Final Design Report

Sharky Lenny - Biomimetic Autonomous Waterborne Craft

ELE218 - Group 8 | University of Sheffield

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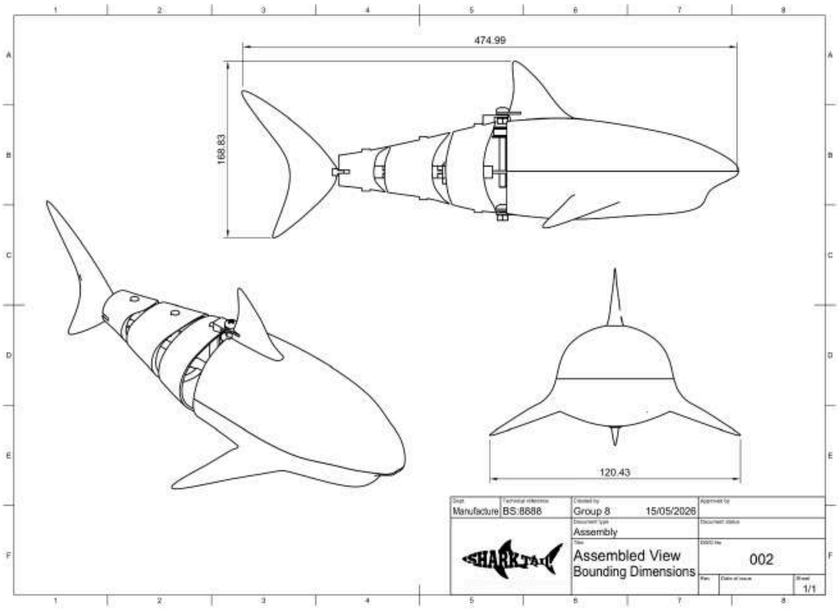
1 Abstract

Sharky Lenny is a biomimetic autonomous waterborne craft designed in response to Doddington City Council's Project Poseidon brief. The craft aims to navigate polluted rivers and water pipes to assist with environmental monitoring, targeting pipe leaks and watercourse contamination resulting from the city's aging infrastructure and flooding from Storm Jonny. Motion is provided by an oscillating tail mechanism inspired by shark movement, avoiding rotating components that risk debris entanglement. The Shark is made up of a 475 mm ABS body, which houses a watertight acrylic electronics enclosure, containing a microcontroller, ultrasonic sensors, servo motor, and radio antenna powered by a 7.2V battery. This includes a synchronous belt drive converting servo rotation into undulating tail motion. The design has been developed with mass production in mind with approximately 4000 units per year projected to be made via injection moulding. A modular architecture allows for future sensor retrofitting, routine maintenance, and easy end-of-life disassembly which greatly contributes to the environmental positives of this design.

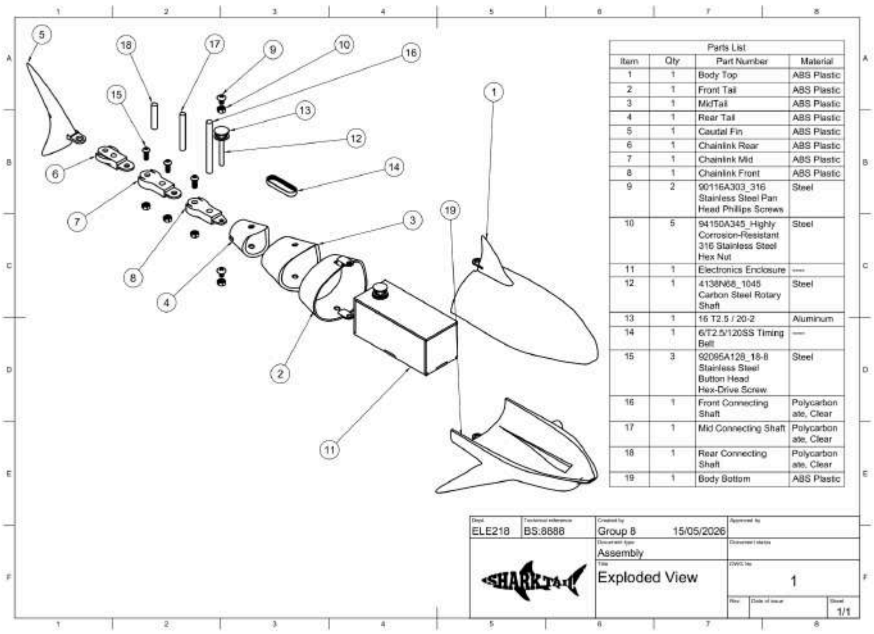
2 Design Drawings

Notes: The shell is a Fusion 360 Form-tool (T-Spline surface). In line with manufacturer's recommendation and BS 8888, the drawing follows a Model-Based Definition approach: the 3D CAD file is the master and the drawing is provided for reference and inspection. Component technical drawings appear in Appendix A. See below for linked resources.

Body Turntable	Assembly Video	STEP Files	Draft Analysis



[Fig 1] Technical Drawing displaying assembled view containing bounding/overall dimensions



Parts List			
Item	Qty	Part Number	Material
1	1	Body Top	ABS Plastic
2	1	Front Tail	ABS Plastic
3	1	MidTail	ABS Plastic
4	1	Rear Tail	ABS Plastic
5	1	Caudal Fin	ABS Plastic
6	1	Chainlink Rear	ABS Plastic
7	1	Chainlink Mid	ABS Plastic
8	1	Chainlink Front	ABS Plastic
9	2	90116A303_316 Stainless Steel Pan Head Phillips Screws	Steel
10	5	94150A345_Highly Corrosion-Resistant 316 Stainless Steel Hex Nut	Steel
11	1	Electronics Enclosure	----
12	1	4138N68_1045 Carbon Steel Rotary Shaft	Steel
13	1	16 T2.5 / 20-2	Aluminum
14	1	6/T2.5/120SS Timing Belt	----
15	3	92095A128_18-8 Stainless Steel Button Head Hex-Drive Screw	Steel
16	1	Front Connecting Shaft	Polycarbonate, Clear
17	1	Mid Connecting Shaft	Polycarbonate, Clear
18	1	Rear Connecting Shaft	Polycarbonate, Clear
19	1	Body Bottom	ABS Plastic

[Fig 2] Technical Drawing displaying assembly view with parts list

3 Bill of Materials

Notes: Costs are estimated using bulk order prices and display exclusively the cost of components and raw materials - manufacture cost is not included. Where bulk prices were not publicly available, an assumed discount of 20% has been applied.

BOM	Component	Material / Spec	Qty	Recommended Supplier / Model	Unit £	Total £
01	Body Half (T)	ABS, injection moulded	1	Contract Casting	0.52	0.52
02	Body Half (B)	ABS, injection moulded	1	Contract Casting	0.64	0.64
03	Tail Front Segment	ABS, injection moulded	1	Contract Casting	0.34	0.34
04	Tail Mid Segment	ABS, injection moulded	1	Contract Casting	0.25	0.25
05	Tail Rear Segment	ABS, injection moulded	1	Contract Casting	0.18	0.18
06	Tail Fin	ABS, Injection moulded	1	Contract Casting	0.18	0.18
07	Bolt, M6	Stainless Steel, SC	5	ACCU: HPN-M6-A4	0.05	0.25
08	Nut, M6	Stainless Steel, SC	5	ACCU: HPN-M6-A4	0.05	0.25
09	Front Connecting Shaft	ABS Dowel	1	Contract Manufacturer	0.14	0.14
10	Mid Connecting Shaft	ABS Dowel	1	Contract Manufacturer	0.12	0.12
11	Rear Connecting Shaft	ABS Dowel	1	Contract Manufacturer	0.10	0.10
12	Timing Belt	Polyurethane	1	RS: 474-4984	5.52	5.52
13	Pulley	Aluminium	2	RS: 236-2789	4.49	8.98
14	Rotary Shaft	Steel	2	Contract Manufacturer	0.20	0.40
15	Servo Motor	Electronics	1	PiHut: SER0060	29.90	29.90
16	Sealed Bearing	Steel	1	RS: 618-9913	1.35	1.35
17	Rotary Seal	Nitrile Rubber (NBR)	1	RS: 229-5300	1.08	1.08
18	Bearing / Seal Housing	Polycarbonate	1	Contract Manufacturer	0.05	0.05
19	Flange	Steel	1	Contract Manufacturer	0.10	0.10
20	Printed Circuit Board (80x50mm)	Electronics	1	Contract Manufacturer	0.90	0.90
21	Microcontroller	Electronics	1	Farnell: STM32f103C8T6	4.29	4.29
22	Push Switch	Electronics	1	RS: 820-7552	3.12	3.12
23	7.2V NiMH Battery	Electronics	1	RS: 176-9352	21.74	21.74
24	Ultrasonic sensor	Electronics	2	RS: 215-3181	1.75	3.50
25	DC to AC converter	Electronics	1	RS: 873-2124	28.18	28.18
26	Radio Wave Antenna	Electronics	2	RS: 704-3439	20.87	41.74
27	Electronics Box	3mm acrylic, laser cut	1	Contract Laser Cutter	0.38	0.38
Total / unit £						**154.20**

Table 1 - A bill of materials that can be used to buy components for future production

4 Manufacture and Assembly Procedure

Procedure for a fleet of ~4000 units / year. Sub-heading numbers cross-reference BOM items and the exploded view. The shark body and tail segments are Fusion Form-tool surfaces and moulded directly from the master CAD; no geometry change required for production.

4.1 Body (BOM 01-11)

The body halves and tail segments are injection moulded in ABS using aluminium cavities and cores. The parting line follows the existing CAD split; a Fusion Draft Analysis has been completed to verify a ≥1° draft and 0.5-0.7% shrinkage allowance [1] (see above). The two pieces will then be bonded along the inner parting line using ABS solvent cement, and a clamp jig should hold this rigid for a full 24h cure. Tail segments are joined using an ABS dowel and the same cement. The body-to-tail joint uses M6 steel hex bolts and nuts as a serviceable interface for battery and electronics access. Selection by random sampling (1 in 20) for a 3D scan of the surface verifies the product against the master CAD model, requiring ≤0.5 mm deviation. Visual inspection is suitable for cement joint testing.

4.2 Drive (BOM 12-19)

The drive assembly is manufactured entirely using standard components to ensure a reliable power transfer. The servo motor is rigidly attached to a 6mm precision-ground stainless steel shaft via a flange coupling. This input shaft is supported by a sealed ball bearing and an NBR rotary shaft seal, both press-fitted (0.02-0.04 mm interference) [2] into a polycarbonate tube, housed in the ceiling of a durable acrylic box to maintain a waterproof barrier. The seal is pressure tested up to 0.5 bar for 60s (5m water submersion distance) before installation to ensure no leaks. Torque is transmitted from the input shaft to the output shaft using a timing belt and a pair of pulleys featuring D-profile holes for high-torque output. The proximal rotation of the output shaft drives the first segment of the tail. The subsequent segments are driven through the kinematic linkage to produce the oscillatory motion.

4.3 Electronics (BOM 20-27)

The electronics, housed in a watertight acrylic enclosure, consists of a printed circuit board (PCB) with a microcontroller, manual switch, sensor headers, antenna connector, servo driver and DC-DC buck converter. The PCB is wave soldered [3] with the battery, 2 sets of ultrasonic sensors, DC to AC converter, radio wave antenna, and a waterproof servo motor. This will be done so that the battery is in series with the manual switch and in parallel with each of: the microcontroller, servo motor, sensors, and radio wave antenna via the DC to AC converter. There will also be connections between the microcontroller pins and the servo motor, sensors, and radio antenna (as shown in Appendix B) in order for it to control the movement and communication of the craft.

4.4 Final Assembly and Test

The acrylic enclosure is laser-cut (bridle joint, 0.18mm kerf compensation) [4], bonded in a clamp and sealed with marine sealant as a secondary moisture barrier. All wire penetrations (sensors, antenna, charging port, switch) use IP68 cable glands as the primary seal. The closed box is leak tested (submersion 0.5m, 5 mins) before the PCB is fitted. Components fit into the enclosure by hand. Drive, body and tail are then fitted together. Entire assembly and all functionalities (motor rotation, circuit power, antenna ping, sensors) tested.

5 Design for…

5.1 Sustainability

Injection moulding was selected for the body and tail segments as it minimises material waste and energy consumption at scale, while naturally producing the thin-walled, organic geometries the design requires. ABS was chosen for its dimensional stability and durability; although it presents end-of-life recycling challenges, its extended service life makes it the most practical choice for repeated deployment. The oscillating tail reduces entanglement risk compared to conventional propellers, and the rechargeable battery is tool-free accessible, extending the product lifespan. While production impacts have not been eliminated, the fleet's ability to identify pollution and pipe leakage would substantially aid environmental remediation efforts.

5.2 Cost-effectiveness

At volume, injection moulding reduces unit expenses due to minimal waste and energy usage, offsetting the tooling costs of the aluminium moulds across the production of the fleet. It also reduces costs associated with post processing, such as surface finishing, dimensional correction, colouring, and sealing. The design uses commercially available components where possible, including bearings, seals, and fasteners. This reduces the complexity and expense of sourcing, as well as replacement cost. Manual assembly requirements were minimised, reducing labour costs, and the design’s modularity allows for damaged or worn components to be individually replaced, reducing lifecycle costs.

5.3 Durability

Materials like ABS, stainless steel, and rubber were selected for use in the craft due to their resistance to corrosion and water ingress, alongside their impact tolerance and durability. Any non-waterproof components are sealed, and necessary outlets use reliable, commercially available cable glands. The segmented tail design also reduces wear and local stress on the shaft system and timing belt, which is one of the most critical aspects of the design. To ensure long-term fleet performance and durability, one in every fifty units should undergo leak, motion, stability, chemical, and impact testing. Periodic inspection and maintenance of key components such as the NBR shaft seal and tail joints is also vital in decreasing the risk of failure during deployment.

5.4 Reuse

Sharky Lenny is designed for repeated deployment and modular repair, rather than short-term, disposable operation. The battery allows for units to be rapidly recharged between deployments, without requiring extensive disassembly or opening the electronics box. The modular construction improves the reusability long-term by allowing damaged, worn, or outdated components to be individually removed and replaced. Firmware and detection systems can also be updated or replaced as necessary depending on the nature of the environment.

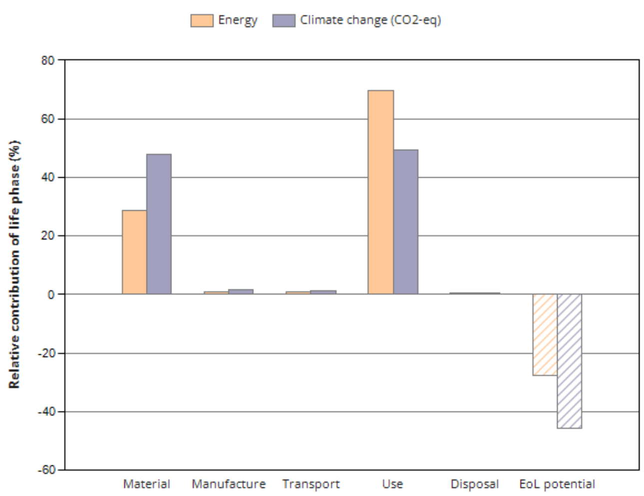
5.5 Circular Economy

The circular economy has been central to the design of Sharky Lenny. The modular structure, using bolted interfaces and accessible fasteners, means worn or damaged parts such as tail segments can be replaced individually without scrapping the entire unit, greatly extending its lifespan. At end of life, the electronics enclosure is designed for full disassembly, with the PCB and battery separated for e-waste recycling and the ABS and polycarbonate structural parts reprocessed as thermoplastic feedstock. This is simplified by ABS being the dominant material across key components, avoiding the complications of mixed-material assemblies. Use of off-the-shelf components further reduces cost and improves repairability, as replacements can be sourced without custom manufacturing.

5.6 Ethics

Sharky Lenny is intended to have a positive environmental and social impact. By allowing rapid, targeted detection of pipe leaks and water pollution, the craft supports remediation efforts that protect local ecosystems, wildlife, and drinking water. A key ethical benefit is that autonomous operation in confined or contaminated waterways reduces the need to send workers into hazardous environments like sewers, improving human safety. The design also avoids toxic coatings and uses recyclable materials wherever possible, so the craft itself does not become an additional source of environmental harm. Compared to more invasive inspection methods, sensor-based autonomous monitoring is a considerably less disruptive approach to assessing watercourse health. At a wider scale, a deployed fleet would support the council's obligations under the Water Framework Directive and provide more consistent environmental protection across the city.

6 Edupack Embodied Carbon Assessment



[Fig 3] Graph showing Relative contribution of life phase (%) of Sharky Lenny

The provided embodied carbon assessment reveals that the Use phase is the primary driver of Sharky Lenny's environmental impact. This is mainly due to the cumulative electricity required to recharge the lithium-ion batteries over a five-year operational life for the City Council. The Material phase also shows a significant contribution, likely due to the embodied energy of specialised components like the rechargeable battery pack and the mechanical internals. The graph displays strong negative value for End of Life potential, particularly in carbon savings. This suggests that the design is highly sustainable at the end of its functional life, as it is designed to be separated and recycled.

7 References

[1] Bang Design, "What is draft angle in injection molding?" *BangID Knowledge Base*, [Online]. Available: https://bangid.com/knowledge-base/manufacturing/what-is-draft-angle-in-injection-molding/ (accessed May 11, 2026).

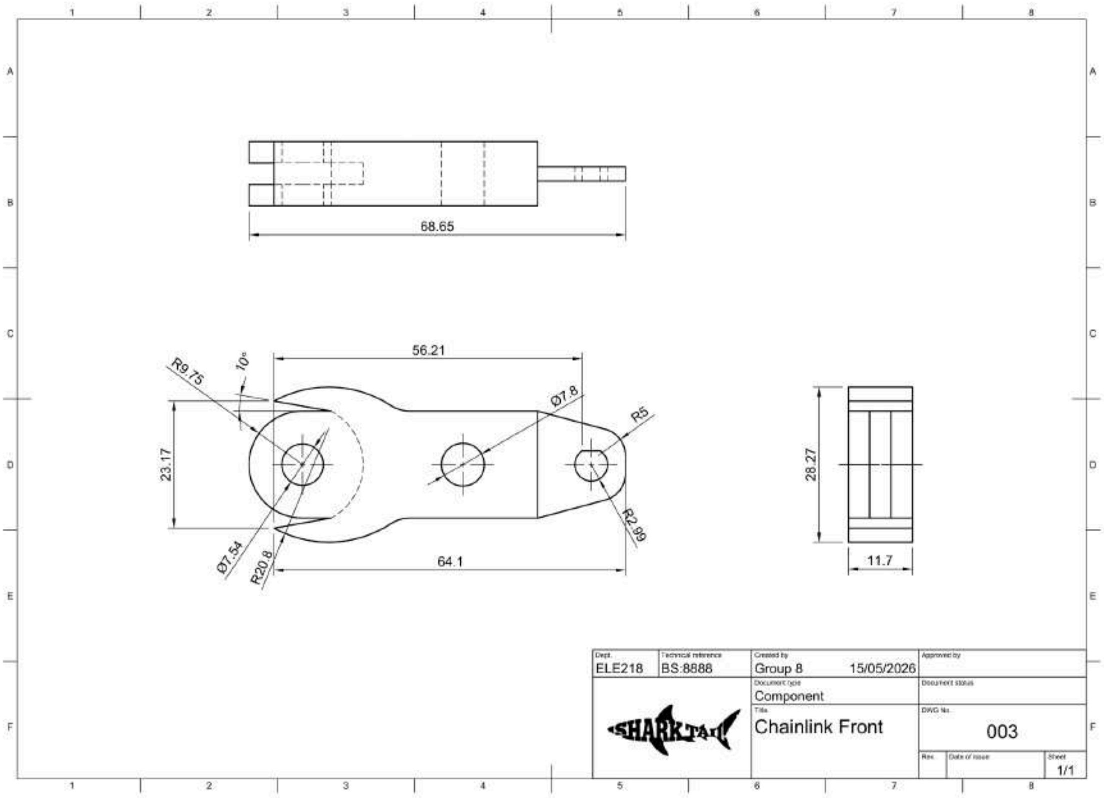
[2] Lily Bearing, "What is a press fit?" *Lily Bearing Blog*, Dec. 12, 2023. [Online]. Available: https://www.lily-bearing.com/resources/blog/what-is-a-press-fit (accessed May 11, 2026).

[3] AllElectroHub, “Selective Soldering vs. Wave Soldering: Which is Right for Your PCB?” *PCB Assembly,* Aug. 26, 2025. [Online]. Available: https://www.allpcb.com/blog/pcb-assembly/selective-soldering-vs-wave-soldering-which-is-right-for-your-pcb.html

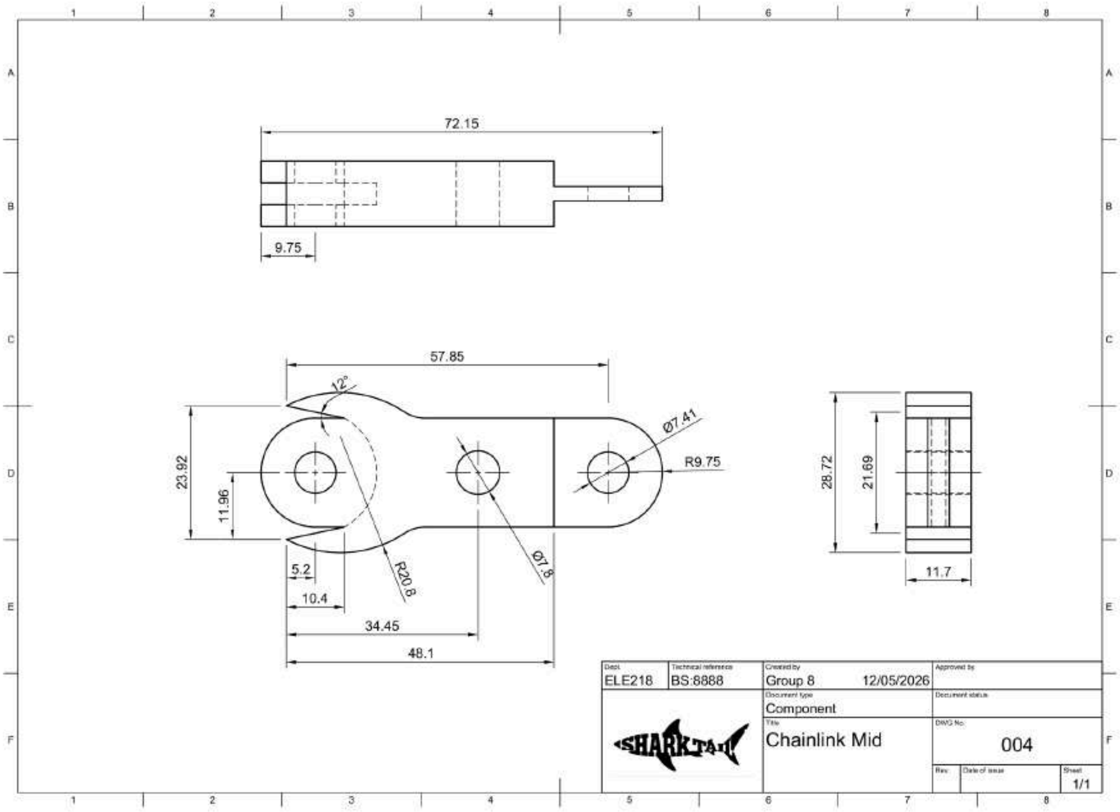
[4] Cut Laser Cut, "Expert tips: Laser kerf," *Cut Laser Cut Drawing Resources*, [Online]. Available: https://cutlasercut.com/drawing-resources/expert-tips/laser-kerf/ (accessed May 11, 2026).

8 Appendices

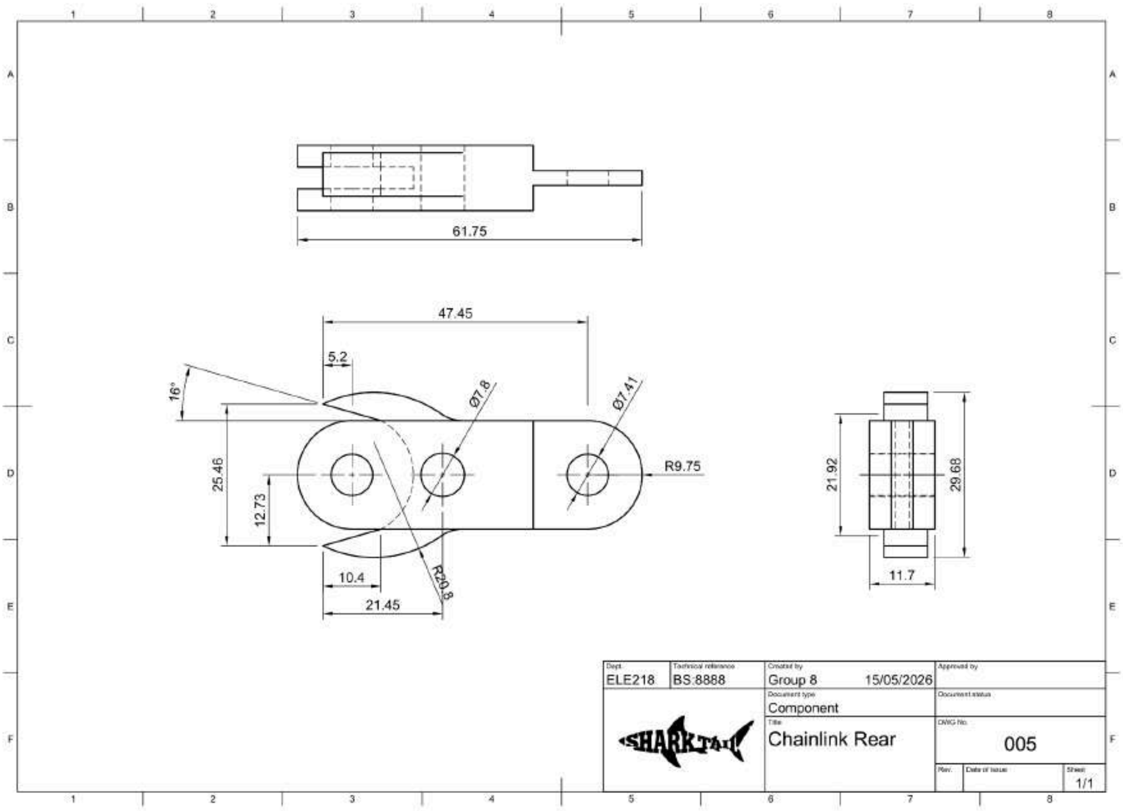
Appendix A: Technical Drawings



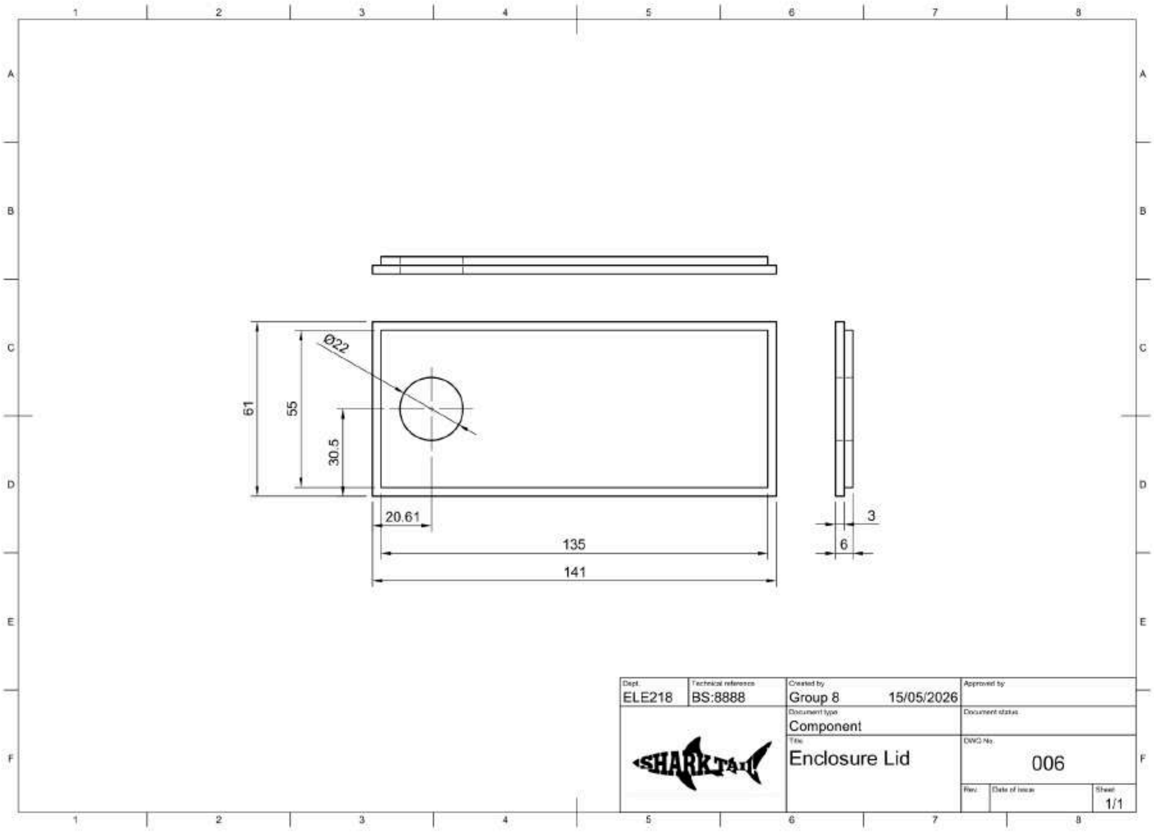
[Fig 4] Chainlink Front Technical Drawing



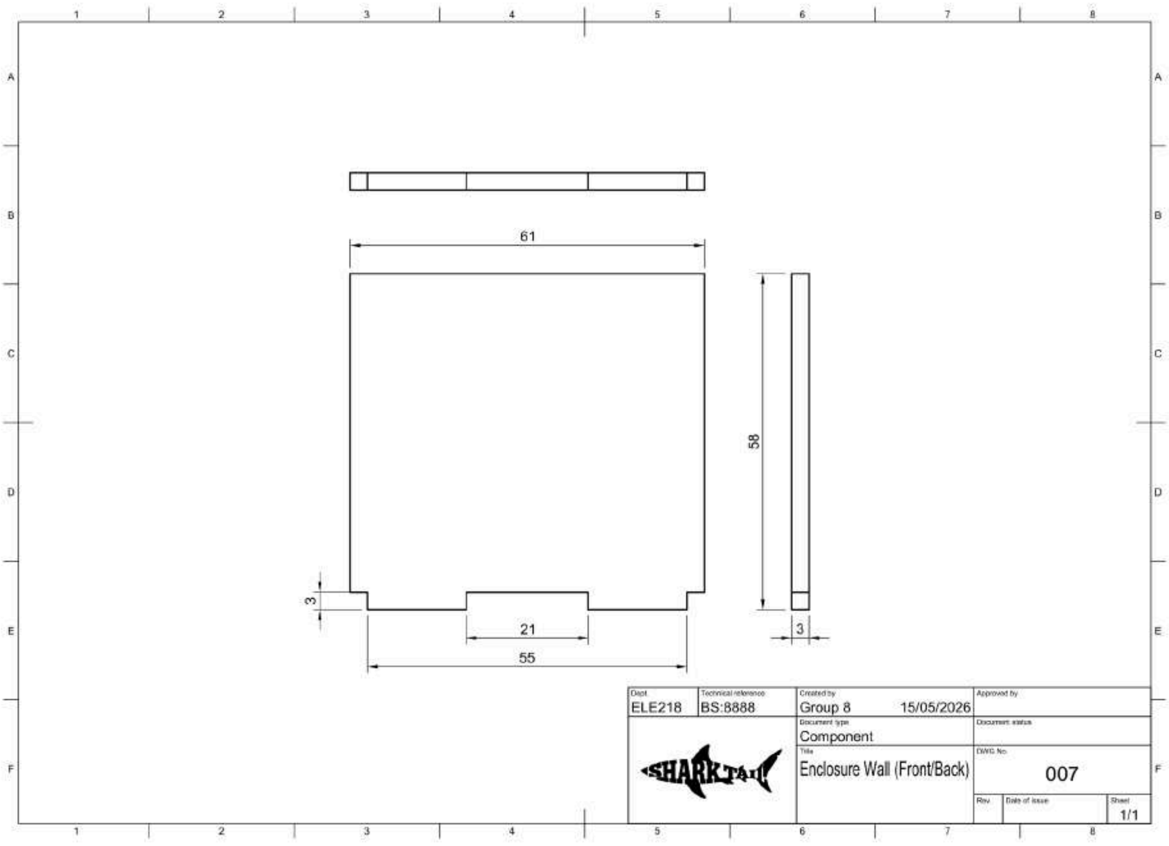
[Fig 5] Chainlink Mid Technical Drawing



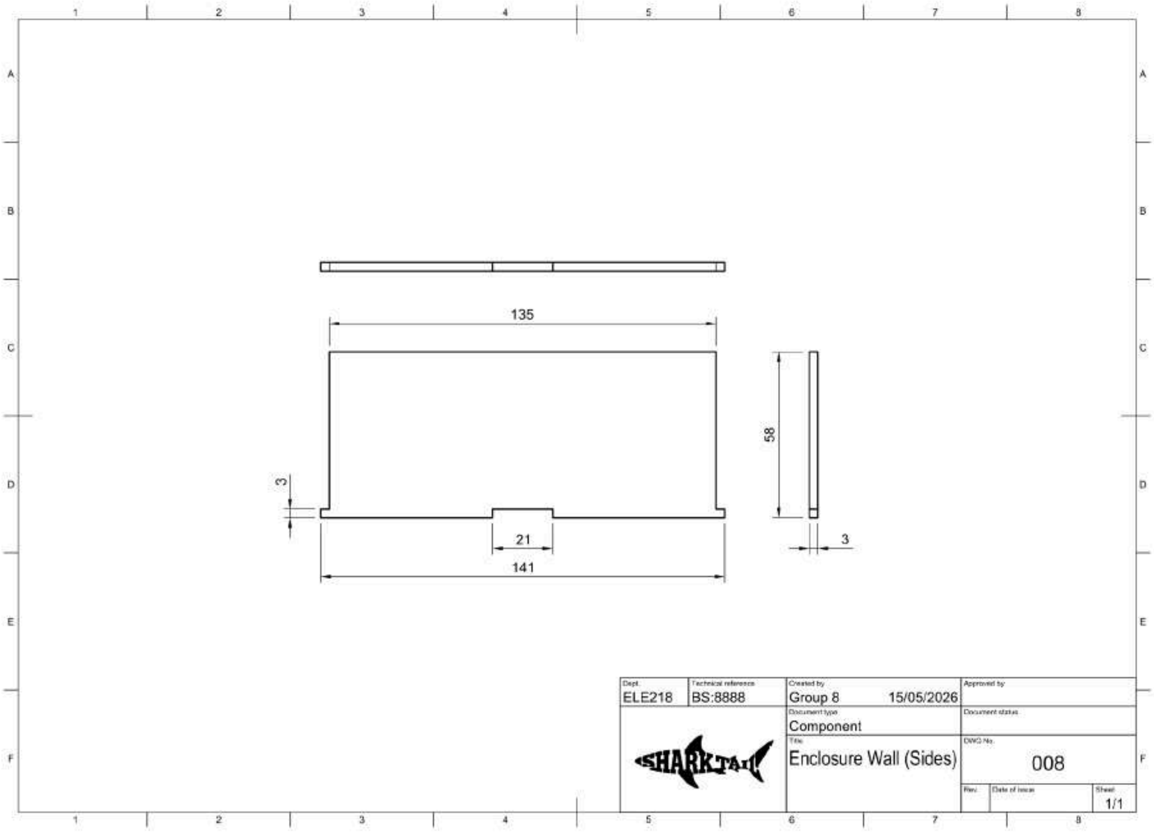
[Fig 6] Chainlink Rear Technical Drawing



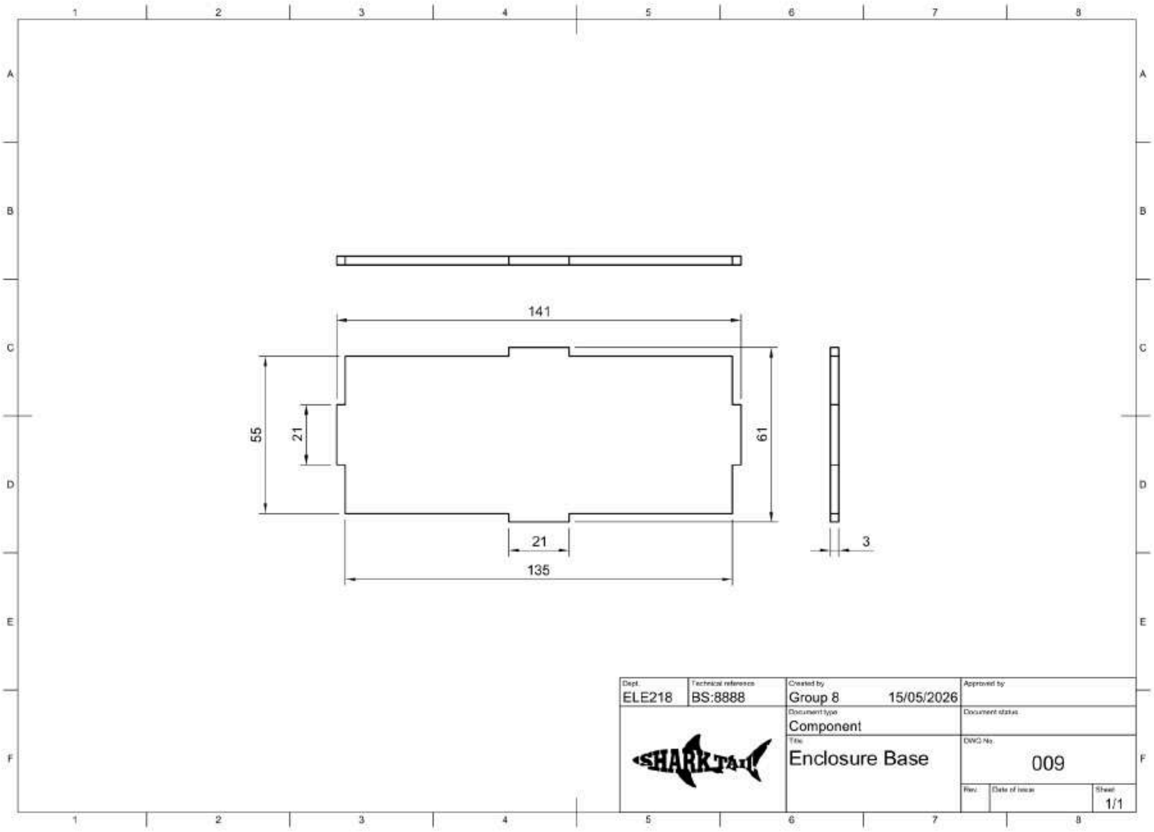
[Fig 7] Enclosure Lid Technical Drawing



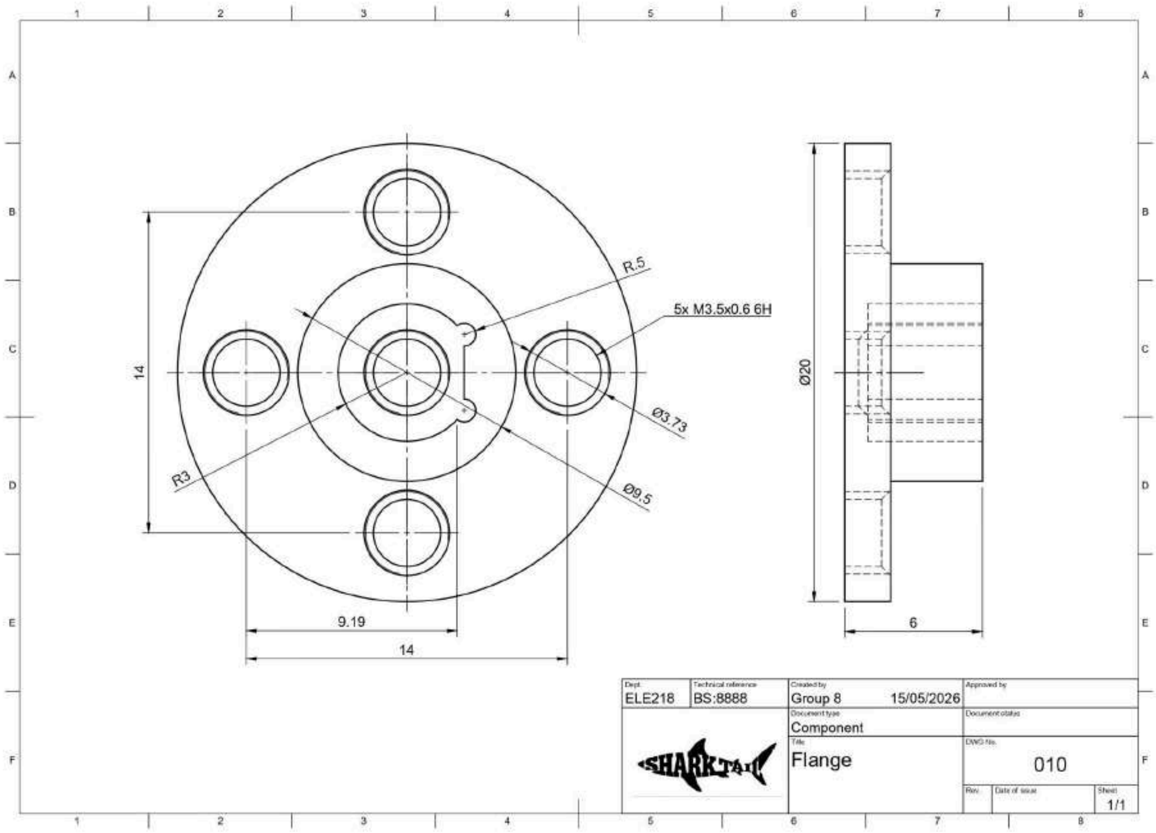
[Fig 8] Enclosure Wall (Front/Back) Technical Drawing



[Fig 9] Enclosure Wall (Sides) Technical Drawing

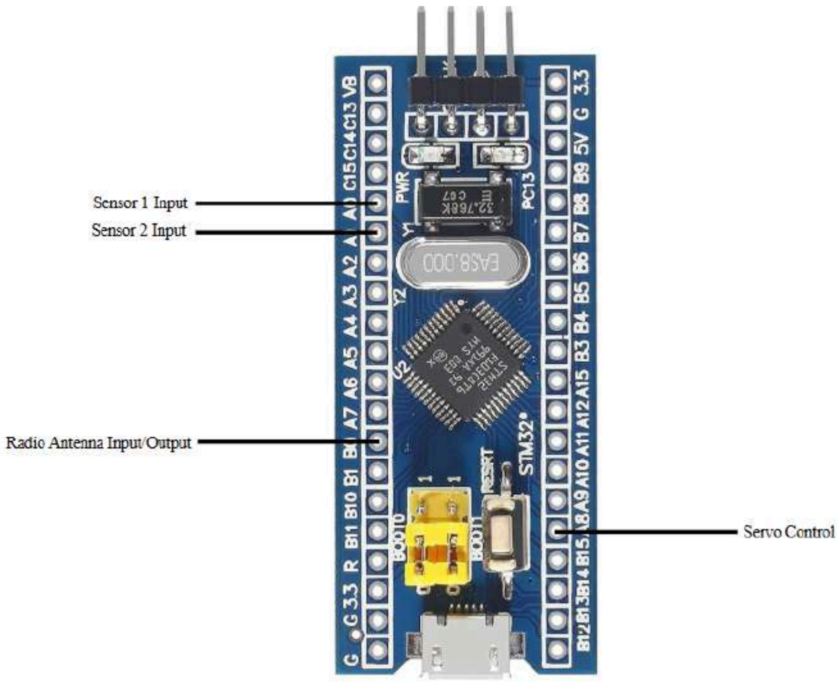


[Fig 10] Enclosure Base Technical Drawing



[Fig 11] Flange Technical Drawing

Appendix B: Electronics



[Fig 12] Microcontroller Pin Diagram

Appendix C: Edupack Results

Component	Material	Recycled content* (%)	Part mass (kg)	Qty.	Total mass (kg)	Energy (MJ)	%
Electronics Box	PMMA (molding and extrusion)	Virgin (0%)	0.13	1	0.13	16	3.7
Body Half (L)	ABS (injection molding, platable)	Virgin (0%)	0.16	1	0.16	16	3.5
Body Half (R)	ABS (high-impact, injection molding)	Virgin (0%)	0.16	1	0.16	16	3.5
Tail Front Segment	ABS (high-impact, injection molding)	Virgin (0%)	0.04	1	0.04	3.9	0.9
Tail Mid Segment	ABS (high-impact, injection molding)	Virgin (0%)	0.04	1	0.04	3.9	0.9
Tail Rear Segment	ABS (high-impact, injection molding)	Virgin (0%)	0.04	1	0.04	3.9	0.9
Tail Fin	ABS (high-impact, injection molding)	Virgin (0%)	0.04	1	0.04	3.9	0.9
Bolt, M6	Stainless steel, ferritic, ASTM CB-30, cast, annealed	Virgin (0%)	0.003	3	0.009	0.43	0.1
Nut, M6	Stainless steel, ferritic, ASTM CB-30, cast, annealed	Virgin (0%)	0.003	3	0.009	0.43	0.1
Front Connecting Shaft	ABS (high-impact, injection molding)	Virgin (0%)	0.02	1	0.02	1.9	0.4
Mid Connecting Shaft	ABS (high-impact, injection molding)	Virgin (0%)	0.02	1	0.02	1.9	0.4
Rear Connecting Shaft	ABS (high-impact, injection molding)	Virgin (0%)	0.02	1	0.02	1.9	0.4
Timing Belt	PCU (unfilled)	Virgin (0%)	0.005	1	0.005	0.38	0.1
Pulley	Aluminum, commercial purity, S150.1: LM0-M, cast	Virgin (0%)	0.018	1	0.018	3.2	0.7
Rotary Shaft	Carbon steel, AISI 1030, annealed	Virgin (0%)	0.05	1	0.05	1.6	0.4
Printed Circuit Board	Printed wiring board production, surface mounted, unspecified, Pb free	Virgin (0%)	0.02	1	0.02	94	21.5
Microcontroller	Silicon, single crystal, Czochralski process, electronics	Virgin (0%)	0.002	1	0.002	10	2.4
Electronics Assembly	Electric connector, peripheral component interconnect buss	Virgin (0%)	0.14	1	0.14	2.5e+02	57.1
7.2V Battery	Li-ion, LiMn2O4	Virgin (0%)	0.045	1	0.045	6.7	1.5
Servo motor casing	ABS (injection molding, platable)	Virgin (0%)	0.005	1	0.005	0.49	0.1
Servo motor internals	Carbon steel, AISI 1030, annealed	Virgin (0%)	0.05	1	0.05	1.6	0.4
Total				**25**	**1**	**4.4e+02**	**100**

[Table 2] Breakdown of material life phase

Breakdown by transport stage

Stage name	Transport type	Distance (km)	Energy (MJ)	%
Electronics Assembly	Truck 3.5-7.5t, EURO 3	2.4e+02	1.7	16.1
Timing Belt	Truck 3.5-7.5t, EURO 3	2.4e+02	1.7	16.1
Pulley	Truck 3.5-7.5t, EURO 3	2.4e+02	1.7	16.1
Nut, M6	Truck 3.5-7.5t, EURO 3	2.4e+02	1.7	16.1
Bolt, M6	Truck 3.5-7.5t, EURO 3	2.4e+02	1.7	16.1
Microcontroller	Truck 3.5-7.5t, EURO 3	58	0.43	3.9
Servo Motor	Truck 3.5-7.5t, EURO 3	2.3e+02	1.7	15.7
Total		**1.5e+03**	**11**	**100**

[Table 3] Breakdown of transport life phase

Static mode

Energy input and output type	Electric to mechanical (electric motors)
Country of use	United Kingdom
Power rating (W)	15
Usage (hours per day)	8
Usage (days per year)	1.6e+02
Product life (years)	5

[Table 4] Breakdown of use life phase