

Bambu Lab SwivelCut

Cardboard Made Even Easier.

Mayli Jones
Ruaridh Murdoch
Arda Kancal
Rhys Wijeratne



Table of Contents

Product Opportunity.....03	Product Packaging.....18
Design Area	Outer Packaging
Existing Solutions	Inner Packaging
Executive Summary	Brand Alignment
Concept Development.....04	Final Design.....19
Original Solution	SwivelCut-SC1
Morphological Analysis	Colour Material Finish
Branding Consideration.....05	User Testing & Validation.....20
Competitive Analysis	Test Aims
Bambu Lab	Observations
Brand Analysis.....06	Feedback
Bambu Deconstructed	Future Improvements.....21
Implementation	Developments
Prototyping Plan Breakdown.....07	Business Implementations
Development Approach	Appendix.....22
Subsystems	
Force Calculations.....08	
Force Testing	
Arm Lengths	
Mechanism Selection	
Battery Selection	
Modular Head Mechanisms.....10	
Latching Mechanism	
Tracing Head	
Cutting Head	
Electronics & Software.....11	
Safety Electronics	
Code	
User Design & Interaction.....12	
Base, Clamping & Accessibility	
Controls, Semiotics & Inclusive Interaction	
Products & Brand Design Language	
Design for Manufacturing & Assembly.....13	
Material Selection	
DFM	
DFA	
Disassembly	
Product Compliance.....16	
Legislations	
Standards	
Documentation	
Labelling & User Guide.....17	
Product Labels	
User Guide	



Product Opportunity

Design Area

Design and Technology

Design and Technology (DT) provides students with early hands-on experience using tools and materials, fostering creativity, problem-solving skills, and technical confidence. Despite these benefits, DT faces increasing challenges in UK schools, as evidenced by **declining GCSE entries** and only 57% of state schools entering students for GCSE DT in 2024/25 [1].

The delivery of practical workshop activities in DT is often constrained by the need for specialist rooms, equipment, materials, trained technicians, and close supervision. These requirements can make it challenging for schools to provide such activities in a safe, cost-effective, and efficient manner.

The Problem

Interviews, workshop observations and a student survey identified **low-fidelity prototyping** as a recurring weakness in DT workshops. Although early modelling should support rapid testing and communication of ideas, many students found it frustrating, messy or not useful enough to do properly.

Cardboard became the main material focus because it is low-cost, widely available and commonly used in schools, especially where tight budgets limit access to foam or specialist modelling materials. However, manual cardboard cutting often produces rough, inaccurate results, particularly for curves, geometric shapes and repeated components. Craft knives are flexible and accessible, but difficult to control and linked to many of the workshop accidents reported by students, reducing safety, accuracy and independence.

The Objective

The objective of this project is to enhance the **quality, safety, and independence** of low-fidelity cardboard prototyping in secondary school design and technology workshops. By addressing the challenges of inaccurate hand cutting, craft knife safety, and low student confidence, the project aims to make early-stage modelling a more valuable and engaging component of the design process.

Existing Solutions

Current solutions fall into **two extremes**:

The ChompSaw is safe, easy to use, and works well in schools, but its cuts are often rough and not very accurate. This makes it less suitable for GCSE and A-level prototypes where a good finish and precision are important.



Figure 1:
ChompSaw

A laser cutter is much more accurate and can cut complex curves cleanly. However, it is expensive, can be intimidating, needs supervision, and relies on CAD skills that many students may not have yet.

This highlights a gap: students need a tool that is **safer** than a craft knife, **more accurate** than ChompSaw, and **simpler** than a laser cutter.

Executive Summary

Swivelcut is a compact cardboard-cutting system designed to make low-fidelity prototyping safer, more accurate, and more accessible in secondary school DT workshops.

The product uses a fold-away arm mechanism with interchangeable cutting and tracing heads. Students can sketch by hand, trace an existing path, or cut from a printed template without using CAD. This supports fast, creative prototyping while improving the consistency and quality of cardboard cuts. Designed for classroom safety, the blade is enclosed during operation, and the tool stops immediately if moved or knocked. Stabilisation helps smooth hand-drawn paths, while a repeat function allows parts to be batch cut. It has a A3 cutting area and compact storage form.

The optional Bambu Handy app integration allows students to access shared templates or CAD inputs when needed, without making digital modelling a requirement.

Mass Market Reach

Although SwivelCut is initially designed for secondary school DT workshops, its use could extend to anyone who needs quick, accurate cardboard models without specialist equipment such as **university** students in **architecture** or engineering.

It could also support **parents, hobby makers** and **community workshops** by making cardboard craft safer and more controlled. For small businesses, SwivelCut could be used to create packaging and display stands too.

Concept Development

Original Solution

The initial design proposed in Term 2 consisted of a desktop cardboard-cutting tool intended to assist design and technology students in converting hand-drawn shapes into precise physical models. In this system, the user manipulated an input arm, which was mechanically linked to a cutting arm that replicated the movement to cut shapes from cardboard. This approach aimed to minimise dependence on CAD, laser cutters, and manual craft-knives, while increasing the accuracy of low-fidelity prototypes. [Refer to Page 1 of A3.](#)

Redefining the Problem

After reviewing the original design, the problem was redefined from simply copying and cutting hand-drawn shapes to supporting the wider cardboard prototyping process in DT workshops. The product needed to consider how students input ideas, improve accuracy, cut safely and work independently. This led to the concept being stripped back into core functions, allowing a more flexible solution to be developed through morphological analysis.

Morphological Analysis

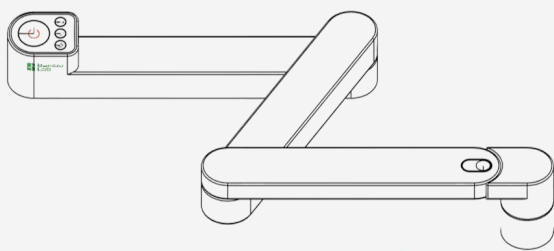


Figure 2: Developed Idea from Morphological Analysis

Input Method: The product required a method for inputting the desired cutting path. Considered options included hand tracing, line following, camera or scanning, CAD upload, and button control. While CAD upload offered high accuracy, it reduced accessibility. Button control was too restrictive for complex shapes. **Hand tracing** was selected because it enables users to work directly from sketches or templates, maintaining system simplicity and low cost. Line following was retained as a potential modular head for the future.

Cutting Method: Blade options included utility blades, snap-off craft blades and scalpel blades. **Utility blades** were chosen because they are cheap, widely available, easy to replace and strong enough for cardboard. Scalpel blades were more fragile, while snap-off blades lacked rigidity. **Drag knife** movement was selected over oscillating or rotary cutting because it provides accurate cardboard cutting with lower cost, complexity and safety risk.

Movement System: Options included the original 4-bar parallel linkage, an XY gantry, handheld guide, moving robot and 2DOF flat arm. The 4-bar linkage lacked flexibility, while the XY gantry was large and intimidating. The **2DOF flat arm** was selected as it offered the best balance of compactness, visibility and suitability for flat cardboard cutting.

Path Control and Software: The tool should enhance cut quality rather than just replicate user movement. Options considered were freehand control, stabilisation, batch cutting, repeatability, symmetry, and shape correction. Fully automatic correction was avoided to preserve student control. **Stabilisation** and **repeated cutting** were selected to improve accuracy while maintaining user involvement.

Feedback and Control: Students needed clear, quick feedback during use. LEDs, icons, buttons, screens, sound and app control were considered. **Simple buttons, icons and light feedback** were preferred as they suit classroom use without relying on screens or external devices. **Sound** was lower priority due to noisy workshop environments.

Maintenance: It needed to be simple for school workshops. Sealed components, replaceable blades, modular heads, accessible screws and replaceable parts were considered. Core electronics were **enclosed for safety**, while the blade was made **replaceable**. **Modular heads** were selected so tracing and cutting modules could be replaced individually, reducing downtime and repair costs. Higher-risk and more complex heads, such as line following, scoring, hot-wire and laser, were kept as future add-ons.

Safety: Features considered include capacitive touch stops, retractable blades, blade guards, emergency stop buttons and resistance detection. A **blade guard** was chosen to reduce the risk of blade contact. The system will also include a large stop button, resistance detection in the arms, and accelerometers to automatically stop operation if unexpected movement or impact is detected.

Branding Consideration

Competitive Analysis

 Bambu Lab is a **modern** 3D printing brand used in homes, schools, universities and small workshops [2]. It quickly gained recognition for making **high-speed automated** prototyping more **accessible** and **affordable** through features such as auto-calibration, sensors, app control and multi-colour printing. Its focus on simple, adaptable and advanced technology makes it the strongest reference for SwivelCut.

 UltiMaker is a **well-established** 3D printing brand used in schools, universities and professional workplaces [3]. It is trusted for reliable, accurate and well-supported prototyping, making it a useful reference for school credibility. However, it feels more professional and is more **expensive**, making it less suitable as the main direction for an accessible classroom tool.

 Glowforge is a desktop laser-cutting and engraving brand used in home studios, small businesses and maker spaces [4]. It makes cutting sheet materials feel creative, polished and easy to understand. However, its high **cost**, ventilation needs and safety requirements make it less practical for school workshop use.

 Cricut is a **craft-cutting** brand used by hobbyists, teachers and small creative businesses [5]. It is simple, approachable and beginner-friendly, especially for card and vinyl cutting. However, it is more associated with craft and personalisation than engineering or prototyping, so it lacks the technical credibility needed for SwivelCut.

Market Positioning

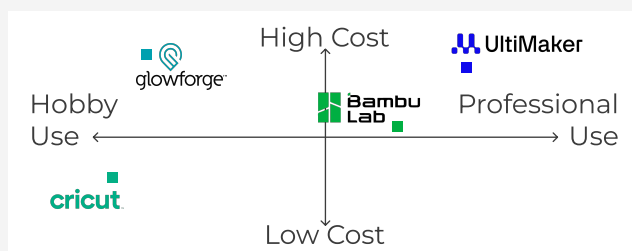


Figure 3: Market Positioning Map

The positioning map compares each brand by cost and typical use case, from hobbyist

products to professional workshop tools. Cricut is positioned towards the hobbyist market, while Glowforge and UltiMaker sit at the higher-cost, more professional end. Bambu Lab occupies a more accessible **middle ground**, with products used across home, education and workshop settings.

Swivelcut should follow a similar middle-ground position. It needs to be affordable enough for schools, simple enough for students to use confidently, and technically reliable enough for regular DT workshop use.

Workshop Procurement

To understand how schools choose workshop equipment, we interviewed Ingrid from ACE workshop at Imperial and Mr Barker, Head of DT at City of London School for Girls (CLSG). Both had previously used UltiMaker printers but had recently switched to Bambu Lab.

The key reasons were **cost, ease of use and maintenance**. Bambu was seen as more affordable, easier for students to use independently, and still reliable enough for school and university workshops. Older UltiMakers required “too much maintenance”, while Bambu parts were cheaper and easier to access. One interviewee added that the “tech is just as reliable as UltiMakers.”

Bambu Lab



Competitor analysis identified Bambu Lab as the strongest brand direction for Swivelcut. Positioned between hobbyist and professional use, it balances affordability, innovation, reliability and student-friendly operation.

Procurement interviews supported this choice, with both workshops switching to Bambu for lower cost, easier maintenance and cheaper replacement parts. This makes it a strong reference for a modern, technical and practical classroom product. *Refer to Page 2 of A3*

Educational Outreach

Bambu Lab has a clear education and STEAM focus, promoting 3D printing as a way for students to turn ideas into physical models through hands-on learning. Its website highlights use across primary schools, secondary schools and universities, reinforcing that Bambu already has a strong standing within education [2]. This supports SwivelCut's brand direction, as the product should also help students prototype independently in a creative, practical and classroom-friendly way.

Brand Analysis

Bambu Deconstructed

Company Overview

Bambu Lab is a consumer technology company specialising in desktop 3D printers. **Founded in 2020**, it operates in Shenzhen, Shanghai and Austin, Texas [2]. Its X1 series, launched in 2022, established the brand's reputation for high-speed, automated printing. Bambu aims to make advanced fabrication more accessible by connecting digital design with physical production. More recently, the H2 series has expanded into laser engraving, cutting and pen plotting, showing a move towards modular desktop prototyping tools.

Company Overview

Bambu Lab's reputation is built on customer satisfaction, industry recognition and its impact on desktop 3D printing. The brand is known for making high-performance printing more accessible to everyday users, schools and workshops. *Refer to Page 2 of A3*

- Customer satisfaction:** Thousands of Trustpilot reviews frequently highlight print quality, ease of use, delivery and overall performance [6].
- Award recognition:** The X1 Series appeared in TIME's Best Inventions of 2022, while the A1 and AMS won Desktop FFF 3D Printer of the Year at the 2024 3D Printing Industry Awards [7].
- Innovation:** Bambu is associated with high-speed, automated and multi-colour printing, supported by features such as LiDAR calibration, auto bed levelling and first-layer inspection.
- User-friendly performance:** Its products reduce the setup and trial-and-error traditionally associated with 3D printing, making them more accessible to beginners.

Values

Bambu Lab does not explicitly present its brand values in a dedicated "Our Values" section. Instead, its brand identity must be inferred from the About Us page, product messaging, and blog content [2]. Four key values emerge from this analysis: creativity, accessibility, innovation, and practical making.

Creativity: Bambu describes its printers as tools that "break the barriers between the digital and physical worlds," emphasising their role in transforming user ideas into tangible outcomes.

Accessibility: Bambu's messaging emphasises **reducing technical barriers** and making 3D printing more accessible and enjoyable for a broader audience, rather than exclusively for expert users.

Innovation: Bambu positions itself as a state-of-the-art 3D printing company, offering advanced features such as automation, integrated sensors, app-connected workflows, and multi-colour printing.

Practical Making: Bambu also presents 3D printing as a practical tool for repair, creation, and problem-solving, rather than solely as a hobby or display technology.

Although not stated in a formal manifesto, these values are clear across Bambu's products and communication. For SwivelCut, this suggests a creative and technically capable brand that remains accessible and student-friendly.

Implementation

SwivelCut would align with Bambu Lab's focus on accessible, innovative and user-friendly fabrication. It would extend the brand beyond 3D printing through a safer classroom cardboard-cutting tool with modular heads, tracing and line-following, while remaining affordable, maintainable and student-friendly.

Visual Identity: Use Bambu's clean, modern style with a white, grey and green palette, rounded forms and enclosed mechanisms.

User Experience: Keep setup simple, feedback clear, and modular heads and worn parts easy and cheap to replace.

Communication: Present SwivelCut as a prototyping tool focused on safety, accuracy, creativity and student independence.

Advertising and Launch: Target schools and universities with short demonstrations from sketch to cardboard prototype.

Support and Maintenance: Provide quick-start guides, teacher resources, repair videos and affordable replacement parts.

Name Justification

SwivelCut describes the product clearly: "Swivel" reflects the 2DOF arm, while "Cut" states its function. **SC1** follows Bambu's letter-number naming style and means Swivel Cut, first generation. It also reflects key values: S for safe, school and student, and C for cut, cardboard and creativity.

Prototyping Plan Breakdown

Development approach

To facilitate the prototyping process and allocate tasks efficiently, SwivelCut was divided into distinct functional subassemblies. This modular architecture enabled multiple prototypes to be developed concurrently by various team members. *Refer to Page 3 of A3*

Development priorities were established based on component dependencies. Major assemblies that determined the product's geometry and operation, especially the movement and arm system, were addressed first. Subsequent components were then designed to fit those dimensions.

User-centred validation

Feedback from teachers and students was collected throughout development to ensure SwivelCut remained appropriate for classroom use. Meetings and prototype testing guided decisions regarding clamping, setup, and user interaction. These findings are included within each subsystem section to show how feedback directly shaped the design, rather than serving solely as a final validation stage.

Subsystems

Refer to Figure Y in the A3 report for a visual breakdown of the numbered subsystems and their locations within SwivelCut.

1. Movement and Arm System

The movement and arm system positions the tracing and cutting heads across the workspace while remaining accurate, rigid and compact.

Requirement: Provide smooth movement across at least an A3 area and fold away neatly.

Preliminary specifications: Minimum 420 × 297 mm workspace, ±1 mm path accuracy, low backlash, limited deflection and sufficient motor torque.

Development plan: Define arm geometry, calculate loads and torque, compare transmission systems, integrate components, then test reach, accuracy, stiffness and folding.

2. Cutting Head

The cutting head pierces and cuts cardboard while keeping the blade controlled and safe.

Requirements: Clean cutting, blade retraction, easy replacement and prevention of contact with the moving blade.

Preliminary specifications: Sufficient cutting force, replaceable utility blade, reliable vertical retraction and a fixed safety guard.

Development plan: Measure cutting forces, test blade angles and depths, develop the retraction and replacement mechanisms, then evaluate cut quality, safety and durability.

3. Tracing Head

The tracing head records a cutting path.

Requirements: Hold the pen securely, and allow quick replacement.

Preliminary specifications: Fit common pens and markers with minimal movement and secure arm attachment.

Development plan: Measure pen sizes, develop an adjustable holder, then test grip, alignment, accuracy and compatibility.

4. Latching Mechanism

The latch secures each head to the arm.

Requirement and specification: Allow quick, tool-free head changes with secure alignment, minimal play and positive locking.

Development plan: Compare latch concepts, prototype the best option, then test fit, retention and repeatability.

5. Base Clamping Mechanism

The base clamping system stabilises Swivelcut and secures the cardboard during use.

Requirement: Prevent movement while keeping the workspace clear and easy to use.

Preliminary specifications: Fit common workshop benches, hold different cardboard sizes and resist movement during cutting.

Development plan: Compare clamping concepts, prototype the best option, then test stability, setup time and material retention.

6. Safety Systems, UI and Controls

The safety, UI and controls system supports clear and safe operation.

Requirement: Make functions easy to understand and stop quickly when unsafe movement is detected.

Preliminary specifications: Clear buttons and lights, an accessible stop control, guarded moving parts and automatic stopping.

Development plan: Develop the controls and safety logic, then test usability, response time and fault conditions.

Arm Mechanisms and Forces

Force Testing

Piercing Force

The force required to pierce through the cardboard was measured using a digital scale. A conductive plate was placed beneath the cardboard, creating a circuit when the blade fully penetrated the final layer. Video footage was used to identify the exact force when the indicator LED activated. Ten tests were done:

- Typical piercing force: 8 N
- Maximum piercing force: 10 N

$$F_{\text{pierce}} = 10 \times 1.5$$

$$F_{\text{pierce}} = 15 \text{ N}$$

The cutting head must therefore withstand a minimum vertical load of 15 N.

[Refer to Page 4 of A3](#)

Drag Force

A fixed blade was pulled through 100 mm of corrugated cardboard using a digital force gauge. Cutting across the corrugation produced higher forces than cutting with it. Fixed blade:

- Typical drag force: **19.6 N**
- Maximum drag force: **28 N**

Initial force testing showed that blade depth was extremely sensitive. Small variations in the knife height, cutting mat or cardboard thickness could increase drag force by approximately five times, making accurate blade levelling difficult and inconsistent.

A trailing-arm blade mount was therefore developed, allowing the blade to rotate upwards and backwards when resistance increased. This reduced snagging and helped the blade accommodate variations in material height.

A test rig was built to compare different pivot positions, spring stiffnesses, spring locations and preload settings. Blade movement and spring compression were measured at controlled cutting heights. The final configuration reduced the maximum drag force from 28 N to approximately 8 N and produced consistent results when cutting both with and across the cardboard corrugation. This means the reduction in the maximum drag force is **71.4%**.

A safety factor of 1.75 was applied to the maximum spring-blade force:

$$F_{\text{design}} = 8 \times 1.75$$

$$F_{\text{design}} = 14 \text{ N}$$

The arm must therefore provide at least 16 N of cutting force.

Arm Size and Rigidity

The first design used two slim, 300 mm 3D-printed arms, providing almost A2 coverage despite the requirement being only A3. However, their length and printed construction would have resulted in excessive flex under cutting loads.

The arm lengths were therefore reduced to 260 mm and 215 mm, giving a total reach of 475 mm while maintaining A3 coverage. As beam deflection is proportional to (L^3) , shortening the reach from 600 mm to 475 mm was predicted to reduce deflection by approximately **50%**.

The arms were then reinforced with 3 mm aluminium extrusions, improving rigidity and providing secure mounting points for the joints and movement mechanism. However, the added height required the overall arm form and internal layout to be redesigned.

Motor and Movement Mechanism Selection

The movement system was required to resist a minimum cutting force of 15 N, move accurately at low speed and fit within the reinforced arm structure. Stepper motors were selected because they provide **controlled incremental movement** and high holding torque without requiring a separate gearbox. As SwivelCut operates slowly, holding torque was used for the initial static sizing calculations, although the available torque will reduce with speed and system losses.

Base Joint

The base joint experiences the largest moment because it must resist the cutting force across the full 475 mm arm reach. A NEMA 23 stepper motor with a holding torque of 1.26 Nm was therefore selected [8]. [Refer to Page 5 of A3](#)

A 20-tooth motor pulley drives a 120-tooth output pulley using a 5 mm-wide GT2 timing belt:

$$\text{Reduction ratio} = \frac{120}{20} = 6$$

$$T_{\text{out}} = 1.26 \times 6 = 7.56 \text{ Nm}$$

The equivalent force available at the maximum reach is:

$$F = \frac{T}{r} = \frac{7.56}{0.475} = 15.9 \text{ N}$$

The theoretical system therefore meets the 14 N cutting-force requirement, although physical testing is required because belt, bearing and motor losses reduce the available output.

Second Joint

The second joint only acts over the 215 mm second-arm length, so the smaller NEMA 17 motor could be used [9]. This motor provides 0.42 Nm holding torque. Two 20-tooth to 60-tooth stages were used:

$$\text{Ratio per stage} = \frac{60}{20} = 3$$

$$\text{Combined ratio} = 3 \times 3 = 9$$

$$T_{\text{out}} = 0.42 \times 9 = 3.78 \text{ Nm}$$

The equivalent force at the end of the 215 mm arm is:

$$F = \frac{3.78}{0.215} = 17.6 \text{ N}$$

This also exceeds the minimum 14 N requirement theoretically.

Gears and Belts

Spur gears and geared motors were considered initially because they could provide the required torque reduction within the joints. However, clearance between mating teeth introduces backlash, allowing the output to move slightly before the motor re-engages the gear train. This angular play would be amplified at the end of the arm:

$$s = r\theta$$

For example, at the maximum 475 mm reach, only 1° of angular backlash would produce:

$$s = 0.475 \left(\frac{\pi}{180} \right) = 0.00829 \text{ m} = 8.3 \text{ mm}$$

GT2 timing belts were selected because their toothed profile prevents slipping, reduces backlash and allows flexible motor placement [10]. Adjustable tensioning removes slack and helps maintain cutting accuracy.

The pulley system was then integrated around the aluminium structure, defining the motor, joint and tensioner positions. Several layouts were explored before selecting the most compact, streamlined solution, which best matched Bambu Lab's minimal design language.

Thrust-Bearing Joint Design

The arm joints needed to rotate smoothly while supporting the vertical load from the arms and cutting head. Early printed joints created friction and uneven movement as surfaces rubbed directly together. **Thrust bearings** were added to carry the axial load while allowing low-friction rotation. This improved movement consistency, joint rigidity and durability.

Belt Tensioner Design

Separate adjustable belt tensioners were mounted directly to the aluminium arm structure. They **removed slack** caused by manufacturing and assembly tolerances, reducing backlash and preventing tooth skipping. The tension could be adjusted during assembly without changing the main movement mechanism. *Refer to Page 5 of A3*

Battery Selection

The stepper drivers operate from approximately 9–12 V, while the cutting-head actuator requires 12 V. A conservative theoretical peak was estimated from the motor current limits of 2.8 A for the NEMA 23 and 1.5 A for the NEMA 17. Allowing for both motor phases and a safety margin gave a design power requirement of approximately 175–200 W. However, measured power consumption during normal drawing operation was approximately 65 W.

A 4S3P lithium-ion battery pack was selected, providing approximately 11.1 V nominal, 12.6 V fully charged and 120 Wh capacity when using twelve 10 Wh 18650 cells [11]. Lithium-ion cells were chosen because they are widely available, reliable and cost-effective, with established supply chains. Estimated continuous runtime is:

$$t = \frac{12 \times 10}{65} \approx 1.8 \text{ hours}$$

Actual runtime will be slightly lower due to conversion losses and battery protection limits. The larger energy-cell pack reduces charge and discharge stress, improving service life while allowing the product to remain available for repeated classroom use.

Modular Head Mechanisms

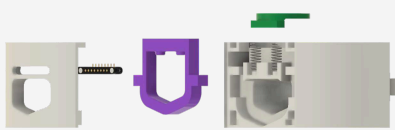
Latching Mechanism

Several attachment methods were explored, including snap-fits, buckles and **twist-lock** mechanisms similar to those used on blender attachments. The connection needed to hold each head securely under cutting and tracing loads, while still allowing the user to change heads quickly without tools.

Figure 4:
Locking Feature



Figure 5: Arm Latch



The final design uses a spring-loaded push-button latch. As the head is inserted into the end of the arm, its shaped locking feature (Figure x) pushes past the internal catch. The springs then return the catch into position, automatically locking the head in place and preventing movement during use.

To remove the head, the user presses the button on top of the housing. This retracts the catch against the springs and releases the locking feature, allowing the head to slide out. Releasing the button returns the mechanism to its locked position. *Refer to Page 6 of A3*

Tracing Head

The tracing head needed to accommodate a wide range of pens while allowing them to be inserted, adjusted and removed quickly. To make the mechanism familiar and intuitive for students, the pen clamp was based on the screw-fastened holder used on a drawing compass.

The pen is secured using an **adjustable screw**, allowing different pen diameters to be held firmly without slipping or rotating during tracing. Its vertical position can also be adjusted so that the nib reaches the drawing surface correctly.

User testing at GERF investigated whether users preferred holding the pen near the top or the bottom. Of **285** responses, 119 preferred the

Figure 6:
Tracing Head



upper position and 166 preferred the lower position. As neither option produced a clear majority, the final design uses a sliding pen holder that can be positioned along the height of the tracing head.

This allows each user to select the most comfortable grip position while maintaining a secure and stable pen connection.

Cutting Head

The cutting head was required to be modular, safe and easy to maintain. It was specified to retract the blade at selected points along a recorded path, fully enclose it when raised, allow straightforward blade replacement, exert at least 15 N of piercing force, and cut paper, card and corrugated cardboard.

The initial concept used two compliant systems: a **spring-mounted blade** and a sprung platform intended to accommodate material-height variation and prevent the blade digging into the cutting mat. However, movement between both systems introduced excessive play, making the blade difficult to align and reducing cutting accuracy.

The final design **retained blade** suspension to accommodate small height variations but replaced the sprung platform with a linear actuator. This improved rigidity while providing controlled blade extension and retraction. The actuator sits within the casing and connects to the blade through a custom shaft extension using commercial collars and locating pins.

Earlier prototypes also showed that free blade rotation was essential when cutting curves. Two thrust bearings were therefore clamped around the actuator extension, allowing the blade to swivel smoothly while supporting the vertical cutting load. The casing supports this assembly under load, while a self-aligning aligning twist-lock secures the removable safety tube. A rotating indicator disc, inspired by the Bambu Lab A1, provides visible feedback when the blade mechanism is moving.

Unit tests assessed blade extension, straight and curved cut quality, swivel response, material penetration and safety-tube retention. These tests helped **reduce play**, refine blade depth and confirm consistent cutting without excessive mat penetration.

Figure 7:
Cutting Head



Electronics and Software

Safety Electronics

As SwivelCut is intended for school workshops, several electronic safety features were integrated into the system. The main power button controls a relay that disconnects power to the drive system when pressed, providing an immediate stop function.

An accelerometer detects if the product is tipped over, lifted or moved unexpectedly, causing the arm motors to stop immediately. At **3% battery**, the blade automatically retracts before the system shuts down, preventing it from remaining exposed if power is lost.

Temperature sensors also monitor the motors and battery, stopping operation if unsafe temperatures are detected.

Prototyping Electronics

The electronic system was initially assembled on breadboards so that each circuit could be tested and modified before final integration. Each subsystem was tested individually before being combined into the complete system. A multimeter was used to check voltage levels, continuity and component connections, helping identify short circuits, incorrect wiring and faulty connections during debugging.

Once the circuit had been fully tested on breadboards, it was transferred to perfboard and soldered to create neater, more reliable connections for final integration. The layout was arranged to reduce loose wiring and fit within the product casing. After soldering, continuity and voltage checks were repeated to confirm that no shorts or faulty connections had been introduced. [Refer to Page 6 of A3](#)

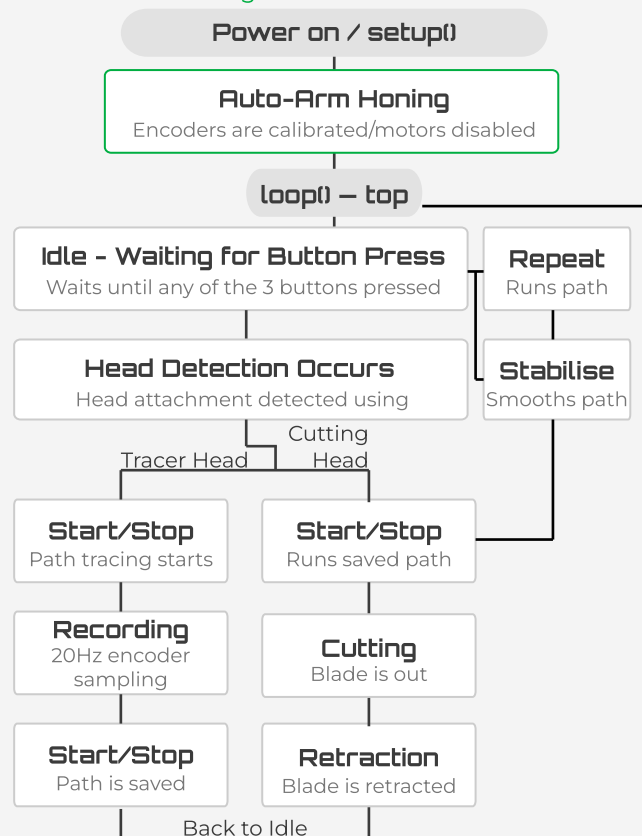
Code

The code section is split to **5 parts**, main loop, motor control, stabilisation, teaching, and unit tests.

Main Loop

The main loop runs continuously to call the three service functions, button and head polling, the state check for the product workflow, and the encoder stream. The action-button trigger is defined by a finite state machine, which allows the SwivelCut to perform different functions based on the combinations of buttons pressed with the heads attached.

Figure 8: Flowchart



Motor Control

The motors are driven through TB6600 drivers and interrupts in the code. Hardware timers are utilised to vary the step rate smoothly within a single move, and the rate is calculated for every segment of taught path for it to not stall or grind from abrupt changes.

Teaching

Teaching records the path through sampling of the encoders at a rate of **20Hz**, which is stored with the timestamps.

Stabilisation

We applied a moving average filter to 150ms windows of recorded joint angles, limiting the correction of the original path to perform stabilisation initially. However, since smoothing angles results in sharp angle changes and corners being lost, the angle values from the encoders are converted into the **Cartesian system** and the smoothing filter is applied to the window in the X/Y space which is again converted to angles.

Unit Tests:

As SwivelCut is a fairly complex system with many parts, unit tests were decided on before working on the code. Each component is testable through the serial to ease debug wiring problems, as well as each function to determine the failing point of the overall code or mechanisms. The overall code was validated through doing accuracy tests of repeated motions with different colour pens, and fine-tuning until exact match.

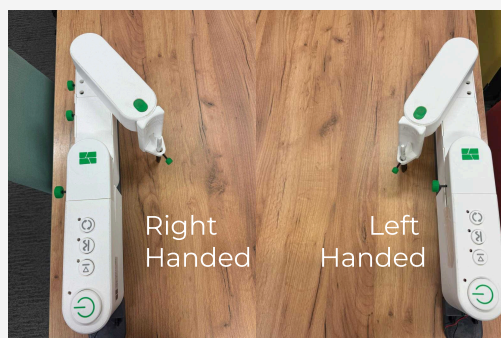
User Design and Interaction

Base, Clamping and Accessibility

The base and clamping system were developed through collaborative testing with teachers and students at CLSG. Mr Barker suggested two possible mounting methods: a flat clamping surface for use with a G-clamp, and a modular table-vice attachment. The G-clamp system was selected for the current prototype, while the table-vice attachment is being considered as a future modular development.

The product does not have a fixed front or back and can be positioned in the orientation that best suits the user. Left- and right-handed students tested the setup and found that the product could be used comfortably when clamped on the appropriate side of the desk.

Figure 9: Left & Right Handed Use



The base houses the battery and motor drivers and has a wide footprint to improve stability and reduce the risk of tipping. The lower panel can be unscrewed to access the motor drivers for maintenance, while the battery is enclosed within a separate compartment that is not accessible during normal use.

Controls, Semiotics and Inclusive Interaction

The interface uses four tactile buttons: On/Off, Start/Stop, Stabilisation and Repeat. The On/Off button is the largest and uses the universal power symbol, establishing a clear visual hierarchy. A **status LED** confirms that the product is powered and provides feedback during operation. *Refer to Page 7 of A3*

Each button includes a high-contrast raised symbol, allowing the controls to be identified both visually and through touch. This was informed by feedback from Mr Barker who supports a **visually impaired** student who relies heavily on tactile interaction.

Rounded buttons make the interface feel **approachable** and provide clear physical feedback. Each button has an LED to communicate its status. The On/Off LED glows white when powered and idle, changes to amber at low battery, and flashes red to indicate errors. Attaching the heads causes a coloured flash to indicate that they have been secured. Start/Stop, Stabilisation and Repeat illuminate green when active. The Start/Stop and Repeat LEDs switch off automatically when their task is complete.

A **spinning yellow-and-black indicator** on the cutting head shows when the blade is extending or retracting. Inspired by the Bambu Lab A1's extruder wheel, it provides clear visual feedback where blade movement may otherwise only be identified by sound, improving accessibility for users with hearing impairments.

The spring-loaded head-release button was shaped around the thumb to make its intended interaction clear. Its 23 mm contact width was compared with UK 95th-percentile thumb-joint breadth data of 22.6 mm for men and 22.9 mm for women [12]. It was designed large enough for 5th-95th percentile, the broad curved surface provides a comfortable contact area and was verified through user testing.

Product and Brand Design Language

SwivelCut adopts Bambu Lab's clean, minimal and approachable design language through a white and grey casing, restrained detailing and softly rounded edges. These features visually connect the product to Bambu Lab's A1-series products while making the tool appear suitable for an educational environment rather than an industrial machine.

Green is used consistently on **adjustable or interactive components**, including the head-release button, belt tensioners and tracing-head thumb screw. This creates a clear visual signifier, showing users which parts are intended to be touched, adjusted or moved.

The combination of rounded forms, enclosed mechanisms, high-contrast symbols and consistent colour coding creates a coherent product identity while supporting intuitive, safe and inclusive use.

Design For Manufacture

Production Volume

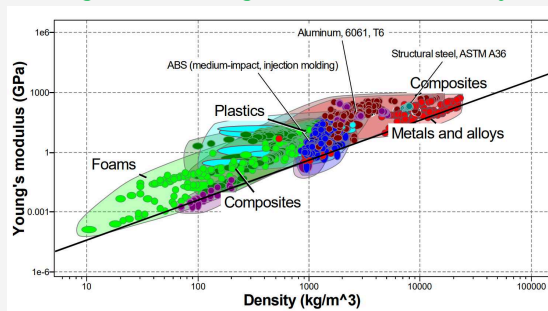
There are approximately 4,182 state-funded secondary schools in the UK, of which roughly 60–70% run active DT provision [13]. At 20–25% adoption and 1.5 units per school, first-year volume sits around 750–1,100 units, growing as the product establishes itself. **5,000** units is adopted as the production volume. This figure drives every process decision that follows.

Material Selection

Materials were selected using Ashby plots generated in Granta CES EduPack 2022 [14]. Two performance indices were used

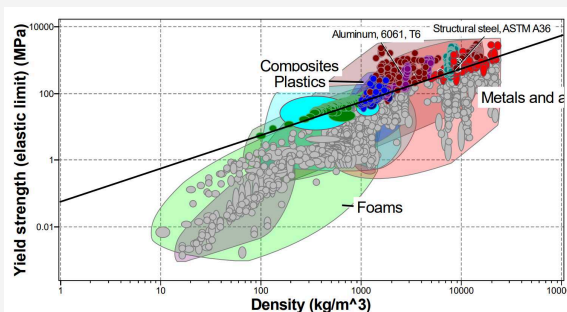
$$M_1 = \frac{E^{1/2}}{\rho} \text{ for bending-limited structures [15]}$$

Figure 10: Young's Modulus vs Density



$$M_2 = \frac{\sigma_y}{\rho} \text{ for parts under direct load [15].}$$

Figure 11: Yield Strength vs Density



Both plots place ABS in a strong position for lightweight casings, and aluminium 6061-T6 and structural steel A36 at the top of their envelopes for structural parts. This informed the three-material strategy: ABS for casings and internal brackets, aluminium for the output pulleys and extrusion, and mild steel for the load-bearing brackets.

Outer Casing & Mounts

Injection Moulded ABS

At **5,000 units**, injection moulding beats 3D printing on cost by a large margin once tooling is spread across the batch. ABS was chosen over PP and PS for its toughness, finish quality, and lower price [16]. Wall thickness is a consistent 2.5 mm. Draft angles, fillets, ribs, bosses and snap fits all follow Fusion's ABS plastic rule. All moulded parts use simple two-part moulds to keep tooling cost down.

There are **two exceptions**: the bottom arm casing and the electronics casing each need holes on their side faces for the belt tensioners, which require lifters or sliders in the tool. Screw bosses are designed with **lead-in lips** so fasteners self-guide and need less alignment effort. Snap fits close parts the user is unlikely to ever open, such as the mounting mechanism, removing fasteners and cutting assembly time. The complex internal brackets and mounts use the same material as the casing to keep the BOM simple and the plastic content recyclable as one stream.

Pulleys

Reduction Pulleys

The two 20T pulleys on the motors are standard off-the-shelf GT2 pulleys bought in and the compound 20T-60T pulley is bought in and stacked on a shared shaft. Cheaper than machining them.

Output Pulleys

The output pulleys are hobbled to cut the GT2 tooth profile, then CNC machined to produce the bearing seat. The output pulleys are hobbled to cut the GT2 tooth profile, then CNC machined to produce the bearing seat. At **5,000** units injection moulding would be cheaper, but the bearing seat needs metal-level precision that no moulded part can hold without secondary machining anyway, and filled polymers risk accelerating belt wear.

Sheet Metal Brackets

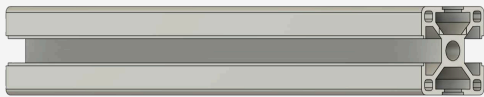
Steel is used here because these parts take the cutting and motor loads where ABS would deflect or creep. Simple flat bends throughout, with bend radius set to material thickness (2.5 mm), K-factor **0.44**, and automatic bend reliefs to prevent tearing. Laser cut from flat pattern then press braked

Design For Manufacture & Assembly

Arm Cores

The arm cores use 30×30 T-slot aluminium extrusion, cut to 200 mm and 140 mm for the upper and lower arms. Extrusion suits this application because the arm cross-section is constant along its length and governed by bending stiffness, with no tooling cost and multiple suppliers keeping sourcing simple.

Figure 12: 30×30 T-slot Aluminium Extrude



From an assembly perspective the T-slot profile is a significant advantage. Joints, motor mounts, belt tensioners and casings all clamp directly into the slots and slide to position before being locked off, meaning the extrusion acts as the structural backbone of each arm with sub-assemblies locating off it in sequence. This removes a large number of alignment operations, reduces the chance of incorrect assembly, and makes adjustment during servicing straightforward without taking the arm apart.

Bought-in Parts

The remaining components are standard catalogue parts: NEMA 23 and NEMA 17 steppers, TB6600 drivers, thrust bearings, GT2 belts, 4S3P 18650 battery pack, cutting-head linear actuator, and 8-pin pogo connectors. The TB6600 is an off-the-shelf driver so a failed unit can be swapped by a technician without soldering, which matters in a school workshop context. Pogo connectors at the head interface were chosen because their spring-loaded pins absorb hand-insertion positional variation, making head swaps fast and tool-free.

Fasteners

Fasteners are **M5 throughout** except M3 at the NEMA 17 faceplate, which is the only interface that motor provides. The full BOM carries 38 fasteners: 10× M5×14, 3× M5×20, 3× M5×35, 11× M5×55, 4× M3×20, and 7× M5 hex nuts. The product assembles with two tools and no adhesives.

Tolerances and Fits

General tolerance is ± 0.5 mm and $\pm 1^\circ$, sufficient for all structural and cosmetic features. Tapped holes in steel brackets are M5×0.8 class 6H. Tighter fits are applied only at bearing interfaces: H7/h6 locational fit on the 5 mm shaft and $\varnothing 11$ bearing bores; thrust bearing seats held by machining on the steel side and moulding tolerance on the ABS side.

Belt centre distance is not held by tight machining. Adjustable tensioners take up accumulated tolerance at build time, so casings and brackets run at the general ± 0.5 mm band while the belt stays correctly tensioned. This was a factor in choosing belt drive over gears, as the tensioners handle what would otherwise need to be tight machined fits. At the head interface, pogo connector lead-in chamfers and pin spring travel absorb positional variation from hand-insertion without any user adjustment.

Assembly Structure

SwivelCut is built from five independent sub-assemblies: the latching mechanism, bottom arm, shoulder mount, stationary base, and casing, all built concurrently before coming together in final assembly which reduces total line cycle time significantly compared to a purely sequential build.. The bottom arm must be complete before the shoulder mount can receive it, and the shoulder mount before it mounts to the base. The critical path runs through the bottom arm into final assembly, with everything else feeding in without holding up the line.

Sub-Assembly	Operations	Est. Time
Latching Mechanism	2× screw, 4× place, 1× snap fit	35s
Bottom Arm	13× screw, 7× place, 2× belt route, 1× mate	223s
Shoulder Mount	5× screw, 4× place, 1× belt route	101s
Stationary Base	2× screw, 3× place, 1× snap fit, 2× wire route	111s
Casing	6× screw, 4× place, 2× wire route	144s
Final Assembly	14× screw, 4× place, 2× wire route, 3× mate	253s
Total		867s

Figure 13: Boothroyd Dewhurst Time Estimate

With a 20% error for handling variability, inspection between sub-assemblies, and minor rework, total assembly time is approximately **1,040 seconds** (20 minutes) per unit. The longest single operations are belt routing and tensioning, and wire management through the arm joints.

Product Costing & Design for Disassembly

Product Costing

Assembly labour cost is derived from the 20 minute assembly time estimate. At a Chinese factory wage of approximately £2.50/hr, this gives an assembly labour cost of £0.83 per unit. ABS moulded part costs were estimated based on part wall volume and projected cycle time, using an indicative moulded ABS material rate of approximately £2.50/kg at 5,000 units.

Sheet metal part costs were estimated based on laser cutting time and material weight at 2.5 mm A36 mild steel, using indicative rates from online instant quote services. Tooling is estimated at £35,000 spread across 5,000 units at £7.00 per unit.

Item	Qty	Unit Cost (est.)	Line Total
NEMA 23 stepper motor	1	£8.00	£8.00
NEMA 17 stepper motor	1	£5.00	£5.00
TB6600 stepper driver	2	£4.00	£8.00
Thrust bearings	4	£1.50	£6.00
ID5/OD11 ball bearings	4	£0.80	£3.20
GT2 belts	3	£2.00	£6.00
GT2 pulleys (off-shelf)	4	£1.50	£6.00
Output pulleys (CNC machined)	2	£5.00	£10.00
30×30 T-slot extrusion	2	£3.00	£6.00
ABS moulded parts (all)	-	-	£11.00
Sheet metal parts (all)	-	-	£6.00
4S3P 18650 battery pack	1	£6.00	£6.00
Linear actuator	1	£8.00	£8.00
Pogo connectors	1	£2.00	£2.00
Fasteners (38 total)	-	-	£2.00
PCB and electronics	-	-	£6.00
Parts subtotal			£99.20
Assembly labour			£0.83
Tooling amortised			£7.00
Total unit cost			£107.03

Figure 13: Unit Cost Breakdown

At a 2.5× retail multiplier, consistent with Bambu Lab's approach of aggressive early market pricing to build volume and market share, the target retail price is approximately £268, rounded to **£299**. This positions SwivelCut directly alongside the Bambu Lab A1 mini, giving a clear and credible comparable for a school audience already familiar with desktop fabrication tools at that price point.

Disassembly

SwivelCut was developed in line with ISO 8887-1:2017 from early in the design process, with a target of **under 5 minutes** to access any serviceable component.

Part count has been kept low by consolidating complexity into key manufactured parts. The two custom output pulleys each combine the belt interface and thrust bearing seat into one component, removing several intermediate parts and reducing alignment operations. The electronics casing was also reduced from four parts in the prototype to two in the production design, cutting both assembly time and the number of fasteners needed to access the internals for servicing.

Fasteners are standardised to M5 throughout. The product can be fully disassembled using the two hex keys included in the packaging. No adhesives are used anywhere, so no parts are destroyed on disassembly

Replaceability

High-wear parts are designed to be replaced quickly without disturbing the rest of the product. The blade is held by two screws, one of which acts as a pivot — twisting off the safety tube and removing the single release screw allows the blade to swing free and be replaced without removing the head assembly. Belts are accessible by undoing 3 screws to open the casing, with no further disassembly required. The modular cutting head detaches as a complete sub-assembly via the pogo connector and is available to purchase separately, meaning the full product does not need to be discarded when a single consumable fails.

The product is designed to be maintained in a school workshop by a technician with basic mechanical familiarity, using tools already present in that environment.

End of Life

At end of life, material variation is kept low to simplify sorting: ABS parts form one stream, aluminium another, and steel a third. Blades, belts and electronics are removed before the mechanical structure goes to recycling. No formal take-back scheme is proposed at this stage, consistent with practice for comparable desktop manufacturing products such as Bambu Lab, but the design supports repair and part replacement to maximise product lifespan and reduce whole-unit disposal.

Product Compliance

Legislations

Swivel Cut is a powered cardboard-cutting tool for UK school DT workshops. Its motorised movement, blade, electronics, sensors and charging system mean it must meet relevant safety, machinery, electrical and environmental requirements before sale.

UKCA / CE Marking

Shows that the product meets applicable safety requirements. SwivelCut would require **UKCA marking** for Great Britain and **CE marking** for the EU, supported by risk assessments, testing and technical documentation [17].

Supply of Machinery (Safety) Regulations

Covers products with powered moving parts. It is relevant because SwivelCut has motorised arms and a blade, creating risks such as cutting, and unexpected movement [18].

RoHS Regulations

Restricts hazardous substances in electrical components. This affects the selection of SwivelCut's circuit boards, wiring, sensors and solder [19].

Electromagnetic Compatibility Regulations

Requires electronic products to operate without causing or suffering harmful interference. SwivelCut must work reliably around computers, chargers and other workshop equipment [20].

Batteries and Accumulators Regulations

Controls battery composition, labelling, removal and disposal. SwivelCut's rechargeable battery must be safely enclosed, protected against faults and removable for replacement or recycling [21].

WEEE Regulations

Controls the disposal and recycling of electrical products. SwivelCut would require appropriate disposal labelling and end-of-life recycling information [22].

Radio Equipment Regulations 2017

Applies because SwivelCut uses Bluetooth to receive DXF files. The Bluetooth system must operate within permitted limits and meet radio, and interference requirements [23].

Standards

BS EN ISO 12100 – Machinery Risk Assessment

Guides the identification and reduction of machinery hazards. For Swivel Cut, this includes blade contact, pinch points, unexpected movement, sharp edges and foreseeable misuse [24].

BS EN ISO 13850 – Emergency Stop Function

Covers emergency-stop controls. Swivel Cut doesn't need a separate emergency stop as its accessible stop button, limited movement and guarded blade allow it to stop safely [25].

BS EN ISO 13857 - Safety Distances and Guarding

Defines safe distances to prevent access to hazards. This applies to the blade guard, enclosed mechanisms and gaps around the cutting head and arms [26].

BS 4163 – Safety in Educational Settings

Provides health and safety guidance for equipment used in UK DT workshops. It is relevant to Swivel Cut's operation, supervision, storage and maintenance [27].

BS EN 60529 – IP Rating

Defines protection against dust and liquids. This is relevant because cardboard fibres, debris and spills could damage Swivel Cut's electronics and sensors [28].

Electrical, Battery and EMC Testing Standards

These verify safe wiring, charging, overheating protection, fault behaviour and electromagnetic compatibility, supporting product approval and technical documentation. [29]. *Refer to Page 10 of A3*

Documentation

Swivel Cut would require documentation showing that it has been designed, tested and assessed safely. This would support UKCA marking and demonstrate compliance.

Technical documentation would include CAD drawings, circuit diagrams, component lists, risk assessments, test results, user instructions and maintenance guidance. It would show how risks such as blade contact, pinch points, charging faults and unexpected movement are controlled.

A UK **Declaration of Conformity** would confirm that Swivel Cut meets relevant UK regulations and standards, including the product model, manufacturer details and authorised signature [17].

Labelling and User Guide

Product Labels

Main Product Label

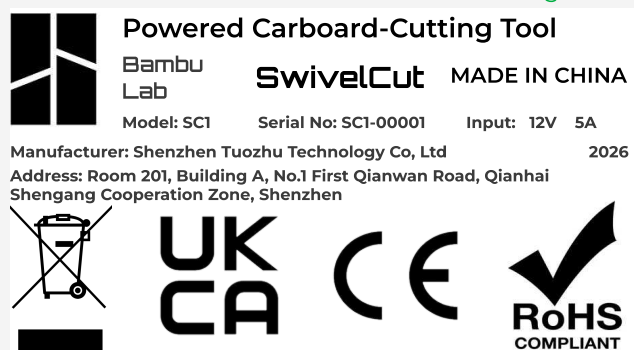
The main label would be placed on the underside of the arm casing. It identifies the product and provides the information needed for compliance, traceability and safe charging.

It would include: [Refer to Page 10 of A3](#)

- Product type: Powered cardboard-cutting tool
- Manufacturer name and postal address
- Serial or batch number
- Year of construction
- Required electrical input, including voltage and current
- UKCA and CE conformity mark
- WEEE crossed-out wheeled-bin symbol

This information allows each unit to be identified for maintenance, warranty claims, recalls and replacement parts. The input rating also ensures that the correct charger and power supply are used.

Figure 15



Replaceable Electronics

The CAD includes a removable bottom service panel for access to replaceable components such as the motor drivers, while the battery remains separately enclosed beneath a fixed protective cover with a safety label.

Figure 16



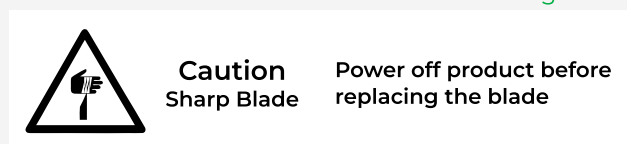
Replaceable Heads

Each replaceable head would display its name or function symbol, such as Cut or Trace, to help users identify the correct attachment. Lock/unlock symbols would show how it connects, while a small part number, such as SC1-CH, would support maintenance.

Cutting Head

The cutting head would include a sharp-blade warning and a clear instruction to power off the product before replacing the blade. Lock/unlock arrows would show how to open the guard compartment, while a blade-orientation mark would help ensure the replacement blade is fitted correctly.

Figure 17



User Guide

The SwivelCut user guide would be designed primarily for teachers responsible for unpacking, setting up and maintaining the product. It would explain the included parts, initial setup, charging, modular heads, controls, operating modes, blade replacement, routine maintenance and common troubleshooting issues, compliance.

The guide would follow Bambru Lab's clear, minimal visual style, using fine-line diagrams, green highlights on important components and short step-by-step instructions. This would make the setup process easy to follow while keeping the booklet visually consistent with the brand. QR codes on the user guide and outer packaging would link to videos showing the unboxing, setup and operation process.

Figure 18

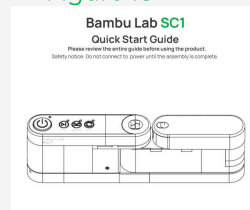
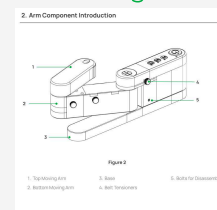


Figure 19

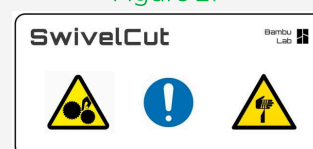


Two reusable classroom reference cards would also be included. The first would summarise the main hazards and safety precautions and could be displayed beside the storage area. The second would provide a simplified operating sequence that students could follow independently if they forget part of the process. [Refer to Page 11 of A3](#)

Figure 20



Figure 21



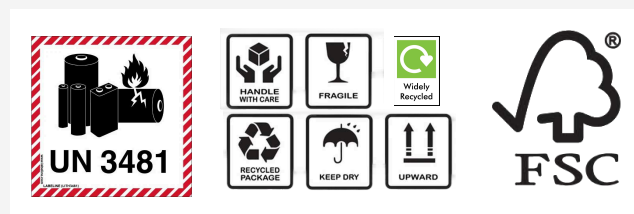
Product Packaging

Outer Packaging

Swivelcut is supplied in a compact, minimally printed cardboard box inspired by the packaging of Bambu Lab's A1 printer. The exterior features only a simple black-and-white product image, the Swivelcut name and essential warning and handling labels, creating a clean and functional appearance.

Packaging Labels

The cardboard packaging would include handling, recycling, compliance and identification labels. These would include Keep Dry, Fragile, This Way Up where needed, PAP 20 / recyclable cardboard, and FSC-certified cardboard where applicable [30]. A UN 3481 lithium-battery mark may also be required depending on the final battery and shipping method [31]. The box would also show the product name, model, manufacturer, package contents, barcode or batch number, plus UKCA, CE and WEEE symbols.



Refer to Page 10 of A3

Inner Packaging

Swivelcut is held securely within shaped cardboard inserts that support the folded arms, base and modular heads. Paper wraps and folded-card supports protect delicate surfaces and prevent components from moving during transport, without relying on polystyrene or plastic foam.

Tools, modular heads and replacement parts are organised within clearly labelled cardboard compartments. Bambu green highlights identify any components that must be removed, tightened or attached during setup.

The packaging also includes:

- Teacher setup and troubleshooting user guide

- Classroom safety card
- Student quick-start card
- Setup tools and initial replacement parts
- Cardboard test sheet with an integrated cutting template

The decision to use entirely cardboard- and paper-based packaging directly reflects Swivelcut's purpose as a cardboard prototyping tool. Once unpacked, much of the packaging can be reused by students as modelling material rather than immediately becoming waste. This also provides a more environmentally responsible alternative to plastic bags and polystyrene inserts.

The packaging relies primarily on folded and interlocking card, with minimal use of adhesives or staples. This makes the materials easier to separate, reuse and recycle while keeping the packaging simple and consistent with Bambu Lab's functional design language.

Brand Alignment

The packaging follows Bambu Lab's existing approach through its minimal exterior, compact arrangement, shaped protective inserts, green setup indicators and wireframe-style instructions.

However, Swivelcut replaces plastic bags and polystyrene with card- and paper-based protection. This better reflects the product's educational purpose and turns packaging waste into a useful classroom resource. The supplied test sheet introduces the complete Swivelcut workflow: trace the printed template, record the movement, attach the cutting head and produce the first cut. This gives teachers a structured setup test while demonstrating the product immediately.

Production/cost

Corrugated card is low-cost, lightweight and widely available. Early packaging prototypes can be cut and scored using a CNC cutting machine, while larger production runs would use die-cutting for faster, lower-cost manufacture.

Using mainly card and paper simplifies sourcing and recycling. Closely fitted inserts also reduce material use, package size and transport costs. Test templates can be printed directly onto the packaging with minimal added cost. At 5,000 units, packaging is estimated at £5-£8 per unit, depending on size, grade, printing and order volume [32].

Final Design

SwivelCut - SC1

SwivelCut SC1 is a compact, two-degree-of-freedom cardboard-cutting system designed for secondary-school DT workshops. It allows users to record a hand-drawn path using the tracing head, then **reproduce it safely and accurately** using the powered cutting head. The final design combines a rigid aluminium-supported arm structure, low-backlash belt-driven movement and interchangeable tool heads within a compact, foldable form.

[Refer to Page 13 of A3](#)

Folding Arm System

The two arms measure 260 mm and 215 mm, providing A3 cutting coverage while remaining compact when folded. **Aluminium reinforcement increases rigidity** and provides secure mounting points for the joints and movement mechanisms. Thrust bearings support vertical loads at each joint while maintaining smooth, low-friction rotation.

Belt-Driven Movement

A NEMA 23 motor drives the base joint through a 1:6 pulley reduction, while a NEMA 17 drives the second joint through a compound 1:9 reduction. GT2 timing belts provide smooth, accurate movement with less backlash than the geared systems considered. Separate tensioners mounted to the aluminium structure allow belt tension to be adjusted during assembly.

Modular Tool Heads

The common head attachment allows users to switch between tracing and cutting functions without replacing the complete product. The tracing head records the user's movement, while the cutting head follows the stored path. The platform could later support additional scoring, plotting or line-following heads.

Cutting Head

The cutting head uses a linear actuator to extend and retract the blade at selected points along the cutting path. A spring-mounted blade accommodates small variations in cardboard height, while thrust bearings allow it to swivel freely when following curves. A removable safety tube encloses the blade area,

and a rotating indicator provides visible feedback when the mechanism is moving.

Controls and Safety

A large power button with an LED indicator provides a clear physical on/off control, supported by three smaller buttons for recording, stabilisation and repeating a previous path. Safety features include blade guarding, movement detection, resistance monitoring and an immediate power-cut system. The simple interface reduces setup time and helps independent classroom use.

Base and Clamping

The low, wide base houses the motors, drivers, battery and control electronics while providing stability during operation. SwivelCut can be clamped from one end and orientated from either side to accommodate different workbench layouts and user handedness. The folded arms sit on top of the base reducing storage space when not in use.

Colour Material Finish

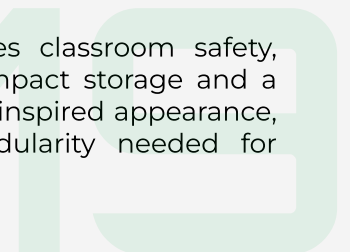
The CMF direction is based on Bambu Lab's clean, technical and approachable design language.

Colour: The main casing uses a clean white finish, combined with dark grey base inspired by the A1 printer and aimed at reducing the perceived height of the product. Bambu green is used selectively for controls, indicators and components that users are expected to touch or adjust.

Material: Injection-moulded ABS is proposed for the main casing and arm covers because it is impact-resistant, cost-effective and suitable for high-volume manufacture. Aluminium forms the internal arm structure, while steel is used for shafts, fasteners and high-load joint components.

Finish: External casing surfaces use a fine matte texture to reduce fingerprints and hide minor wear. Controls and removable components use slightly contrasting finishes to communicate interaction, the internal metal structure remains functional and not exposed.

The final design balances classroom safety, cutting performance, compact storage and a recognisable Bambu Lab-inspired appearance, while retaining the modularity needed for future development.



User Testing and Validation

Test Aims

Final user testing was carried out with Year 7–10 students at City of London School for Girls. The aim was to evaluate whether SwivelCut could be understood and operated safely by its intended users, and whether the **tracing, cutting and control interactions were intuitive** without extensive instruction.

Refer to Page 12 of A3

Location: City of London School for Girls

Users: Year 7–10 students

Target group: Secondary-school DT students

Environment: School DT workshop

Number of participants: 18

Testing Method

Students first watched a short demonstration of how SwivelCut should be set up and operated, similar to the way a DT teacher would introduce a new workshop tool. They were then asked to clamp the product to the workbench, attach the tracing head, trace a shape, change to the cutting head and complete the cutting process.

The **students completed the task independently** after the demonstration, while observations were made to identify any unclear controls, awkward interactions or safety concerns. Short feedback questions were then used to assess comfort, ease of use, confidence and the quality of the final result.

Observations

Students found the **head-swapping mechanism easy to use** and understood the purpose of the different heads and control buttons following the initial demonstration.

The tracing movement was less intuitive at first. Students initially found it difficult to coordinate both arm joints and guide the pen accurately around a shape. However, their control improved throughout the task, and by the end of the drawing process they appeared more confident and able to manipulate the arms effectively. This suggests that the interaction has a short learning curve rather than being immediately familiar. This is okay for the product as it is for schools where learning new things is encouraged.

Some students were initially hesitant to adjust the belt tensioners, as **interacting with a mechanical adjustment felt unfamiliar and slightly intimidating**. With brief reassurance, often from a more confident peer, they were able to complete the adjustment correctly. As belt tensioning would only be required occasionally, this is unlikely to affect normal use, although simple guidance could help improve confidence during maintenance.

Clamping created the greatest uncertainty. Some students secured the product before realising that it had been positioned incorrectly on the table and then needed to reposition it. Students also frequently asked for reassurance that the clamp was tight enough, as they were concerned that the product might move or fall during use. A **clearly marked clamping zone**, positioning guide and more obvious confirmation of secure attachment **would improve confidence** and reduce setup errors.

Feedback

Student

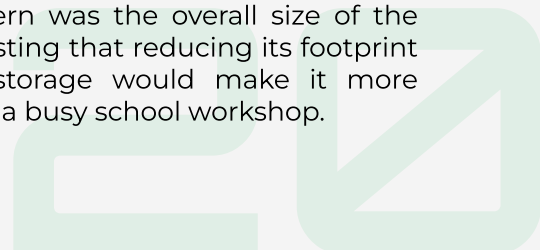
Students found the **information card useful and referred back to it** whenever they were unsure of the next step. Some were initially nervous about drawing the shape incorrectly or producing a poor result. Once they were shown that the recorded path could be reset and repeated, they appeared more relaxed and confident using the product.

Overall, **students responded positively to SwivelCut**, describing it as interesting and enjoyable to use. Several commented that the arm moved slightly slowly, although this did not significantly affect their ability to complete the task.

Teacher

The DT teacher felt that the **product had been received well by the students** and that, following an initial demonstration, he would be confident allowing them to use it with normal workshop supervision. He considered the **proposed price reasonable** and said that he would consider purchasing several units for the classroom once the design had been fully refined and polished.

His main concern was the overall size of the product, suggesting that reducing its footprint or improving storage would make it more practical within a busy school workshop.



Future Improvements

Developments

Expanding the Modular Head System

The interchangeable head mechanism allows SwivelCut to grow into a **wider prototyping platform** rather than remain a single-purpose cutter. Schools could purchase the base unit and add heads suited to different activities and materials.

A **line-following head** could use an optical sensor or camera to follow printed or hand-drawn paths without requiring CAD. A **scoring head** could create fold lines for packaging, nets and structural models, while a pen-plotting head could reproduce drawings, labels or construction lines.

Future heads could also support **thin foam board**, perforation, creasing or specialist blades. The shared attachment system would allow these functions to be added without replacing the full product.

Mounting and Classroom Accessories

The current G-clamp system could be supported by a **modular table-vice attachment**, as suggested during school testing.

A dedicated charging dock could store SwivelCut folded alongside its interchangeable heads and spare blades. This would create a clear classroom storage point, **reducing the risk of damage**, loss or the product being left uncharged.

A removable lid could also close the bottom of the cutting-head safety tube during storage, fully enclosing the blade and preventing any accidental contact.

Software and Shared Resources

Optional software could allow users to save, repeat and share recorded paths. Teachers could provide templates for shapes, packaging nets and classroom activities through a shared library.

The core tracing and cutting functions would **remain usable without an app or computer**, keeping the system accessible in classrooms with limited devices.

Business Implementation

Product Offering

SwivelCut could be sold as a base unit with a standard tracing and cutting head. Schools could then purchase additional heads, mounting systems and storage accessories separately.

This would allow **each department to build a system suited to its curriculum and budget**, rather than paying for functions it may not use.

An education package could include:

- SwivelCut base unit and arm
- Tracing and cutting heads
- Charging and storage dock
- Replacement blades
- Teacher guidance and classroom activities

Additional heads could be introduced as optional upgrades, extending the life and capability of the original product.

Commercial Model

The modular design creates several possible revenue streams beyond the initial sale of the base unit. These include additional heads, replacement blades, mounting accessories, classroom storage and maintenance parts.

Schools could initially purchase a small number of base units and expand their setup over time. This may be more realistic for school budgets than requiring a large upfront investment.

Route to Market

The product could **first be introduced through pilot schemes with secondary-school** DT departments. Wider teacher and technician feedback would help establish suitable classroom packages, durability requirements and training resources.

Following successful trials, SwivelCut could be sold through educational equipment suppliers or developed as part of Bambu Lab's education range. Demonstration videos, lesson resources and repair guidance would support adoption within schools.

Commercial Potential

Teacher feedback at CLSG indicated that the proposed price was reasonable and that **several units could be considered once the product was fully refined**. This suggests potential demand for a classroom package rather than a single shared machine.

Further commercial validation would require testing with more schools, a detailed bill of materials and comparison between manufacturing cost, selling price and expected production volume.

References

1. D&T could be gone from National Curriculum in four years, business leaders warn | Design | The Guardian [Internet]. [cited 2026 Jun 25]. Available from: <https://www.theguardian.com/artanddesign/article/2024/jun/15/dt-could-be-gone-from-national-curriculum-in-four-years-business-leaders-warn>
2. Shop 3D printers, filaments and accessories | Bambu Lab USA Store [Internet]. [cited 2026 Jun 25]. Available from: <https://us.store.bambulab.com/>
3. Ultimaker: Professional 3D printers that Empower Innovation [Internet]. [cited 2026 Jun 25]. Available from: <https://ultimaker.com/>
4. Your at-home 3D laser printer | glowforge [Internet]. [cited 2026 Jun 25]. Available from: <https://glowforge.com/>
5. Cricut Shop [Internet]. [cited 2026 Jun 25]. Available from: <https://cricut.com/en-gb/>
6. Bambu Lab Reviews | Read Customer Service reviews of bambulab.com [Internet]. [cited 2026 Jun 25]. Available from: <https://uk.trustpilot.com/review/bambulab.com>
7. Bambu lab named amongst "The best inventions of 2022" by Time [Internet]. [cited 2026 Jun 25]. Available from: <https://blog.bambulab.com/best-inventions-of-2022-by-time/>
8. 23he22-2804s | E series NEMA 23 Stepper Motor Bipolar 1.8deg 1.26nm(178.4oz.in) 2.8a 57x57x56mm 4 wires | stepperonline UK [Internet]. [cited 2026 Jun 25]. Available from: <https://www.stepperonline.co.uk/e-series-nema-23-stepper-motor-bipolar-1-8deg-1-26nm-178-4oz-in-2-8a-57x57x56mm-4-wires-23he22-2804s.html>
9. NEMA 17 Bipolar 59Ncm(83.55oz.in) 2A 42x42x48mm 4 wires W/ 1M cable & connector - 17HS19-2004s1 | stepperonline [Internet]. [cited 2026 Jun 25]. Available from: <https://www.omc-stepperonline.com/nema-17-bipolar-59ncm-84oz-in-2a-42x48mm-4-wires-w-1m-cable-connector-17hs19-2004s1>
10. [Internet]. [cited 2026 Jun 25]. Available from: <https://www.makerstore.com.au/blog/timing-pulleys/>
11. 12.8V-14.8V (4s) li-ion battery packs | high-capacity power - overlander batteries [Internet]. [cited 2026 Jun 25]. Available from: <https://overlander.co.uk/browse/li-ion/voltage/12-8-14-8v/>
12. Anthropometric Data & Human Body Dimensions Chart (5th-95th percentile) | Roymech - Roymech [Internet]. [cited 2026 Jun 25]. Available from: https://www.roymech.co.uk/Useful_Tables/Ergonomics/Human_sizes.html
13. [Internet]. [cited 2026 Jun 25]. Available from: <https://www.tes.com/magazine/analysis/general/how-many-schools-in-the-uk>
14. Ansys Granta Edupack | Software for Materials Education [Internet]. [cited 2026 Jun 25]. Available from: <https://www.ansys.com/en-gb/products/materials/granta-edupack>
15. Bending moment formula and equations | skyciv engineering [Internet]. [cited 2026 Jun 25]. Available from: <https://skyciv.com/docs/tutorials/beam-tutorials/bending-moment-equations/>
16. [Internet]. [cited 2026 Jun 25]. Available from: <https://www.protolabs.com/en-gb/resources/blog/abs-vs-polypropylene-pp-deciding-between-two-popular-plastics/>
17. [Internet]. [cited 2026 Jun 25]. Available from: <https://www.gov.uk/guidance/placing-ukca-or-ce-marked-products-on-the-market-in-great-britain>
18. [Internet]. [cited 2026 Jun 25]. Available from: <https://www.legislation.gov.uk/ukxi/2008/1597/contents>
19. [Internet]. [cited 2026 Jun 25]. Available from: <https://www.gov.uk/guidance/rohs-compliance-and-guidance>
20. [Internet]. [cited 2026 Jun 25]. Available from: <https://www.legislation.gov.uk/ukxi/2016/1091/contents>
21. [Internet]. [cited 2026 Jun 25]. Available from: <https://www.gov.uk/guidance/batteries>
22. [Internet]. [cited 2026 Jun 25]. Available from: <https://www.gov.uk/guidance/regulations-waste-electrical-and-electronic-equipment>
23. [Internet]. [cited 2026 Jun 25]. Available from: <https://www.legislation.gov.uk/ukxi/2017/1206/contents/data.html>
24. ISO 12100:2010 [Internet]. [cited 2026 Jun 25]. Available from: <https://www.iso.org/standard/51528.html>
25. [Internet]. [cited 2026 Jun 25]. Available from: <https://www.iso.org/standard/59970.html>
26. [Internet]. [cited 2026 Jun 25]. Available from: <https://www.iso.org/standard/69569.html>
27. [Internet]. [cited 2026 Jun 25]. Available from: <https://knowledge.bsigroup.com/products/health-and-safety-for-design-and-technology-in-educational-and-similar-establishments-code-of-practice-3>
28. [Internet]. [cited 2026 Jun 25]. Available from: <https://www.iec.ch/ip-ratings>
29. [Internet]. [cited 2026 Jun 25]. Available from: <https://knowledge.bsigroup.com/categories/electromagnetic-compatibility>
30. [Internet]. [cited 2026 Jun 25]. Available from: <https://www.gwp.co.uk/guides/pap-20-logo/>
31. [Internet]. [cited 2026 Jun 25]. Available from: <https://www.gwp.co.uk/guides/un3480-regulations/>
32. [Internet]. [cited 2026 Jun 25]. Available from: <https://www.omnicalculator.com/everyday-life/price-per-unit>
33. K. A, W. R., J. M., M. R. IDE 2nd Tem Report: Imperial College London; 2024.



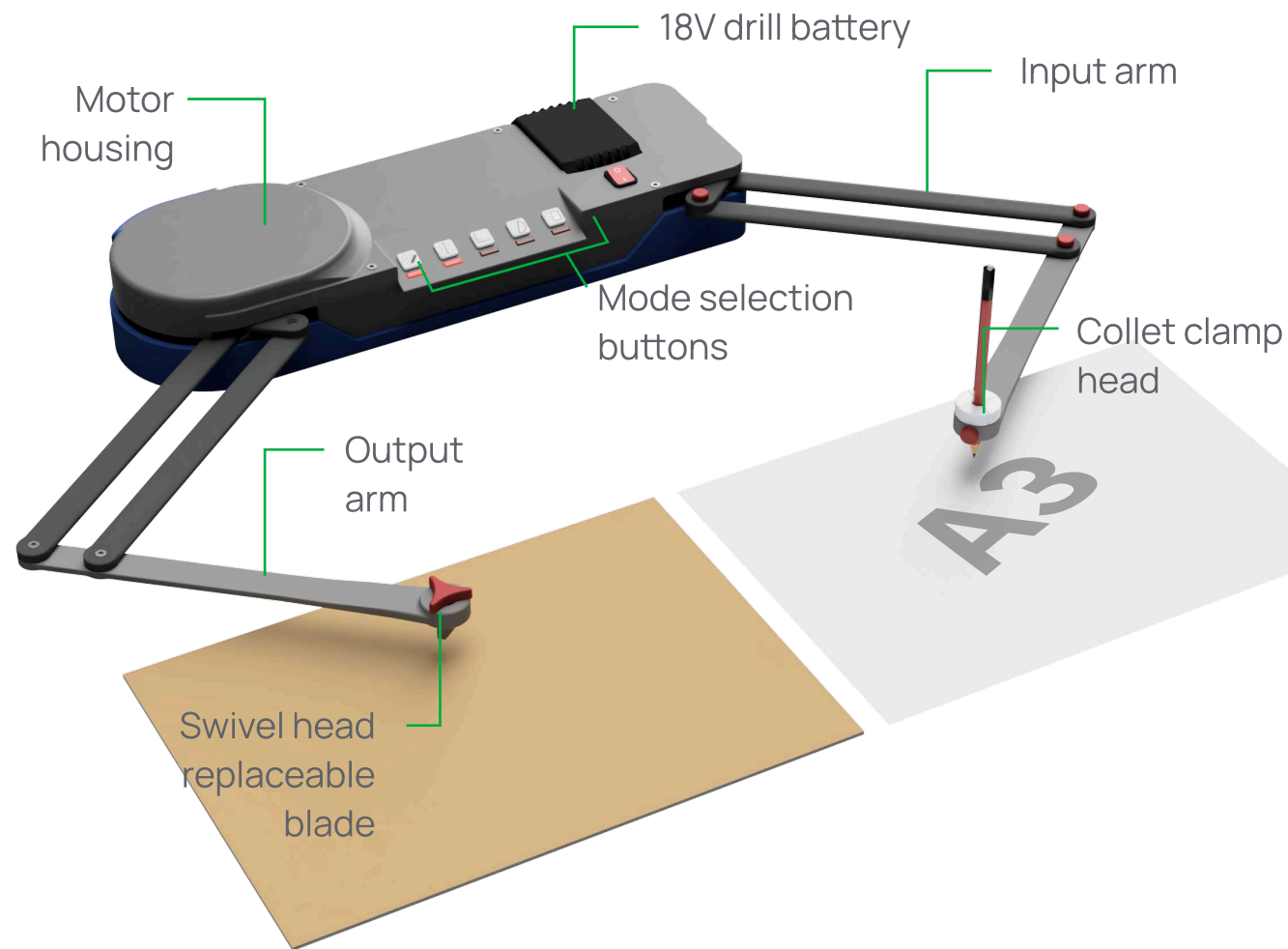
Bambu Lab SwivelCut

Cardboard Made Even Easier.

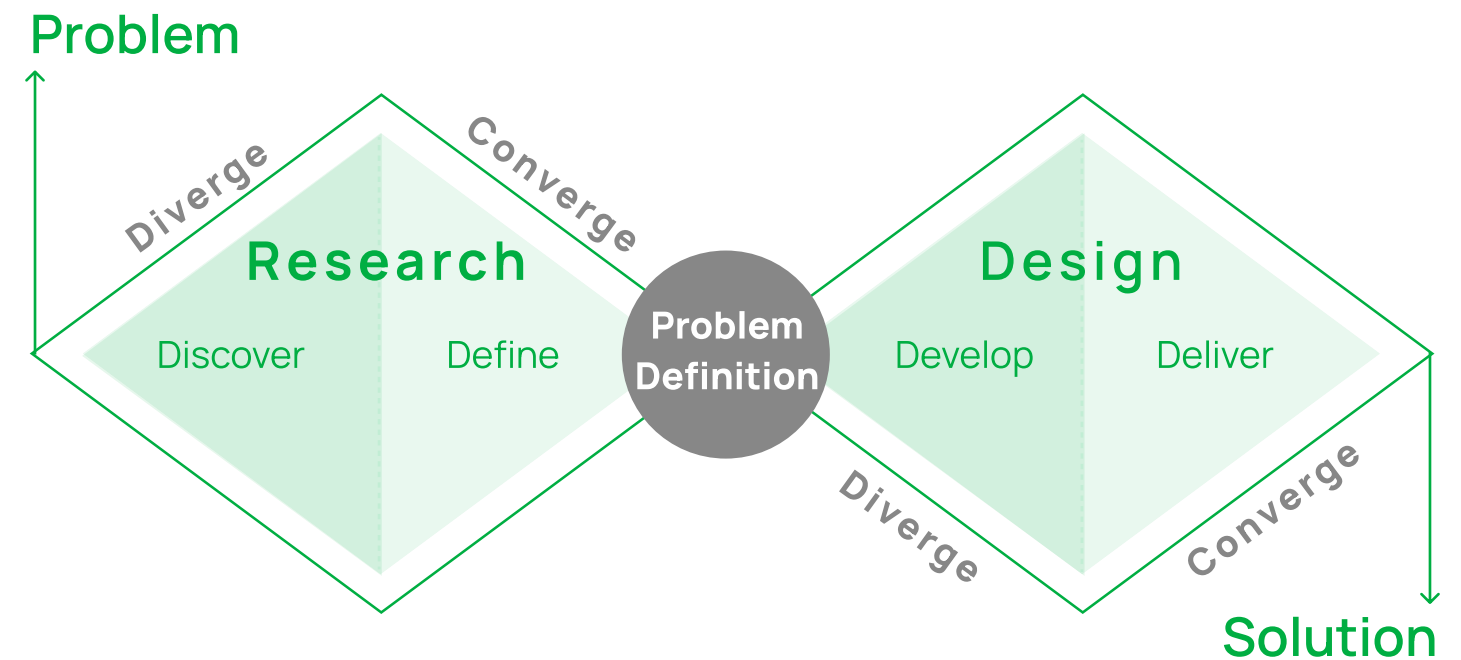




Initial Design



Double Diamond



Discover

Understand the user, concept and key challenges



Define

Narrow insights into a clear design opportunity



Develop

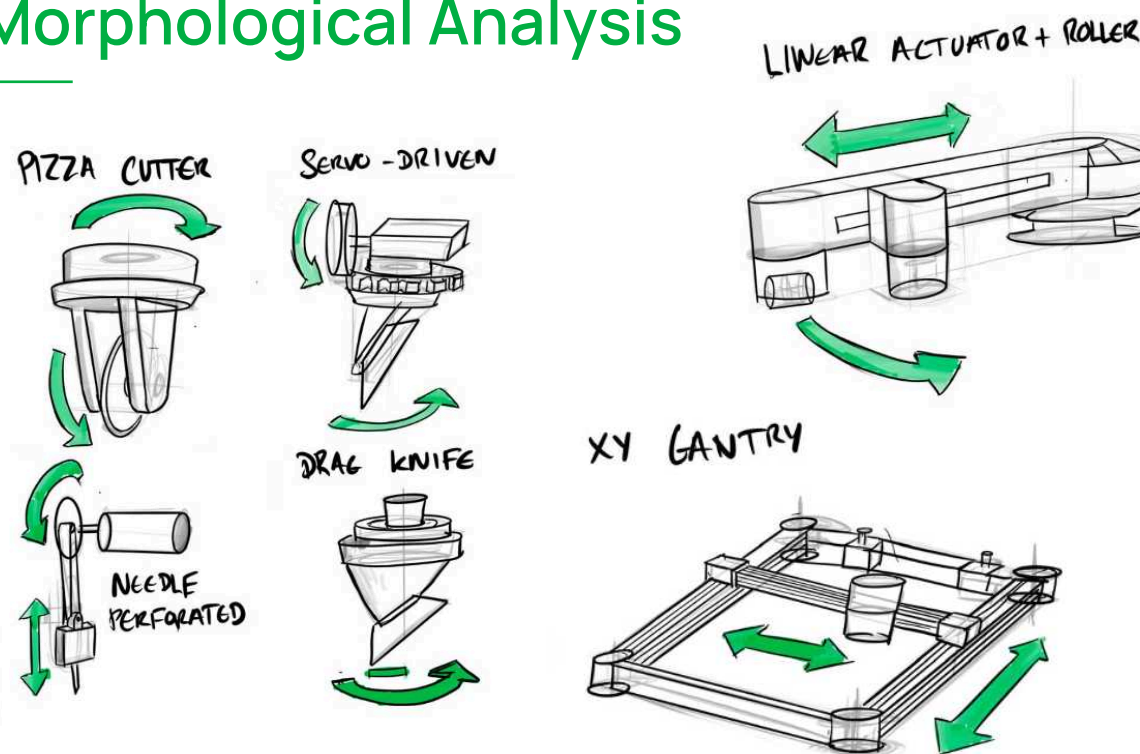
Generate ideas and explore multiple solutions



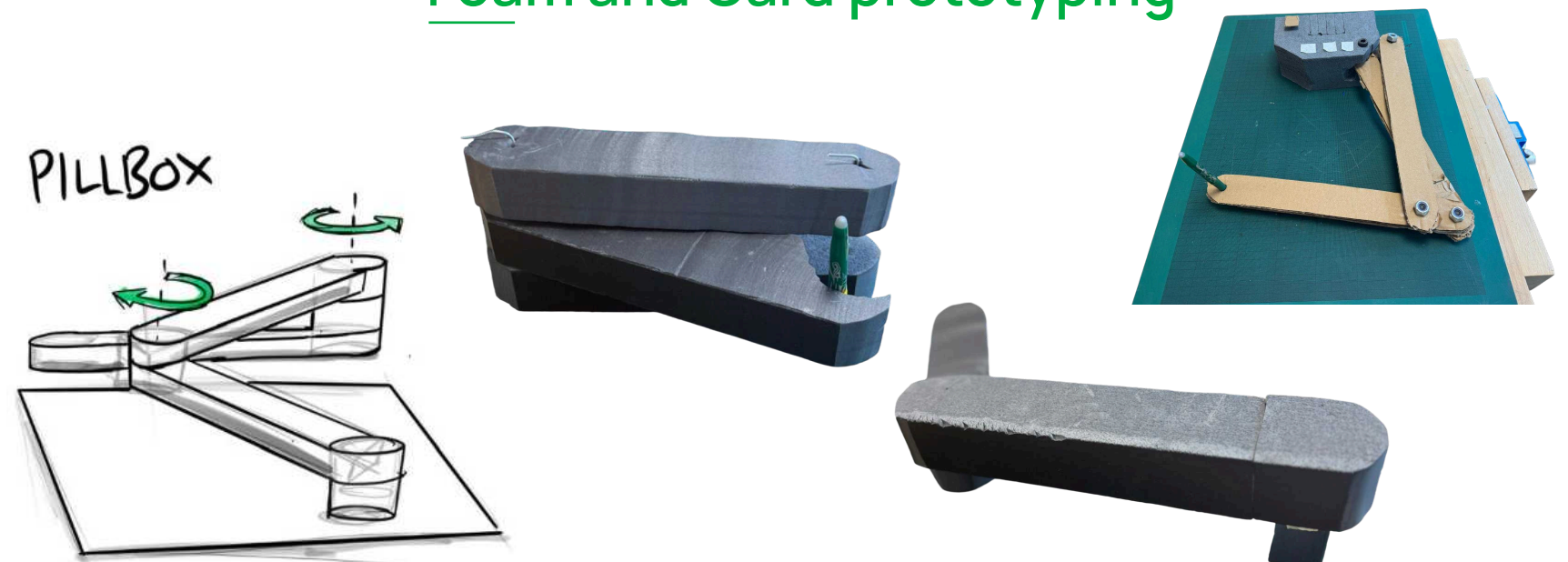
Deliver

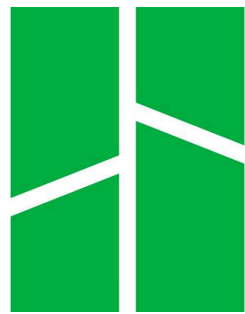
Refine, validate and test the best solution

Morphological Analysis



Foam and Card prototyping





Bambu
Lab

Founded:

2020

Headquarters:
ShenZhen

Market Share:
37%

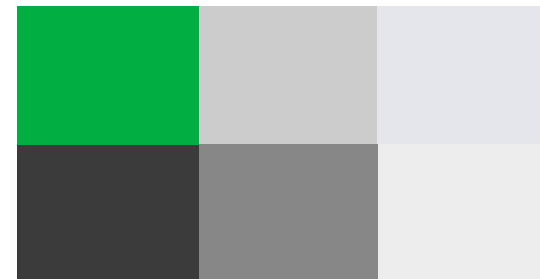
Median starting price:

£429

Monthly Users
10M

Estimated Revenue:
\$211.9M

Colours



Typography

Manrope

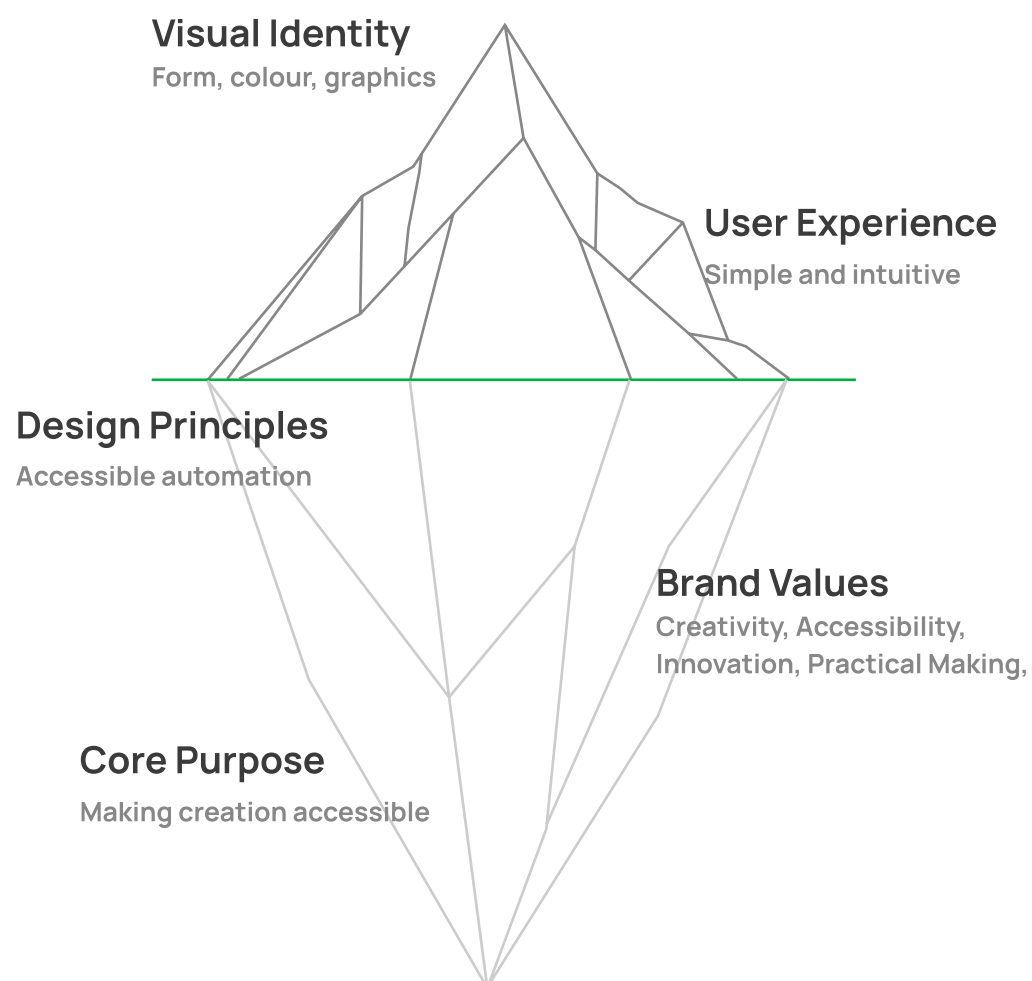
Used for information
on website and within
User Guide

Orbitron

Used for the Bambu Lab
logo and product name
logos

Brand Iceberg

The iceberg model separates Bambu Lab's visible brand identity from the deeper values and design principles that shape its products and user experience.



Existing Products



A1

A stands for
affordable and
accessible for entry
level use

1 for the first series



X1C

X for Extreme

1 for the first series

C for carbon-fiber
reinforced capability



P1S

P for performance or
prosumer.

1 for the first series

How SwivelCut Fits In

S C 1

Swivel
School
Safety

Cut
Create
Carboard
Craft

Clean form - Accessible automation - Simple
controls - Reliable creation - Modular versatility

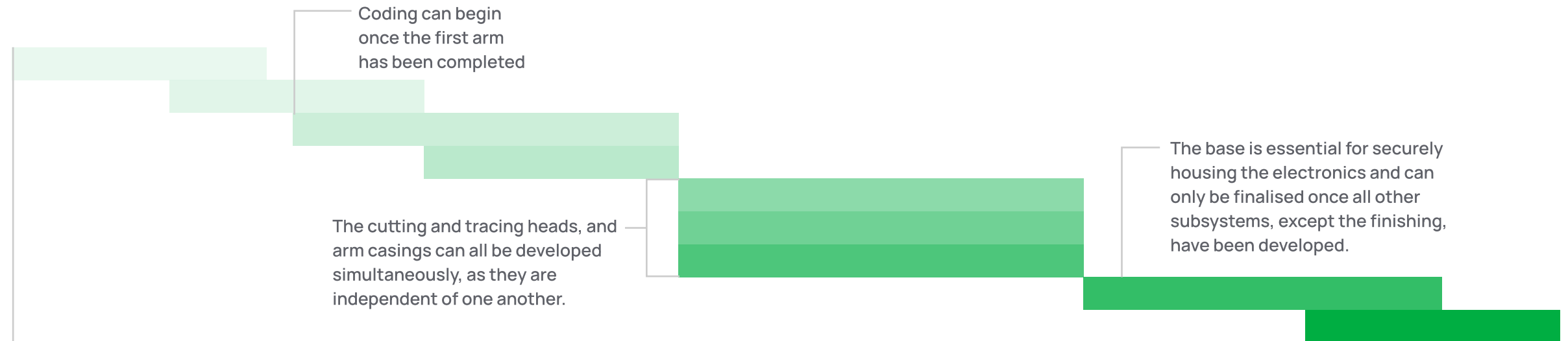
Hobbyist ————— Professional

SwivelCut reflects Bambu Lab's professional
performance while remaining accessible to students.

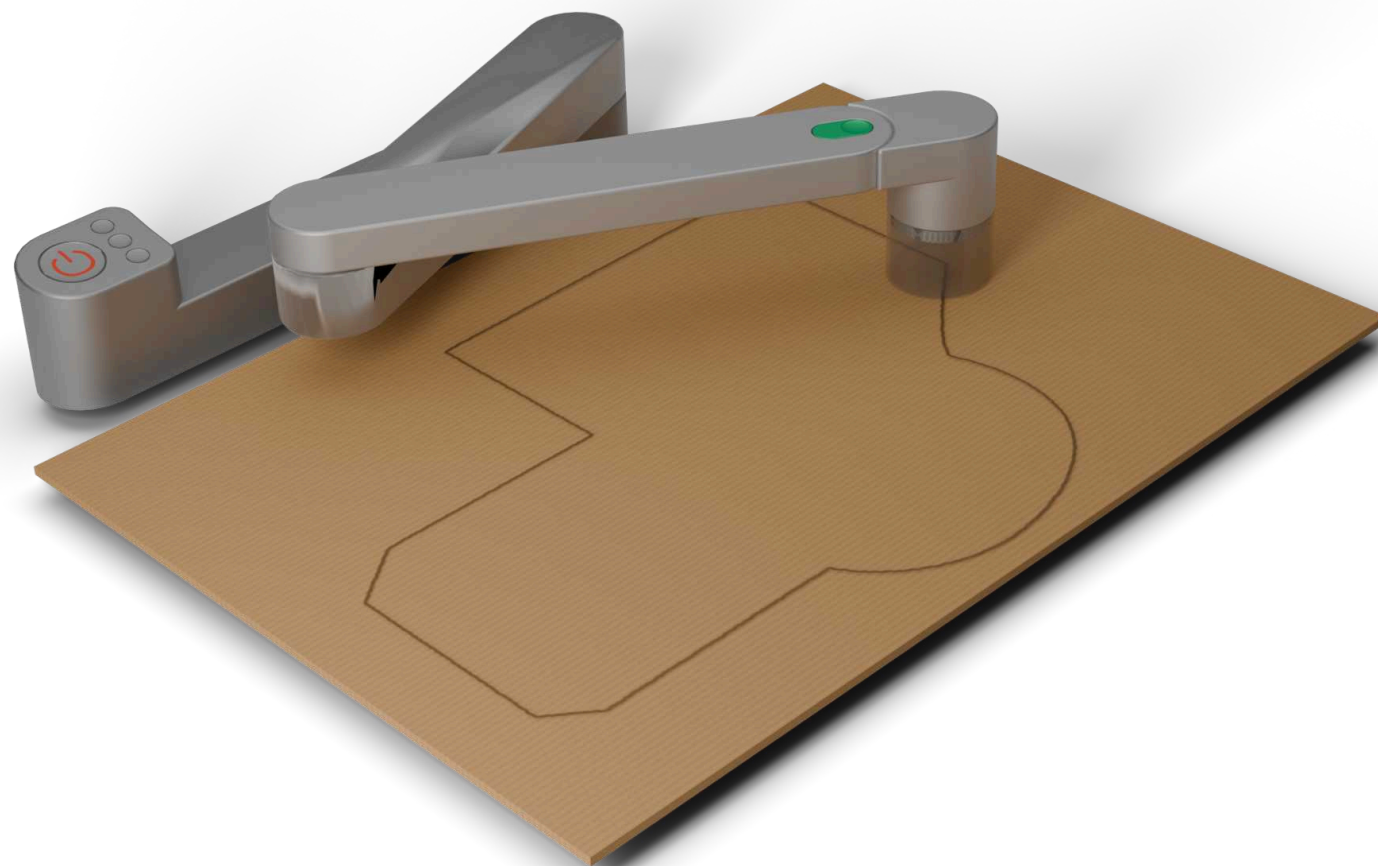


Gantt Chart

Force Calculations and Tests
Arm Mechanics
Code for Arm Movements
Latching Mechanism
Arm Casings
Cutting Head
Tracing Head
Base and Clamping
Controls and Finishing



Morphological Analysis Outcome

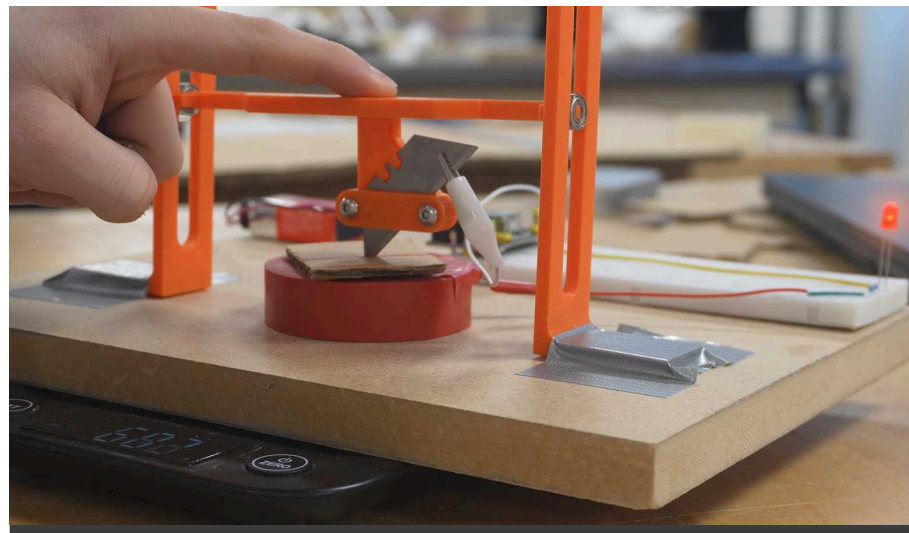


Requirements and Specification

Subsystems	Requirements	Specification
Movement and Arm	Move both heads accurately across an A3 workspace	420 × 297 mm reach, ±1 mm accuracy, low backlash and limited deflection.
Cutting Head	Cut cardboard cleanly and safely.	Sufficient cutting force, blade guard, vertical retraction and blade replacement
Tracing Head	Hold pens securely and record the path accurately.	Fits common pens, minimal play and quick attachment.
Latching Mechanism	Secure and release interchangeable heads.	Tool-free latch with accurate alignment and repeatable retention.
Base and Clamping	Prevent movement during use.	Fits common benches, supports left or right clamping.



Piercing Force

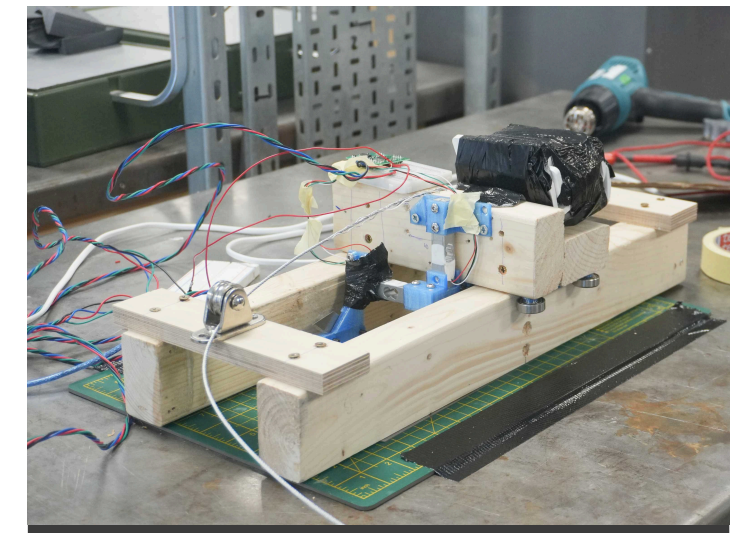


A custom test rig measured the force needed to pierce cardboard. The scale recorded the force, while an LED lit when the blade broke through.

Drag Force

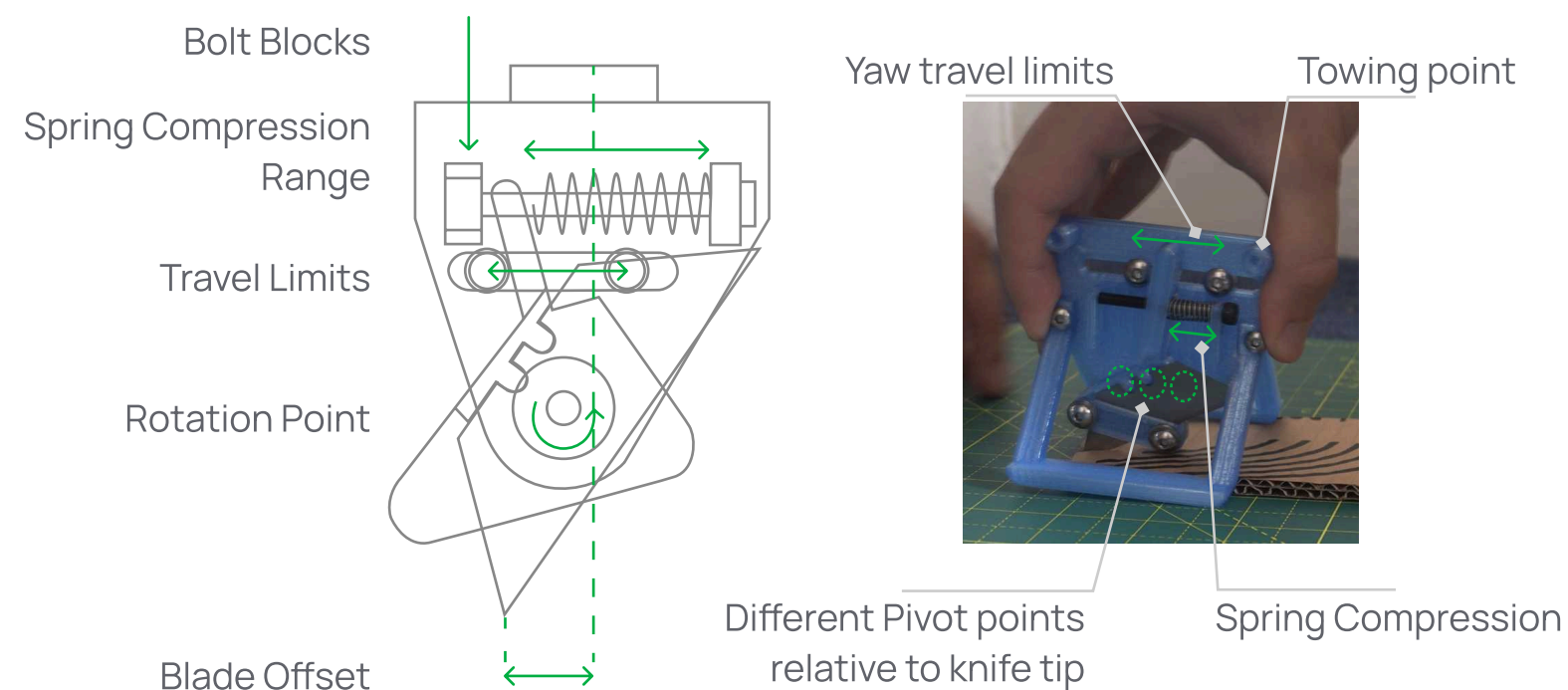


The weighted blade rig was pulled through cardboard using a Newton meter to measure the drag force during cutting.

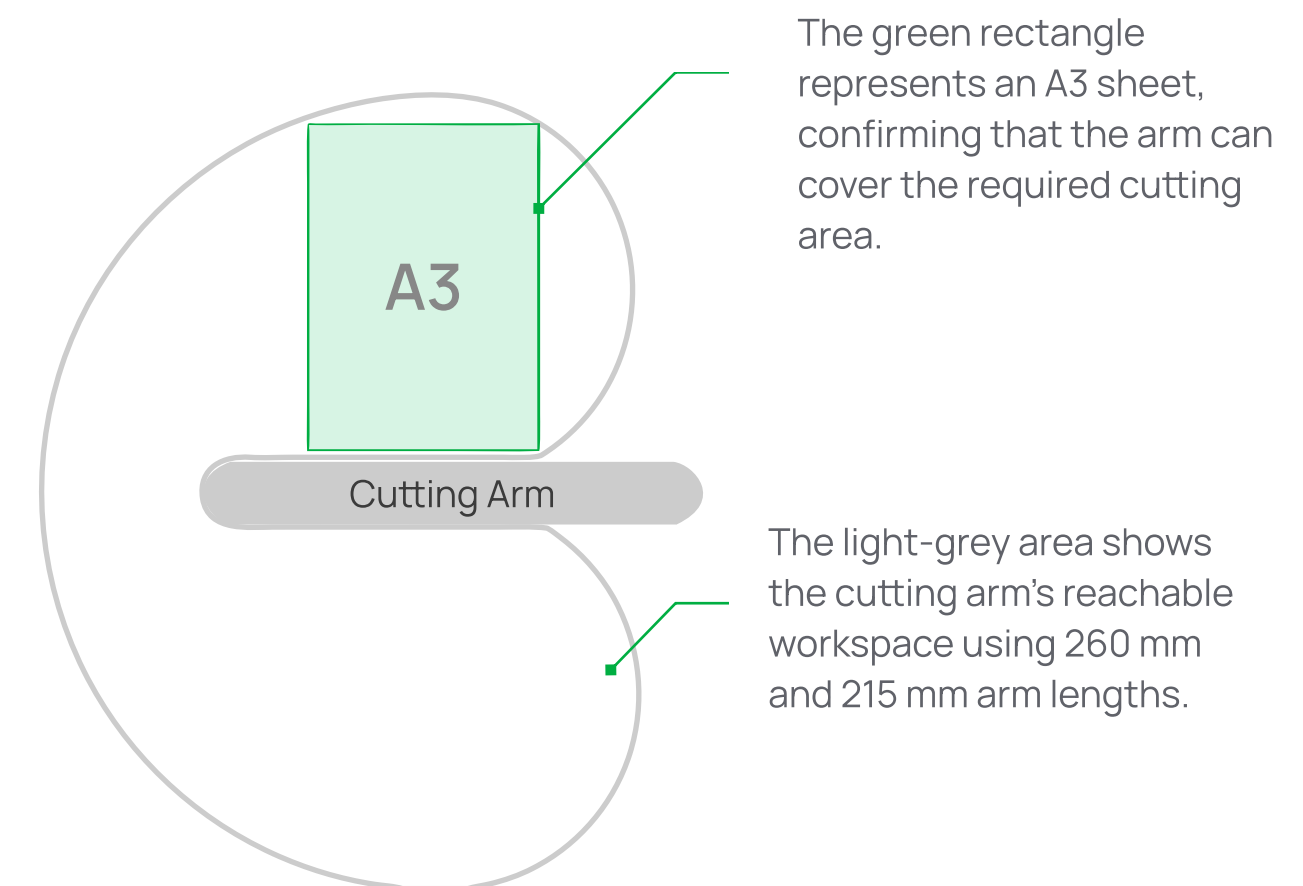


A second rig using load cells was then developed to obtain more accurate and consistent force measurements.

Suspension System

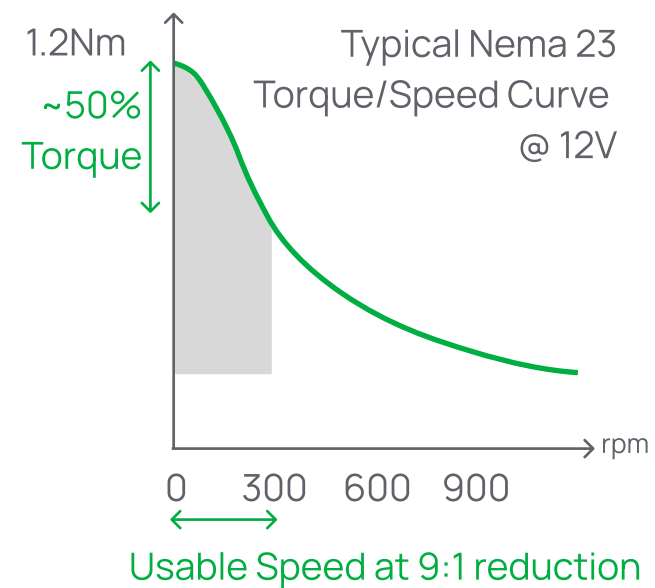


Arm Reach



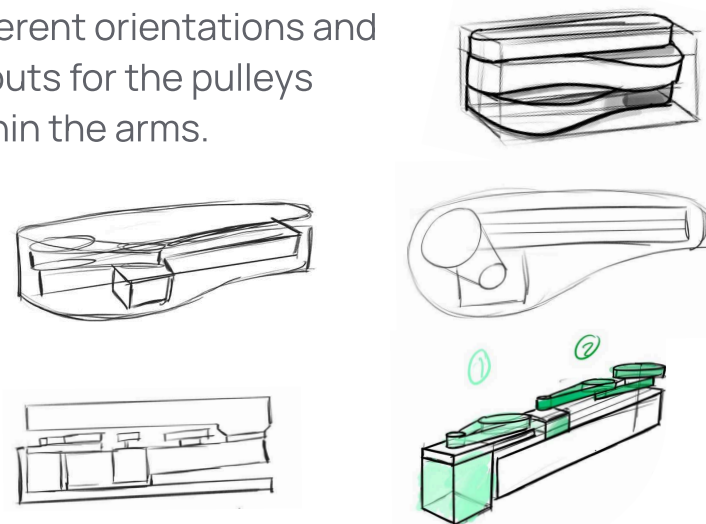


Looking at Motors



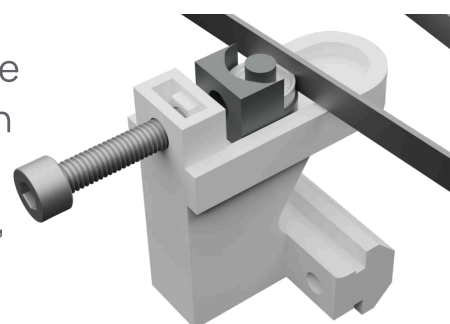
Further Form Iteration

Different orientations and layouts for the pulleys within the arms.

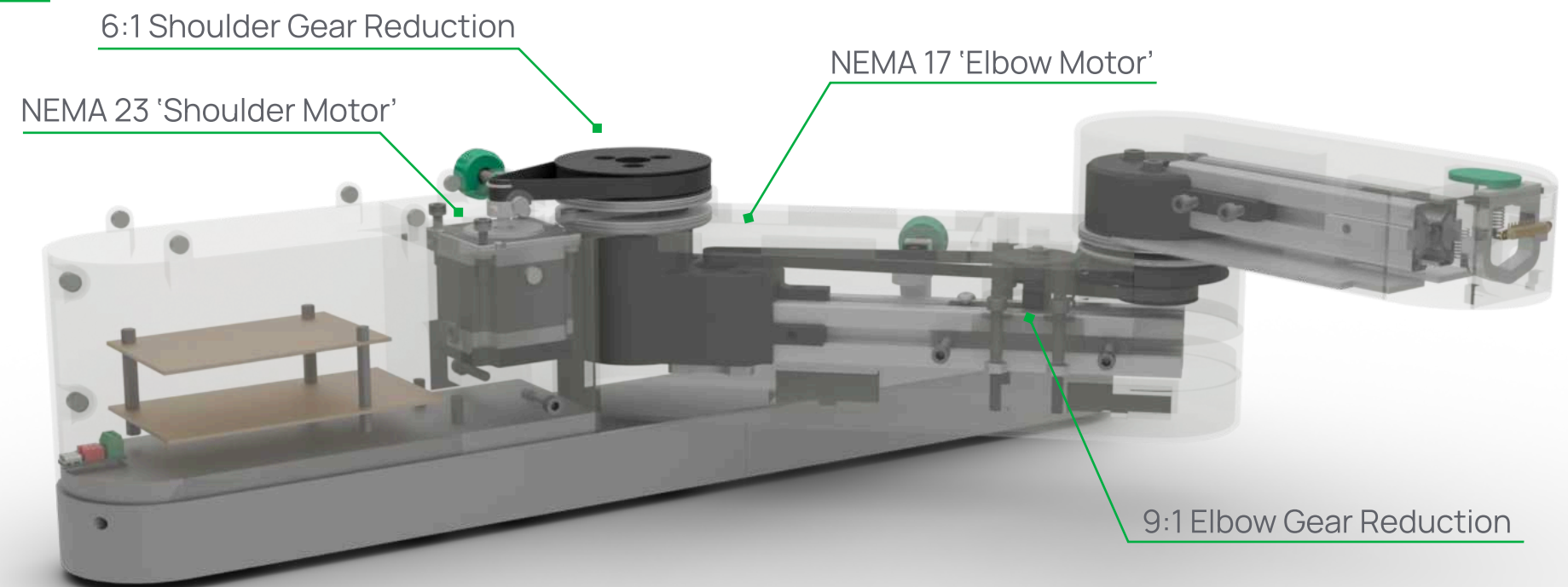


Belt Tensioners

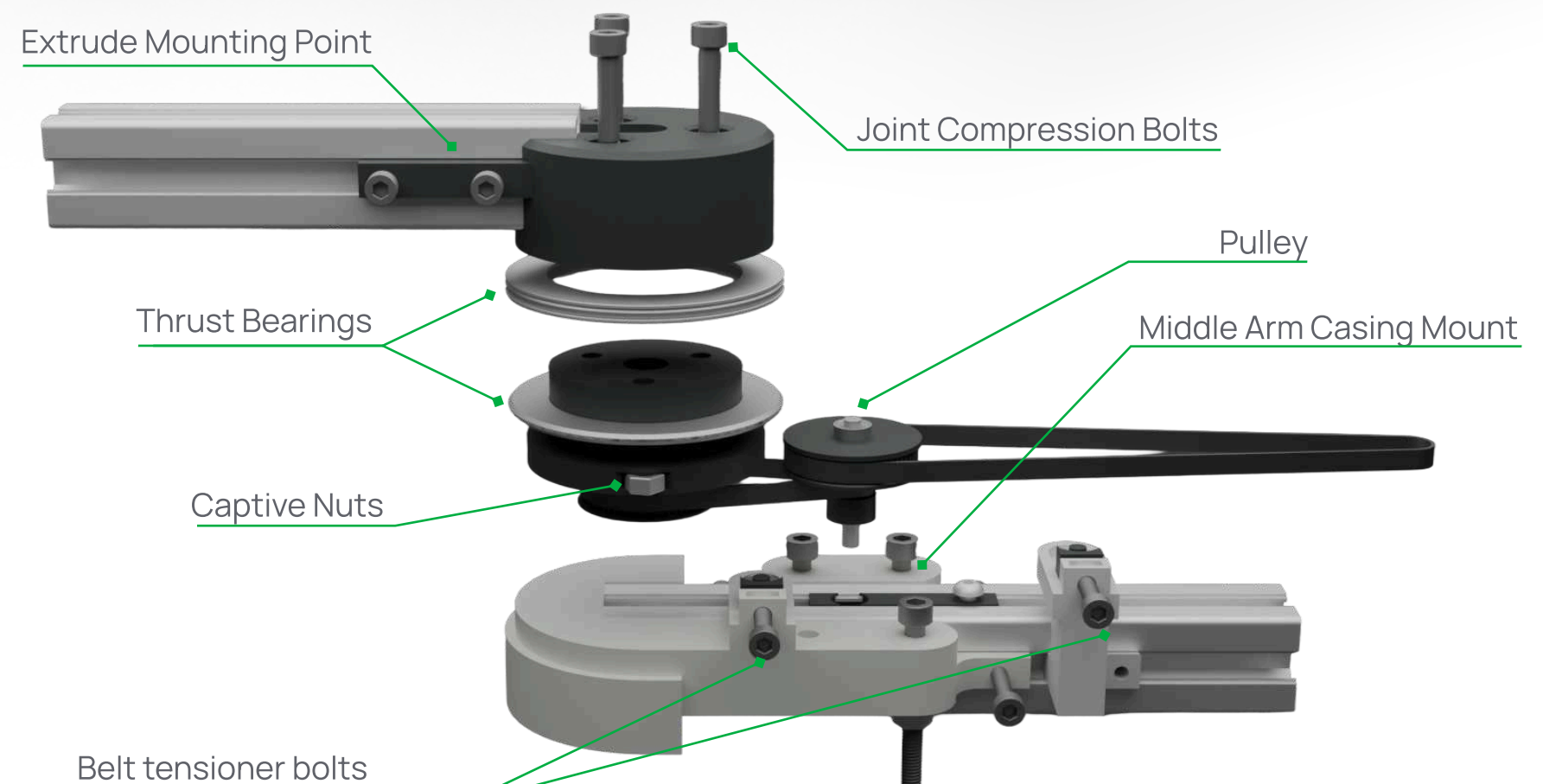
Belt tensioners remove slack, reduce backlash and prevent tooth skipping for smoother, more accurate movement.



Final Arm



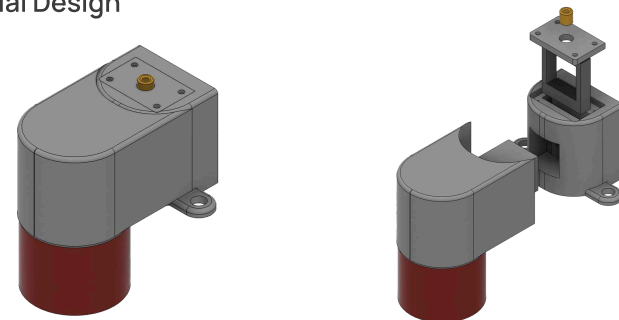
Extrude Mounting Point



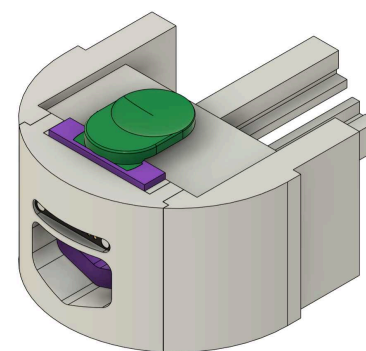


Latching Mechanism

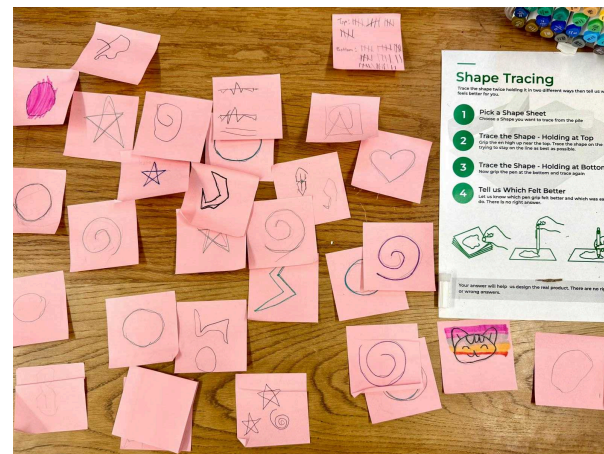
Initial Design



Final Design

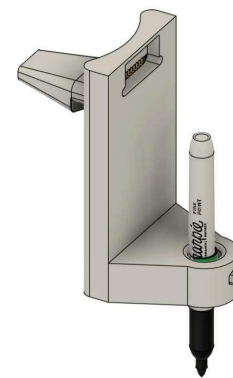


Tracing Head



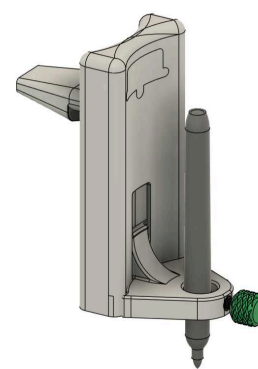
GERF shape-tracing activity testing preferred pen grip position.

Initial Design



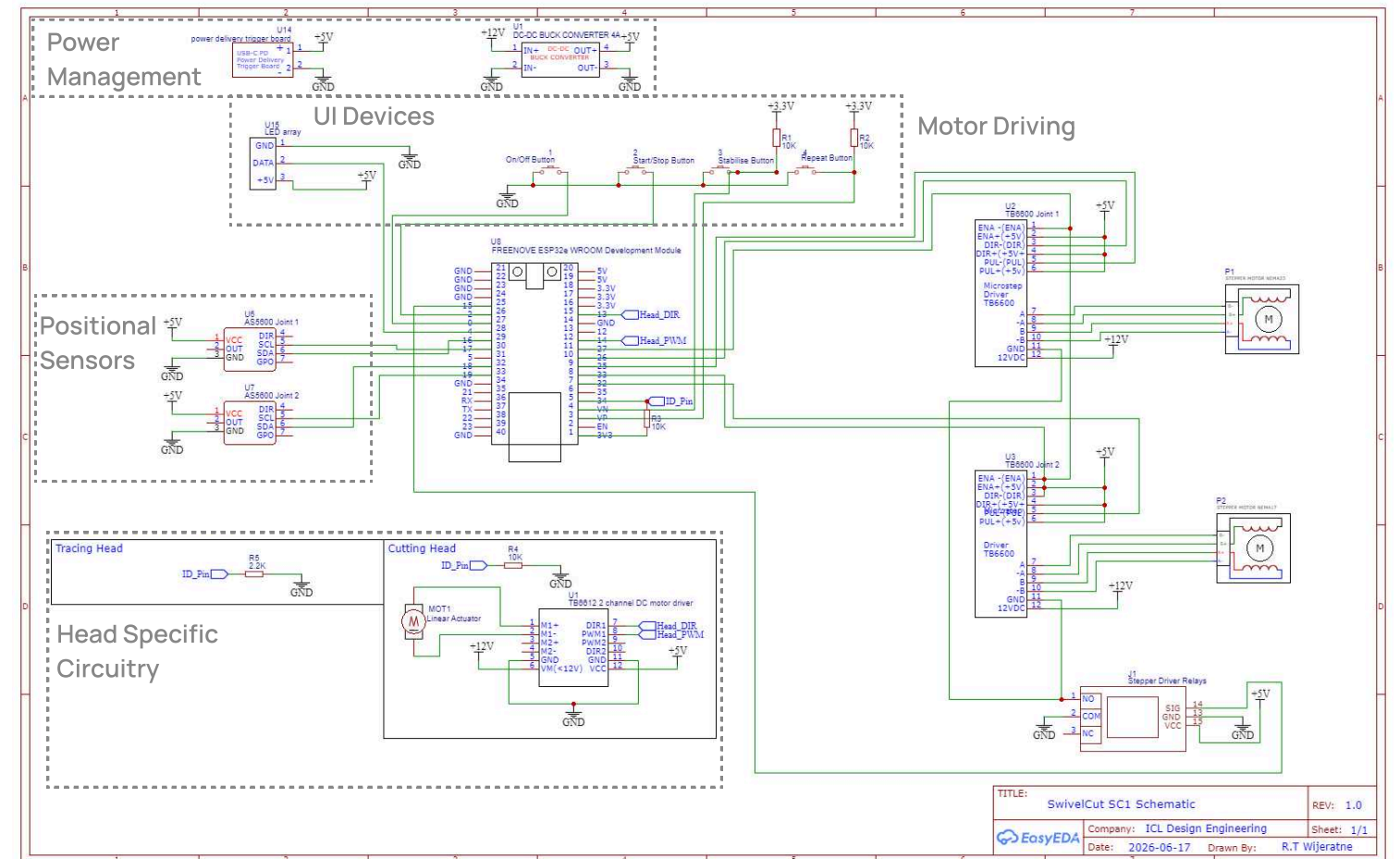
Fixed pen held at the bottom

Final Design

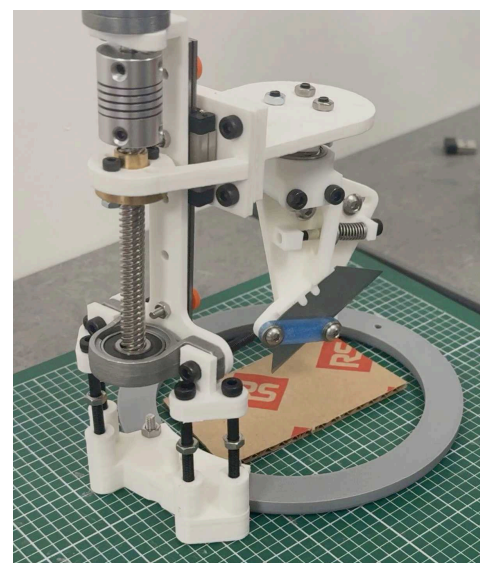


The pen can be fixed at the bottom or middle for greater flexibility.

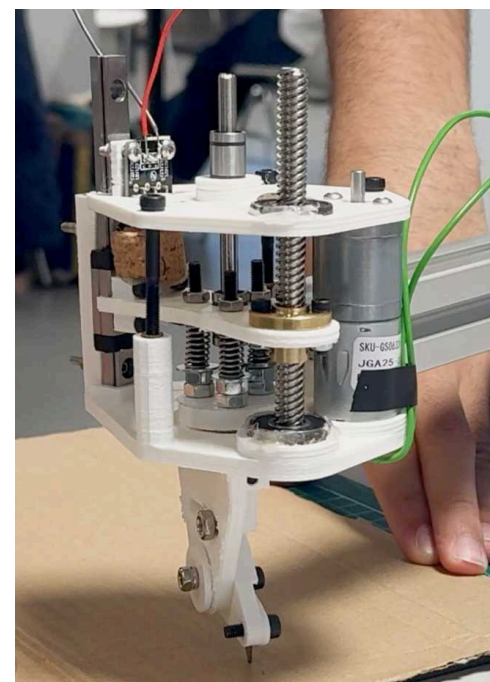
Circuit Diagram



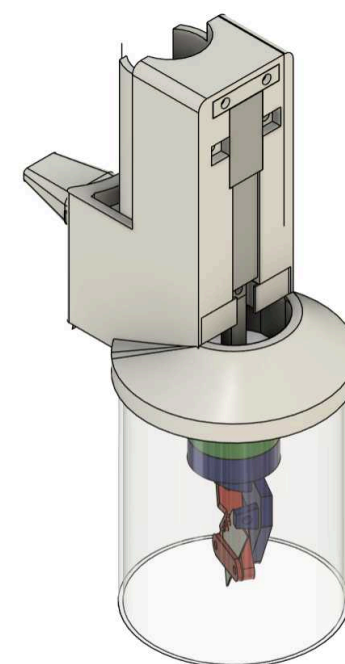
Cutting Heads



Initial Design



First Iteration



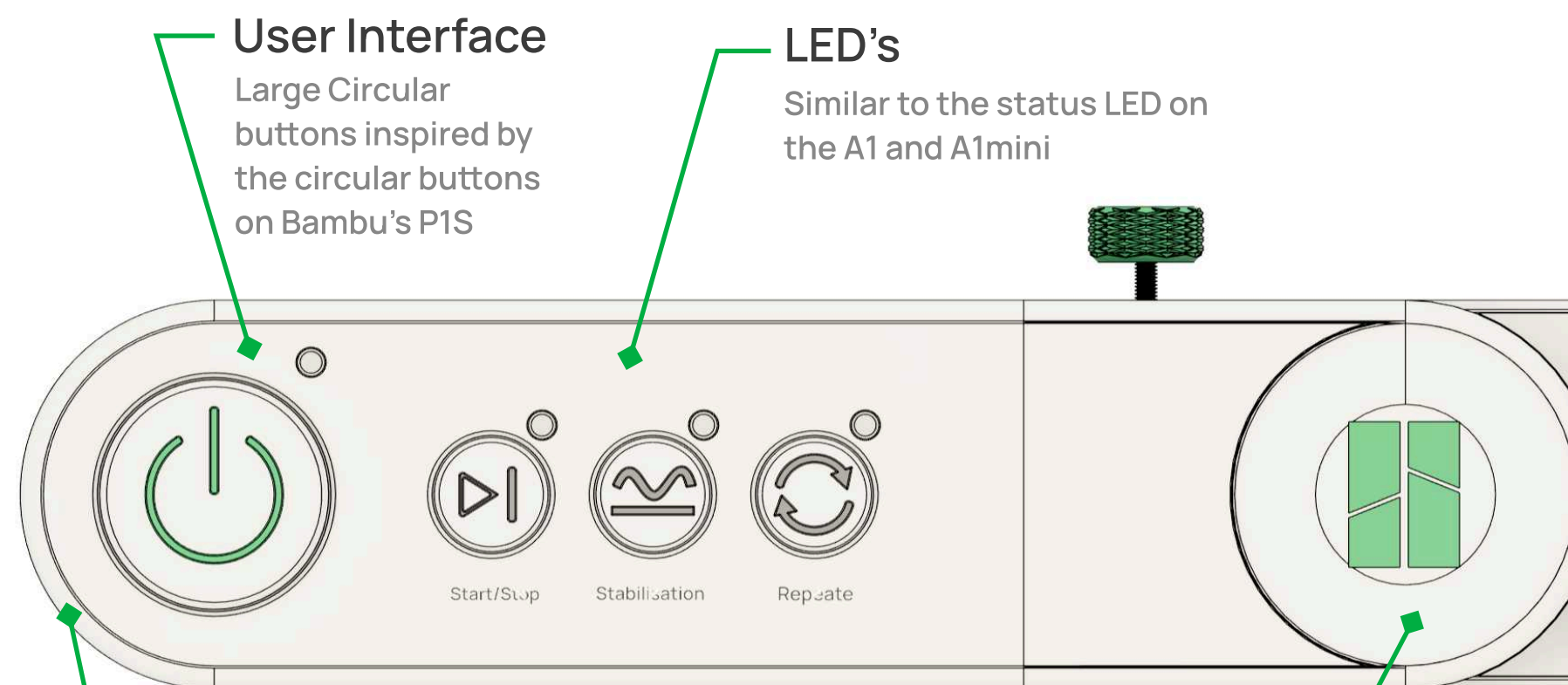
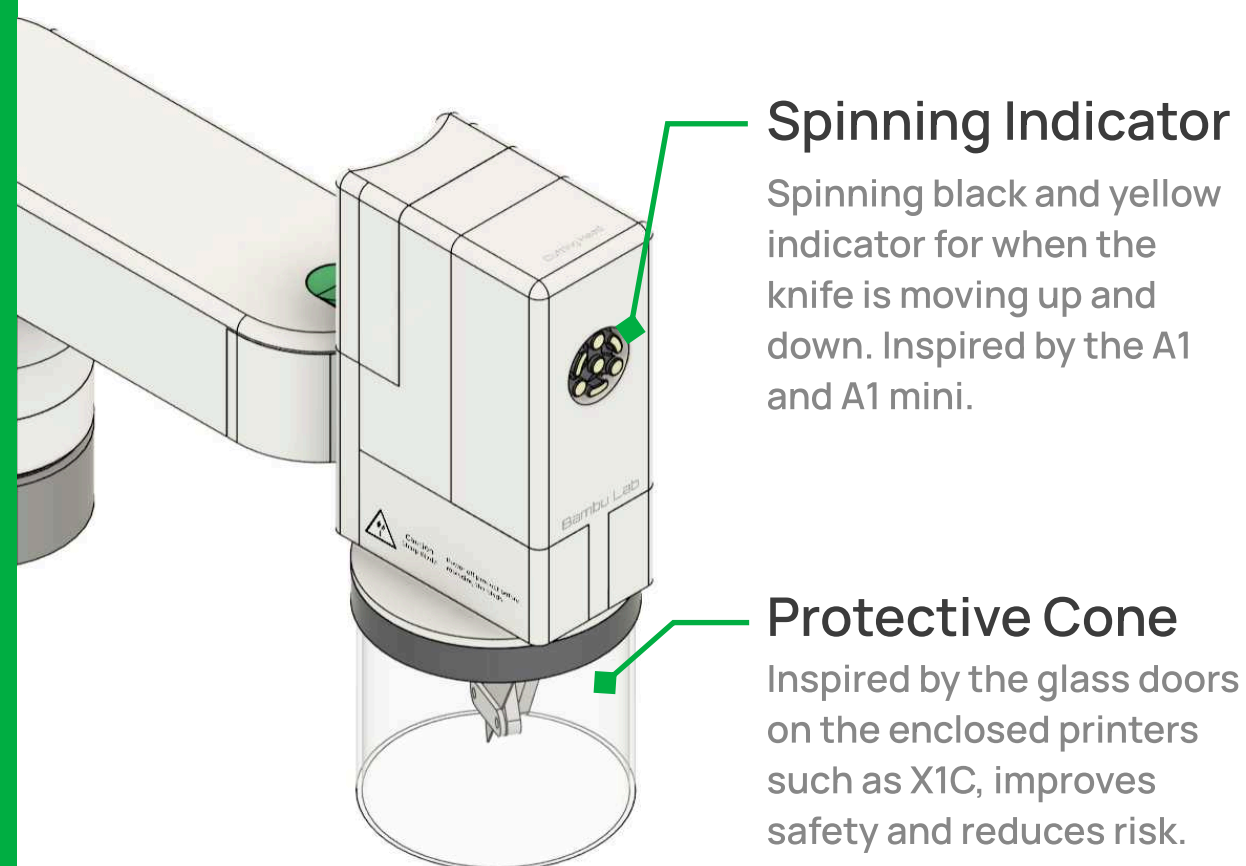
Linear Actuator Iteration



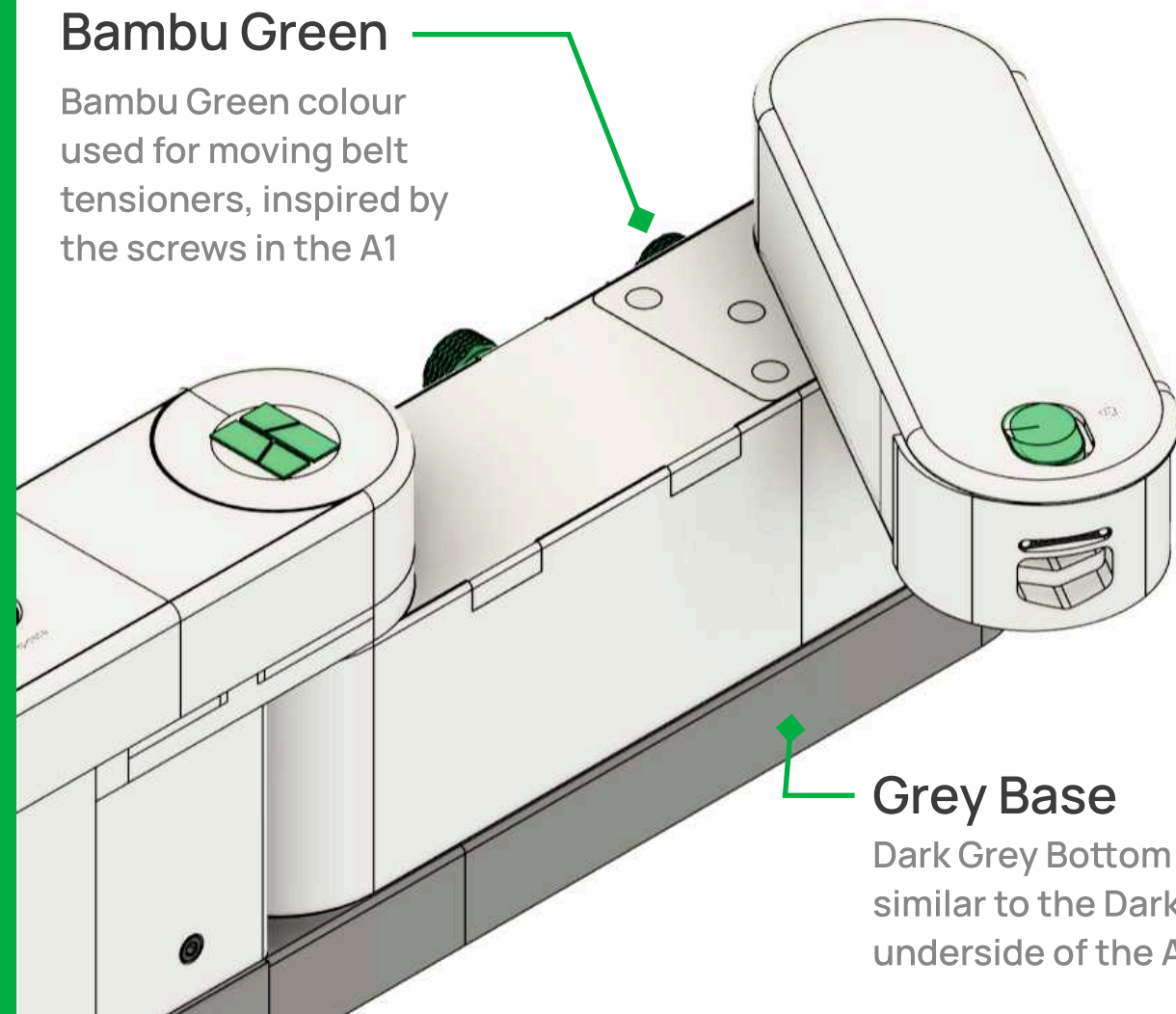
Final CAD Render



Final Design



Bambu Green
Bambu Green colour used for moving belt tensioners, inspired by the screws in the A1



Rounded Edges

Filleted corners similar to all bambu printers and makes the product less intimidating to use

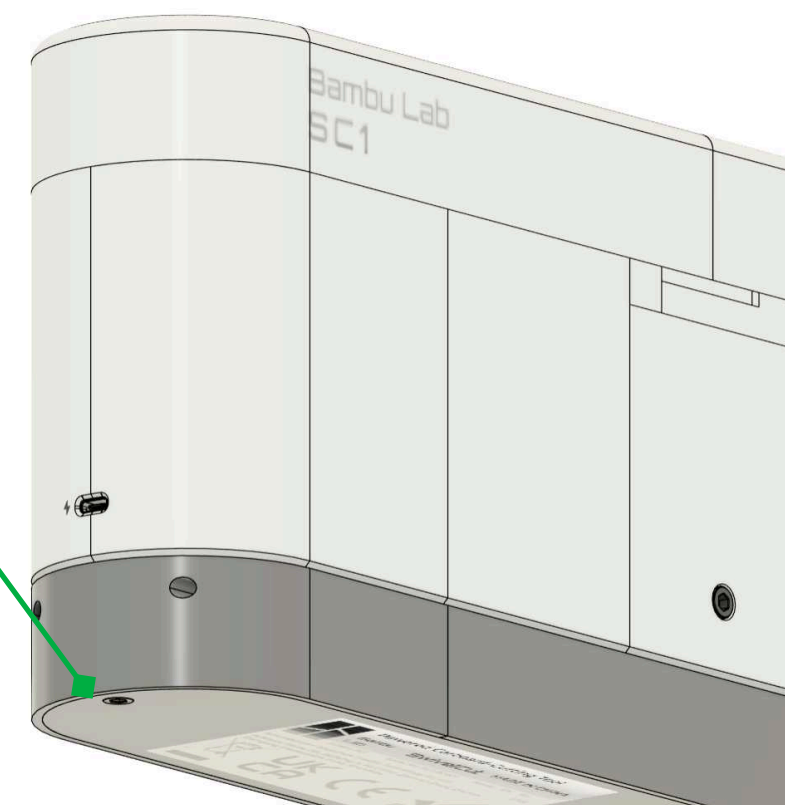
Logo

Large Bambu Lab logo on the product

Bambu Lab
SwivelCut

Disassembly

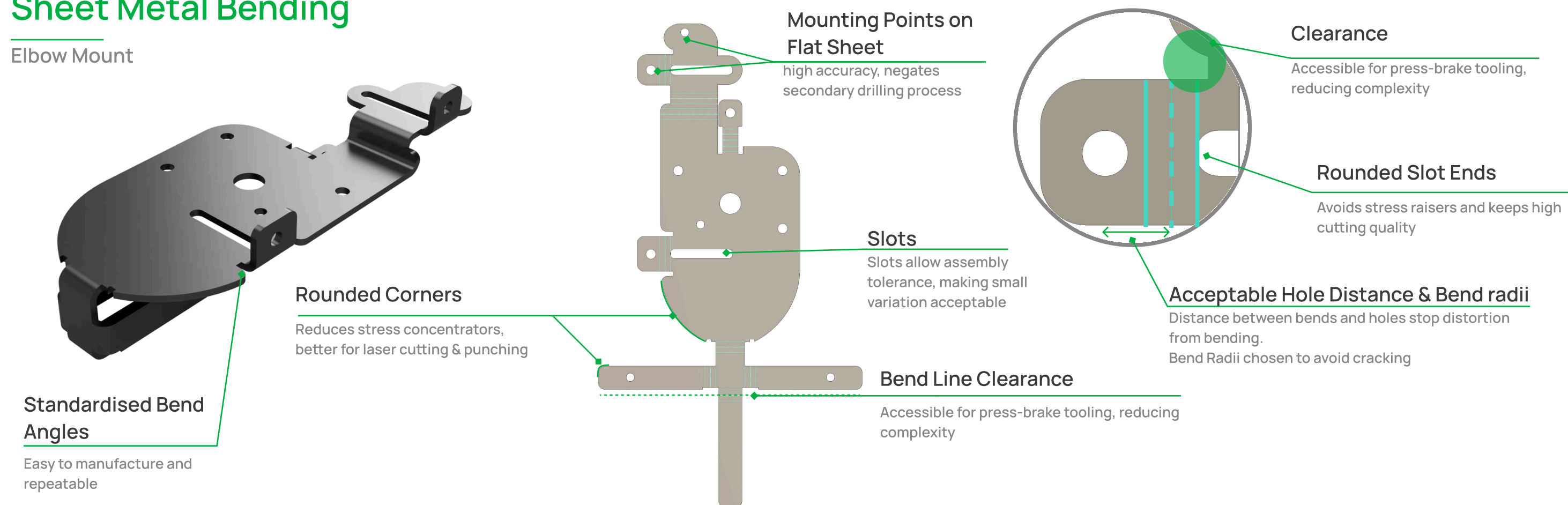
Bolts make the entire product disassemblable and reparable similar to the Bambu Lab 3d printers





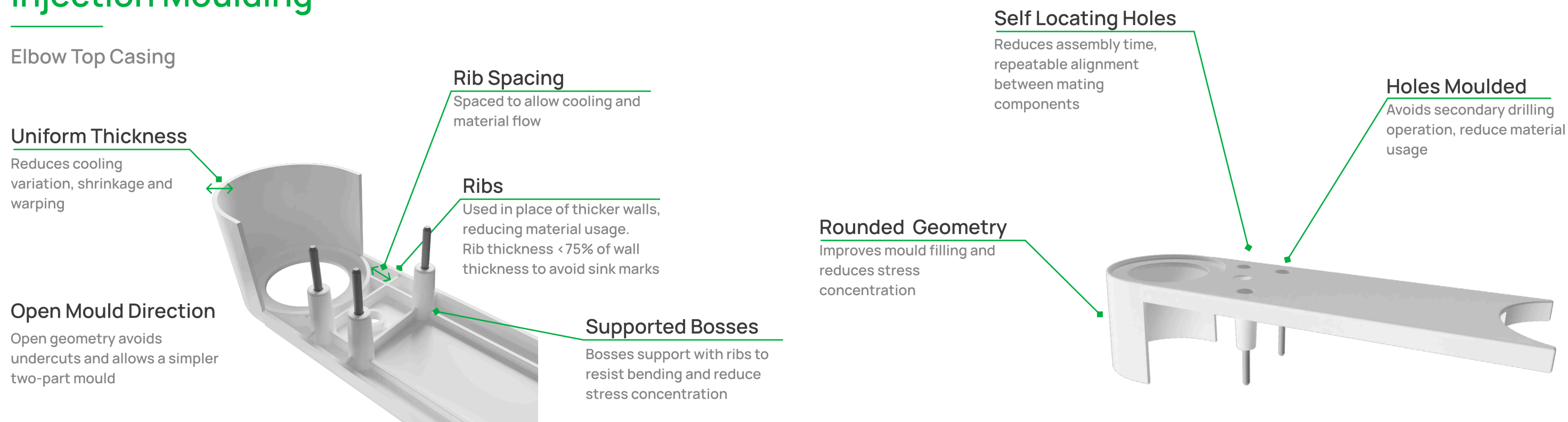
Sheet Metal Bending

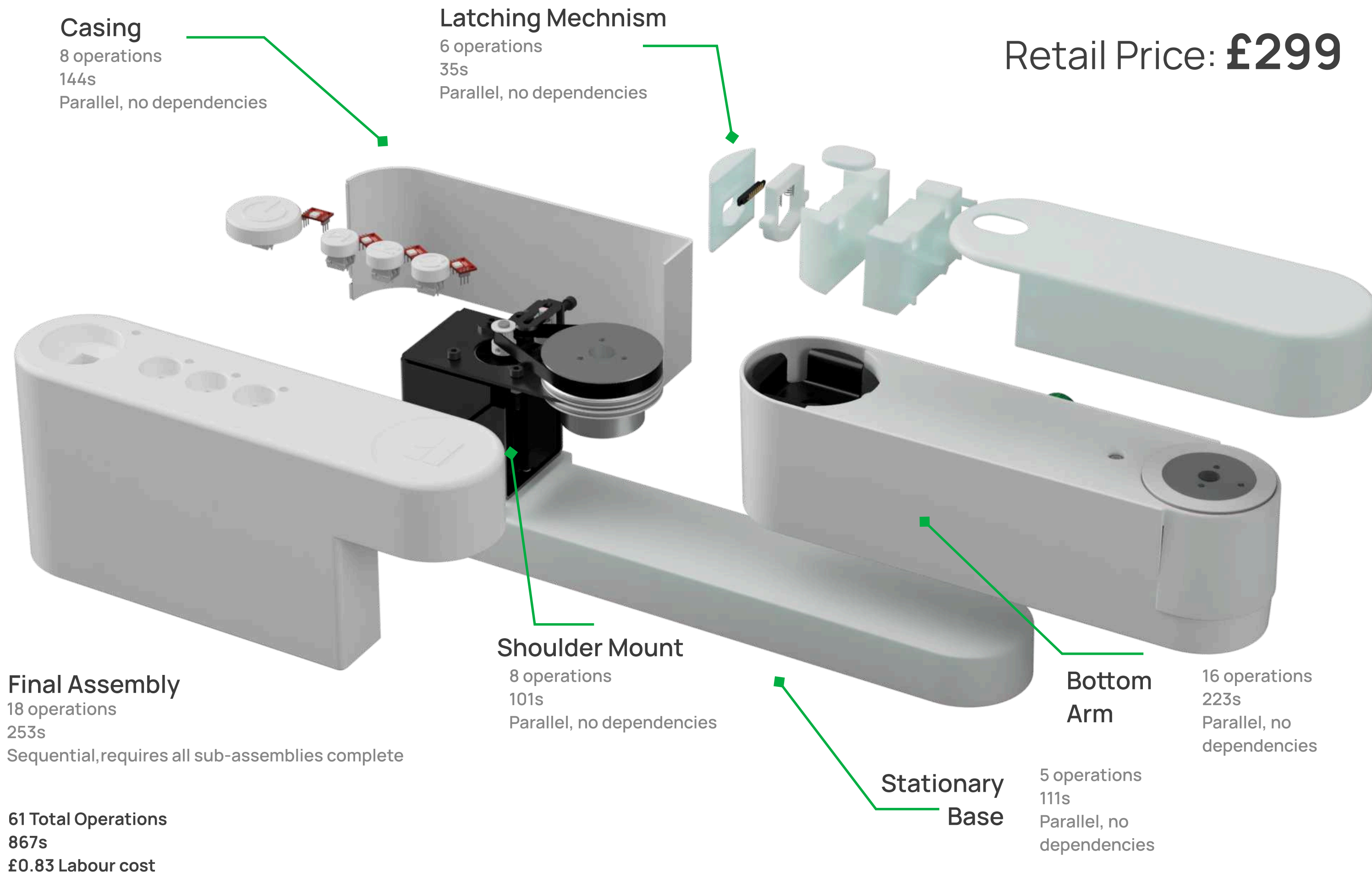
Elbow Mount



Injection Moulding

Elbow Top Casing





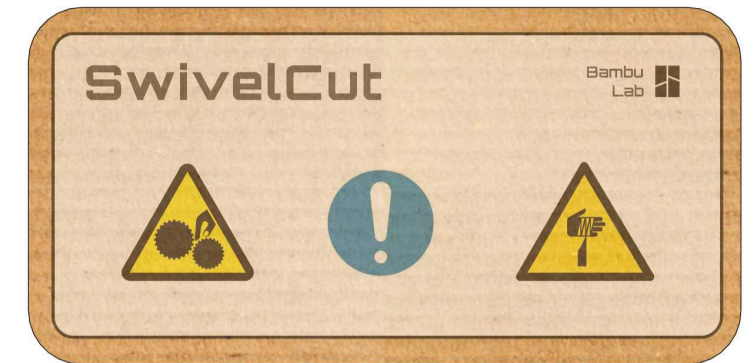


Product Labels



Packaging

The plastic-free packaging uses recycled cardboard boxes for each component, paper padding where needed, and nests all smaller boxes inside the main outer box.

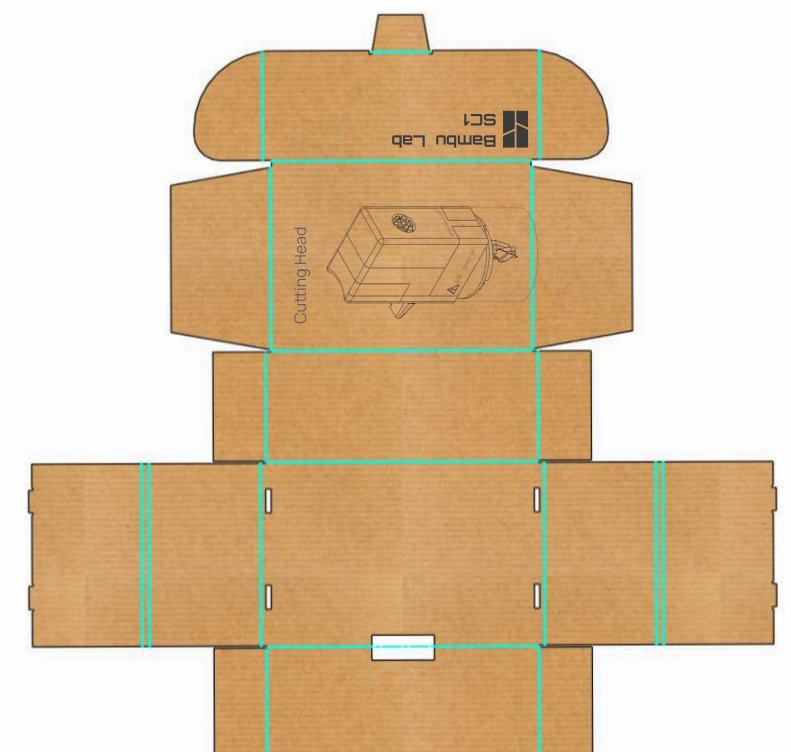


Two safety placards are supplied with every SwivelCut. One for hazards and another for reminder of how to use the machine.

- SwivelCut**
1. Place SwivelCut at the edge of a workbench and clamp it down securely.
 2. Clamp the cardboard and cutting mat in front of the tool.
 3. Unfold the arms and attach the tracing head.
 4. Press Start, draw the design, press Stop to save the path.
 5. Replace the tracing head with the cutting head, select stabilisation if needed, and press Go.
 6. Keep hands, hair and loose clothing away while cutting.
 7. Remove the finished shape. For an identical copy, insert new cardboard and press Repeat.



The internal cardboard boxes use interlocking folds rather than glue or staples, allowing them to be easily unfolded after unpacking and reused as prototyping material instead of becoming immediate packaging waste.



Powered Carboard-Cutting Tool

Bambu
Lab

SwivelCut

MADE IN CHINA

Model: SC1

Serial No: SC1-00001

Input: 12V 5A

Manufacturer: Shenzhen Tuozhu Technology Co, Ltd

2026

Address: Room 201, Building A, No.1 First Qianwan Road, Qianhai Shengang Cooperation Zone, Shenzhen



**UK
CA**

CE





3. Tracing Head Component Introduction

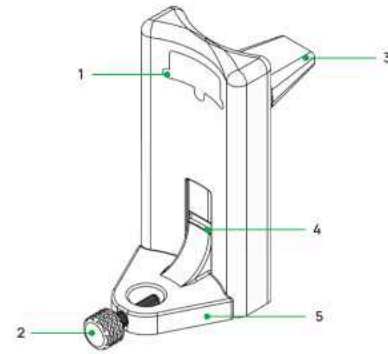


Figure 3

- 1. Pogo Pins
- 2. Thumb Screw
- 3. Arm Insert
- 4. Sliding Mechanic
- 5. Sliding Base

4. Cutting Head Component Introduction

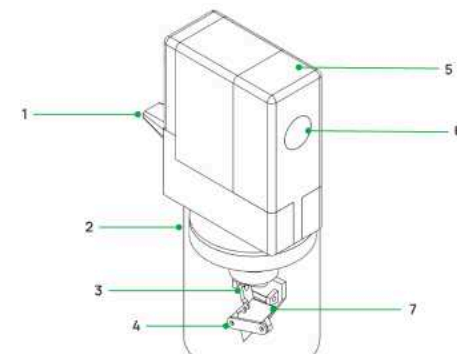
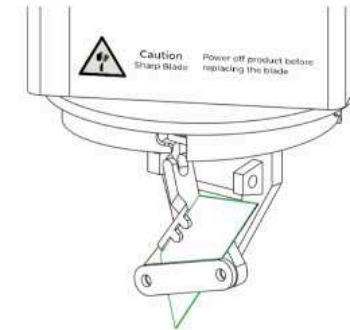


Figure 4

- 1. Arm Insert
- 2. Safety Cone
- 3. Spring Suspension
- 4. Knife Plate
- 5. Magnetic Front
- 6. Cutting Indicator
- 7. Stanley Blade

10. Regular Maintenance

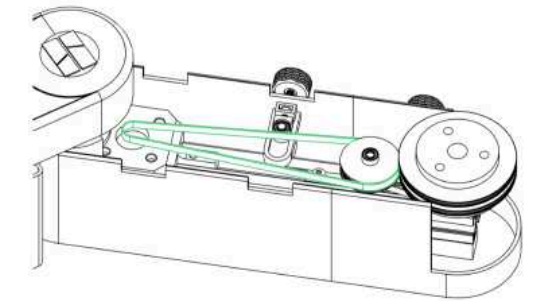


The knife blade will need replacing when dull. Twist off the safety cone and unscrew the bolts to replace the blade.

Warning: Blade is sharp. Turn off the power completely before attempting to replace the blade.

23

10. Regular Maintenance



The Belts will need lubrication and tightening periodically. This can be done by unscrewing the top casing and revealing the belts. If they have worn down, they may need replacing. Watch the full belt replacing video on the Bambu Lab website.

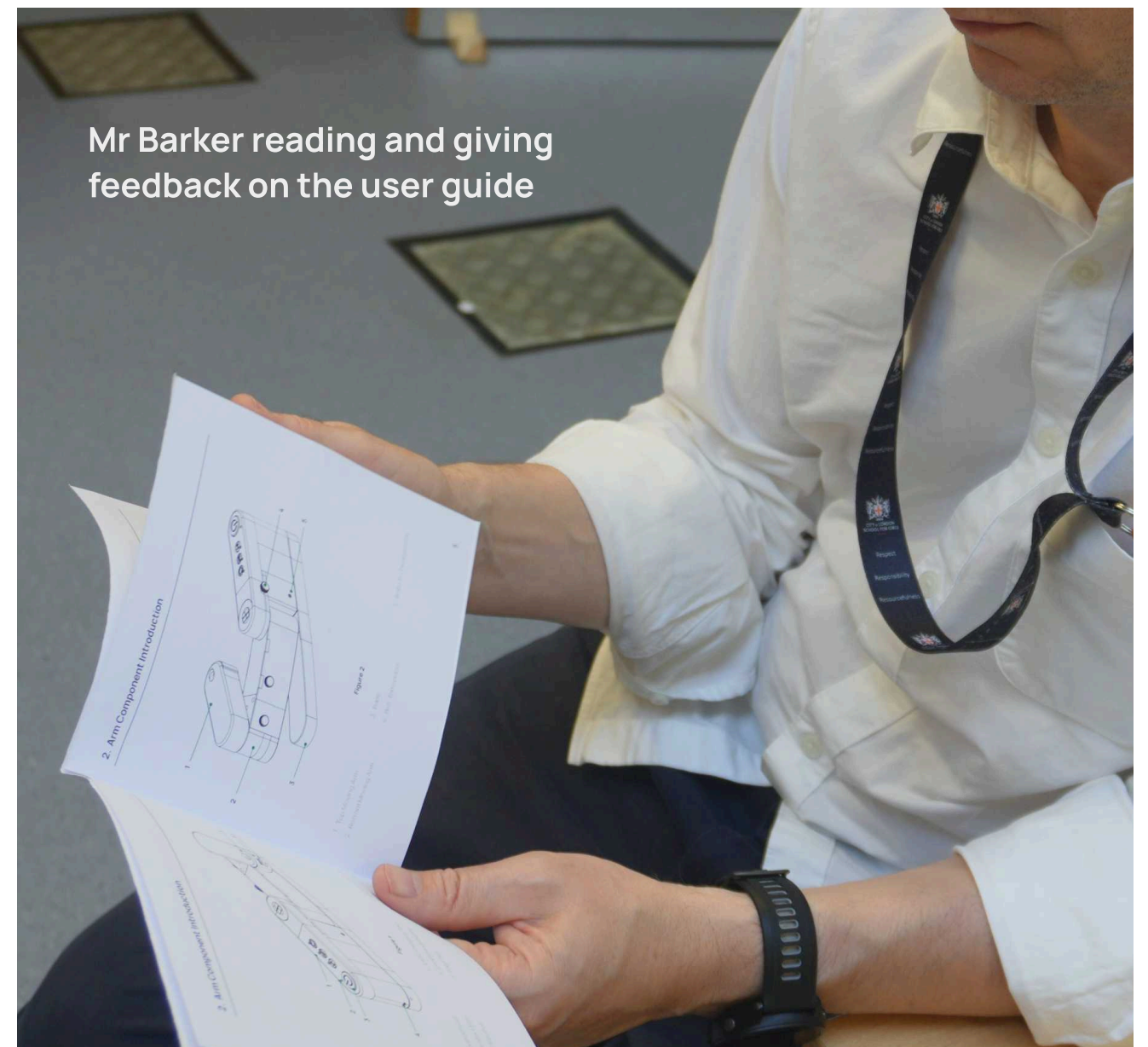


24



7

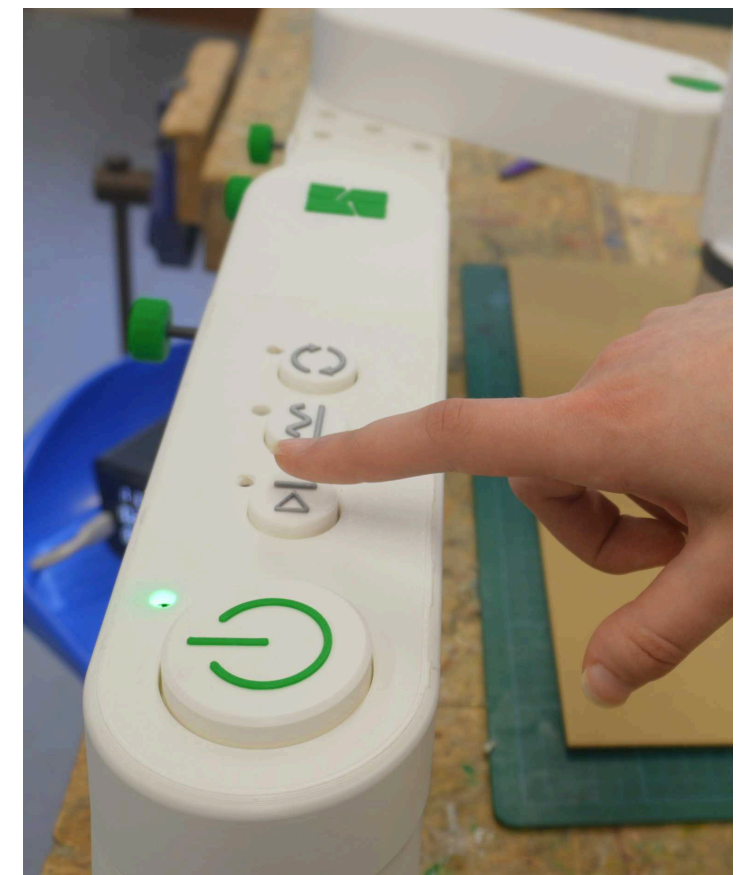
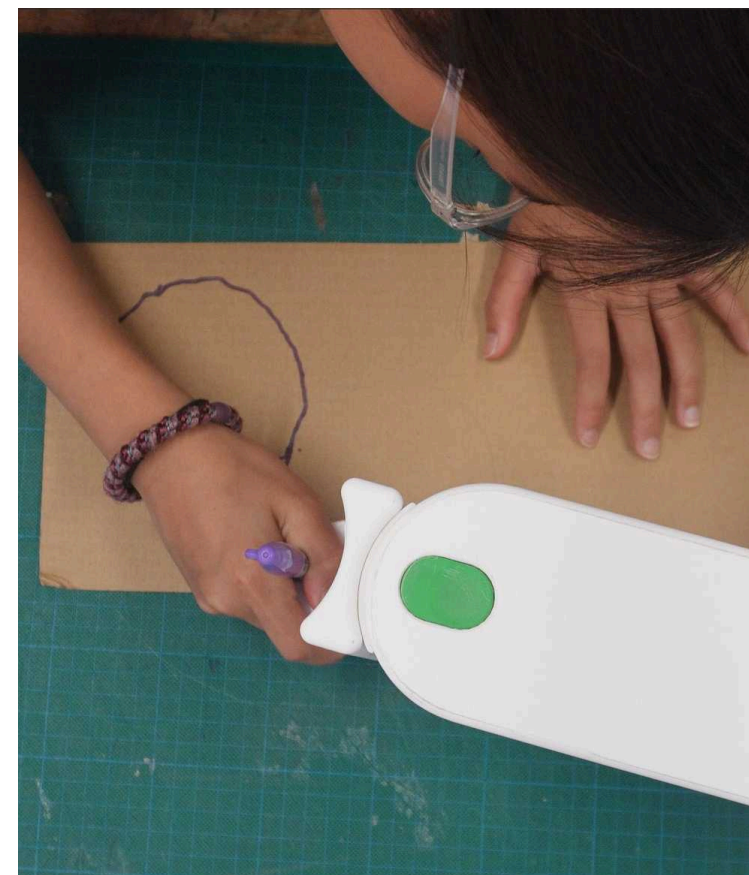
Mr Barker reading and giving feedback on the user guide

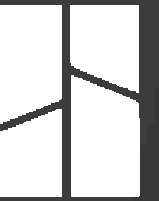




User testing was conducted over two days at City of London School for Girls with 18 DT students from Years 7-12.

Students tested the setup, tracing process, interchangeable heads and controls, helping identify areas for final refinement.





SwivelCut

