ImpROVise

Technical Report for R.O.V. - Proteus

Keith Grammar School, Moray, Scotland

Distance to Long Beach, California: 8351Km

The Team

Maximillian Siegrist-*CEO, Electronics, 17*

Benjamin Williams-*Chief Engineer, 16*

Gregor Stratford-*Head of Graphic Design, 16*

Jack Duncan-*Vice CEO, 17*

Adam Featch-*Head of Finance, 16*

Tom Watson-*Engineer, 13*

Gregor McHardy-*Senior Engineer, 18*

Louise Regazzoni-*Safety Manager, 16*

Niamh Duncan-*Graphic Design, 16*

Kayleigh Tidball-*Graphic Design*, 17

Jamie Herd-Engineer/ *Tether Manager, 14*

Lewis Roger-*Engineer, 13*

Mentors

Teachers: Yvonne Stuart and Steven Tubbs

Company Mentor - *Buccaneer Ltd*

Fig. 1: Keith Grammar School

Fig. 2: The Scotland Flag

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Fig. 3: ImpROVise Company photo “https://twitter.com/RobertGordonUni?ref_src=twsrc%5Egoogle%7Ctwcamp%5Eserp%7Ctwgr%5Eauthor”

Abstract

The company name “impROVise” reflects our ability to adapt and find unique solutions to problems where we may have to “improvise” a solution in a cost, time and resource effective manner. Based in Moray (Scotland) we are concluding our 2nd year of active development, evolving our makeup, as we improve and alter our system specifications in response to changing mission themes, provided by the M.A.T.E. R.O.V. competition.

Proteus is the result of our 12-company member’s hard work and dedication over the past year. As we have progressed we have slowly tweaked and fine-tuned the design, using our test facilities, which allow for immediate practical evaluation. Proteus’ design has been tailored to the shapes and sizes of the mission tasks to be attempted. Proteus is equipped with: 3 high definition cameras, a buoy deployment system and an array of interchangeable manipulators to interact with the specific missions to be attempted.

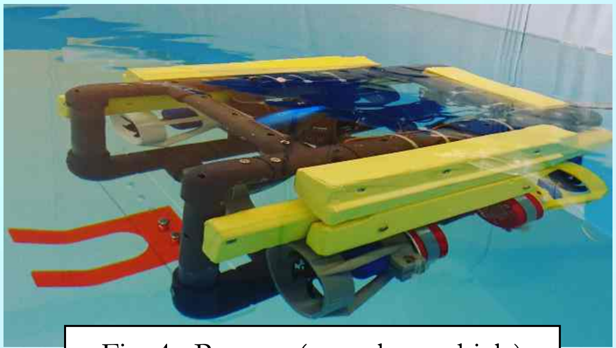


Fig. 4: Proteus (complete vehicle)

We designed Proteus to be as small and lightweight as possible. Proteus can fit inside a circle diameter of 48cm and including its tether weighs less than 11kg. This results in the R.O.V. being safer to handle and interact with as any risk of injury is minimised by its lightweight and compact design.

To our company, Proteus represents the pinnacle of the past year’s hard work, learning and effort put in by all.

Teamwork, Company Effort and Project Management

To our company, teamwork is one of our most important values. It is crucial to us being able to succeed and continue to improve and develop our R.O.V. - “Proteus”. The vehicle we constructed is the culmination of all our team’s hard work, and hence every member of the team has contributed ideas to the final design.

Schedule

Good timekeeping is highly important to our company, not only is it desirable from a professional standpoint but it shows a level of commitment and dedication that reflects our company member’s passion to the project. Due to this we constructed and adhered to (to the best of our ability) a strict timeline of our company’s year which would allow us time at the end of the year for pilot practice and minor tweaking of the R.O.V. This also ensured that all technical documentation was handed in on time and to a high standard so we can reach our team’s full potential.

	Aug-16	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17	Feb-17	Mar-17	Apr-17
ROV	Research and Initial plan	Finalising Design	Construction			Testing and Safety Checks	Minor Adjustments and Practice		
Technical report	N/A	Rough plan Developed	Technical Report Written					Proof Reading	
SID	N/A	Outline developed					Finalised		
Poster	N/A	Company Abstract Finalised	Poster Written/designed					Proof Reading	
Company Wide Tasks	Job Roles/Budgeting/Develop Schedule	Improve Corporate Image	Developing Presentation			Presentation Practice/Financial Report			

In practice, we found that having a guide to stick to helped us be aware of approaching deadlines. However, in some tasks, such as writing the technical documentation we vastly underestimated the quantity of time that would need to be invested and hence wavered from the schedule slightly. Fortunately we pulled together as a team and produced the final product on time. This challenge was underestimated because of our team’s reasonably limited experience competing in the competition. On a positive note the problem will not arise again as we discussed the issue as a team and intend to leave more time for technical documentation in years to come.

Team Roles

Team roles were decided mutually. If a member desired to carry out a specific role they can pitch themselves to the team to potentially carry out that role. Factors such as previous competition experience, qualifications, desire to learn and natural ability were considered. For example, someone with no prior competition experience could take up a role in any area provided they show dedication, an interest and a willingness to learn about that area. We make sure never to discriminate against less knowledgeable members because the most important value to our company is learning and progress. Everybody must start somewhere.

Resource Management

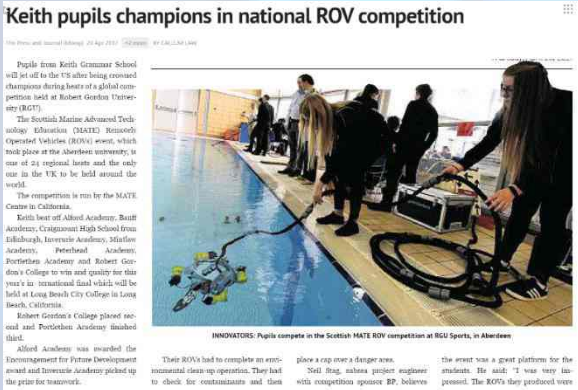
Our physical resources such as building materials were kept track of throughout the season (see accounting page “”). However, our company’s most valuable resource was time. Most of our members are studying qualifications to gain entrance to higher education. This meant the amount of time each team member could dedicate to the group was limited. This has become a more significant problem during exam time (May) when our team members found it especially difficult to balance both studies and the R.O.V. However, we all put in a little amount of time each and we pushed through to hopefully succeed in both areas.

Brainstorming

When the group faced a new challenge that one person could not solve alone we came together and pooled our knowledge to come up with a solution. During these "brainstorming" sessions we try to emulate a company as much as possible. For example, one person would take the role of creating a summary of the session and another would keep everyone on task. Using this method, we collectively found unique solutions to many of our problems that we would not have been able to solve individually. These meetings also provide a perfect time to share knowledge and information we have learned.

Fundraising

After our success in the regional finals in Scotland, to proceed to the next stage in the competition; the finals in Long Beach, we would need to fundraise £12500 in 6 weeks so we could take all twelve members of our team. At first this seemed like an impossible task but after much "brainstorming" we devised a plan. First, we reached out to business' in the local (and not so local) area seeking sponsorship. We also launched a "Just Giving" crowd funding page so individuals in the community could sponsor us directly and finally we organised a series of fundraiser events to run in the local community to generate some money but also to encourage more people to get involved with S.T.E.M. Because of our team's hard work we raised the money required and instilled a sense of pride in the community.


Keith pupils champions in national ROV competition

INNOVATORS: Pupils compete in the Scottish MATE ROV competition at RGU Sports, in Aberdeen

Fig. 5: News of our success in the press "http://www.pressreader.com/uk/the-press-and-journal-moray/20170420/282690457070332"


The Banffshire Herald

Maroon magic

Grammar school team members are US bound after win

California dream comes true for ROVing engineers

In the NEWS

What a cracker

Time out

Dog eat dog

Youngsters score with great day with Maroons

Shortbread

Fig. 6: frontpage news "https://www.facebook.com/banffshireherald/photos/a.346436525481399.1073741828.346423515482700/693291270795921/?type=3&theater"

Design Rationale

Planning and Design

To our company the most important thing about our R.O.V. is that it completes the most tasks it possibly can in the most functional and efficient way possible. It was also decided from an early stage that we would construct it to be as small and lightweight as possible, without compromising function. Not only would this reduce shipping costs and improve the safety of our R.O.V. but it would allow us to score bonus points for low size and weight.

The frame design of our R.O.V. was inspired by the "ROV 1000" from "Outland Technology". We first saw this R.O.V. when our company mentors "Buccaneer" visited us and took along a couple of R.O.V.'s to show us. We liked its functional aesthetic and how the frame was laid out. Lots of room was left on the inside allowing easy mounting of additional tooling.

Fig. 7: Millennium Plus R.O.V. "http://www.oceaneering.com/wp-content/uploads/2009/08/Millennium-Right-side-Low-Res1.jpg

Fig. 8: R.O.V. 1000 "http://www.buccaneer-rov.co.uk/s/cc_images/cache_866855.JPG?t=1465569441"

The tool bar featured on Proteus was inspired by work class R.O.V.'s from Oceaneering, specifically the "Millennium Plus ROV" (fig.7). We visit Oceaneering's facility in Aberdeen where we learnt more about how R.O.V.'s operate in industry. We then applied what we saw there to our own project as it was already tried and tested in industry.

After discussing possible designs and layouts for the components of the R.O.V. we constructed a CAD model so we could easily see what the finished R.O.V. was going to look like. This proved invaluable as we quickly identified that we were 2cm over the lowest size limit. We thus changed the size of some PVC cross sections on the software to gain those bonus points. Had we not constructed a CAD model, changing the size of the R.O.V. would have drained more of the company's time amongst other resources.

Mechanical Drawing

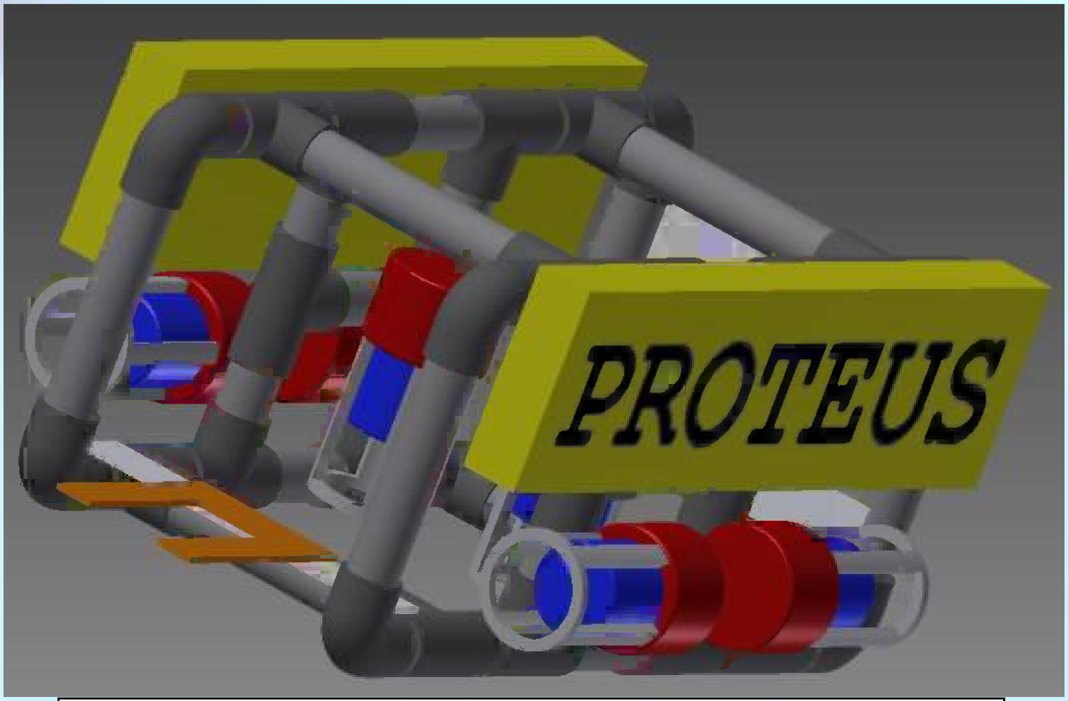


Fig. 9: Mechanical drawing of Proteus (designed by Maximillian Siegrist)

Propulsion

To get our R.O.V moving through the water there must be propulsion, and this can be provided in many ways. The key factors to be considered were; thrust, weight, size, cost and current used from our 12V 25A power supply.

There are many motors which can be purchased online and to reduce the cost for our ROV, we decided to modify Bilge pumps because they provide a yaw motion and are already sealed. These were modified to reveal the shafts of the motors where we could fit prop shaft adapters onto them. From here we could then add an array of propellers to compare thrust and current drawn.

For our six motors, we had the choice of multiple different propellers to attach. We have three, four and six blade props to choose from, with the possibility of more given the ability to 3D print possible designs. To make an informed choice on the correct props a 'force testing rig' was set up. A frame held a vertical, and freely rotating, length of wood in place; with a motor attached to one end and a pencil on the other. A board was attached behind, as to allow a piece of paper to be positioned against the pencil lead (Fig 2). When a propeller was fixed to the motor it could be spun forward and back and this would draw a line showing how far it could push the pencil along the set-up, this showed the extent of the force for each propeller design, the longer the line the greater the force provided.

Fig. 10: Vertical Thruster Arrangement

The motors on our ROV are attached by a large and small jubilee clip each, and this allows a huge number of positions for our motors. To keep things simple, and equally balanced, a symmetrical layout made most sense. We opted to have two positioned in the middle for the vertical thrust and one at each corner of the R.O.V. for the horizontal direction plane. We initially had the motors inside the body of the ROV (position 1(see fig.14)), for the safety and size aspects, but upon testing found this offered limited manoeuvrability as far as rotation was concerned. So, to overcome this it was decided that the motors should be repositioned on the outside of the frame (position 2(see fig. 14)). This however took us slightly outside the 48cm circle we were aiming to fit inside. Positioning the thrusters outside the boy of the R.O.V. also meant the exposed props were no longer safe and, although we had already printed shrouds to account for this, the addition of shrouds would have a negative effect on the overall speed. Testing recommenced with these attached; the turning circle drastically decreased and the overall manoeuvrability was improved, so we are happy with the results despite the minimal drop in thrust due to the shrouds. A goal for the company next year is to develop Kort nozzle's tailored to each style of prop, this would allow us to simultaneously shroud and improve force from each thruster. The problem of size was still imminent so to account for this we simply moved the thrusters onto the inner posts (position 3(see fig.14)of the frame and flipped there direction.

Fig. 11: Thrust Test Jig

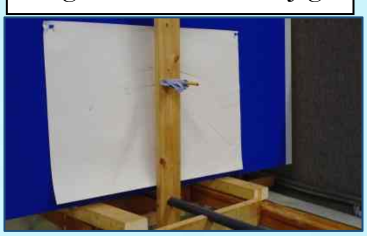


Fig. 12: Thruster

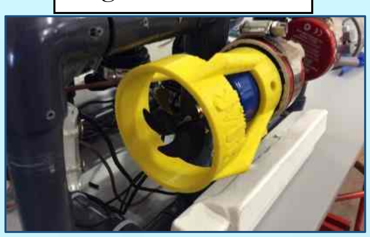


Fig. 13: Proteus

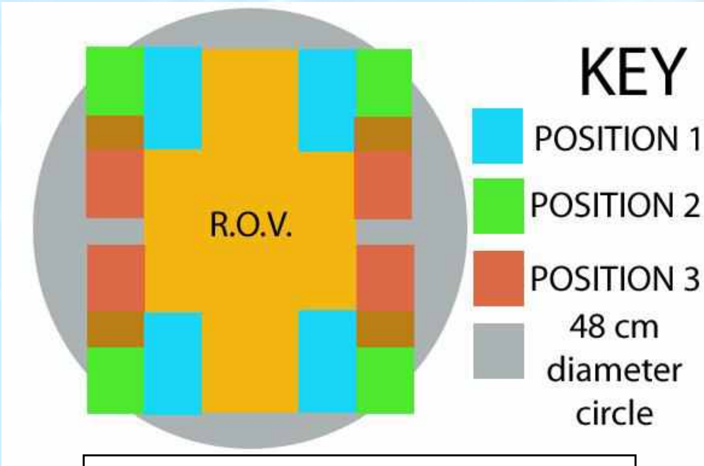


Fig. 14: Thruster Arrangement Diagram

Fig. 15: Thrusters Arranged in position

Frame

Another fundamental portion of any ROV is the frame. It allows a basis for the motors, tools (manipulator or measuring equipment) and flotation to be attached to, and form a working ROV. There are endless possibilities of materials and shapes which could be used but we based our decisions around; cost, weight and ease of alteration (addition of equipment).

Initially the materials considered for the frame were metal, acrylic plastic and PVC pipe. Metal was disregarded as it was difficult to work with, can corrode/oxidise and most importantly was much denser/heavier than the alternatives. Acrylic plastic was at first appealing as we have access to a laser cutter; this would make manipulating the acrylic easier than metal. However, after experimenting with a design we found the material was quite fragile. Finally, we looked to PVC pipe. It ticked all the boxes: it was strong, easily modified and most importantly was the lightest/less dense. This meant that we could have a durable frame that would allow us to keep the weight of the R.O.V. less than 11kg (5.803Kg) for improved safety when deploying and handling as well as achieving maximum points for weight restrictions.

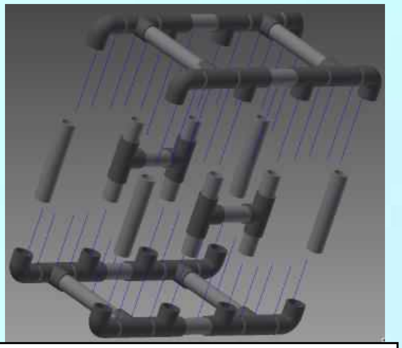


Fig. 16: Explosion of frame

The Frame has been built to create as many vertical and horizontal points of attachment whilst still providing room for you to adjust things. This has allowed us to easily attach the six motors, cameras, and tool bar whilst still allowing any additional equipment (like the tool tray) to be added. The design of the frame also focusses on size, it was designed to fit inside a 48cm diameter circle to achieve maximum points and to improve the safety and ease of handling the R.O.V.

Cameras

Proteus has 3 high definition cameras attached to its frame; one of these has been reused from last year after it was broken, but we were able to fix it. They each offer a clear image of the environment on a monitor situated in the control box (fig. 23), at the end of the 15m tether. Initially they had been fixed onto the frame with Jubilee clips but to make things safer, and more secure, specific camera mounts were 3D printed (to get rid of sharp bits of metal on the clips). The cameras also came with small buoys which we quickly realised could be altered and used for the buoy required to identify the contaminated cargo crate in the fourth task

One camera is fitted facing down towards the vertical propellers; this is to aid in the detection of crate cargo and sediment analysis, by shining the cameras own light into the samples. Another camera is pointed straight forward, to allow a full view of the forward surroundings, and the third camera is angled towards the tool bar to offer a good view of any tools and their interaction with the environment.

Fig. 17: Front cameras

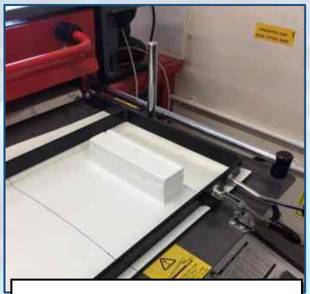


Fig. 18: Vacuum Forming

Floatation

The floatation has been drastically improved from last year, both aesthetically and physically. We realised that as the R.O.V. spent time in the water it was soaking up water and releasing trapped air. This meant that as the R.O.V. went about its tasks its buoyancy would decrease and would become increasingly difficult to fly. The floats were wrapped in vacuum formed plastic and any gaps in the plastic sealed with silicon. This meant the floats would keep constant buoyancy and the R.O.V. would remain neutrally buoyant. The plastic was painted yellow as this colour is the easiest to see underwater which improves safety for any persons or marine life sharing the water with the R.O.V. also if Proteus were to become detached it is easier to locate from afar.

Experimenting was done to decide what buoyancy to make Proteus, slightly positive buoyancy would we favourable in some circumstances, for example if observing something on the sea floor moving up using buoyancy would disturb the silt on the sea floor less than switching on thrusters this would impair the vision of pilot however if the R.O.V. had positive buoyancy the use of thrusters would not be necessary. Positive buoyancy can also be favourable when there is a high risk of the tether being severed in which case the R.O.V. would simply float to the surface. However, for the purposes of our R.O.V. the above were not applicable so the benefits of neutral buoyancy were more favourable, hence Proteus is neutrally buoyant.

Fig. 19: High Visibility Floats

Buoyancy Calculations:

The buoyancy for our Proteus was calculated through trial and error. However, in all future projects and R.O.V.'s of our company the following method will be used.

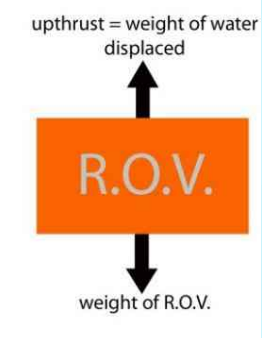


Fig. 20: Free Body Diagram

Archimedes principle states

"The upward buoyant force that is exerted on a body immersed in a fluid, whether fully or partially submerged, is equal to the weight of the fluid that the body displaces and acts in the upward direction"

For the R.O.V. to remain at neutral buoyancy all forces on it need to be balanced. We know this from Newton's 1st law

"In an inertial reference frame, an object either remains at rest or continues to move at a constant velocity, unless acted upon by a force."

This means that if the weight of the R.O.V. is equal to the weight of the water it displaces all forces on the R.O.V. will be balanced and it will be neutrally buoyant.

Fig. 21: Water Displacement

To calculate the weight of the R.O.V. we would measure the mass and multiply this by gravitational field strength ($9.81NKg^{-1}$) according to the formula W=mg.

To calculate the volume and hence the weight of the water displaced by the R.O.V. we would place the R.O.V. in a container of water filled to the top. The volume of water that spills out of the container is equal to the volume of the R.O.V. From this data, we can derive the weight of the water displaced, again according to the formula W=mg.

By simply adding the forces we can calculate the unbalanced force acting downward for the R.O.V. without floatation. By the same method as above we can calculate the force acting upwards for every cubic unit of floatation. And hence we can find the volume of floatation required to make all force balanced on the R.O.V.

After investigating and experimenting with the above principles we tested it by measuring the weight and volume of our already neutrally buoyant R.O.V. we found that the weight of Proteus was roughly equal (human error, trapped air etc) to the weight of the water it displaced.

Tool Bar

Our custom tool bar has been made on Autodesk Inventor (CAD software) and then laser cut in clear acrylic which was then heated, to enable the bending of the ends to fit to the round PVC pipes that make up the frame. The use of clear acrylic was to prevent the otherwise obstructive bar from impeding the view of the environment. Our main tool (fig. 24) is a piece of PVC pipe sized specifically to fit inside the model clams (TASK 3) and fit the RFID "T" piece in TASK 4. A small notch was cut into the pipe to prevent clams accidentally slipping off when returning to the surface.

Fig. 22: Prong Manipulator

Fig. 23: Camera Array

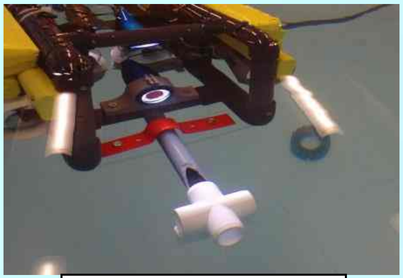


Fig. 24: PVC tool

Our two-pronged orange manipulator (fig. 22) was originally designed specifically for TASK 1 to interact with the rebar reinforcement rods, however, after brainstorming tool ideas for TASK 4 we found if we simply flipped the manipulator we had ourselves a simple, yet highly effective method for deploying our buoy.

Robotic Claw

Initially we designed a robotic claw that was powered by a linear actuator (Fig. 27). We successfully designed and manufactured a prototype using our 3-D printer, and it was a success. However, in practice we found it was far simpler and easier for the pilot to not have the hassle of a moving manipulator and after designing the tool bar (above) we decided that the function of the manipulator was precedent to its "flashiness" and decided to remove the actuator altogether. This also reduced the weight of the R.O.V. making it safer to interact with. A convenient bi-product of this decision was that once the large mass of the actuator was removed, stability of the R.O.V. in the water greatly improved as the centre of mass was much closer to the middle of the R.O.V.

Fig. 25: Dualshock 2 and Arduino

Fig. 26: Old Control Box

Fig. 27: Claw and Linear Actuator

Electronics (Software vs Hardware only)

Originally the design for Proteus' electrical systems used an arcade style joystick (Fig 15) and switches alongside a system of relays mounted onto the R.O.V., this proved effective but the circuit proved unnecessarily complicated and only resulted in repeated electrical failures due to low quality components. With the mind-set of being "simple yet effective" we took a step back and devised a simpler more reliable circuit using DPDT (Dual Pole Dual Throw) switches. In addition to this no "potting" was required on board the R.O.V. as all electrical components were on the surface. We built the circuitry into a modified plastic container which served as a handheld controller. This was a huge success and we later introduced variable speed control through a linear rheostat which could limit voltage supplied to motors by acting as a voltage divider; increasing the resistance of the rheostat would increase the potential difference across it and hence limit the potential difference for the rest of the circuit. After the success of the electronics being relatively early in the season, we later looked at programming a PlayStation 2 "Dualshock 2" controller (Fig 14). We successfully programmed an Arduino microcontroller to receive analogue signal from the controller and output digital signal to a set of LEDs'. However, 2 problems arose. The output from the Arduino was pulse width modulating which resulted in slight increase of inflight turbulence. The Arduino also required relays to be integrated back into the circuit as it only produced current in one direction and had a maximum output of 5V. The new circuit for the Arduino is in development and will be integrated into the R.O.V. for next year's competition.

Tether

Proteus' tether is made from 15m of 6 core copper "speaker wire" and camera signal/power cables. Originally a Cat 6 cable was used however we found a worryingly high voltage drop down the tether and concluded that the thin signal wires were too high a resistance to be carrying the current to our motors. The tether was then pleated and fed through a cable shroud. This improved the aesthetic of the tether as well as improving our safety as before it was held together using cable ties which can snag on the tether managers hands and cause cuts. It was now also less prone to get caught on the environment and tangled up within itself.

The tether has floatation attached at regular intervals (fig. 26) to make the tether as close to neutrally buoyant as possible. This proved successful in that it was better than having no floatation on the tether but also leaves room for improvement as in practice the number of floats and length of tether under the water constantly changes so the tether is rarely exactly neutral. To combat this, we increased the distance between floats making the tether slightly negatively buoyant as we found this caused the least disruption to the R.O.V. In the future, we will invest into a professionally manufactured neutrally buoyant tether to combat this issue.

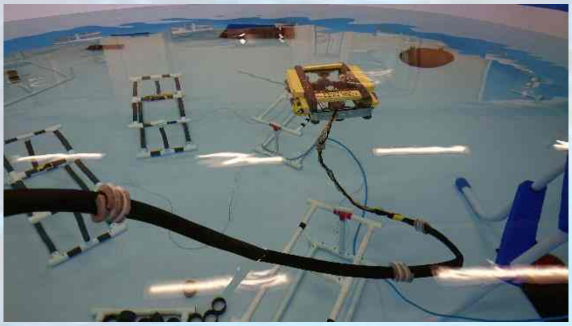


Fig. 28: Tether with floats

Strain Relief

Strain relief was of paramount importance as any strain applied directly to the heat shrunk connections could break them and cause danger of electrocution to all those interacting with Proteus. We constructed an aluminium bar to tie down the tether as it leaves the R.O.V. and hence relieving any strain from the connections.

Fig. 29: Handheld Control Box

Control box

On the control box end of the tether we have safely contained all conductors in a secure container which removes all risk of electrocution to the pilot. The control switches have been modified to their purpose. For example, the switch that control vertical thrust is self-locking so the pilot can interact with all the control simultaneously. The two lateral switches have custom 3-D printed thumb caps to make controlling the R.O.V. feel more natural and prevent any injury to the pilot from the uncomfortable metal switches.

Build Vs Buy/New Vs Used

Building our own parts for Proteus has many positive consequences: lower cost, no delivery time, easily replaceable parts, it allows us to tailor tooling to the tasks and allows us to further our knowledge as a company. On the other hand, buying parts also has positive attributes for example they are potentially more reliable components and generally more aesthetically pleasing however buying parts nearly always costs more. This year we believe we found a good compromise between the two pathways. We designed and built all the tooling for Proteus and 3-D printed many mounts and shrouds. We did print propellers for thrusters but after testing/comparing against bought propellers (see thrust test jig above) we found that we could not design anything as powerful as purchased propellers. Our 3-D printer also has a limit to how much detail it could print in. This was only a problem for propellers as the rough texture generated a lot of turbulence in the water. We reused the same frame as last year apart form a couple of joints where wear and tear was starting to make them unsafe. These were replaced with new PVC pipe joints. By only replacing the parts we need to we can keep our running costs low.

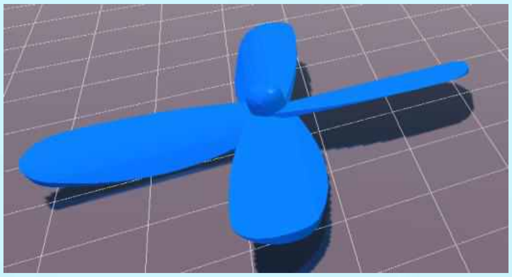


Fig. 30: CAD Design for props

System Integration Diagram

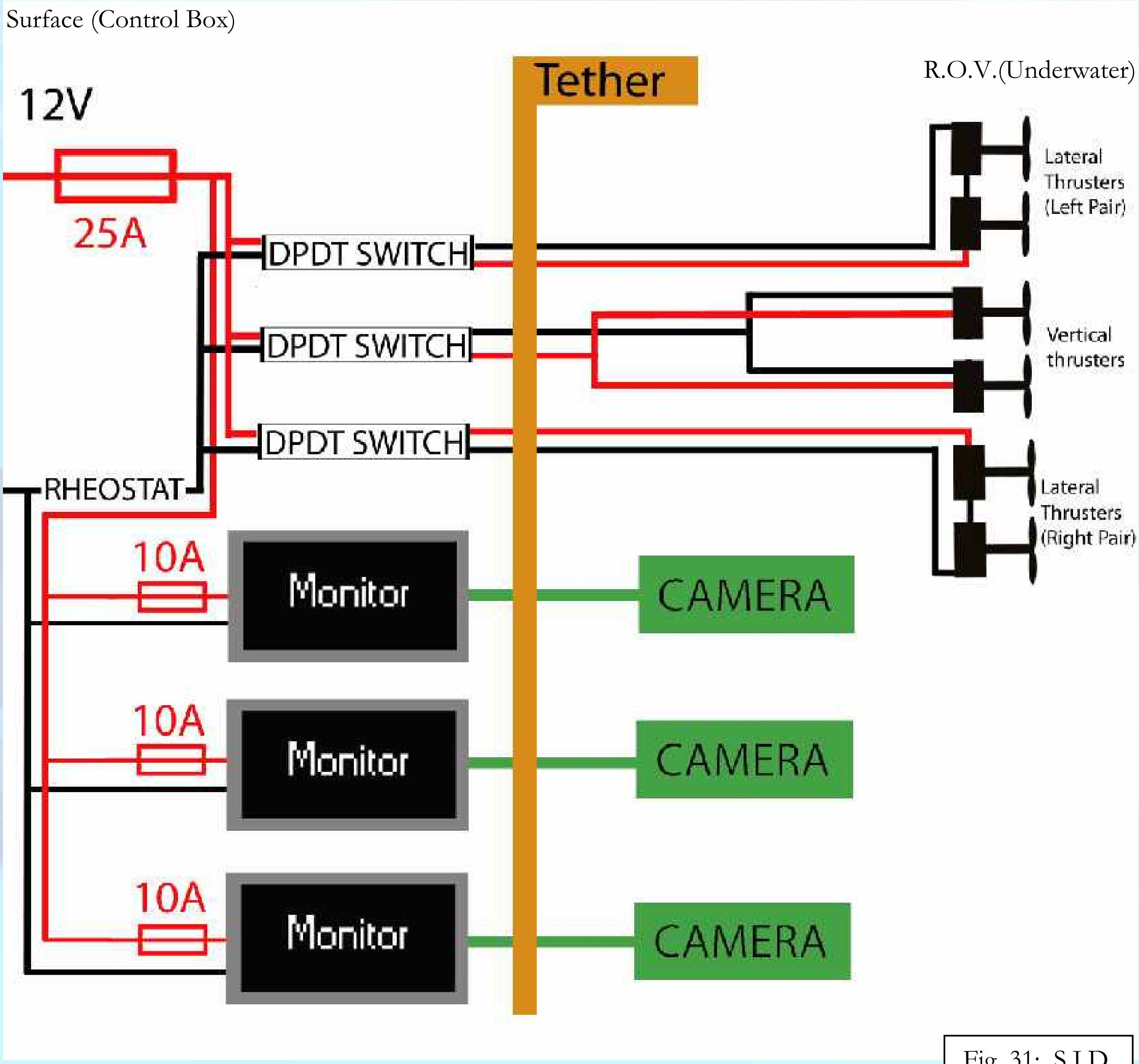


Fig. 31: S.I.D.

Fuse Calculations (Note: Values are for max current - when R.O.V. is in water)

6 Thrusters: (2 x 1.24) + (4 x 0.84) = 2.48 + 3.36
Total Amps = 150% x 5.84A = 8.76A
Each camera and monitor uses 4.5A. Total Amps = 150% x 4.5 = 6.75A
Each camera and monitor has a 10A fuse fitted. Total current drawn is 19.34A. Main powerline is fitted with a 25A fuse.

Safety

First and foremost; safety. Here at impROVise everything done by our members is carried out with the upmost attention to safety, from soldering to drilling; the necessary precautions are always taken. When soldering or heating acrylic (needed to form the tool bar) protective gloves and goggles are worn and heatproof mats placed on any work surfaces. When drilling or working with any power tools, the object is held firmly in a vice and gloves are worn, a partner is also prsent to ensure safe protocols occur. When using the test tank, we must always be wearing buoyancy aids to minimize the risk of drowning. When handling the ROV poolside team members must wear protective gloves to protect their hands from any potential moving/sharp objects. All the tasks are also carried out in pairs to ensure assistance can be given if a problem or safety issue were too arise. High visibility vests are also worn by all team members at the poolside to avoid the unlikely scenario that someone should be bumped into the pool. Having these high visibility vests makes us stand out to everyone that is around us while also allowing our members too to be recognized (see fig), not only is this our uniform but it shows that safety is high priority for impROVise. This allows us to perform at are best at poolside while also being safe.

Fig. 32: Test Tank with appropriate safety warnings

Fig. 33: Team Members are easily identifiable

Fig. 34: Electrical Safety at Poolside

Pre-flight checklist
No loose items or hands are obscuring propellers or in the frame.
All Items attached to ROV are secure.
Fuses are in not blown, in place and secure
No exposed connections or propellers
Tether firmly secured at control boxes and at ROV.
Test all cameras to check correct function
Test all motors for safe and correct function
Ensure Tether is not tangled and safely coiled

Safety features exist for those working around the craft as well. All sharp frame edges have been rounded or marked as sharp. Our ROV can be dangerous if it is not properly attended to. To reduce the threat of the spinning propellers custom 3-D printed shrouds have been attached to those on the outside and inside of the frame to hinder items (including fingers) from meeting them. We also make sure that whenever handling the ROV that the power is off to stop spinning parts causing damage. All team members are required to wear safety glasses and closed-toed shoes when operating or modifying the robot. Sharp edges are all filled down (like those on jubilee clips) and sealed in rubber, and loose wires are held together with cable ties. The tether is also covered by a flexible sheath to protect the wires from sharp objects and prevent entanglement. No connections are left exposed (sealed using heat shrink) and the tether is attached so there is no direct pulling of the wires (strain relief). A 25A fuse is also fitted into the main positive line (see S.I.D.) and smaller 10A fuses are fitted for the cameras, adhering to safety specifications provided by M.A.T.E.

In the workshop, electrical hazards are identified and warning signs placed accordingly (fig. 32). Cables running across the ground are place underneath cable protectors (fig. 34) to prevent tripping over them or damage to the cable. (see above)

Critical Analysis

Testing

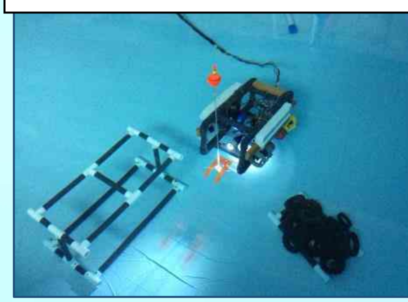
In our previous year of development, we have used a small cubic metre tank to test our ROV. This only allowed for limited testing of our manoeuvrability, so this year we decided to make a large investment into a new test tank. This took the form of an outdoor swimming pool with a capacity of 10,000l. This allowed for thorough and in-depth testing. The pool was populated by numerous PVC made pieces from the mission manual to enable exact scenario testing, where we could interact with similar (if not the same) objects to those we knew would be in the real tasks. Using this experience, we could prioritise tasks we knew could be achieved quickly and work hard on overcoming the obstacles of the more difficult tasks. This created data which we could use to determine which tasks had the highest 'points to time' ratio.

To best assign the roles of pilot and co-pilot several timed manoeuvres had to be carried out by possible candidates, this was everyone other than those who we knew were already predisposed to being poolside. First a general skill test was carried out: hoops of decreasing size were held around the pool and had to be flown through in the quickest time. Those who did well in this then performed a more complex task, interacting and moving a shape of PVC pipe at the bottom of the pool, with the assistance of different co-pilots.

Fig. 35: Louise Safe by the Pool

Fig. 36: Mission Models

Fig 21: Deploying the Buoy



Troubleshooting

If a fault occurs in the system the strategy is to always identify whether it is a break or a short circuit. First fuses are checked, if blown, the control box is the most likely the issue as is where many lines come into proximity, if not, the R.O.V. itself is inspected and lastly the tether is checked for a severed wire. If fuses are intact and power is reaching the system the fault is a break in the circuit. The system will be checked for breaks at all points of connection and inside the control box. If nothing is obviously severed then a multimeter will be used to find where in the whole circuit the break lies.

Challenges

One of the most problematic challenges encountered was the accidental snapping of a piece from our previous manipulator. This rendered it non-functional and we quickly tried to repair the damage, however we realised that the design was not as clean as we thought, leading to the redesign of many of its parts. We decided, after reviewing the drawbacks of using the manipulator; which included the weight and chance of it breaking again, to remove it all together and replace it with the tool bar, which could be tailored more specifically to the tasks and resulted in us having an improved set of tools that could really be tailored to the specific tasks.

This year we struggled with the floatation for a while. We discovered that the foam we were using became quite saturated after being in water for a while, leading to the ROV becoming negatively buoyant. We knew a way to stop this was to cover the floats and make them water tight. A quick and cheap way to do this was to seal the float in plastic (using a vacuum former) and fill in any gaps with silicon. This has allowed us to keep a constant buoyancy and at the same time made Proteus easier to see underwater, making our ROV safer.

An interpersonal challenge we faced this year was some of the team members feeling undervalued and as a result began to feel withdrawn from the group and consequently company productiveness suffered. However, as a group we talked through the problem in a meeting and devised an action plan so the company could continue development and all members could fell equally valued.

Lessons Learned

Technical

- The whole group has learnt how to design and build electrical circuits and how to use various tools in the workshop
- The team has developed their knowledge of safety in the workplace
- Team members have had invaluable experience working with power tools they would not have had the opportunity to otherwise
- Team members have gained knowledge of the process of designing, testing and manufacturing and advertising a product

Interpersonal/Management

- The team has developed team working skills
- All have learned how to overcome difficulties such as time management and task delegation
- The higher authority figures within the company have learnt how to manage employees and to do so in a way to maximise company efficiency

Development of Skills

As the season progressed we noticed a significant increase in the productiveness of the company – we were getting more done in increasingly shorter lengths of time. We believe this reflects how the company has learnt and improved the above skills throughout the season.

Future Improvements

Proteus' control system is effective because it is simple. However, we realise that although it is effective there is a lot of room for improvement in terms accuracy and ease of use. We have already started planning a control system for next year including an Arduino, ESC's and a flight controller. We hope to purchase these and begin building the new control system in the autumn months.

Our tether at present is neutrally buoyant when all tether is submerged however the way we achieved this was by placing floats at intervals throughout the tether. This means that in practice when different lengths of the tether are under the water, depending on how many floats are under the water the R.O.V. and tether will never be fully neutrally buoyant. To solve this issue, we would like to invest into a custom made neutrally buoyant tether for next year. This would ensure that the R.O.V. is always exactly neutrally buoyant allowing more consistent and precise control in the water.

Reflections

One of the best things about the ROV this year was the vast collection of 3D printed and reused parts included. The 'recycling' ranged from a camera to many of the screws holding the frame together, whereas the 3d printing helped to make more complex parts like the shrouds that keep the R.O.V. safe to use and camera mounts. These elements have made Proteus far more practical and safe compared to our previous model.

Accounting

Following the redesign of the R.O.V. from last year's model, it became apparent that many components could be re-used. This meant that we could allocate this year's funds to not just the R.O.V. but also to improving our corporate image, through investing in business cards, uniforms and marketing displays. Amongst this we purchased a 10,000L pool to be used in our department as a "test tank" which provided us adequate room to simulate mission tasks.

Re-Used Components					
Item	Description	Obtainment Type	Units	Use	Price/Estimated Value
PVC pipe	3/4" 5m PVC piping	Purchased	2	Construct frame of R.O.V.	£26.00
Fishfinder Camera	Submersible Camera 15m	Donated (RGU)	1	Vision	£110
Assorted Screws and Bolts	Miscellaneous Screws and Bolts	Donated (School)	N/A	Hold together frame and weights	£20
Low density floatation	Miscellaneous Shapes of Floatation	Donated (Buchaneer)	N/A	Floatation	£60
Bildge Pumps	28Lmin^{-1} 12V Submersible	Purchased	6	Thrusters	£317.70
Total Spent					£343.70
Total Value					£533.70

New (Non-R..O.V.) Items					
Item	Description	Obtainment Type	Units	Use	Price/Estimated Value
Testing Pool	10,000L pool	Purchased	1	To test fly the ROV	£234.99
IBC Tank	1000L Hollow, plastic, container	Donated (Ian S. Roger)	2	To test bouyancy of ROV	£76.00
PVC Pipes	1/2" 5m PVC Piping.	Purchased	3	To create the mission props	£12.24
White PVC T-Pieces	1/2" T shaped pieces of PVC.	Purchased	56	To create the mission props	£66.53
Business Cards	Advertisement/Contact details	Purchased	1000	Convenient contaact detail sharing	£30.06
Marketing Display	Company display board	Purachased	1	To improve corporate image	£63.00
White PVC Cross Piece	1/2" PVC Cross Piece.	Purchased	1	To create the mission props	£2.75
Total Spent					£409.57
Total Value					£485.57

New (R.O.V.) components					
Item	Description	Obtainment Type	Units	Use	Price/Estimated Value
2 Fishfinder Cameras	Underwater cameras with 15m tethers.	Purchased	2	To provide more vision whilst flying the ROV	£204.00
DPDT Switches	Switches	Purchased	4	Used to control the movement of the ROV	£4.48
bullet connectors		Purchased	50	Connecting motors/tether	£5.00
Jubilee Clip	Large	Purchased	10	Metal clip mounting	£9.69
Jubilee Clip	Small	Purchased	10	Metal clip mounting	£4.19
16 Gauge Wire	1.3mm diameter 30m	Purchased	2	Tether	£10.99
Heat Shrink	0.5mm diameter	Donated (School)	1	Insulate connections on R.O.V.	£3.00
Vacume Forming Plastic	Sheet of formable plastic	Donated (School)	6	Wraps Floats	£24.00
Total Spent					£238.35
Total Value					£265.35

Detail Of Trip	Travel/Accomodation Cost
Subsea Expo 2017	£250
Regional Mission Briefing	£250
Regional Prop Demonstration	£97
Competition Regional Final	£97
Competition National Final	£12,500

	Totals
Opening Balance 9/9/16	£683
Total amount spent 16/17	£647.92
Total Amount Spent on R.O.V. 16/17	£238.35
Total Value of R.O.V.	£799.05
Closing Balance 10/4/17	£35.08

The table on the bottom left shows the cost of the trips we have been on (first four) all paid for by our members, equally. The last journey on the list is one from Scotland to California for the competition final and is the cost we raised through our sponsors and fundraising activities (detailed at the end of report) to take our team to the final. All funds use for constructing Proteus are left over from last year's fundraising. Our sponsors are detailed at the end of the report.

Events, Fundraising and Community Outreach

Subsea Expo 2017

Earlier this year our team were invited to hold a stall as part of the 2017 Subsea Expo; the world's largest subsea exhibition and conference where we represented the M.A.T.E. R.O.V. competition. This entailed us bringing our ROV down along with to the AECC (Aberdeen Exhibition and Conference Centre) to show our progress to the visitors and to explain the background of the competition. We really enjoyed the day; learning about current ROV's and the infrastructure within the industry, new technologies which could soon be used in mainstream ROV building, and the opportunity also saw us gain additional sponsorship. The most notable of these was from Trojan Crates (limited) who showed a great interest in our work and agreed to make us flight cases for our ROV and equipment, which we are incredibly grateful for.

Fig 21: ImpROVise at Subsea expo "https://blogs.glowscotland.org.uk/my/keithgrammar/files/2017/02/The-Banter-January-2017.pdf"

Fig 21: Subsea Expo "http://www.subseauk.com/editorialimages/editorialimages17/_expo08.jpg"

Oceaneering

Organised by RGU, our team was given the opportunity to visit Oceaneering's facility in Dyce, Aberdeen. There we were given the opportunity to use the simulator they use for training pilots and to fly a real work class R.O.V. in their test tank. It was a truly inspiring and eye-opening day for all of us and showed us just how vast the industry is.

Quiz Night

To raise funds for the trip to the final in Long Beach we advertised, organised and ran a quiz night for the community. We had a total of 28 teams and the night raised over £1000. This allowed us to present our project to over 140 people teaching them more about what we do as a group, thus improving the interest in S.T.E.M. in the community.

Presentations to community

After the community heard of our success we were overwhelmed by the support they offered us. Many donated to our fundraising through our crowdfunding page and at various events where we held stalls throughout the year. We felt it was fitting to hold an information evening to formally present to the community (as well as sponsors) about our journey in developing our R.O.V. and provide them with information about our experience. The attendance of youth groups in the local area allowed us to engage younger people into S.T.E.M. subjects and promote the M.A.T.E. philosophy.

Engineering taster day and R.O.V. workshop

In our area, there is a lack of progression to higher and further education in S.T.E.M. subjects. To attempt to remedy this we held an information session to the younger year groups in our school. At this we had stalls such as R.O.V. football (thanks go to R.G.U. for the use of micro R.O.V.'s), and ones providing detailed information as to how to start a career in engineering. We saw a great turnout and an increase in interest engineering clubs/subjects ran in the school.

Scout League

In our school and potentially primary schools in the local area we are hoping to provide students with the resources and knowledge required to compete in the M.A.T.E. scout league. This would promote engineering to a younger age group and benefit our group in years to come as team members will be more experienced with R.O.V.'s.

Fundraising

To help raise the funds for the trip to the final in Long Beach, California our team ran several fundraising events/stalls which also allowed the team to form rapport with the community and inspire more people to get involved with engineering as well as generating funds for the group. The fundraising events are listed below:

- Bag packing in local supermarket
- Stall held at "Maynes of Buckie Coaches" 50th anniversary event
- Coffee morning
- Soup and sweet
- Quiz night
- Fete/car boot sale
- Stall at Keith show

Acknowledgements

The results of our teams' hard labour are in no small part thanks to the encouragement and investment of our various sponsors. Some have donated money, others parts, but to each we are very grateful and we would like to deservedly thank them all.

- RGU (Robert Gordon University) - given us parts and some funds
- Trojan Crates Limited - made us a flight case free of charge
- Buccaneer – mentored us and donated floats

Thanks to company's who donated raffle prizes

- Dean's Shortbread
- Johnstons of Elgin
- Glenfiddich
- Chivas Brothers
- Glengassaugh Distillery
- The Grampian Arms Hotel

Thanks also go to the use of the Keith Golf Club for use of the facilities to hold a quiz and to Tesco for allowing us to run a bag pack.

Special thanks go to all of our financial sponsors, without whom competing in the final would not be possible: SSE, RES, Forsyths, SMD, KD Marine, Sonistics, Ian S. Roger Haulage, Keith 50+ club, Burton Roofing, Dingwall Panel Beaters, Houghton Parkhouse, Dingwall and Highland mart Ltd., Simmers Contracts Ltd., Ace Roofing, Keith Builders Merchants Ltd., Standfast precision engineering Ltd., MGS logistics Ltd, Kirkwood Homes, The Phoenix Ladies Club, Barry Fettes Joiner Ltd and Bryan Roger Joiner.

Thank you to the M.A.T.E. centre and the sponsors provided through the M.A.T.E. competition as well as RGU for organizing the regional competition.

- Our mentor Steven Tubbs – devoted much of his time to oversee our progress and assist us whenever needed, to him we are especially grateful.
- All photos/diagrams and captions by Kayleigh Tidball unless otherwise stated