RED ROV Report

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Abstract

The following report details the design and manufacture of the Robert Gordon University's ROV for this year's MATE international competition. The theme is based around the Loihi underwater volcano in Hawaii, upon which research is being carried out. The ROV has to accomplish various tasks related to this theme.
Due to constraints such as a limited budget, travel and time; the ROV was designed to be low cost, easy to transport and easy to repair. It was also designed to be simple, reducing the chance of failure and also increasing the rate of manufacture. The frame is made out of PVC pipe and other PVC parts. This provided easy and quick manufacture while being strong light and buoyant. The ROV has eight 24 V motors linked in series to give the appropriate manoeuvrability and utilise the full supply voltage.
The ROV has three main tools. The simple grabber at the front will be used to complete most of the tasks. There is also a scoop at the back to collect samples and a removable suction device for collecting the bacterial sample. Temperature and frequency sensors are also attached. The ROV has two cameras which can view all the tooling and also allow the ROV to travel in both directions.
The report also details the electronics used in the control box, for the tooling and thrusters.

Contents

Figure 1. The ROV and the team photos.

Description:

Top left – ROV from the front, showing the grabber.
Top right - ROV from the rear, showing the scoop.
Centre - ROV from side, showing both tools.
Bottom left – Team photo. From the left: Bilal, Ian, Kamil, Slimane.
Bottom right – ROV during the tests.

Formation and Geological Activity

The Hawaiian Islands originate from volcanoes; each island being made up of a primary volcano, some with others also helping to make up the land mass. For instance the Big Island is made up of five volcanoes. The primary volcano (also known as the shield volcano) is a gently sloping mountain produced by large amounts of fluid flow. The type of rock that mostly is produced in the area is basalt, which is very fluid, causing these gently sloping sides (1).
The reason there is so many volcanoes in the area is because there is a 'hot spot,' which is presently below the big island. The pacific tectonic plate is always on the move, moving 5 – 10 cm/yr in a North West direction. A 'hot spot' is a fixed spot below the plate where magma forms. As the plate moves the magma can break through, as a volcano, forming an island. Once the volcano stops it moves away with the plate, and a new volcano may form again over the hot spot. As the earth's crust on the plate cool, and the island erodes, it sinks slowly down, then eventually back into the sea. This is how the Hawaiian Islands were formed, and are still currently forming (1).
A similar example is the hot spot below Iceland. These hot spots are the best known in the world. Iceland was created in a similar way to the Hawaiian Islands (5). To show how ferocious these can be you just have to look at the news over the last few weeks, as the eruption of the Eyjafjöll volcano over the Icelandic hot spot has caused severe problems all over Europe due to the ash clouds.
Three active volcano's share Hawaii's hot spot: Kilauea, Mauna Loa and the volcano we're concerned with, Loihi. See figure 2 (1).

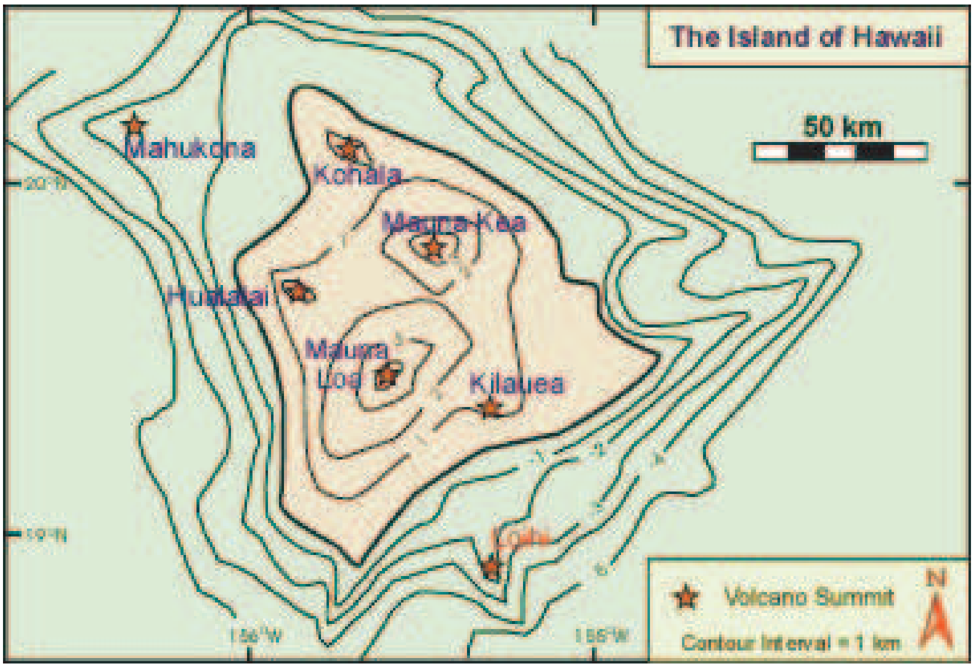


Figure 2. Big island of Hawaii, and the volcanos on and surrounding it (2).

Loihi is the youngest volcano in the Hawaiian chain. It is also very large, 3000m from the sea floor. Previous to the 1970's, Loihi was thought to be a common dormant volcano, however, after an earthquake swarm it was found to be young and active, with hydrothermal venting at the summit. During 1996 there was a very large earthquake swarm and direct evidence of a volcanic eruption – first confirmed for Loihi (2).

This took place over a two week period. The effects of which were increased carbon dioxide emissions to the atmosphere; Tsunami made by landslides; and the destruction of biota which was there. A quick response team took an expedition there, with further expeditions to follow. It was found that the southern part of Loihi's summit had collapsed, forming a crater 1km across and 300m. A previously stable area called Pele's vents disappeared into a giant pit, now known as Pele's pit. This pit made exploration of the area dangerous as water flowing into the crater would mix with bacteria and minerals and flow over the lip, causing unpredictable water currents. Visibility also made exploration non ideal as there was a high concentration of dissolved materials and floating mats of chemosynthetic bacteria in the water (3).

The most hydrothermally active area is at the southern rim and rift. Bacteria feeding on the dissolved nutrients were found to be colonizing vents – indicating that inorganic material is being ejected from the new vents (3).

Future work in the area includes monitoring ongoing changes, assessing the risk of explosive volcanism or landslides and also preparing for the installation of the Hawaii Undersea Geological Observatory (HUGO) (3).

The submersible that is used mostly to do the work in the area is called the Pisces V. This is a three person battery powered craft. One pilot and two observers are onboard during a mission, which will last 6 to 8 hours. The maximum depth the vehicle can go to is 200m. This is a major advantage for study as there is direct observation of the area, photographic and video evidence and it can be used for instrument placement (3).

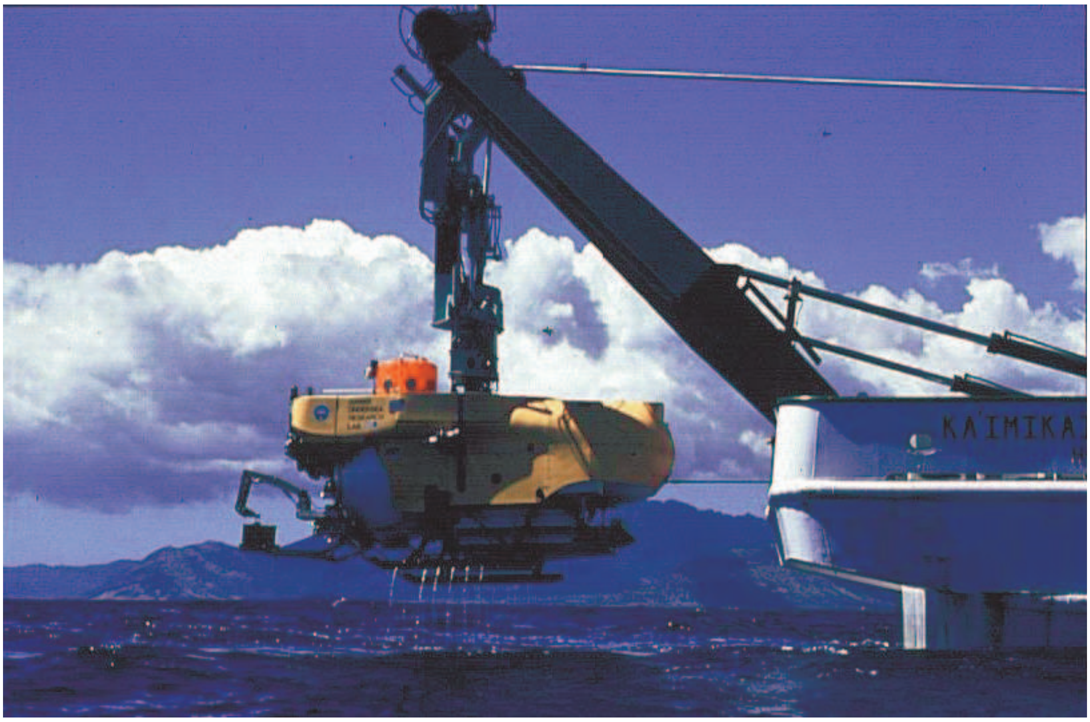


Figure 3. Pisces V Submersible during launch (4).

3. Design Rationale

There are several constraints that the ROV needs to overcome out with the mission tasks. First, due to a limited budget the ROV needs to be low cost. Secondly due to the large distance of travel it needs to be easy to transport. Thirdly, because we will be away from workshops, it needs to be easy to repair. Also, due to the short time available the ROV needs to be simple, but still effective.

3.1 Frame

The frame needs to be:

- Cheap and quick to manufacture
- Light and buoyant
- Symmetrical to provide perfect centre of gravity
- Provide protection to the propellers whilst providing clear water
- Provide mounting for the cameras/thrusters/tooling

The ROV was designed in Solid works. Using CAD software, the 3D model can be prepared. The answers to any design questions can thus be found. The model can be refined and modified many times until the best configuration is created. From the software, the way the parts fit together can be checked and any collisions can be found. A parts list can also be generated.

The frame of the ROV is made from PVC piping – straight sections, elbows and tees. The parts fit together well, without glue (thus allowing easy disassembly and repair). But for security the connection points are screwed. Last year the ROV was made out of aluminium which was time consuming to manufacture; whereas PVC is inexpensive, readily available, easy to assemble and light.

The frame design was based on the above rationale. Three possible designs of construction were modelled in Solid Works, and are shown in appendices three, four and five. The main assumption in all of these was the idea that the frame should be symmetrical. This is to keep the point of gravity central in the ROV so that the vehicle can remain in the upright position all the time. The thrusters and cameras are located symmetrically to the central and horizontal planes. The design that was chosen is shown below in figure 4:

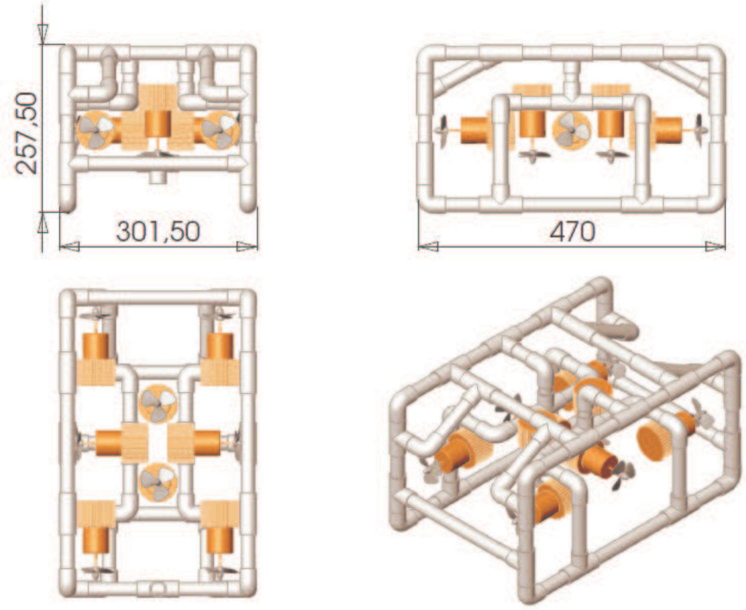


Figure 3. Original Final design of frame

There are reasons why the design two was chosen. All of them are shown and described below:

- Round corners – minimize possibilities of hooking the cables during the maneuver.

This is one of the reasons why the first or the third construction has not been chosen. During the ROV diving or ascending there is a possibility of hooking cables. This can lead to loss of vehicle control and failure of the mission. The chosen construction has round corners which minimizes this problem.

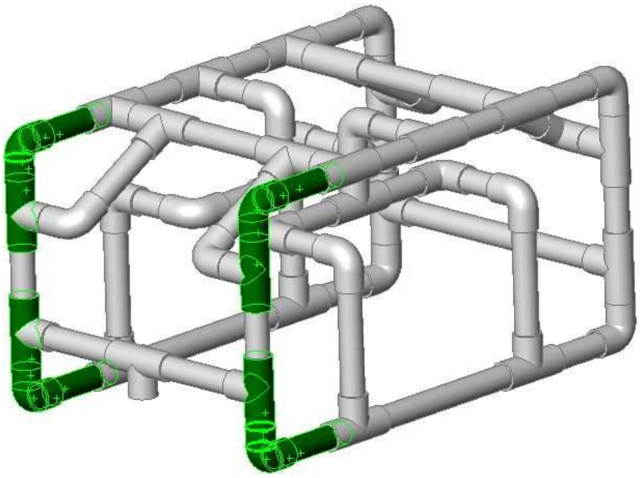


Figure 4. Frame – round corners

- Propellers protection – to prevent damage to cables.

The ROV has eight propellers and each of them needs to have plenty space to work properly but at the same time each of them need to be protected. There is a possibility of damaging the cables which can lead to losing the drive. The chosen construction has the propellers protected within the frame of the ROV, but also gives them plenty of space for water flow.

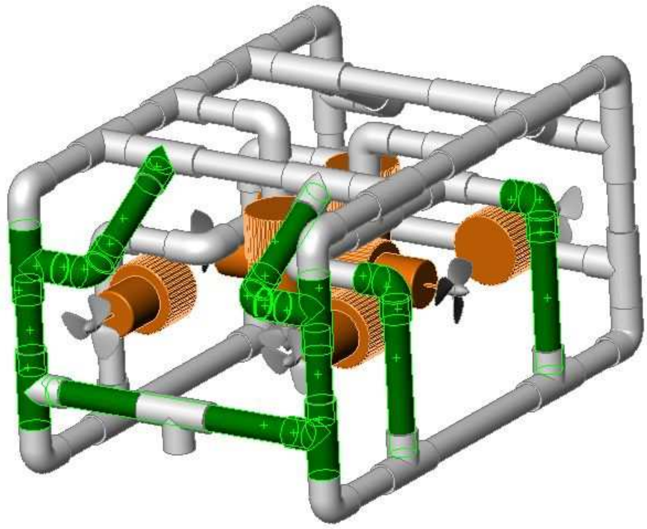


Figure 5. Frame – propellers protection

- The foam "cage" – retains foam blocks without additional fixings

On the left and right top sides of the ROV frame the special "cage" for the foam buoyancy was designed. Following the calculation and considering the needed volume, the size and shape of the foam was prepared and mounted in the special "cage". Thanks to Solid Works and the 3D model, the foam shape and cage could be designed. The fitted foam does not need any other clamp.

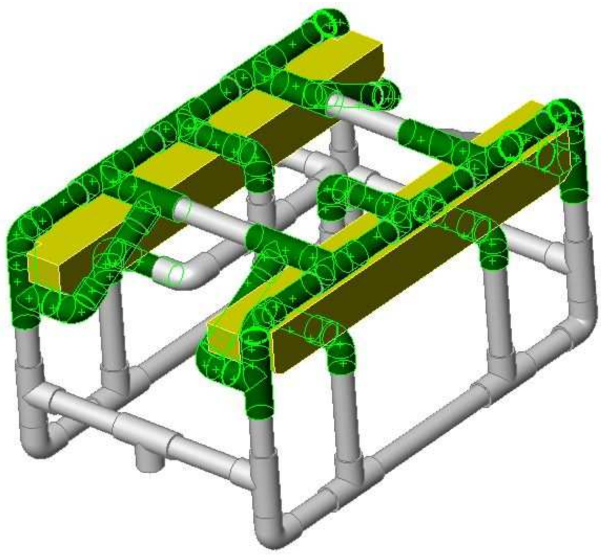


Figure 6. Frame – foam "cage"

- The top bar for cameras – allows for greater angle of view

The top cameras are mounted on the hidden cross top bar which gives the greatest angle of view. The central location of cameras makes the driving easy and more precise. Two of the three tools are mounted on the bottom front bars on both ends of ROV and they are visible by camera which allows us to do the task precisely.

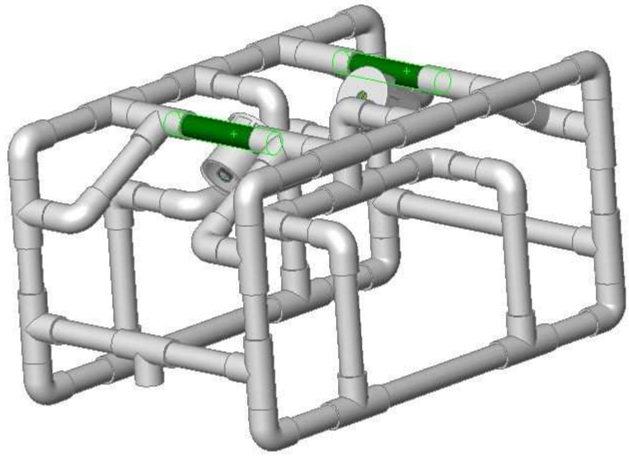


Figure 7. Frame – cameras fixed

- The front bottom bars for tools – tool fixed on the center

The bottom front bars are visible to the camera so the best option was to fix the tools to them. On the one end the grabber is fixed and the scoop on the other.

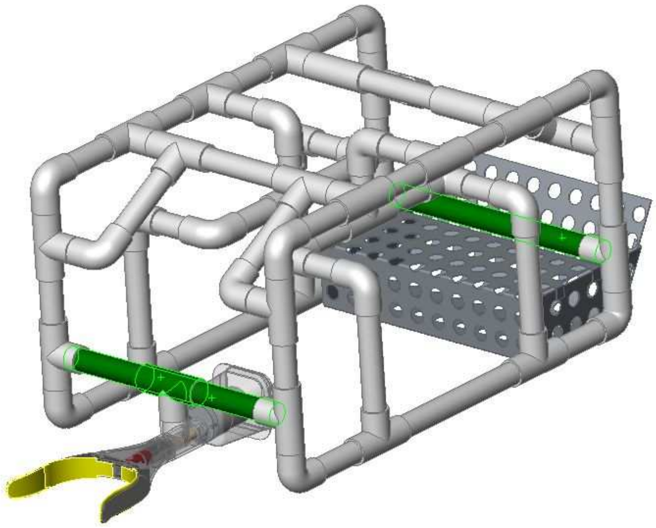


Figure 8. Frame – front bottom bars

- Motors placed – two fixing points required

During the work the motors create the torque. To prevent the changing of position of the motors they need to be fixed to the frame in two points. The best solution is to place the motors in the angle close to the elbows. Following this rule the center frame was designed to allow suitable thruster mounting points.

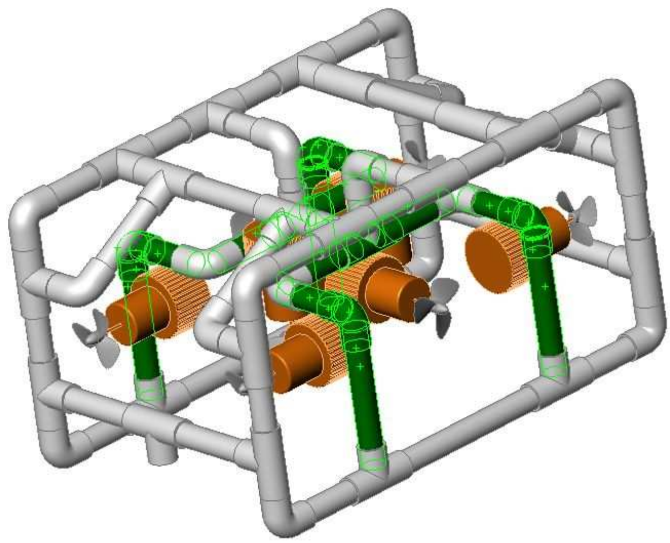


Figure 9. Frame – motors fixed

3.2 Electrical Components

Control Circuit

The control circuit has the following requirements:

- Delivers 48 V supply to the motors
- The direction of flow must have reversible/off states
- Control switches to all sets of motors for propulsion
- Must provide a lower voltage to the grabber motor
- Safety fuse attached
- Indicator LEDs to show where power is going

Below in figure 10 is the electrical schematic of the control circuit board:

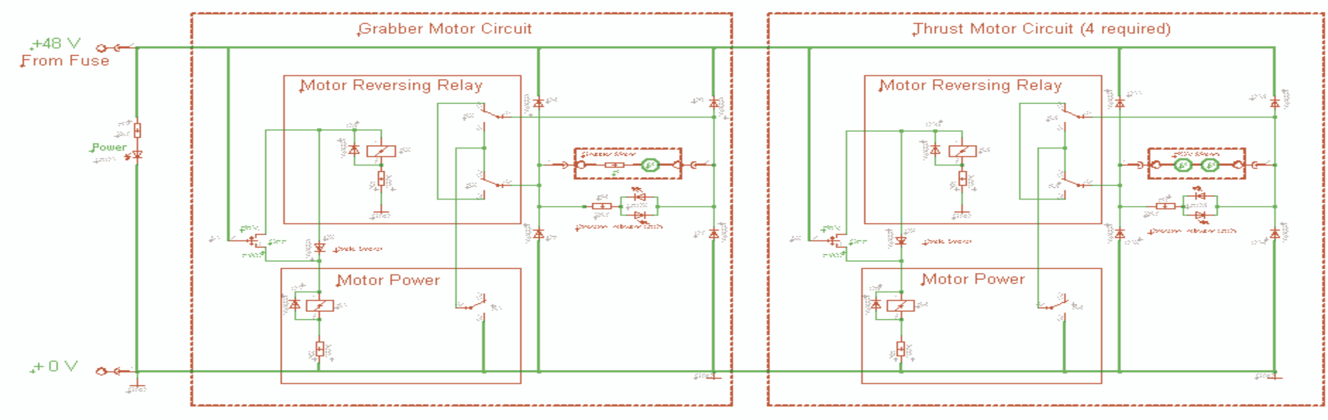


Figure 10. Electrical Schematic of control circuit.

For safety purposes power is fed through a 40 A fuse from the supply. There is also an LED in series with a current limiting resistor used as a power indicator in the circuit.

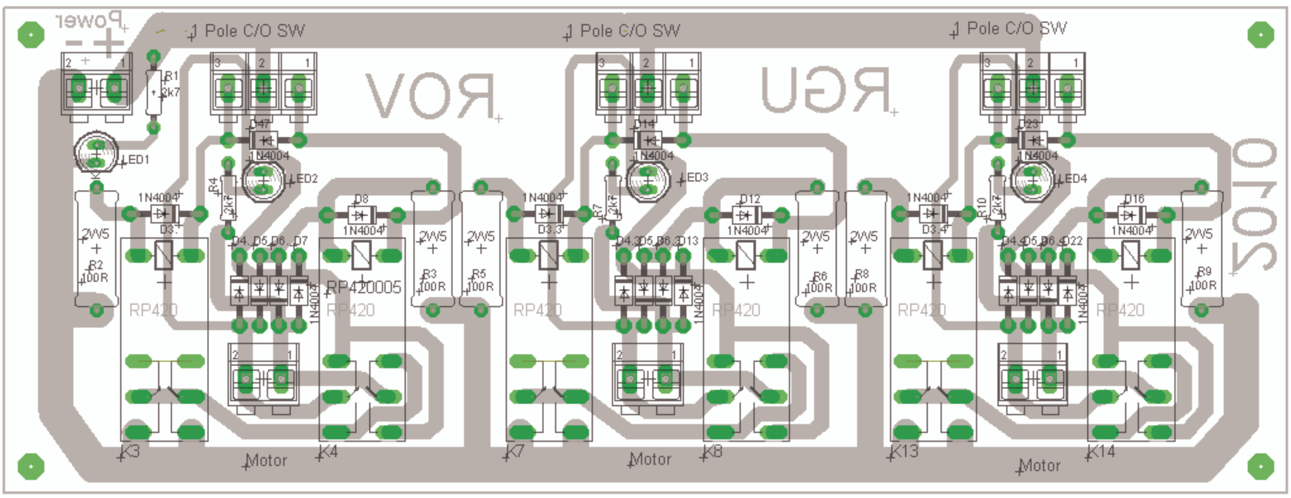


Figure 11. Layout of the PCB board.

Shown above is the layout of one of the two identical PCBs used in our control box.

Figure 12 on the right shows the grabber motor circuit part of the control board. This works by:

- Switch in forward position, Relay 1 energises allowing current to flow forward through the motor
- Switch in reverse position, Relay 1 and 2 both energise (with the aid of the diode switch), causing current to flow in the opposite direction through the motor.

The circuit is attached to a one pole changeover switch (centre off). The voltage is reduced in the motor by dropping 36 V across the resistor. Diodes are in place to limit switching transients.

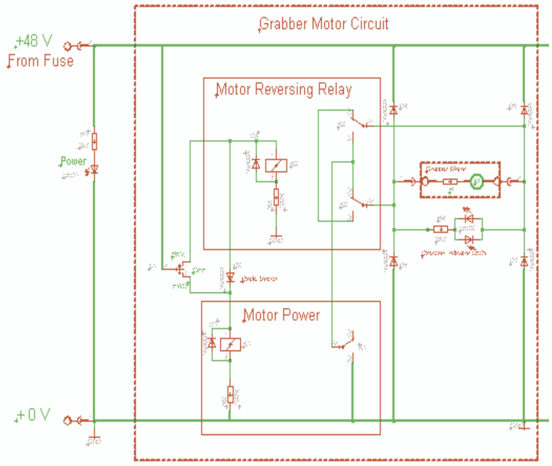


Figure 12. Grabber motor circuit.

Figure 13 on the right shows the thrust motor circuit. This circuit is used four times to provide the supply voltage to the motors. These are attached each to one pole changeover switches (centre off). In this way the ROV can manoeuvre in all directions.

The switching circuitry is the same as above in figure 11. However, the difference is the circuit is running two 24 V motors in series drawing the 48 V. This means there is no voltage drop on any resistors. As before, diodes are used to limit switching transients.

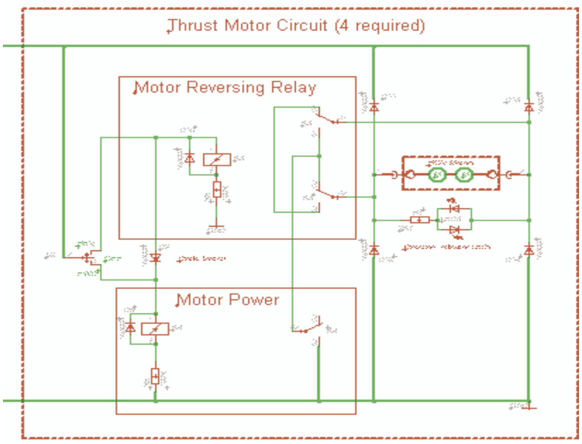


Figure 13. Thrust motor circuit

In both circuits LEDs are used to indicate the direction that the motors are polarised. The original intention was to use PWM speed control for the motor, which would allow accurate vertical positioning of the ROV. However, we were unable to get the circuit we designed to function reliably. A diagram of the proportional control circuit is shown in appendix 1.

Temperature Sensor

An LM35 temperature IC is used to determine the temperature to ±0.5 ^{0}C. This IC produces a voltage proportional to the temperature i.e. if the LM35 read out 0.1 V, the actual room temperature would be 10 ^{0}C. We considered using Lab View to process the data, however due to limited time we were unable to complete this task. Therefore an Arduino microcontroller was used to digitise the voltage from the LM35, transmit it through its serial port to a laptop where it is displayed.

This is shown below in figure 14:

After testing the sensor under water, it was found that the LM35 was subject to noise and therefore produced erratic results and required a noise filter. To filter the distortion a resistor and capacitor are placed in series to the output of the LM35 and is connected to ground to smooth the output voltage. The Arduino had to be programmed to convert the analogue input to the digital output. This is shown in appendix 2.

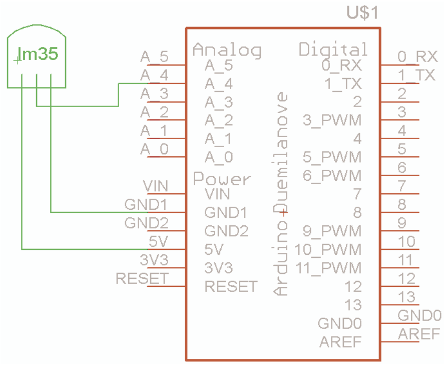


Figure 14. Configuration of temperature sensor and Arduino board.

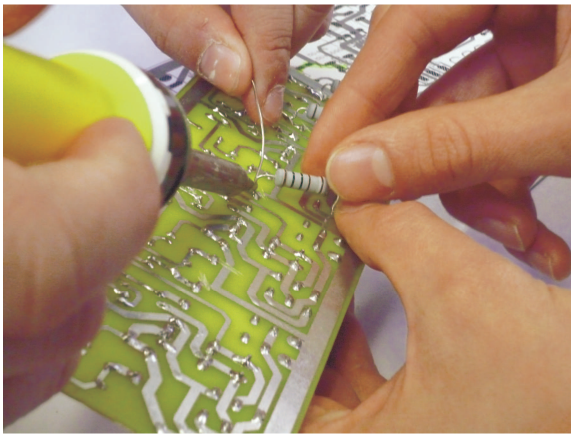


Figure 15. Manufacturing of circuit.

Modifying the original circuit board to take a 48 V supply. A new circuitboard has now been made.

Frequency Sensor

To detect the sound underwater, an electret microphone will be used, which will then feed into an LM386 to amplify the original sound until it is able to drive the loudspeaker.

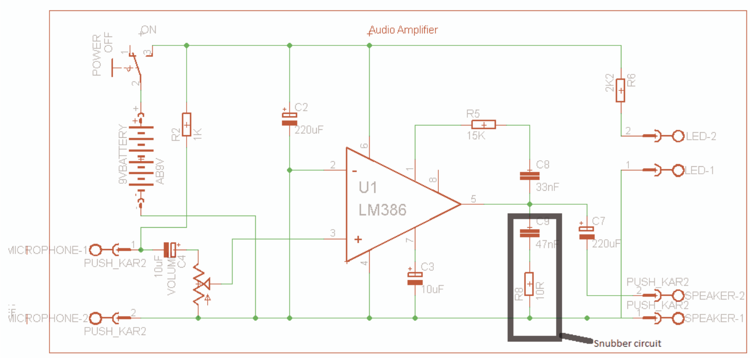


Figure 16. Amplifier circuit.

Figure 16 shows a simple circuit for detecting frequency and amplifying it to a discernable sound. When the circuit is on, an electret microphone picks up sound, passes it though a capacitor and potentiometer to the amplifier. This is done to remove distortion and adjust the volume. The output of the amplifier is passed through a snubber circuit as shown. This ensures high-frequency stability. This is then heard through a speaker. The circuit was designed and used by the Robert Gordon University as part of a taught module to be used for a similar task.

3.3 Tooling -Mission Tasks

The tasks are based around the exploration of undersea volcano Loihi, and the work being carried out around the area.

Task 1 – Resurrect HUGO

The HUGO box is positioned on the sea bed. The HRH needs to be removed from the elevator and placed on the rumbling site; and then, the HRH power/communication connector needs to be attached to the HUGO junction box for monitoring. See mission notes (5).
ROV employs a simple grabber for removing the pins, lifting the HRH and the connector. A water proof microphone is also mounted on the ROV to allow the pilot determining the rumbling site in order to place the HRH on the appropriate location, and the rumbling frequency is then measured using frequency sensor by placing it next to the speakers.

Task 2 – Collect samples of a new species of crustacean

The Pisces V is used for various tasks including sampling species from the seabed around Loihi. One sample that it is required to collect is a type of crustacean from a cave. The ROV is required to navigate into a cave and take three samples back to the surface. See mission notes (5).
A scoop was designed and mounted on the other end so that the ROV simply moves up the wall to collect, and a specified area inside the frame will be used to collect and take back to the surface. This provides simplicity and ease of manufacture and manoeuvrability. This is seen in figure 17.

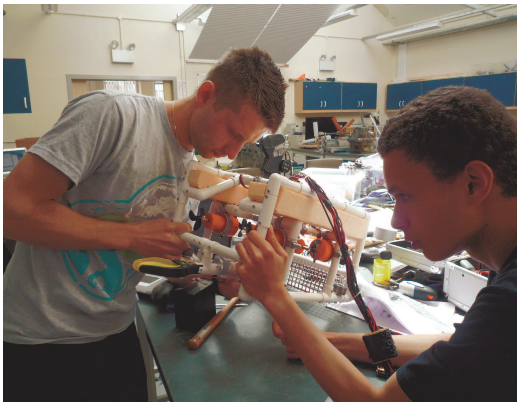


Figure 17.


Figure 18.

Task 3 – Sample a new vent site

Another aspect of sampling work Pisces V has to do is take temperature measurements and samples of geology – such as vents. For this task the temperature of a vent is measured at 3 different points and a sample of a spire is taken back to the surface. See mission notes (5).
A grabber used in task one is used to collect the sample of spire, hence cutting down on the tooling needed for the ROV. It is also used to hold the temperature sensor to take measurements at different angle which is connected to a simple circuit in the control box, and the temperature read off a computer screen. See above for temperature sensor details.

Task 4 – Sample a bacterial mat

The Pisces V also had to sample a type of iron-oxidizing bacteria from Pele's pit, and this by collecting a specific amount of a bacterial mat and return it to the surface. See mission notes (5).
Using suction in the form of displacing the air in a cylinder by pushing it into the mat. The air cannot escape if using a one-way valve which should then lift the mat. This proved to have a flaw which needed addressing. Something was needed to provide a path for air to the bottom of the mat out with the cylinder. Parts were to be put on the outside of the cylinder to cut up the mat when the ROV turns. This is shown below in figure 18.

3.4 Thrusters

The thrusters need to be several things:

- Use the 48V supply to maximum effect
- Propeller driven for maximum thrust (as opposed to water jet)
- Waterproof/Safe
- Mounted in a way to give full control
- Need clear water yet protected from the tether and other obstacles.

The team decided to use Ocean Secure bilge pumps (24V D.C) (6) for the thrusters. The casing was removed so that the motor could be accessed. It was decided to use these motors as they had been tried and tested in the University before, proving to be reliable, of sufficient thrust and waterproof. They are well within the budgeted cost even with two spares; although there have been no faults with the motors during manufacture and testing. Two of each motor are connected in series as to use up the full 48V supply voltage. The propellers were then attached using a simple technique to the motors as shown in figure 19. The propeller size we are using is 65mm, providing 1.3Kg of thrust forwards and 0.5Kg backwards. See appendices for thrust measurement.
The required directions the ROV would need to complete the tasks were: up/down, forward/reverse, clockwise/anticlockwise and right/left (sideways). For the tasks it was not thought that vector propulsion was needed. The motors were mounted on the ROV as shown in figure 20. With the buoyancy and tooling attached, the thruster's placement leaves clear water for the propellers. Also the frame is such that the propellers are protected from the tether and other obstacles.

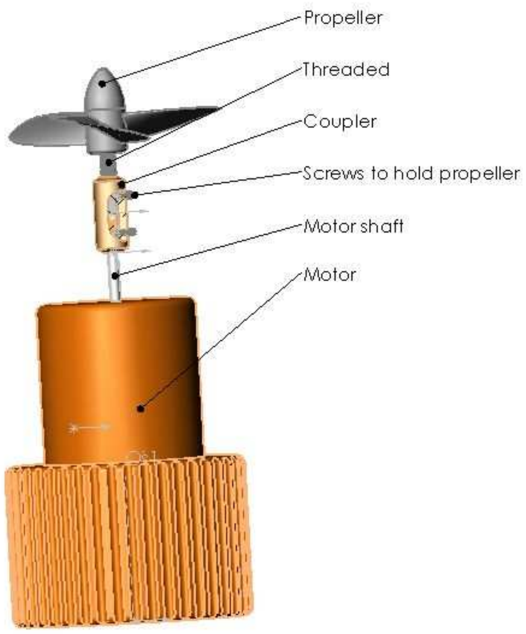


Figure 19. Prop attachment

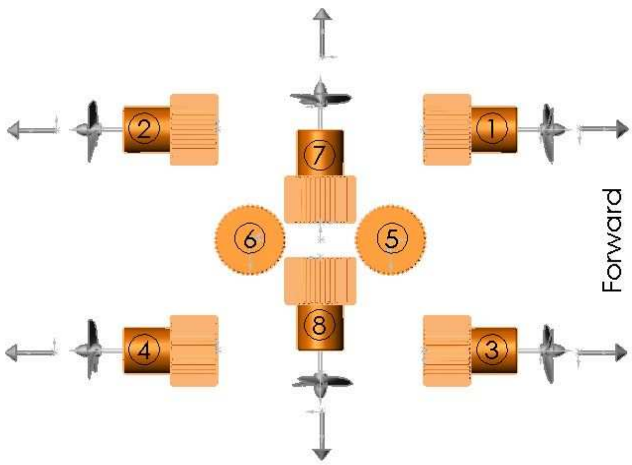


Figure 20. Thrusters positioning

Motors 1 and 2 connected. Motors 3 and 4 connected. Motors 5 and 6 connected. Motors 7 and 8 connected.

The motor combinations can be reversed in polarity providing forward and reverse directions relatively.

3.5 Buoyancy

The Buoyancy needs to be:

- Neutrally buoyant – The ROV does not have proportional up/down control thus neutral is needed to give smoother control
- Metacentrically stable
- Changeable

The team decided to drill holes in the frame to flood it. This is a safety measure in case the ROV does flood, this way we the buoyancy is constant in all situations. The team decided to add buoyancy first of all to make the ROV heavily positively buoyant, then to add trimming masses to make it neutral. This was done to give the ROV a good metacentric height, making it far more stable in the water. Also, so that as the tooling was added the masses could be moved or adjusted so that the ROV is neutrally buoyant and level, as not all the tooling was on for the regional competition. Sample calculations are shown in appendix 4. The masses were placed on the bottom of the frame at four corners, with the buoyancy at the top, out of the way of the thruster's path. Shown in figure 21.

3.6 Camera

The camera's need to be placed in such a way to satisfy:

- Full view of tooling, mission props and forward/reverse directions
- Waterproof

The team decided to use two cameras on the ROV; forwards and backwards. These were placed as such to both see where the ROV is moving, but also to have an optimum view of the tooling. The camera looking backward will see both the scoop and the tooling for collecting the bacterial sample. There is space in the frame so that the cameras can sit back and have a much wider view. A view of their placement is shown below in figure 21. The camera was bought in, but the casing was made using standard plumbing fittings, and a PCB was designed and fabricated. A diagram of this is shown below in figure 22. The camera is reliable providing the circuitry is waterproof.

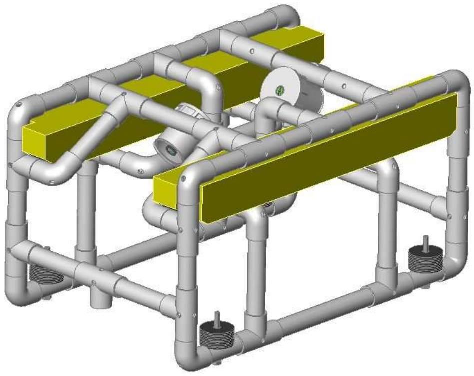


Figure 21. ROV with buoyancy, masses and cameras

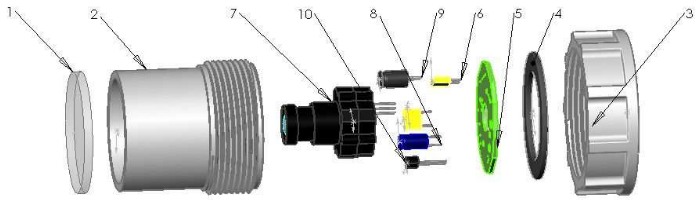


Figure 22. Exploded view

4. Challenges

The main issue about the control of the ROV was the pulse width modulation speed control for the up/down thrusters. This would have aided the ROV in maintaining constant depth. Due to high currents involved, the control circuit burnt out and there was insufficient time to redesign it. The competition involves a lot of electronics and there is only one electronic engineer on the team which limited the amount of electronic design that was possible.

5. Troubleshooting

Whilst trouble shooting the teamwork was at its strongest. Much testing to find a problem, and then discussion over a possible solution was done. Then of course the changes implemented. Doing this as a team as opposed to individually was much more beneficial as the rate at which a problem could be found and fixed was much quicker and the solution would be most effective.

One example of this is when developing the tooling for task four – to take a sample of bacteria. The details of this tooling can be seen in the design rationale. Originally the basic idea was the same – of using suction to pick up the sample – however it was not effective. The problems we had was that underwater, the suction cup required much force to push into the agar, and then when removing the cylinder, the agar was left behind due to the slippery inside surface.

First of all, several designs were considered. A rotating auger and also a grabber were considered as possible solutions. However the original idea was chosen, but had to be modified.

These were to make the wall thickness of the cylinder less and to give it a sharp edge, so it was easier to penetrate the agar. The most suitable cylinder we found was a drinks can, which would also pick up the correct amount of agar for full points.

Then came how to make the inside less slippery, and to provide better suction. We glued a strip of thin sand paper to the inside wall, which when tested worked. In this way a good working solution was found.

Figure 23. Testing the bacterial tooling.

6. Lessons Learned

During the design stage, a tool for collecting a sample of bacterial mat was developed using two syringes. At one end, the two plungers of syringes were connected together to a thick aluminium plate, through a middle there is a screw rod fixed on a DC motor. Hence, once the motor is on, the two plungers fixed to the aluminium plate travel upwards or downwards depending on the rotation direction. On the other end of the syringes, the two tips were used to suck the agar through them. However, once the agar mat was prepared to carry out some dry tests, it was found that the agar has very high viscosity and the tool developed was not suitable. Hence, an alternative tool was made using aluminium can cut in half with a one way valve fixed on the top of a can allowing water to move in one direction only, to create vacuum inside the can.
As a result, the team learned to analyse and clarify each mission task carefully before designing tools in order to avoid the same mistake from happening in the future.

7. Future Improvements

Speed control

The first thing that could be improved is the speed control which could be achieved by using PWM. If this was implemented the ROV could maintain constant depth even when lifting masses. Also for example; on the way to the task area, the ROV should be moving fast, but when more precise tasks need to be done, the ROV should move slowly.

Moving cameras

This function can save a time during the mission and can reduce the numbers of cameras. Right now the cameras are direct, they see only the tool working area. But when the ROV is diving and looking around, it would be better to have a further and greater view which will be helpful in finding the task area.

Similarly while looking for the task area; the ROV has to be moving. With movable camera's, it can remain still while the camera moves.

Robotic arms

The present grabber can be changed by having two or more axes. This allows us to do precision tasks or missions. The best way is to use two arms with three axes which are similar to human arms. Depending on the mission, the arms could be equipped with special tools.

The ideas for improvement is a lot and will be more after every practice hour and after new situation where the ROV will be used.

8. Reflections

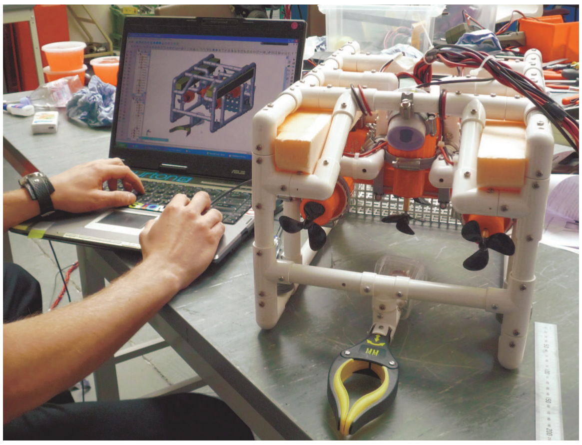
Being involved in the MATE ROV competition has not only been a great learning experience, but it's also been enjoyable. The engineering side of the project has been challenging but as with challenges I've learned from it; in all areas of ROV design. Being a part of a smaller team of only four has allowed me to participate in all area's which has been rewarding for me. I've gained knowledge and skill in all areas from electronics to buoyancy to the frame work to the tooling.

I've also had a great time with the team, building the ROV has been a very social experience. Before this, the idea of ROV, or robotic engineering hadn't crossed my mind much, but being part of this team has made me really think about these as possible career routes, particularly on the ROV side as our University has many ties with the oil industry.

Overall this has been a project I will never forget, and which may actually affect the rest of my working life. I look forward to the final competition and to what I can gain from being around so many accomplished engineers and capable students at the competition in Hawaii. – Ian Adamson

Every group/team project teaches us something new. Everyone is different even if the scope of project is narrow. The most important thing is to know what each team member's strength and weaknesses are, and to share the duties properly. Even if we are good at certain parts, it is good to consider somebody's opinion and broaden our horizons.

This project once again showed me how many working hours and how much money the 3D model can save. Using SolidWorks all of my questions were answered very fast and precisely. During the designing it was really helpful to try all options and choose the best one.

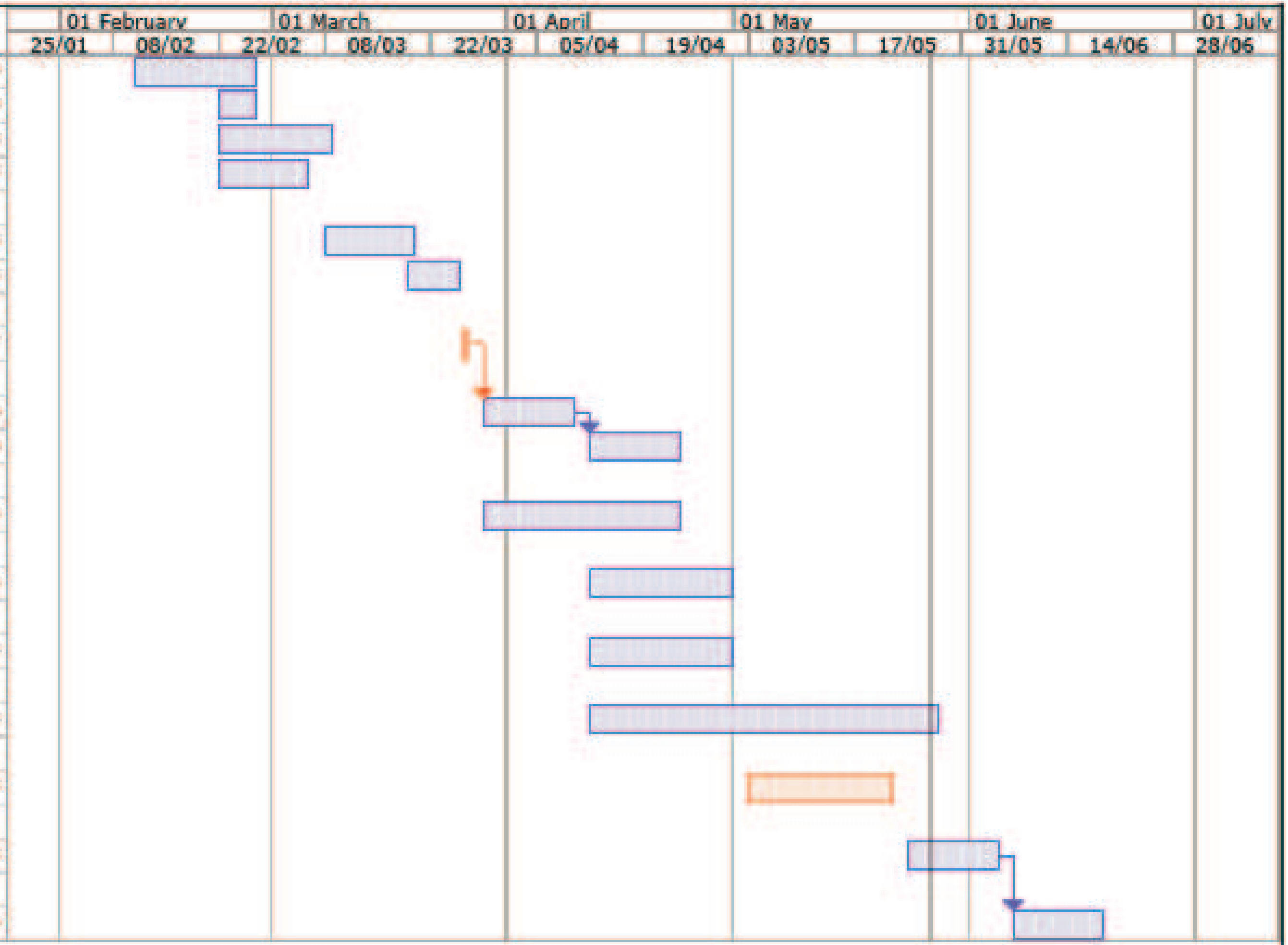


Experience is the most required skill in industry, and gives the greatest ideas during the designing process. Experience allows us to find the proven best solution and establish the engineering point of view. – Kamil Sobolewski

RGU ROV - Bill of material / Price list

Nr	*Part*	*Description*	*Supplier*	*Qty*	*Price*	*Subtotal*
1	**motor**	Ocean Secure 24 V 1100 GPH	SecureFix Direct	8	£19,50	£156,00
2	**motor cable**		University stores	8	£0,00	£0,00
3	**propeller**	Graupner 65 mm M4	Cornwall	8	£2,70	£21,60
4	**shaft coupler**	M4-M4 brass coupler	Rapid Electronics	8	£3,55	£28,40
5	**shaft**	M4 SS threaded rod	RS components	1	£3,47	£3,47
6	**frame**			1	-	£21,84
6.1	L piece (elbow)		Fascias.com	22	£0,38	£8,36
6.2	T piece		Fascias.com	25	£0,38	£9,50
6.3	pipe ø21mm	4889 mm	Fascias.com	2	£1,99	£3,98
7	**foam**	volume 0.0009542 [m²]	University stores	2	£0,00	£0,00
8	**extra mass**	ø40 mm rings made from lead	University stores	40	£0,00	£0,00
9	**camera module**			2	£39,60	£79,20
9.1	front window		University stores	2	£0,00	£0,00
9.2	pipe	40mm Access Plug	Fascias.com	2	£0,58	£1,16
9.3	cap	40mm Access Plug	Fascias.com	2		
9.4	rubber seal	40mm Access Plug	Fascias.com	2		
9.5	printed circuit board	made in university	University stores	2	£0,00	£0,00
9.6	capacitor	100nK63	University stores	4	£0,00	£0,00
9.7	video camera	C-CAM8-PAK	conrad-uk.com	2	£19,03	£0,00
9.8	capacitor	100uf10v	University stores	2	£0,00	£0,00
9.9	capacitor	220uf16v	University stores	2	£0,00	£0,00
9.10	voltage regulator	FK102 LM78L 05ACZ	University stores	2	£0,00	£0,00
9.11	camera cable	36 m CCTV Audio/Video&Power	Maplin	2	£19,99	£39,98
10	**scoop**	68% of open area	Perfored plate-RS	1	£16,87	£16,87
11	**grabber**			1	£32,96	£32,96
11.1	conector	made in university	University stores	1	£0	£0
11.2	shaft coupler	M5-M5 made in university	University stores	1	£0	£0
11.3	shaft seal	-	University stores	1	£0	£0
11.4	T piece	-	Fascias.com	1	£0,38	0,38
11.5	part2	made in university	University stores	1	£0	£0
11.6	jaw	part of "easy reacher"	Argos	2	£9,99	£9,99
11.7	midle part	part of "easy reacher"	Argos	1		
11.8	hinge	part of "easy reacher"	Argos	2		
11.9	pin	part of "easy reacher"	Argos	1		
11.10	waterproof cover	small plastic box	ASDA	1	£0,35	£0,35
11.11	geared motor	HN-GH12-2217Y 12V-200RPM	Active Robots	1	£22,24	£22,24
11.12	shaft	M4 SS threaded rod	RS components	1	£0,00	£0
12	**screw**	pan head self-tapping	Rapid Electronics	1	£2,50	£2,50
13	**jubilee clip**	45-60 mm	RS components	10	£0,69	£6,90
14	**jubilee clip**	17-25 mm	RS components	18	£0,57	£10,26
15	**control box**	taken from last year ROV project	University stores	1	£0,00	£0,00
15.1	control box	Additional components	Rapid electronics		£163	£163
					Total price	£543,00

ID		Task Name	Duration
1		Frame design	12 days
2		Tool design for task 1	5 days
3		Control system design	11 days
4		Cameras design + build	10 days
5			
6		Building stage	10 days
7		Buoyancy + Test	5 days
8			
9		Regional competition	1 day
10			
11		Temperature sensor	10 days
12		Sound sensor	10 days
13			
14		Grabber design + build	20 days
15			
16		Tool design for task 4	15 days
17			
18		Control system improvement	15 days
19			
20		Report writing	34 days
21			
22		Exam break	15 days
23			
24		Finish the build + assemble	10 days
25			
26		Buoyancy + Test	10 days



Project: ROV Project
Date: Thu 27/05/10

Task		Milestone		External Tasks	
Split		Summary		External Milestone	
Progress		Project Summary		Deadline	

11. Acknowledgements

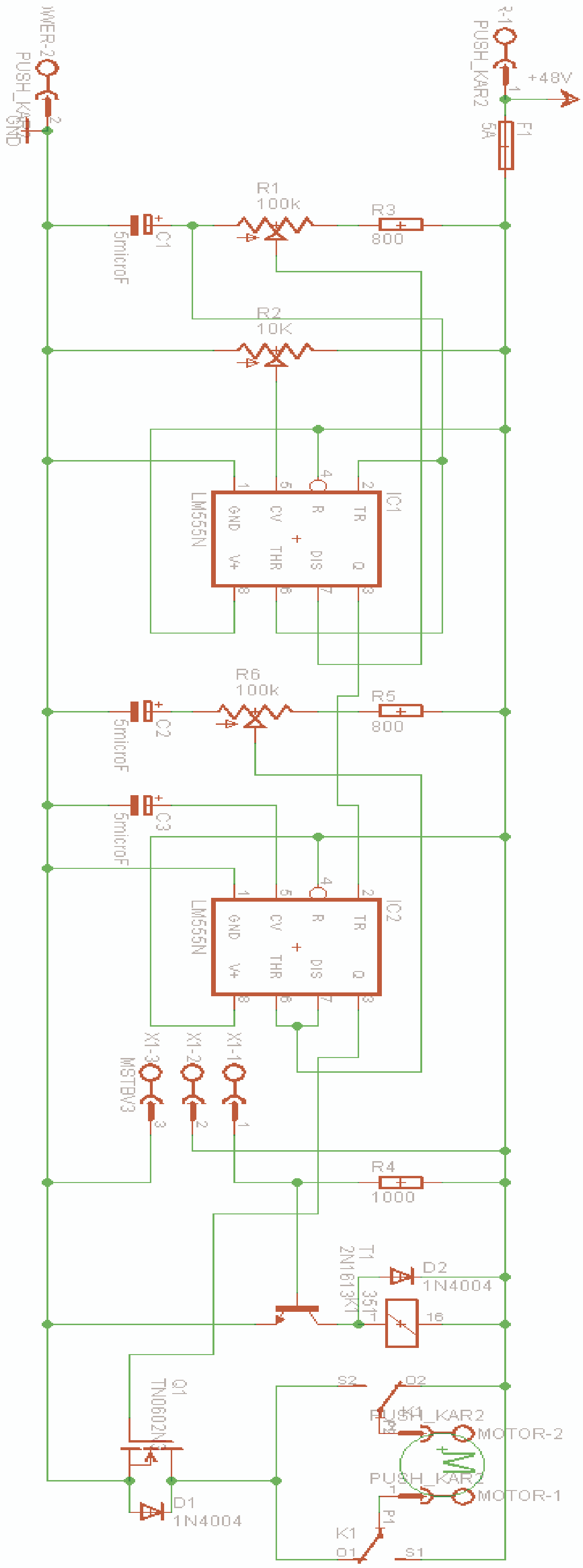
We would like to thank firstly Robert Gordon University for giving us the opportunity to be involved and also the MATE centre for organising the overall competition. Also we'd like to thank our sponsors BP and Acergy, who supplied our budget of £500 and also our travel costs. Also thanks to Opito who sponsored the regional competition.
We would also like to thank our mentors: Graeme Dunbar, John Still and Steve Allardyce for all their help, knowledge and wisdom.

12. References

(1) The Formation of the Hawaiian Islands. Available at: http://www.soest.hawaii.edu/GG/HCV/haw_formation.html. Accessed 05/07, 2010.
(2) Hawaii Centre for Volcanology - Loihi Volcano. Available at: http://www.soest.hawaii.edu/GG/HCV/loihi.html. Accessed 05/07, 2010.
(3) HURL Current Research. Available at: http://www.soest.hawaii.edu/HURL/hurl_loihi.html. Accessed 05/07, 2010.
(4) Picture of Pisces V submersible. Available at: http://www.oar.noaa.gov/spotlite/archive/images/loihi_3.jpg. Accessed 05/08, 2010.
(5) A BRIEF INTRODUCTION TO THE HISTORICAL FORMATION OF ICELAND IN THE ATLANTIC OCEAN. Available at: http://www.iceland-nh.net/lands/background_lands.html . Accessed 05/15, 2010.
(6) SecureFix Direct. Available at: http://www.securefixdirect.com/24v-dc-1100gph-ocean-secure-bilge-pump-234-p.asp. Accessed 05/12, 2010.

PWM

Circuit description:
The circuit consists of two 555 timers leading into a simple relay circuit. The first timer is configured as astable to produce a continuous pattern of pulses which will control the speed of the ROV depending on the delay between each pulse. Potentiometer R1 determines the frequency of the continuous pulse. The output of the first timer is then fed into the trigger pin of the second 555 timer which is set as a monostable. The reason for this monostable is to adjust the width of the pulse it is receiving from the previous circuit. This would then determine the speed of the ROV. An external voltage divider limits the voltage down to 5 V to feed into the trigger input of the 555 timer. Pin 2 is connected to pin 6 and discharges through Pin 7. The voltage divider sets the time intervals for the pulsing. Pins 4 and 8 are both connected to the supply rail whereas pin 1 is grounded. Voltage feeding into Pin 5 is controlled through a potentiometer (R2) which adjusts the internal voltage divider of the 555 timer IC. The second 555 timer circuit (which will adjust the width of the pulse and output through pin 3) is fed into the gate of the MOSFET allowing it to switch on and control the speed of the motor. Circuit 3 is a simple relay circuit that acts as a voltage divider with a resistor and toggle switch connected together. When the switch is ON the current travels into the base of the transistor (npn) and turns it on when the threshold of 0.7 V is across the base emitter junction. This then energises the relay coil and causes the motor to turn in one direction (clockwise.). When the switch is toggled OFF, It is pulled down causing the relay to switch over hence changing the direction of the motor (anti-clockwise).



Arduino programme

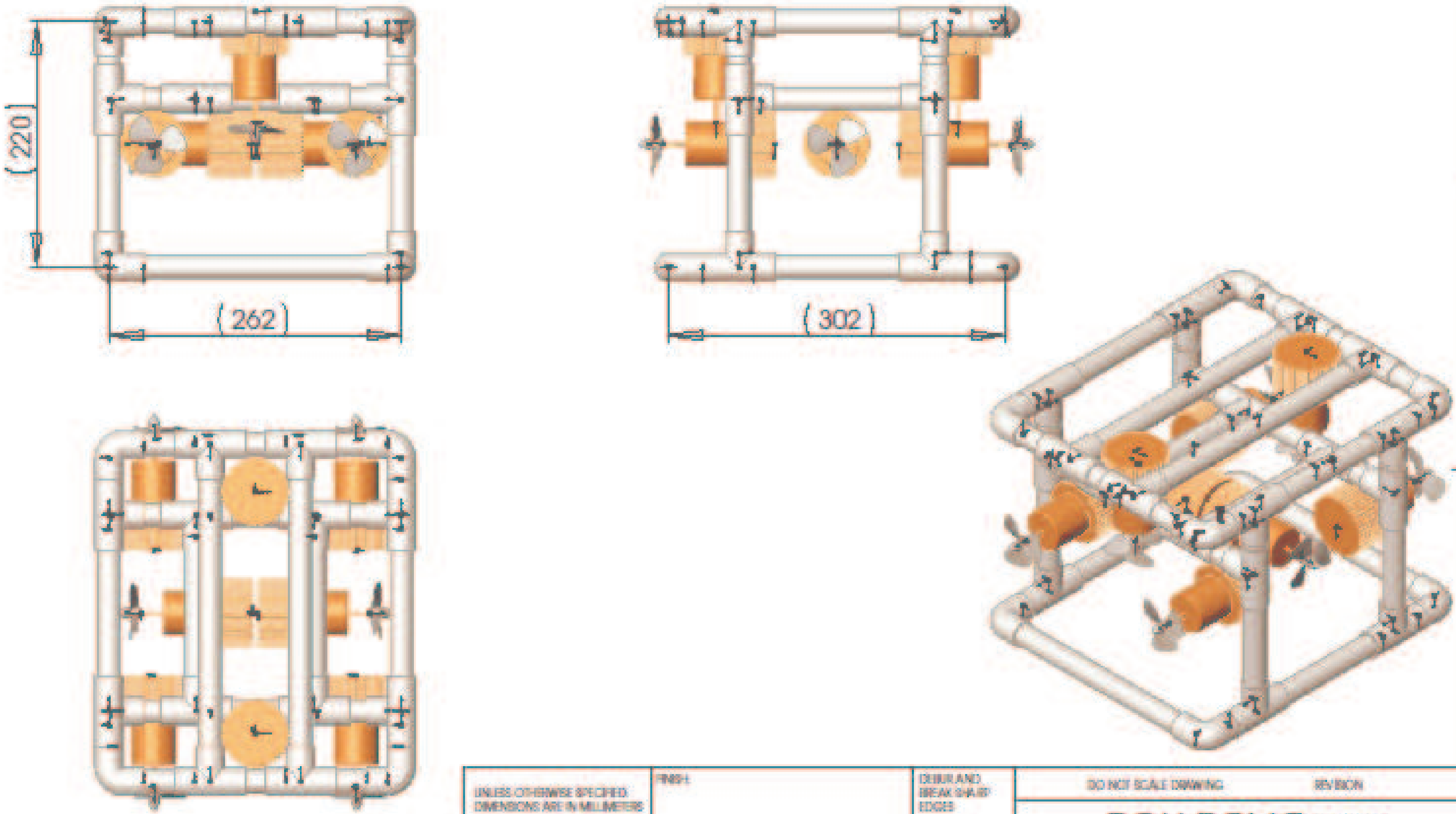
```
int maximum = -55;                    //set max and min temps
int minimum = 150;
float temperature = 0;
int temprecorder(50);
float sensor = 4;                     // Analogue sensor pin
int T;
void setup()
{
Serial.begin(9600); // start communicating with temp sensor at 9600 bauds
}
void loop()
{
 for(T = 0;T<=49;T++)                 // record 50 temperature readings
{
temprecorder(T) = ( 5.0 * analogRead(sensor) * 100.0) / 1024.0;
// changes the digital converted signal into a voltage equal to degree elcius
temperature = temperature + temprecorder(T);         // add to set 0 deg
delay(150);                           //wait for 150 milliseconds
Serial.println(temprecorder(T));      //print the temperature
}
temperature = (temperature/50); / / calculating average temperature

if(temperature > maximum) {maximum = temperature;}
// set max temperature if(temperature < minimum) {minimum = temperature;}
// set min temperature

Serial.print(temperature,DEC); // print the results in the serial communications
window
Serial.print(" Celsius ");
Serial.print(maximum,DEC);
Serial.print(" Maximim, ");
Serial.print(minimum,DEC);
Serial.println(" Minimum");

temperature = 0;              //set temperature back to 0

delay(150); // wait 150 milliseconds before loop
}
```



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					RGU ROV Team	
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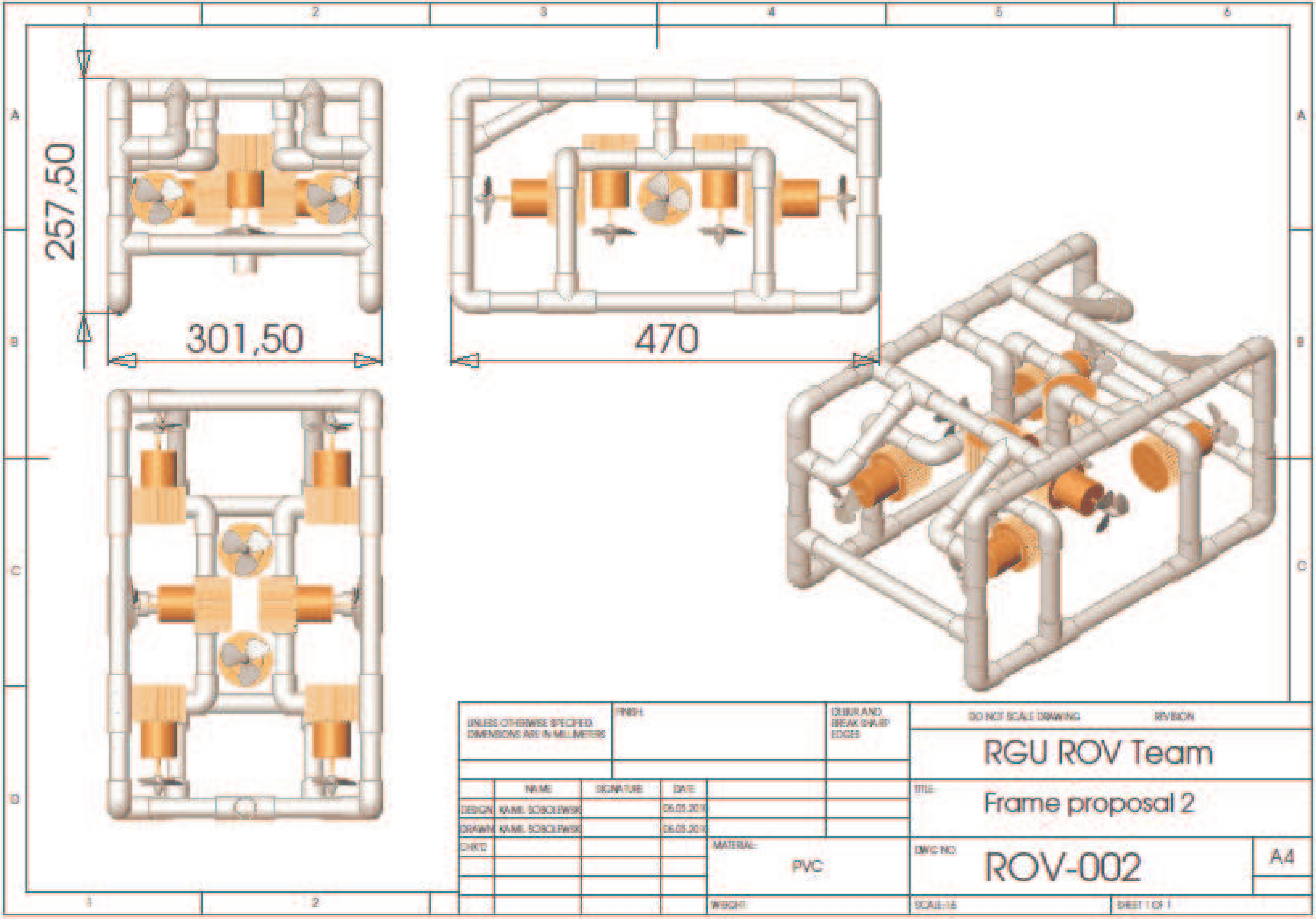
DESIGN	KAMIL SOBOLEWSKI		06.05.2010		Frame proposal 1	
DRAWN	KAMIL SOBOLEWSKI		06.05.2010			
CHK'D				MATERIAL: PVC	DWG NO. ROV-001	A4
				WEIGHT:	SCALE:1:5	SHEET 1 OF 1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301,50
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TITLE:
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MATERIAL:
PVC
DWG NO.
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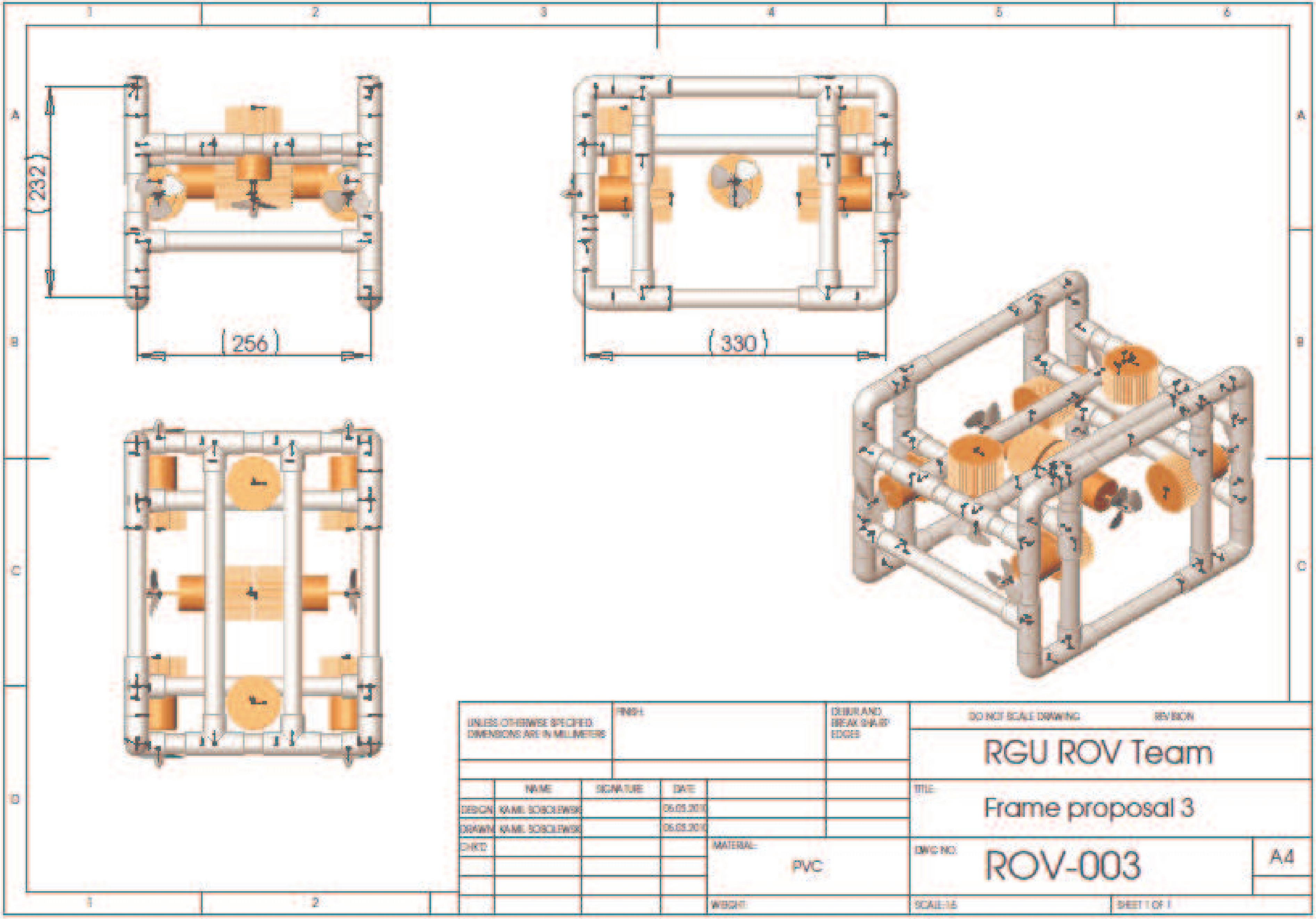
WEIGHT:
SHEET 1 OF 1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REVISION
RGU ROV Team
NAME
SIGNATURE
DATE
DESIGN
KAMIL SOBOLEWSK
06.05.201
DRAWN
KAMIL SOBOLEWSK
06.05.201
CHK'D
TITLE:
Frame proposal 3
MATERIAL:
PVC
DWG NO.
ROV-003
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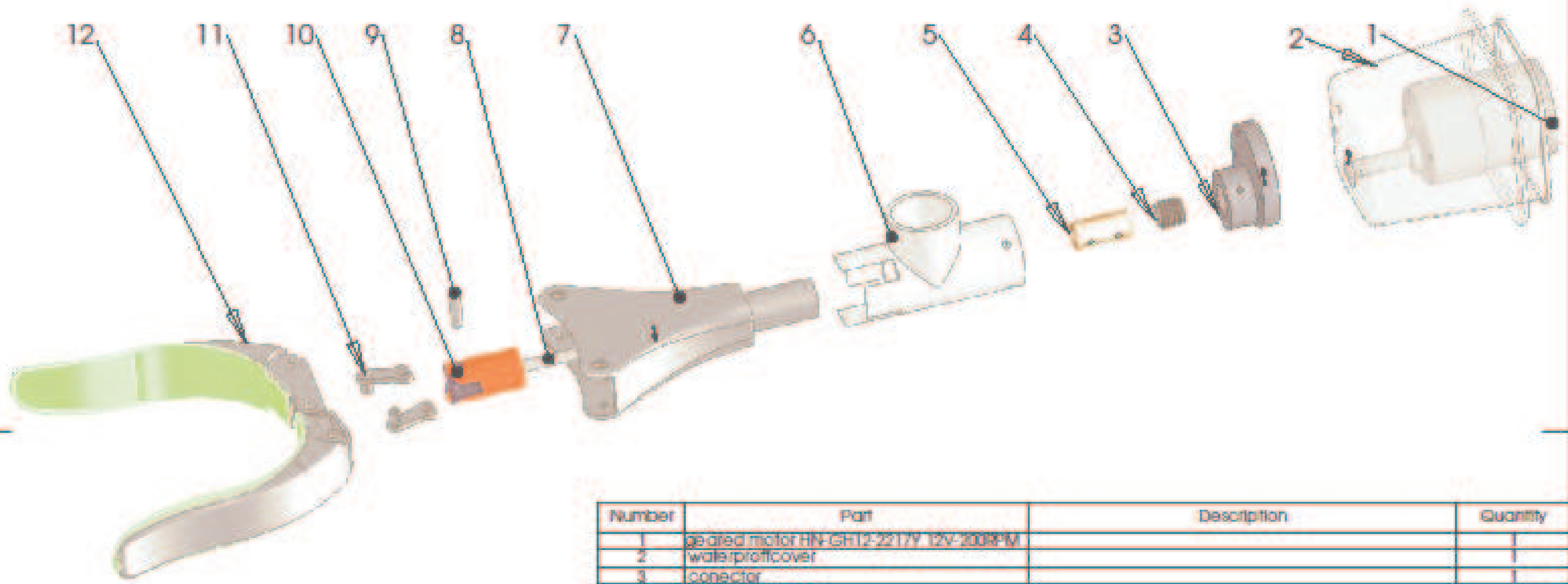
SHEET 1 OF 1



Number	Part	Description	Quantity
1	geared motor HN-GH12-2217Y 12V-200RPM		1
2	waterproffcover		1
3	conector		1
4	rubber shaft seal		1
5	part1		1
6	1grabberpart		1
7	main part		1
8	threaded shaft		1
9	pin		1
10	part2		1
11	hinge		2
12	jaw		2

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FINISH:

DEBUR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION

RGU ROV Team

	NAME	SIGNATURE	DATE
DESIGN	KAMIL SOBOLEWSKI		
DRAWN	KAMIL SOBOLEWSKI		
CHK'D			

MATERIAL:

WEIGHT:

TITLE:

Exploded view of grabber

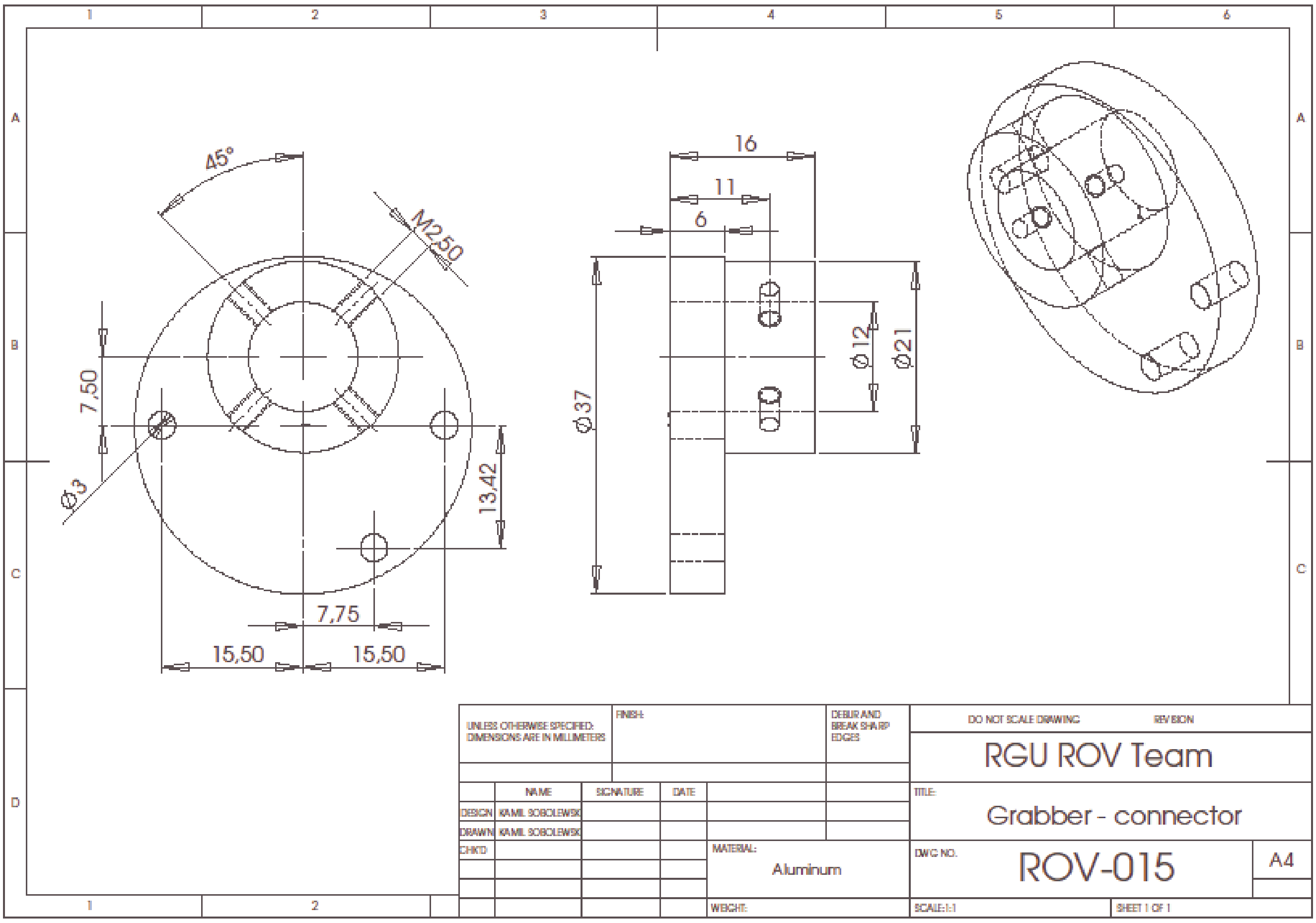
DWG NO.

ROV-12

A4

SCALE:1:2

SHEET 1 OF 1


45°
M2,50
7,50
⌀3
13,42
7,75
15,50
15,50
16
11
6
⌀37
⌀12
⌀21
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RGU ROV Team
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SIGNATURE
DATE
TITLE:
DESIGN KAMIL SOBOLEWSKI
DRAWN KAMIL SOBOLEWSKI
CHK'D
Grabber - connector
MATERIAL:
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DWG NO.
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WEIGHT:
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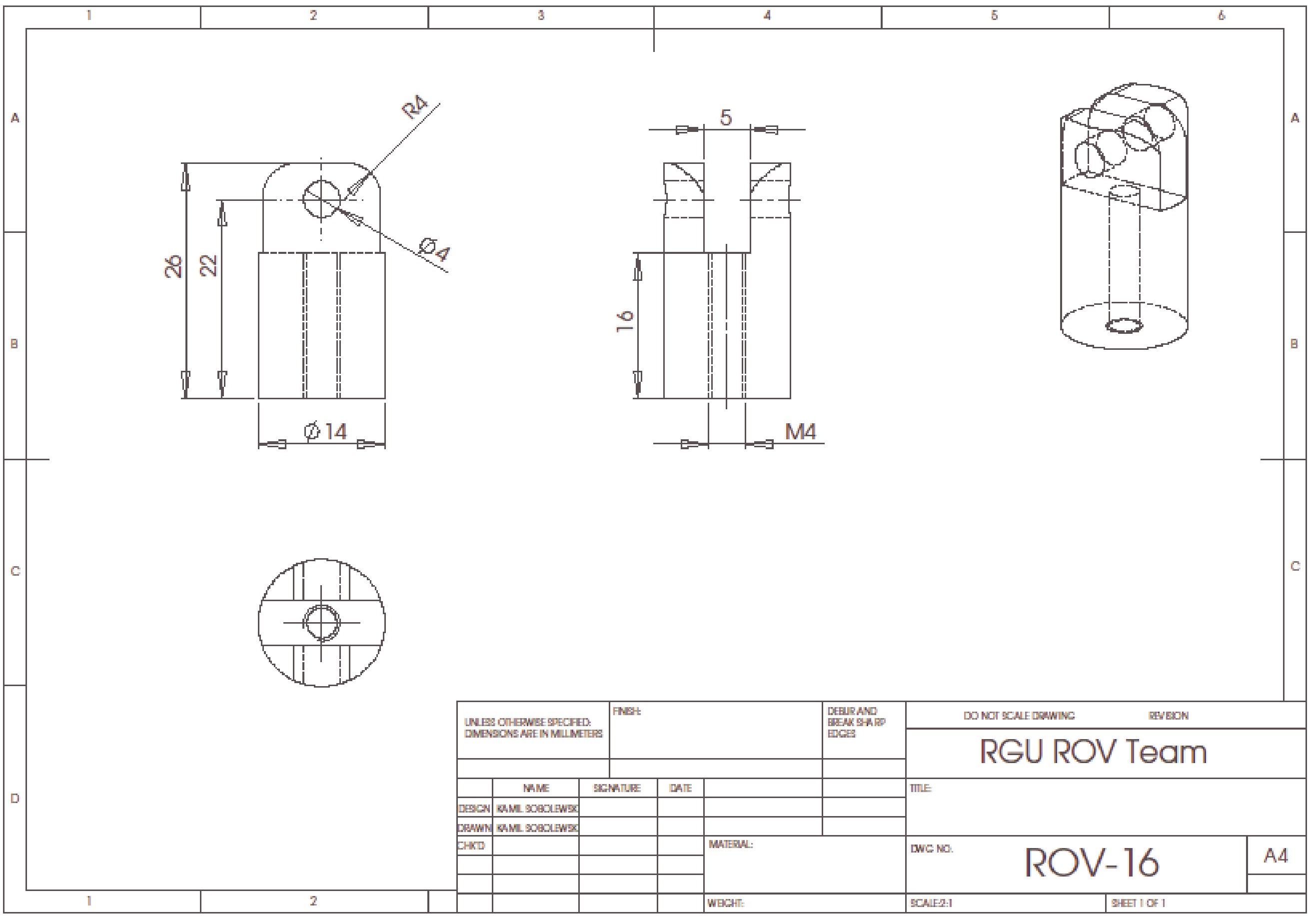
SHEET 1 OF 1


R4
⌀4
26
22
⌀14
5
16
M4
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RGU ROV Team
NAME
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DATE
TITLE:
DESIGN KAMIL SOBOLEWSKI
DRAWN KAMIL SOBOLEWSKI
CHK'D
MATERIAL:
DWG NO.
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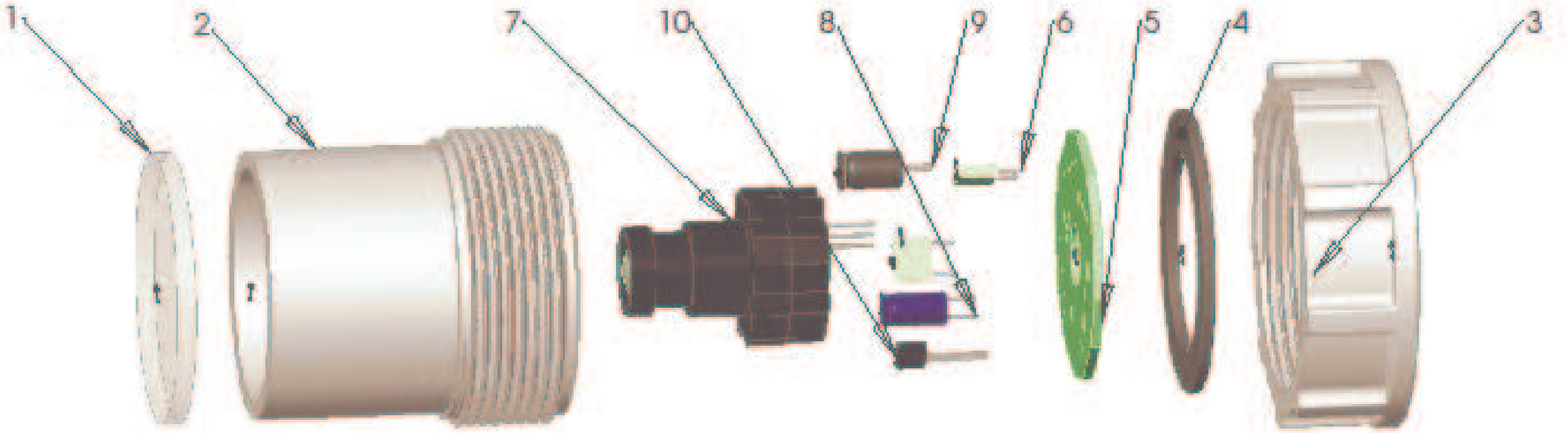
A4
WEIGHT:
SCALE:2:1
SHEET 1 OF 1



Number	Part	Description	Quantity
1	front screen		1
2	cover		1
3	part3		1
4	rubber seal		1
5	plate		1
6	100nK63		2
7	PAL		1
8	100uf 10v		1
9	220uf 16v		1
10	PK102 LM78L 05ACZ		1

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REVISION

RGU ROV Team

	NAME	SIGNATURE	DATE
DESIGN			
DRAWN	KAMIL SOBOLEWSKI		
CHK'D			

MATERIAL:

WEIGHT:

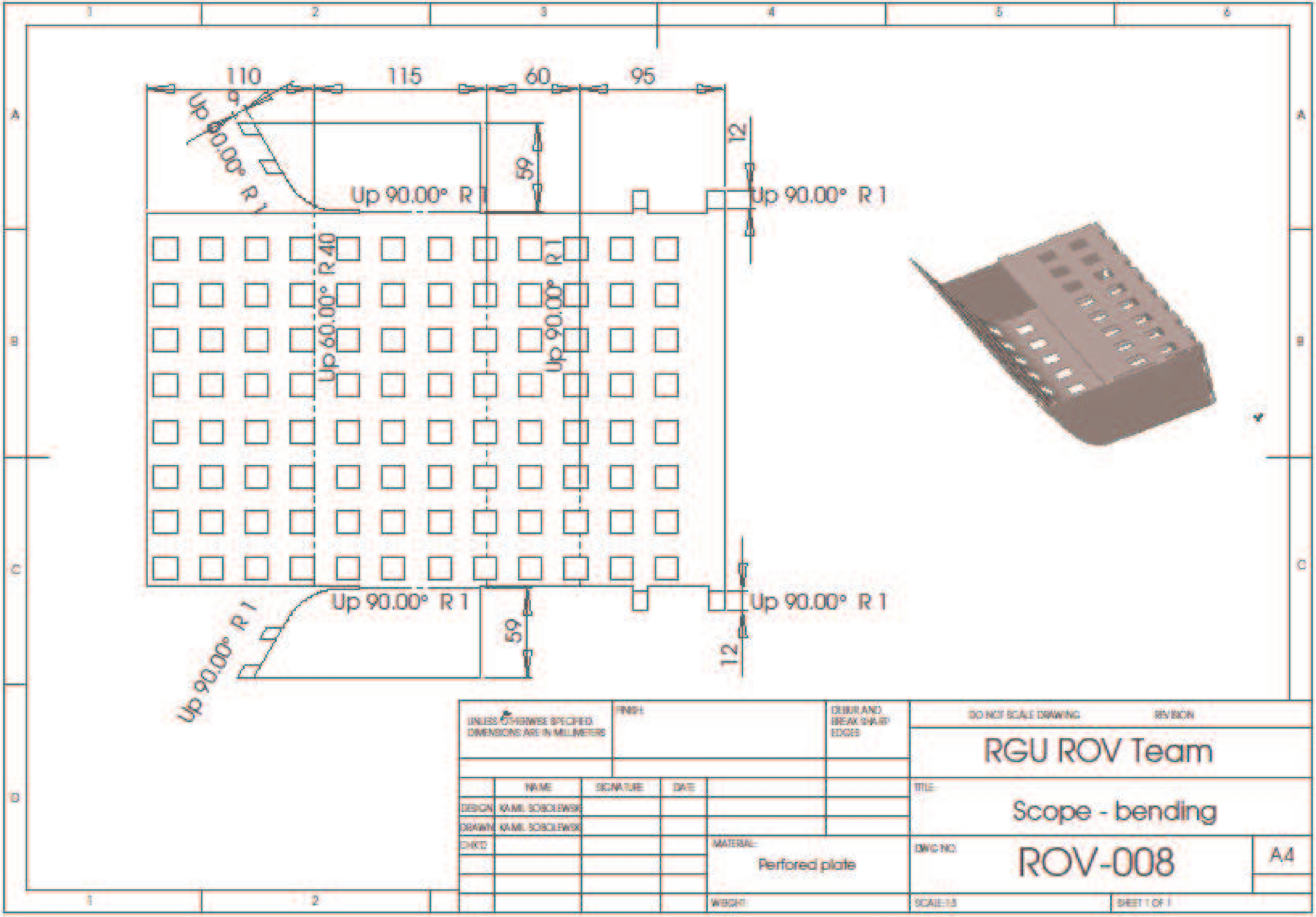
TITLE: Exploded view of camera asembly

DWG NO. ROV-11

A4

SCALE:1:1

SHEET 1 OF 1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115
60
95
9
Up 90.00° R 1
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Up 90.00° R 1
59
12
Up 60.00° R 40
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Up 90.00° R 1
Up 90.00° R 1
Up 90.00° R 1
59
12
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FINISH:
DEBUR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
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RGU ROV Team
NAME
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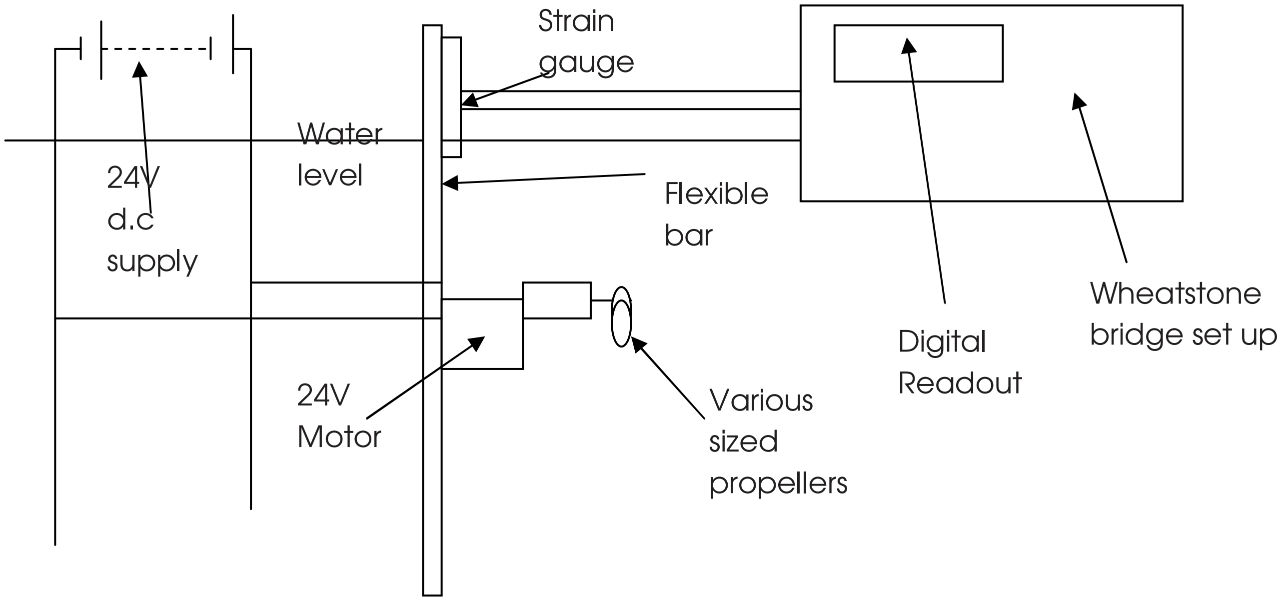
DATE
TITLE:
Scope - bending
DESIGN KAMIL SOBOLEWSKI
DRAWN KAMIL SOBOLEWSKI
CHK'D
MATERIAL:
Perfored plate
DWG NO.
ROV-008
A4
WEIGHT:
SCALE:1:5
SHEET 1 OF 1

Thrust measurement

The thrust per motor was measured for three sizes of propeller available to us: 45mm, 55mm, and 65mm. This was done using the set up shown below.



The bar with the strain gauges is calibrated then the thruster is attached with the first size of propeller on it. The supply is turned on and the thrust measured on the digital read out. The supply is reversed so the motor is now going backwards and the thrust measured again. This is repeated for the three sizes of propeller.

Prop Size (mm)	Thrust forward (g)	Thrust backward (g)
45	1100	250
55	1350	450
65	1300	500

Table 1. Thrust for the three sizes of propeller from the experiment.

Buoyancy Calculations

The buoyancy can be calculated using two simple formulas:

$$V_{ROV} = \frac{W_{air} - W_{water}}{\rho_{water} \times g}$$

$$V_{foam} = \frac{m_{ROV} - (\rho_{water} \times V_{ROV})}{\rho_{water} - \rho_{foam}}$$

Where:
V_{ROV} = Volume of the ROV (m^3)
V_{foam} = Volume of the foam (m^3)
m_{ROV} = Mass of the ROV in air (kg)
W_{air} = Weight of the ROV in air (N)
W_{water} = Weight of the ROV in water (N)
ρ_{water} = Density of water – 1000kg/m^3
ρ_{foam} = Density of the foam – 27.72kg/m^3
g = Acceleration due to gravity – 9.81m/s^2

Using these calculations the Volume of foam needed can be calculated:

ROV mass (kg)		ROV weight (N)		ROV Volume (m^3)	Foam Volume Required (m^3)
Air	Water	Air	Water		
4.55	1.85	44.64	18.15	0.0027	0.0019

Table 2 – Buoyancy calculation values

$$V_{ROV} = \frac{44.64 - 18.15}{1000 \times 9.81} = 0.0027m^3$$

$$V_{foam} = \frac{4.55 - (1000 \times 0.0027)}{1000 - 27.72} = 0.0019m^3$$

This information can now be used to calculate the dimensions of the foam on the ROV. The ROV is to be positively buoyant so extra volume is added, and masses used to trim the ROV.