Team OTAKI - Robert Gordon's College, Scotland

"Success is the ability to go from one failure to another with no loss of enthusiasm"

Sir Winston Churchill (1874 – 1965)

From Left: R. Wakeford, J. May, C. Ashcroft, D. Theron, M. Rose, A. Stevenson and H. Mayeux

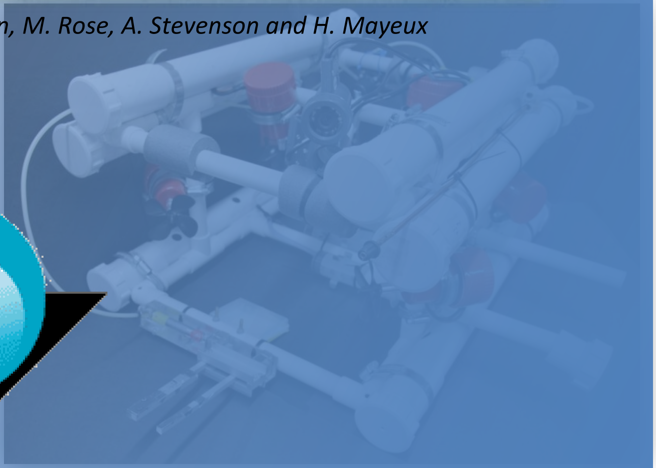

Table of Contents

Meet the Team

Name: Alexander Stevenson

Role: Project Manager

Next Year: Chemical Engineering at Imperial College London

Interests: The Great Outdoors; Climbing, Mountaineering, Skiing, Scuba Diving, Rugby and Science.

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Role: Design and Safety Manager

Next Year: Physics at Imperial College, London

Interests: Skiing, Guitars, Physics, Space, Music, Sailing, Math and Science.

Name: Damien Theron

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Next Year: Architecture at The university of Edinburgh

Interests: Architecture, Rugby, Badminton, Design and Music

Name: Hugo Mayeux

Role: R.O.V Pilot / Tool Design and Construction

Next Year: Dentistry at Dundee University

Interests: Skiing, Army, Rugby, Gaming and Music.

Name: Jonathan May

Role: Technical Report and Poster Manager

Next Year: Gap Year pending application to Medicine

Interests: Sky Diving (One day!), Gaming, Medicine, Technology, Snowboarding and Singing.

Name: Marcus Rose

Role: Design and Finance Manager

Next Year: Aeronautical Engineering at Imperial College London

Interests: Aircraft, Jet Engines, RC Nitro Cars, Golf, Kayaking, Hill Walking, Running, Watches, Computers, Science and Math.

Abstract

Figure 1 ROV and Sonar Survey of shipwrecks RMS Titanic and HMS Royal

The company was tasked with a two-stage mission:

1. The underwater survey of a WW2 era shipwreck, the SS Gardner.
2. Extraction of oil from fuel-oil tanks on the wreck, followed by capping of these tanks.

A similar casualty of War, the HMS Royal Oak, sunk in Scapa Flow in Orkney, was researched when preparing for the Regional Competition in Scotland. Our approach to the two challenges was devised in a staged design process.

Firstly, our frame was produced, with emphasis on providing a stable platform on which to mount all systems. Secondly, a propulsion and remote electronic piloting control and camera system was developed, to ensure a wide range of movement during the mission. Research and Development of mission tools was the final stage, with focus on assuring an effective economical design capable of completing tasks quickly and consistently.

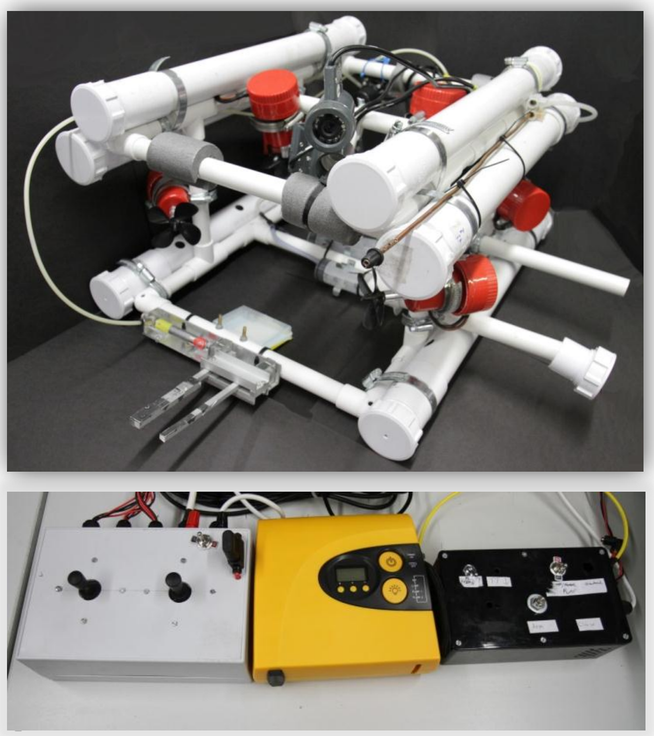


Figure 2 ROV and Surface Controls

The company operated on a budget of £900($1414), based on existing capital and annual funding from industrial sponsorship. Building on prior company experience, tools were designed to be passive devices wherever possible. Tools developed included: length and orientation measurement systems, a ferrous metal sensor, a simulated self-aligning ultrasonic sensor and neutron backscatter device, a pneumatically driven gripper and a system for oil extraction.

The team members felt that there has been some significant improvement to our problem solving, design and group communication skills. Particularly, it has been exciting exploring new avenues for tool design that we did not previously have the necessary confidence to pursue.

Design Rationale – ROV

Propulsion

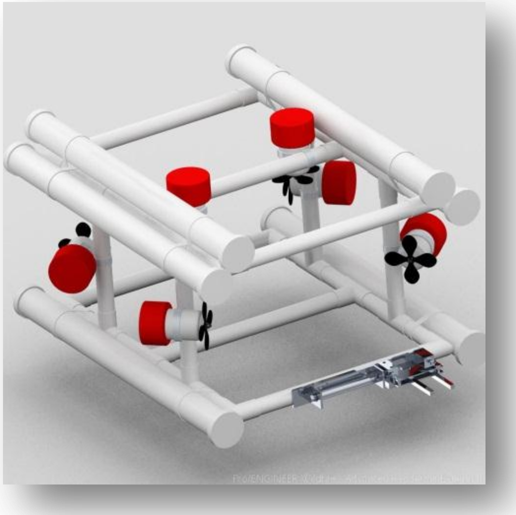
When designing the placement of the motors the key targets to be met were:

-The ability to crab (move from side to side), turn left/ right, gain/drop depth and move forward/backward

-Use as few motors as possible

-Motor placement would not obstruct any tool/camera/buoyancy.

It was decided that motors would be placed at all four corners of the ROV, 45° to the horizontal axis. Figure 3 show the movements that can be produced by controlling the direction of rotation of the motors:



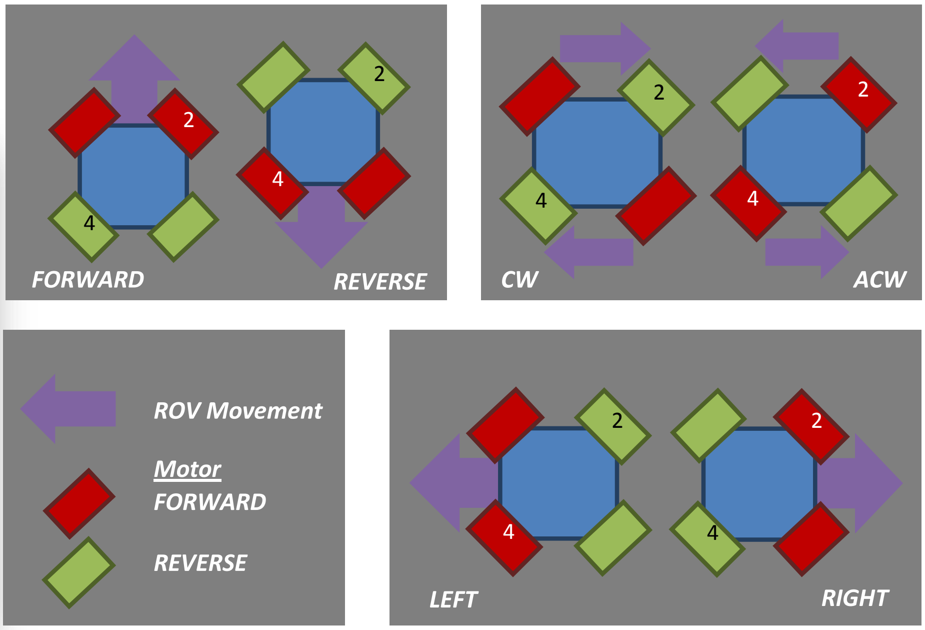


Figure 3 Propulsion diagram

It was discovered that the speed at which the ROV moved forward did not equal the speed at which it was able to move backwards. At first it was thought this was to do with the umbilical resisting moving back on itself, however through some thinking behind the physics behind the propulsion the following reasons were found. Due to the nature of the shape of the propellers used, the profile at which the blades move through the water is not the same in both directions. The water flow produced for both directions is not the same due to the motor casing presenting a resistance against the flow of water.

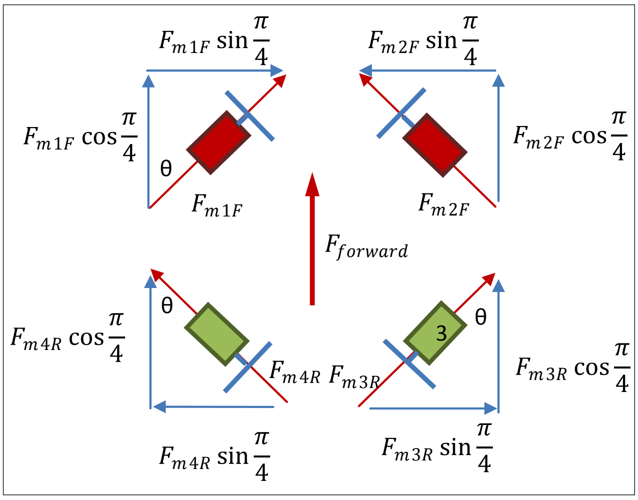


Figure 4 Thrust vectors of horizontal motors for forwards movement

The diagram shown in Figure 4 ignores the fact that the motors do not produce equal thrust in both directions; the aim is to show the thrust vectors produced and how two components of the thrust can be used in the manoeuvring of the ROV.

See Appendix 1 for a table showing the combination of which motors are going backwards/forward for each movement.

Serious consideration was given to the choice of motors and the propellers. Historically, ROVs at the College had used 500GPH bilge pump motors with 30mm 3 bladed props. At the MATE competition, the team ROV was much slower than other competitors, and it was decided that the propulsion system would be altered.

It is well known that electric motors can be run underwater with ease and hence the popularity of bilge pump motors in the MATE competition was surprising. It is thought that this is due to the fact that an unsealed motor would have no corrosion protection and having an electrical item submerged with no protection is a safety issue.

It was decided to remain with bilge pump motors, but they were improved in two ways: firstly, by buying 6 brand new 750GPH motors, which were of higher quality and more powerful than the predecessors; secondly, by buying new propellers that not only had more blades (4 compared with 3), but the individual blades were longer (34mm). This dramatically improved the speed of the ROV.

Buoyancy/Balance

The buoyancy for the ROV frame is constructed of six, 500mm long sealed plastic pipes, of radius 19mm. By Archimedes principle, an object displacing a volume of water, V, will experience an upwards force equal to the weight of the water displaced, i.e. $F = p_w g V$.

The volume of one tube is calculated as follows:

$V = \pi r^2 l$

$V = \pi \times 0.019^2 \times 0.5$

$V = \mathbf{5.67057 \times 10^{-4}\ m^3}$

Upthrust for one pipe $= p_w g V$

$= \mathbf{5.55N}$ Upthrust for six pipes = **33.3 N**

The weight of the ROV is 69.6N. Hence it can be calculated that the frame has an upthrust of 36.3 N, and displaces 0.0037 m^3 of water.

The ROV frame has been widened from last year to give added stability. When the ROV is in a stable state (figure 4), the buoyancy force, and the weight, is equal on both sides of the centreline of the ROV, and hence no rotational force is produced. However, when the ROV initially moves, the drag on the top of the ROV is greater than on the bottom, and the ROV tilts [Figure 5]. When this occurs, the distance from the left hand buoyancy to the centre of buoyancy is greater than the distance from the right hand buoyancy to the centre. As moment, M= Fs, the left-side buoyancy produces a greater moment, leading to a resultant clockwise moment. The weighted tubes have the same effect, leading to a resultant clockwise moment. This will rotate the ROV, and level it. As the width of the ROV increases, the resultant moment increases, meaning that, as the ROV gets wider, it will return to the normal position faster.

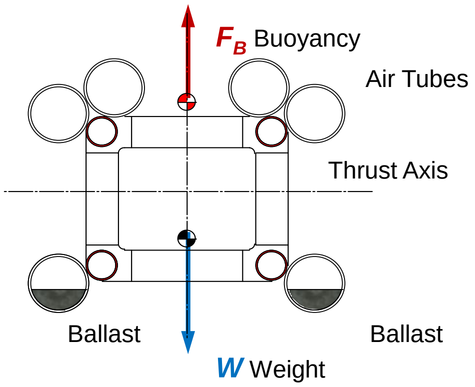


Figure 5 Stable position

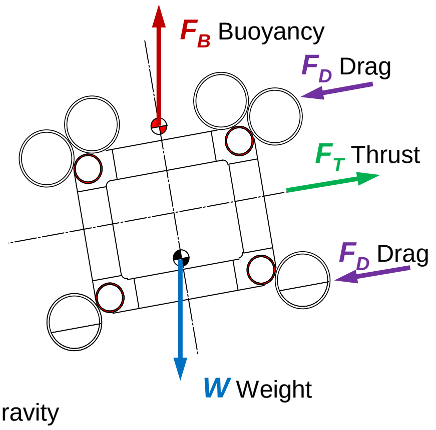


Figure 6 Movement induced tilt

Umbilical/Tether

The umbilical carries the following: electrical power to the six 12V 2.5A bilge-pump motors for the propulsion, electrical power to the 12V fuel pump and compressed air supply to the double-acting cylinder actuating the gripper. This is transferred to the surface via a 15 m umbilical comprising 12-off 15m lengths of electrical cable and two 15m lengths of PVC compressed-air tubing, rated to 20 bar.

Each motor requires two power cables (+ve and -ve), these cables were twined together to minimise the risk of tangling and so that the individual cables for each motor could be easily identified. To do this the previous year's torque tool shown in Figure 7 was used. The role of the torque tool was to close the shut-off valve on the BP Macondo oil well. Each cable was attached to a different prong on the tool and the motor was turned on until the wires were twined together. This dramatically reduced the time in making the umbilical and made use of the previous year's tools.

Figure 7 Torque tool

Figure 8 is a schematic of the components of the Umbilical.

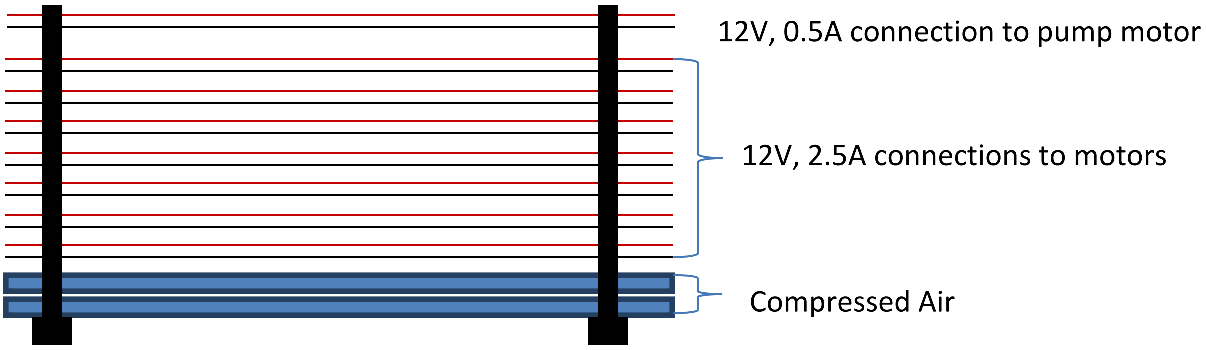
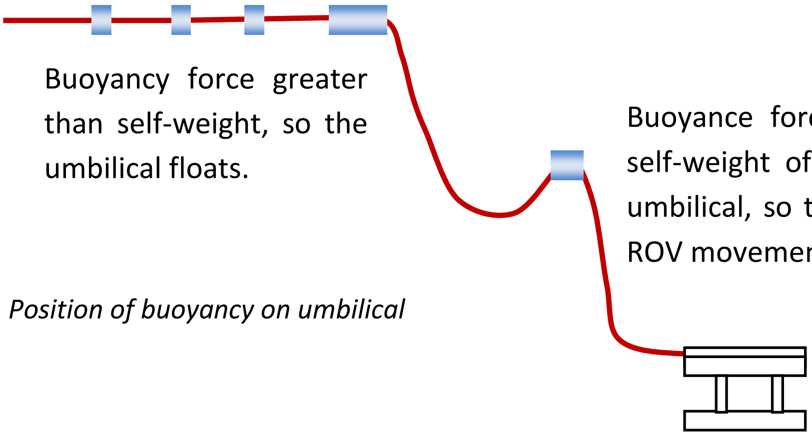


Figure 8 Umbilical Components

As shown by Figure 9, the umbilical's self-weight is uniformly distributed and buoyancy is attached at varying intervals to provide a weight-in-water profile that minimises the effect on the dynamics of the ROV. The bounacy used is plumbing insulation attached by nylon zip-ties. Figure 9 also shows the stategic positioning of the buoyancy.



Buoyancy force greater than self-weight, so the umbilical floats.

Buoyance force equal to the self-weight of the submerged umbilical, so that its effect on ROV movement is minimised.

Figure 9 Position of buoyancy on umbilical

ROV Frame / Camera Placement

The first decision to be made was the frame material. Originally aluminium was researched for the ROV frame. The bars researched were hollow square pipes of aluminium, which were of interest as attachment of tools, cameras and motors would have been easy. This would have been beneficial as the accuracy of the placement of our motors and tools is vital to the manoeuvrability of the ROV. However the aluminium frame was heavy and would have been difficult to achieve neutral buoyancy. The aluminium frame was rejected and plastic piping chosen as a more cost efficient frame material. Hollow piping was used as it is light and still very rigid.

[Figure 10] Hollow piping is rigid as when it bends the pipe bends along the neutral axis (2), this forces the upper section to be stretched (1) whilst forcing the lower section to be compressed (3). For the pipe to bend a higher force has to be applied as it has to both strech and compress around the neutral axis, because the pipe's mass is concentrated at a distance from the neutral axis, making the hollow plastic piping a strong, cheap and effective alternative to aluminium.

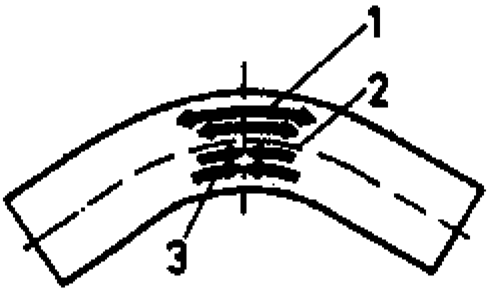


Figure 10 Bending stress

The frame was designed based upon solutions to problems found with previous ROVs. It was found that on the last ROV that there was a lack of space to fit tools and buoyancy whilst maintaining a clear view for the cameras. This year a wider frame was built, giving a larger attachment area for tools and wider undisrupted views for the cameras for better depth perception, see Appendix 4.

The cameras were placed in the same pattern as recent ROVs. A main camera was placed in a central position at the rear of the ROV facing forward to give a wide view of the ROV's position. This camera is used as the general driving camera as it can be combined effectively with the other cameras to give good depth perception as well as spatial awareness. A second camera was placed on the upper left of the ROV looking down the probe used for fuel extraction to give a direct view of where the probe was facing, making it easier to guide it into the ships fuel tank. To look at the gripper and Metal/non-metal indicator a camera was placed on the central upper support beam facing 45° downwards, at this angle both the tips of the claw and the Metal/non-metal indicator are in shot allowing clear view of the tools. The fourth camera was placed on the same horizontal tube but facing the right side of the ROV looking directly down the Neutron backscatter sensor and support prop, and allows the ROV to be piloted easily.

Electronics

The Electronics design is a key component to developing a successful ROV. The ROV required electronics to control several important functions. Therefore it was essential to create an efficient and safe electrical system. With these objectives in mind a reliable control system was built, emphasising originality, thus all of the circuits were made by the team and no commercial products were used. The circuit board was designed by the team and then etched by the school technician to ensure accuracy.

The main power (12V DC) enters the control box (appendix 2) and immediately passes through a quick-change, bladed 20 Amp fuse, providing safety. It then passes through a DPDT switch (double pole double throw) where both live and neutral lines are isolated from the power supply when the switch is off. This means that the master kill switch provides an extremely quick and useful way to "kill" all power to the control box. The circuit then uses a series of relays to power the motors as shown in Figure 4; there are 8 relays in total. Two SPDT 12V DC 10A relays control power to the motors. One relay controls power to the four horizontal motors and the other controls power to the two vertical motors. The other six DPDT 12V DC relays control the direction in which the motors spin. As the relays are double pole double throw when they are activated they reverse the power to the motor, thereby spinning the motors in the opposite direction. The motors are never isolated from the 12V supply line by these relays. The SPDT relays must be rated to 10A to allow the current for up to four motors to run through them.

Another aspect of safety incorporated into the control box is the use of electromechanical relays, which would fail open-circuit, rather than short-circuit. Within each relay is an electromagnetic coil, which is supplied with current when the relay is turned on, causing the electromagnet to act as an inductor creating a back EMF that is potentially harmful to other components as the coil switches off. To prevent the EMF from damaging the driver and other components a diode is connected in parallel to the coil, so suppressing any back EMF and adding a second layer of protection to the components, in addition to the 20A fuse.

The table below shows the different movements of the ROV and the combinations of relays that must be switched on or off to facilitate the corresponding movement. For example forward horizontal movement occurs when relays 1, 4 and 5 are on.

SWITCH	MOVEMENT	RL1	RL2	RL3	RL4	RL5	RL6	RL7	RL8	MT1	MT2	MT3	MT4	MT5	MT6
SW1	Forward	On	Off	Off	On	On	Off	Off	Off	Fwd	Fwd	Bck	Bck	Off	Off
SW2	Reverse	On	On	On	Off	Off	Off	Off	Off	Bck	Bck	Fwd	Fwd	Off	Off
SW3	Rotate CW	On	On	Off	Off	On	Off	Off	Off	Bck	Fwd	Fwd	Bck	Off	Off
SW4	Rotate ACW	On	Off	On	On	Off	Off	Off	Off	Fwd	Bck	Bck	Fwd	Off	Off
SW5	Crab left	On	Off	On	Off	On	Off	Off	Off	Fwd	Bck	Fwd	Bck	Off	Off
SW6	Crab right	On	On	Off	On	Off	Off	Off	Off	Bck	Fwd	Bck	Fwd	Off	Off
SW7	Up	Off	Off	Off	Off	Off	On	On	On	Off	Off	Off	Off	Fwd	Fwd
SW8	Down	Off	Off	Off	Off	Off	Off	Off	On	Off	Off	Off	Off	Bck	Bck

<u>Table key:</u>

RL1…8	Relays 1 to 8
MT1…6	Motors 1 to 6
SW1…8	Switches 1 to 8

The power is also supplied to 7805 Voltage Regulator 5V DC, this steps the 12 V supply voltage down to 5V for the low power combinational logic control circuitry producing the driver inputs.

The driver takes a low power signal from the logic gate outputs and if the input signal on a line goes high, then the corresponding output pin goes low, turning on the output device i.e. the relay. The logic gates are attached to a pair of directional joysticks. The right joystick controls the first four movements and the left joystick controls the next four movements.

Design Rationale – Mission Tasks

Task 1-Measuring Shipwreck Length

The company was required to survey the *SS Gardener* and the wreck site. This involved measuring the overall length of the ship, determining the orientation of the ship on the seabed floor and examining the debris field that was present alongside the wreck.

Measuring the length of the wreck was a difficult task. After brainstorming, two techniques were decided upon. The first involved measuring angles and using trigonometry to calculate the length of the wreck and the second involved using a tape measure that stretched between the two marker posts at either end of the ship wreck.

The trigonometry method was initially researched more because it was considered to be less time consuming. The concept requires that the observation point move a known distance. It was decided that this was best achieved by keeping the depth constant, with the only movement being in a horizontal plane. This concept evolved to the point where the ROV was kept at a fixed position with the camera being moved horizontally a precise known distance as shown in Figure 11. The trigonometric angles and distance relationships of this concept are shown in Figure 12. The typical position of the ROV is also shown in Figure 12.

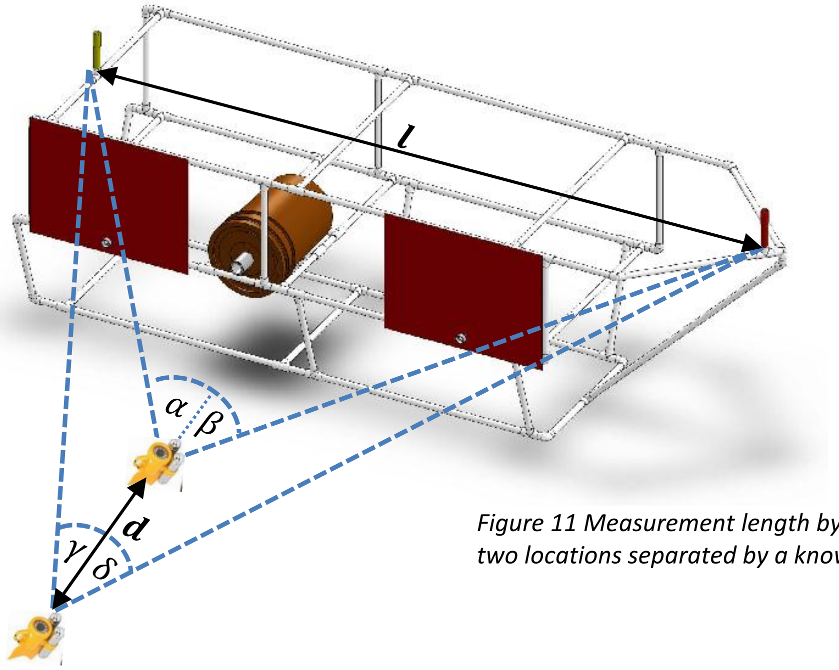


Figure 11 Measurement length by determining angles at two locations separated by a known distance.

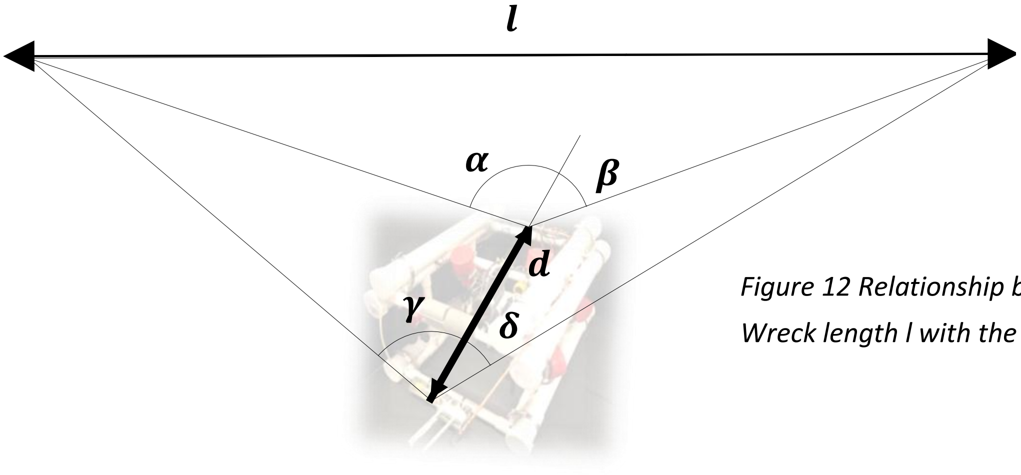


Figure 12 Relationship between measured angles and Wreck length l with the typical position of the ROV

Therefore the following equation was used to determine the wreck length:

$$l = d\sqrt{\left(\frac{\sin^2\gamma}{\sin^2(\alpha-\gamma)} + \frac{\sin^2\delta}{\sin^2(\beta-\delta)} + \frac{2\sin\alpha sin\beta\cos(\gamma+\delta)}{\sin(\alpha-\gamma)\sin(\beta-\delta)}\right)}$$

Angles $\alpha, \beta, \gamma,\ \delta$ were to be measured by attaching a stepper motor to a camera, this stepper motor would then move the camera round in an arc, this camera could be then aligned with one of the posts and a microcontroller would count the number of steps that the stepper motor took to turn the motor, and two of the four angles could be calculated. The camera would then be moved from its initial position by attaching it to a piston and the two new angles could be calculated.

This equation proved to be much more inaccurate than was considered acceptable because the same angle is used many times, meaning that any inaccuracy in the angle significantly increased the error in the measured length. So it was decided that a more accurate method of measuring the length was required.

A technique using a tape measure was then devised. The objective was to stretch a tape measure between the vertical posts on the ship wreck. The tape measure was attached to the first post with a weighted metal ring to reduce the chance of it becoming loose. The ROV was then driven backwards to the other marker post. To ensure that the length was measured accurately, a plastic self-aligning cone, was placed over the second marker. Finally the length of the wreck was determined by reading the tape measure with a camera.

Task 1-Determine the Orientation of the Shipwreck

Initially a diver’s compass was attached to the ROV allowing a camera to easily read the orientation of the shipwreck. However it was noticed that the permanent magnets inside the motors were interfering with the compass and causing it to become locked in one position. So it was decided to counteract the magnetic field of the motors by placing small permanent button magnets at strategic points around it. The button magnets would counteract the pull of the magnetic motors and thereby allow the compass to spin freely. This technique is still being refined and developed at the time of writing this report.

Task 1-Determine if Debris is Non-Metal or Metal

A number of solutions to this problem were found, ranging from using a simple button compass as an indicator that would point at the metals when they were approached, to using to a small magnet within a Petri dish. It was decided to explore the loose magnet within a transparent case that could be observed by a camera. A sealed Petri dish was used with a loose button magnet to indicate when a metal object was passed over by being attracted and following the position of the metal. There were problems with this however as the magnet moved when the ROV was moving making it hard to tell the difference between the magnet being attracted by a metal or the magnet moving due to the ROV moving. To combat this it was attempted to place a pressure sensor between the bottom of the Petri dish and a secured magnet causing a variance in resistance of the sensor, as the magnet would exert a greater force upon it when attracted to a metal object. This variation could be measured by an ohmmeter at the surface. This idea was unsuccessful in practice as the force exerted on the sensor by the magnet when close to a metal pipe was small and fluctuated too much to be certain the material was metal. Another idea which worked was the use of a commercially available underwater metal detector. However, the actual detector is very bulky and hence took up too much valuable space on the ROV. Finally a basic design was selected [Figure 13]: 2 small magnets together in a small transparent box attached to the ROV by a hinge which allowed it to hang at 45° below the ROV. This allowed easy contact between the container and the material as the ROV could drive and land on top of the material. If the material is metal the magnets align with the pipe and can clearly be seen to be moving with the pipe. Once this design was tested it was discovered that this method gave absolute certainty if the tube was metal or non-metal. Also being a passive tool, there is little chance it could fail in the pool, which is a possibility with the commercial metal detector[Figure 14].

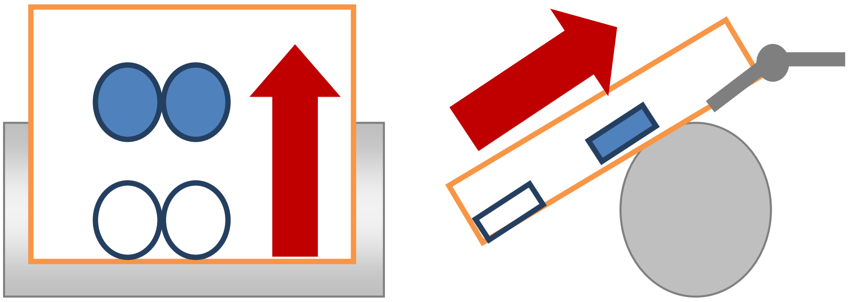


Figure 13 Ferrous metal sensor

Figure 14 Commercial metal detector

Task 2-The Gripper

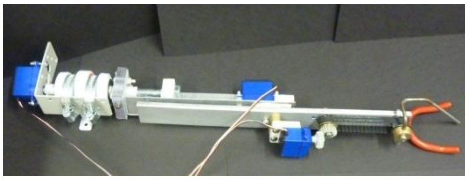


Figure 15 Articulated servo-driven gripper

This year, a pneumatic controlled gripper was used to try and avoid the problems faced last year regarding servomotors. Last year, the waterproofing of the electronics was a problem, expensive servos were bought but in the end they ended up cross-talking (signal lines interfering). Also, the previous arm was exceedingly heavy which put a lot of stress and strain on the plastic geared servos. We used a range of different materials which were mostly salvaged, such as Perspex, Lego gears and steel plates, see Figure 15. This year it was decided to make the gripper out of aluminium L- and U- piece sections. Aluminium has a very good strength to weight ratio which made it easy build the gripper by just using hand tools because of its relatively soft nature (compared to steel). Another advantage of aluminium is that it does not oxidise or deteriorate in water, essential for any ROV gripper. A support for the cylinder was also designed so that all the gripper components were on the same back plate. This meant that the entire tool could be easily taken off the ROV for maintenance. [Appendix 5]

The final design has evolved from testing a prototype, which involved a driven jaw sliding on two parallel guide rods to maintain a uniform gripping force and to prevent the jaw from twisting. Unfortunately, it proved impossible to align the guides accurately enough to ensure free movement of the jaw with the manufacturing resources available. The support rods were removed and two plates were fixed on the top and bottom surfaces of the moving rod. Using the fixed rod as a guide, the rods are now moving horizontally. To further improve the rod guidance, a wheel was placed to stop the moving rod from rotating/bending when the gripper was closed. The piston originally used was single-acting spring return, this allowed a fast closing time controlled by a set/reset 3/2 valve. However, the opening time was an issue; the spring return was too slow for the job partially due to water resistance and the age of the spring. It has been replaced by a double acting cylinder to maximise speed in completing the tasks but also to ensure that the gripper will definitely open [Figure 16]. The gripper is now controlled by using a set/reset 5/2 valve to control each state of the piston.

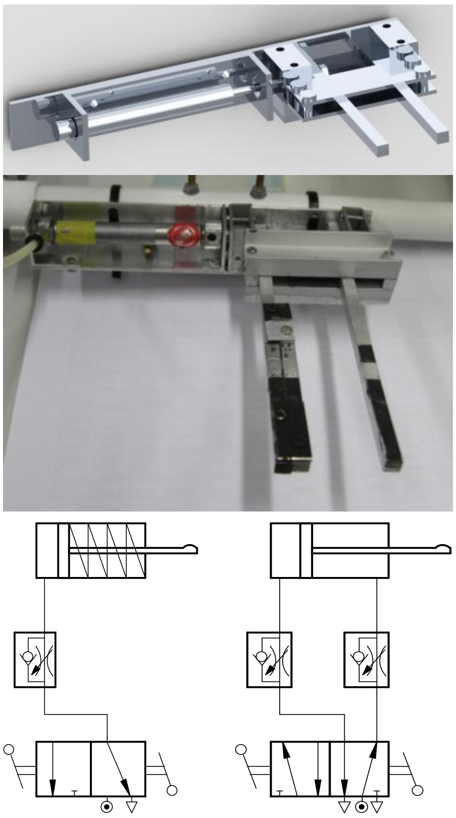


Figure 16 Pneumatic gripper – CAD 3D-model, gripper and control system

When the gripper was used in the swimming pool, it was discovered that the aluminium did not have enough grip to hold onto other metal objects (the hook on the blowbag). Therefore, to increase the friction at the jaws' extremities, rubber was added which vastly improved the grip.

Overall, the switch to pneumatics from electrical servo driven has been highly successful. The pneumatic gripper can be seen as a passive tool which could only fail due to mechanical reasons which makes much more reliable than the electrical counterpart.

Task 2-Determine if Fuel Tank is Empty

In order to determine whether the fuel tank was empty a tube was designed, which when placed on the fuel tank/calibration box would auto align so that it was always touching. Figure 17 shows how this was achieved.

When the tool was first placed on the ROV, it was not placed directly between the thrust produced by the motors. This caused a moment around the sensor. To counteract this moment we installed a second tube of equal length from the other centre post, preventing rotation.

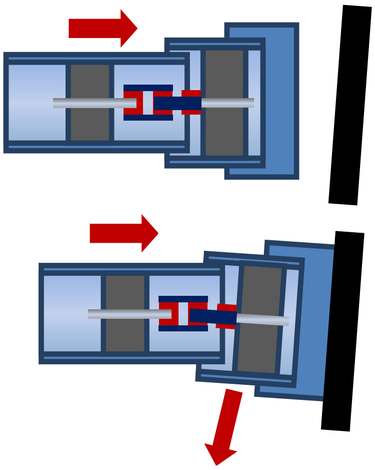


Figure 17 Auto aligning sensor

Task 2-Removal of Fuel

The first idea was to use a syringe with a spring inside. The syringe would be compressed with the spring inside and a pin placed in to prevent the spring expanding. When the fuel was collected, the pin would have been pulled out. This would have sucked the fuel sample into the syringe. This design had many problems, firstly finding the correct size and strength of spring. It was important that the spring had the right strength. The second problem with this idea was that this tool would only have one use, once the pin was pulled out the only way of compressing the syringe would have been to bring the ROV to the surface using up valuable time.

The next idea was to use two 60ml syringes with a rack and pinion.[Figure 18] Both syringes would have been attached to a metal plate with the plungers attached to another plate. Between the two plates would have been a rack and on the lower plate a bilge pump motor with a pinion. This would have meant that the tool could have been used multiple times if need be, without surfacing, and a 100ml sample could have been taken easily.

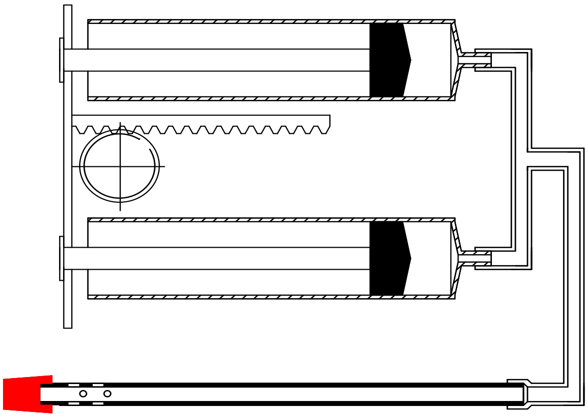


Figure 18 Syringes driven by motorised rack and pinion

The final design used a 12V Gaupner water pump[Figure 19]. The water outlet would have been split using a t-piece into two tubes attached to two 60 ml syringes. The pump would be turned on once the probe was in the fuel tank and the syringes filled so that 100ml sample could be taken. Before adapting the syringes, during tool development, it was discovered there was a fine balance between collecting 100ml and losing the sample. To prevent the plunger escaping the syringe, a hole was drilled in the neck and a bolt secured with a nut through the hole. This meant that the plungers would not be able to be removed from the syringe by accident.

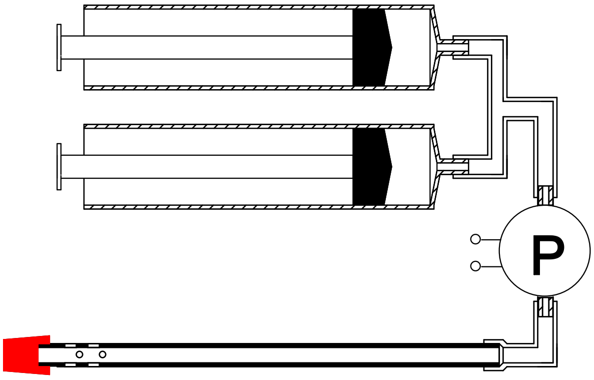


Figure 19 Syringes filled by motorised pump

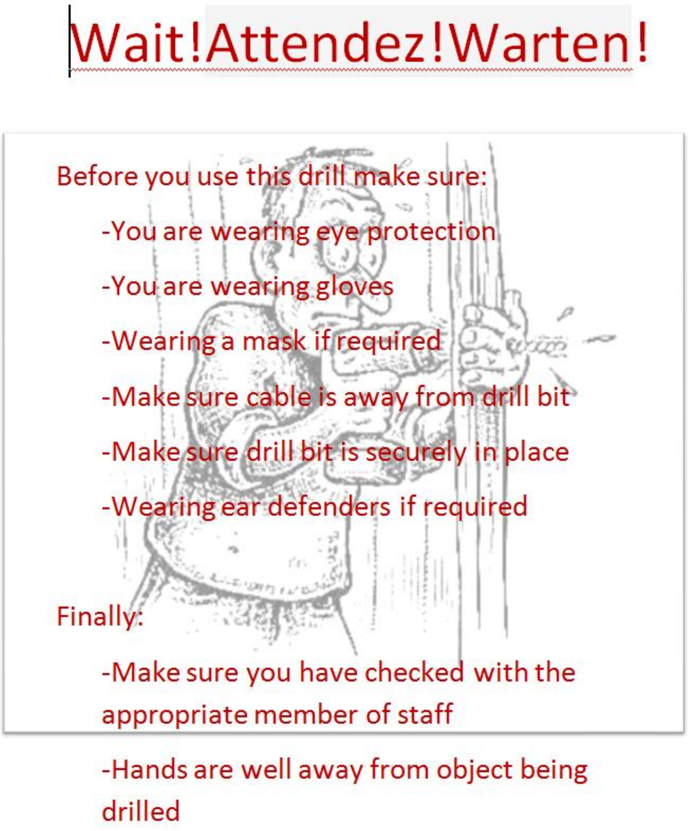
Before any liquid could be extracted from the fuel tank the Vaseline seal would have to be pierced. Copper tubing was used for the probe as it is malleable which makes it easy to shape, and strong enough to remain rigid.

After tool development it was discovered that the copper was able to pierce through the Vaseline with ease however, the tubing would become blocked, so no fuel could be collected. Hence a plastic cap was placed on the end of the tubing to seal it, and small holes were drilled in the side of the copper tubing so that the fuel could be collected. Having the holes on the side meant that they were never in contact with the Vaseline and hence did not become blocked.[Figure 20]

Figure 20 Fuel extraction probe

Safety

Safety was the greatest concern when building the ROV as any injury would have most likely forced the team to stop taking part in the ROV competition. It was therefore paramount that a teacher was always present when building any part of the ROV. When using solvents for bonding plastic and soldering, it was always made sure that the room was well ventilated. At the beginning of last year various posters were made, which were placed in the respective tool boxes. Figure 21 is an example of such a poster.



Wait!Attendez!Warten!

Before you use this drill make sure:

- -You are wearing eye protection
- -You are wearing gloves
- -Wearing a mask if required
- -Make sure cable is away from drill bit
- -Make sure drill bit is securely in place
- -Wearing ear defenders if required

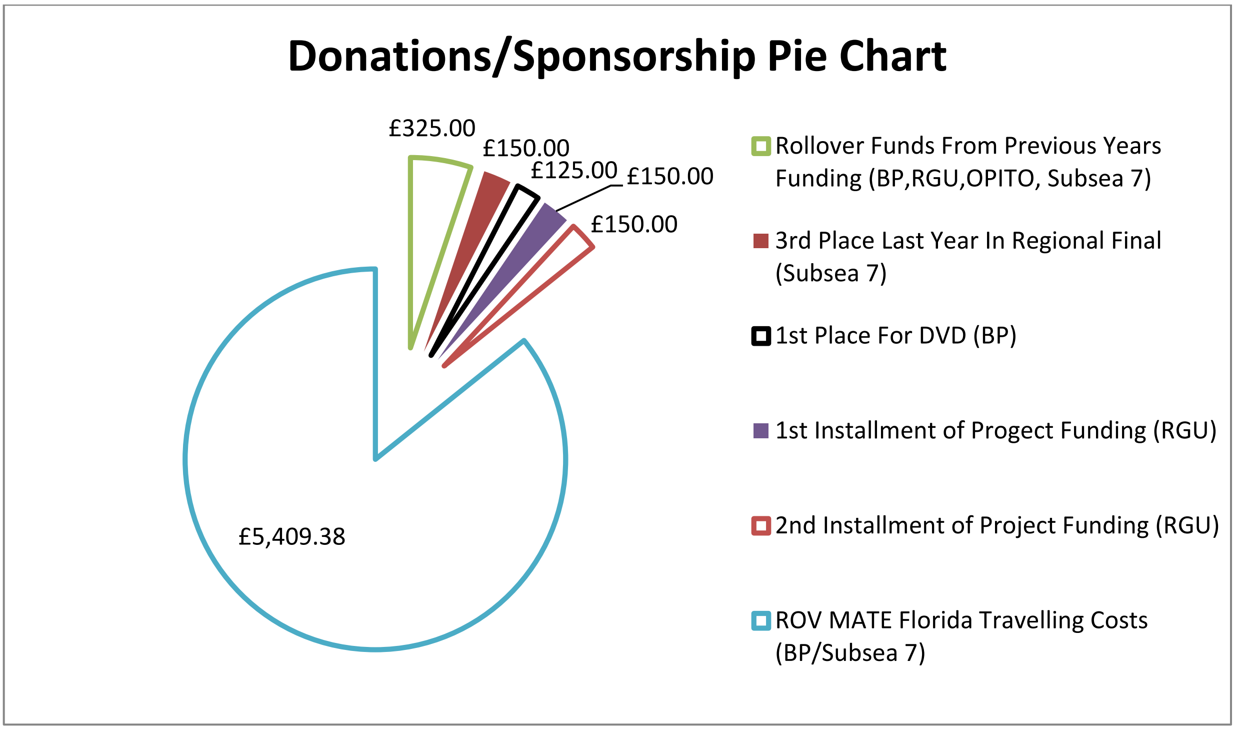
Finally:

- -Make sure you have checked with the appropriate member of staff
- -Hands are well away from object being drilled

Figure 21 Drill safety poster

In terms of the safety when handling the ROV, a checklist was devised to make sure that any possible safety hazards on the ROV were checked before use. Examples of what this list included is making sure that the couplings holding the propellers to the CNC attachment on the bilge pump were tight, that there was no exposed wires coming out of the control box, the pneumatic pump was set to a maximum of 2.75 bar (40 PSI) and all tubing was secure and that no one was present in the pool when the ROV was being used. There have been no injuries over the past two years and it is believed that this is down to the care taken and the extensive safety protocols used.

Balance/Economics



Item	**Cost**	**Quantity**	**Total cost**	**Supplier**
750 GPH bilge pump	£13.90	1	£13.90	Ebay- 238Ricardo
750 BULK *5	£59.00	1	£59.00	Ebay- 238Ricardo
Couplings and Propellers	£12.56	6	£75.36	Cornwallmodelboats
55mm-70mm Hose Clips x10	£5.43	2	£10.86	Ebay
Grey Pipe Insulation	£0.97	2	£1.94	B&Q
40mm end pipe	£1.09	8	£8.72	B&Q
Zip Ties	£2.49	5	£12.45	Bits and Bobs Hardware
12V Compressor	£16.99	1	£16.99	Maplin
Components for electronic drive and box	£60.30	1	£60.30	RS Components
Aluminium Sections for Gripper	£15.50	1	£15.50	B&Q
20-25mm Jubilee clips (bag)	£9.90	1	£9.90	B&Q/local hardware
40mm PVC Pipe	£4.19	2	£8.38	Screwfix Ltd
5 40-40mm PVC pipe connectors	£4.29	2	£8.58	Screwfix Ltd
21.5mm PVC L piece *3	£2.69	3	£8.07	B&Q
21.5mm PVC T piece	£1.79	10	£17.90	B&Q
Graupner Water Pump 6V - 12V	£11.24	1	£11.24	Cornwallmodelboats
White 3m x 21.5mm PVC Pipeing	£2.99	3	£8.97	B&Q
International Competition Costs				
Flights From Aberdeen To Florida	£635.55	7	£4,448.85	KLM Airlines
Hotel	£112.00	7	£784.00	WYNDHAM
Airport Transfers	£176.53	1	£176.53	

Total £	**£5,757.44**
Total $	**$9,082.00**

Budget Remaining: **£551.94 ($871.00)**

Future Improvements/Developments

In order to improve the manoeuvrability/stability of the ROV, if we had more time we would investigate the use of a gyro positioned centrally on the ROV. The Gyro would be connected to a computer at the surface. The computer would be able to determine any changes from the norm (i.e. movement not intended by the pilot) and would send appropriate feedback to the motors to correct the movement.

In order to improve safety and perhaps performance of the motors, a development may be to design motor housings. This would remove the swirl effect produced from the propellers and would direct more of the flow into thrust. Possible drawbacks to this idea are that the bulkiness of the housings would reduce camera visibility and add more drag.

Several improvements can be made to the umbilical, the first and most beneficial would be to reduce the size of the umbilical and so reduce the drag caused by it. This could be done a number of ways, the easiest to implement would be to simply use smaller diameter cables, however this has several drawbacks, the most notable being the increased resistance so decreasing the max power available to the motors. Another method would be to store all electronics on the ROV itself, meaning only one large power supply cable would be required. However, this has a number of problems, the greatest being the fact that the control system on the ROV must be thoroughly waterproofed or else the time and effort spent on it will be wasted if it gets wet. Also, large power supply cables usually lack flexibility, so what initially was a plan to reduce drag may actually increase it.

Another improvement for the umbilical, is to remove the current buoyancy attached and replace it with a hollow tube that extends the whole length of the umbilical. This hollow tube would displace enough water to cause the umbilical to be neutrally buoyant. This is an improvement over the current buoyancy because the foam used currently absorbs water causing it to actually weigh the umbilical down after any length of time in the pool.

Presently all of the controls for the ROV are split into two control boxes (one for tools and the other for ROV movement). By incorporating a gaming controller attached to a microcontroller we would be able to control both the tools and the ROV from one small controller, which is ergonomically more comfortable. This idea has been taken from the USAF and RAF using XBOX controllers to pilot their UAVs. Possible problems with this design are that the programming is potentially very challenging and there is a greater chance for a fault.

In terms of improvement which will be made before the Florida final; we are hoping to change the way we view the cameras. Presently 2 bulky B/W monitors are being used with the ability to switch between two cameras on each. This makes the pilot’s job harder as he constantly has to change the camera view in order to carry out tasks which require multiple perspectives. Therefore we are going to use 4 USB s-video capture devices attached to a 17inch laptop so all cameras can be viewed simultaneously.

Another improvement to the visibility of the ROV could be to design cameras with the ability to rotate on their axis by making use of Traxxas waterproof servos. This would dramatically improve visibility and could potentially reduce the number of cameras to two. However, from past experience, underwater servos cannot be relied upon entirely. If one was to fail, the ROV pilot would be blind. Incorporating moving cameras gives the pilot another task to concentrate on, taking away from the task in hand. Also. moving cameras could disorientate the pilot because of the changes in angle of the camera relative to the main axes of the ROV.

Reflections from Team Members

Alexander Stevenson -The past two years, working through the many challenges presented by the MATE ROV competition, has truly been an adventure. I relished the opportunity to be part of a team which was focused on building a working ROV capable of completing the defined set of arduous tasks. The challenge presented by the competition has not only led us to build a great ROV it has also built great friendships. Perhaps my happiest memories are those when we pulled together as a team, to solve a problem and make things work. This project has given me real practical experience of what engineering involves, it has also made me aware of the importance of safety attitudes and practices; both of these learning's will be of value in the future. I now look back with some fondness and pride when I think of the long hours spent working to understand and resolve the challenges of ROV design and operation.

Calum Ashcroft-For the past two years, participating in the MATE ROV competition has provided me with many great experiences and memories. It has taught me the value of thinking out a solution before proceeding and has allowed me to develop my problem solving and team working skills. The best aspects of my time in ROV have been making good friendships that will last forever, and the attitude to never give up when struggling in life.

Damian Theron -During the last two years, I have been able to experience engineering and practical problem solving while designing and constructing the ROVs. I have improved my teamwork skills through many sessions working together with my friends. Being part of the ROV team has greatly enhanced my understanding of how projects operate, that each step has to be done in the correct order to maximise the efficiency of the work being produced. I have found that the most important aspect for success in a project such as this is perseverance.

Hugo Mayeux-Over the last two years ROV has given me something to focus on and enjoy. I am confessing to being a bit of a procrastinator but ROV has shown me that if I motivate myself I can enjoy myself and achieve things I never believed I could. Being part of our ROV team has been fantastic, all the fun times and the great sense of achievement you get when something you have been working on works really well in the pool have been the highlight for me. I think the most important lesson ROV has taught me over the years is that approaching a problem with a positive proactive attitude gives the best results and this I feel can apply to all walks of life.

Jonathan May-You should never mix friends and work! Or so I would fervently have said a couple of years ago. The most amazing thing that's resonated with me over this experience must therefore be the fun and ease of co-operation that everyone in the team has made possible. Lacking a great deal of knowledge regarding construction and design of a motorised vehicle relative to the impressive experience of some of the other team members, it has also been greatly enjoyable gaining some small acumen in this regard. I truly wish everyone that has been involved in this project the best of luck in their future as they each move on to university.

Marcus Rose-Two years ago, when I took the decision to join the schools ROV competition little did I know how much fun I was going to have. From being a member I have learnt the importance of planning before any execution in order to avoid wasting time; the importance of a team, as some of the best ideas have been from brainstorming; testing tools to ensure that they meet their specification and to not be put off if things don't go to plan. From taking part in this competition it has confirmed my choice of studying engineering and to pursue engineering as a career in the future. Lastly being a member of the team has made me some of the best friends I could ever have dreamt for, I am so glad that I joined!

Acknowledgements

The Company would like to thank:

Marine Advanced Technology Education Center: organisers and administrators of the International MATE ROV competition, for their invitation to compete at the international event and the administrative work undertaken in its organisation.

Robert Gordon University: Hosts and administrators of the Regional Event in Scotland, for their administrative efforts on our behalf and for the advice and guidance made available to schools in preparation for the regional competition.

OPITO: sponsors and administrators of industrial sponsorship for the Ranger Class MATE ROV regional competition in Scotland.

BP.plc: Industrial Sponsors of the Ranger Class MATE ROV regional competition in Scotland.

Travel Grant provider for a school team to compete in the International Competition.

Subsea 7: Industrial Sponsors of the Ranger Class MATE ROV regional competition in Scotland.

Travel Grant provider for a school team to compete in the International Competition.

Young Engineers organisation and their industrial sponsor, Shell UK, for a special equipment grant in 2011.

And finally we would like to express our sincere thanks to our favourite teacher and mentor; Mr Wakeford who has encouraged and supported us every step of the way.

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http://oceanexplorer.noaa.gov/technology/subs/rov/rov.html

List of Figures

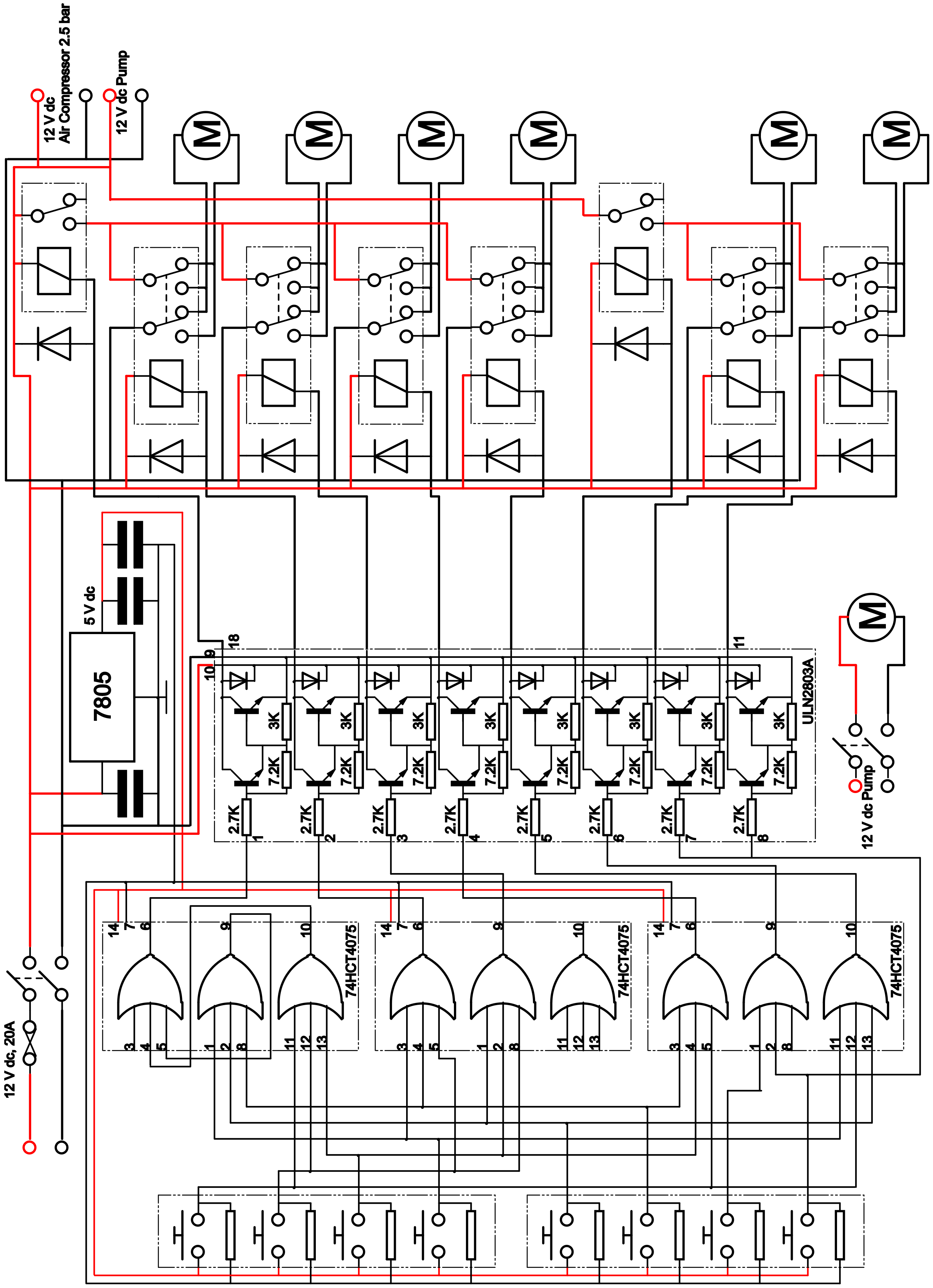
Appendix 1 - Joystick Positions and Motor Movement

		MOTORS					
SWITCHES		1	2	3	4	5	6
JOYSTICK 1							
1	FWD	FWD	FWD	BCK	BCK		
2	BCK	BCK	BCK	FWD	FWD		
3	CW	FWD	BCK	FWD	BCK		
4	ACW	BCK	FWD	BCK	FWD		
JOYSTICK 2							
5	CRAB LEFT	BCK	FWD	FWD	BCK		
6	CRAB RIGHT	FWD	BCK	BCK	FWD		
7	UP					FWD	FWD
8	DOWN					BCK	BCK

The table above may be used to identify the combination of joystick positions for which a particular motor runs either forwards or backwards.

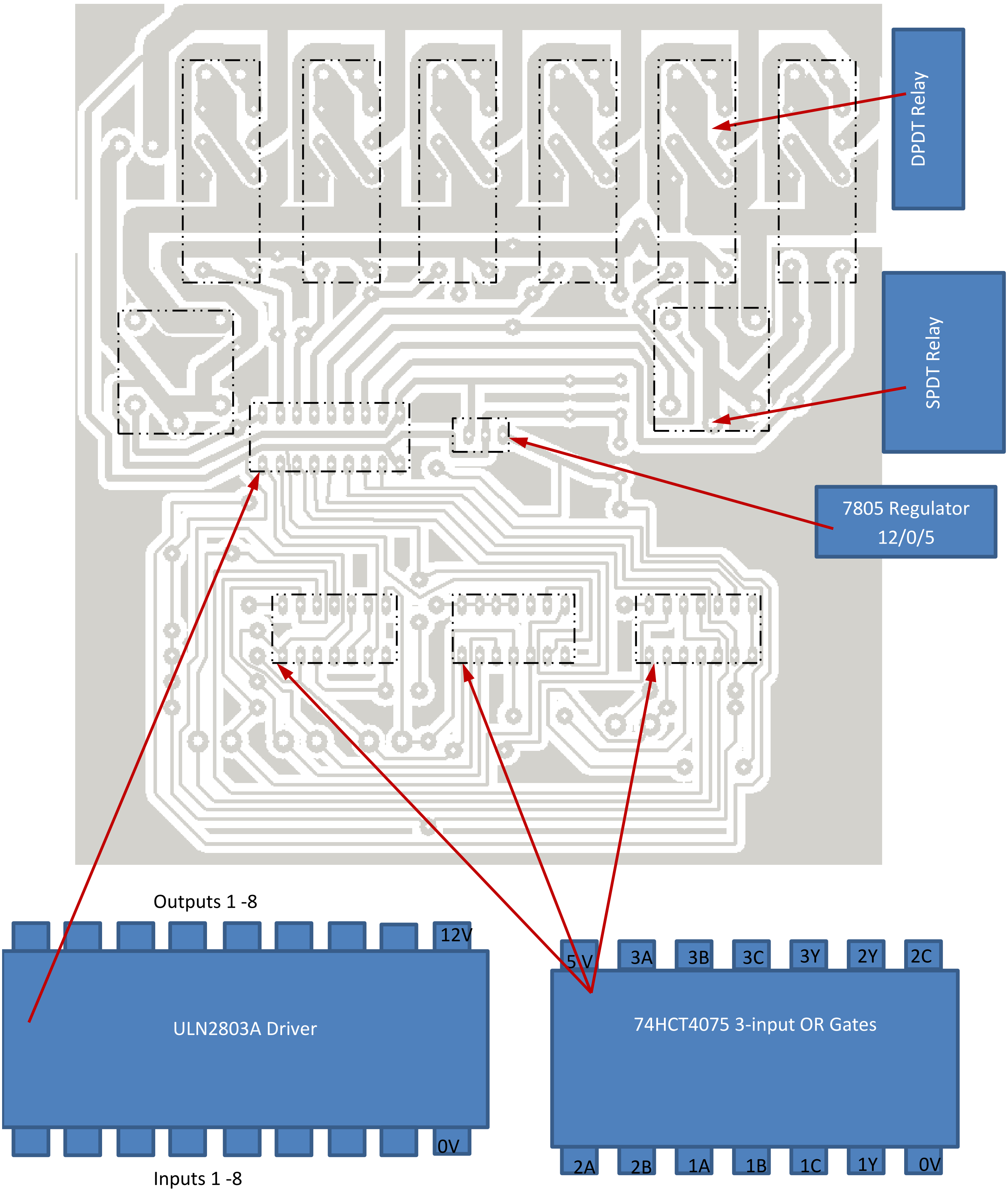
		MOTORS					
		1	2	3	4	5	6
	FWD	1+3+6	1+4+5	2+3+5	2+4+6	7	7
	BCK	2+4+5	2+3+6	1+4+6	1+3+5	8	8

Appendix 2 - Electrical Schematic

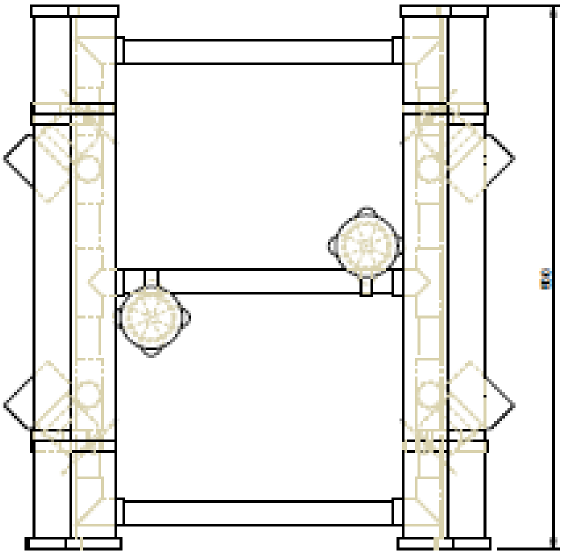


Appendix 3 - Circuit Board

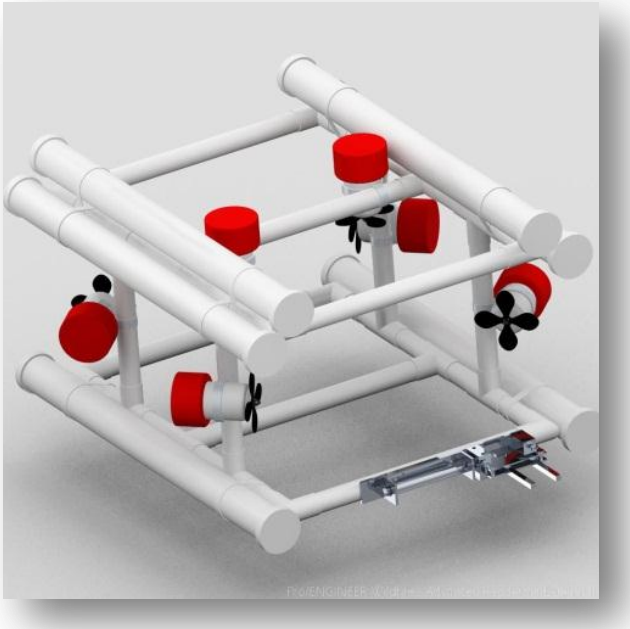
View Looking "through" board from component side to track side

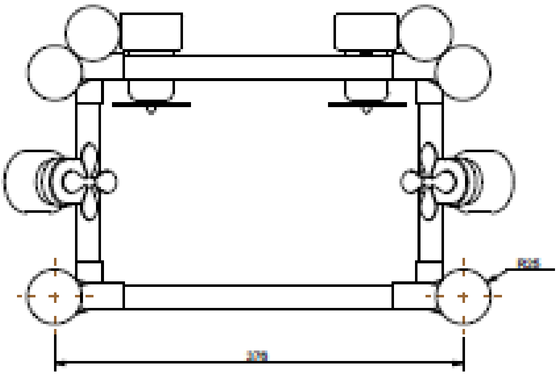


Appendix 4 – ROV Orthographics

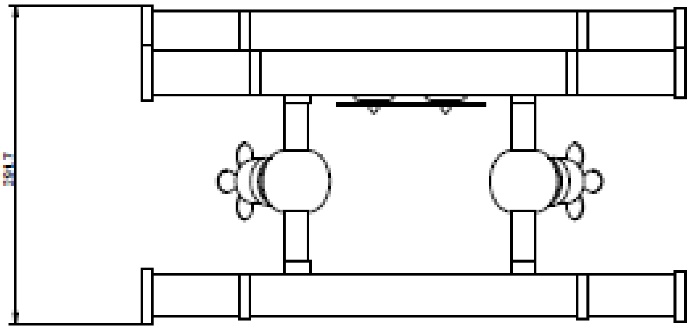


Plan



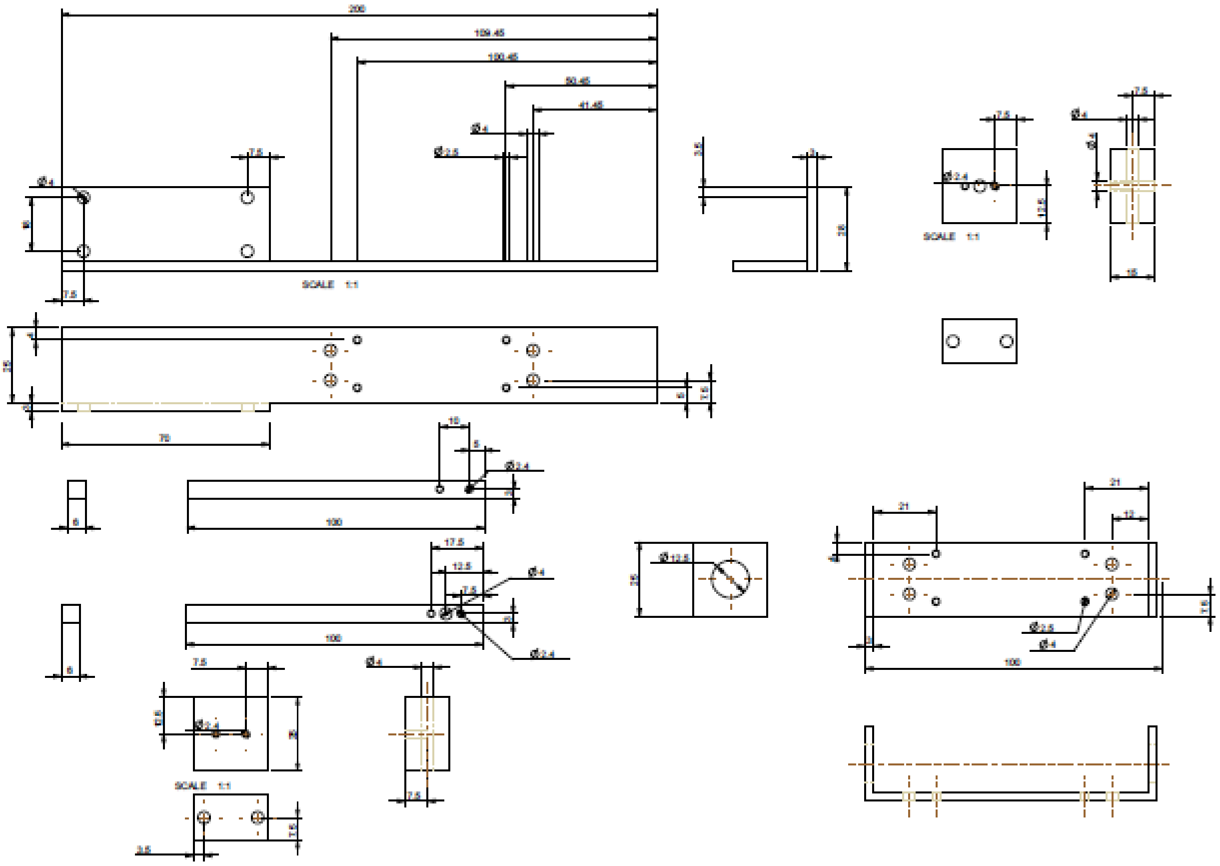


Elevation

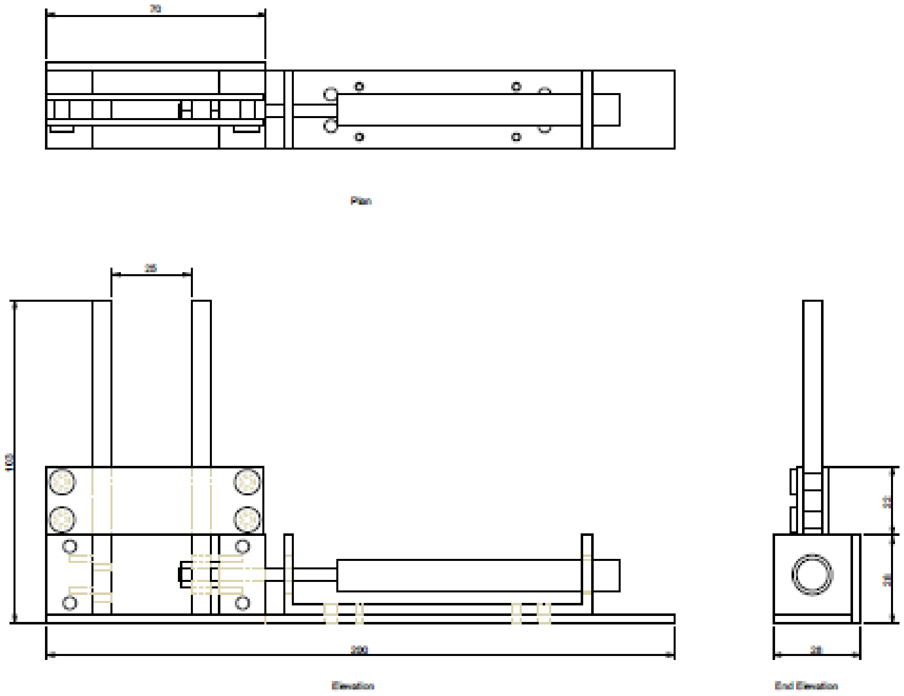


End Elevation

Appendix 5 – Gripper Orthographics and Assembly



Component orthographics



Gripper Assembly