BUCKSBURN ACADEMY

Aberdeen, Scotland

Presents

Bucksburn Aquablazers
Subsea ROV Team

Photo by Raymond Besant © RGU

Pictured L-R:

David Adams	(CFO, Electrical and Software Engineer, Co-Pilot)
Cameron Wallace	(Head of Government and Legal Affairs, Mechanical Engineer)
Stuart Green	(Head of Advertising, Chief Electronic Engineer)
Ross McDonald	(CEO, Chief Tooling Design Engineer)

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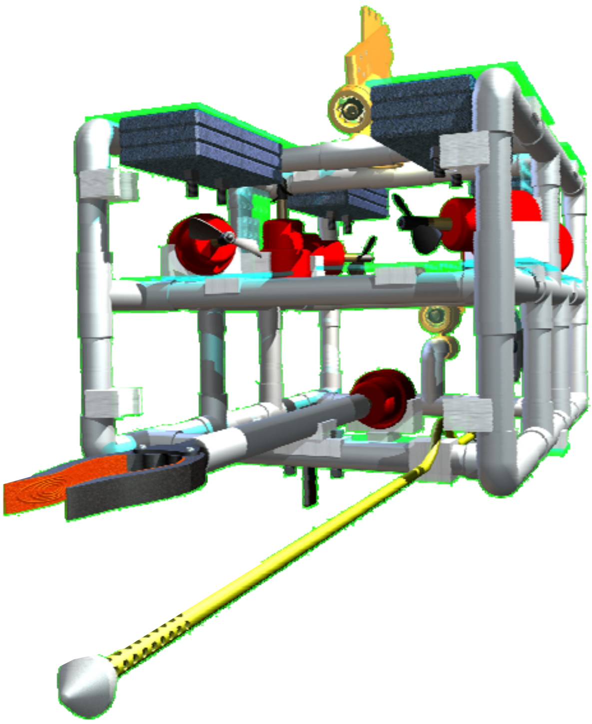
1. Abstract

This report details the efforts of the Bucksburn Aquablazer's latest deployment: using ROV technology to assess the condition of the WWII shipwreck S.S. Gardner, and intervene to make safe. With four years experience and hailing from Aberdeen, the oil capital of Europe, the company are ideally placed to deal with the challenges of the subsea environment. WWII shipwrecks, with their historic importance and environmental impact are a growing concern and this is first explained in more detail.

The company's ROV, SCOTIA, is the result of four years design, experimentation, trial, error and reflection. SCOTIA is designed to both suit the tooling required for this particular deployment whilst remaining flexible enough to suit new tooling requirements. The general design of SCOTIA, and the particular design of it's tooling systems are described by explaining initial design ideas and concepts, challenges faced, trouble shooting techniques used and lessons learned. This cycle of design, test, evaluate and modify was focussed around the specific tasks for the S.S. Gardner:

- Measure the length and orientation of the S.S. Gardner.
- Examine the debris field alongside the shipwreck.
- Clear the sight of debris.
- Take a sample to determine if fuel remains on board.
- Confirm the presence of oil in the fuel tank by calibrating and placing two sensors – an ultrasonic thickness gauge and a neutron backscatter device – on the wreck.

Further detail about the electronics and programmable control used in the SCOTIA ROV is provided in appendices, and the company's finances are listed.



The SCOTIA ROV concept design

2. Information on WWII Wrecks and S.S. Gardner

Estimates show that there are currently 3 million shipwrecks dotted around the world, 8,500 of them thought to be holding vast quantities of oil. Of those, over 6,300 are believed to be from World War Two; the conditions that these sit in vary from ship to ship. The S.S. Gardner, which was sunk by a German U-Boat, was reported to leak oil when survivors were rescued from the wreckage but since then it has been noted that the S.S. Gardner is not leaking oil or any other hazardous material.

The challenges posed by marine explorers when it comes to shipwrecks, especially from this era, are great as in most cases they are entering the unknown with regards to the condition and dangers that a specific shipwreck may present.

Managing these wrecks pose several challenges. One of the most important challenges to consider is the environmental effects of each individual wreck. Many WWII shipwrecks contain oil and some leak chronically such as the USS Arizona, which leaks between 2 and 20 gallons of oil each day. Marine wildlife could be harmed by such substances and could deter some forms of wildlife from breeding in these waters, possibly causing some types of marine wildlife to become endangered. In this respect it is important that wrecks from the World War Two era are properly managed.

However, managing these wrecks could also harm wildlife. Often, marine wildlife will adapt to their conditions and makes homes from shipwrecks. If managed poorly, explorers could damage the wildlife living on a shipwreck and so this has to also be taken into consideration.

Finally, shipwreck managers have to consider the economic and social effects on the local area surrounding a wreck site. If a shipwreck, such as the S.S. Gardner were to begin chronically leaking oil it could spell disaster for the local area. Some localities depend highly on income from fishing and/or tourism of which a clear, unpolluted seafront is important.

When managing WWII shipwrecks, there are several significant challenges facing the managing body and it is no mean feat that so far most wrecks have been stabilised in the amounts of oil and other hazardous material they leak. However, new challenges continue to arise, and increasingly so now that there is deep rooted economic recession.

3. Design Rationale

Since 2008 Bucksburn Aquablazers have been developing ROV and subsea intervention tooling systems to suit the needs of it's clientele. Each year the company have been able to develop unique systems, and learn valuable lessons which have been put into the design of SCOTIA.

SCOTIA's design is underpinned by the following rationale:

- Provide a stable working platform.
- Simplicity in tooling systems.

Furthermore, the company were keen to make best use of the CAD/CAM facilities in the school, to develop bespoke parts for the ROV.

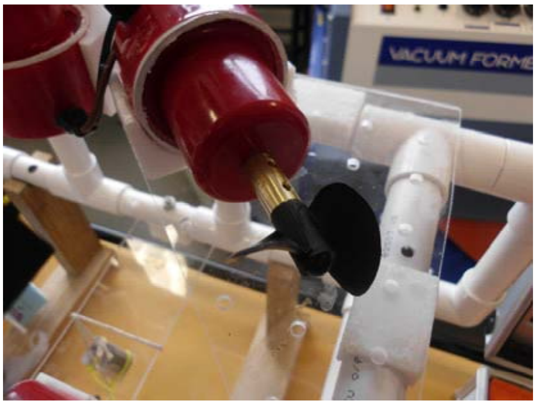
The following sections explain in detail each sub-system of the Aquablazer's SCOTIA ROV.

3.1 Frame

The frame of SCOTIA was constructed from 21.55mm PVC piping. This was chosen as it provided ample strength for minimal mass. The lengths of piping and combination of 90° bends and T-pieces were bonded together with solvent. 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

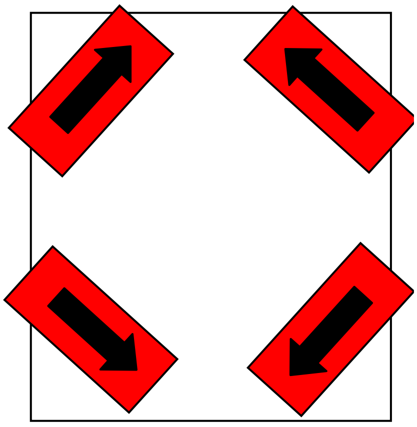
SCOTIA is powered by 4 horizontal and 2 vertical thrusters, positioned close to the buoyancy aids to ensure stable movement. Each thruster is an 800 gallons per hour bilge pump with the casing and impeller removed, and a twin blade model boat propeller added. The propellers are within the ROV frame to stop tangling with underwater debris and to aid the safety of the poolside team on launch and recovery. Under normal working conditions each thruster draws around 2.6 amps and provides even thrust to allow stable movement. In previous ROVs the propeller was directly mounted onto the motor shaft. Whilst this provided reasonable thrust, the motor impeded the flow of water through the propeller and an improvement was required.



One of SCOTIA's six thrusters

SCOTIA's propellers are mounted onto a 20mm long coupling which is then attached to the motor shaft, thus providing a clear flow of water through the propeller and improving the thrust. Initially right hand propellers were used but the initial pool test indicated that these should be replaced with left hand propellers. The corrosion resistant brass couplings also allow the propellers to be easily removed and replaced. Placing the horizontal thrusters at 45 degrees to the centre SCOTIA allows 3 axes of movement with no thrusters required to run in reverse. Switching on pairs of motors at a time allows SCOTIA the following movements: forwards, backwards, strafe left, strafe right, rotate clockwise, rotate anticlockwise, surface and submerge.

As the ROV moves it tends to dip in the direction it is travelling. This is due to the fact that the centre of thrust is behind the centre of buoyancy i.e. as the ROV moves forward the rear two thrusters are in operation. To counteract this a future improvement would be to reverse the opposite pair of thrusters i.e. as the ROV moves forward the rear two thrusters run forwards and the front two thrusters run in reverse.



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

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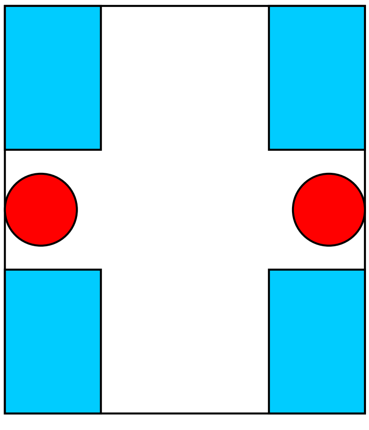
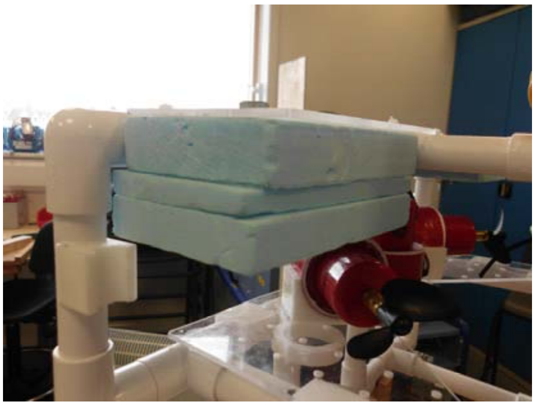
3.3 Buoyancy and Ballast

SCOTIA is kept neutrally buoyant by 4 blocks of high density foam positioned at each of the top corners. The positioning was decided to ensure that the ROV does not flip over with the points of buoyancy being beneath the ROV. The amount of foam used was calculated for fresh water using the principle that neutral buoyancy occurs when the mass of the object is equal to the water it displaces.



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

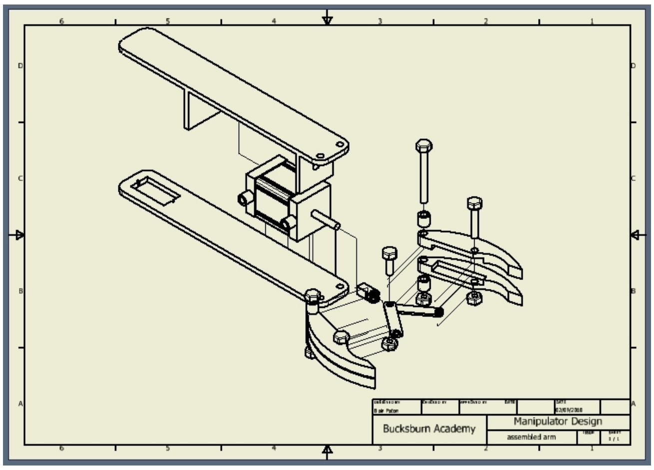
Each of the four buoyancy blocks is cut into slices which allows the buoyancy to be changed depending on salinity/chlorination of water, water temperature and mass of tooling. The ROV buoyancy is then trimmed to perfect neutral by adding galvanised steel ballast to the bottom.



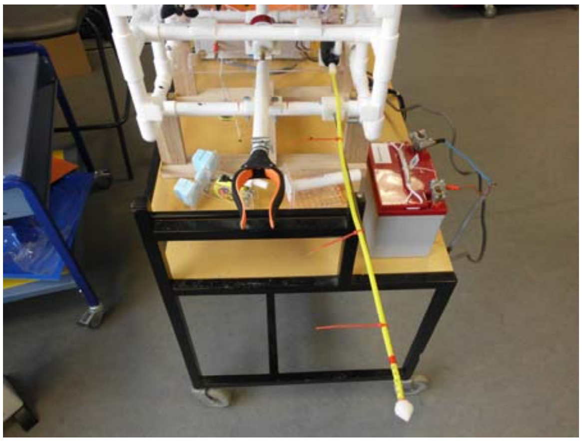
Photograph of one of the four buoyancy blocks on board SCOTIA. The slices of foam can be easily removed to adjust the buoyancy for different conditions, whilst fine tuning is done by adding or removing ballast to the underside of the ROV.

3.4 Manipulator

The front of SCOTIA's frame features a manipulator jaw to help perform tasks on the S.S. Gardner, and represents the major innovation undertaken by the company this year. An original concept design was generated using 3D CAD software Inventor, for discussion and consideration. This concept model utilised servo at the shoulder for horizontal rotation, a double acting cylinder to control the jaws, and is shown to the left.



Manipulator concept model



SCOTIA's frontal manipulator

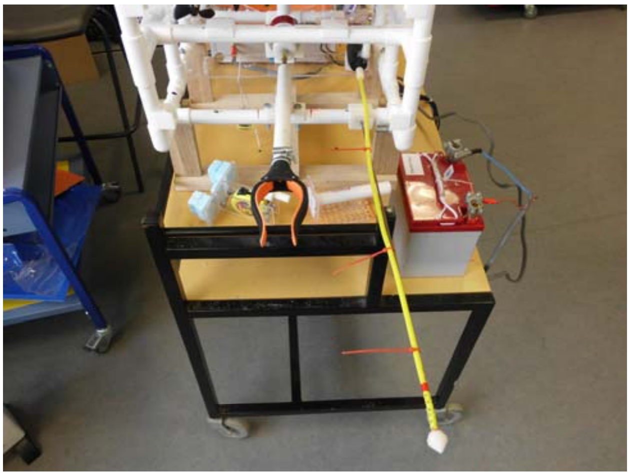
It was decided that horizontal movement was not required, and that a fixed position manipulator would suffice. It was decided, however, that using reciprocating motion to control the jaws was a solution that should be investigated further. SCOTIA was already equipped with a small bilge pump that had been utilised in previous deployments and it was decided that this could be utilised to control the manipulator. The manipulator is adapted from an EasyReacher, an extended grabber for picking up rubbish, which opens and closes a sprung jaw mechanism when a trigger is pulled.

This mechanism is pulled by a cable which was found to be inadequate for use in the manipulator as the cable only worked well when pulling the jaws closed, not pushing them open. Thus the cable was replaced with a brass rod which works equally well in tension as in compression. The brass rod connects to the jaw mechanism at one end and to a specially designed coupling at the other, which was designed on Inventor and manufactured by the school's 3D printer. The coupling holds an M8 nut which is threaded onto an M8 threaded bar, coupled to the bilge pump. In this way, as the motor rotates it pulls the coupling up the threaded bar, thereby closing the jaws, and when the pump is reversed is pushes the coupling down the thread to close the jaws. The coupling is keyed to stop it rotating and the whole assembly is inside a 21.5mm pipe clamped to the front of SCOTIA. The manipulator is especially useful for holding several items such as the lift bag and also the air tube from the surface to the shipwreck. The development of a manipulator also meant that tooling could be designed as removable: held by the manipulator when in use, released when not in use to be replaced with another tool.

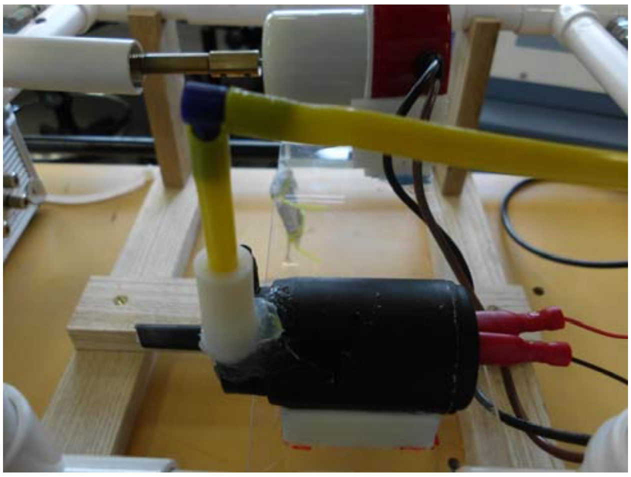
Smooth operation of the manipulator relies upon the centres of the manipulator, mechanism assembly, and motor being perfectly in line and perfectly horizontal. This was discovered after making the first full manipulator which had intermittent movement and a very poor grip. This meant that the entire assembly had to be taken apart and realigned.

3.5 Tooling

One of SCOTIA's most innovative features is it's capacity to handle several different removable tools, with each tool specifically designed for a task or combination of tasks required by the S.S. Gardner. It's most striking feature is the spear and pump system which is quickly and easily attached and removed from the ROV. The spear and pump system allows SCOTIA to pierce through materials in order to take a liquid sample. The spear protrudes past the manipulator and has a conical end to clear debris from fouling the holes on the hose which take the liquid sample.



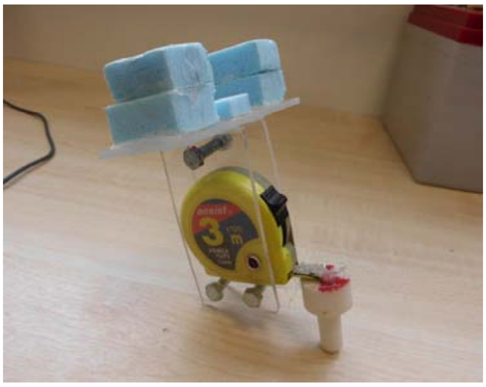
SCOTIA's frontal spear



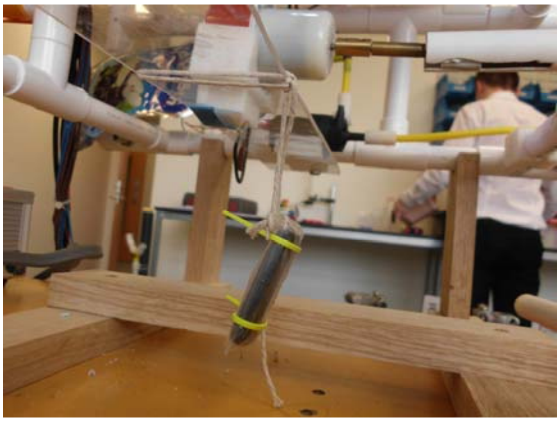
Inline pump, without spear attached

The pump is an inline car windscreen wash pump which has been waterproofed. Another innovative feature of this design is that it uses a recycled drinks container to securely hold up to 330ml of a liquid sample. Many parts of this feature are recycled or made through the 3D printing techniques. The original design for taking a liquid sample used a bag which would be pulled open by the manipulator thus sucking liquid into. However, after development it was found that the vacuum effect created by the opening bag was too great, and the manipulator did not provide sufficient force to open it.

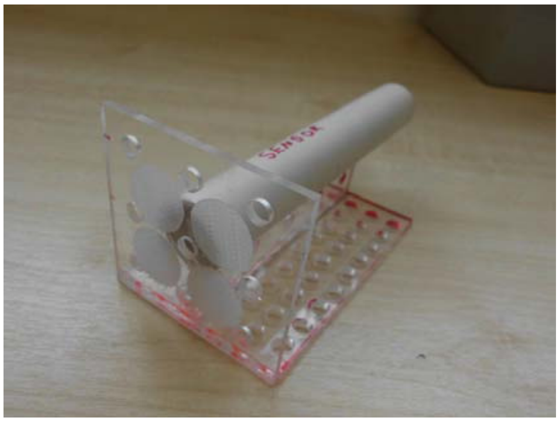
Another innovative removable tool is the Shipwreck Measurement and Orientation device. This is simply a 5 metre tape measure encased in a Perspex protection shield . This also features on top of it a ball compass to measure orientation from North and high density foam, making it slightly positively buoyant. This means that the device can be released by the manipulator once it has been used, and it can be recovered on the surface by the poolside team. The initial concept model is shown to the left, which highlighted the main weakness with this design: the tape being made from ferrous metal quickly rusts and must be painstakingly cleaned, dried and oiled after each deployment. Furthermore, it was discovered that the thrust provided by SCOTIA was not enough to pull the tape measure once hooked onto a wreck. To solve this problem the company devised a simple solution to measure the length of a ship: the ROV pulls a string down to the wreck, the other end of the string held by a poolside technician. When the ROV is at one end of the ship the string is marked, it then flies to the opposite end of the wreck and the string is marked again. The tool is then released by the manipulator, pulled onshore via the string and the distance between the two marks is manually measured by a poolside technician.



Measurement and orientation concept model



Magnetising device



Neutron backscatter and ultrasonic thickness guage

SCOTIA also features a small magnetising device which can be used to detect ferrous metals within the debris pile at the S.S. Gardner site. Many complex solutions, electronic and mechanical were considered and tested to try to solve this problem. It was discovered, however, that observation of the device in the pilot’s monitors provided sufficient evidence of ferrous metals.

Also, an ultrasonic thickness gauge and neutron backscatter device were designed and manufactured for SCOTIA: it features Velcro affixing points on its rear to be attached to the shipwreck and has also been designed to glide smoothly through the water by adding ventilation holes. Again, this is a removable tool held by the manipulator and released when no longer required.

3.6 Electrics

Main control suite (control circuit housed within)

SCOTIA's electrics system is designed to give the pilot the best and most simplistic control. Power is taken from a 12 Volt car battery which is then stepped down to 5 Volts via a voltage regulator. SCOTIA is controlled by a joystick and switch set up, managed by microcontrollers programmed with a PBASIC programme. The commands from these are passed to the desired motors and tools which perform the physical tasks. The motors are driven by SPDT relays which allow the signal level voltage from the microcontrollers to control the high power signal required by the motors. The initial design for the control circuit used MOSFETs because of their low power consumption and voltage drop. However, this was found to be ineffective with the PICAXE 18M2 microcontrollers used as the microcontrollers gave an indeterminate floating voltage, referenced to V+ as opposed to a low floating voltage referenced to ground. A complete electrical schematic can be found in Appendix I, and the program listing is shown below. During testing it was discovered that the 'strafeleft' and 'straferight' sub procedures resulted in the wrong motors rotating, thus the wrong movement by the ROV. However, this was easily fixed by modifying the high commands within the sub procedures.

```
main:
        low 1
        low 2
        low 3
        low 4
        if pin7 = 1 then forwards
        if pin6 = 1 then backwards
        if pin1 = 1 then strafeleft
        if pin0 = 1 then straferight
        goto main

forwards:
        high 4
        high 3
        if pin7 = 1 then forwards
        goto main

backwards:
        high 2
        high 1
        if pin6 = 1 then backwards
        goto main

strafeleft:
        high 1
        high 4
        if pin1 = 1 then strafeleft
```

```
        goto main

straferight:
        high 2
        high 3
        if pin0 = 1 then straferight
        goto main

main2:
        low 1
        low 2
        low 3
        low 4
        if pin7 = 1 then rotateCW
        if pin6 = 1 then rotateACW
        goto main2

rotateCW:
        high 2
        high 4
        if pin7 = 1 then rotateCW
        goto main2

rotateACW:
        high 1
        high 3
        if pin6 = 1 then rotateACW
        goto main2
```

Co-pilot controls

SCOTIA is ideally controlled by a crew of 2: a pilot and a co-pilot. The Co-pilot controls the electrical tooling (manipulator and pump) and the control system is a ‘bolt on’ to the main control suite. In this way SCOTIA is highly versatile as supplementary controls can easily be swapped out.

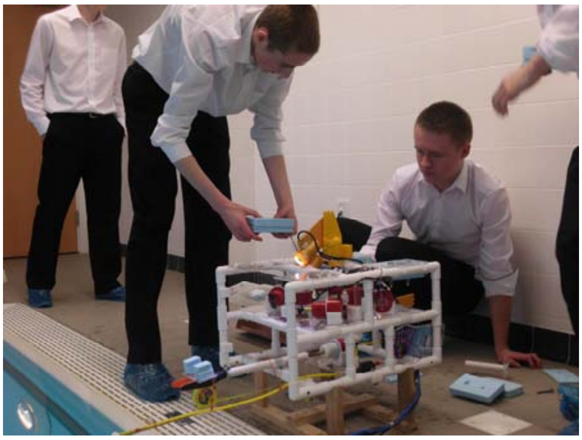
3.7 Cameras

SCOTIA features 3 full colour underwater cameras which are positioned to give the best possible viewing angles for the pilot. One camera faces horizontally straight on through the middle of the frame towards the front; another pointing vertically down through the ROV and another angled facing towards the front to give the pilot a feeling of depth perception. The use of the cameras in this way ensures that the pilot is able to see the main tooling area of the ROV thus making it easier for SCOTIA to complete the tasks required by the S.S. Gardner.

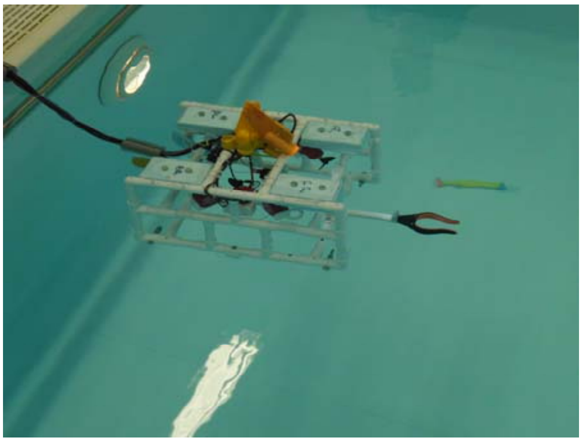
View from the front of SCOTIA, showing the three cameras. These give views of the area in front of the ROV, the frontal manipulator and spear, and magnetising device on the underside.

3.8 Overall Design

Through Gant chart planning, sticking to deadlines, and delegation of tasks Bucksburn Aquablazers have been able to design, build, test and modify the SCOTIA ROV. The company also developed a strategy allowing them to prioritise important tasks during the deployment period whilst bearing in mind that certain elements must be completed in order. Furthermore, the company also developed a safety protocol that ensures the utmost safety for all staff during set up, deployment and recovery. This was commended at the Scottish regional qualifier. The company held four test sessions in the school hydrotherapy pool, prior to the regional contest. Some pictures of these tests are shown below.



Final adjustments are made to SCOTIA's buoyancy with a full load out of tooling



First test mission: 1st March 2012

4. Discussion of Future Improvements

This year the MATE ROV competition has presented many engineering challenges that have allowed us to use our knowledge and skills in a real life situation. We are particularly proud of our brand new manipulator which allows us to meet several different challenges without the need for specific tooling and in some cases with only the slightest of adjustments.

Of course the most rewarding part of this experience has been to see our hard work pay off in the form of a live working ROV. It has inspired all of our team members to seriously consider roles and in engineering and some of us hope even to pursue a career working with ROVs.

We have, however, highlighted areas for further development. These include:

- enhancing the control system to incorporate speed control.
- developing the manipulator further to include both X-axis and Y-axis movement.
- Altering the propulsion control program to stabilise SCOTIA’s movement.

5. Budget Sheets

Bucksburn Aquablazers Expenditure 2012

Date	Supplier	Quantity	Item	Unit Cost	Total Cost
15/11/2011	Rapid Electronics	10	in line coupling 4mm-4mm	£2.93	£29.30
02/12/2011	cornwallmodelboats	10	2 blade racing propeller 45mm RH M4	£2.10	£21.00
		1	shipping	£1.99	£1.99
16/02/2012	Autosave	1	12 V pump	£12.95	£12.95
18/02/2012	B&Q	1	Hose Clip	£1.99	£1.99
		1	Loc EASYBRH	£4.98	£4.98
	Cotsworld	1	Field Compass 2011	£15.00	£15.00
	Maplin	2	Banna Plug Gold Blk	£2.29	£4.58
		2	Banna Plug Gold Red	£2.29	£4.58
		1	Ins Lucar Fem Red	£1.79	£1.79
02/03/2012	Ebay	6	55X M4 Propeller	£3.45	£20.70
		1	Postage & Packaging	£2.70	£2.70
15/03/2012	Amazon	1	Dashboard Compass	£8.40	£8.40
		1	Postage & Packaging	£2.75	£2.75
19/03/2012	Compass Print	1	A0 poster	£34.00	£34.00
	School Storage	14	Bolts	£0.00	£0.00
		18	Nuts	£0.00	£0.00
		3	Piece of copper coated steel	£0.00	£0.00
		1	Wooden Stand	£0.00	£0.00
		1	Easy reacher	£0.00	£0.00
		1	Flexible Tube	£0.00	£0.00
		1	Assorted Perspex	£0.00	£0.00
				Total:	**£166.71**

Bucksburn Aquablazers Income 2012

Date	Supplier	Description	Amount
23/12/2011		Rollover from 2011	£398.63
08/11/2011	RGU	Grant	£150.00
23/12/2011	RGU	Grant	£150.00
12/04/2012	RGU	Prize money	£125.00
		Total:	**£823.63**

Bucksburn Aquablazers Salvage 2012

Item	Details	Likely Cost
6 x 800gph bilge pumps	Salvage from 2010 ROV	£180.00
1 x tether (motor connections only)	Salvage from 2010 ROV	£20.00
3 x colour underwater camera kit	Salvage from 2011 ROV	£450.00
1 x control suite	Salvage from 2011 ROV	£50.00
1 x ROV frame	Salvage from 2011 ROV	£100.00
	Total	£800.00

Bucksburn Aquablazers Balance 2012

Total Income	£823.63
Total Expenditure	£166.71
Balance	**£656.92**

6. Reflections on the Experience

Ross McDonald, S6 student:

“This is my fourth year taking part in the MATE ROV competition, and my last year at school. Throughout my time in the team I have taken part in four regional qualifiers as well as the international finals in Hawaii 2010 and Florida 2012. The competition has taught me a lot about subsea engineering, teamwork and leadership. Qualifying for two international finals is my greatest achievement in the team, and Florida 2012 is a great way to end my school career before starting my degree in Mechanical and Offshore Engineering.”

Stuart Green, S6 student:

“This is my fourth year in the MATE ROV competition, and my last year at school. Like Ross, I have competed four times and qualified for the international event twice. As head of electronics my biggest achievement was making a brand new control circuit for the ROV in 2011 which has been used again this year. The entire control system fits neatly into a small briefcase and is easily connected to the ROV. The competition has shown me that my ideal job is working in subsea engineering.”

David Adams, S5 student:

“I have been a member of the Aquablazers for two years. I was first brought into the team last year to develop the software part of the control system. It has been incredibly rewarding to see how easy it is to develop a well performing programmable system, and how I have been able to solve problems within my area of specialism and as part of the team. Florida 2012 is a great way to see our hard work pay off and I am looking forward to showcasing our school in the USA.”

Cameron Wallace, S5 student:

“I am the rookie in the team, and was brought in as I have had extensive experience in other areas of the Young Engineers Club. The MATE ROV project has allowed me to use my problem solving skills and learn about an area of engineering that is a major part of the local area of Aberdeen. I have been able to develop my skills in engineering and this has provided an excellent point of interest on my C.V. Competing in the international final in Florida is a fantastic way to finish my school career before I start my mechanical apprenticeship at Wood Group.”

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.
- 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 to test SCOTIA.

8. Bibliography

- *en.wikipedia.org/wiki/shipwrecks*
- *MATE ROV 2012 Competition Missions Document*

Appendix I. – Electrical Schematic