal data. However, should smart features be introduced, compliance with GDPR (EU 2016/679) would be ensured [20].

7.1.4 CE-specific Legislations and Standards

Product Safety Legislation:

- **Radio Equipment Directive (RED) 2014/53/EU** – This directive sets essential requirements for the safety and electromagnetic compatibility of radio and wireless devices, including communication modules embedded in consumer products. It ensures devices do not interfere with each other or other equipment [21].
- **Electromagnetic Compatibility (EMC) Directive 2014/30/EU** – Ensures that devices function correctly in their electromagnetic environment and do not produce excessive electromagnetic emissions. The relevant harmonised standards include EN 55032, EN 55035, EN 61000-3-2, and EN 61000-3-3 [22].

Environmental Legislation:

- **REACH Regulation (EC) No 1907/2006** – Regulates the use of chemical substances in materials to protect human health and the environment. We have reviewed all material suppliers to ensure compliance [23].

Data Protection Legislation:

- **ePrivacy Directive (2002/58/EC)** – While not currently applicable, this directive has been reviewed for future consideration if the device incorporates data transmission features [24].

7.1.5 UKCA-specific Legislations and Standards

Product Safety Legislation:

- **Electromagnetic Compatibility Regulations 2016 (as amended)** – UK standards covering interference mitigation and safe electromagnetic emissions from electrical equipment [26].

Environmental Legislation:

- **UK REACH** – The UK version of REACH, which maintains chemical safety standards post-Brexit. Our internal documentation supports full compliance [27].

Data Protection Legislation:

- **UK GDPR** – General data protection rules to safeguard user privacy. Currently not applicable but evaluated for future features [28].
- **Privacy and Electronic Communications Regulations (PECR)** – These regulations govern communications and cookies. Not currently relevant, but monitored for future compliance [29].

Traceability: Every product will be marked with a unique identifier, enabling traceability for warranty, manufacturing, and recall information. This meets the requirements under both CE and UKCA frameworks.

7.1.6 Ingress Protection (IP Rating)

Given that the product is designed for indoor and occasional semi-outdoor use by children, ingress protection is a necessary consideration to ensure safe and reliable operation. The enclosure is engineered to meet a minimum rating of **IP54**, as defined by IEC 60529 [30] [31]:

- **Dust Protection:** Limited ingress permitted but does not interfere with function.
- **Water Protection:** Protection against water splashes from any direction.

This rating is suitable for consumer electronics placed in homes, classrooms, or damp environments. Design choices such as rubber gaskets and sealed joints were implemented to meet this standard.

7.1.7 Risk Assessment and Mitigation

To ensure the product is safe for child users and suitable for use in household environments, several key risks were identified.

- **Electrical Safety:** All power-carrying components are equipped with overcurrent protection fuses and polarity safeguards to prevent short circuits. Internal wiring is isolated within dedicated channels to avoid accidental contact and overheating risks.
- **Mechanical Safety:** The internal button mechanism was reinforced after early prototypes showed breakage at the actuator shaft. The final version features a thicker stem with a structural collar at the base to prevent snapping. All sharp edges are filleted to minimize injury risk.
- **Ingress Protection (IP):** The enclosure was designed to meet the **IP54** standard, providing **partial dust protection** and **resistance to water spray** from any angle.
- **Drop Resistance:** To mitigate accidental drops from table height, critical internal modules (such as the PCB and camera) are supported with internal ribs in the case design. Prototypes were tested under 0.8 m drop conditions without functional failure.
- **Child Safety:** Buttons and rotating modules cannot be removed without tools, minimizing choking hazards. The entire casing is sealed and fixed using recessed screws to prevent tampering.
- **Thermal Safety:** The case openings and wall thicknesses are optimized to promote airflow around key heat sources like the ESP32 camera module.

7.1.8 Sustainable Packaging

The packaging adopts a retro cardboard box design with a clear cellulose window, inspired by vintage children's electronics such as *My First Sony*. All materials are recyclable and printed with biodegradable ink. The design complies with the EU Packaging and Packaging Waste Directive 94/62/EC[32] and UK Packaging Waste Regulations SI 1997/648[33], which require:

- Minimal and efficient use of packaging materials.
- Clear labelling for material identification and recyclability.
- Avoidance of toxic components and excessive volume.

Chapter 8

Product Labelling & User Guide

8.1 Essential Information and Labelling

General Information:

- Product Name – MY FIRST SONY:Nature Kit
- Model Number – LZYS-2025
- Manufacturer Name – Sony Corporation
- Manufacturer Address – Sony Global Headquarters
- Serial Number – SNX20206010001
- Product Barcode – EAN: 4905523456789

Compliance Marks:

- CE Marking – Meets EU safety, health and environmental requirements.
- UKCA Marking – Complies with UK legislation for consumer electronics.

Safety Labelling:

- RoHS – Compliant with hazardous substance restrictions and safe for children's use.
- Age Warning – Not suitable for children under 3 years due to small parts.

Environmental Labelling:

- WEEE – Contains electronics and must be properly disposed of.
- Green Dot – Manufacturer contributes to recycling and recovery of packaging.
- The Mobius Loop – Packaging is made of recyclable material.

8.2 User Guide

Overview: The user guide is designed with both children and parents in mind, using simple visual language, bold commands, and parent-assist instructions to encourage joint exploration and learning.

Packing List:

- Handheld camera module
- Rotating base station
- Charging cable (USB-C)
- Power adapter
- Illustrated user guide

Getting Started:

1. Insert the camera handle into the base to charge and transfer photos.
2. Press the top button to begin exploring and taking plant pictures.
3. Rotate the handle to browse saved photos.
4. Press side buttons to play audio stories generated by AI.

Features:

- Multi-sensory interaction: vibration, sound, motion, and light.
- Screen-free controls using rotation and button input.
- AI-powered storytelling and plant recognition based on photo capture.

Safety Notes:

- Use under adult supervision.
- Do not immerse the product in water.
- Avoid use near strong magnetic sources or heat.

Parent-Assisted Learning Tips:

- Encourage outdoor exploration and guide children to look for interesting plants.
- Assist with photo capture, rotation direction, and audio listening.

Warranty: This product includes a one-year warranty covering hardware failure under normal use. Please retain your receipt for any support queries.

Chapter 9

Product Packaging Design

9.1 Branding and Visual Identity

Inspired by Sony's iconic *My First Sony* line from the late 1980s, the packaging embraces a playful yet structured design language aimed at evoking nostalgia.

The design incorporates bold, primary colours—red, blue, and yellow—along with geometric forms that align with Sony's legacy of intuitive, child-friendly interfaces.

The use of retro aesthetics combined with simplified iconography and high visual contrast reflects the original brand's ambition: to spark children's curiosity in technology while gaining the trust of parents.

Visual elements such as the official *My First Sony* logo and *multilingual naming* labels reinforce both brand recognition and global accessibility.

9.2 Target Customer

The packaging is designed primarily for children aged 4 and above To appeal to this group, the product features rounded edges, colourful plastic parts, and an interactive button design.

Equally important are the parents, who act as the **main purchasing decision-makers**. Safety considerations such as the use of non-toxic materials, a non-removable battery unit, and successful completion of **high-durability drop tests** are clearly communicated through the packaging.

Finally, the nostalgic aesthetic and faithful tribute to Sony's 1980s design language also attract adult collectors and design enthusiasts, expanding the audience beyond its original demographic.

9.3 Functionality and Design

The packaging features a side-opening book-style structure secured by a magnetic flap, allowing for both secure closure and intuitive unboxing. Once opened, the interior **fully unfolds** to reveal the product in its entirety, creating a gift-like presentation designed to spark curiosity and excitement in children.

This layout enhances the **ceremonial aspect** of unboxing, encouraging a sense of discovery while ensuring the product remains well-protected during transport.

The structural integrity is maintained without adhesives, and foldable panels support efficient flat-packing and sustainability.

(a) Closed Packaging View

(b) Opened Packaging View

Figure 9.1: Packaging Design: Book-style magnetic flap box before and after opening

9.4 Materials and Production Processes

To meet sustainability goals, the Sony Nature Kit packaging is constructed using 0.5 mm FSC-certified cardboard, which provides sufficient structural stiffness while remaining fully recyclable. Figure 9.2 shows the flat net layout used in production.

Figure 9.2: Net Design of the Sony Nature Kit Packaging

9.5 Packaging Compliance

Proof of Conformity: Although formal documentation is not physically included inside the Sony Nature Kit packaging, a declaration of conformity is accessible via a QR code printed on the box, linking to the full online user guide. This ensures compliance transparency for parents, educators, and relevant authorities.

Sustainable Certifications: All paper-based packaging materials are sourced from FSC-certified suppliers to guarantee responsible forest management. Where applicable, Cradle to Cradle certified materials are used to reinforce the product's alignment with circular design principles.

Clear Recycling Instructions: The packaging includes printed guidance and icons to help users correctly recycle or dispose of materials after use.

FSC Certification: Ensures all cardboard components are responsibly sourced and meet Forest Stewardship Council (FSC) standards.

Recycled Content Certification: All molded inserts and secondary packaging layers meet the Recycled Content Standard (RCS), ensuring verified use of post-consumer recycled fiber.

Chapter 10

Final Design

10.1 Features

AI-Enhanced Learning: The product leverages AI to analyze plant images taken by children and generate corresponding educational stories. This turns each exploration into a learning opportunity, offering contextual knowledge based on the species and condition of the plant.

Handle–Base System: The design features a detachable handle that functions as a camera when used outdoors. Upon returning home, the child inserts the handle into the base, which initiates data transmission and simultaneously charges the device.

Screen-Free Interaction: To reduce screen exposure, the product uses a multi-sensory feedback system including vibration, speaker narration, buttons ,and mechanical rotation. Children navigate plant photos by rotating the handle left or right, while tactile buttons let them select and play AI-generated content. **Multi-Sensory Feedback:** The device provides real-time feedback through **vibration** upon capturing a photo, **visual cues** when data is processed, **rotational controls** for browsing, and **auditory storytelling** for plant information.

10.1.1 Software – Story-Driven Interaction System

The software layer bridges exploration and learning through a multi-modal storytelling system. Captured plant images are transmitted from the ESP32-CAM to a Raspberry Pi 5 over Bluetooth SPP, where they trigger AI-generated educational content. When network connectivity is available, GPT-4o creates a personalised story, which is then converted to speech and synchronised with image display using a multi-threaded TTS pipeline. This enables low-latency, real-time narration aligned with children's attention span.

A local HTML-based interface (800×480) provides two modes: **slideshow and gallery**. In slideshow mode, images cycle with soft animations and the system can enter storytelling on demand. Gallery mode allows manual browsing via GPIO-mapped hardware buttons,

eliminating the need for touchscreens. The UI uses large, high-contrast elements to support bedtime readability and cognitive accessibility for young users.

All core functions operate offline by default, with cloud access gracefully integrated when available. Future upgrades may include gesture support, progress indicators, and dynamic font scaling.

Chapter 11

Project Plan Report

11.1 Project Plan Report

Week 1: Concept and Research – The project began with broad ideation around encouraging nature exploration in early childhood. Sketches explored camera-style, stamp-based, and magnifier-like forms. Desk research and stakeholder input confirmed an opportunity to combine AI with tactile play to reduce screen dependency.

Week 2: User Research and Interaction Insights – Interviews with parents and observations of children interacting with mock-ups revealed a clear preference for physical feedback over touchscreens. Insights emphasized the need for intuitive, screen-free control and multi-sensory engagement.

Week 3: Design Refinement – Two-Part System – Informed by user insights, the design shifted to a modular two-part system: a handheld camera and a rotating base. Multiple form factors and interface layouts were tested, including screen size, button placement, and docking methods.

Week 4: Interaction and Feedback Logic – The handle-to-base interaction was developed to support rotation-based photo browsing and tactile button control. Haptic vibration and audio feedback were introduced to reinforce action-outcome relationships without relying on visual UI.

Week 5: Form Selection and Symbolism – The final handle form drew inspiration from a magnifier, reinforcing the metaphor of exploration. For plant status display, inflatable silicone leaves were selected for their soft movement, visual expressiveness, and safety for children.

Week 6: Hardware Integration and Software Architecture – High-fidelity prototypes were assembled using ESP32-CAM, Raspberry Pi 5, and GPIO components. Bluetooth SPP enabled wireless image transfer, while a multi-threaded AI + TTS pipeline generated real-time audio stories from plant images.

Week 7: Full Assembly and Testing – Mechanical CAD, circuit design, and software modules were integrated into a working system. All interactions including camera capture, docking, rotation, button selection were tested for consistency and child-friendly operation.

Week 8: Branding and Presentation – The product was positioned as an educational tool blending STEM learning and outdoor play. Final deliverables included branding assets, CAD& Packaging renders, interface visuals, and a 120-second video showcasing the concept.

Chapter 12

References

[1] Louv, R. (2024). What is Nature Deficit Disorder? Richard Louv. https://richardlouv.com/blog/what-is-nature-deficit-disorder

[07mattel] Mattel. (2025). Fisher-Price Collection. Mattel Shop. Available at: https://shopping.mattel.com/en-gb/collections/fisher-price

[07hasbro1] Hasbro. (2025). Products - Hasbro. Available at: https://products.hasbro.com/en-gb

[07hasbro2] Hasbro. (2025). Corporate - Hasbro. Available at: https://corporate.hasbro.com/en-us

[07sony1] Engadget. (2021). My First Sony: The 80s Kids' Gadgets That Started It All. Available at: https://www.engadget.com/my-first-sony-80s-kids-gadgets-13250608.html

[07sony2] PRNewswire. (2018). Sony's New KOOV Educator Kit Makes Science and Technology Learning Accessible to Everyone. Available at: https://www.prnewswire.com/news-releases/sonys-new-koov-educator-kit-makes-science-and-technolog.html

[07osmo1] Wikipedia. (2025). Osmo (game system). Available at: https://en.wikipedia.org/wiki/Osmo_(game_system)

[07osmo2] Tangible Play. (2025). About Us - Osmo — Play Beyond The Screen. Available at: https://www.playosmo.com/en-US/about-us/

[07osmo3] Belenky, D. (2025). Osmo Review - The Smarter Learning Guide. Available at: https://smarterlearningguide.com/osmo-review/

[07osmo4] Osmo Education. (2022). Osmo in Schools. Available at: https://schools.playosmo.com/

[07nin1] Nintendo. (2025). About Us - Nintendo. Available at: https://www.nintendo.com/us/about/

[07nin2] Nintendo. (2025). Educational Games for Kids for Nintendo Switch. Available at: https://www.nintendo.com/us/store/products/educational-games-for-kids-switch/

[07nin3] Parents. (2025). The Best Educational Nintendo Switch Games for Kids Who Have a Brand New Switch. Available at: https://www.parents.com/fun/educational-nintendo-switch-games-for-learning/

[8CE] European Union. CE marking - Product Requirements. europa.eu

[8.2CE] UK Government. CE marking guidance. gov.uk

[8.3] UK Government. Using the UKCA marking. gov.uk

[8.4] UK Government. UKCA marking: conformity assessment and documentation. gov.uk

[15] European Commission. Low Voltage Directive (2014/35/EU). single-market-economy.ec.europa.eu

[16] European Commission. RoHS Directive Harmonised Standards. single-market-economy.ec.europa.eu

[17] UK Government. WEEE Regulation Guidance. gov.uk

[18] European Union Law. CELEX Summary of Environmental Directives. eur-lex.europa.eu

[19] European Union Law. Ecodesign and Energy Labelling Summary. eur-lex.europa.eu

[20] GDPR Info. General Data Protection Regulation (EU 2016/679). gdpr-info.eu

[21] F2 Labs. RED Directive Overview.
f2labs.com

[22] ProductIP. EMC Standards Overview.
productip.com

[23] European Commission. REACH Regulation – Official Source.
eur-lex.europa.eu

[24] Information Commissioner's Office. PECR Guidelines.
ico.org.uk

[25] ETSI. Radio Equipment Compliance Details.
etsi.org

[26] UK Government. Electromagnetic Compatibility Regulations (2016).
gov.uk

[27] UK Government. UK REACH Substances Prioritisation Strategy.
gov.uk

[28] ICO. UK GDPR Guide.
ico.org.uk

[29] UK Legislation. PECR – Full Text.
legislation.gov.uk [30] IEC. IP Ratings Explained: IEC 60529 Standard.
iec.ch

[31] ANSI. IP Rating Code Definitions and Applications.
ansi.org [32] European Union. Packaging and Packaging Waste Directive 94/62/EC.
eur-lex.europa.eu

[33] UK Government. Producer Responsibility Obligations (Packaging Waste) Regulations 1997.
legislation.gov.uk