RGSea

Technical Document

Robert Gordon's College Aberdeen, Scotland

THE TEAM

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Callum Angus	**R&D Director**
Matthew Fossett	**Tooling and Structure Director**
Jack Noble	**CFO and CTO**
Adam Stephen	**Control and Power Director**
Andrew Webb	**Safety and PR Director**
Calum Lovie	**Graphic Designer (Creo, In-Design)**
Nimrod Libman	**Programming**
Michael Dow	**Tool Design**
Aidan Parker	**Tool Design**
Murray Coueslant	**Electrical**
Thomas Santini	**Electrical**
Matthew Briggs	**Electrical**
Mr Wakeford	**Mentor, Robert Gordon's College**
Mr Hinks	**Mentor, BP**

ABSTRACT

We are RGSea: a team from Robert Gordon's College, a city-centre school located in Aberdeen, Scotland. Our team consists of 13 students, whose specialties range from Physics and Mathematics to Graphic Design.

Mission tasks are based around the scientific exploration of Europa, one of Jupiter's moons, as well as service tasks in the Gulf of Mexico oil-fields. The team's design strategy aimed to minimise weight and physical dimensions: an additional 1kg of mass adds approximately £14,000 to the costs of a space mission.

When on Europa, some of the tasks the ROV will have to complete include: measuring the temperature of venting fluid, measurement of the thickness of the ice-crust and the depth of the ocean and finally making connections from sensors to a power hub.

To complete these tasks we have designed and created a self-centering temperature sensor, a depth measurement device and a grappling hook. The tools are fitted to a new compact, lightweight frame.

The newly developed gripper allows us to pick up and move a range of objects, such as CubeSats, coral samples and oil samples. This functionality is also vital for the required oil-field service tasks; installing flanges and wellhead caps subsea.

The company's specialised tools and sensors will help maintain our planet's environment and give science the capability to search for new life within our solar system.

TABLE OF CONTENTS

INTRODUCTION

The following elements of the report cover the design rationale that RGSea developed in response to this year's mission specification:

- Frame
- Propulsion
- Depth Measurement
- Temperature Sensor
- Buoyancy
- Control
- Safety

The second half of the report details the project management, finance and evaluation of the company's approach to this year's mission.

FRAME

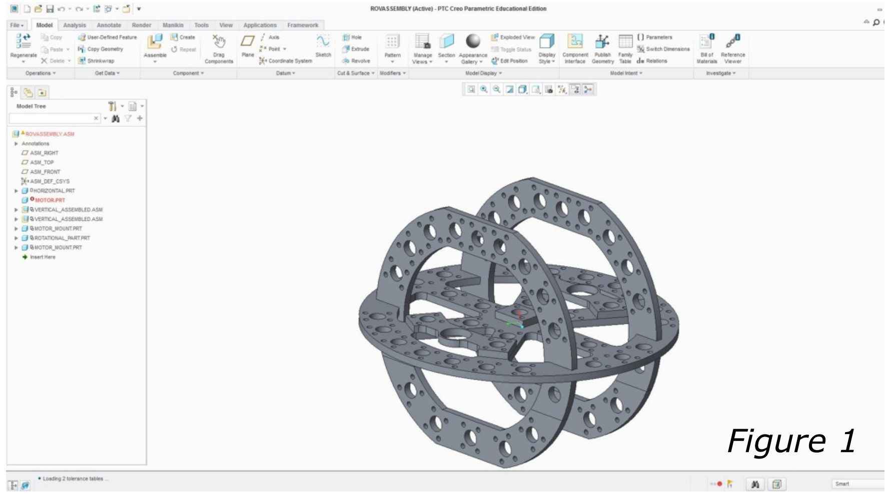


Figure 1

The ROV was designed to be compact, light and structurally strong, all important factors in subsea operations and space exploration. The new frame is 420mm across its largest diameter and (as it's spherical) will meet the size specification in any direction. The spherical design also means ROV has the largest possible volume, which allows more space for tools. A sphere maximises the volume of a given diameter, whereas a cube or cuboid leaves a lot of wasted space.

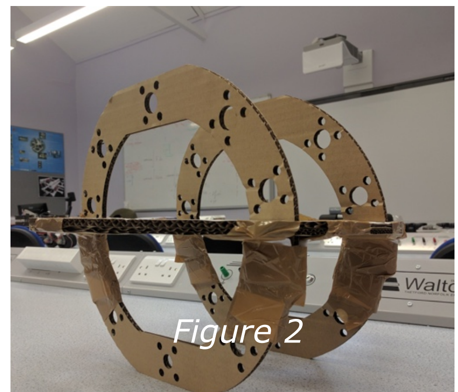


Figure 2

We selected 420mm as our diameter for two reasons: firstly, it allows “wiggle room” for larger tools to edge out of the sphere and secondly the diameter allows for the umbilical to be wrapped around the ROV (fig. 4) and still remain comfortably inside the 480mm diameter set out in the specification. The frame was drawn on Creo Parametric CAD software (fig. 1), in 3D form and in 2D for laser cutting. We created a prototype out of cardboard (fig. 2) to gain sense of the sizing and placement of the motors, before moving forward with the final construction (fig. 3). The holes in the structure allow tools to be added modularly with PVC pipe and be easily updated for future missions. By introducing acrylic we were able to create a custom, lasercut frame which is 31% lighter than last year’s PVC pipe based frame. The new material is only 8mm thick which minimises drag in the water and provides the best combination between strength and weight. In all previous years we have used PVC pipe to create a frame, so this was a great leap in a new direction and gave us a lot more flexibility to get creative. Ultimately, the ROV has met the size and weight specifications, and the key factor in this was the successful redesign of the frame.

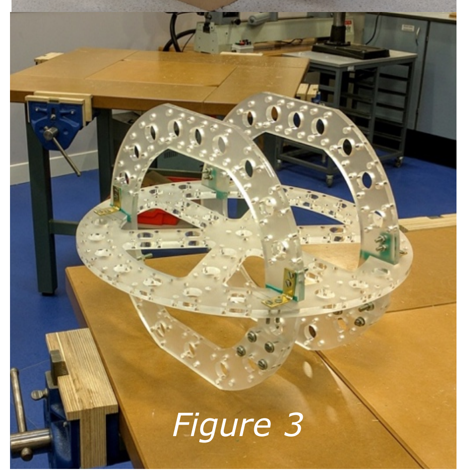


Figure 3

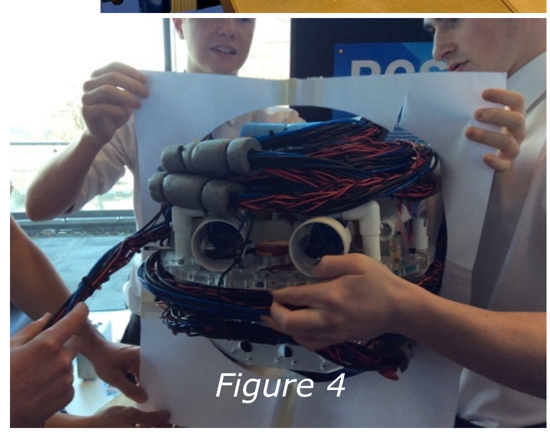


Figure 4

PROPULSION

The propulsion system is comprised of six thrusters, four for movement in the horizontal plane and two for vertical movement. Bilge pump motors with the housings removed were used to make the thrusters because they were pre-waterproofed and provided plenty of torque without too high a speed. The propellers were chosen from a wide selection in a trial to determine which produced the greatest thrust with the lowest current draw, to maximise power efficiency. The vertical motors provide thrust up or down to change the ROV's depth.

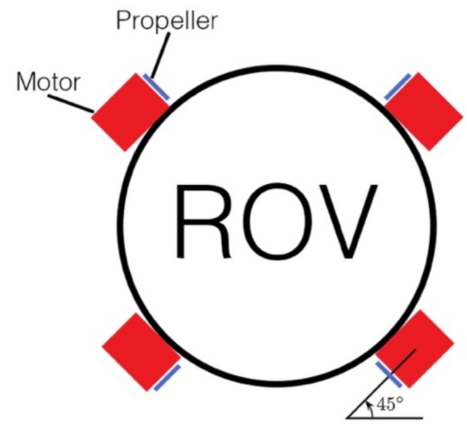


Figure 5

The other four motors are each angled at 45° to the forward direction and positioned at each "corner" of the frame (fig. 5). Calculations were made to demonstrate where the force from our thrusters was dissipated (fig. 6) and how the ROV would manoeuvre based on the control signal (fig. 7). They are attached to the horizontal frame disc on swivel joints with locking bolts. This allows them to be tucked out of the way for measurement (fig. 4) and then rotated out into their operational positions, before being put in the pool (see front cover). This preparation must be done manually, but in a real world application this process would have to be automated. The motors are positioned the way they are to produce maximum forward/backward and strafing thrust, as well as a good turn speed. This arrangement grants the ROV exceptional manoeverability in all the ways that matter. Each thruster has a propeller guard. These not only act as protective shields for the propellers and any stray fingers, but also improve the drive unit's propulsive efficiency. The guards have a funneling effect that means that more of the water pushed by the propellers is directed straight in line with the motor axis and less water producing turbulence but no thrust.

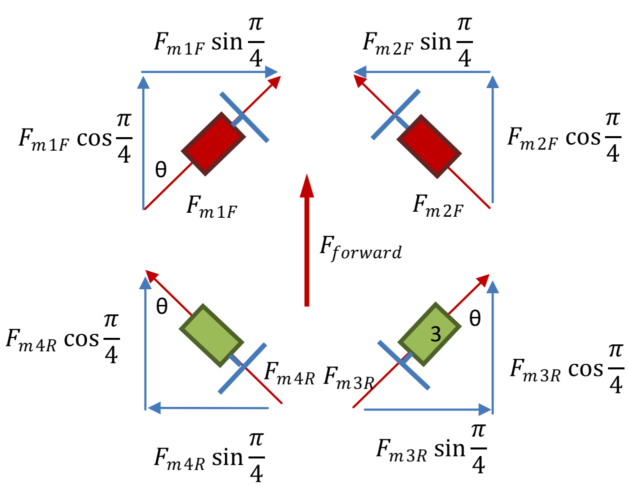


Figure 6

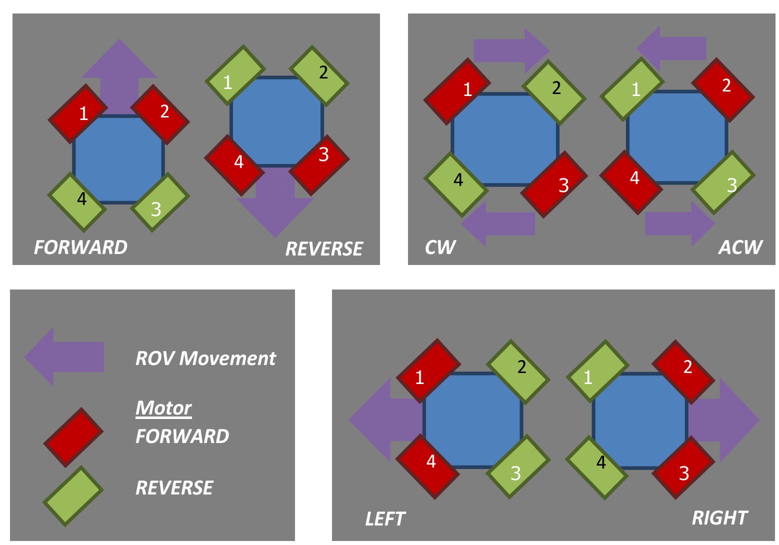


Figure 7

Vision

Ensuring a fully functioning and well developed vision system is in place on the ROV is imperative to its ability to deal with tasks. Thus the cameras chosen were pre-waterproofed fishing cameras to reduce risk in this aspect. The objective of camera placement was to maximise the usage of each camera. For example, our rear camera is able to view the temperature sensor and give a second perspective of the gripper. Another camera simply provides a frontal view, angled slightly downwards, to allow the pilot to control the ROV accurately. Our third camera allows vision of both the gripper for positioning the ESP and another view on the hook. The final camera allows vision of the hook as well as providing a good vision of the bottom of the pool for identification and retrieval tasks.

The power to the vision circuit is fed through a noise filter (PC3-FO8) in order to reduce the effect that other components like the compressor and motors have on the quality of vision. The actual footage is displayed on a 16 inch screen, but first travels through a video splitter. This allows for all of the channels to be viewed all at once in split screen, or full screen for individual tools and components to be focused on. The flexibility this provides is only enhanced by the ability to freeze screens with ease; ideal for tasks like the photographing and surveying of corals.

Retrievable Self Aligning Hook

The hook has two main uses in relation to the tasks. Firstly, it allows the port door for the ESP to be opened without the need for the ROV to follow an arc shaped path. Secondly, to assist with manipulating various objects, including the CubeSats. The tool incorporates a self-aligning system which means the 4 hooks will always be in the correct orientation with 90˚ spacing between them (fig. 8). The retrieval system is powered by a bilge pump motor that has been stripped down and attached to a 3D printed, custom designed reel. Fishing wire is then attached from the reel to the hook assembly. We considered using a spring to retract the hook, but the use of a motor allows us to move and lift objects in a much more controlled manner, along with the overall design being much more compact.

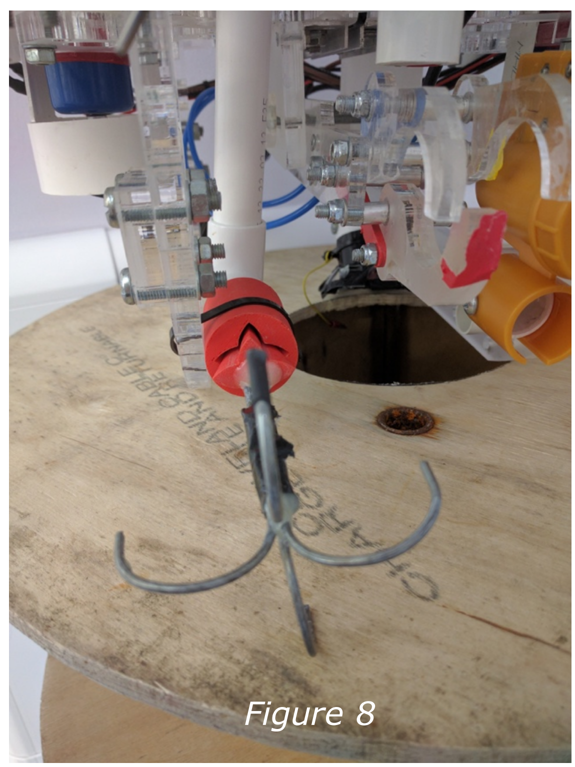


Figure 8

Gripper

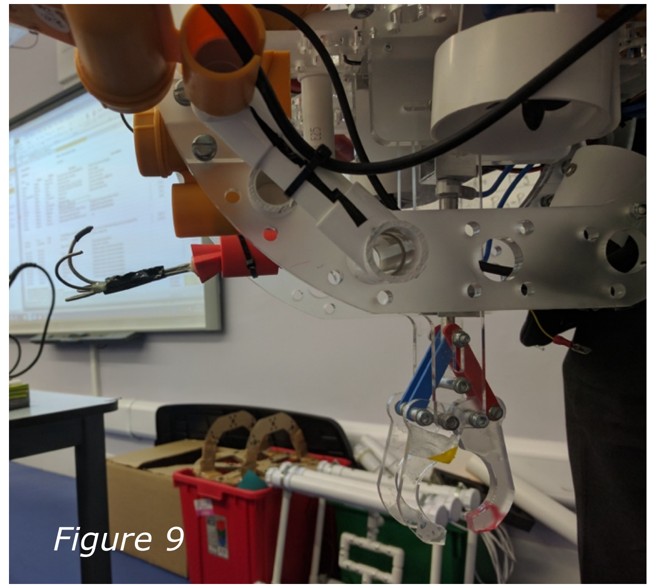


Figure 9

Like the frame, the gripper was designed with the same objectives of being compact and light. The gripper was 'laser cut' out of perspex and acrylic, and is constructed into layers which form the claw and housing. The whole assembly is rotatable so that the gripper can 'tuck' away into the ROV's underside, this allows the ROV to meet the size specification. When needed the gripper extends beneath the ROV's frame (fig. 9), this is done manually through a pin system. Future developments would see the process operate remotely.

The claw pieces are designed to grip a variety of objects. We selected 3 claws in a scissor mechanism for our gripper to make picking up T-pieces (coral, bolts) and larger diameter pipes (ESP, oil samples) as simple as possible. The claws themselves have been designed in such a way that when opening and closing the 'radius of movement' does not extend out (fig. 10). For example, when picking up items from the seabed, the gripper will not force the ROV up when the claws close around the object.

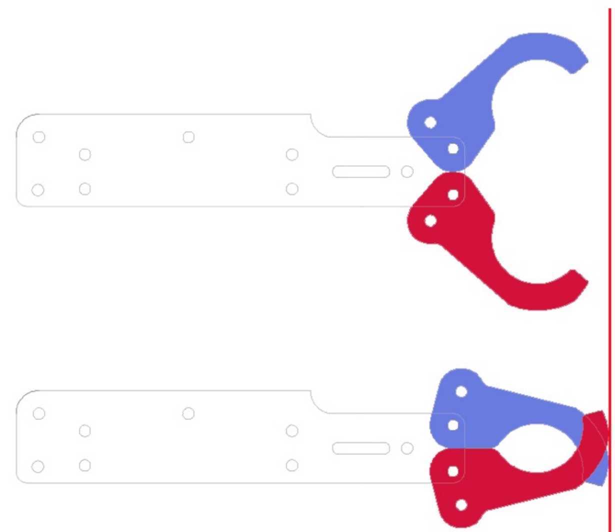


Figure 10

The gripper is pneumatically actuated. We were able to achieve full open/close movement using a piston with only 10mm extension, making for a compact piston housing. What's more, pneumatic tubes are much lighter than the copper wires which would have been necessary had we opted for a motor alternative. This helps minimise the weight of the umbilical. Overall, the gripper mimics many of the design elements of the frame; being compact, light and custom-made for the job at hand. It has been designed and built specifically for this year's competition, but it's design remains flexible for future years and new tasks.

DEPTH MEASUREMENT

LASER

This system utilises two lasers mounted on the ROV and the front view camera. The lasers must be orientated so that their beams intersect at a set distance from the ROV (fig. 11). When attempting to measure an object the ROV must be positioned at the set distance by moving into a position where the laser points merge and the ROV points in a direction normal to the axis of the distance being measured. When in position, a square grid is placed over the screen and the ends of the object marked on the grid. The number of squares is then multiplied by a scaling factor to determine the distance measured. The vision system has a "freeze frame" function. The scaling factor was determined in pool testing with all the apparatus submerged, as it would be in operation, to avoid any potential optical variation between water and air interfering with the results. This technique does rely on the object being straight and having a large enough visible area for the laser dots to be seen easily.

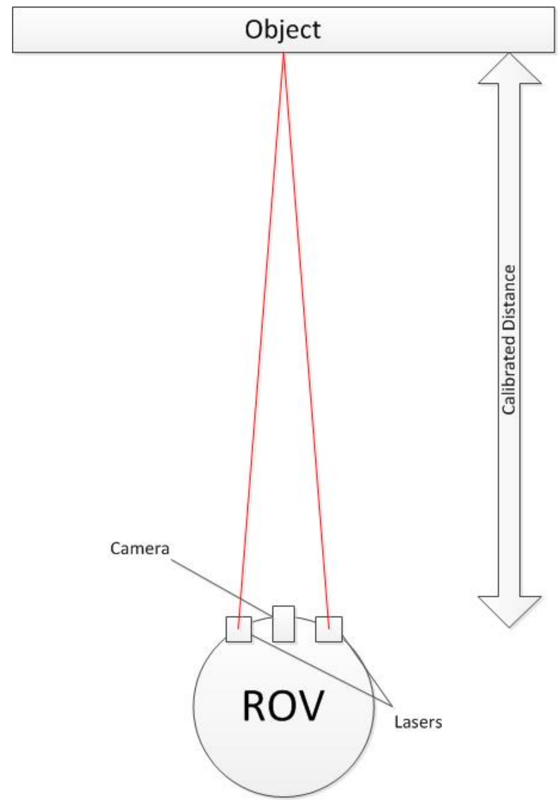


Figure 11

REFERENCE BAR

This system is similar to the laser system in that it uses a grid measurement and a scaling factor to determine the distance but varies in the way that the initial measurement is taken. The "reference bar" itself is an aluminium rod with a hook and loop on one end. There is also a reference marker at each end and they are spaced exactly 400 mm apart. The rod is held on the ROV by the loop, which fits in a slot on an extension of the frame. To be used for measurement the rod must be hooked onto the object to be measured or something level with it. The rod will then hang vertically and the markers can be used as a scale reference when viewing the object. When both the rod and the object are in view, the screen can be frozen and a plastic sheet with grid placed over it. The ends of the reference bar and the extents of the objects being measured are all then marked on the sheet. Real life lengths can be calculated from the lengths marked on the grid, using the following equation:

$$Real\ Length = \frac{Viewed\ length\ on\ grid}{Rod\ length\ on\ grid} * 400\ mm$$

Once the measurement is complete the rod can be retrieved by the loop using the hook and returned to the surface. This method has some drawbacks:

- It relies on there being a place to hook the rod on, in this case the poles representing depths
- It is time consuming to position and retrieve the rod
- It is possible to lose the rod without a skilled pilot
- The system cannot be used with a fish-eye lens due to distortion

Despite these drawbacks the system has proved to be incredibly accurate in testing; its simplicity has proved to be one of it's greatest assets.

PRESSURE SENSOR

The pressure sensor is a tool used specifically for depth measurement. It consists of a medical pressure sensor connected to an instrumentation amplifier in a fully waterproofed casing. The sensor produces a voltage signal proportional to the pressure. However, the signal that it produces is very small so any attempt to measure it directly would have a very large error - which is unacceptable for this application. The solution is to connect the sensor to an instrumentation amplifier which would boost the signal to a significant strength. This enables an accurate measurement with drastically reduced error to be taken on the surface with a voltmeter. The system is waterproofed using PVC piping and araldite. A short tube is glued onto the pressure sensor chip and then used to create a channel through an araldite "plug" at one end of the pipe.

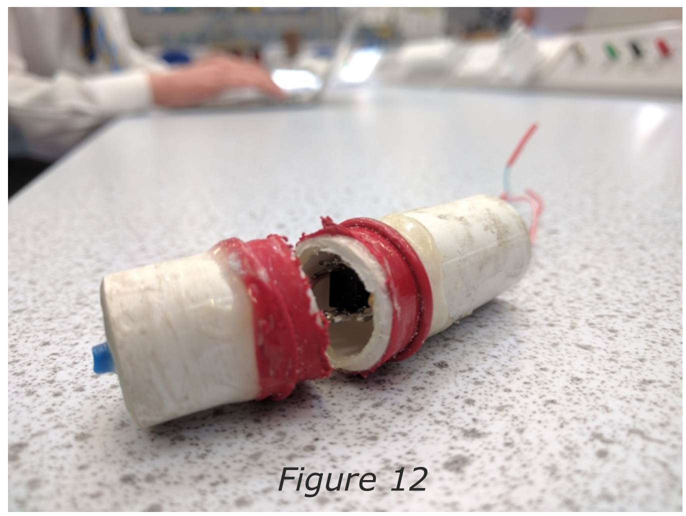


Figure 12

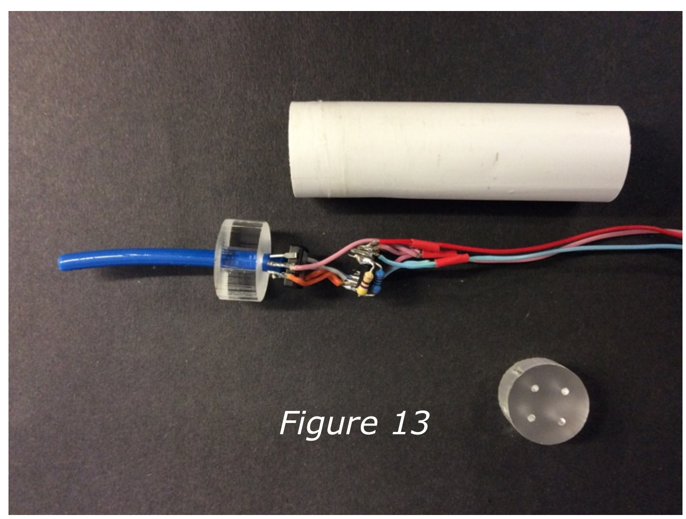


Figure 13

In the end, the pressure sensor was not as accurate as required and did not produce a large enough signal at the shallow depths of the pool for us to read and convert. We had aimed to create two of the sensors to have at the top and bottom of the ROV, and as we know the distance between them we could have calculated the pressure with greater accuracy. This system would have also provided redundancy should one sensor fail. Figure 12 shows the pressure sensor dissected with the waterproofing measures we had taken. Figure 13 shows an exploded view of the pressure sensor, including the sensor, amplifier, tubing and the PVC pipe used to house the system.

TEMPERATURE SENSOR

Based on the challenge matrix (Page 16) the temperature sensor was given high priority - with a good points-to-time ratio. As this task was identified as being key early on, we had time to explore the possibility of making our own temperature sensor rather than using a ready-made instrument.

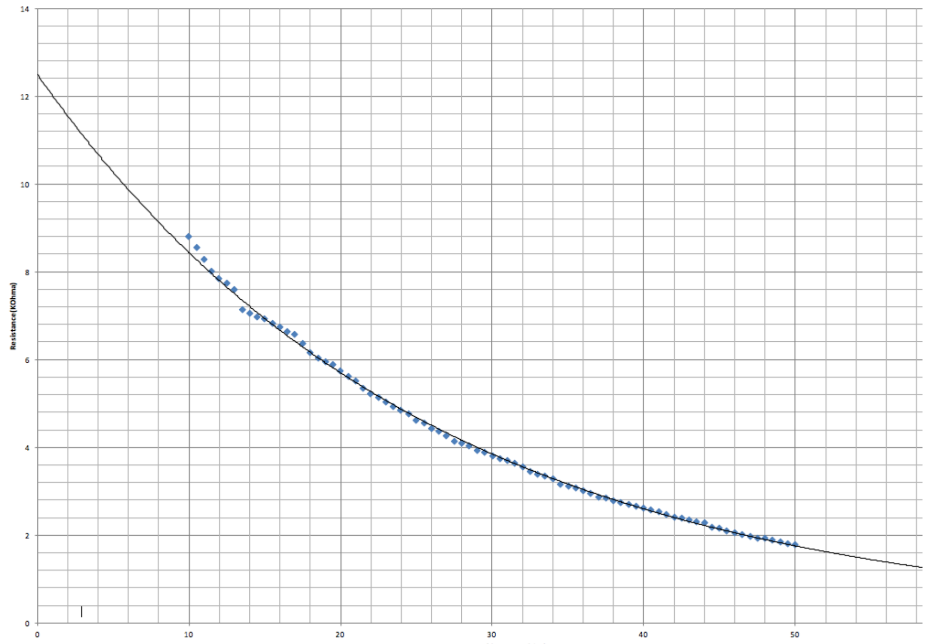


Figure 14

From the knowledge that we had gained from our studies at school, we knew that a thermistor is an electronic device that can change resistance depending on the temperature of the fluid or gas it is placed in. We soldered two 10 meter long copper wires on to the thermistor.

We then tested the thermistor in different temperatures of water, forming a graph to show the relationship between temperature and measured resistance (fig. 14). We took readings of temperature (using a thermometer) and the resistance of the thermistor at every 0.5 degree Celsius from 50 to 10 degrees.

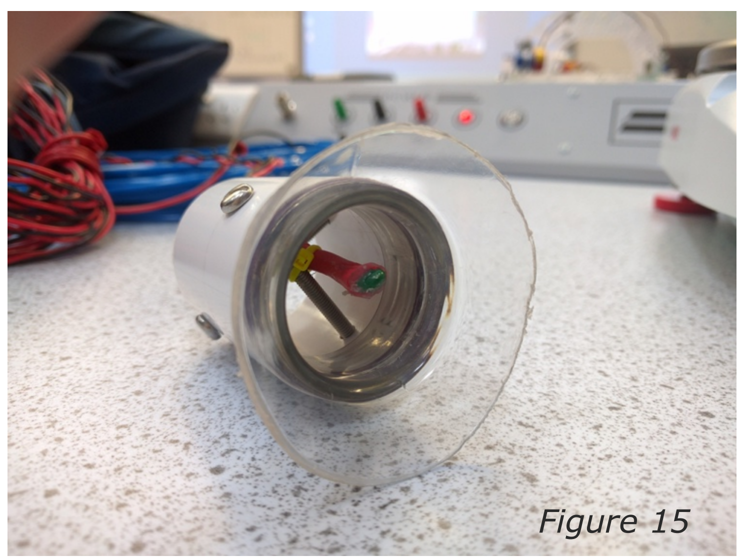


Figure 15

The final part of the task was to insert this temperature sensor into the venting fluid. We decided that to aid the pilot in inserting the thermistor, we would utilise a self-centering design. This involved attaching the top part of a plastic bottle to a section of PVC pipe and fixing the thermistor in place (fig. 15). This will allow the pilot a wider area to aim for, thus making the task quicker and simpler.

BUOYANCY

Previously, air-filled pipes have been used as buoyancy. With the size and weight limits specified for the mission, alternatives were sought. Using floats allows for greater flexibility when working to achieve neutral buoyancy. We experimented with pipes and found them to be awkward to connect to the new frame. We found the ROV would need either larger or more pipes in order to be effective. This means that to reach the equivalent buoyancy with pipes it would have taken up much more space and likely been heavier in air. For these reasons we used floats. Whilst using standard swimming floats during the regional competition, it was noticed that the ROV lost buoyancy as it got deeper, causing the ROV to sink. Following expert advice, we switched out the floats for medium density styrene, which is stronger and less prone to compression underwater thanks to being 'closed cell' foam.

We calculated the buoyancy required using the following equations:

(Density of water = 1000 kg/m^3)

1. $Buoyancy\ Force = 1000 \times 9.8 \times Volume\ of\ ROV$
2. $Buoyancy\ Force = Foam\ Volume\ \times (1000 \times 9.8 - foam\ density \times 9.8)$

By making equations 1 and 2 equal to each other, the volume of foam can be calculated. The foam density can be calculated using: $p = \frac{m}{V}$. In practice, we found that the buoyancy still required fine tuning so we strapped extra styrene to the top of the ROV until it was 'over buoyant'; any buoyancy over the water surface was not required and was removed. This is how we achieved neutral buoyancy.

The volume of the ROV was found by placing the ROV in a small tank of water and collecting the overflowed water as the ROV was inserted. The volume of the collected water was then measured.

CONTROL

Arguably one of the most important elements of the whole project, the control box, incorporates a range of electrical components. There are six H-Bridge motor drivers which allow the control program to govern the speed in all degrees of movement, allowing total control in the water. The input voltages are controlled by a 'Wii' nunchuk, which means that the ROV can be piloted in a way which is as intuitive as possible. The nun chuck allows the following movements: Forwards, backwards, left, right, clockwise rotation, anticlockwise rotation, ascent and decent. The ROV incorporates Pulse Width Modulation (PWM) to allow us to control the speed of the vehicle with greater accuracy than with on/off control. It was felt this would be really important when tackling precision tasks, such as picking up small T-pieces. Our flowchart (fig. 16) highlights the step-by-step process taken by the control when maneuvering the ROV.

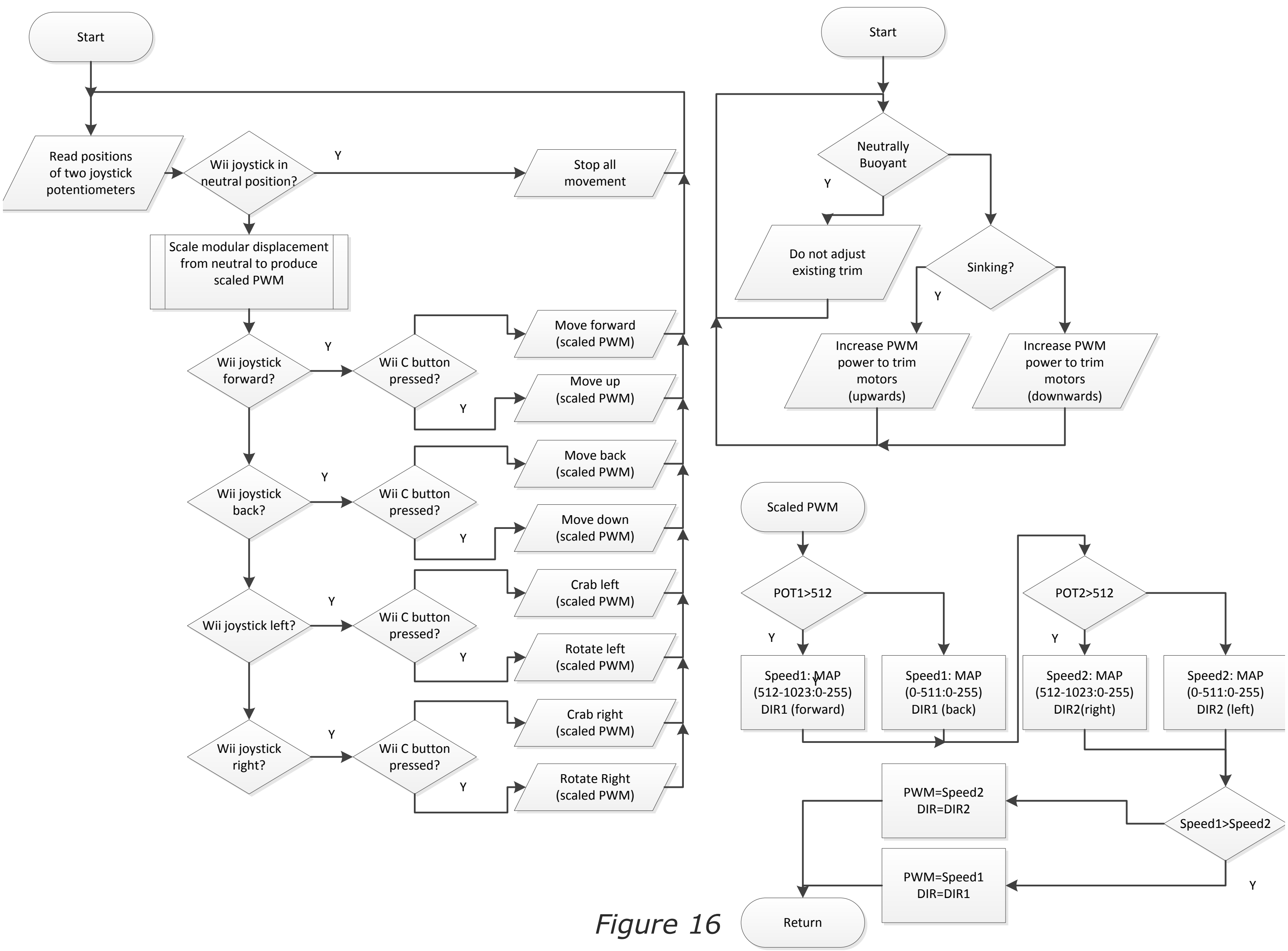


Figure 16

The main flowchart dictates overall movement of the ROV based on user input from the wii nunchuk. The detailed sub-flowchart gives an indication of data processing required to drive the output functions based on the input conditions. For example, if the nunchuk joystick is moved further to the left than up or down, then movement is to the left at a speed proportional to the joystick distance from centre. The upper right flowchart shows the control structure for trimming the ROV's buoyancy using an additional pair of thrusters.

We used an Arduino UNO as the hardware for our program. Figure 17 indicates how the Arduino was wired using a purpose-designed shield to link output pins to six L298N H-Bridge power modules.

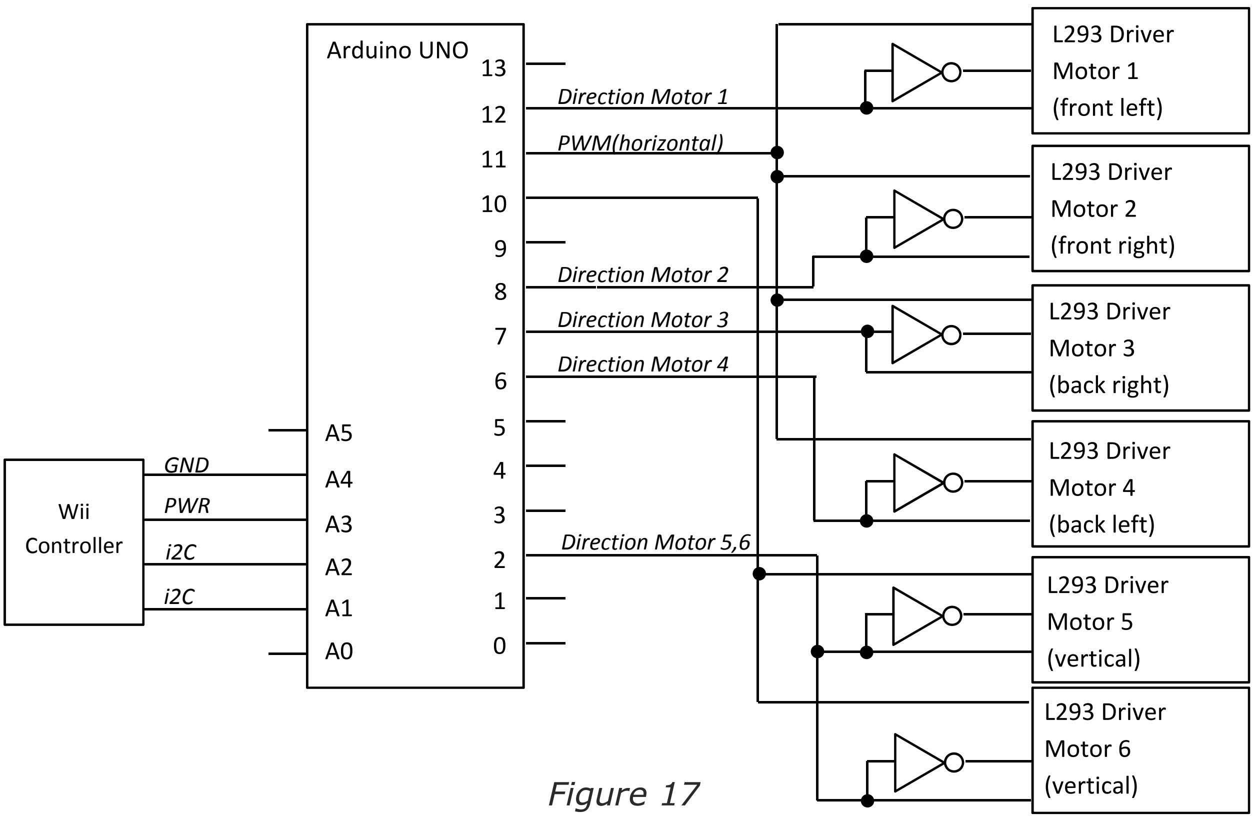


Figure 17

SAFETY

POOLSIDE SAFETY CHECKS

- All motors have been rotated into set positions with bolts tightened.
- Gripper is secured in place with two bolts. This goes for when it is deployed and when it is in the tucked away position.
- Tools required for set-up are placed away from the pool.
- Ensure no sharp edges.
- Propellers are shrouded.
- All cables are fastened securely.
- Pneumatic connections are secure.
- Single inline fuse is in correct position.
- Tether is secure to the ROV and to the surface control.
- All poolside connections for power and cameras are made correctly, with two team members assigned to check.
- All team members are wearing appropriate clothing and footwear, including safety goggles for pneumatics.

SAFETY FEATURES

- Shrouded propellers using large PVC pipes, which are stronger than 3D printed shrouds.
- No sharp edges.
- All underwater connections (e.g. to temperature sensor) have adhesive heat shrink to prevent leaks.
- Cable management on the ROV is neat and secure, with wires being channeled to the rear of the frame to join the umbilical.
- Single inline 20 Amp fuse

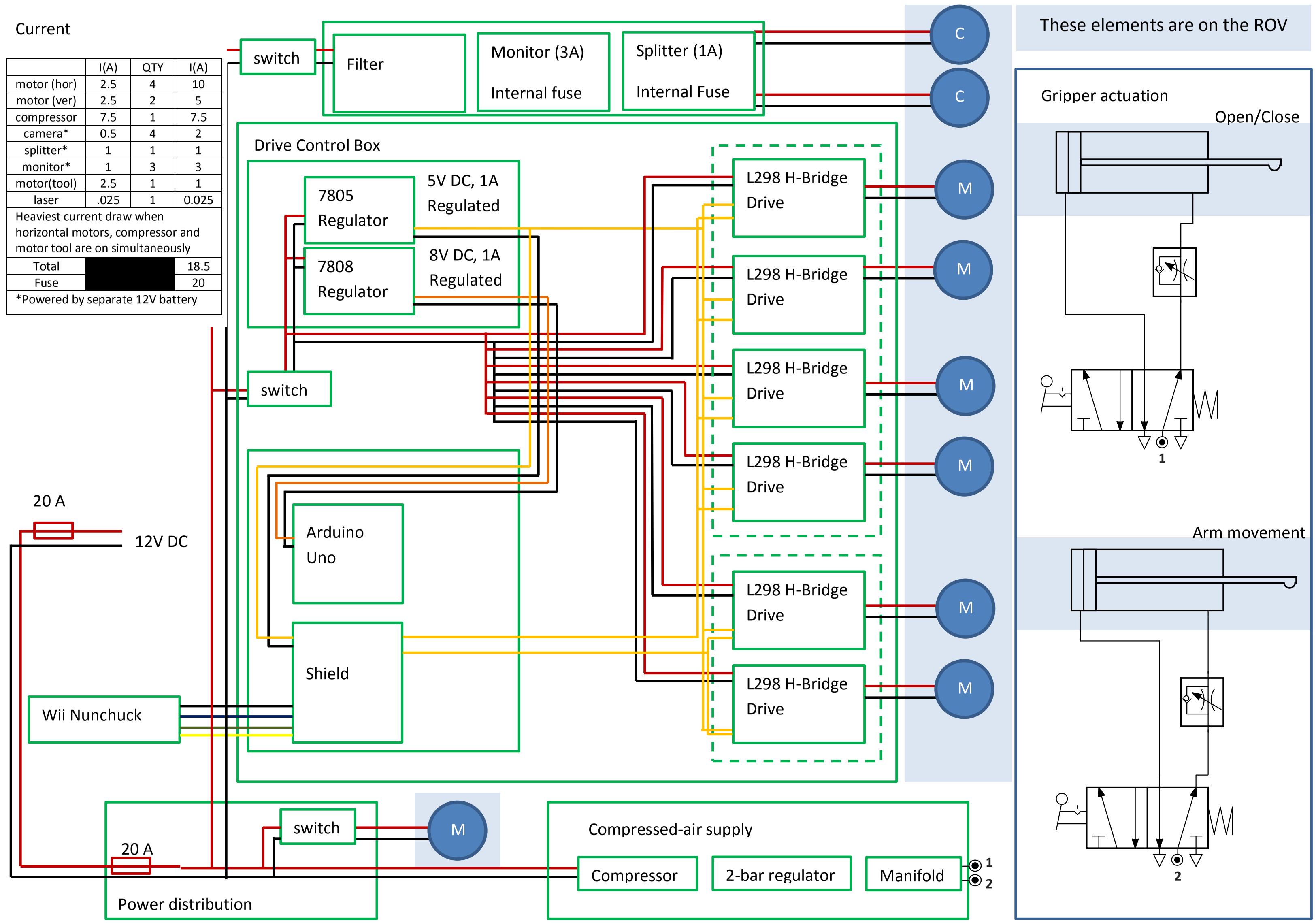
SAFETY PHILOSOPHY

Our safety philosophy is simply to operate in a way which does not cause danger to yourself or others. Examples of this include: ensuring a mentor is supervising when using heavy/potentially dangerous machinery (such as drills, sanding machine, heat gun, saw…); wearing safety clothing such as goggles in the workshop; helping one another with tasks and setting up to provide a safe environment for all. The team is encouraged to run through any possible dangers or obstacles which might arise before engaging in the task. These measures have helped make the construction of the ROV very safe and has promoted a safety conscious attitude in all the team members.

SYSTEM INTEGRATION DIAGRAM (SID)

Current

	I(A)	QTY	I(A)
motor (hor)	2.5	4	10
motor (ver)	2.5	2	5
compressor	7.5	1	7.5
camera*	0.5	4	2
splitter*	1	1	1
monitor*	1	3	3
motor(tool)	2.5	1	1
laser	.025	1	0.025
Heaviest current draw when horizontal motors, compressor and motor tool are on simultaneously			
Total	[redacted]		18.5
Fuse			20
*Powered by separate 12V battery			



PROJECT MANAGEMENT

TASK MATRIX

In order to be time efficient in the pool and maximise points based on the 15 minutes pool time, we developed a matrix (fig. 17) which highlights tasks which we should target. The team was aware that 15 minutes was not enough time to realistically complete every single task and so we categorised the tasks based on the points available and the estimated time to complete. The matrix was then utilised to make the task order, which also takes into account the ease of the tasks and spatial considerations (e.g. grouping tasks at certain depths).

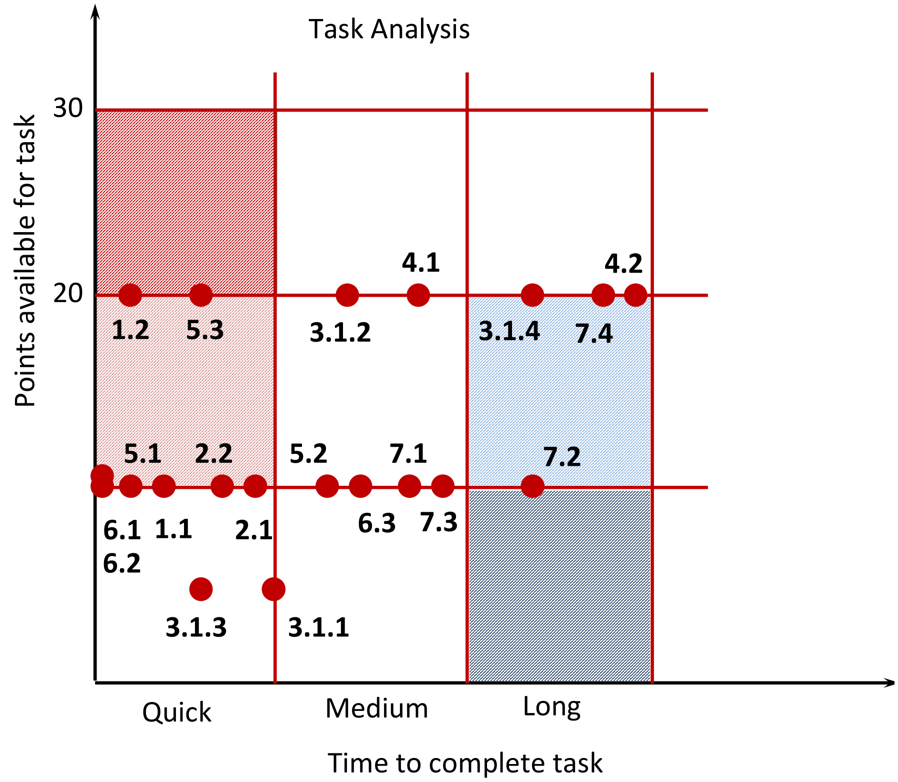


Figure 17

TASK ORDER

Task Number	Description
2.1	Measure the thickness of ice
2.2	Measure the depth of ocean
1.1	Temperature insert
1.2	Temperature measurement
6.1	Photo colonies
6.2	Compare photos
6.3	Return coral samples
5.1	Collect 2 oil samples
5.2	Return samples to surface
5.3	Analyse oil samples (surface)
3.1.1	Retrieve ESP from elevator
3.1.2	Lay ESP through 2 waypoints
3.1.3	Open door
3.1.4	Insert ESP into port
4.1	Find and Identify 4 CubeSats out of 8
4.2	Recover 4 CubeSats and place into basket
7.1	Install flange to top of wellhead
7.2	Secure flange with 'bolt'
7.3	Install wellhead cap over flange
7.4	Secure cap with 2 'bolts' - vertical bolts

PROBLEM SOLVING AND TROUBLESHOOTING

The team incorporated two problem solving structures into our workflow. Whenever we encountered an issue we would aim to resolve it in a professional way which would represent the aims of the team and the competition. Both methods are used in industry, and in utilising them reflects one of the competition's aims: to gain insight into what it is like to run a company to improve business acumen.

The first model is called **POGADSCIE**, it enables time to be taken to ensure the best decision is made, by gathering evidence and preventing rash decisions. We used this method when developing the ROV's unique frame.

P - Identify the problem

O - Identify the objective

G - Gather information

A - Analyse the information

D - Devise possible solutions

S - Select the best solution

C - Communicate the decision

I - Implement the decision

E - Evaluate the effectiveness of the decision

The second model is known as **SWOT Analysis**, and it provides a quick structured approach to problem solving. We used this method when evaluating company performance periodically.

S - Strengths Internal areas or activities which are positive

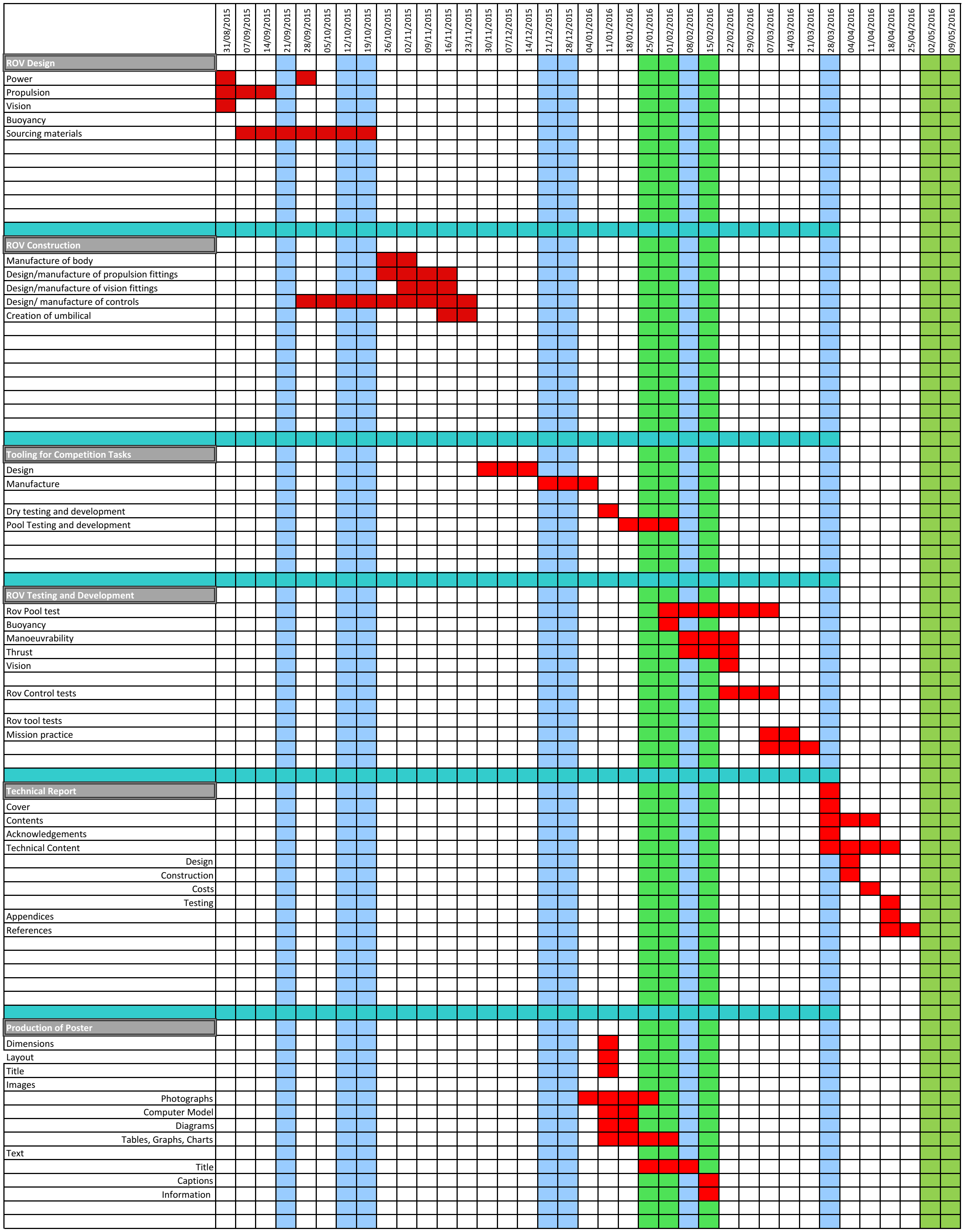
W - Weaknesses Internal areas or activities that need to improve

O - Opportunities External areas or activities that RGSea could benefit from

T - Threats External areas or activities which could be problematic

PROJECT GANTT CHART

Below is the timescale plan that was developed by the team to identify tasks and control available time.



PROJECT COSTING AND BUDGET

PROJECT COSTING

Reporting period

Company Name: RGSea - Robert Gordon's College — From: 11/09/2015

Completed by: Jack Noble — To: 20/05/2016

Funds

Type*	Category	Expense	Description	Sources/Notes	Cost as new	Years of planned use	Cost this year
Purchased	Hardware	Acrylic sheets	Large acrylic sheet, frosted white (2@32.50)	Used for vehicle frame and gripper	£ 65.00	1	-£ 65.00
Re-used	Hardware	Perspex sheet	Small acrylic sheet, transparent	Used for gripper	£ 10.00	1	-£ 10.00
Re-used	Harware	PVC 70 mm Wastepipe	Propeller shrouds	3m pipe	£ 3.45	3	-£ 1.15
Re-used	Electronics	Joystick	Wii nunchuck remote	Used for control system	£ 10.00	3	-£ 3.33
Re-used and purchased	Sensors	Camera	4 underwater cameras. (2 new, 2 re-used)	Used in vision system	£ 400.00	3	-£ 266.67
Re-used	Harware	Umbilical	Hook-up Wire Stranded PVC (100m Reel)	All cables in umbilical (2-off@24.95)	£ 49.90	6	-£ 8.32
Re-used	Hardware	Air Compressor	Report an error	Used to actuate gripper	£ 36.00	3	-£ 12.00
Re-used	Harware	Piston	Small piston	Double acting 10mm stroke	£ 35.02	3	-£ 11.67
Purchased	Harware	Pneumatic hose	30m nylon air hose	(2-off@17.54)	£ 35.08	1	-£ 35.08
Re-used	Electronics	Drive control	Arduino Uno(2-off@19.50) - L298 Driver (8off@4.13)		£ 72.04	3	-£ 24.01
Re-used	Hardware	Bilge-pump	Rule-sumersible Bilge-pump	(8-off @ 26.95) Shrewsbury Marine Services	£ 215.60	4	-£ 53.90
Re-used	Hardware	Coupling	2436.5 Graupner Precision Coupling 3.2-4mm	(8-off @7.99) Cornwall Model Boats	£ 63.92	5	-£ 12.78
Re-used	Hardware	Propeller	Plastic RH thread M4 (8-off @ 2.99)	(8-off @ 2.99) Cornwall Model Boats	£ 23.92	3	-£ 7.97
Purchased	Hardware	Carry case	Maplin waterproof 700mmx600x200 carry case		£ 49.99	5	-£ 49.99
Purchased	Electronics	Video filter			£ 8.15	5	-£ 8.15
Re-used	Electronics	Colour Monitor			£ 35.00	5	-£ 7.00
Re-used	Electronics	Video Splitter			£ 35.99	5	-£ 7.20
							-£ 584.22
				Total ROV Purchase this year			-£ 424.89
Purchased	Travel	Airfare	7 round-trip flights to from Aberdeen to Houston	Flights for 6 team members plus mentor, plus cost to transport ROV	£ 7,264.35	1	-£ 7,264.35
Purchased	Accomodation	Hotel	Cost of rooms	4 rooms in nearby hotel	£ 2,576.00	1	-£ 2,576.00
Purchased	Team shirt			(7@29.50)	£ 206.50		-£ 206.50
Cash donated	Sponsorship		Robert Gordon's University	Annual Regional Sponsorship -			£ 300.00
Cash donated	Sponsorship			Regional Prize -2nd Place			£ 200.00
Cash donated	Sponsorship		Nexen	Donated for purpose of travel and accomodation			£ 6,000.00
Cash donated	Sponsorship		Subsea 7	Donated for purpose of travel and accomodation			£ 2,000.00
Cash donated	Sponsorship		Hunting International	Donated for purpose of travel and accomodation			£ 500.00
Cash donated	Sponsorship		Marcliffe Hotel	Donated for purpose of travel and accomodation			£ 500.00
Cash donated	Sponsorship		Gordonian's Association	Donated for purpose of travel and accomodation			£ 500.00
Cash donated	Sponsorship		Individual donors	Donated for purpose of travel and accomodation			£ 1,500.00
Cash donated	Sponsorship		Balmoral	Donated for purpose of travel and accomodation			£ 3,000.00
Cash donated	Sponsorship		Brewin Dolphin	Donated for purpose of travel and accomodation			£ 500.00

***Items must fall into one of the following:**
Purchased - defined as items that are purchased new or services paid for.
Re-used - defined as items that were purchased in previous years. Amount MUST be listed as the current market value.
Parts donated - defined as equipment, materials, and time that were contributed to your company. Do NOT include items given to your school for general use.
Cash donated - defined as funds contributed to your company. Do NOT include funds given to your school for general use.

Total Raised	£ 15,000.00
Total Spent	-£ 11,640.18
Final Balance	£ 3,359.82

FINANCE

We set out a budget of £500 ($735) to spend this year. The team aimed to re-use and recycle wherever possible from past years' ROVs, in order to save money. It is worth noting that all of the sponsorship and donations which we raised came after the regional competition and were gathered in order to fund our travel and accommodation so that we may participate in the international finals. Our total cost this year on the ROV was £425 ($624), and overall, by attaching monetary value to recycled components, our ROV's estimated value is £585 ($860) – *though to us it's priceless.*

CHALLENGES

One major technical challenge we encountered was an issue with buoyancy at our regional competition. When the ROV started to descend in the dive pool, the vehicle seemed to become very under-buoyant. Despite having completed testing in our school pool, for some unknown reason, our vehicle could not even get off the pool floor. Having realised that we had a major problem, the team made the decision to bring the ROV back up to the surface and try and add more buoyancy. This quick thinking meant we were able to complete some tasks and the points we gained from these enabled us to achieve second place. After the competition day, we still didn't know why our buoyancy had failed. We then decided to reach out to local companies for technical advice. One of these companies told us it was because we had been using 'open cell' foam. Little force is required to compress open cell foam, so as depth increased volume reduced, this meant that the buoyancy force reduced. This insight allowed us to change our buoyancy to 'closed cell' foam and means we won't have the same problem again.

A non-technical challenge that we faced was having to raise £12,000 to get to the international finals. Since we live in Aberdeen, the oil capital of Europe, we felt that the MATE ROV competition was related to many local companies' sectors of work. Therefore, we decided to write a letter requesting sponsorship and mentorship. We sent the letter, along with digital copies of our poster and spec sheet, to a selection of companies. This enterprising thinking paid off, as we received £15,000 in total from local companies or individuals. The generosity of people in the local area combined with the team's determination, allowed us to attend the international competition.

FUTURE IMPROVEMENTS

Below is a list of improvements which we aim to make over the coming years:

- Variable buoyancy. To make it easier to add and remove mass (in the form of future tools) without having to overhaul the buoyancy with each development.
- Automation of mechanisms, for example the gripper and motors deployment could be motorised or spring loaded.
- Gripper's claws should use a servo motor to allow the jaws to be moved to any position between fully opened and fully closed.
- Wider field of view for the cameras. The cameras we selected have a wide field of view, but by adding a fisheye lens to one or more of them the pilot could get a better sense of the underwater surroundings.

REFLECTIONS ON EXPERIENCE

RGSea's competition performance in 2016 has been the team's best yet. Not only did we completely re-make the ROV from scratch, but we also met deadlines, thus allowing the vehicle to go through a better testing process than in previous years. Although we placed second in our regional competition, our biggest achievement was probably fundraising the money required to compete in Houston. This challenge taught the team the power of determination and perseverance. We also found that the fundraising process brought us closer as a team, and we can now say that we have formed life-long friendships through the ROV club.

Furthermore, during the year we have encountered practical situations that we never have to deal with in a classroom environment. This has allowed the team to hone skills that will aid us later in life, whether it be at university or in the workplace. We all agree that the MATE ROV competition has been a highly positive experience and hope that the team continues to thrive next year.

LESSONS LEARNED

TECHNICAL

With a rectangular PVC frame being the standard in previous years our initial plan was trying to figure out how we could simply improve this design. However, with the implementation of the size and weight restraints we instead developed the “out of the box” idea to design a spherical ROV. The importance of being able to adapt, despite what had already been achieved, to complete the required tasks was a key lesson. With varying levels of skills throughout the team we tried to maximise productivity by assigning members tasks based on their mathematical knowledge or practical ability. However, we discovered that developing everyone's skills in areas unfamiliar to them allowed far more versatility on tasks as they were not held up by only one person being able to complete it. An example of this is that members of the team who had never soldered before can now build circuits and connect wires to a good standard. Additionally, everyone furthered their skills using equipment like a laser cutter, handheld tools and drills. Several member’s software abilities were enhanced also with the use of design programs like CREO and 2D design, which were used to create the frame.

INTERPERSONAL

With a larger team than we have had in previous years it would be expected that coordination may be difficult. However, this year the team, despite being from two school year groups, became very close and we realised how much productivity increased when the team taught each other how to complete tasks. Throughout the project everyone developed their communication and time management skills through the twice weekly meetings and other afterschool sessions. Many of the team who are familiar with the competition will be leaving for university at the end of the year; so the importance of ensuring the younger members of the team were confident for future years was paramount. All were given opportunities to pilot the ROV and the ones who could make it came along to the regional competition. The importance of understanding how the competition works is crucial. This further enhanced the skills and cooperation of the team as a whole.

ACKNOWLEDGEMENTS

RGSea would like to thank:

Our mentors, Mr. Wakeford and Mr Hinks, for assisting us with their knowledge, experience and advice throughout the year. The Robert Gordon's College Marketing Department for their advice on the poster design. MATE and NASA for hosting this fantastic competition. Robert Gordon's University, BP, ROVOP, Subsea UK and the Underwater Centre for hosting the regional competition. And of course we'd like to say a huge thank you to our team sponsors for making our participation in this competition possible.

TEAM SPONSORS

Nexen	**Subsea 7**	**Hunting International**
Balmoral Group	**Brewin Dolphin**	**Marcliffe Hotel**
	Gordonian Association	

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William F Hughes and John A. Brighton. 1999. *Schaum's Outline if Fluid Dynamics.* 3rd Ed, McGraw-Hill Education

Page 16, Fluid Forces on Submerged Bodies. Details mathematics required for buoyancy calculations.

'Wired' article on OpenROV, a company creating consumer grade underwater robots, written by Mark Brown

wired.co.uk/news/archive/2012-07/03/openrov-kickstarter

Data Sheet for H-Bridge

sparkfun.com/datasheets/Robotics/L298_H_Bridge.pdf

Information about Jupiter's moon, Europa

www.space.com/15498-europa-sdcmp.html

Article on 'How ROV's work', by Rigzone used for training. Includes image of a 1976 spherical ROV.

http://www.rigzone.com/training/insight.asp?insight_id=343

PHOTO AND DIAGRAM CREDITS

Cover	Ross Johnston, Newsline Media
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Fig. 6	Matthew Fossett
Fig. 7	Matthew Fossett
Fig. 8	Jack Noble
Fig. 9	Jack Noble
Fig. 10	Jack Noble
Fig. 11	Matthew Fossett
Fig. 12	Jack Noble
Fig. 13	Mr Wakeford
Fig. 14	Hamish Campbell
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Fig. 16	Nimrod Libman
Fig. 17	Adam Stephen