MENZIESHILL HIGH SCHOOL

DUNDEE

SCOTLAND

SCOTLAND REGIONAL COMPETITION WINNERS

TECHNICAL REPORT

BEANO

Andrew Rae	**Team Captain/ Pilot**
Craig Mays	**Pilot**
Callum Fowlie	**Technical Support**
Amy Dow	**Tether Management**
Charli McCabe	**Pneumatic Support**
Louise Fox	**Poolside Support**
Jack Waghorn	**Principal Teacher (Mentor)**
Nicola McCubbin	**Teacher (Mentor)**

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1. Abstract

After 2 years of finishing podium place in the Scottish Regionals, Menzieshill High School brought in a new team with new ideas, new focus and a rekindled determination to win. To compete in the finals at NASA was what we were entirely focused upon, spending lunchtimes and even some of our holidays practicing and perfecting. Under supervision and assistance of Jack Waghorn, Principal Teacher of Design & Technology Department we modified and enhanced our existing ROV to be highly competitive. The result of this was "Beano", a fast, accurate and adaptable ROV.

This year, our mission tasks were based upon the ill-fated Deep water horizon oil spill which involved repairing a leaking oil valve, collecting a water sample, measuring depth and collecting marine life. Together the team brainstormed and thought of the best way of overcoming these tasks. We designed a water sample system, improved ROV speed and accuracy, repositioned cameras to allow better field of view and improved our pneumatics system.

Getting "Beano" ready for the Texas finals has been strenuous and problematic but we have thankfully taken it in our stride and are ready for the international competition.

"Beano" was born through hard work and determination not to mention hour upon hour at poolside. The dedication and enthusiasm of all involved cannot be recorded in this report but can easily be seen in the faces of our team every time "Beano" successfully dives.

2. Information on Deepwater Horizon

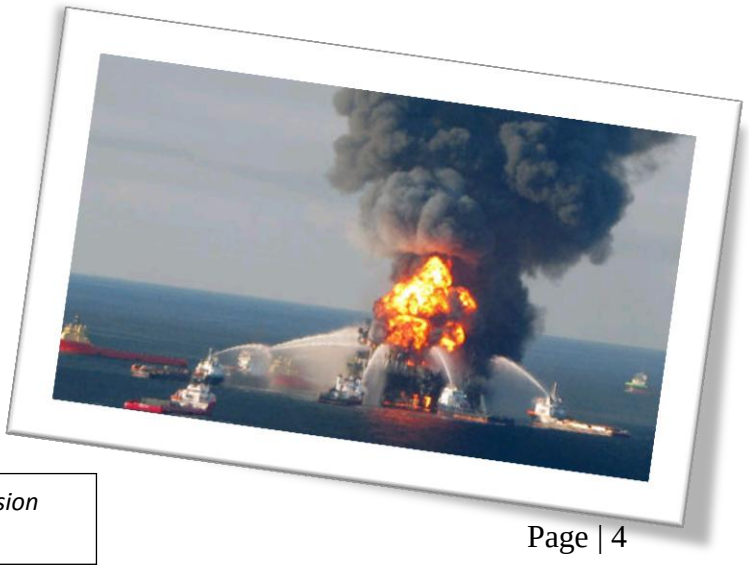
Deepwater Horizon oil rig

The Deepwater Horizon oil spill took place in the Gulf of Mexico in April 2010 following an explosion on the Deepwater horizon drilling rig releasing around 4.9 million barrels of crude oil into the sea.

The Deepwater horizon rig was a nine year old semi-submersible mobile offshore drilling unit, owned by Transocean which operated in waters up to a depth of 2400m and which could drill to a depth of 9100m. At the time of the explosion it was working in the Macondo prospect, just off the Louisiana coast, drilling an exploratory well. However on the 20th April 2010 methane gas (under a very high pressure) from the well shot up and out of the drill column and on to the platform which then ignited and exploded killing 11 workers and injuring many more. Luckily most workers evacuated the rig by either lifeboat or helicopter and, after burning for around 36 hours the flames were eventually extinguished.

Following the explosion the well continued to leak until it was capped on the 15th July and finally permanently sealed on the 19th September. There were ten different techniques used to cap the well including the use of ROV's, injecting heavy mud into the well and finally after a number of failures bolting a sealing cap on top of the blowout preventer.

As of November 2010 BP has claimed that the oil spill in the Gulf of Mexico has cost them nearly $40 billion dollars and temporarily halved the company's value. As far as the clean-up is concerned it is thought that the Gulf of Mexico recovery will be complete by 2012 but a spokesman for the NOAA has claimed that there is no basis to conclude this.



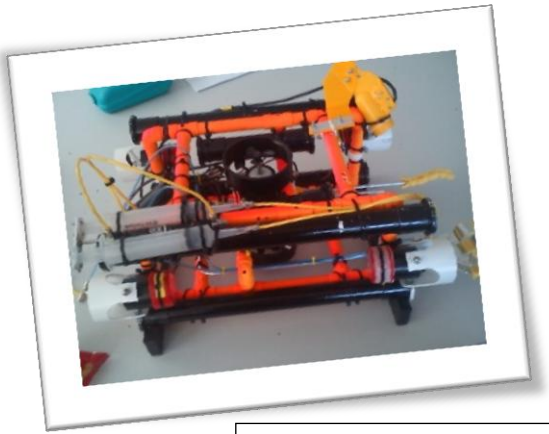
Deepwater Horizon Oil rig after the explosion

3. Design Rationale

In 2009 Menzieshill High School built our first ROV, Rosie Roy. Being the first time a project like this was undertaken by our school, we based our ROV on the concept of simplicity. As well as this we opted for a bright pink colour scheme, allowing the ROV to be seen easily whilst completing tasks in the pool (as well as making the team stand out at the regional competition.) Rosie Roy was designed to be simple yet practical, with no complex electronics on the actuators or tooling. During the competition Rosie Roy performed well, narrowly missing out on the top spot. Hence, it was decided that the basic yet perfectly functional design would be kept when we returned to the competition in following years.

Rosie Roy (2009)

2010 saw us return to the competition for the team and a new, improved ROV, Roxie Roy. Although Roxie's design was based hugely on the design of Rosie Roy, it was much smaller and much more streamlined in the water allowing her to move faster and more efficiently. Roxie Roy, uses the same pink colour scheme from the year before which again made us stand out from the rest of the competition. Although much more technologically advanced and more practical than the year before, a problem in the pool meant that Roxie finished third and it was back to the drawing board for the next year.



Beano (2011)

Along with a completely new team, 2011 brought a few changes to the way things had previously been done. Instead of redesigning and building a new ROV we decided on renaming and modifying Roxie (along with a new colour scheme). After a fresh coat of paint, we thought about redesigning, repositioning and replacing the cameras and tooling systems. The tooling systems had to be designed to complete the tasks given. After much deliberation and a plan put in place, our latest ROV "Beano" arrived at the competition and took the first place, along with our first chance to compete at the international competition.

3A. Structure

"Beano" is constructed from standard PVC piping. We chose this piping due to the waterproof properties, wide availability, relative inexpensiveness and strength. We fixed "Beano" together with water resistant, solvent based adhesive using elbow joints and t-pieces.

We decided a symmetrical, rectangular frame was best due to the low centre of gravity given through this. This allows the ROV to be highly stable in the pool as it does not rock due to air leaks etc.

To achieve neutral buoyancy we drilled the ROV's frame, flooding it with water. Due to less air being within the frame, there is less lift so less drag. This means the ROV is more agile within the pool.

We added two support structures to the ROV framework to hold the cameras and thrusters. These additional supports are also symmetrical to keep our ROV's centre of gravity low.

3B. Electronics

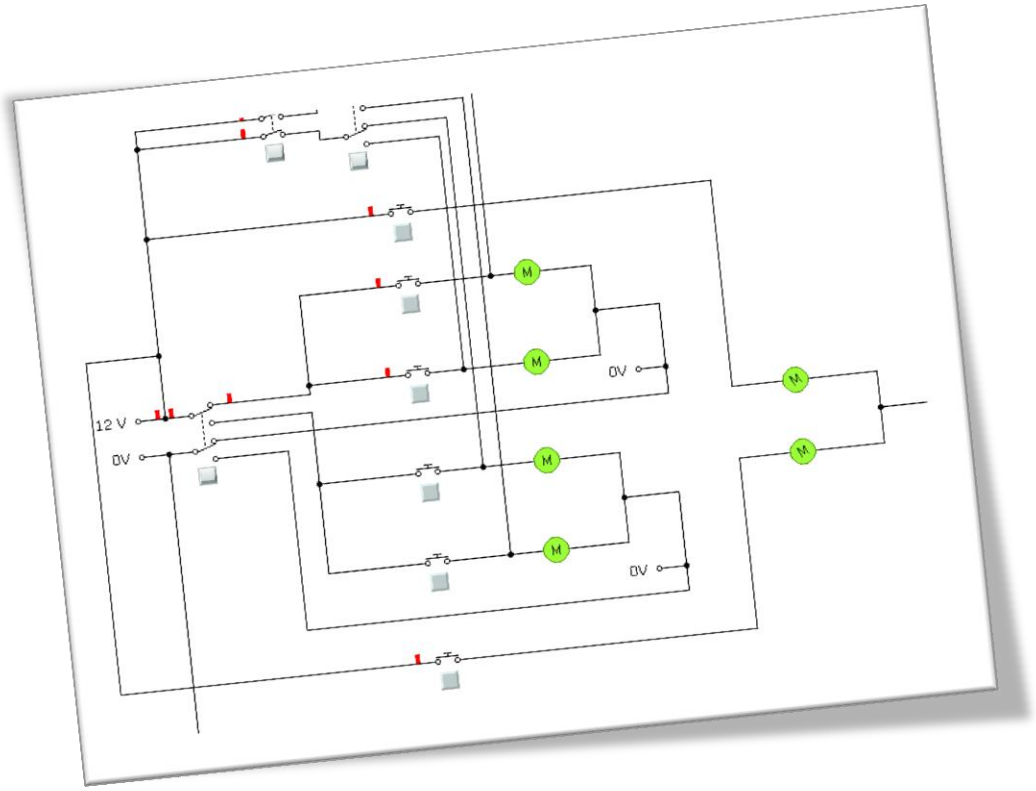
The electronics circuit for "Beano" is a fairly simple circuit, designed with functionality in mind. We decided it would be best to have a hardwired system rather than a microcontroller circuit meaning we didn't have to worry about programming, expensive microcontrollers or possible malfunctioning within the microcontroller PCB. It also means that if an error occurs it is relatively easy to find out where the fault is through use of a multi-meter.

The components we used to put this circuit together were:

- 1.5 mm^2, tri-rated cable.
- Push-to-make buttons
- Double pole, double throw switches
- Triple pole, triple throw switches
- Banana plugs
- 32A Bulgin Maxi Buccaneer 7 Core Connector
- 5A Bulgin Buccaneer 6 Core Connectors

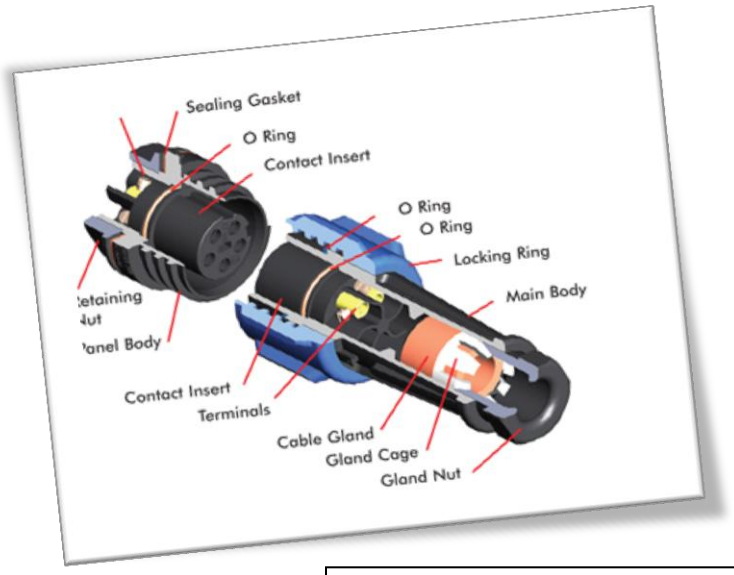
The circuit is designed to control the directional motors of the ROV. First of all the power is split from the positive and negative power terminals down two separate power lines. This connects to a power box/junction we designed. From this we can connect the battery to the air compressor and the ROV motors. We have one slot spare for adaptions if we need to next year. The advantage of our power junction is the ROV becomes fully modular. If a malfunction with our electrical equipment were to occur we could easily and safely cut all power to the ROV or just that specific circuit.

The thrusters work in either forwards or backwards circuits. Not both. To do this we have the forward and reverse thrusters on separate circuits. We can choose which circuit to use through use of a double pole, double throw switch. One problem that was posed when the following circuit was created was allowing the up and down thrusters to still work. To do this, we bypassed the main circuitry and linked it back to the battery. The diagonals work by turning the opposing corner thrusters on. This allows the ROV to turn on the spot. This is controlled by a triple pole, triple throw switch. The simulation programme we used did not have a triple pole, triple throw switch so we created one using a double pole, double throw switch and a double pole single throw switch.



Above –The circuit for "Beano", our ROV.

To connect the tether to the ROV we used three Bulgin Buccaneer connectors. These waterproof connectors allow the ROV to be detached from the umbilical which increases the ease of transport of the ROV and allows us to safely work on the ROV without power connected to it. The connectors are IP68 compliant meaning they are waterproof to certain standards. They are incredibly safe and are certified to work in hazardous, dangerous conditions meaning they can withstand the strain and do not wear from the stress placed on the umbilical.



Above - An exploded view of our Bulgin Buccaneer Connector

3C. Propulsion

"Beano" moves under the power of six modified 500GPH Bilge Pumps with marine propellers attached. Each Bilge Pump was stripped down to its motor and has a tri-bladed marine propeller. For lateral movement, there is a Bilge Pump Motor attached to each corner of the structure (centred vertically) which point directly in front of or behind the ROV, as seen in Figure 2. Therefore, we can move forwards and backwards, and turn and left and right. For turning on the spot, the motors are wired to operate so that the diagonal opposites work in reverse. To ensure safety at the poolside, we added a protective cowling around each of the propellers. These were made from 70mm drain water pipes. The remaining two motors control vertical movement and are positioned back-to-back, pointing up and down in the centre of the frame, as shown in Figure 2. Also, these motors work simultaneously in reverse to provide more force. These motors also have cowlings around the propellers for safety, but these were made from 100mm drain water pipe. Like all the other electronic equipment on "Beano", the motors are powered by the 12V car battery which is situated next to the pilot by the poolside. Under normal conditions each pump motors operate at 12V with 2.5A current consumption.

The original Bilge Pump

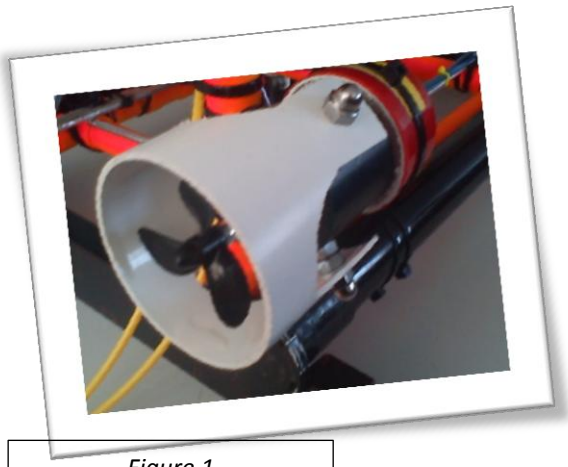


Figure 1

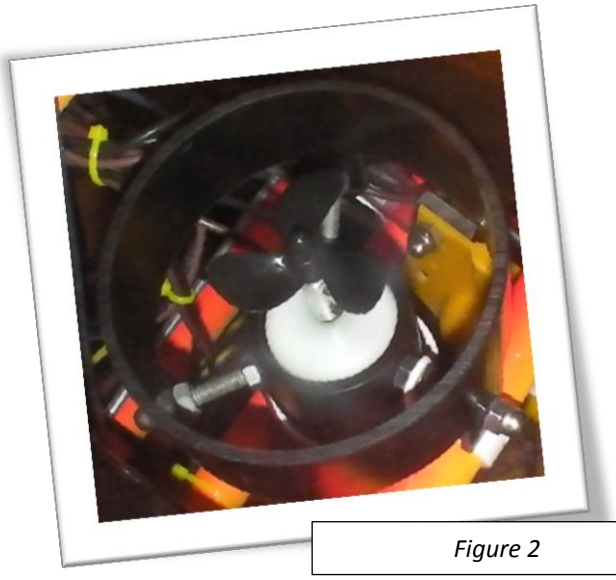


Figure 2

3D. Tooling and Actuators

Figure 1

In order to collect the water sample in Task 3, we decided to use two 50ml syringes. These were then connected to a Double Acting Cylinder (DAC), which in turn was connected to "Beano's" pneumatic system, with cable ties (Figure 1). We then attached pipes securely to each syringe's nozzle and fed these through "Beano". The pipes were then attached vertically to the side of the gripper, with the support of a short aluminium rod, so that they could be directed into the barrel easily. The piston to which the syringes are attached are tied to the top of "Beano's" frame with cable ties.

"Beano" uses two actuators, on the right-hand side is a pneumatically controlled, two-pronged gripper (Figure 2). This gripper is lined with a thin layer of foam (which is attached with cable ties) to provide a better grip. It was initially just a single prong, but after several attempts at Task 2, we decided to add a second as the T-piece would continually slip from the gripper's hold. Now the gripper can hold the T-piece on both "handles" so that it can maintain a good grip. Another problem with the gripper was that the T-piece would fall to an angle that meant it could not be inserted into the new pipe when in the gripper. The solution for this was to add an under slung arm made from Aluminium sheet. This meant that the angle of the T-piece in the gripper could be controlled by the arm, and the angle could also be adjusted due the Aluminium's malleable nature. The second actuator (Figure 3) is situated on the left hand side of "Beano". Like the gripper it protrudes directly out from the front of "Beano"; however this actuator is a lot more

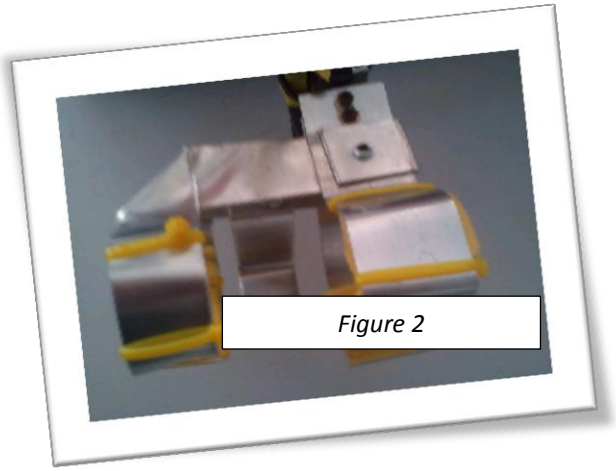


Figure 2

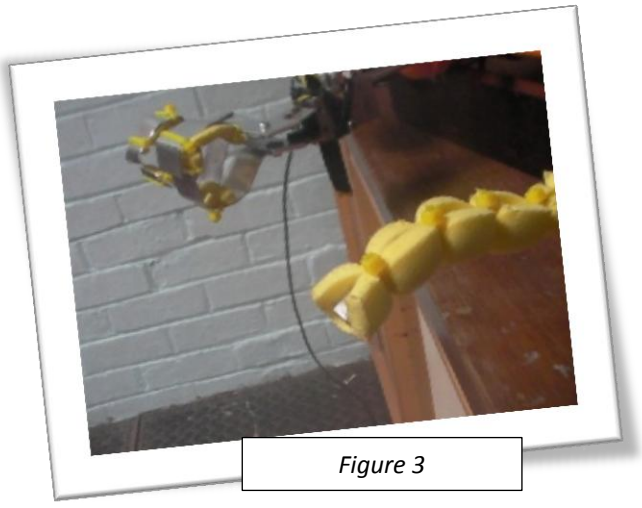


Figure 3

basic in its nature. The actuator is a single rod of Aluminium that had had a shallow hook bent into its end. Also like the gripper this hook had been lined with foam (attached by cable ties) to increase friction. The purpose of this actuator is to allow "Beano" to turn the valve in Task 2.

3E. Control System

The control box is based on an IP68 control box. It has two push to make switches for the forward/reverse motion of the ROV. There are also two rocker switches, one for the rotate function and another for the vertical movement. In the centre of the control box there is a toggle switch for the reversal of the motors. This allows us to use the same switches for both the forward and reverse movements of the ROV.

To make it user friendly, we have made the control system hand held. By having all the controls at your fingertips, it makes the whole system more ergonomic. With less arm movement needed, the pilot does not need to look around the control box meaning the system is extremely intuitive.

The controls are hardwired. Rather than going through an integrated circuit. We felt we should go with this system because it is more reliable, with less to go wrong. It also cut out the need for programming, saving valuable time.

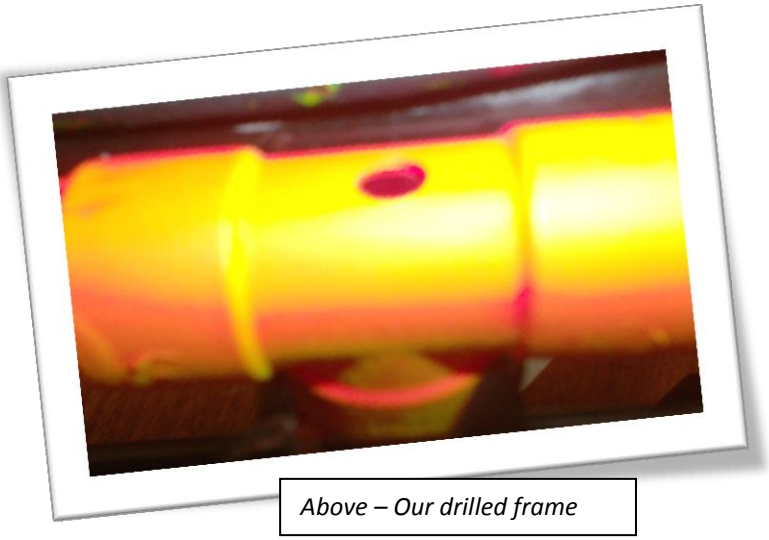
3F. Buoyancy and Ballast

The ROV has been designed to be neutrally buoyant. To allow this, we set up a fully adjustable buoyancy system allowing the ROV to adapt to variable water conditions. This system allows us to add or remove weight to adjust the buoyancy of "Beano".

Above – A Ballast tank with Iron and Steel Rods

We have four sealed buoyancy tanks which are full of air on the top of "Beano" and on the bottom of the ROV we have two adjustable, sealed ballast tanks. To configure the ballast tanks we use steel and aluminium rods of varying diameter inserted in the ballast tanks. These can be changed easily with a cap removal system. This allows us to have a fairly accurate and highly adjustable solution to our buoyancy problem.

Having the ROV neutrally buoyant is essential in the pool. We found through testing that the ROV is more responsive and accurate when neutrally buoyant, although it does make it harder when lifting objects over 1N in water. We felt that better handling was more important than lifting ability during our tasks. In the case where we found it too hard to pick up an object, creating positive buoyancy is quick and easy by simply removing an aluminium bar from each ballast tank.

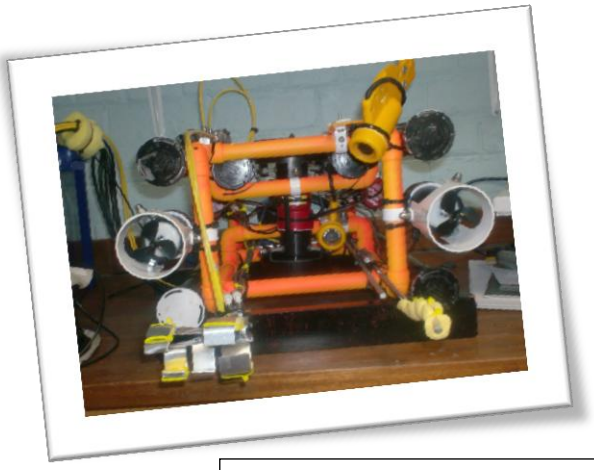


Above – Our drilled frame

To increase the stability of "Beano", the fame was drilled to allow it to flood. Without air in the frame neutral buoyancy became a lot easier to achieve. Because the frame was no longer filled with air, we could remove extra weight. This reduced the sluggishness of the ROV and allowed easier transportation.

3G. Cameras

"Beano" is fitted with two cameras. One is situated in the centre of the ROV on the lower frame support bar to provide a wide view straight ahead of the ROV. The other camera is mounted on the top right of the ROV to provide a close up view of the pneumatic gripper. The cameras were manufactured to be waterproof so no modification was needed to make them suitable for use in the pool. Each unit is available to purchase from Maplin, however we were gifted ours from the hosts of the competition. We have continued to use these original cameras due to their durability, good picture quality and the fact that they are light weight.



Front View of "Beano" showing its camera positions

Close up of the camera showing the LEDs

The cameras have nine LED's built in surrounding their lenses to provide light in dark water and areas we are working in. Both cameras give a full colour image, are high quality and have a 420H resolution. We found using the coloured cameras more efficient than using black and white ones as they gave us a better idea of the surroundings in the pool enabling us to work more efficiently.

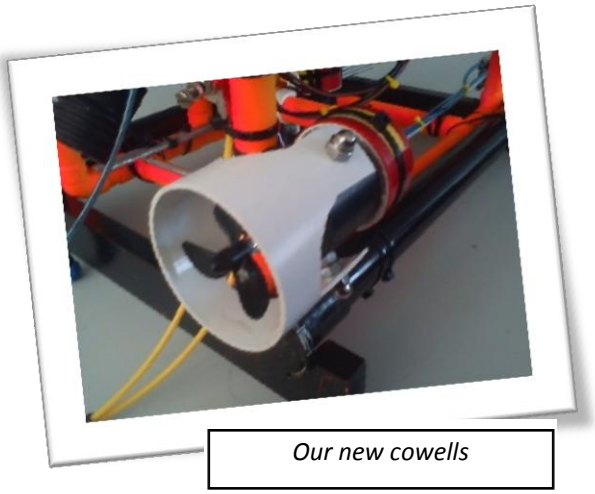
The case holding the monitors and batteries

Along with the cameras we use two 125mm, Sony LCD monitors. Each camera has 1W consumption and each runs on a separate 12V battery which is stored in the case with the monitors. As well as this, both of the cameras are fitted with a fuse for safety.

4. Challenges & Troubleshooting

During the construction of "Beano" our team encountered what seemed to be a series of never ending problems. Just as one was resolved another seemed to arise. Thankfully by the time the regional competition came around everything had been sorted.

Firstly, the team decided on switching the propellers from aviation props to marine props. The marine propellers were much smaller and worked more efficiently in the water increasing the speed and manoeuvrability of the ROV in the water. However as the aviation props were larger in size, the cowells protecting the motor were too large and let in a lot of excess water, slowing "Beano" down a considerable amount. In order to resolve this, the size of the cowells was reduced in order to fit the new propellers. However even this seemed to have a slowing effect. We then came up with another solution. We cut curved shapes in the back of the cowells in order to increase the water flow to the motor. This acted almost like a jet stream, propelling the ROV and giving the team the desired speed.



Our new cowells

Our camera positions. The one on top gives a view of the gripper and the other gives a wide view of both actuators

Next came problems with positioning the cameras. We had two cameras to use and decided it would be best if we could have one to give us a view of each of the actuators (both the grabber and the manipulator arm). Although after testing this in the pool we discovered this was in fact not practical. After much deliberation we came to the conclusion that one camera would be placed further back in order to give us a wide field of vision so both actuators could be seen and the other would be focused on the grabber in order to

allow us to see where items such as the t-piece and cap were being placed. However when we put this in the pool the cameras seemed to move and we could not understand why. Eventually we discovered the problem this time was due to the refraction of light and the differences in refractive index. We then had to position the cameras so that they were slightly off when out of the water in the hope they would be in the right place when it came to putting it in the water, which luckily they were.

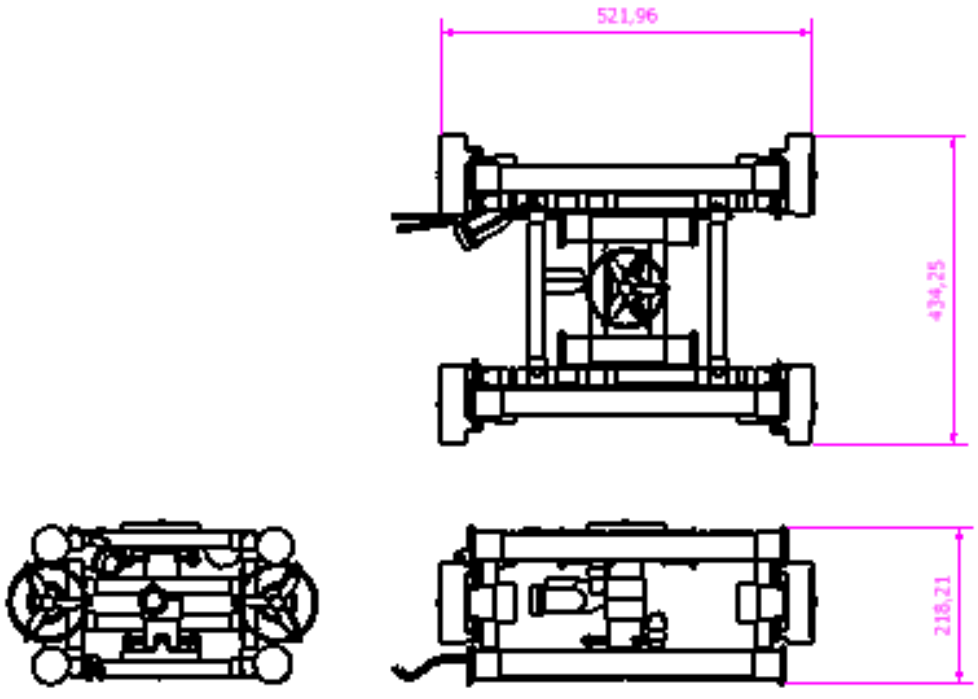
The buccaneer connecters before the malfunction

Finally, just as we thought everything was fine, a last minute problem arose in the wiring. As the bulgin buccaneer connecters we had used for connecting the cameras had faced a lot of wear, and had been used more than was recommended the waterproofing in them had started to malfunction. From the outside everything seemed to be fine, so there was quite a bit of panic to find out where the problem was (considering this was now the day of the competition). On removing the connectors however we discovered that the wiring behind the plug had begun to corrode and rust. Thankfully after a lot of last minute soldering we managed to resolve our final problem and everything worked perfectly in the pool.

5. Lessons Learned & Future improvements

One main feature we found as a main point to improve is the control system. The change we think is necessary is the controller. We would like to change this to a Playstation controller or a joystick.

Another feature which could be improved is the umbilical and the pneumatic pipes within. The pipes within the umbilical are quite rigid and stiff. On some other parts of the ROV we have new pipes which are much more flexible and to improve the flexibility of the umbilical we want to replace the existing pipes with these.



6. Budget

Item	Quantity	Supplier	Unit Cost	Total Cost
Cameras	2	Maplin	£139.99	£279.98
70mm Pipe	3M	B&Q	£2.40/M	£7.20
Piping	4M	B&Q	£1.22/M	£4.88
90 Degree Elbow	12	B&Q	£1.62	£19.44
T-Pieces	12	B&Q	£1.64	£19.68
End Caps	12	B&Q	£0.84	£10.08
Motors(Bilge Pumps)	6	Sea and Shore	£24.00	£144.00
Cable	1	Rapid Electronics	£12.00	£12.00
Syringes	2	Allardyce Health Care	£1.50	£3.00
Double Acting Clamp Cylinder	1	SP Technology	Donated	FREE
Pneumatic Piping	1	SP Technology	Donated	FREE
Cable Ties	150	Rapid Electronics	£8.00/100	£12.00
Rocker Switches(DPDT)	2	Rapid Electronics	£4.00	£8.00
Push to Make Switches	4	SP Technology	Donated	FREE
Control Box	1	SP Technology	Donated	FREE
Aluminium Bar	3M	Strathmartine Metals	£2.00/M	£3.00
Bulgin Connectors Small	2	Rapid Electronics	£12.00	£24.00
Bulgin Connectors Large	1	Rapid Electronics	£36.00	£36.00
Woggle	1	Menzieshill High School	Donated	FREE
Waterproof Tape	1	Rapid Electronics	£12.00	£12.00
Pressure Gauge	2	Menzieshill High School	Donated	FREE
Foam Pad	1	Menzieshill High School	Donated	FREE
Aluminium Sheet	1M X 1M	Strathmartine Metals	£15.00	FREE
			TOTAL:	£595.26

Date	INCOME	Description	Amount
Jan-11		From Previous Year	£156.00
Jan-11	RGU	Start Up Grant	£150
Jan-11	Menzieshill High School	School Fund	£350.00
		Total:	**£656.00**

Item	Details	Likely Cost
Bilge Pumps	Salvage from 2010 ROV	£161.94
Cameras	Salvage from 2010 ROV	£139.99
Framework	Salvage from 2010 ROV	£47.40
Control Panel	Salvage from 2010 ROV	£40.00
Teather	Salvage from 2010 ROV	£70.00
Pneumatics	Salvage from 2010 ROV	£35.00
	TOTAL:	£494.33
	Total cost - salvage	£100.93

7. Reflections

Andrew Rae (S5):

I am a 5th year student at Menzieshill High School. This is my 3rd year on the ROV team, first year as captain. I decided to stay on this year to lend my experience to the new team members. Due to my previous involvement the team we decided it would be best for me to take role as team captain. I have improved my leadership skills, improved my problem solving and budgeting abilities. The original reason for joining the ROV team was to practically apply the theory taught in class. I believed that the technical experienced gained will benefit me in the line of work I am looking to go into.

Amelia Dow (S5):

I have been a member of the Design and Technology department at Menzieshill High School for the past four years and six months. I have studied Technological Studies for three years. At the start of my 5th year at school (my 3rd year of Tech Studies) I was asked to join the ROV team. I thought this was a great opportunity and I was really looking forward to putting the skills gained in class to work. My role in the ROV team is Tether Management. I have found the experience really enjoyable, although it was challenging at times, and it has helped me to develop teamwork and leadership skills along with further improving my technical knowledge, which will be of great use later on in life.

Callum Fowlie (S5):

This was my first year in the Menzieshill High School ROV Team for the MATE ROV Competition. Throughout the time spent in the team I have learnt a lot about engineering and ROV's. I have found the experience enjoyable and insightful and hope to continue this next year. Throughout this year I have helped with problem solving and thinking of solutions to the tasks. However my main job was designing the poster (with the help of Louise and Charli). Through building "Beano" I have found that my relatively new knowledge of Technological Studies has been furthered by the opportunity to apply such knowledge and see it in action. I now look forward to the International Finals in Houston, Texas.

Charli McCabe (S4):

This is my first year in the Menzieshill High School ROV Team. I think that this project has been a very good experience and I have also made new friends. My jobs in the team is the pneumatic support and to help design the poster with Louise and Callum. I feel that I have started to gain some basic technological knowledge which will help me later in life. I am now looking forward to going to Texas for the International Final.

Craig Mays (S4):

This year was my first year in the ROV team from Menzieshill High School. I was pilot of the ROV through both the testing of the ROV and the piloting in the competition. I have greatly enjoyed this position within the ROV team. Through the building of the ROV I have learned many more aspects of Technical Studies and Graphic Communication and found it a very interesting way of learning the subjects on a different level. I found this all very exciting, an interesting project and an enjoyable competition and I wish to continue being a part of the ROV team.

Louise Fox(S4):

This year was my first in the Menzieshill High School ROV team. I feel that during the experience I increased my knowledge of Technical Education. I found the experience enjoyable and I made a few new friends and became closer with old ones. My job in the team was to help design the poster with Callum and Charli and also to use the grapple to remove the riser pipe during the actual competition. I feel that I will be able to use my gained knowledge later on in life and I am looking forward to going to Texas for the International Final.

8. Acknowledgements

Menzieshill High School would like to thank the following for all of their help and support throughout the year, for without this we would not would not have made it this far.

- Firstly, MATE for the organisation of the competition and allowing us to take part.
- Robert Gordon University, Aberdeen, for bringing the competition to the UK and for holding the regional competition and sponsoring our involvement in the finals.
- OPITO for supporting our team throughout the competition.
- BP for financial support.
- ACERGY for financial support.
- Mr Waghorn for all of his support and guidance throughout the project.
- The Physical Education department for allowing us the use of the pool during lunchtimes and even holidays.
- And lastly to all of our sponsors who gave us financial support allowing us to travel to Texas.

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