SUBS in Schools Australia

2019

Build Manual

Level 4: SUB Class

National Sponsor

Australian Government

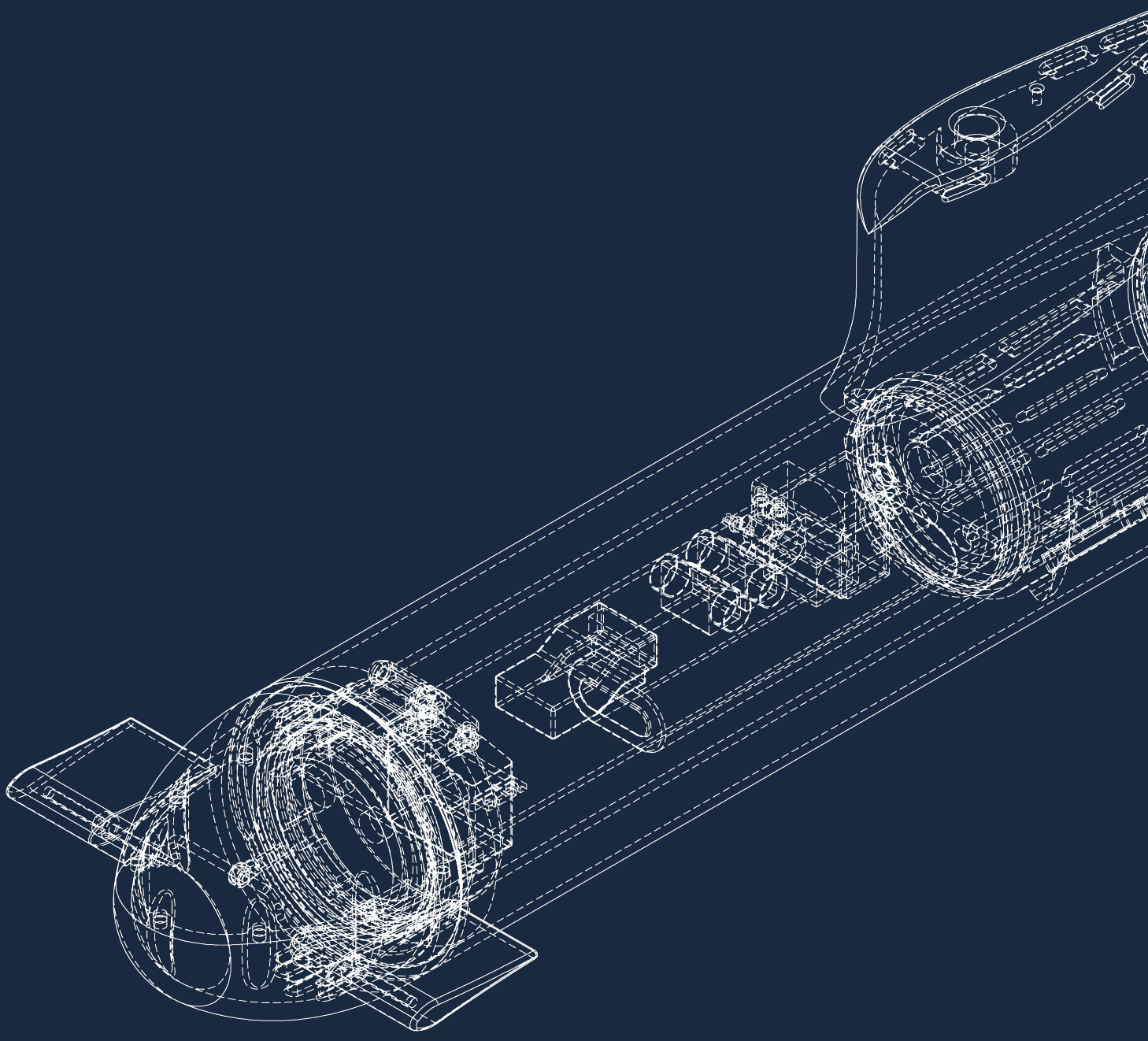
Department of Defence

in Schools

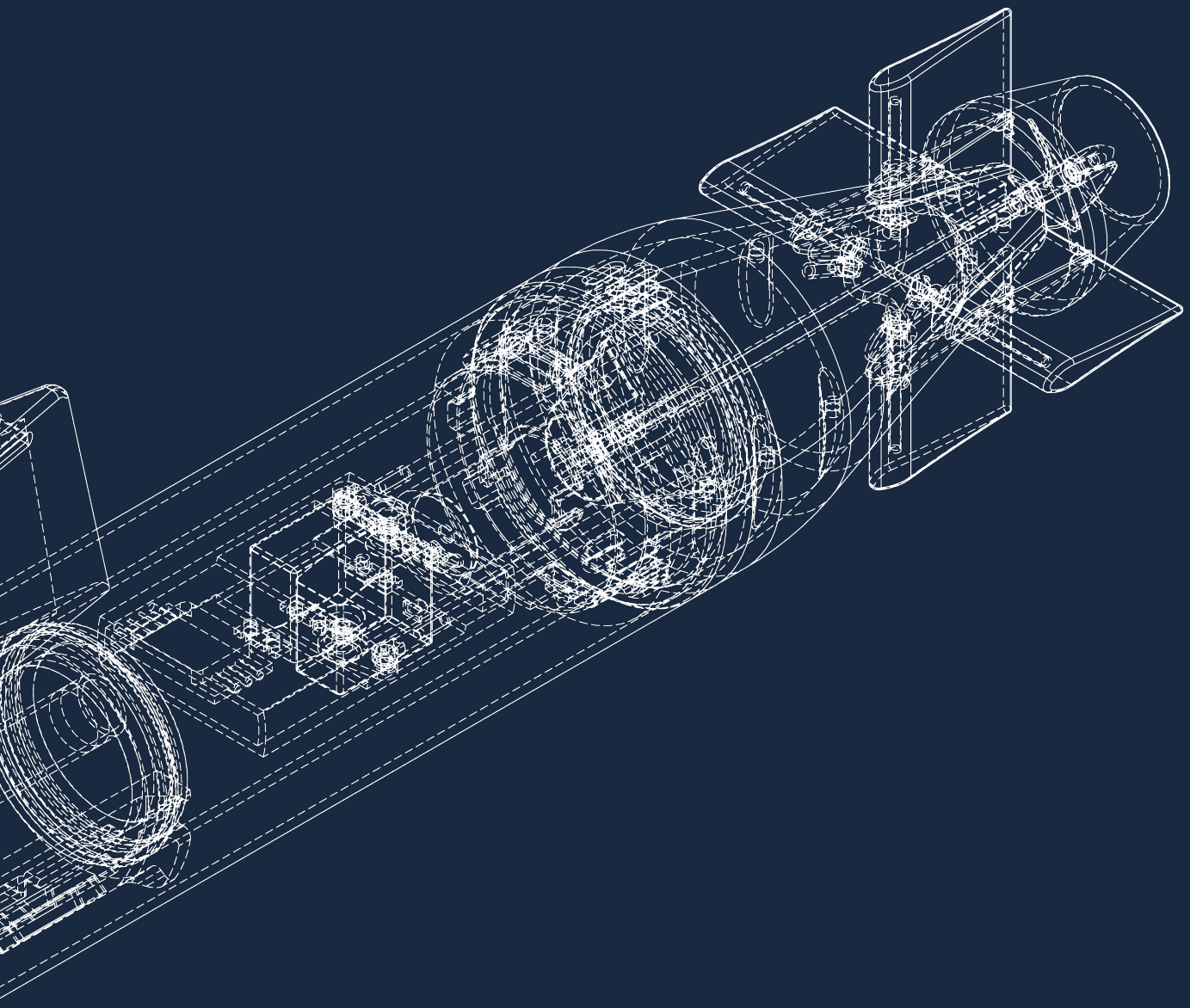
Re-Engineering Australia Foundation Ltd

2016 National Championship 2017

Contents | 2017 Build Manual



in Schools
Re-Engineering Australia Foundation Ltd



Introduction

Welcome

The “Subs in Schools” program challenges year 10 to year 12 high school students to build a fully functional remote controlled (RC) submarine. The program aims to create an exciting and fun learning environment for students.

This manual provides students with step by step instructions on how to build a baseline model submarine. If time permits, students are encouraged to go beyond the baseline model and be creative and innovative. Some of the problems the students will face when designing the submarine will be similar to challenges faced by engineers building a full scale submarine.

This program will expose students to scientific and construction challenges that will provide opportunities for creativity. It will also help them to develop their problem solving skills, and teach them about working and contributing in a team environment.

How a Submarine Works

General Functionality

The control surfaces are used to maneuverer the submarine in the water. Each control surface is connected to a metal rod, which is attached to a servo. A servo has an arm that moves in a circle. When the servo moves, the corresponding control surfaces move accordingly. These control surfaces are similar to that of flaps on an airplane's wings.

The motor pushes the submarine forwards and backwards in the water depending on its direction of rotation. The air bladders control the buoyancy of the submarine to allow it to move up and down.

Buoyancy

To understand how a submarine works, you first need to understand how buoyancy works. The force exerted upwards by the water is called buoyancy force. This force is equal to the weight of the fluid displaced:

Buoyancy Force = weight of fluid displaced

Note: Buoyancy is measured in Newtons (N)

Remember from your physics classes that weight is directly proportional to mass and the acceleration of gravity:

$$Weight = m \times g$$

Where m is the mass (in kg) and g is the gravitational acceleration (m/s/s).

Using this definition, the buoyancy force (B) is equal to the mass of the fluid multiplied by the acceleration due to gravity:

$$B = M_{fluid} \times g$$

Density is defined as:

$$Density = Mass / Volume$$

Or using common symbology:

$$p = m / v$$

Where P is density in kg/L, M is mass in kg, and V is the volume in m^3.

Rearranging this equation to solve for mass gives:

$$m = p \times v$$

Therefore for a fluid the mass is equal to:

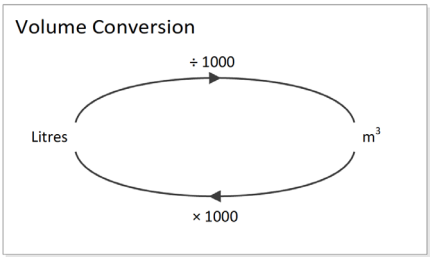
$$m_{fluid} - p_{fluid} \times v$$

Substituting this equation into Equation

$$B = p_{fluid} \times v \times g$$

Example:
Imagine if I threw a basketball into a pool of water. If the volume of water displaced by the basketball is one litre, then what is the buoyancy force acting on the basketball?

To answer this equation we first need to convert 1 litre into m^3. Figure 2 diagrammatically shows how to convert volume in litres to volume in m^3.



Therefore 1 litre is equal to 0.001 m3:

$$v = 0.001 m^3$$

But what is the density of water (P_{water})? The answer is in the definition of a litre. 1 litre is defined as:

the volume of 1 kg of water at 'standard temperature and pressure'

This translates to 25ºC under atmospheric pressure of 1 atm.
Note: 'atm' is the symbol for 'standard atmosphere' (which sometimes also referred to as 'standard pressure').

This means that 1 litre of water has an approximate mass of 1kg. Therefore:

$$m_{water} = 1kg$$

Substituting this into Equation (2) gives:

$$P_{water} = m / v = 1 / 0.001$$

$$P_{water} = 1000 kg/m^3$$

So we know (or can calculate) p and v.

We also know g at sea level is approximately 9.8 m/s2.

Therefore, using Equation (3), the total buoyancy force for the basketball is:

$$B = p_{fluid} \times v \times g$$

$$B = 1000 \times 0.001 \times 9.8$$

$$B = 9.8 \text{ N upwards}$$

What is interesting about this finding is that the force of displacing 1 litre of water is also equal in magnitude to the weight of a 1 kg object.

Now it's your turn!

What is the buoyancy force if the basketball displaced 2 litres of water? What if it was 3 litres (or 4 litres or 10 litres)? You should notice a trend, or a

relationship, between the buoyancy force and the displacement. The buoyancy of displacing 2 litres is equal to the weight of a 2kg object and the buoyancy of displacing 3 litres is equal to the weight of a 3kg object.

Neutral buoyancy is when the buoyancy force is equal to the gravitational weight of the object. In the above example, neutral buoyancy is achieved if the basketball weighs 1 kg. If the ball weighed less than 1 kg it would float on the surface of the water. If it weighed more than 1 kg then it would sink in the water. If it weighed exactly 1 kg then the ball would hover in the water.

Summary: To achieve neutral buoyancy in water, the mass of the object in kilograms must equal the volume of the object in litres. This result only applies for water. That is:

Mass (kg) = Volume displaced (Litres)

Mechanicals

The submarine contains two air bladders and an acrylic water-tight cylinder. By using pumps, air from the cylinder can be blown into the air bladders, causing them to inflate. This creates positive air pressure in the bladders and negative air pressure in the cylinder. As the bladders expand they displace a greater volume of water without increasing the mass of the submarine and therefore the buoyancy increases. When the buoyancy of the submarine exceeds neutral buoyancy the submarine rises in the water. When the submarine is ready to descend into the water, valves in the submarine release the air back into the water tight container. This causes the bladders to contract, hence the buoyancy decreases. When the buoyancy is below the neutral buoyancy the submarine descends.

Remember buoyancy is equal to the volume of water displaced. It is not equal to the amount of air in the submarine. By making the air take up a greater volume in the submarine it can change the buoyancy of the submarine accordingly.

Electronics

The battery provides power to all electrical components. The receiver picks up radio waves from the transmitter (controller). The receiver can then send signals to servos and relays, which can turn on the pumps and valves. The battery can be recharged by disconnecting the wires between the battery and power harness. Because this wire is outside the water-tight container, it means the battery can be recharged without having to open the container.

Battery

The battery stores an electrical charge. When the circuit is completed, negatively charged electrons travel from the negative terminal of the battery to the positive terminal. These moving charges release energy. The amount of energy can be calculated from two quantities, voltage and current:

Power (Watts) = Current (Amps) x Voltage (Volts)

These two quantities are best explained with a water analogy.

An electrical current is a flow of charged particles. In a river, current is a flow of water particles. Because of these similarities, electrical circuits can be related to a flowing river. A battery is like a hill. Water travels from the high ground to the low ground. In a similar way electrons travel from areas of high negative charge to low negative charge.

Current can be thought of as the amount of water going down the hill. In electrical circuits the current is simply the number of electrons that pass a certain point in the circuit.

Voltage can be viewed as the difference between the high ground and the low ground. If the hill was steep then we would expect the water particles to be pushed by gravity more and hence travel faster down the hill. In electrical circuits the voltage is the electrical potential difference between the positive and negative terminals of the battery.

Power Harness

The power harness connects all the required electronic parts to the battery.

Receiver and Transmitter

The Transmitter is the controller. The controller sends radio waves through the air and water to the receiver. The receiver picks up these waves and can decode these signals. Each button and direction on the joystick corresponds to a channel. For example, channel 1 on the receiver is normally the backwards and forwards motions on the right joystick.

Each channel on the receiver has three pins. Three wires (normally red, black, and white) are connected to these three pins. The black and red wires provide power to the part connected to the receiver and the white wire sends the control signal.

The only exception is the channel that goes to the electronic speed controller (ESC). In that special case the black and red wires power the receiver instead of the receiver powering it. Some ESCs do not have a battery elimination circuit (BEC), which means the receiver needs to be powered by other means.

Valves

Valves have an inlet and outlet. When the valve is powered on, air is allowed to flow from the inlet to the outlet.

Pumps

Just like valves, pumps have an inlet and outlet. When the pump is powered on air is sucked in from the inlet and blown out the outlet.

Relays

A relay is an electronic switch. When it receives a signal (from the white cable) it turns on the connection. The receiver is not powerful enough to power the valves and pumps by itself. The receiver sends a signal to a relay. The relay then switches on another circuit that connects the battery directly to the valves. In other words instead of powering the valves with the receiver the relay is powering the valves with the battery.

DC Motor

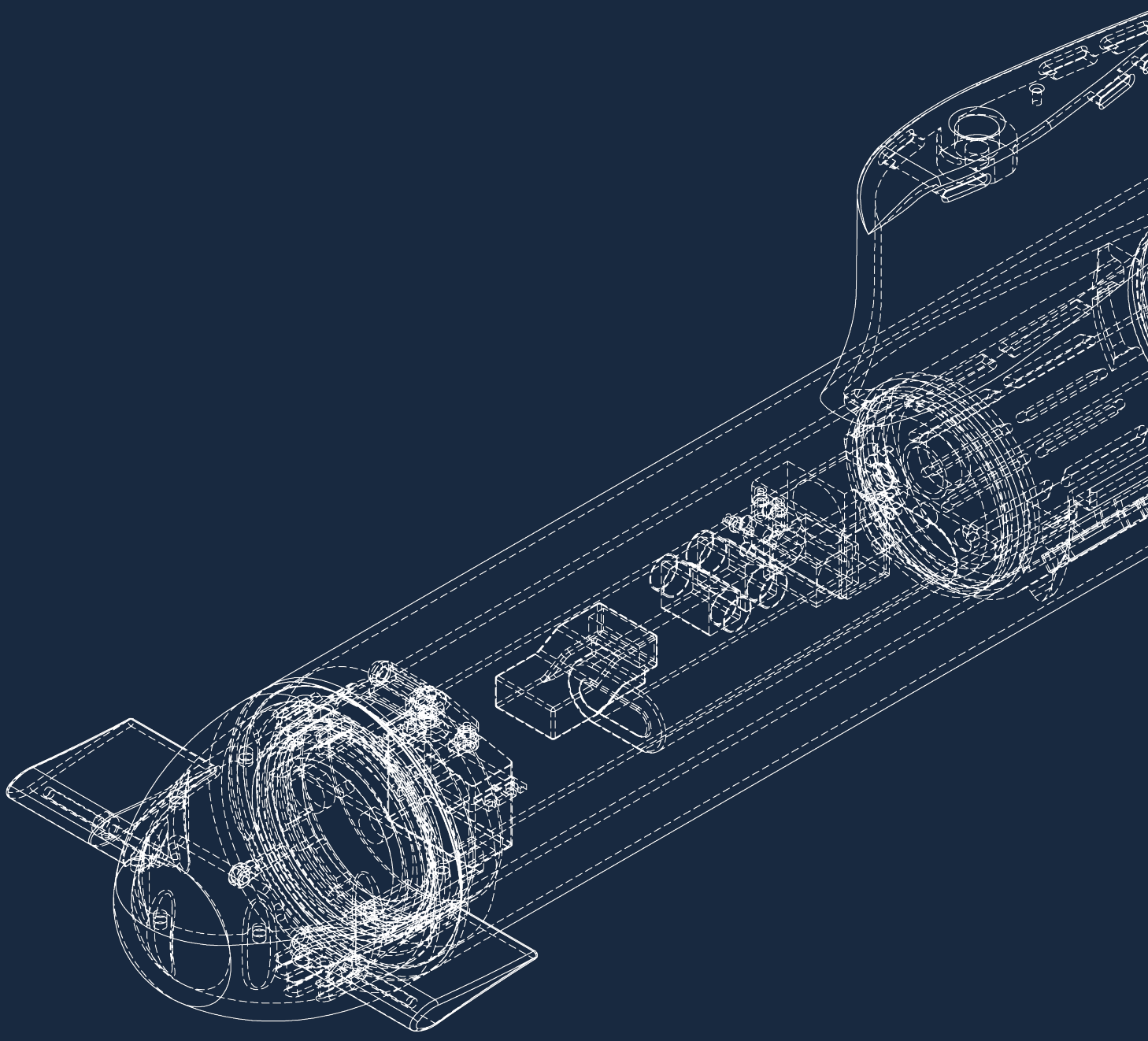
There are two main types of DC motors, brushed and brushless. The brushed motor has wire coils on the shaft of the motor, which needs brushes to provide contacts to transfer the electricity to the turning components. These are simpler electronically and require just two power cables. The brushless motor has the wire coils in the casing of the motor, so no brushes are needed to transfer power to moving parts, but more cables are needed for the stationary electronics, typically three cables are used.

Speed Controller

Unlike valves which are either on or off,

the motor can rotate at many different speeds. The speed controller decodes the signal from the receiver and adjusts the power to the motor according to the signal. This allows the motor to spin at a wide variety of speeds. The speed controller also powers the receiver, unless it has no BEC.

Servo
A Servo is similar to a motor however it knows how many degrees it has rotated to a much higher precision level. This makes it ideal to move the control surfaces of the submarine. It also can be powered directly from the receiver and does not need a speed controller or a relay.



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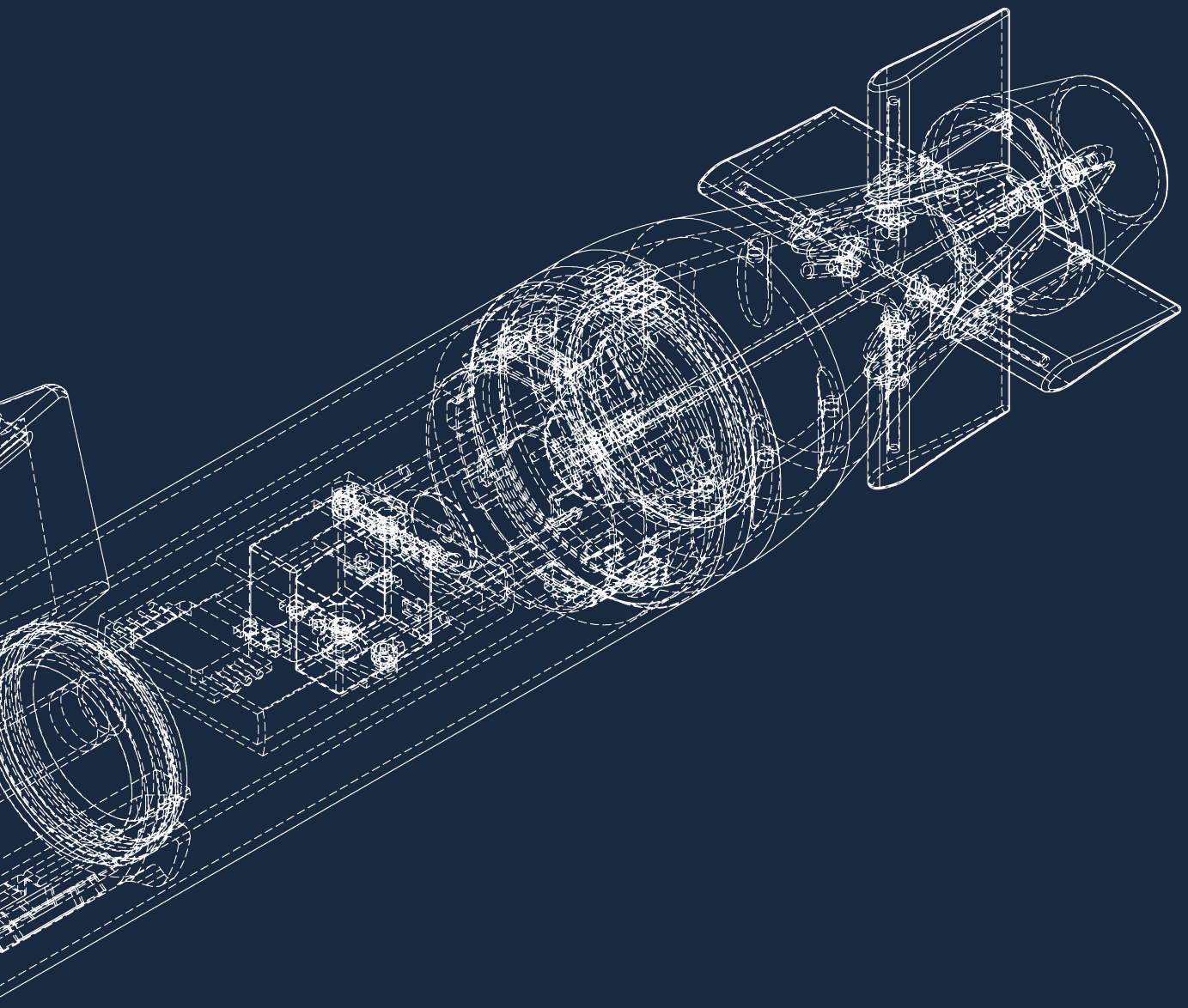
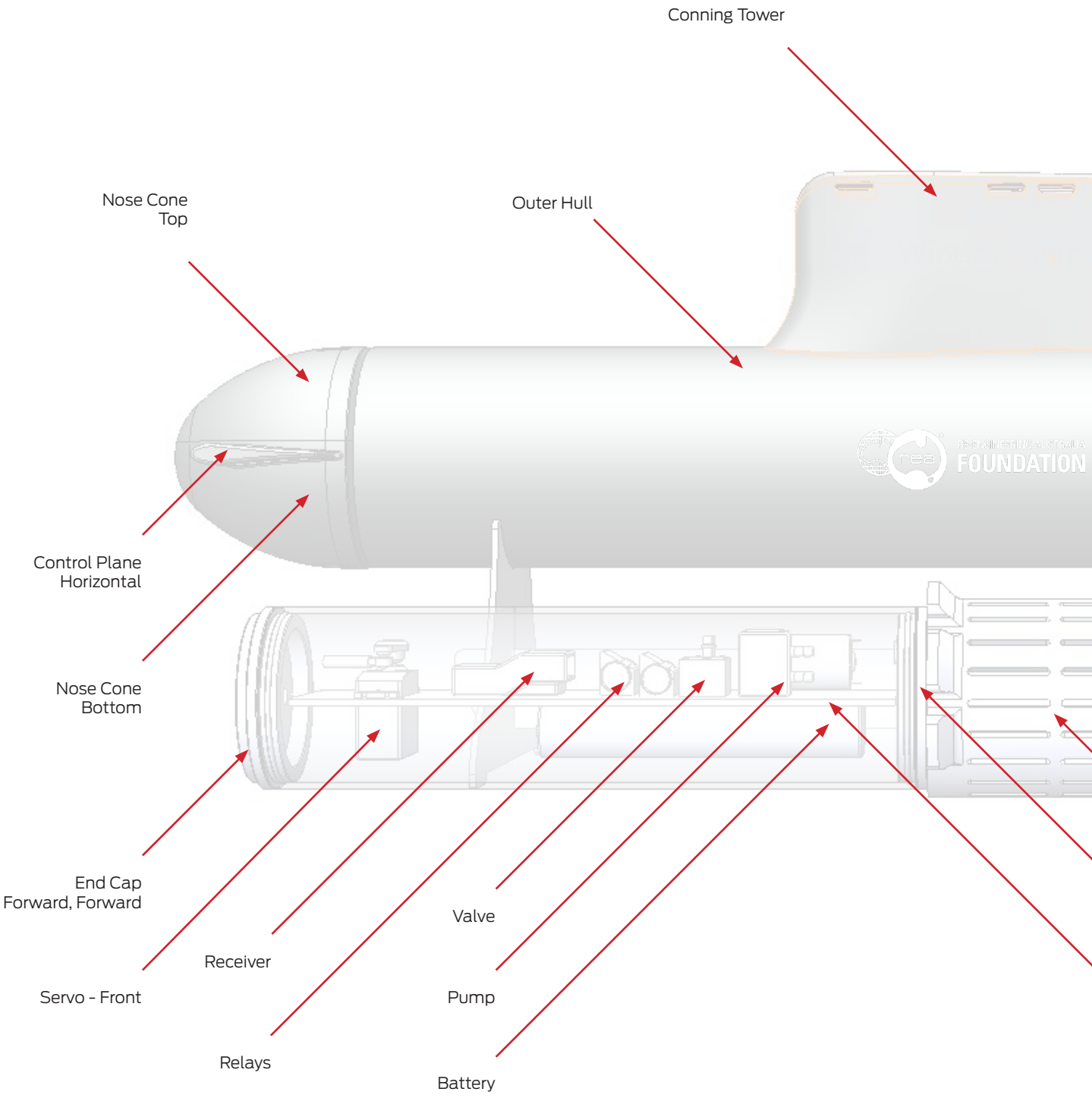
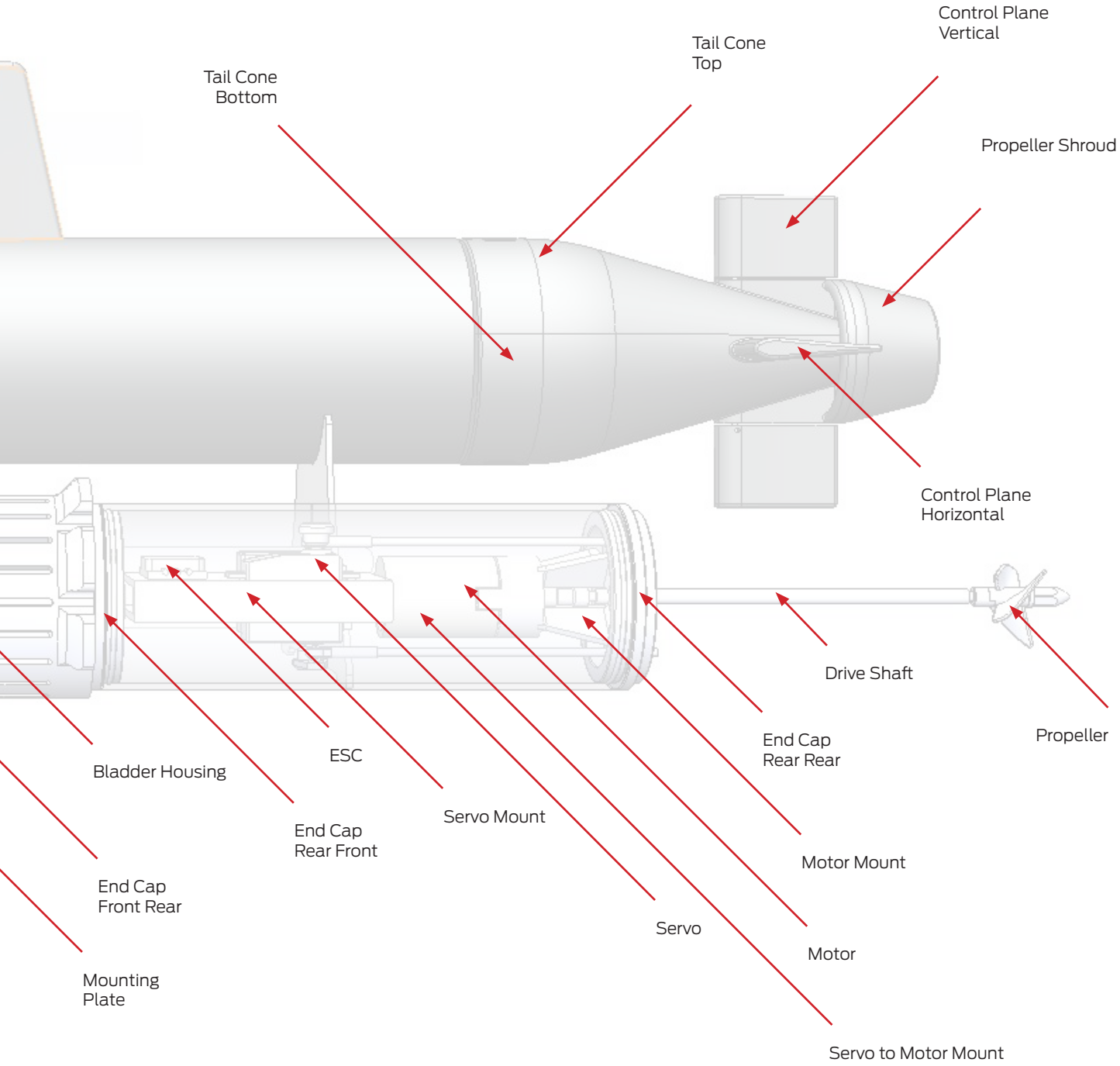


Parts List

Exploded Parts List




Control Plane
Vertical
Tail Cone
Top
Tail Cone
Bottom
Propeller Shroud
Control Plane
Horizontal
Drive Shaft
Propeller
End Cap
Rear Rear
ESC
Bladder Housing
Servo Mount
End Cap
Rear Front
Motor Mount
End Cap
Front Rear
Servo
Motor
Mounting
Plate
Servo to Motor Mount

Mechanical/ Electrical Parts List

Part #	Part Name	Supplier	Description / Dimensions	Quantity	Image
1	Outer Hull	REA	PVC drain water pipe. Dimensions: 100mm ID x 1000mm L	1	
2	Pressure Hull	REA	Transparent acrylic pipe. Dimensions: 80mm OD x 1000mm L	1	
3	End Cap (Front Front)	REA	End caps seal the ends of the pressure hull to stop water ingress. Front front endcap seals the front of the front pressure hull. Dimensions: 80mm OD x 20mm L	1	
4	End Cap (Front Rear)	REA	End caps seal the ends of the pressure hull to stop water ingress. Front rear end cap seals the rear of the front pressure hull. Dimensions: 80mm OD x 20mm L	1	
5	End cap (Rear Front)	REA	End caps seal the ends of the pressure hull to stop water ingress. Rear front end cap seals the front of the rear pressure hull. Dimensions: 80mm OD x 20mm L	1	
6	End cap (Rear Rear)	REA	End caps seal the ends of the pressure hull to stop water ingress. Rear rear end cap seals the rear of the rear pressure hull. Dimensions: 80mm OD x 20mm L	1	

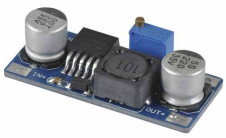
Part #	Part Name	Supplier	Description / Dimensions	Quantity	Image
7	Control Rod Sleeve - 4mm OD	REA	Hollow brass tubing - 4mm OD 300mm L x 4mm OD	1 x 300mm	
8	Control Rod - 3mm OD	REA	Solid brass rod - 3mm OD. 300mm L x 3mm OD	2 x 300mm	
9	Push Rod Threaded - 2.5mm OD	REA	Threaded push rod - 2.5mm 300mm L x 2.5mm OD	1 x 300mm	
10	Drive Shaft Sleeve	REA	The drive shaft sheath has several purposes; it allows you to secure the drive shaft in place as well as providing a water tight seal. 300mm L x 5mm OD (4.5mm ID)	1 x 300mm	
11	Drive Shaft	REA	The drive-shaft transfers the rotation from the electric motor to the propeller. 300mm L x 4mm OD	1 x 300mm	
12	M3 Bolts	REA	M3 x 10mm L	7	

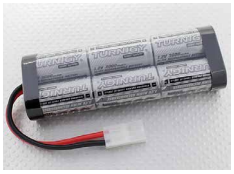
Part #	Part Name	Supplier	Description / Dimensions	Quantity	Image
13	M2.5 Bolt	REA	M2.5 x 20mm L	20	
14	M2.5 Nut	REA	M2.5 Nut	8	
15	M15 Nut	REA	M15 x 3mm Nut	4	
16	M20 Washer	REA	Galvanised washer/ rubber washer	4	
17	Cable Tube	REA	Irrigation Riser 150mm x 21mm OD (14mm ID)	1	
18	Silicone Tube - 3mm ID	REA	3mm ID silicone tube	1 x 100mm	

Part #	Part Name	Supplier	Description / Dimensions	Quantity	Image
19	Rubber Boot	REA	35mm L x 10mm OD Push Rod Boots	2	
20	Grease (Water Proof)	REA	Water resistant grease	1	
21	Power Cable - 16 gauge	REA	16 awg cables	500mm or red and black	
22	Antenna Cables	REA	26 awg cables	5m	
23	On/Off Switch	REA	Switch 6A + Waterproof Cover	1	
24	IP 67 - 4pin Chassis (Male)	REA	P9364 4 Pin 2A Locking Male Chassis IP66 Waterproof Plug	1	

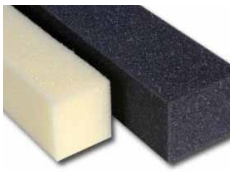
Part #	Part Name	Supplier	Description / Dimensions	Quantity	Image
25	IP 67 - 4pin Line (Female)	REA	P9354 4 Pin 2A Locking Female Line IP66 Waterproof Socket	1	
26	IP 67 - 4pin Chassis (Male)	REA	P9464 4 Pin 5A Locking Male Chassis IP67 Waterproof Plug	1	
27	IP 67 - 4pin Line (Female)	REA	P9484 4 Pin 5A Locking Female Line IP67 Waterproof Socket	1	
28	T- Connector (Male)	REA	Nylon T-Connector Male	4	
29	T - Connector (Female)	REA	Nylon T-Connector Female	4	
30	Servo	REA	High Torque Servo MG/BB W/ Proof 12.8kg / 0.22sec / 58g	3	

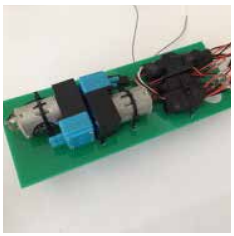
Part #	Part Name	Supplier	Description / Dimensions	Quantity	Image
31	Servo Arm Tree	REA	Futaba Servo Arm Set	1	
32	Servo Extension Cable	REA	20cm Futaba 26AWG Straight Extension Lead M to F 5pcs	10	
33	EZ Connector	REA	Nylon clip connectors	3	
34	Pump	REA	Air Water Pump 370M Square (One Way Pump / DC5v -13v)	2	
35	Barb to Bulkhead Fitting	REA	airline x airline barb bulkhead 5/16" (8 mm)	2	
36	Air Bladder	REA	Two Tube Ballast Tank Liner L220mm x W110mm (TPU-L) (630ml / 630g)	1	

Part #	Part Name	Supplier	Description / Dimensions	Quantity	Image
37	Relay	REA	TX Controlled Relay Switch	2	
38	Step Down Resistor	REA		1	
39	Brushless Motor	REA	2900kv , 7.4 Volt, 1/8" Shaft	1	
40	ESC	REA	4 ~ 9 NiMh, 30A, BEC 6V @ 1A	1	
41	Shaft Coupler	REA	Motor shaft to drive shaft	1	
42	Dog Drive	REA	4mm Stainless Steel	1	

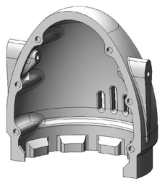
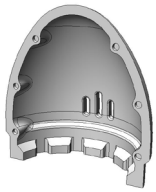
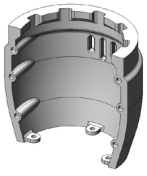
Part #	Part Name	Supplier	Description / Dimensions	Quantity	Image
43	Propeller	REA	3 blade propeller	1	
44	Propeller Nut	REA	Stainless Steel Propeller nut	1	
45	Battery	REA	3000 mAh, 6 Cell, 7.2V	1	
46	Battery Charger	REA	Ultra Power (4-8S)	1	
47	Transmitter - Remote Control	REA	6 Channel 2.4 GHz	1	
48	Transmitter Adapter	REA	Only use if your supplied remote control is not orange. If you have received any other controller please install this device in the back of it to allow it to sync with the orange receiver and sattelite receiver.	May not be required	

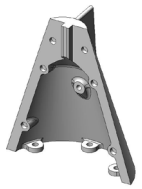
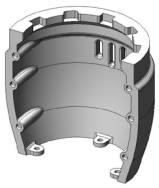
Part #	Part Name	Supplier	Description / Dimensions	Quantity	Image
49	Receiver	REA	OrangeRx R720X V2 7Ch 2.4GHz DSM2/DSMX Comp Full Range Rx w/Sat, Div Ant, F/Safe & SBUS	1	
50	Satellite Receiver	REA	OrangeRx R110XL DSMX/DSM2 Compatible Satellite Receiver	1	
51	Magnets	REA	Neodymium Magnets 4mm OD x 1.5mm H	38	
52	Ball Joint	REA	Ball ID M3, M3 Shaft	3	
53	Shaft Collets	REA	Stop Collar For 3mm Axle (10pcs)	5	
54	Valve	REA	Solenoid Valve 2Hole (Air / Water / DC6v-24v)	1	

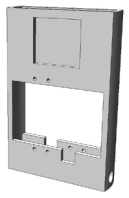
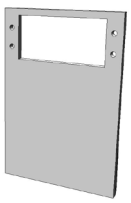
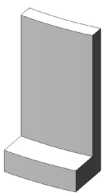
Part #	Part Name	Supplier	Description / Dimensions	Quantity	Image
55	Silicone Tube 5.5mm OD x 2.5mm ID	Other	Dimensions: 5.5mm OD (2.5mm ID) x 200mm L Silicone tube is used to connect the brass pushrods to all thread rods.	1 x 200mm	
56	Cable Ties	Other	A cable tie is a type of fastener, for holding items together, primarily electric cables or wires.		
57	Lead Sheeting	Other	Used to apply ballast to submarine and weigh down the bottom of the submarine for it to stay upright.		
58	Silicone Sealant or Araldite (Epoxy resin)	Other	Used to water proof and seal up joints and components within the submarine assembly.		
59	Foam	Other	Used to make the submarine more buoyant in areas where it needs more		
60	Hose Clamp	Other	Used in conjunction with the pressure hull locator 3D printed part to secure the pressure hull in the outer hull assembly.	2	

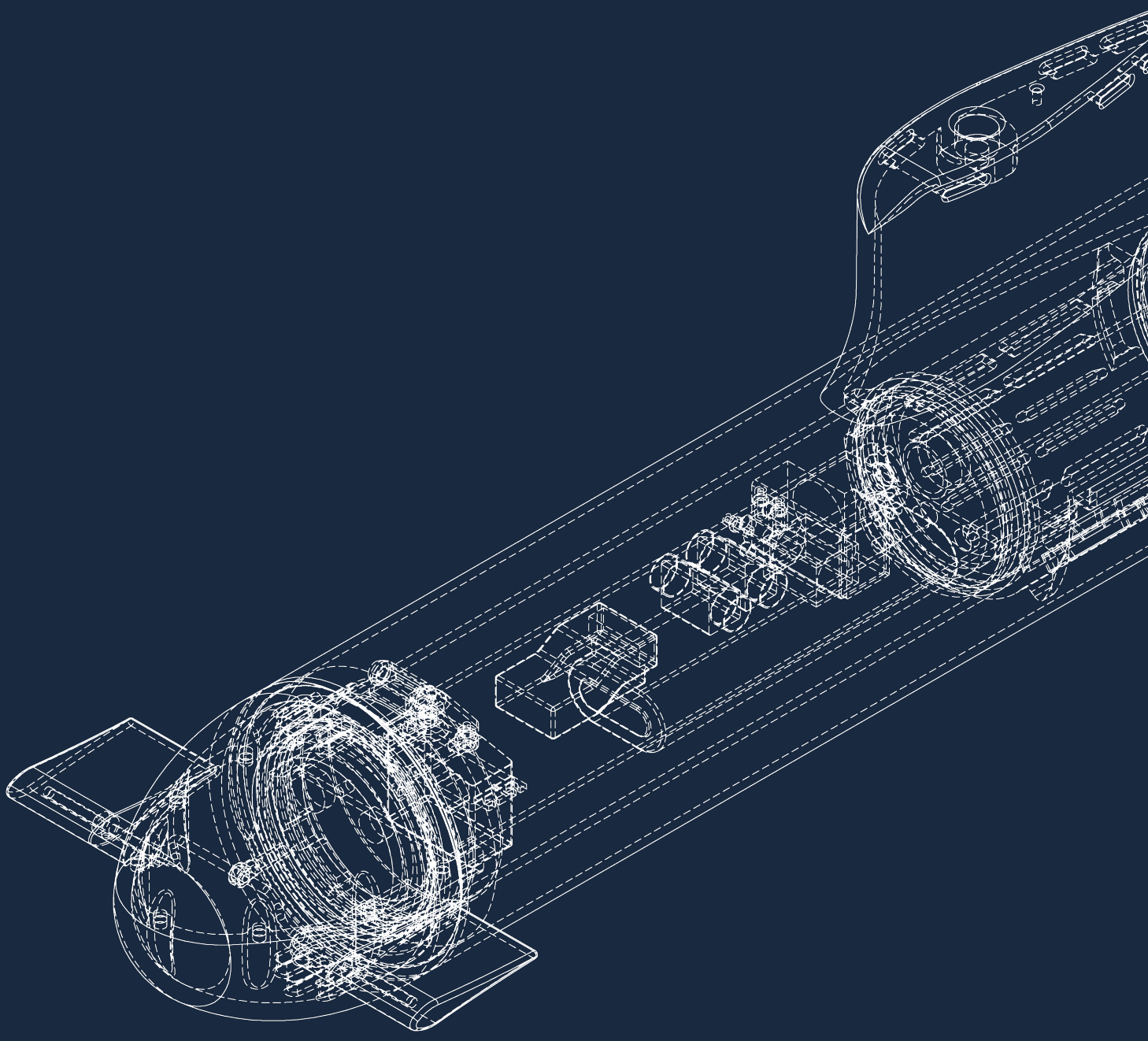
Part #	Part Name	Supplier	Description / Dimensions	Quantity	Image
61	Heat Shrink	Other	Heat-shrink tubing is a shrinkable plastic tube used to insulate wires, providing abrasion resistance and environmental protection for stranded and solid wire.		
62	Electrical Mounting Plate	Other	The elctrical mounting plate can be made from an assortment of materials. You could use acrylic sheeting or deisgn your own 3D printed part to mount your electronics.		

3D Printed Parts List

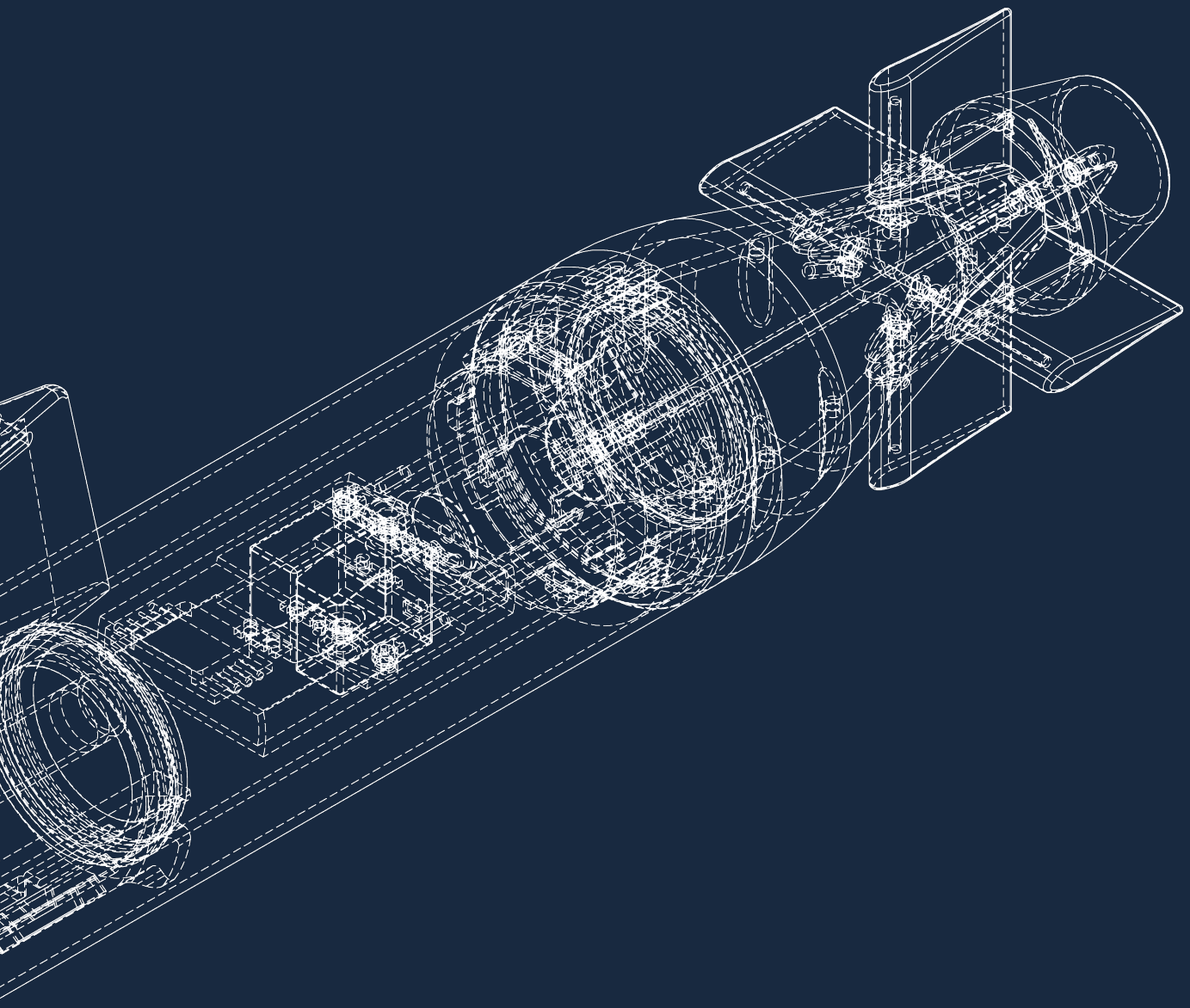
Part #	Part Name	Supplier	Dimensions/ Description	Quantity	Image
1	Nose Cone Bottom 2017	REA STL File	110mm L x 55mm W x 200mm H The nose section of the submarine outer hull. The nose section is broken into 2 sections. Connect 'Nose Cone Bottom - Half 1' to 'Nose Cone Bottom - Half 2w	1	
2	Nose Cone Top 2017	REA STL File	110mm L x 55mm W x 200mm H The nose section of the submarine outer hull. The nose section is broken into 2 sections. Connect 'Nose Cone Top - Half 1' to 'Nose Cone Top - Half 2'	1	
3	Tail Cone Bottom - Complete	REA STL File	100mm L x 55mm W x 200mm H The tail section of the submarine outer hull is broken into 2 or 4 sections depending upon the size of your 3D printing bed. Connect 'Tail Cone Bottom' to 'Tail Cone Top	1	
3.1	Tail Cone Bottom - (A)	REA STL File	100mm L x 55mm W x 200mm H The tail section of the submarine outer hull is broken into 2 or 4 sections depending upon the size of your 3D printing bed. Connect 'Tail Cone Bottom' to 'Tail Cone Top'	1	
3.2	Tail Cone Bottom - (B)	REA STL File	100mm L x 55mm W x 200mm H The tail section of the submarine outer hull is broken into 2 or 4 sections depending upon the size of your 3D printing bed. Connect 'Tail Cone Bottom' to 'Tail Cone Top'	1	
4	Tail Cone Top - Complete	REA STL File	100mm L x 55mm W x 200mm H The tail section of the submarine outer hull is broken into 2 or 4 sections depending upon the size of your 3D printing bed. Connect 'Tail Cone Bottom' to 'Tail Cone Top'	1	

Part #	Part Name	Supplier	Dimensions/ Description	Quantity	Image
4.1	Tail Cone Top - (A)	REA STL File	100mm L x 55mm W x 200mm H The tail section of the submarine outer hull is broken into 2 or 4 sections depending upon the size of your 3D printing bed. Connect 'Tail Cone Bottom' to 'Tail Cone Top'	1	
4.2	Tail Cone Top - (B)	REA STL File	100mm L x 55mm W x 200mm H The tail section of the submarine outer hull is broken into 2 or 4 sections depending upon the size of your 3D printing bed. Connect 'Tail Cone Bottom' to 'Tail Cone Top'	1	
5	Air Bladder Housing	REA STL File	80mm L x 80mm W x 95mm H The air baldder housing secures the air baldder in location.	1	
6	Control Planes	REA STL File	60mm L x 10mm W x 40mm H Control planes maneuver the craft underwater.	6	
7	Motor Mount	REA STL File	Motor Mount fastens to rear rear end cap and is used to secure the motor to servo mount.	1	
8	Motor to Servo Mount	REA STL File	The motor to servo mount rests between the motor mount and servo mount acting as a link to hold the motor.	1	

Part #	Part Name	Supplier	Dimensions/ Description	Quantity	Image
9	Servo Mount	REA STL File	Servo mount holds the servos in location.	1	
10	Conning Tower	REA STL File	Conning tower is located on top of the outer hull and is used to house the on/off switch and aerial antenna.	1	
11	Propeller Shroud	REA STL File	Protects the users from the rotating propeller.	1	
12	Front Servo Mount	REA STL File	Front servo mount secures to the front front end cap and holds the servo in location.	1	
13	Pressure Hull Locator	REA STL File	Pressure hull locator is using in conjunction with a hose clamp to secure the pressure hull in a set location withing the outer hull assembly.	1	

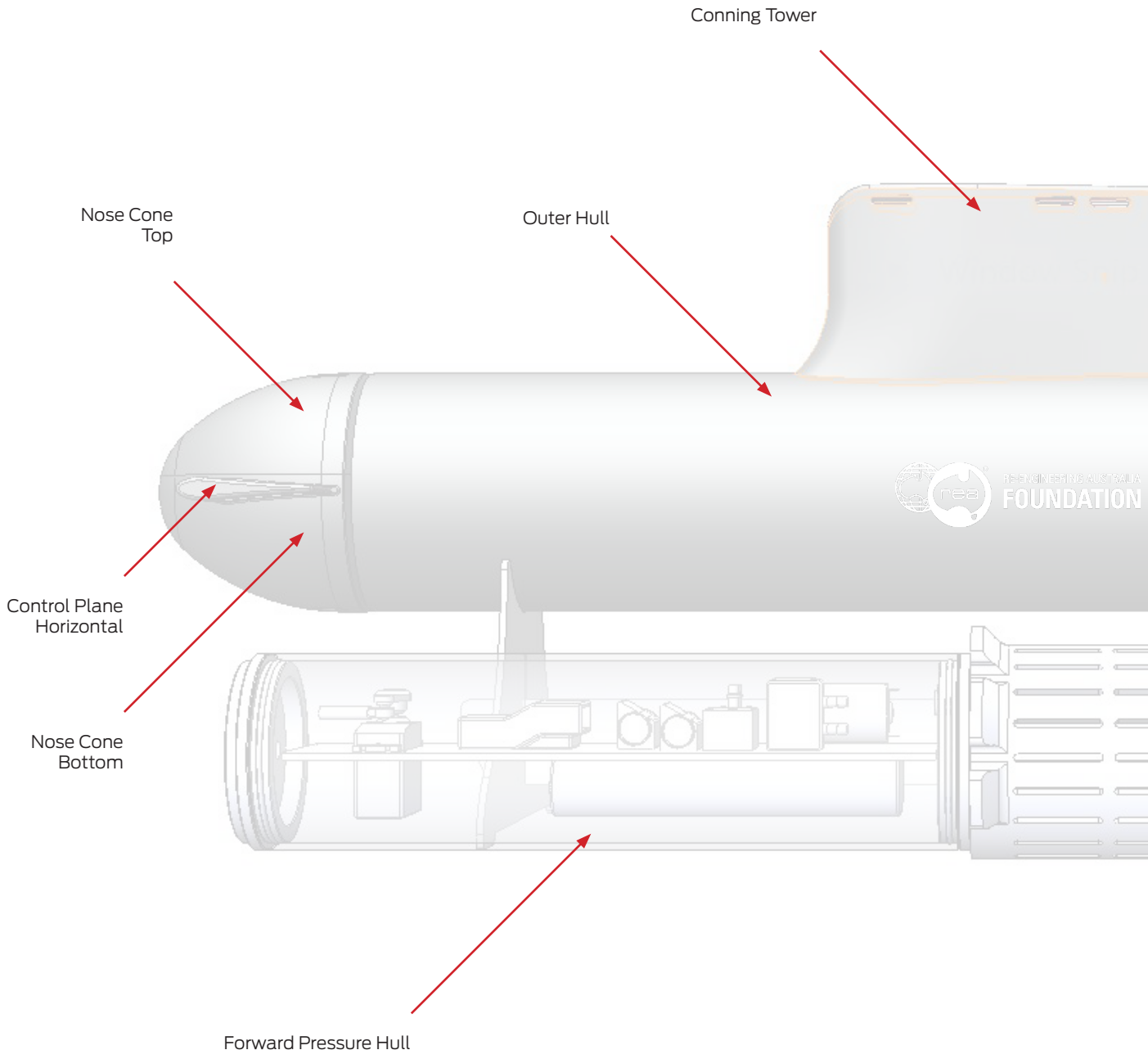


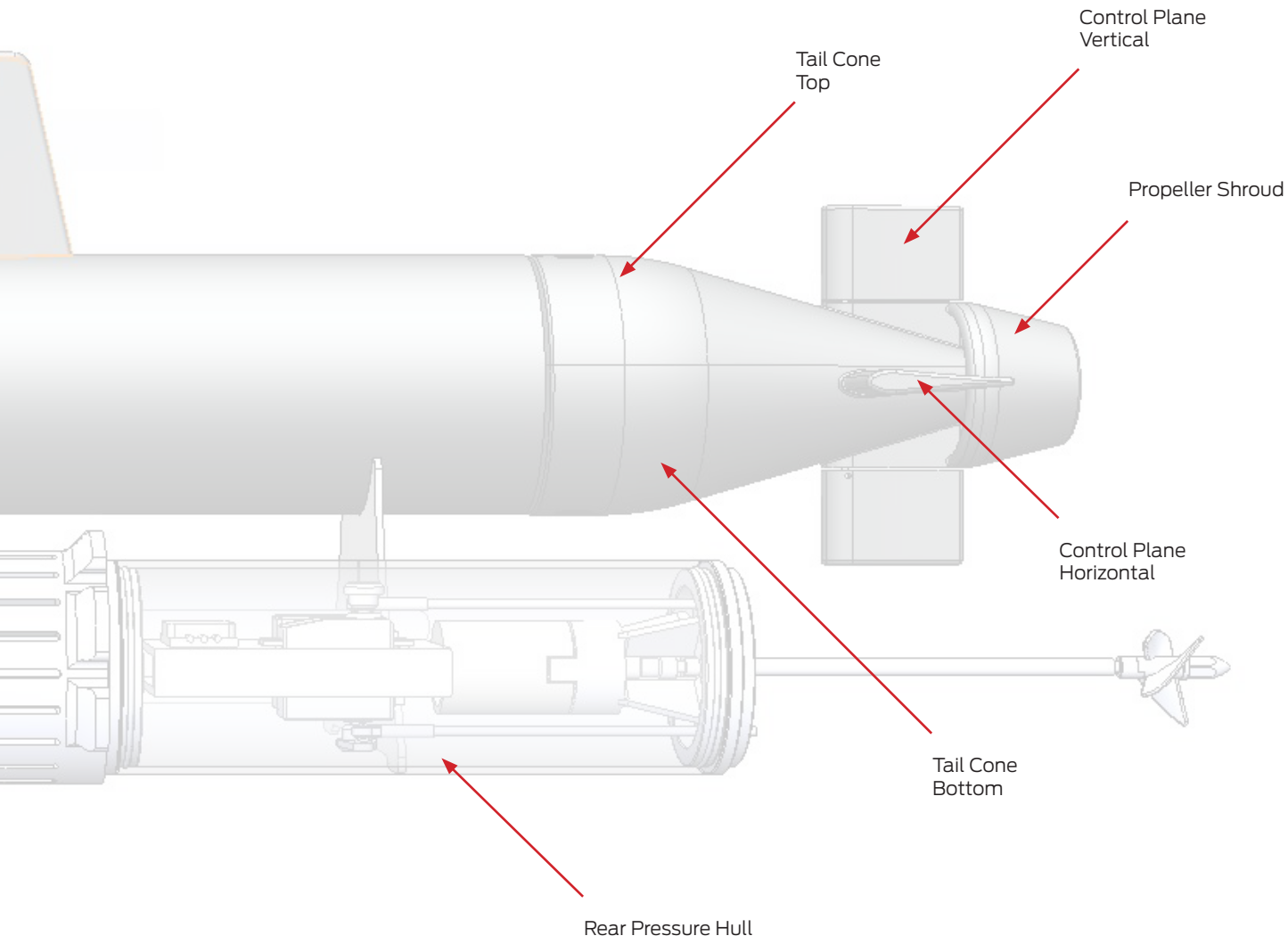
RE-ENGINEERING AUSTRALIA
FOUNDATION



Build Instructions

Assembly Overview



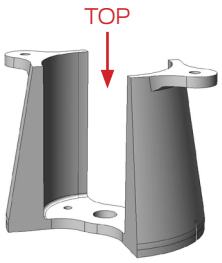

Control Plane
Vertical
Tail Cone
Top
Propeller Shroud
Control Plane
Horizontal
Tail Cone
Bottom
Rear Pressure Hull

0.0 3D Printed Parts Sequence

Print 1st - Motor to End cap Mount

The motor to end cap mount is as the name suggests a mount from the motor mount to the end cap. The part aligns the motor mount to the drive shaft by attaching the motor to end cap mount to the end cap.

Note:
Print the part in the orientation shown to minimise the support material required.

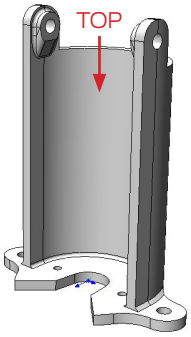


Brushed Motor

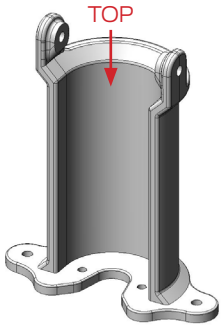
Print 2nd - Motor to Servo Mount

The motor to servo mount is as the name suggests a mount from the motor to the servo housing. The part holds the motor in place and secures the servo housing.

Note:
Print the part in the orientation shown to minimise the support material required.



Brushed Motor

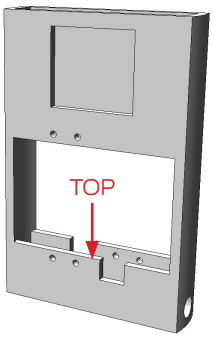


Brushless Motor

Print 3rd - Motor to Servo Mount

The motor to servo mount is as the name suggests a mount from the motor mount to the servo. The part aligns the servos to the centre of the pressure hull as well as a set distance from the end cap for controlling the push rods.

Note:
Print the part in the orientation shown to minimise the support material required.

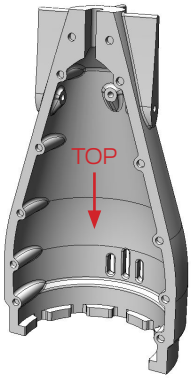


Brushed Motor

Print 4th - Tail Cone Bottom (Complete A+B)

The tail cone bottom is the bottom half of the complete tail cone assembly. This part is suited to large 3D print beds that are capable of printing to a height of 200mm. If your 3D printer has a smaller print height please use parts (A) and (B).

Note:
Print the part in the orientation shown to minimise the support material required.



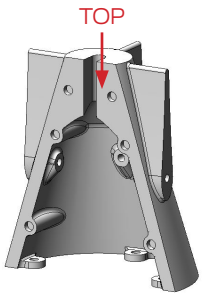
NOTE

This part is 200mm tall and may not fit all 3D print beds. Please use Part (A) and (B) if this is the case

Print 4.1th - Tail Cone Bottom (A)

The tail cone bottom is the bottom half of the complete tail cone assembly. For 3D printers with a smaller printer bed use this part and assemble part (A) with part (B) to make the complete tail cone bottom half.

Note:
Print the part in the orientation shown to minimise the support material required.

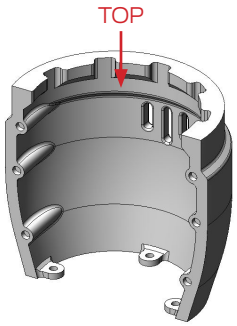


NOTE
'Tail Cone Bottom' is available as a complete part (A + B)

Print 4.2th - Tail Cone Bottom (B)

The tail cone bottom is the bottom half of the complete tail cone assembly. For 3D printers with a smaller printer bed use this part and assemble part (A) with part (B) to make the complete tail cone bottom half.

Note:
Print the part in the orientation shown to minimise the support material required.

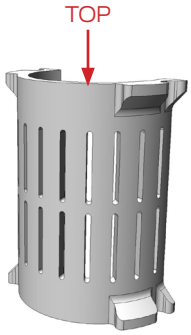


NOTE
'Tail Cone Bottom' is available as a complete part (A + B)

Print 5th - Air Bladder Housing

The air bladder housing orientates the air bladder in its set location. The vents on the side of the housing allow water to rush in and out when the air bladder inflates or deflates.

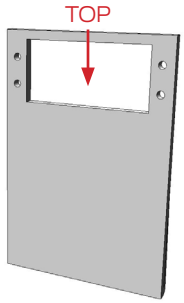
Note:
Print the part in the orientation shown to minimise the support material required.



Print 6th - Front Servo Mount

The front servo requires a mount to the front front end cap. It ensures the servo does not move and remains in a set location.

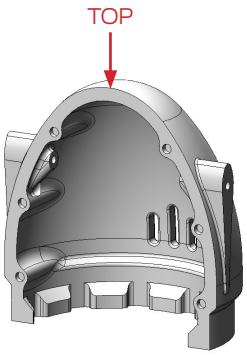
Note:
Print the part in the orientation shown to minimise the support material required.



Print 7th - Nose Cone Bottom

The nose cone bottom is the bottom half of the complete nose cone assembly.

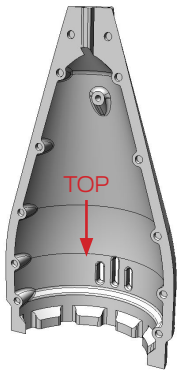
Note:
Print the part in the orientation shown to minimise the support material required.



Print 8th - Tail Cone Top (Complete A+B)

The tail cone top is the top half of the complete tail cone assembly. This part is suited to large 3D print beds that are capable of printing to a height of 200mm. If your 3D printer has a smaller print height please use parts (A) and (B).

Note:
Print the part in the orientation shown to minimise the support material required.



NOTE

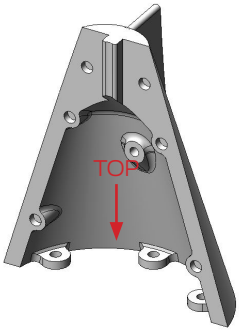
This part is 200mm tall and may not fit all 3D print beds. Please use Part (A) and (B) if this is the case

---

Print 8.1th - Tail Cone Top (A)

The tail cone top is the top half of the complete tail cone assembly. For 3D printers with a smaller printer bed use this part and assemble part (A) with part (B) to make the complete tail cone bottom half.

Note:
Print the part in the orientation shown to minimise the support material required.



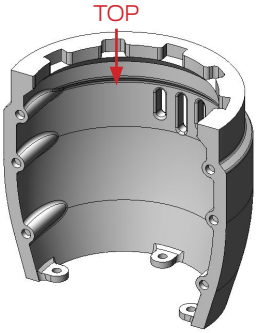
NOTE

'Tail Cone Top' is available as a complete part (A + B)

Print 8.2th - Tail Cone Top (B)

The tail cone top is the top half of the complete tail cone assembly. For 3D printers with a smaller printer bed use this part and assemble part (A) with part (B) to make the complete tail cone bottom half.

Note:
Print the part in the orientation shown to minimise the support material required.



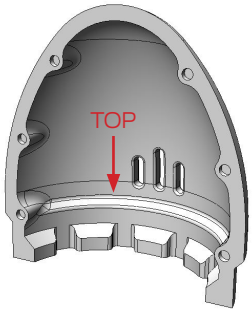
NOTE

'Tail Cone Top' is available as a complete part (A + B)

Print 9th - Nose Cone Top

The nose cone top is the top half of the complete nose cone assembly.

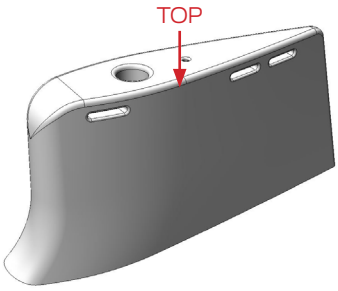
Note:
Print the part in the orientation shown to minimise the support material required.



Print 10th - Conning Tower

The conning tower is connected to the exterior hull. It houses the power on/off switch and antenna aerial.

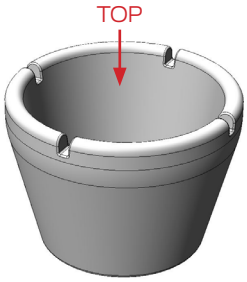
Note:
Print the part in the orientation shown to minimise the support material required.



Print 11th - Propeller Shroud

The propeller shroud protects the user from the propeller. It also reduced the effects of cavitation on the propellar blades.

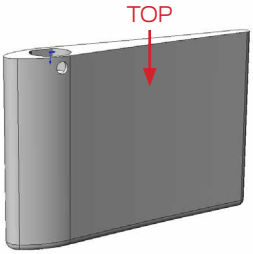
Note:
Print the part in the orientation shown to minimise the support material required.



Print 12th - Control Planes

Control planes are the 'control' surfaces of the submarine. They control directional movement as well as assisting on diving or surfacing the submarine.

Note:
Print the part in the orientation shown to minimise the support material required.



IMPORTANT

The submarine requires 6 control planes. Don't forget to print all 6!

1.0 Rear Pressure Hull Assembly

1.1 End cap Assembly

Step 1 - End cap Push-rod Guides

Cut 2 x 35mm lengths of 4mm OD hollow brass tube. You can use a hacksaw or bandsaw to cut the tube to length. Once cut to length remove the sharp edges with a file.

REMINDER

Print 3D parts
- #7 Motor Mount
- #8 Motor to Servo Mount
- #9 Motor Servo Mount

Step 2 - Mark-out Rear Rear End cap

Using a scribe, mark out the centres of the two servo guide holes as shown drawing a line vertically. From the centre of the end cap draw a line perfectly perpendicular to the line. This line will be your reference line later when you install the Motor mount to End cap.

Step 3 - Placement of Push-rod Guides

Insert a 25mm 'push-rod guide' into each of the two 4mm ID holes located on the rear rear end cap in the location shown. The tubes should be quite tight and may require a gentle tape with a hammer. Centre the tube in the end cap to allow around 15mm to protrude each side of the end cap.

Step 4 - Gluing Push-rod Guides

Mix up around 1cm^3 of Araldite (epoxy resin), ensuring it is thoroughly mixed. Use the radiused edge of a paddle pop stick and apply the glue around the perimeter of the Pushrod guides to end cap. You can remove any excess glue with acetone (nail polish remover).

IMPORTANT

You need to ensure the glue is consistent and has no weak points as this join needs to be water tight. (Leave to dry for 12 hours)

Step 5 - End cap Drive-shaft Sleeve

Cut 1 x 250mm lengths of 6mm OD hollow brass tube. You can use a hacksaw to cut the tube or a bandsaw. Once cut to length remove the sharp edges with a file, this will become the drive-shaft sheath. Cut 1 x 300mm length of 4mm OD brass rod. This will become the drive-shaft. Use a metal file to apply a slight chamfer the edges on the ends of the rod.

1.1 End cap Assembly

Step 6 - Mounting Motor

Place the electric motor in the 3D printed '#8 Motor to Servo Mount'. Insert 2 x M3 bolts into the designated holes to fasten the motor in place.

Step 7 - Installing Shaft Coupler

Insert the shaft coupler onto the end of the electric motor. Ensuring the flat spot on the shaft of the motor is aligned with the grub screw on the shaft coupler. Tighten the grub screw using the supplied allen key, tightening the grub screw on the shaft flat spot first and then rotating the shaft 180° and tightening the second grub screw.

Step 8 - Mounting Motor to Support

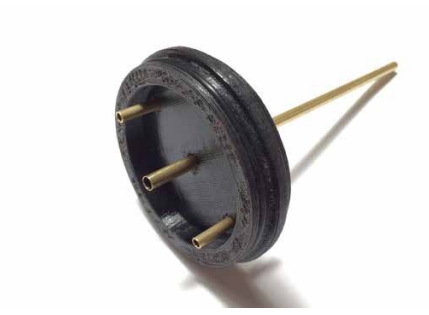
Mate 3D printed parts '#7 Motor Mount' with '#8 Motor to Servo Mount' using 2 x M2.5 nuts and bolts. It is important to align the faces the best you can at this point.

Step 9 - Attaching Drive Shaft

Insert the 4mm OD solid brass rod into the vacant end of the shaft coupler. Tighten the grub screws using the supplied allen key. This is the drive shaft, transmitting power from the electric motor to the propeller.

Step 10 - Installing Drive-shaft Sleeve

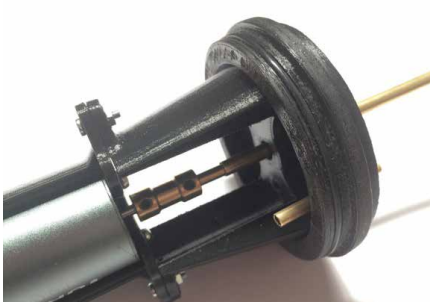
Insert the drive-shaft sleeve into the centre 6mm ID hole of the rear, rear end cap. The tube should be a tight fit and may require a gentle tap with a hammer. Push the tube through the end cap until it is exposed around 20mm out of the inside face of the end cap. The inside edge of the end cap has an O-ring seal.



1.1 End cap Assembly

Step 11 - Aligning Motor to End cap

Slide the drive-shaft sleeve over the end of the drive shaft to allow the motor mount to sit flush with the inside facia of the end cap. The motor mount should automatically centre to the end cap. There are two alignment notches on either side of the motor mount which are used to align with your previously marked horizontal line.

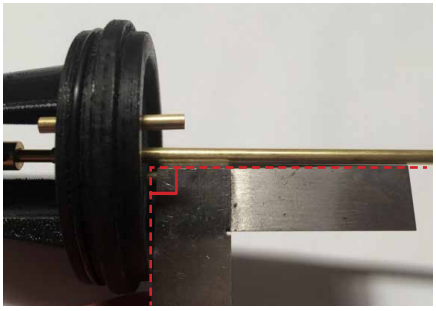


IMPORTANT

The motor mount should be mounted to the inside edge of the end cap. The inside edge of the end cap has an O-ring seal.

Step 12 - Checking Mount to End cap

The motor and mount should feel quite secure at this point. Use a set square to check the drive shaft is perfectly perpendicular to the end cap. Carefully slide the drive-shaft and motor assembly out of the drive-shaft sleeve so there is only the end cap and drive-shaft sleeve together.



IMPORTANT

The motor to end cap mount must be aligned as accurately as possible. If it is not aligned it will later effect the servo mounts and engine drive-train.

Step 13 - Gluing Mount to End cap

Mix up around 1cm^3 of Araldite. Using a paddle pop stick apply the Araldite to the base of the motor mount and around the drive-shaft sleeve on the end cap. Slide the drive-shaft back into the drive-shaft sleeve and press the motor mount onto the facia of the end cap. Apply glue to both sides of the end cap around the drive-shaft sleeve. (Leave to dry for 12 hours)

IMPORTANT

Ensure the drive-shaft and sleeve are perfectly perpendicular to the end cap. If not aligned properly you'll be unable to fit the tail section.

Step 14 - Rear Front End cap Cable Tube

Insert one of the M15 nut onto the end of the cable tube , tightening it until it tightly sitting on the base of the thread. Place a washer on top of the nut. Mix up around 1cm^3 of Araldite and apply to the thread of cable tube and facia of washer. Slide the rear front end cap onto cable tube. glue.

IMPORTANT

You need to ensure the glue is consistent and has no weak points as this join needs to be water tight. (Leave to dry for 12 hours)

Step 15 - Gluing End Cap

Apply Araldite to the inside face of the second washer and exposed cable tube thread. Insert the nut onto the end of the exposed cable tube and tighten the nuts to sandwich the glue, nuts and end cap together.

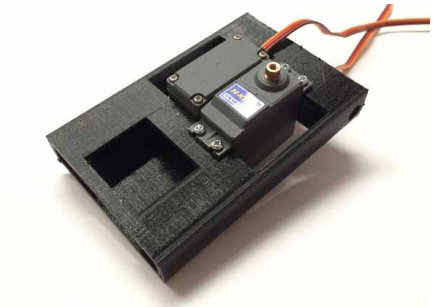
IMPORTANT

You need to ensure the glue is consistent and has no weak points as this join needs to be water tight. (Leave to dry for 12 hours)

1.2 Installing Servos, Motor and ESC

Step 1 - Installing Servos

Install servos as shown into 3D printed servo mount , ensuring the gear shaft is orientated towards the Electric motor. To install the servos you may need to tilt the cable end in first and then lower it down. Install 4 x M2.5 bolts in the specified locations. Being careful not to over-tighten as the thread is only biting into the 3D printed component.



REMINDER

Print 3D parts
- #3 Tail Cone Bottom
- #4 Tail Cone Top
- #10 Conning Tower

Step 2 - Protect Motor Terminals

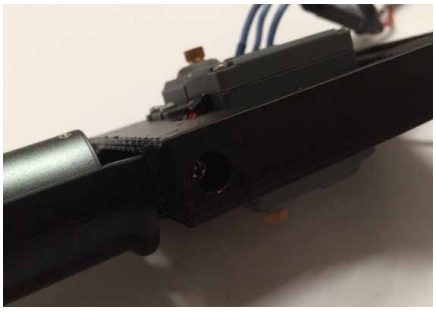
It is good practice to heat shrink all electrical connections. Remove motor from motor mount/ end cap assembly. The supplied motor may have exposed solder connections, if this is the case cut a 15mm length of heat-shrink. Slide the heat-shrink down the wire until it covers the terminals. Apply heat-shrink over connections with a heat gun.

IMPORTANT

You will only need to heat shrink the exposed motor terminals on the brushed motor as the brushless motor terminals are already sealed.

Step 3 - Connecting Motor

Run the electric motor wires through the centre of the servo mount and connect them to the ESC . Connect the red male connector from the motor to the red female connector on the ESC, and vice versa for the black cables.

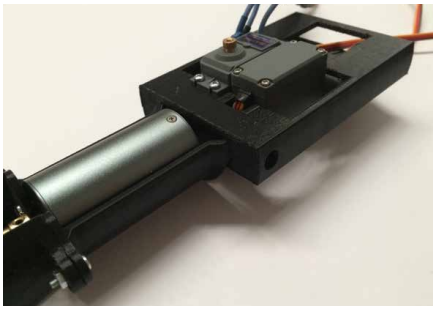


NOTE

The motor cables are directional, if the motor runs in reverse swap the two outside cables with each other and it will reverse the polarity.

Step 4 - Motor mount to Servo Mount

Slide the motor mount into the servo mount housing aligning the screw holes to one another. Insert a M3 screw into each side of the servo mount to fasten the motor mount in location. Do not over-tighten.

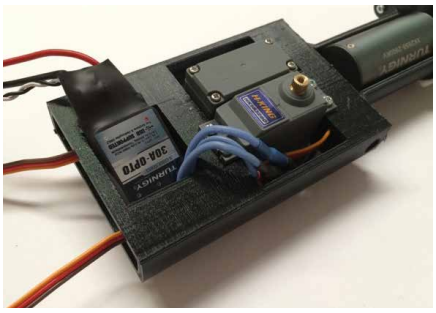


NOTE

Tighten the screw until you feel a change in the pressure you require as over-tightening will strip the thread of the 3D printed part.

Step 5 - Mounting ESC

Place the ESC in its designated location recess as shown. You may like to change the way the cables run to neaten up the assembly at this point.



NOTE

Try to run the cabling as neatly as possible as this will ensure it is not entangled in the servo push rod assembly.

1.3 Servo Push-rod Assembly

Step 1 - Cut Push-rod

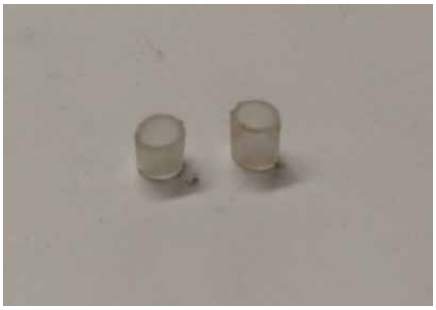
Cut 2 x 100mm lengths from the 2.5mm OD threaded push-rod .

Step 2 - Push-rod to EZ-connector

Thread an EZ-connector onto one end of the precut 100mm threaded rod lengths. You should now have two identical push-rod and connectors as shown.

Step 3 - EZ-Connector to Servo Arm

Cut 2 x 5mm lengths off the 4mm OD silicone tubing . Put these aside as these will be used later for securing the EZ-connector closed.



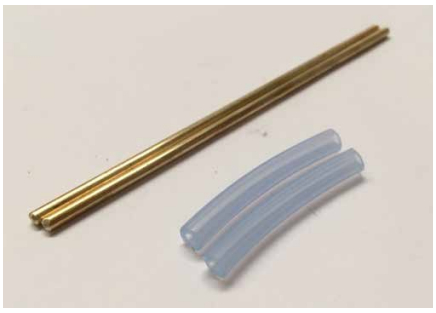
Step 4 - Servo Arms

Remove 2 x servo arm #5 from your tree of servo arms . Clip the EZ connector assembly through the last hole in the servo arm as shown. Once assembled slide a 5mm length of silicone tube down over the EZ-connector to avoid the clip from accidentally coming loose.

Step 5 - Cutting parts

Cut 2 x 150mm length of 3mm OD solid brass tubing .

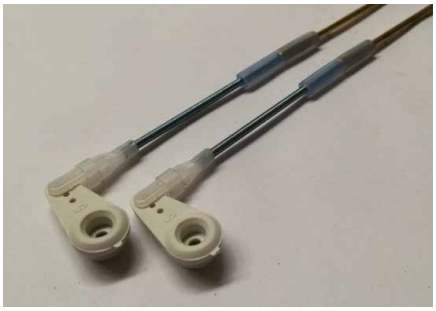
Cut 2 x 40mm length of 4mm OD silicone tubing .



1.3 Servo Push-rod Assembly

Step 6 - Push Rod Assembly

Slide half the 40mm length of silicone tubing (20mm) onto one end of each 150mm push-rods. Slide the 100mm 3mm OD brass tubing down the remaining length of silicone tubing. You should have a silicone join from your threaded rod to solid brass tubing.



NOTE

The silicone tubing allows the push-rod to flex as the servo arm rotation pushed the rod through the end cap.

Step 7 - Servo Arm installation

Place the servo arm onto the output shaft of the servo perpendicular to the length of the servo housing. Secure it in place by installing a M3 screw in the top.

Step 8 - Installing Rubber Boots

Get your pre assembled rear rear end cap and insert the brass push-rod through the top and bottom brass sleeves in the end cap. Slide a rubber boot over each of the outer section of brass tubing in the end cap until the flat section of the boot is seated nicely on to the tube. Slip a hose clamp over the rubber boot and tighten in location.

IMPORTANT

Ensure the push-rod rubber boot are watertight.

Step 9 - Adjusting Servo Throw

Twist the servo so that it is in its furthers back position where it retracts the brass push-rod through the end cap. Compress the rubber boot and slide a hose clamp over the boot while compressed and tighten. Fully extend the servo and ensure the boot is adjusted properly to avoid restriction to the servos movement.

IMPORTANT

Ensure the rubber boots are adjusted correctly to avoid any restriction to the servos movement.

1.4 Drive-train Assembly

Step 1 - Tap a thread

Remove drive-shaft from the previous assembly. Measure 10mm from the end where the propeller will sit. Tap a M4 x 0.7mm thread down the drive-shaft until your mark.

NOTE

If you're unsure how to tap a thread you can reference the how to section of this build manual.

Step 2 - Cut Silicone Tubing

Cut 2 x 10mm lengths of silicone tubing. Slip one of the 10mm lengths of silicone tubing over the drive-shaft sheath that rests inside the pressure hull, allow 5mm of tubing to overhang off the end.

Step 3 - Applying grease to Drive-train

Squeeze around 1cm^3 of grease inside the drive-shaft sheath from the propeller end of the silicone tube. Insert the drive-shaft inside the tube holding the threaded section in your hand spinning it as you do to move the grease up the tube, if theres very little grease when the drive-shaft enters the silicone tube remove the drive-shaft and apply some more grease inside the drive-shaft sheath.

Step 4 - Completing Drive-shaft Assembly

Once you think you've got the drive-shaft sheath filled with grease slide the remaining 20mm long silicone tube over the drive-shaft and drive-shaft sheath until only 5mm of tubing is off the drive-shaft sheath. The silicone tubing should be lightly touching the drive-shaft acting as a seal to ensure the grease remains inside the tube.

Step 5 - Clean up excess grease

Use dry paper towel remove any excess grease from outside the drive-shaft sheath from the drive-shaft. You may benefit from applying a small dollop of dish washing liquid to damp paper towel to remove the final bit of grease from the exterior of the drive-shaft assembly.

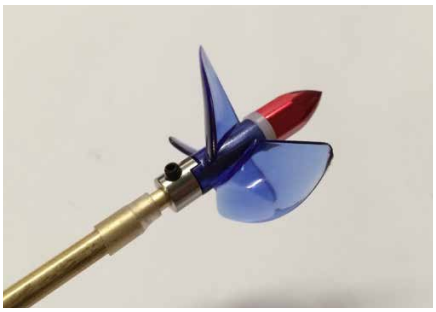
1.4 Drive-train Assembly

Step 6 - Installing Drive-shaft

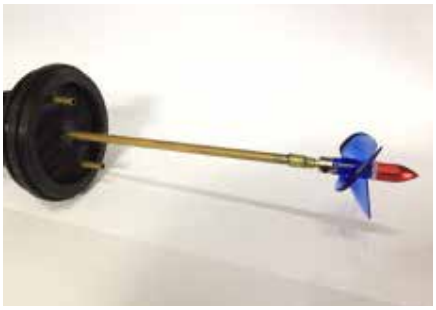
Push the drive-shaft up into the drive-shaft collet. Tightening the grub screws on top and bottom.

Step 7 - Installing dog drive/ propeller

Slide the dog drive on the drive-shaft as shown. Ensuring the teeth of the drive-shaft are facing the threaded end. Push the dog drive down the shaft until the propeller rests on the propeller cap, tighten the grub screw on the dog drive. Tighten the propeller cap until tight.



Step 8 - Complete assembly

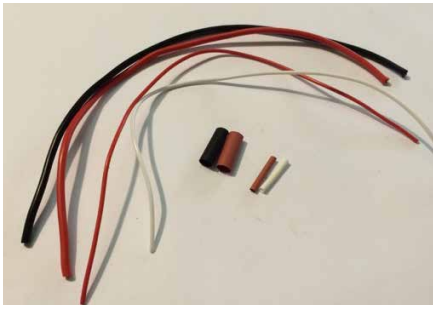


2.0 Front Pressure Hull Assembly

2.1 End cap Assembly

Step 1 - Cutting cables to length

Cut 2 x 250mm length of 16 gauge electrical cable.
Cut 2 x 250mm length of 32 gauge electrical cable.
Cut 4 x 20mm length of heat-shrink (2x red and 2 x black).



NOTE

It is best practice to use red wire for positive connections and black wire for negative connections. If you only have a cable of one particular colour try to use red and black heat shrink.

Step 2 - Preparing Power Cables

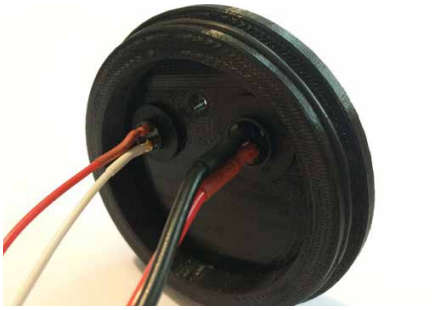
Strip 5mm off each end of the 250mm 16 gauge electrical cables. Twist the exposed wires until tight. Tint the end of the cable with solder. Tint one pin on the 4amp female IP67 connector. Slide heat-shrink on to cable. Solder cable to pin and then apply heat-shrink. Complete for both cables.

Step 3 - Dry fit 4amp IP 67 Connector

Test assemble the as shown to ensure you're comfortable with how it's assembled before applying glue. If you're confident with this process you're ready to seal it up.

Step 4 - Sealing 4amp IP 67 Connector

Mix up 1cm^3 of Araldite using a paddle pop stick. Apply liberally around the base of the connector where the heat-shrink is applied. Slide on the thin gasket, clamp ring, long gasket and sealing nut. Tightening the clamp ring first and then the sealing nut. Use a paper towel with acetone to remove any excess Araldite from around the fitting, ensuring the threads are 100% clean.



IMPORTANT

You need to ensure the glue is consistent and has no weak points as this join needs to be water tight. (Leave to dry for 12 hours)

Step 5 - Preparing Antenna Cables

Strip 5mm off each end of the 250mm 32 gauge electrical cables. Twist the exposed wires until tight. Tint the end of the cable with solder. Tint one pin on the 2am female IP67 connector . Slide heat-shrink onto cable. Solder cable to pin and then apply heat-shrink. Complete for both cables.

2.1 End cap Assembly

Step 6 - Dry fit 2amp IP 67 Connector

Test assemble the as shown to ensure you're comfortable with how it's assembled before applying glue. If you're confident with this process you're ready to seal it up.

Step 7 - Sealing 2amp IP 67 Connector

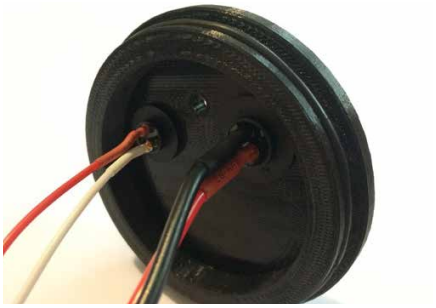
Mix up 1cm^3 of Araldite using a paddle pop stick. Apply liberally around the base of the connector where the heat-shrink is applied. Slide on the thin gasket, clamp ring, long gasket and sealing nut. Tightening the clamp ring first and then the sealing nut. Use a paper towel with acetone to remove any excess Araldite from around the fitting, ensuring the threads are 100% clean.

IMPORTANT

You need to ensure the glue is consistent and has no weak points as this join needs to be water tight. (Leave to dry for 12 hours)

Step 8 - Installing IP 67 to End cap

Mix up around 1cm^3 of Araldite using a paddle pope stick. Apply liberally around the facia of the IP 67 connectors as shown. Be careful not to get any glue on the pins or anywhere that will restrict the join of the male and female connectors.



IMPORTANT

You need to ensure the glue is consistent and has no weak points as this join needs to be water tight. (Leave to dry for 12 hours)

Step 9 - Install Front Servo Mount

Mix up around 1cm^3 of Araldite using a paddle pop stick. Apply liberally on the face of the servo mount. Adhere servo mount to from front end cap so that the top of the mount is parallel with the IP 67 connectors.

IMPORTANT

The alignment of the servo housing is critical as this will later effect the assembly of servo housing.

Step 10 - Cut push-rod Guides

Cut 1 x 35mm long 4mm OD hollow brass tube. This will become your push-rod guides for the front front end cap.

IMPORTANT

The motor mount should be mounted to the inside edge of the end cap. The inside edge of the end cap has an O-ring seal.

2.1 End cap Assembly

Step 11 - Installing Push-rod Guides

Insert a 35mm 'push-rod guide' into the 4mm ID hole located on the front front end cap in the location shown. The tube should be quite tight and may require a gentle tape with a hammer. Centre the tube in the end cap to allow around 15mm to protrude each side of the end cap.

IMPORTANT

You need to ensure the glue is consistent and has no weak points as this join needs to be water tight. (Leave to dry for 12 hours)

Step 12 - Front Rear end cap Barb fittings

Insert one of the bladder hose fitting into the end cap holes as shown. Complete a dry fit and ensure you're comfortable with this process before gluing. Once you're comfortable with the process you can glue.

IMPORTANT

You need to ensure the glue is consistent and has no weak points as this join needs to be water tight. (Leave to dry for 12 hours)

Step 13 - Gluing barb fittings

Mix up around 2cm^3 of Araldite with a paddle pop stick. Apply a generous amount of Araldite to the thread of the barb fitting. Push the fitting through the hole. Apply more Araldite to the exposed thread protruding through the end cap. Seat the washer and tighten the nut to sandwich the fitting against the end cap wall. Complete for the second barb fitting.

Step 14 - Front Rear Servo

Insert one of the M15 nut onto the end of the cable tube, tightening it until it is tightly sitting on the base of the thread. Place a washer on top of the nut. Mix up around 1cm^3 of Araldite and apply to the thread of cable tube and facia of washer. Slide the rear front end cap onto cable tube.

Step 15 - Gluing End Caps

Apply Araldite to the inside face of the second washer and exposed cable tube thread. Insert the nut onto the end of the exposed cable tube and tighten the nuts to sandwich the glue, nuts and end cap together.

IMPORTANT

You need to ensure the glue is consistent and has no weak points as this join needs to be water tight. (Leave to dry for 12 hours)

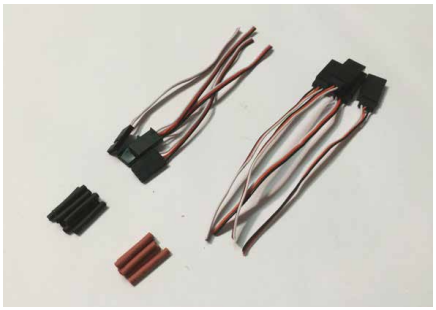
2.2 Wiring Pumps, Valves, Relays, Battery and Power Harness

Step 1 - Cutting Servo Extension Cables

Cut 5 x 200mm servo extension cables in half to make 5 x 100mm male and 5 x 100mm female connectors. Trim the white connector off all plugs.

Cut 8 x 20mm red 3mm OD heat-shrink.

Cut 8 x 20mm black 3mm OD heat-shrink.

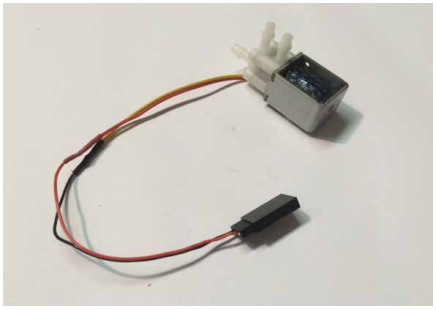


NOTE

It is best practice to use red wire for positive connections and black wire for negative connections. If you only have a cable of one particular colour try to use red and black heat shrink.

Step 2 - Preparing Valve

Cut the cable exiting the valve to a length of 100mm. Strip the cable ends and prepare for soldering. The electrical valve is non directional so it doesn't matter which side is positive and negative. Slide heat-shrink over cables and solder on a 100mm female connector. Apply heat-shrink over connections with a heat gun.

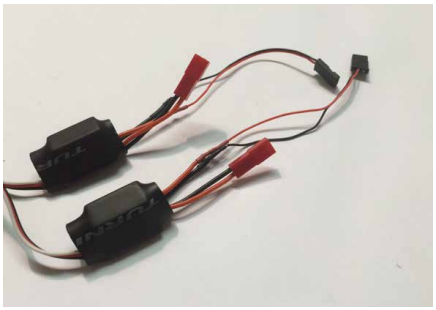


NOTE

If you're unfamiliar with how to solder then please read the how to section of this booklet titled soldering.

Step 3 - Preparing Relays Male Connector (to power Harness)

Cut the male connector off the relay at the base of the plug, leaving as much existing cabling as possible. Strip the cable ends and prepare for soldering. Slide heat-shrink over cables and solder on a 100mm male connector. Apply heat-shrink over connections with a heat gun. Complete for both pump and valve relays .

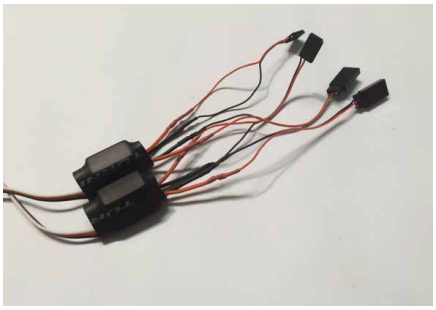


IMPORTANT

Relays are directional! Male connector goes to power supply. Female connector goes to valve or pump. Relays only operate below 5V so a step down module may be required.

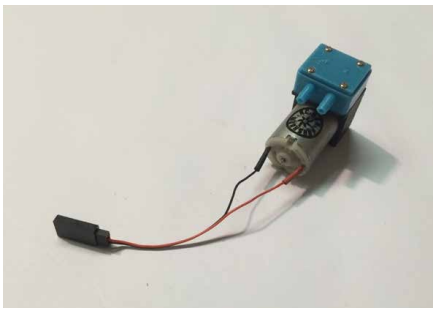
Step 4 - Preparing Relays Female Connector (to power pump/valve)

Cut the female connector off the relay at the base of the plug, leaving as much existing cabling as possible. Strip the cable ends and prepare for soldering. Slide heat-shrink over cables and solder on a 100mm female connector. Apply heat-shrink over connections with a heat gun. Complete for both pump and valve relays .



Step 5 - Preparing Pump

Tint the points on the pump with solder. Slide heat-shrink onto a male connect and solder it to the pump terminals. Ensuring the positive cable aligns with the '+' symbol on the motor. Apply heat-shrink over connections with a heat gun.



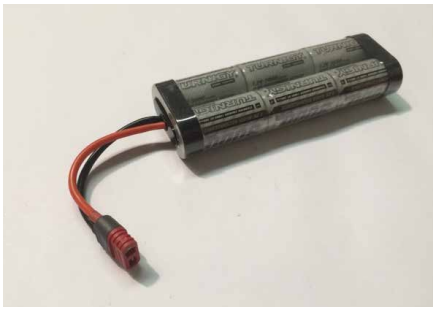
IMPORTANT

The pump is directional, wire the positive cable to the '+' symbol near the positive terminal on the pump motor.

2.2 Wiring Pumps, Valves, Relays, Battery and Power Harness

Step 6 - Fitting battery T-connector

Cut and strip only one of the battery cables at a time to avoid short circuiting. Cut the black cable at the base of the plug, prepare cable for soldering and slide on heat-shrink. Solder to a female T-connector. Apply heat-shrink over connections with a heat gun. Repeat process for the red (positive) cable.



IMPORTANT

Battery is fitted with a female T-connector to reduce the lickely hood of short circuiting.

Step 7 - Wiring Harness

Cut 2 x 200mm 13 gauge power cables . Prepare the ends for soldering.

Step 8 - Power Harness Servo cables

Select three male servo connectors. Twist the exposed cables of the two positive cables together and the two negative cables together.

Step 9 - Servo to power cables

Prepare the ends of the 200mm long power cables for soldering. Solder the negative cable to the negative group of servo cables in line to expose one end of soldered cables as shown. Complete the same process for the positive side. Slide heat-shrink up each double connection.

Step 10 - Power cables T-connector

Solder the group of servo and power cables to a male T-connector. Apply heat-shrink over connections with a heat gun.

2.2 Wiring Pumps, Valves, Relays, Battery and Power Harness

Step 11 - Power cables to T-Connector

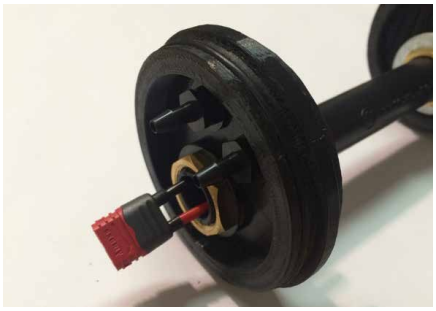
Slide heat-shrink over the ends of the power cable. Solder the other end of the power cable to a male T-connector. Apply heat-shrink over connections with a heat gun.

Step 12 - Cable Tube Wiring

Cut 2 x 200mm 13 gauge cables. Prepare all ends for soldering. Solder a pair of cables to a female T-connector as shown. Apply heat-shrink over connections with a heat gun. Thread the cable through the cable tube as shown.

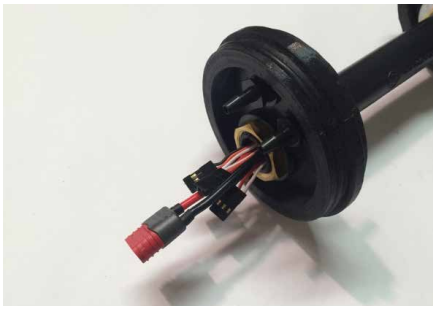
Step 13 - Cable Tube Wiring Continued

Slide heat-shrink over the remaining cables. Solder a female connector onto the remaining end of the power cable. The cable should sit in the cable tube and have a female connector at either end.



Step 14 - Servo cables in Wiring Tube

Thread 3 x 200mm long servo cables through the cable tube. These servo cables will be attached at a later point in the assembly.



2.3 Wiring Receiver and Satellite Receiver/ Antenna

Step 1 - Connecting Receiver to Electronics

BIND = Syncing receiver to controller
THRO = ESC/Motor
Ch 2 = Tail Elevation
Ch 3 = Tail Yew
Ch 4 = Nose Elevation
Ch 5 = Valves
Ch 6 = Pump
Ch 7 = Power from Battery

Step 2 - Extending Antenna

Cut 2 x 2000mm 26 gauge electrical cables. Prepare ends for solder

Step 3 - Feed antenna cables through the conning tower location shown.

NOTE

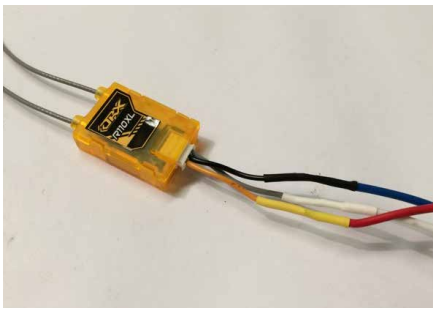
If you're planning on heat shrinking your antenna cables you may need to apply it now at this step prior to soldering on connectors plug in the following steps.

Step 4 - Satellite Receiver Plug

Prepare the ends of the short satellite receiver plug for solder. Cut 3 x 20mm lengths of heat-shrink and feed one onto each wire end.

Step 5 - Soldering Satellite Receiver Plug

Solder the antenna extension wire ends that come out the top of the conning tower to the satellite receiver plug wires. Heat shrink connections to secure and protect the cables.



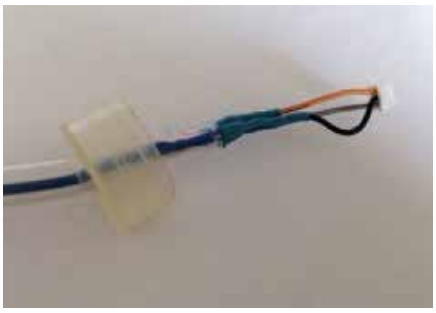
2.3 Wiring Receiver and Satellite Receiver/ Antenna

Step 6 - Preparing Surface Float

Drill an 5mm hole in the cap of a container for the antenna plug to fit through.

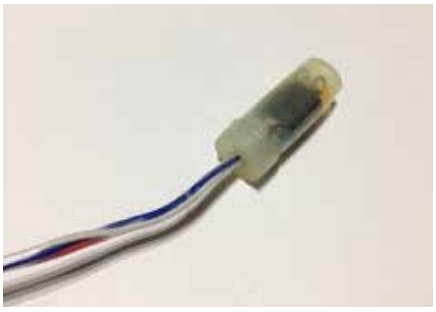
Step 7 - Thread Plug through Lid

Threat the satellite receiver plug through the hole in the lid so that you end up with the plug on the inside of the container (float).



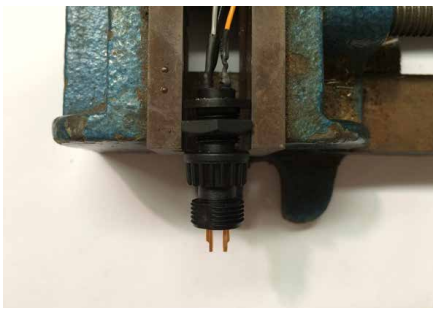
Step 8 - Seal Surface Float

Connect the satellite receiver plug into the base of the satellite receiver. Dry fit the components into the container to ensure you are comfortable with the process. Apply silicone around the drilled hole in the lid and around the seal of the lid to container to ensure it is water tight.



Step 9 - Fitting IP67 Connector

Prepare the ends of the antenna extension cable that run through the base of the conning tower for solder. The IP67 connector was placed in a vice to make it easier to solder. Solder each

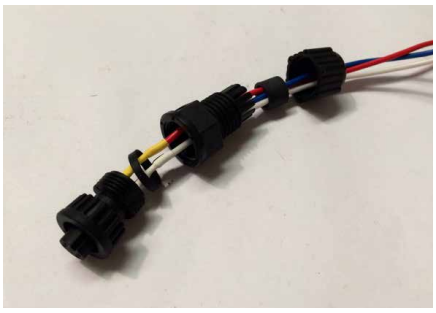


IMPORTANT

The antenna cables must be aligned with the correct cable on the chassis IP67 connector which is located on the end cap to ensure faultless operation.

Step 10 - Dry fit IP 67 Connector

Before you apply any sealant to the connector it is best to complete a dry test fit to ensure you are confident with the process. If there are any issues with assembly you can rectify this now.



2.3 Wiring Receiver and Satellite Receiver/ Antenna

Step 11 - Sealing up IP67 Connector

Once you have completed a dry fit and are confident with the process begin to apply silicone or Araldite to the inside of the IP 67 connector.

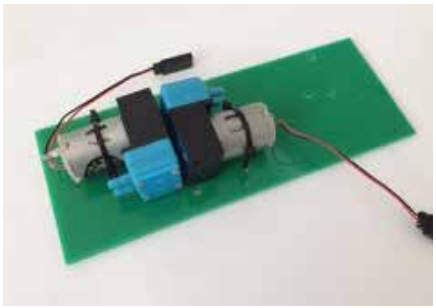
IMPORTANT

Ensure the sealent is free of air pockets where moisture could seep in. This connection is important as it will allow you to control your submarine once it is submerged.

2.4 Securing Components to Electrical Mounting Plate

Step 1 - Secure the Pumps

Position the pumps in the position shown. Orientate the pump, using two cable ties secure the pump to the mounting plate .

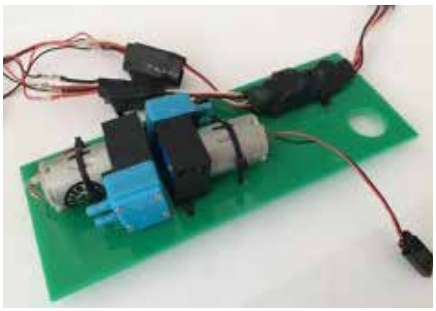


NOTE

You may opt to include valves in your assembly as the pumps are not perfectly air tight and suffer from slight air leaks. Slowly deflating the air baldder.

Step 2 - Secure the Voltage Regulator

Position the valve in the position shown. Orientate the valve, using two cable ties secure the valve to the mounting plate .

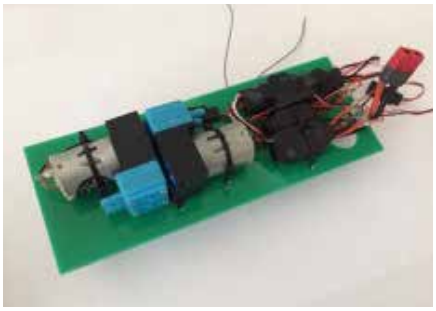


NOTE

The mounting plate can be made from an array of materials. You could even design and print a 3D mount!

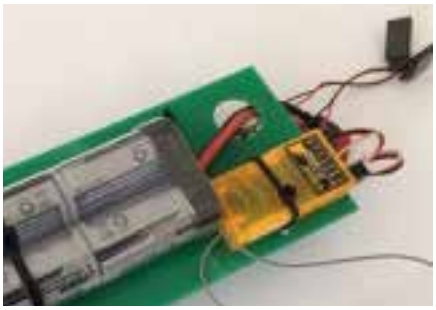
Step 3 - Secure the Relays

Position the relays in the position shown. Orientate the relays, using one cable tie for each, securing the relays to the mounting plate .



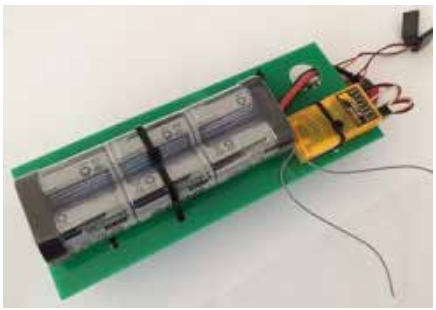
Step 4 - Secure the Receiver

Position the receiver in the position shown. Orientate the receiver, using two cable ties secure the receiver to the mounting plate .



Step 5 - Secure Battery

Using two cable ties secure the battery to the underside of the electrical mounting plate in the orientation shown. Feed the T-connector through the hole in the mounting plate.



2.5 Ballast System

Step 1 - Trim Bladder Tubing

Trim both bladder tubes so they are no longer than 30mm from the edge of the bladder.

Step 2 - Bladder tubing to end cap

Attach each of the bladder tubes to the each of the barb fittings on the front rear end cap assembly. Ensure you attach the air bladder tubes to the exterior of the pressure hull as shown.

Step 3 - Fitting the Bladder Housing

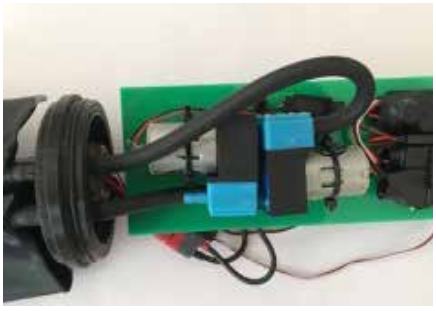
Slip the bladder housing over the two end-caps forming an enclosure to secure the air bladder in location while it inflates or deflates.

Step 4 - Cutting the old tubing

Using the offcuts of the air bladder tubing cut 1 x 150mm long section and 1 x 100mm long section.

Step 5 - Plumbing the Pump

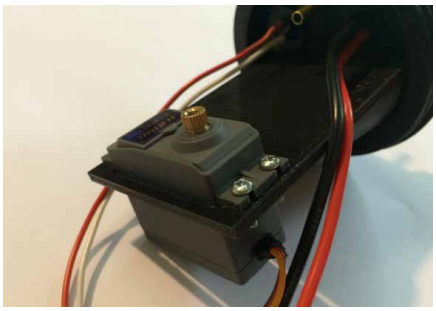
Select the 100mm long tubing and attach one end to either barb fittings on the front rear end cap. Slide the remaining end over either of the pump inlet/outlets.



2.6 Servo Push-rod Assembly

Step 1 - Inserting Servo

Install servo as shown into front servo mount . To install the servos you may need to tilt it cable end in first and then lower it down. Install 4 x M2.5 nuts and bolts in the specified locations.

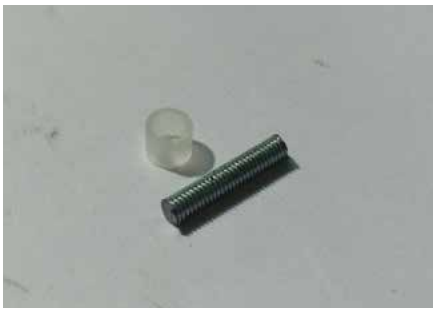


Note

Tighten the screw until you feel a change in the pressure you require as over-tightening will strip the thread of the 3D printed part.

Step 2 - Cut Push-rod

Cut the 1 x 30mm lengths from the 2.5mm OD threaded push-rod .
Cut 1 x 5mm length off the 4mm OD silicone tubing . Put this aside as it will be used later for securing the EZ-connector closed.



Step 3 - Push-rod to EZ-connector

Thread an EZ-connector onto one end of the precut 30mm threaded rod lengths.

Step 4 - Servo Arms

Remove 1 x servo arm #5 from your tree of servo arms . Clip the EZ connector assembly through the last hole in the servo arm as shown. Once assembled slide a 5mm length of silicone tube down over the EZ-connector to avoid the clip from accidentally coming loose.

Step 5 - Cutting parts

Cut 1 x 100mm length of 3mm OD solid brass tubing .

Cut 1 x 40mm length of 4mm OD silicone tubing .

2.6 Servo Push-rod Assembly

Step 6 - Push Rod Assembly

Slide half the 40mm length of silicone tubing (20mm) onto one end of each 30mm push-rods. Slide the 100mm 3mm OD brass tubing down the remaining length of silicone tubing. You should have a silicone join from your threaded rod to solid brass tubing.

NOTE

The silicone tubing allows the push-rod to flex as the servo arm rotation pushed the rod through the end cap.

Step 7 - Servo Arm installation

Place the servo arm onto the output shaft of the servo along the length of the housing towards the centre. Secure it in place by installing a M3 screw in the top.

Step 8 - Installing Rubber Boots

Insert the brass push-rod through the top brass sleeve in the end cap. Slide a rubber boot over the outer section of brass tubing in the end cap until the flat section of the boot is seated nicely on to the tube. Slip a hose clamp over the rubber boot and tighten in location.

IMPORTANT

Ensure the push-rod rubber boot are watertight.

Step 9 - Adjusting Servo Throw

Twist the servo arm so that it is in its furthest back position where it retracts the brass push-rod through the end cap. Compress the rubber boot and slide a hose clamp over the boot while compressed and tighten. Fully extend the servo and ensure the boot is adjusted properly to avoid restriction to the servos movement.

IMPORTANT

Ensure the rubber boots are adjusted correctly to avoid any restriction to the servos movement.

3.0 Outer Hull Assembly

3.1 Wiring On/Off Switch

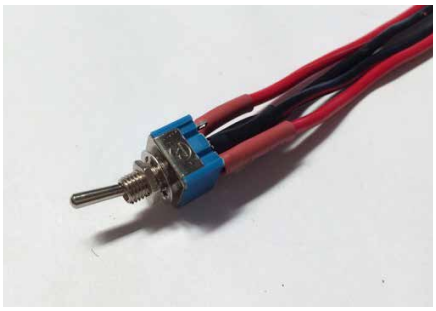
Step 1 - Cut wires to length

Cut 2 x 350mm long 16 gauge power cable to length. Prepare cable all cable ends ready for solder.

Cut 4 x 15mm lengths of 4mm OD heat-shrink.

Step 2 - Solder Cables to Switch

Solder the power cable as shown in the illustration. Apply heat-shrink over connections with a heat gun.



Step 3 - Solder IP 67 4amp Connector

Solder IP 67 Male connector to the remaining cables on the on off switch. Apply heat-shrink over connections with a heat gun.

Step 4 - Mounting Switch to Conning Tower

Dry fit the switch assembly as shown to the location in the conning tower. Once you're comfortable with this process mix up around 1com^3 of Araldite apply a small amount to the top of the switch assembly. Fasten the top nut down and fit rubber switch cover.

3.2 Tail Cone Assembly

Step 1 - Gluing Magnets Cone Base

Check the magnets fit into each location on the tail cone before applying any super glue. Carefully drill out any holes that are too tight. Only use one drop of super-glue per magnet location. Slip one magnet into each location

IMPORTANT

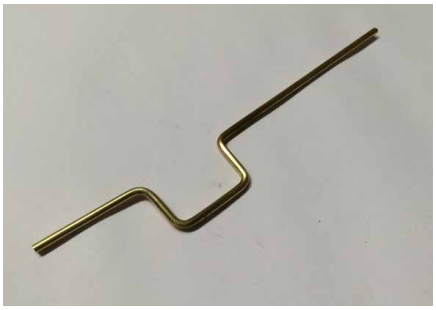
Ensure the magnets on each half of the tail cone attract. If this is not done correctly the two halves will never mate correctly and hold the halves together.

Step 2 - Cutting Control Rods

Rough cut control rods to length as you'll make more accurate cuts later post making the bends.

Step 3 - Bending Control Rods

Bend the control rods as shown ensuring you make the bends as tight and accurate as possible.



Step 4 - Cutting Control Rod Sleeve

Cut control sleeve as to allow a 5mm overhang off the end of control rod.

Step 5 - Cut Items to length

Cut 2 x 25mm 2.5mm OD threaded rod to length. Use a file to remove the sharp edges of the cut ends.

Cut 2 x 20mm 4mm OD silicone tubing to length

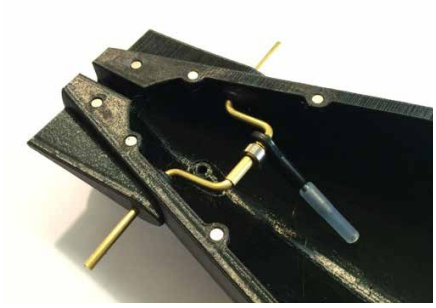
3.2 Tail Cone Assembly

Step 6 - Thread Ball joints

Thread a 3mm ID ball joint on to one end of either 25mm threaded rod. Slip the 20mm silicone tube 10mm up on to the end of the threaded rod.

Step 7 - Assembling Control Arms

Slip starboard and port control arms in to horizontal locations and assemble as shown. Tighten collet.



Step 8 - Bend Vertical Control Arm

Rough cut control rods to length as you'll make more accurate cuts later post making the bends.

Step 9 - Assembling Vertical Control Arms

Slip bottom vertical control arm in location and slip sleeve over the top. Slip the top vertical control arm through a ball joint and in to the sleeve.

Step 10 - Assembled Tail Section

3.3 Nose Cone Assembly

Step 1 - Gluing Magnets Cone Base

Check the magnets fit into each location on the tail cone before applying any super glue. Carefully drill out any holes that are too tight. Only use one drop of super-glue per magnet location. Slip one magnet into each location

IMPORTANT

Ensure the magnets on each half of the tail cone attract. If this is not done correctly the two halves will never mate correctly and hold the halves together.

Step 2 - Cutting Control Rods and Sleeves

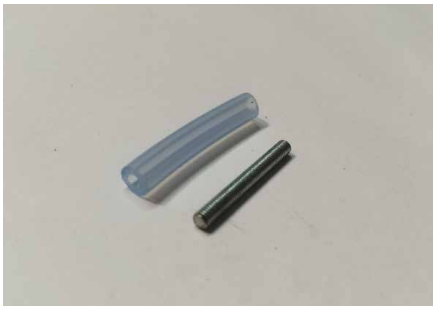
Cut controrods to a rough length. Making the bends as tight and neat as possible. Cut the sleeve as to allow a 5mm overhang off the end of control rod.

Step 3 - Assemble Collets and Ball Joint

Layout the elements on a table and become familiar with how they assemble. You can check the fitment of the parts in the nose cone assembly prior to completing any more steps.

Step 4 - Cut Threaded Rod To Length

Cut the threaded rod to 25mm in length.



Step 5 - Assemble Ball Joint

Assemble ball joint and threaded rod. Leave 15mm exposed of the threaded rod for the silicone tube to slip over. Slip the silicone tube up the remaining section of threaded rod.

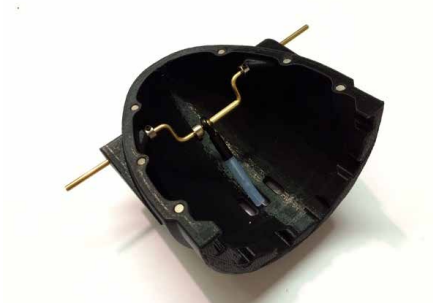
3.3 Nose Cone Assembly

Step 6 - Assemble Collets and Ball Joints

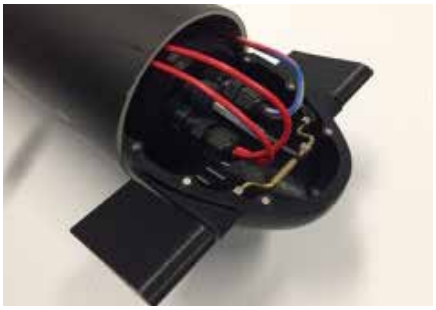
Thread a collet on either long side of the control arms ash show. Slide a single collet as shown followed by a ball joint.

Step 7 - Assemble in Nose Cone

Assemble the control plane in the nose cone, first inserting the control arms adding the collet, ball joint and finally the sleeve.



Step 8 - Assembled Nose Cone



Controlling the Centre of Buoyancy

Once the submarine is assembled fine tuning of the buoyancy, balance and flotation of the submarine will need to be undertaken by the students. This will require the students to undertake significant testing to fine tune the submarine before the submarine will performs effectively in sea trial.

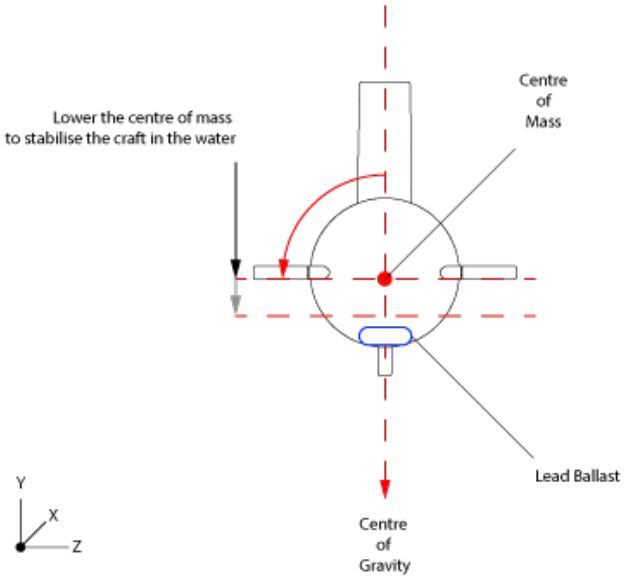
Key to this will be to add lead ballast to the submarine to achieve the following:
1. Set the floating high of the submarine when on the surface
2. Stability around the X axis:_

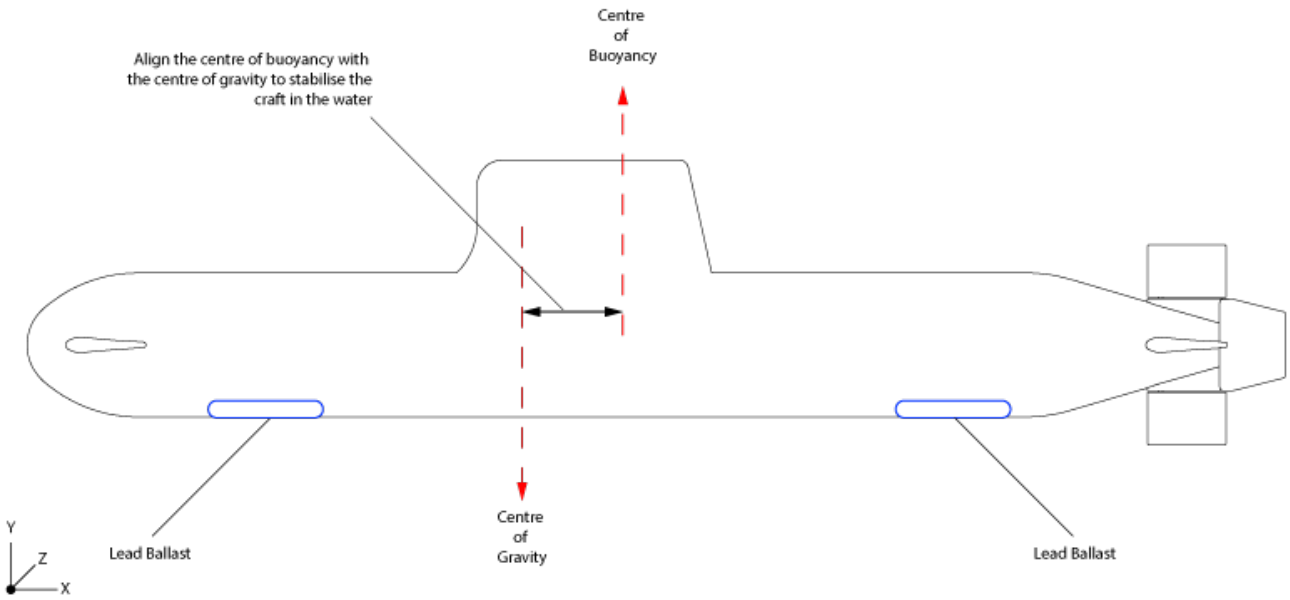
When the hull is upright the centre of gravity and centre of buoyancy should be in the same vertical line and the centre of gravity should be below the centre of buoyancy. This will create a righting torque which will ensure the conning tower remains upright.

3. Stability around the Y axis:_

In the Y axis the centre of gravity and centre of buoyancy should be in the same vertical line. If they are not the submarine will immediately pitch up or down. The amount of lead ballast and its position along the submarines length will vary for every design. Note that when the submarine dives or rises in the water the alignment between the centre of gravity and centre of buoyancy will change and this will impact the performance of the submarine.

The amount and position of lead ballast will need to be determined by the students. This will require significant testing and caluculation.





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