BUCKSBURNACADEMY

Scotland Regional Competition Winners
Technical Report
B.U.S.T.E.R

Bucksburn Aquablazers:

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1. Abstract

About 35Km off the south-east coast of Hawaii lies Loihi, an undersea volcano considered to be dead by scientist until 1970. Then major seismic activity in 1996 produced over 4000 earthquakes between July 16 and August 9. After this, scientists realised that the seamount would need to be monitored closely. Remotely Operated Vehicles (ROVs) now play a major part in monitoring the volcano and collecting information concerning its activity.

Pisces V, a submersible.

It has played a very important role in the exploration of Loihi volcanoes. During it's life it has completed over 50 dives including a range of tasks involving collecting data, sampling organisms and deploying instruments.

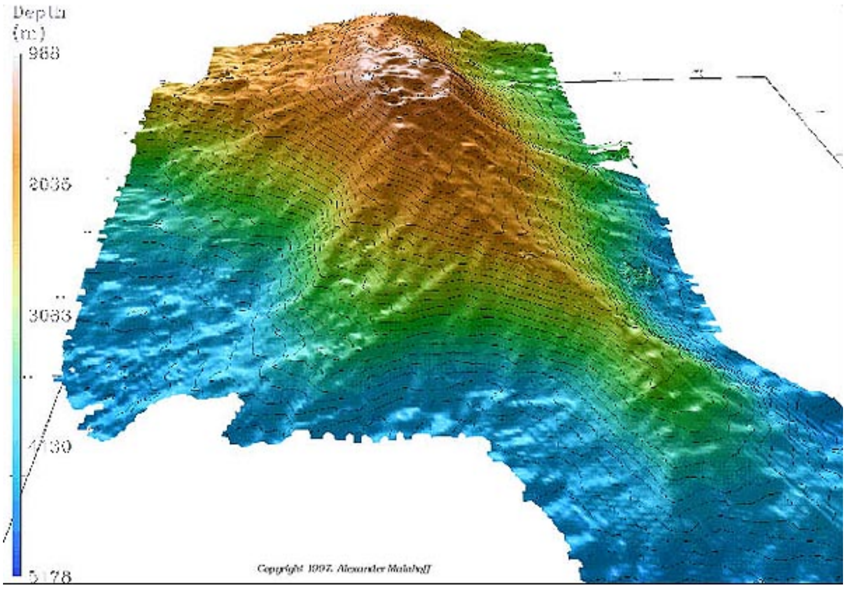
The task:

To design, build and pilot a ROV capable of undersea exploration and equipped to complete several tasks including:

- Resurrecting the Hawaiian Undersea Geological Observatory (HUGO)
- Collecting samples of a new species of crustacean from an undersea cave
- Sampling temperature of a vent site and collecting a vent spire
- Collecting a sample of bacterial mat.

2. Information on the Loihi Seamount

[1]The Loihi seamount is an active underwater volcano positioned about 35 Kilometres off the South-East coast of Hawaii. It is often known as the youngest volcano in the Hawaii chain and began forming around 400,000 years ago. It currently stands at over 3000 metres above the floor of the Pacific Ocean and is anticipated to begin rising above sea level in anything between 10,000 and 100,000 years. Scientists originally considered Loihi to be an old, dead seamount that is found commonly around the Hawaiian Islands. However, after the 1970 seismic activity their views changed. This showed Loihi was a young active volcano, rather than an old dead seamount. In August 1996, Loihi once again produced major seismic activity. Between July 16 and August 9, more than 4,000 earthquakes were recorded. This series included more earthquakes than any other swarm in Hawaiian history. This event made it clear to scientists that they needed a better way to monitor the seamount and collect information about its activity using more efficient methods.



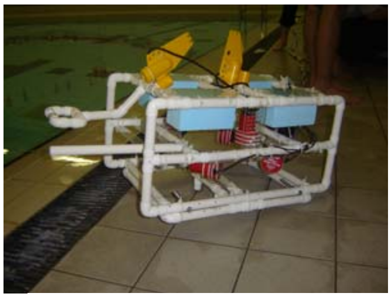
This image shows clearly the size and shape of the Loihi underwater volcano on the Pacific Ocean floor.

[2]

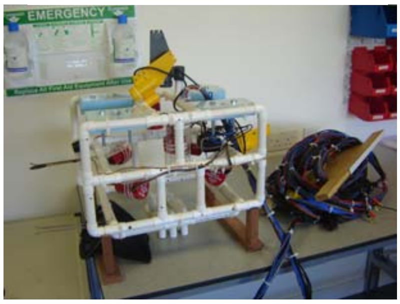
The depth and activity of the Loihi seamount makes investigation and research of the site extremely difficult. For this reason, it is increasingly through the use of remotely operated vehicles (ROV) that further information on the seismic activities of Loihi can be found. Both in the collection of data by the ROV itself, and also by using the ROV's capacity to install and maintain permanent underwater research equipment.

[11] http://www.soest.hawaii.edu/GG/HCV/loihi.html#general
[2] http://www.drgeorgepc.com/volcLoihiSeamount.jpg

3. Design Rationale



Above: SIRIUS
Below: BUSTER



In 2009 the Bucksburn Aquablazers designed and built an ROV and specialised tooling systems suitable for submarine rescue called SIRIUS (Submarine Inspection and Rescue In Underwater Strife). The entire design of this ROV was built around two concepts: manoeuvrability and simplicity. The ROV itself was designed to be a solidly functional underwater tractor, capable of carrying a variety of tools for a variety of missions; and the tooling systems were intentionally designed without complicated electronics or mechanisms. SIRIUS was modelled in card and then built into a working model for further refinement. SIRIUS performed well during its' deployment and as such, the decision was made that the basic design would be kept for future ROVs. However there were a number of areas that were targeted for improvement: reducing the size of the ROV frame, increasing the speed and manoeuvrability, reducing the mass of the tether, and improving the pilot's view.

In 2010, the Bucksburn Aquablazers produced an ROV capable of undersea exploration named BUSTER (Biology Undersea Tool for Exploration and Recovery). The design process involved brain storming the mission tasks and sketching out ideas for discussion. A solution was modelled using AutoCAD Inventor which then directed the build of the final ROV. The tooling systems were designed to accomplish the following tasks:

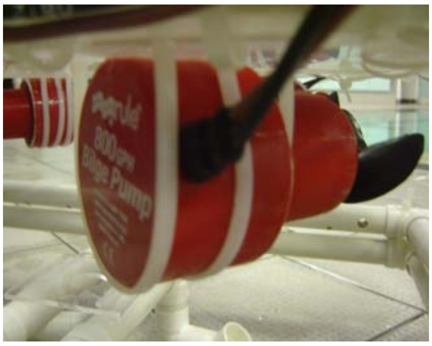
- Resurrect undersea observation station, HUGO
- Collect samples of a new species of crustaceans from inside a underwater cave
- Sample an underwater vent site
- Collect a sample of a bacterial mat and return it to the surface

The following pages explain in detail each sub-system of the Aquablazer's BUSTER ROV.

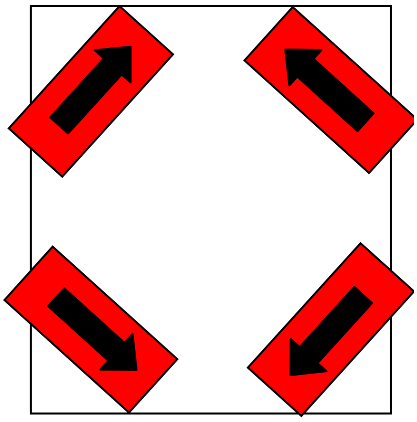
3.1 Frame

The frame of BUSTER was constructed from 21.55mm PVC piping. This was chosen as it provided ample strength and was very compact. The lengths of piping and combination of 90° bends and T-pieces were bonded together with plumber's solvent weld glue. To eliminate any potential issues with the structural integrity of the frame under water it was decided that the frame would be free flooding. Once the frame was constructed, holes were drilled to allow water to flood the frame so when immersed in water the pressure inside the frame would equalise with the pressure outside the frame and thus would perform equally well at any depth.

3.2 Propulsion



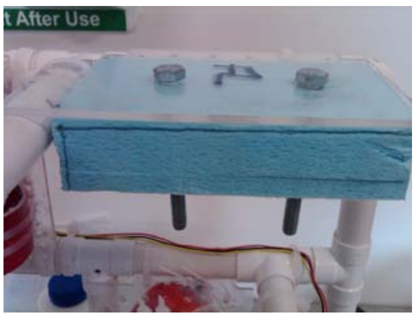
BUSTER is powered by four horizontal thrusters and two vertical thrusters: this provides the pilot with an increased level of manoeuvrability. Each thruster has been modified from an 800 gallons per hour bilge pump. This was achieved by removing the casing and impeller and adding a twin blade propeller from a radio controlled model boat. All of the six propellers are situated within the ROV frame to minimise tangling with underwater debris and to ensure that the safety of the poolside team, during launching and recovering, is at an optimum. Under normal working conditions each thruster draws an approximate current of 2.6 amps and provides even thrust to enhance the stable movement. Due to restrictions in testing facilities the amount of thrust produced by each thruster is unclear. The thrusters are rated at 12 Volts and are therefore driven directly from the 12 Volt D.C. supply via hard wired switches on the pilots' control panel.



This diagram shows the thruster configuration and also the arrows indicate the direction the water will be flowing when a motor is operating.

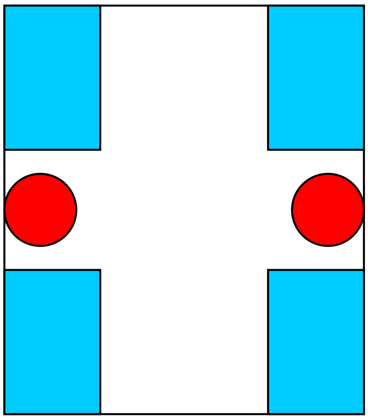
Each of the four horizontal thrusters are configured so that vector thrusting can be achieved. As the thrusters are positioned at 45° from the outer edges of the frame, this creates a central axis upon which BUSTER can rotate 360°. Diagram 1 shows the positioning of each thruster and also the directional flow of water if each thruster were to be actuated. It also shows that due to the positioning of the four horizontal thrusters any directional movement (forward, backward, strafe left or right, rotate left or right) can be achieved by forward thrust of the correct motors. This was an important design breakthrough as it meant no horizontal thruster would be required to be run under reverse polarity which would have resulted in a reduction in thrust.

3.3 Buoyancy and Ballast

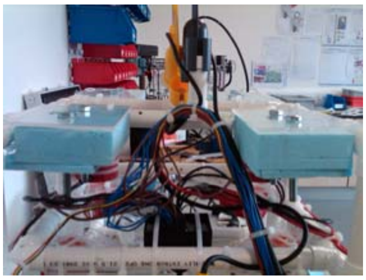


Neutral buoyancy is a condition where the weight of a body's mass is equal to the upwards force produced by a medium, meaning that the body can remain at a certain depth with out raising or falling. It was critical in the construction of BUSTER that neutral buoyancy was achieved. To acquire the desired natural up-thrust the team attached four high density foam blocks to four sheets of rectangular cut out clear sheets of

Perspex. Then to achieve maximum stability in the movement of BUSTER these were secured in place in each of the four corners, thus providing an even distribution of floatation. Also these blocks were made to be adjustable by slicing them into evenly thick layers which can be changed depending on the different water temperatures and densities that BUSTER is operating in.



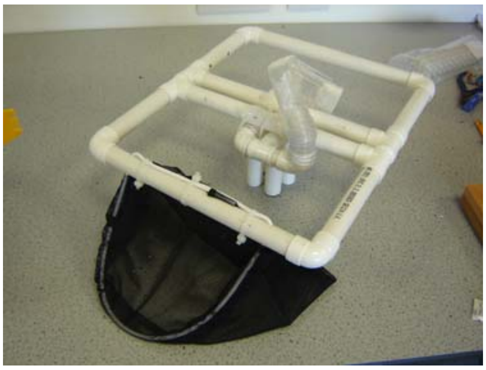
This diagram shows the configuration of the high density foam blocks (Blue rectangles) and also the configuration of the two vertical thrusters (Red Circles)



For fine tuning the buoyancy the team added additional weight (trim) in the form of bolts. These are positioned at the bottom four corners directly below the buoyancy blocks. It is also essential that the high density foam is located on the top of the ROV and the trim is on the bottom and not the other way around as this will prevent the ROV from turning upside down when fully immersed in water. Stability with any ROV is crucial as with out it the simplest of tasks would be impossible and also very inaccurate.

3.4 Tooling

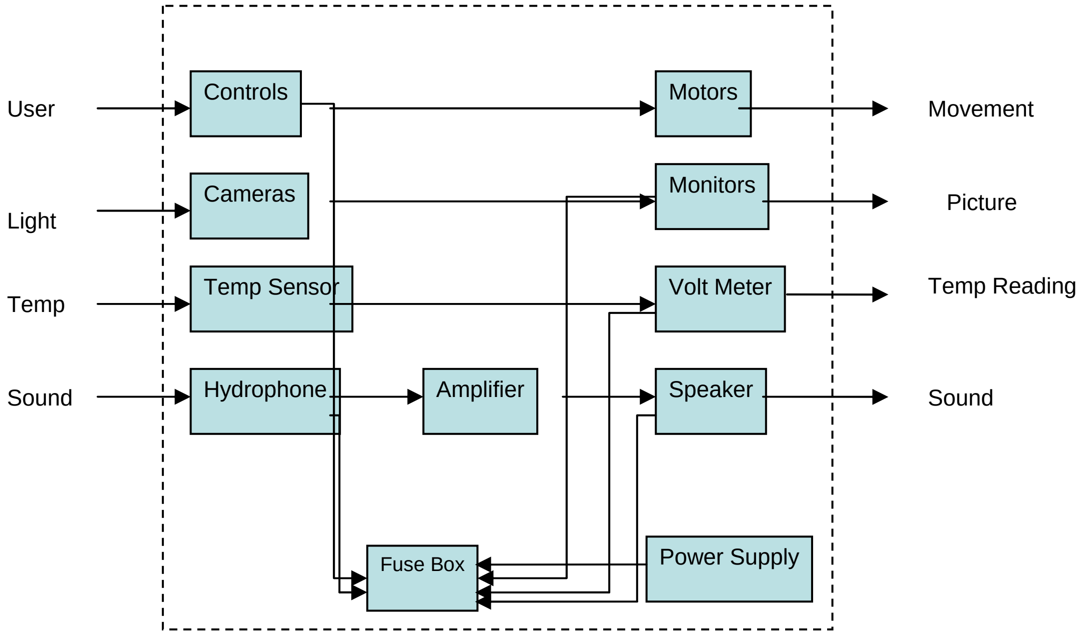
Attached to the front of BUSTER are two sets of copper coated steel chopsticks, painted with lacquer to prevent corrosion. These are designed to slide through objects and hold them until they are brought to the surface. On one of the 4 chopsticks there is a LM35CZ temperature sensor. This tool is designed to measure temperature readings produced by the volcanic vent sites. Located at the front right of BUSTER there is a Hydrophone. This tool is designed to detect the sound produced from active volcanic rocky outcroppings. The hydrophone was made by submersing a condenser microphone element in vegetable oil inside a 35mm film canister. This is connected to it's own 1.5V power supply, and an amplifier located in the pilot's control suite. The underside of BUSTER is equipped with a dual purpose tool incorporating two functions: A self vacuum agar collection tool which consists of six narrow pipes connected together, with an open bottom and a one way diaphragm valve at the top, designed to hold the agar inside them until the rov can surface. This operates under the principle of the weight of the water outside the tool being greater than the weight of the agar inside the tool, thus the agar is held inside. The second tool is a basket which is made from a net fitted to white piping. This is designed to drag along the sea bed collecting and retrieving small crustaceans.



This shows the dual purpose underside tool for BUSTER. The crustacean net can be seen at the front, with the self vacuum agar tool located in the middle.

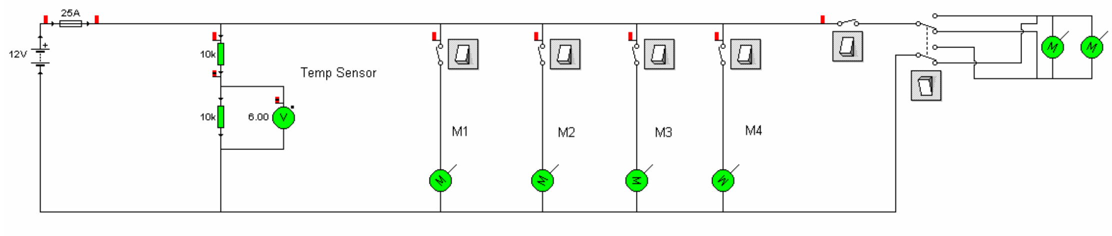
Side view of BUSTER, showing the two sets of chopsticks protruding from the front. The top chopstick also incorporates an LM35CZ temperature sensor that give a voltage output proportional to temperature. The hydrophone can also be seen underneath this set of chopsticks.

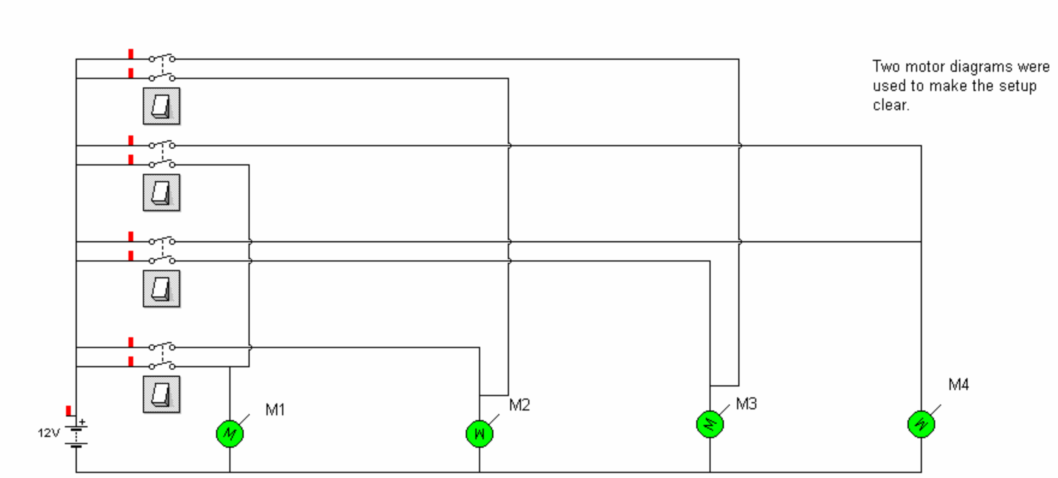
3.5 Electrics



The electrical systems for BUSTER were designed around a modular approach. This means that every system can be connected to one 25A fuse box and can be disconnected for maintenance. This also means that the complete ROV system can be broken up for transport and assembled at the deployment site. Every sub-system is connected using standard 4mm banana plugs and sockets.

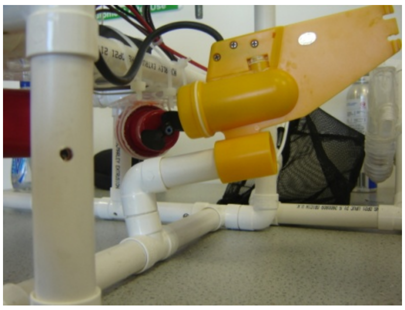
The following diagrams show how the motors and are wired. For clarity it has been shown as two separate circuits.





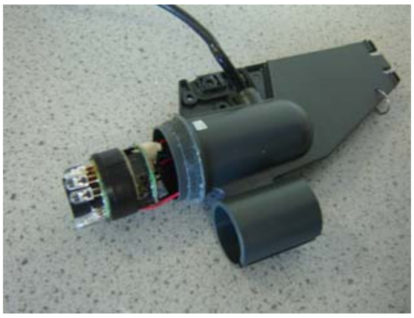
It should be noted that this configuration gives the pilot two sets of switches on the control suite: one that controls each motor independently, and one that controls a combination of two motors at once. The former allow the pilot to perform rotational movement whilst the latter allow the pilot to move forwards and backwards or strafe left and right. This is all done by thrusting the motors in a forward direction.

3.6 Cameras



Buster was built with a total of three cameras positioned to give a clear view of all the tooling whilst providing a wide field of vision of the areas in front and directly below the ROV. Each is an underwater camera unit, available from www.maplin.co.uk and was chosen as it was already waterproofed, lightweight and durable. The cameras had eight built in LEDs, thus enabling Buster to operate in light and dark conditions such as underwater caves. The main camera is colour while the other two are black and white. This was a cost saving measure, as it was reasoned that the marginal benefit of all colour displays did not justify the substantial rise in cost. They all run on 12v and draw a current of 1.13amps and can therefore be run directly off the main power supply. Each camera has its own monitor and fuse in addition to the main fuse.

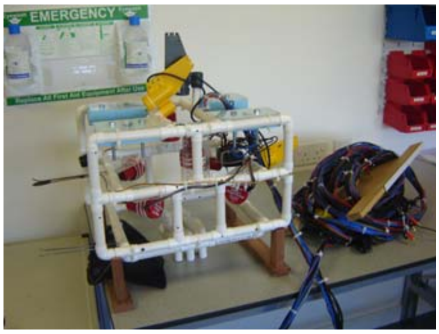
The cameras are sold as a waterproof unit, so at the start of the project the team purchased one unit and fitted it to the ROV, in addition to the two salvaged from last year. During the first test session the new camera began to cut out and display static interference intermittently and eventually cut out completely. Afterwards it was found that the casing had been leaking water which had shorted the camera circuits. After drying the circuits out for 36 hours the camera appeared to be operational again, although the picture quality was reduced. This was probably due to corrosion that had built up on the PCB solder terminals, but was deemed not to be a major problem so the terminals were cleaned and the circuit was re-waterproofed in it's casing. The camera continued to work, but over a 48 hour period the picture quality had diminished enough to make objects undistinguishable. It was concluded that the corrosion must have continued to form on the PCB due to residual moisture inside the casing and that the most effective solution would be to simply buy a new camera unit (this one could not be returned as it had been modified by the team).



These pictures show the faulty camera after being disassembled. The PCBS underneath the array of LEDs had a large amount of corrosion and this is probably why the camera ultimately failed.

3.7 Overall Design

Front and side views of BUSTER fully equipped with payload tools. Note the wooden stand that prevents damage to the underside tool before and after deployment.



BUSTER control suite. The colour monitor on the left gives the pilot a frontal view of the terrain whilst the black and white monitors show close up detail of the tooling. The control box houses the two sets of switches for motor control, and also has a voltmeter for temperature readings. The system can provide both analogue and digital readings. Not shown in this picture is the amplifier that allows the pilot to 'hear' underwater. This is located on the right hand side of the colour monitor.

BUSTER being set up for deployment. Here Ross is setting up the modular control suite whilst Struan is measuring distances along the tether where the flotation collars should be fitted. Through experimentation it was found that these collars should be 1m spaced to make the tether neutrally buoyant. The whole set up procedure can be done in around 3 minutes.

4. Discussion of Future Improvements

Although the team was happy with the design and performance of the ROV, it was still felt that there was room for improvement. Next year it is the teams' intention that the current digital hardwired system be replaced with an analogue system providing variable motor speed, which would be particularly useful on the vertical axis, controlling the depth of the vehicle. This would be achieved by using a microcontroller based system and a joystick-style input, with the advantage of greater ease of control.

Dependent on future requirements and tasks required of the ROV, the team may find it necessary to investigate and introduce electronically actuated tooling enabling greater flexibility in the use and ability of one tool.

The distance between the propeller and motor-casing should be increased to improve the flow of water around it to increase the efficiency of the motors. It may be necessary to develop a test rig that will allow different motor configurations to be tested for thrust and current draw.

While doing all of the above the team wishes to maintain the simplicity of the previous and current designs, as this is a key design principle.

5. Budget Sheets

Bucksburn Aquablazers Expenditure 2010

Date	Supplier	Quantity	Item	Unit Cost	Total Cost
22/02/2010	B+Q	2	2m pipe	£1.58	£3.16
	B+Q	3	pipe insulation	£0.62	£1.86
	B+Q	1	sealant	£7.48	£7.48
	B+Q	3	cable ties	£5.23	£15.69
	B+Q	6	90 degree tee piece	£1.58	£9.48
	B+Q	1	insulating tape	£0.98	£0.98
	B+Q	10	90 degree tee piece	£1.58	£15.80
04/02/2010	Maplin	1	potting box	£0.99	£0.99
	Maplin	10	banana plug	£0.80	£8.00
	Maplin	6	banana socket	£1.09	£6.54
	Maplin	1	underwater camera kit	£49.99	£49.99
01/03/2010	Ebay	1	snorkel	£8.90	£8.90
02/03/2010	Rapid	1	potting box	£0.42	£0.42
	Rapid	1	ABS box	£2.75	£2.75
	Rapid	2	25A fuse	£0.43	£0.86
	Rapid	1	potting compound 500g	£7.05	£7.05
	Rapid	1	100m audio cable	£25.00	£25.00
	Rapid	2	LM35CZ temp sensor	£3.50	£7.00
	Rapid	1	voltmeter	£5.57	£5.57
	Rapid	1	amplifier project kit	£7.60	£7.60
08/03/2010	Rapid	1	amplifier PCB kit	£10.86	£10.86
	John Lewis	1	net curtain offcut	£0.50	£0.50
	John Lewis	1	curtain wire	£2.50	£2.50
	Maplin	1	pack of 4 banana plugs	£4.99	£4.99
	Maplin	2	banana socket	£1.99	£3.98
	Maplin	1	30A terminal blocks	£6.99	£6.99
	B+Q	1	pool net	£5.98	£5.98
	B+Q	4	45 degree bend	£0.94	£3.76
	B+Q	4	90 degree bend	£0.94	£3.76
11/03/2010	Rapid	1	fuseholder	£2.50	£2.50
18/03/2010	Maplin	1	underwater camera kit	£59.99	£59.99
20/03/2010	Maplin	1	3.5mm mono plug	£0.99	£0.99
		1	3.5mm stereo plug	£1.49	£1.49
		1	condenser microphone	£19.99	£19.99
		1	cable ties	£4.99	£4.99
				Total:	**£318.39**

Bucksburn Aquablazers Income 2010

Date	Supplier	Description	Amount
26/01/2010		Rollover from 2009	£183.89
26/01/2010	RGU	Start up grant	£150.00
18/03/2010	BP/Acergy	Grant	£100.00
		Total:	**£433.89**

Bucksburn Aquablazers Salvage 2010

Item	Details	Likely Cost
6 x 800gph bilge pumps	Salvage from 2009 ROV	£180.00
perspex thruster mounts	Salvage from 2009 ROV	£5.00
1 x colour underwater camera kit	Salvage from 2009 ROV	£150.00
1 x b/w underwater camera kit	Salvage from 2009 ROV	£75.00
1 x control panel	Salvage from 2009 ROV	£10.00
1 x tether (motor connections only)	Salvage from 2009 ROV	£20.00
1 x 35mm film cannister	Free of charge	£0.00
	Total	£440.00

Bucksburn Aquablazers Balance 2010

Total Income	£433.89
Total Expenditure	£318.39
Balance	**£115.50**

6. Reflections on the Experience

Chris Hardie (S6 student):

"Throughout this project I have learned a lot about myself as well as subsea engineering. Last year was my first year in the project and it was a fantastic opportunity to learn about ROVs, which play a major part in the local economy in Aberdeen. During this time I developed a keen interest in ROVs and saw this area as a rewarding and challenging career. Now in my second year of the competition I have been able to put right all the technical mistakes from last year and have been able to develop my management and team working skills."

Ross McDonald (S4 student):

"This is my second year taking part in the MATE ROV competition. As the team's CAD specialist I have been able to develop my CAD draighting and design skills dramatically. Last year the CAD work was done at the same time as the build was taking place. This year I was able to complete the CAD drawings before the start of the build, thus making a much better use of time. This time around I was also able to iron out all the mistakes and difficulties I faced when making the 3D model of the ROV. In addition, as pilot it has been great to be able to take control of the ROV I helped to design."

Stuart Green (S4 student):

"I joined the ROV team last year, and was keen to continue this year because I have found the project very rewarding in many different ways. It was a great opportunity to expand my knowledge in engineering and biology. In particular, I feel I have learned a lot about pressure, density, and buoyancy which is not taught in class. I have also been able to contribute my knowledge of electronics to produce the electronic subsystems on board BUSTER. I would definitely recommend this project, and am keen to continue it in the future."

Struan Henderson (S4 student):

"I am the newest member of the team and was asked to join as a poolside crew member through my Tech. Studies class. The project has been a good experience as I have been able to put my knowledge of Tech. Studies to good use. In class you learn about a lot of stuff but it is good to be able to see it happen! Winning the Scottish Regional contenst was a pretty amazing experience and was made even better by the fact that the international final was to be held in Hawaii!"

7. Acknowledgements

The Bucksburn Aquablazers would like to extend thanks to the following parties and individuals for their help and support during the project:

- MATE for allowing us to take part.
- OPITO for supporting our young engineers club.
- Young engineers and Science clubs for supporting our young engineers club.
- The Robert Gordon University for bringing this competition to the UK.
- BP for financial support.
- ACERGY for financial support.
- Mr Paton for support and guidance throughout the project.
- The staff in the ASN wing of the school for allowing access to their hydrotherapy pool for testing BUSTER.
- The art department in the school for donating paper for the poster display.
- The music department in the school for donating a condenser microphone.

8. Bibliography

Bohm, H., Jensen, V. (1997) *Build Your Own Underwater Robot and Other Wet Projects*, Vancouver, Westcoast Words.

DOSITS How to Build a Hydrophone
http://www.dosits.org/resources/all/classroom/buildhydrophone/