GONZAGA ROBOTICS

Technical Report
Ranger Class

Atlantis Angler

Submitted by the
Gonzaga Coalition Robotics Team
The Eastern School District, NL, Canada

to the
Marine Advanced Technology Education (MATE) Center

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Abstract

Throughout preparation for the Marine Advanced Technology Education (MATE) underwater robotics competition, the Gonzaga Atlantis Angler's Robotics Team sought to demonstrate the versatility of remotely operated vehicles (ROVs) in the work place and in real life situations. The MATE competition challenges technical ability and innovation in the design of the ROV while encouraging team efficiency and good team organization.

The 2006 competition simulates the production of a deep sea cabled observatory located on the sea floor. There are two missions to be preformed in no specific order. The first of these missions in the transport of an electronics module from the surface to an existing trawl-resistant frame. The electronics module must be accurately placed in the frame in order to line up the ports of the cable connector. The second part of that mission is to open the door of the frame. A submarine cable, located near the frame, must be retrieved and inserted into the appropriately labeled open port on the electronics module. The second mission is to manually trigger a malfunctioned acoustic release transponder to release an instrument package.

Teams will have two attempts at completing the mission tasks. There are certain time constraints allotted in the completion of the mission tasks. The mission performance period includes 20 minutes plus an additional 5 minutes to set up the system and another 5 minutes to demobilize the equipment and exit the control shack. The ROV does not need to return to the pools surface between the mission tasks and bonus points will be awarded for completing the tasks faster than the limit specified above. The tasks need not be performed in any specific order.

Many people and agencies contributed to the success of the design process, development and testing and refinement of our ROV project and its many facets. We would like to thank these individuals and agencies for their generous mentorship and support. They are listed in Appendix 4 (Acknowledgements)

Particular thanks are offered to our dedicated mentors who advised us all throughout this project great personal sacrifice. We hope we make you proud of us.

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1.   Team Introduction

The Gonzaga Atlantis Angler's Robotics Team (Ranger Class) has students predominantly from Gonzaga High School but also welcomes students from three other local High schools in the Eastern Avalon area. These schools include Mount Pearl Sr. High School, Holy Trinity High School and Holy Heart of Mary High School. The team consists of 19 students from grades 10 to 12 of which approximately one third are female. (See Appendix 5))

The team was formed in December 2005 about the same time as the Mission Scopes for the 2006 MATE ROV competition were initially released. Our team is illustrated in the photograph below (Figure 1)

For those of us who are graduating this year, we are looking forward to joining an Explorer team, next year.   For the students in Levels 1 and 2, we now feel so much more competent and confident of our abilities, that we can contribute a lot more to the team from Gonzaga next year.

2.   Team Organization

With 19 people on the team, some from other schools, it was important to devise a way to manage members ensuring each person was included in the project in a role which interested them and contributed to the team's initiative. All team members were involved in the initial design phase of the project, including the analysis of the missions, development of design specifications; brainstorming general design features and specific tool design ideas. This arrangement provided the divergent thinking which produced a number of different ideas for the ROV design.

Then we divided the team into three working groups, each concentrating on one of the major tasks of the 2006 MATE ROV competition: Finance and Fundraising; Communications and Engineering.   Each group was advised by teacher mentor and led by a responsible team member.   The organization of these working groups and their functions is portrayed below in Figure 2.
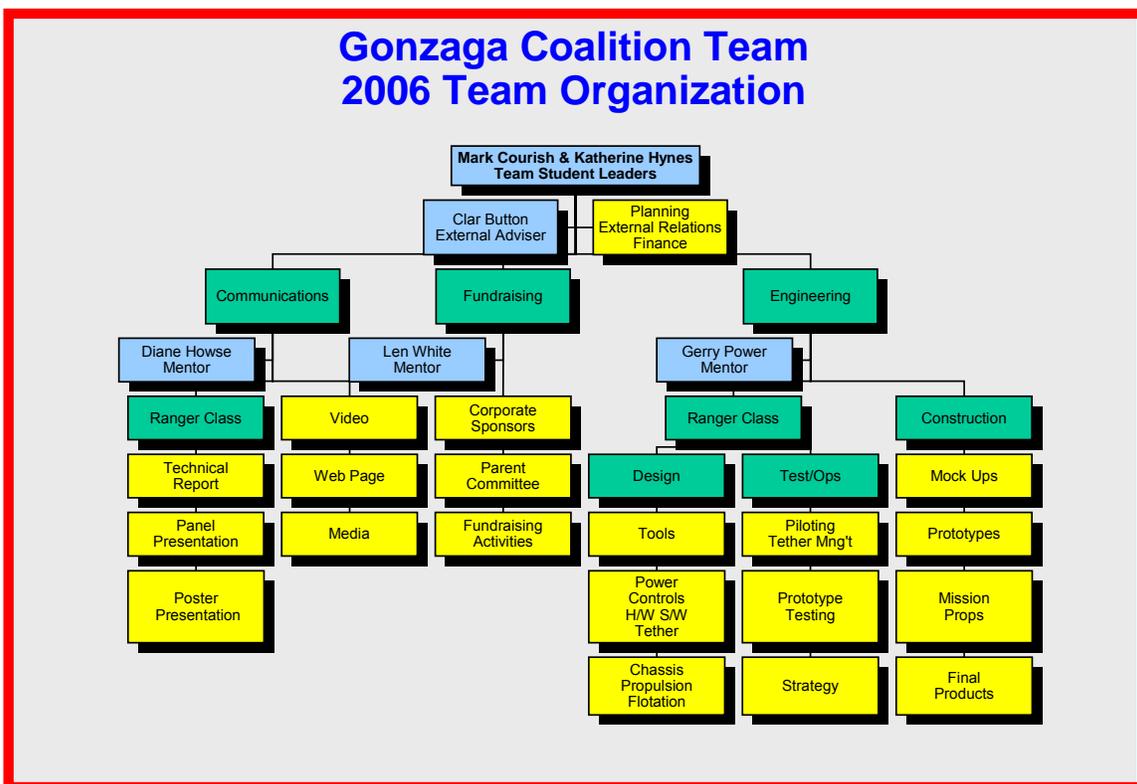

Figure 2. Team Organizational Chart

The working group organization allowed the work of the team to proceed in three simultaneous tracks - a highly efficient arrangement. However, team members could move from one group to another depending on the priorities and needs of the day. An example is the development of this document, to which all working groups contributed when the deadline for submission approached. This also permitted our team members to have a broader view of the whole team's activities, and learn about the different parts of the ROV's technology.

The largest group was Engineering, which implemented the designs approved by the whole team, planned, built and tested our ROV over a period of six months. The "working groups" were also split into smaller units which developed specialized expertise required by the team. Examples are task squads which focused on electronics, programming, tool design, frame development, thruster building and mounting, as well as other specialized fabrication tasks.

The fundraising group sought sponsorship, contacted potential contributors of ROV components, approached firms and agencies who might support the cost of the ROV equipment and to help in the team's travel costs, and organized fundraising efforts. This working group also took charge of planning the travel to the Regional and International competitions, booked accommodations, arranged ground transportation, prepared and compiled the required forms and organized travel and medical insurance.

The remaining team members worked in the Communications group, being responsible for the development of the Engineering Panel presentations support materials, the preparation of the Poster Display and the Technical Report. Of course each of these working groups required involvement of many of the team members in some parts of their work

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3.   Project Management and Finance

Our mentors suggested that the team approach this year's operations as a professional engineering project, in terms of its planning and management. Microsoft Project, a time and resources management program was used to assist in the management of the complete project. Within this program, a list of vital tasks was developed, timelines and expected completion dates were specified and all the required resources, materials and people were identified.

This allowed us to delegate specific people willing to be involved in each task to ensure that the design, fabrication and testing of the ROV and all its components progressed efficiently. This program was consulted each week and revised to reflect the actual progress of the tasks. We met on Thursday afternoons and all-day Saturdays. An example of a MS Project screen is provided below.

ID	Task Name	Duration	Start	Finish
1	Brain Storming Sessions	22.5 days	Mon 1/2/06	Sat 2/11/06
2	Build Electronics Module	29 days	Thu 1/5/06	Wed 2/8/06
3	Build Electronics Module Reci	24 days	Sat 1/28/06	Fri 2/24/06
4	Build Probe With Cable	19 days	Sat 1/28/06	Sat 2/18/06
5	Build Acoustic Transponder	12 days	Sat 2/11/06	Fri 2/24/06
6	Build Tool Prototypes	44 days	Sat 1/28/06	Wed 3/22/06
7	Design Chasis	18 days	Sat 2/11/06	Sat 3/4/06
8	Build Chasis Prototype	17 days	Sat 3/4/06	Fri 3/24/06
9	Electronics design and Brains	13 days	Sat 2/4/06	Sat 2/18/06
10	Order Cameras and Electroni	12 days	Sat 2/18/06	Sat 3/4/06
11	Build Electronics System and	22 days	Sat 3/4/06	Fri 3/31/06
12	Develop Webpage	71 days	Sat 1/28/06	Fri 4/28/06
13	Documentation	71 days	Sat 1/28/06	Fri 4/28/06
14	Fundraising/ Sponsorship	24 days	Sat 1/28/06	Fri 2/24/06
15	Accounting	71 days	Sat 1/28/06	Fri 4/28/06
16	First Prototype	11 days	Sat 3/18/06	Fri 3/31/06
17	Second Prototype	11 days	Fri 3/31/06	Fri 4/14/06
18	Final Prototype	11 days	Fri 4/14/06	Fri 4/28/06
19	Technical Report	22 days	Sat 5/6/06	Fri 6/2/06
20	Modifications on ROV	22 days	Sat 5/6/06	Fri 6/2/06

Figure 3. Gonzaga Coalition Team, Sample Project Gantt Chart

Other project management tools and procedures included a weekly presentation of each task group which reported on the previous week's progress and identified the current week's objectives. We used a work order system with design drawings to document the approved design and required fabrication for the week. These efficiency measures saved time and prevented confusion during our meetings.   Financial and fund-raising matters were scheduled and completed by team members. (Please see Appendix 3 for Team Budget and Financial statement.)

4. Design Specifications and Rationale

4.1 General Design Specifications

Our research and brainstorming produced a detailed set of Design Specifications for this year's ROV and its component tools and equipment. These Design Specifications described what our ROV must be able to do in a very detailed manner. For example, the frame was to be light, inexpensive, accessible material, of low density, which would minimize drag, permit great visibility, be non-corroding, be easily cut and bent as well as be strong and resistant to breakage. The design specifications formed a check list against which all design ideas for the frame were measured and ultimately selected for fabrication. The same procedures were applied to all of our ROV components.

The name of our ROV comes from the abyssal "Angler Fish". The unique features of the 'Atlantis Angler' are its: low-drag frame shape and materials, novel pressure compensation methods, highly maneuverable thruster configuration and control, multi-function, proportional control tool design, dual video camera view, team-designed, multi-source electronics control system, hi-efficiency tether design, an low drag buoyancy shape in all axes. (See also Appendix 1)

4.2 Structural Frame

The structural frame was created from 0.32 cm (3/16") thick, clear polycarbonate plastic (Lexan®) bent into a deepened Octagon shape. Lexan fulfills the design specifications admirably. It has a specific gravity of 1.2 g/cm^3, a high impact resistance (Charpy) of 20 KJ/m^2, and light transmittance (ASTN-D) of 89. It's resistance to impact damage and great flexibility permit us to use a very thin sheet material which reduces weight, presents a very small profile to the water, and reduces drag. It is easily conformed by using a strip heater to any shape required in the ROV. In an underwater environment it is almost transparent, permitting great visibility. (Please see Appendix 6 for buoyancy and drag calculations)

Our ROV frame uses all stainless steel and brass hardware to prevent corrosion. The motor mounts for our thrusters are made of high density polyethylene (HDPE) disks in combination with PVC piping and brackets.
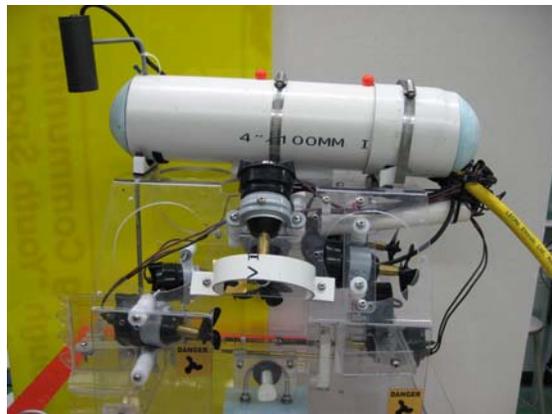
4.3   Thrusters

Eight (8) Johnson Mayfair Marine 1250GPH sealed bilge pump motors are the basis of the thrusters which provide propulsion to the ROV. They have a maximum current draw of 4 amps (recommended fusing at 4A) when operating at 12 volts DC. The thrusters were pressure compensated by filling the casing with a non-corrosive dielectric liquid.   Based on commercial ROV manufacturers advice we initially used a hydrocarbon liquid solvent trade named
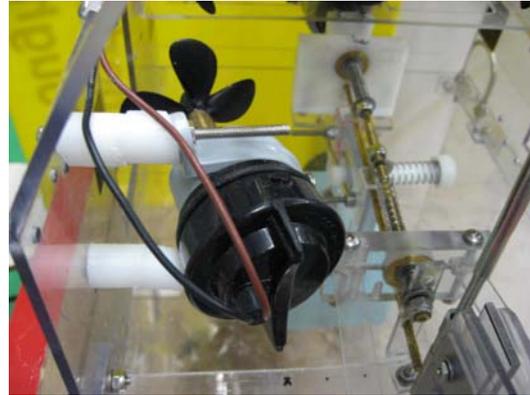
Varsol ™. Although functioning well in our time trials and Bollard Pull tests, this liquid has a pronounced odor, is flammable and constitutes a hazardous substance for air travel. We adopted a low molecular weight, low viscosity (20 cs) dielectric, type 200® silicone liquid from Dow Corning which had the added advantages of no odor, no toxicity, increased lubrication and low flammability, making it ideal for being transported by air. Contrary to what we expected, the thrusters using this fluid exhibited greater thrust than those which were not pressure compensated.

The 70mm diameter, 30 mm pitch, plastic, four-bladed Grupner™ propellers were the most effective in thrust delivery from our selected bilge pump motors. A battery of Bollard Pull tests were performed with different propeller types at voltage ranges between 13.5V and 6V DC before selecting this propeller.   Our experiments found these propellers work best. (Please see Appendix 7 for Bollard Pull test results)

These thrusters are positioned as follows:

SIDE	PORT	STARBORD	PORT VERT.	STBD VERT.
Location 1	Front vectored	Front vectored	Inner vectored	Inner vectored
Location 2	Rear vectored	Rear vectored	Outer vectored	Outer vectored

There is a forward and aft thruster on each side of our ROV. These are each 'vectored" or turned horizontally from the axis of forward motion by 25 degrees. The forward thrusters are vectored outward and the aft thrusters are vectored inwards, towards the axis of movement. This configuration provides pinpoint turning maneuverability, at the expense of forward speed. This compromise was required to more effectively perform the mission tasks.

This year we used an additional vertical thruster on each side of the ROV to provide additional lift for the positioning of the negatively buoyant instrument module in the trawl resistant frame. In order to provide downward thrust which avoided the top surface of the instrument module, these thrusters were vectored 30 degrees outward from the vertical, mounted on an inward leaning ROV frame.

4.4   Power Supply
Our power supply is a 12V nominal, deep cycle, 200Ah gel battery which produces 13.5 V at full charge.

4.5   Remote Control System
The remote control system for our ROV is a combination of components from a variety of sources.   The Logitech® Extreme 3D Pro joystick sends input through the USB port of a laptop computer. The joystick moves on the x and y axis, and also twists around the y axis, offering three dimensions of control. Movement on the x and y axes of the joystick control forward-reverse motion and horizontal turning movements of the ROV respectively.
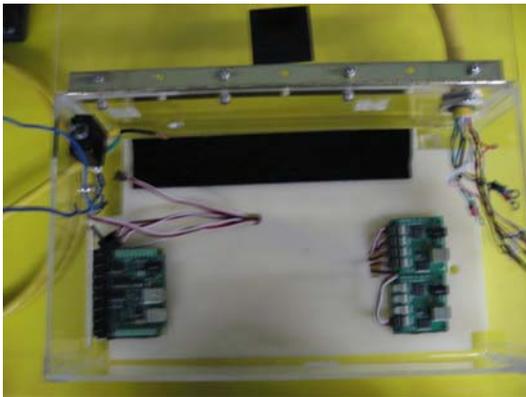
Phidgets, analog and digital interface.   Victor 883 Pulse Width Modulators

The twisting joystick can toggle by depressing an additional button, between controlling heave (vertical) and sway (sideways) motion. The sway motion is extremely useful in achieving precision movements for inserting the instrument probe into the instrument module. The data from the joystick is interpreted using DirectX and read by Visual Basic 6.0 (VB6) programming language developed by team members specifically for this function, operating on the laptop computer. We send analog signals from the VB6 program through a USB bus to a small model 888 USB interface produced by Phidgets® Inc. The analogue signals activate two 5V, 4-output controllers which connect to four (4) pulse width modulated (PWM) Victor 883 motor controllers produced by IFI Robotics. These PWMs regulate current and provide proportional control of our thruster motors, allowing more precise maneuvering as required by the Mission tasks.

An additional PWM provides proportional control for the multi-function tool system on our ROV. This permits firm, but controlled gripping of the frame door handle, the instrument probe and the pin release tasks. The probe can be grasped and manipulated with great accuracy. (Please see Appendix 8 for the hardware and software logic control schematic)

4.6   Electrical wiring and Tether

The topside electrical control system for our ROV is contained within an acrylic box to protect it during travel and use. It contains all the components of the Remote Control system described in 4.5 (above) AWG 14 wired are used for main power conductors to the PWMs. AWG 24 , three conductor signal wires convey data from the computer USB bus through the 888 Interface board and a pair of 4-motor controllers, to the PWMs. We have decided to eliminate the risk of electronic failure by keeping these components on the surface. The components might have been imbedded (potted) in epoxy to ensure waterproof housing, but they could not easily be reused for future ROVs if we had done so.

The tether for our ROV has been custom designed by the team, to fit our motor and actuator requirements. It contains five (5) pairs of AWG 18 power wires. A pair of these wires comes from a PWM to each pair of thruster motors identified in 4.3 (above). The fifth pair powers the multi-function tool motor.
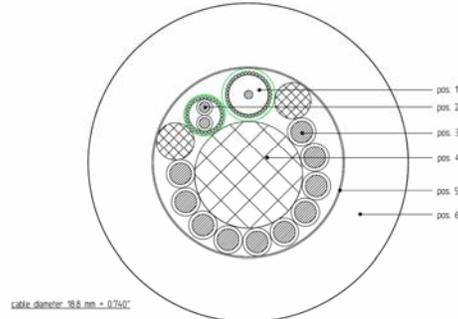
An additional twisted pair of AWG 24 wires in the tether is used to power the underwater video cameras and a solid state relay, potted with the joined wires on the ROV, which switches the video output signal between the two video camera sources.

A 75 ohm small coaxial cable in the tether carries brilliant video signals to the topside monitor. (Please see Appendix 8 for Onboard power wiring diagram)

The tether is neutrally buoyant in fresh water. This is achieve through the addition of flexible filler material in the core of the tether and the use of a low density closed micro-cell foam on the outside. The tether is covered with a smooth clear plastic coating which adheres to the foam later, and reduces drag.

4.7 Video Cameras

Our ROV carries two video cameras. We used an *Inuktun*® ***fireflEYE*** underwater video camera as the forward view camera. Inuktun is a Canadian hi-technology firm with products in the underwater services sector. This primary camera can operate to a depth of 300m. It contains a 0.64 cm CCD chip with a 5 Lux minimum light level. It has a field of view of 47° (H) in air. It also contains 10 8W LEDs distributed in a circle around the main camera lens.

A LCA7700C model underwater video camera (from Lights Cameras Action® of Mesa Arizona) operates at depths up to 30 m , This camera is contained in a brass housing which is approximately 10 cm long and 3.5 cm in diameter. It has a 3.6 mm lens surrounded by a ring of 6 Infra Red LEDs (a 0.0001 lux low light rating), and 380 TV lines resolution. This camera operates on 12 volts DC, 150 milliamps, and has a 92 degree field of view in air. It is used to provide a downward looking view of the front of the ROV, the front of the instrument module and the forward tool gripper. The camera views are switched by means of activating a SPDT solid state relay imbedded in the onboard electronics, with a button on the joystick.

4.8 Separate Tasks and Tools

Mission #1: Complete the Central Node

Step 1 – The electronics module must be transported from the surface to the trawl-resistant frame already located on the ocean floor. It then has to be installed (dropped) into the frame in the correct position such that the inside ports of the module line up with the outside ports of the frame.

Tool Design 1
Our design specifications for the tools on this year's ROV included that it perform multiple functions.
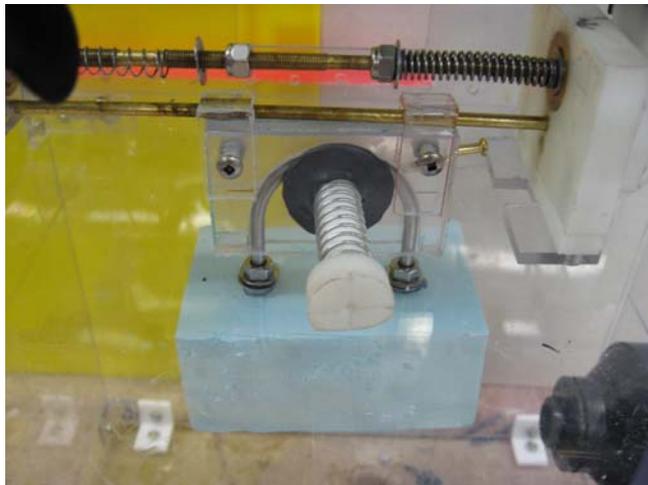
We have devised a tool system which operates on a single waterproof bilge pump motor. The advantage of this power sources is that it is waterproof and proven to be reliable. The disadvantage is that this motor produces high rotational speeds but low torque. We overcame this limitation by using a screw thread on a stainless steel threaded rod as the drive train for the tool system.

The tool for Step 1 is a 8cm x 8 cm x .7 cm Lexan sheath or envelope which covers the middle 'U'-bolt on the instrument module.   Penetrating this Lexan envelope from the side is a 2 cm diameter x 10 cm long HDPE shaft which secures the 'U'-bolt to the ROV.   This HPDE shaft is spring loaded and secured by a 10 cm long brass pin. When the threaded rod is turned by the bilge pump motor, a threaded traveler moves aft on the threaded rod and withdraws the pin from the shaft, releasing it. The spring removes the HPDE shaft from the sheath, releasing the U-Bolt on the Instrument module.

Step 2 – The frame door must be opened to expose the two open ports, one of which is labeled **Power Cable**.

Step 3 – The submarine cable connector must be retrieved from a small platform 20cm from the corner of the trawl-resistant frame. The connector has a U-bolt attached to the trop and a 3m length of wire fastened to the end simulating the submarine cable.

Step 4 – The cable connector must then be inserted into the power cable port where it will attach with an industrial-strength Velcro, half of which is attached to the connector, the other half is inside the power cable port.

Tool Design 2
The gripper component of our tool system has multiple functions and serves to complete steps 2-4 and Mission 2.

For Step 2. There is a vertical set of Lexan plates with interlocking teeth on their forward edge which are joined by a stainless steel hinge. The hinge swivels on a vertical stainless steel rod. When the plates are moved apart, they form an open palmed gripper and when closed, they grip the door handle of the trawl-resistant frame, which is then opened by backing up the ROV.
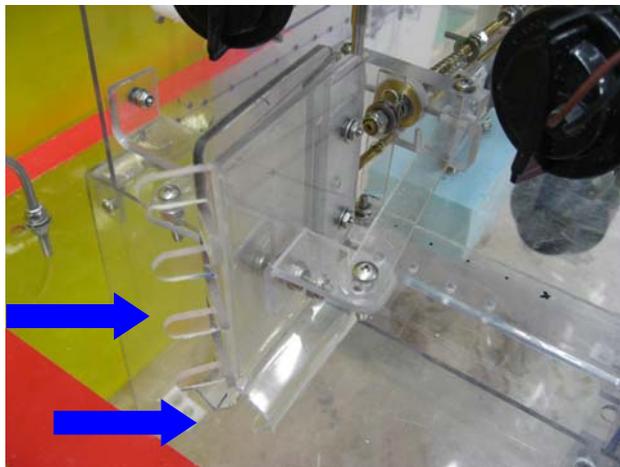
For Step 3. On the bottom edge of the vertical these Lexan plates, running forward, is a bent channel, of 3.7 cm width and 15 cm long, designed to grip the horizontally-oriented power connector.   This operates by the same mechanism as for the frame door handle gripper, through opening and closing the Lexan plates.

Both these functions are accomplished by a stainless steel internally tapped threaded traveler, running along the threaded rod, It is attached on both sides to short outriggers on the outer surfaces of the Lexan gripper plates.   When the threaded rod turns by the action of the bilge pump motor, the traveler moves aft a distance of about 4 cm to open the gripper jaws and forward to lose them. (Please see photo below)

Mission #2: Trigger a malfunctioned acoustic release transponder to release an instrument package.

Step 1 – A metal cotter pin has to be pulled out of a link chain to release a buoyant instrument package floating above the work area. Once released, the instrument package will float to the surface.

Tool Design 3
The same gripper as used for opening the frame door by gripping its vertical handle is used for gripping the pin which must be pulled to release the buoyed instrument package.   The forward teeth on the Lexan plates adequately hold the pin to permit its being removed from the chain holding the buoyed instrument package.

(Please see Appendices 1 and 2 for additional photographs of the tools on our ROV.)
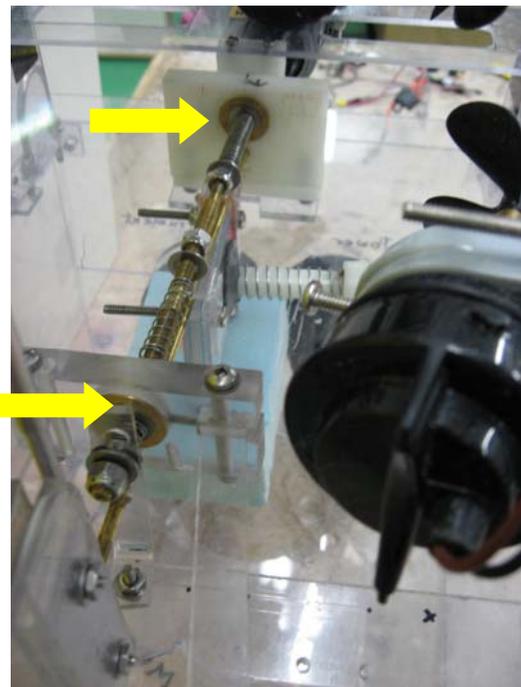
Threaded rod showing traveler plates for the front gripper and rear 'U'- bolt attachment sleeve

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5.   Challenges

Throughout the construction process of the ROV ranger class "Atlantis Angler", the group as a whole encountered several obstacles which required a various array of problem solving skills, and creative thinking in order to surmount them.

Primarily our group challenged itself through the establishment of multiple expectations, which demanded both time and resources virtually unavailable to the average high school student. Fortunately, the team displayed an abundance of commitment and fortitude throughout the ROV construction process that eliminated our limited-resource problem and replaced it with innovation in design, and improvisation in construction.

This displays the persistence of the team, and more so the overall importance of our teams' goals in our community.

One problem we encountered involved the interfacing and programming to get the ROV to respond as we needed.   Our team members were inexperienced I this area and we needed outside help from other students who agreed to teach us.

The group also encountered several problems in the construction phase of our ROV module. As all great things take time to refine, our Robot underwent various phases of design and development prior to the finished product. Throughout each stage the group brainstormed multiple options for improving our ROV, (e.g. using Lexan® (Polycarbonate Resin thermoplastic) instead of PVC piping (less streamlined) or Plexiglas (less durable), as well as vectoring our propulsion motors for increased maneuverability.

The design of the multi-function tool system is another triumph, requiring a huge amount of thought, building, experimentation and refinement. The produce is unmistakably elegant in its simplicity and reliability.

The shape of the frame was drastically altered after our first experience in lifting the instrument module with a PVV pipe-framed ROV.   We achieved a major leap in performance by attaching additional outrigger thrusters on the ROV to increase vertical thrust, enabling us to move the negatively buoyant instrument module.

The Gonzaga Robotics Team encountered many challenges and obstacles in its robot project development and, as a result, we experienced team growth and the creation of a unique ROV.

6. Lessons Learned/Skill Gained

There are many lessons learned while planning and building an ROV. They are clustered in three categories: Knowledge, Skills and Attitudes.

Our knowledge individually and collectively expanded dramatically to include familiarity with mechanics, materials science, mathematics, physics, hydrodynamics, electrical and electronics, programming in several languages. We also learned the value of collective thought and brainstorming.

In the skills area, many of us for the first time became proficient in the use of shop tools, soldering, machining, precision measurement and tool operation. Now we are much more comfortable in doing precision work than we ever were.

Some of us learned new computer skills and the use of new programs for the electronic control an project management. We learned effective methods of communication though the poster development and presentation. We also practiced and became very good at presenting the information on our ROV to our mentors and the panel of judges at the Regional ROV competition. We developed a wide variety of skills which we never thought we could do.

We also learned a number of things about ourselves and other people. We learned the importance of teamwork, of recognizing peoples' strengths and accommodating for their weakness in a team. We learned that with hard work and applying our intellect, there is no limit to what we can achieve. We also learned to become friends and the value and fun of working together. We found that the normal rivalries between school sports teams dissolve when students from other schools which didn't have teams joined us. We are grateful for their work to the team and their friendship.

From our experience on this robotics team, many of us have firmed up our ideas and plans to become involved in some sorts of technical career. These ideas range from marine biologist to computer programmer and some engineers. But we now know that these careers can be fun as well as productive and provide good salaries.

In conclusion, we think, as a group that this was one of the best educational experiences we had ever had in school. We are looking forward to the competition in Houston, working together as a team and meeting NASA scientists, engineers and astronauts. We are looking forward to meeting other teams, learning from them and seeing other designs.

7.   Troubleshooting Techniques

As a result of our practice and trial times our team discovered several limitations in the early design of our ROV and there were several troubleshooting techniques that the team employed during the building of our ROV.

One of the most significant was the placement of the negatively buoyant instrument module in pipe frame.   With small 12V thrusters, there was difficulty in generating enough thrust to lift the module.   We suspect many ROVs encountered similar problems as we witnessed in our Regional Competition..

We examined the root of the problem and evaluated two alternatives:
i.   added buoyancy, or
ii.   more thrust and practice in maneuvering the ROV

The first option seemed easier to achieve, but the difficulty of what to do with the additional buoyancy after release of the module became apparent. There was no clean way to get rid of the buoyancy except release it to the surface,. We felt that this added risk as it would ruin our chances for a good score on the rest of the tasks, if the buoyancy didn't release.

The second option was more controllable, in our view, and we chose that route. We found that the added vertical thrust , combined with vectoring the thrusters to provide thrust outside the top of the instrument module worked well. We also found that depositing the instrument module in the pipe frame became much easier with additional practice, so we established that as a major focus.

When we encountered difficulties with the interfacing of several different pieces of hardware, requiring a knowledge of a couple of different software programs, the first response was to undertake widespread research for solutions. With the basic premise that "The truth is out there", our team members explored the types of programs which could be used and independently learned them, with some help from external mentors, and applied them to our own control system.

The process was challenging and time consuming, but the result is really great.

8. Future Improvements

Our ROV is being continuously modified and refined, and will be up until the International ROV competition.

Generally, we would like to refine and decrease the size and reliability of our multi-function tool, although it's pretty good right now. If the financial resources were available we would certainly attempt to acquire more powerful thrusters, as this has been a problem in the 2006 Missions.

With the buoyancy, we would attempt to use syntactic foam for reduced compression with depth, although the hi-rigidity H-100 model Styrofoam SM currently used compresses less than 0.5% in 5m of water, trough our tests.

One of the limitations of our current design relates to the requirement to control the thrusters with multiple wires from a topside electronic control apparatus. This limits the size of the wires and the current they can individually carry to the ROV thrusters, since the tether's dimensions and weight increase with additional or larger gauge electrical power wires. In future, we may risk inserting the power control electronics package in a water-tight container onboard the ROV, to overcome this limitation.

The challenges are ensuring that the design of the housings is absolutely water-proof (something we have not had great success with yet). The difficulties arise from the need to penetrate the water proof housing ("can") with tether cable in and power and sensor wires or video cables out from the "can". Effective methods of using bulkhead connectors do exist and we have explored them, but these solutions and products are mighty expensive.

As we acquire experience in underwater robotics in future years, one of the directions we would like to go in is mimicking the more sophisticated commercial ROVs in their use of sophisticated on-board electronics. Our new control system has the opportunity for digital and analogue inputs which, if onboard the ROV, could supply data on depth, temperature, conductivity, motor efficiency and orientation or 'attitude' in the water. Right now, all this must be sent up extra wires in the tether which we don't have. Onboard electronics could alleviate this. We would also like to explore the use of fiber optics for signal transfer: data up and down the tether and video signals to the topside. The advantages are significant in terms of the variety of sensors we could use and the quality of multiple video signals, however, so is the cost of the connectors and signal mixers, so this may have to wait for a period of years.

9.   Schematics
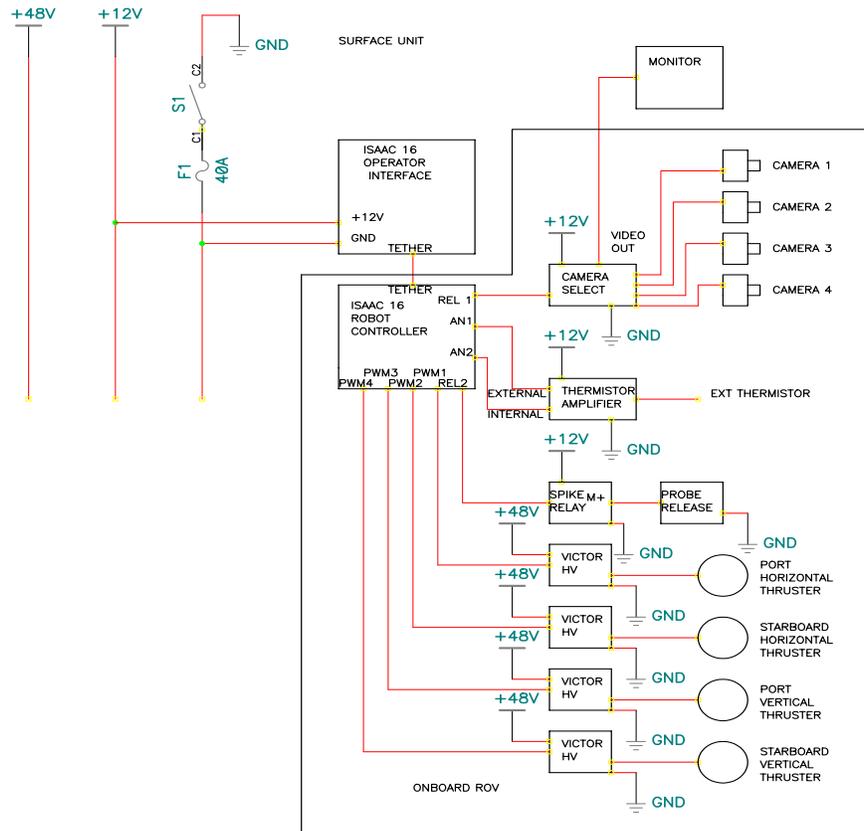
10. Ocean-based careers

Our team has been developing an interest in ocean-base activities and careers as a result of participating in our robotics team. This was facilitated by our school mentors and external advisers who arranged seminars, staged informal lectures and discussions, introduced us to ocean scientists and engineers who were available for seminars and informal questioning as well as advising us on our ROV design and components. We also had a try SCUBA evening at which many of the team members really had fun.

One of the external advisers was an oceanographer and described to us the intriguing training, education and research which is involved in becoming an ocean scientist. Several members of the team are looking at this career.

Oceanography is science that combines all of the classic disciplines, but is focused on the marine and coastal environment. So there are oceanographers with backgrounds and under-graduate decrees in biology, geology, chemistry, physics, geography, meteorology who focus their expertise on the oceans.   The fact is that the oceans are a system which includes all these subjects and their interaction makes up the complex system.

The professional oceanographer cannot afford to be ignorant of any of these subjects.   That's the reason that universities which teach oceanography almost all require their students to take courses in all these areas.   In addition, because doing research in the oceans is more difficult than on land, or even in space, scientists often study it remotely with sampling and data collection devices that are deployed from ships, aircraft. This means that the oceanographer must be comfortable in the use of technology and instruments.

Because oceanography is also conducted in a 3-dimensional environment and the oceans cover a vast area and can be extremely deep, the data collected sometimes covers enormous areas and depths. This means that a lot o data s collected so the oceanographer also has to be comfortable in the use of computers for data analysis, mathematics and statistics for understanding and condensing the information coming from it. So the oceanographer must become specialist in many areas – a "master of all trades".

Oceanographers work as research scientists in universities, government agencies, and for industries exploring or working in the ocean. Oceanographers may spend as much as 50% of their time to as little as 5% of their time in field research. Ship-board research is very expensive so many scientists have to plan their expeditions very well to complete their research. The sacrifice of being away from home for long periods is balanced by the excitement of research.

Appendix 1.   ROV Photographs: Atlantis Angler
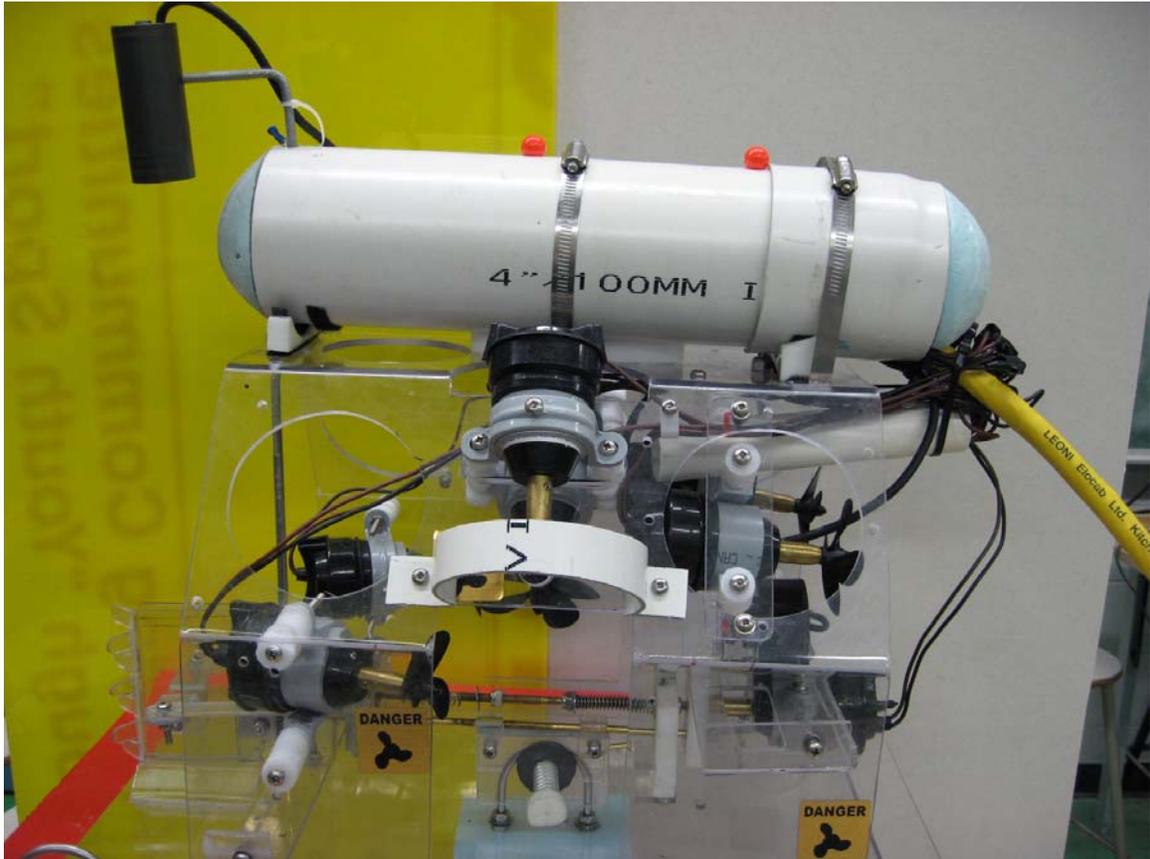
Side View (All tools attached)
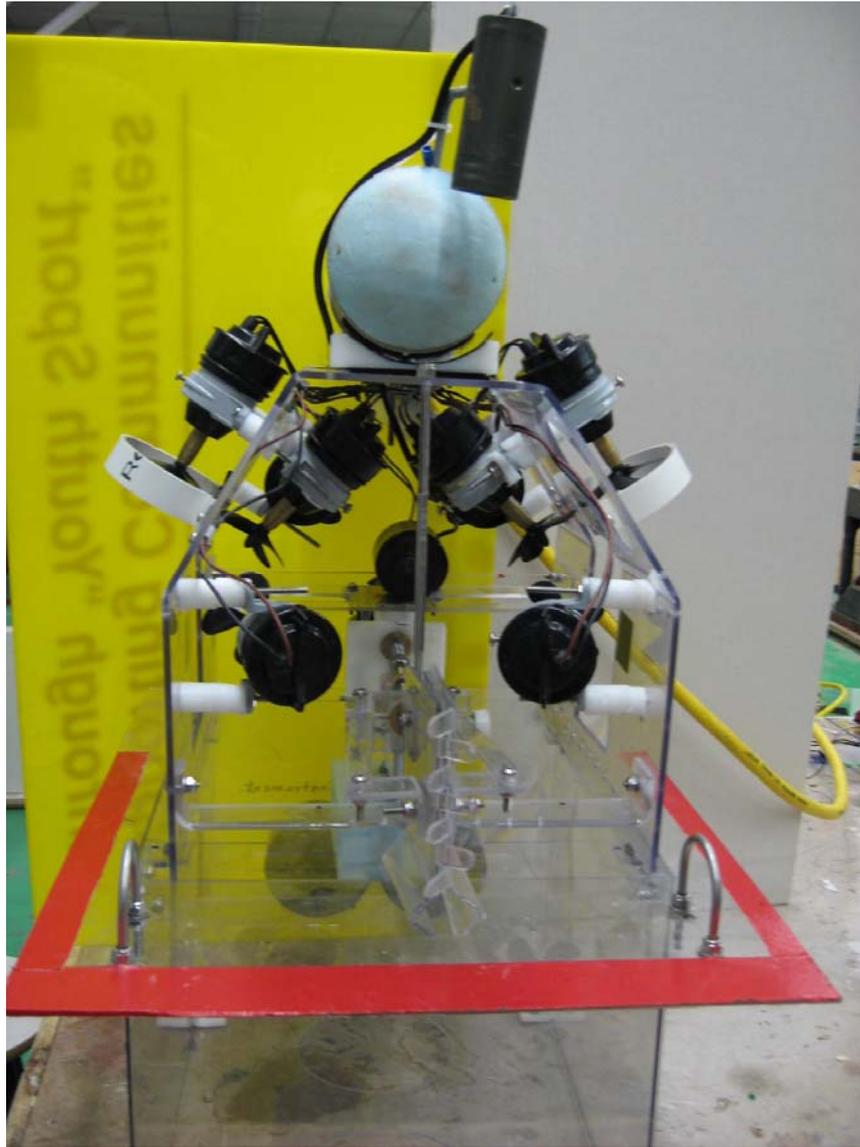
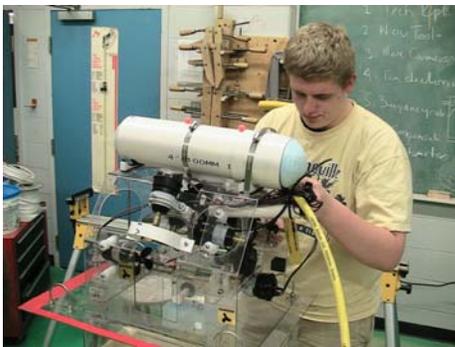Front View (all tools attached)

Appendix 2.   Team Photo Album

Working on electronics

Working on the chassis

Attaching the wiring

Drilling a hole into Lexan

Filing Lexan

Making cameras

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Appendix 3.   Budget and Financial Statement
(as of June 1, 2006)

Rev/Exp	Date	Source / Item	Amount
Rev.		Petro-Canada	$1000.00
Rev.		Marine Institute	$395
Rev.		Holy Trinity High School	$200
Exp	21/02/06	Terminal kit and stripper	$55.11
Exp	28/02/06	PVC Pipe and connectors	$29.10
Exp	23/02/06	Camera	$225.00
Exp	14/02/06	Props	$68.93
Exp	03/03/06	U-bolts,T's, ABS caps & fittings	$16.04
Exp	23/03/06	Stainless steel kit	$45.85
Exp	19/03/06	Materials for acoustic transponder	$12.70
Exp	10/03/06	Screws	$0.77
Exp	16/03/06	Lexan	$32.80
Exp	06/03/06	Plastic bender	$335.80
Exp	05/05/06	Phidgets eqpt..	$223.20
Exp	04/03/06	PWMs	N/A (loaned)
Exp	05/01/06	Tether	$106.00
BALANCE (exclusive of travel)			**$443.70**

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Appendix 4.   Acknowledgements

The Gonzaga Coalition High School Robotics Team would like to thank the many contributors who helped make this project possible. We would especially like to thank the following:

Our mentors (for their guidance, patience and dedication)

Our parents (for their generous support)

Marine Institute of Memorial University, St. John's, NL (test facility, .expertise and and financial aid)

Eastern School District, NL. (use of facilities and personnel)

Mayfair Marine, Johnson Pumps (thrusters)

Gonzaga High School, St. John's, NL (use of facilities)

Innovation, Trade and Rural Development, NL (thrusters, $395, materials, tether)

IPEX inc. (supplied plastic pipe frames)

Petro Canada ($1000 contribution)

Husky Energy ($1500 contribution, not received)

RBC ($50)

Exxon Mobil ($500 contribution, not received)

Holy Trinity High School ($200 contribution to HTHS student travel)

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Appendix 5: Student Team Member List

NAME	GRADE	SCHOOL
Thomas Allston	Level 3	Gonzaga High School
Jessica Anstey	Level 2	Holy Trinity High School
Josh Banfield	Level 2	Mount Pearl Senior High School
Matthew Bannister	Level 2	Gonzaga High School
Heather Bonnell	Level 3	Mount Pearl Senior High School
Trevor Brown	Level 2	Holy Trinity High School
Cait Button	Level 3	Gonzaga High School
Mark Courish	Level 3	Gonzaga High School
Kristin Courish	Level 1	Gonzaga High School
Iwan Davies	Level 3	Gonzaga High School
Maggie Dawe	Level 3	Gonzaga High School
Jon Howse	Level 3	Mount Pearl Senior High School
Katherine Hynes	Level 3	Holy Heart High School
Peter Phillips-Davis	Level 1	Gonzaga High School
Alex Ryan	Level 3	Gonzaga High School
Andrew Snelgrove	Level 1	Gonzaga High School
Scott Stevenson	Level 3	Gonzaga High School
Jacob White	Level 3	Gonzaga High School
Thomas Allston	Level 3	Gonzaga High School
Jessica Anstey	Level 2	Holy Trinity High School
Josh Banfield	Level 2	Mount Pearl Senior High School
Matthew Bannister	Level 2	Gonzaga High School
Heather Bonnell	Level 3	Mount Pearl Senior High School

Appendix 6. Flotation, Buoyancy & Drag Calculations

4 Inch ID PVC Pipe

Volume $_{part\ spheres}$ = 4/3 π r^3 x % of sphere

$\quad\quad\quad$ = 4/3 π $(5.08)^3$ [(Arc covered÷360)((Arc covered – interior triangle)÷360)÷(Arc Covered)]

$\quad\quad\quad$ = 4/3 π r^3 ((Central Angle/360) π r^3)(((Central Angle/360) π r^3) – (½ a b sin C)) ÷ ((Central Angle/360) π r^3)

$\quad\quad\quad$ = 4/3 π $(5.08)^3$ ($2\cos^{-1}$(1.2/5.08)÷360)(((($2\cos^{-1}$(1.2/5.08)÷360) π 5.08^2) – (.5x5.08x5.08sin($2\cos^{-1}$(1.2/5.08)))÷(($2\cos^{-1}$(1.2/5.08)/360) π 5.08^2)

$\quad\quad\quad$ = 4/3 π $(5.08)^3$ 0.354

$\quad\quad\quad$ = 232.884 cm^3

Volume $_{Pipe}$ = h π r^2

$\quad\quad\quad$ = 40 π $(5.08)^2$

$\quad\quad\quad$ = 3242.928 cm^3

Volume $_{Extra\ Flotation}$= h π r^2

$\quad\quad\quad$ = 5 π $(4)^2$

$\quad\quad\quad$ = 5 π 16

$\quad\quad\quad$ = 251.3274123 cm^3

Volume $_{Total}$ = 3242.928 + 2 x 232.884 + 251.327

$\quad\quad\quad$ = 3959.023 cm^3

5 Inch ID Pipe

Volume $_{Part\ Spheres}$ = 4/3 π r^3 % of sphere

$\quad\quad\quad$ = 4/3 π $(6.35)^3$ [(Arc covered÷360)((Arc covered – interior triangle)÷360)÷(Arc Covered)]

$\quad\quad\quad$ = 4/3 π r^3 ((Central Angle/360) π r^3)(((Central Angle/360) π r^3) – (½ a b sin C)) ÷ ((Central Angle/360) π r^3)

$\quad\quad\quad$ = 4/3 π $(6.35)^3$ ($2\cos^{-1}$(1.2/5.08)/360)((($2\cos^{-1}$(1.2/5.08)/360) π 6.35^2)-.5x6.35x6.35sin($2\cos^{-1}$(1.2/5.08)))/(($2\cos^{-1}$(1.2/5.08)/360) π 6.35^2)

$\quad\quad\quad$ = 448.435 cm^3

Length $_{Pipe}$ = 3959.023 cm^3 – 2x448.435 = h π r^2

$\quad\quad\quad$ = 3959.023 – 2x448.435 = h π 6.35^2

$\quad\quad\quad$ = 3063.153 ÷ (π 6.35^2) = h

$\quad\quad\quad$ = 24.181 cm = h

Formula For Drag

$Cd = D \div (.5\ r\ V^2\ A)$

Cd = Coefficient of drag in water (0.7)
D = Drag on the object
r = radius of sphere
V = Velocity
A = Reference Area

Area $_{4\ inch\ pipe\ cover}$ = 4 π r^2 x % of sphere

= 4 π (5.08)^2 [(Arc covered÷360)((Arc covered – interior triangle)÷360)÷(Arc Covered)]

= 4 π r^2 ((Central Angle/360) π r^2)(((Central Angle/360) π r^2) – (½ a b sin C)) ÷ ((Central Angle/360) π r^2)

= 4 π (5.08)^2 (2cos^{-1}(1.2/5.08)÷360)((((2cos^{-1}(1.2/5.08)÷360) π 5.08^2) – (.5x5.08x5.08sin(2cos^{-1}(1.2/5.08)))÷((2cos^{-1}(1.2/5.08)/360) π 5.08^2)

= 137.530 cm^2

Drag $_{4\ inch\ pipe\ cover}$ = $Cd = D \div (.5\ r\ V^2\ A)$
= 0.7 = D ÷ (.5x5.08 (1)^2 137.530)
= 244.578 N

Area $_{5\ inch\ pipe\ cover}$ = 4 π r^2 x % of sphere

= 4 π (6.35)^2 [(Arc covered÷360)((Arc covered – interior triangle)÷360)÷(Arc Covered)]

= 4 π r^2 ((Central Angle/360) π r^2)(((Central Angle/360) π r^2) – (½ a b sin C)) ÷ ((Central Angle/360) π r^2)

= 4 π (6.35)^2 (2cos^{-1}(1.2/5.08)÷360)((((2cos^{-1}(1.2/5.08)÷360) π 6.35^2) – (.5x6.35x6.35sin(2cos^{-1}(1.2/5.08)))÷((2cos^{-1}(1.2/5.08)/360) π 6.35^2)

= 212.865 cm^2

Drag $_{5\ inch\ pipe\ cover}$ = $Cd = D \div (.5\ r\ V^2\ A)$
= 0.7 = D ÷ (.5x6.35 (1)^2 212.865)
= 470.856 N

Appendix 7.   Bollard Pull Test Results

Johnson (Mayfair brand) 750 gph bilge pump motor -unaltered)

Time	Motor	Blade	Voltage	Amperage	(N)	
		Trial 1 - 3-blade propeller (50 mm diameter)				
2:29	750 GPH	3 Blade, 50mm Diameter		4	16	trial
2:30	750 GPH	3 Blade, 50mm Diameter	13.5	4	15	trial
2:30	750 GPH	3 Blade, 50mm Diameter	13.5	4	16	trial
2:35	750 GPH	3 Blade, 50mm Diameter	13.5	4	14.5	
2:36	750 GPH	3 Blade	12	5	12	
2:35	750 GPH	3 Blade	10	5	9	
2:36	750 GPH	3 Blade	8	4	7.5	
		Trial 2 - 4-blade propeller (70 mm diameter)				
3:19	750 GPH	4 Blade, 70mm Diameter	13.5	4	15	
3:21	750 GPH	4 Blade	12	5	13	
3:19	750 GPH	4 Blade	10	5	11.5	
3:20	750 GPH	4 Blade	8	4	9	
		Trial 3 - 4-blade propeller (70 mm diameter)				
3:25	750 GPH	4 Blade	13.5	9	16	
3:25	750 GPH	4 Blade	12	7	11	
3:26	750 GPH	4 Blade	10	6	8	
3:26	750 GPH	4 Blade	8	4.5	6	

Johnson (Mayfair brand) 750 gph bilge pump motor - compensated)

Time	Motor	Blade	Voltage	Amperage	(N)	
		Trial 4 - 3-blade propeller (50 mm diameter)				
4:12	750 GPH	3 Blade	13.1	10	18	
4:13	750 GPH	3 Blade	12	8.5	11	
4:14	750 GPH	3 Blade	10	7	9	
4:15	750 GPH	3 Blade	8	5.5	6	
		Trial 5 - 3-blade propeller (50 mm diameter)				
4:18	750 GPH	3 Blade	13.5	10	17	
4:19	750 GPH	3 Blade	12	9	13.5	
4:20	750 GPH	3 Blade	10	7.5	10	
4:21	750 GPH	3 Blade	8	6	6.5	
		Trial 6 - 4-blade propeller (70 mm diameter)				
4:30	750 GPH	4 Blade	13.5	10	19	Off Scale
4:31	750 GPH	4 Blade	12	9	14.5	
4:32	750 GPH	4 Blade	10	7	8.5	
4:33	750 GPH	4 Blade	8	5.5	6	

Unaltered motors			**Silicone Compensated motors**		
Voltage	4 blade N	3 blade N		4 blade N	3 blade N
13.5	16	14.5		19	17
12	11	12		14.5	13.5
10	8	9		8.5	10
8	6	7.5		6	6.5

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Measured Thrust of Unaltered and Compensated 750gph Bilge Pump Motors

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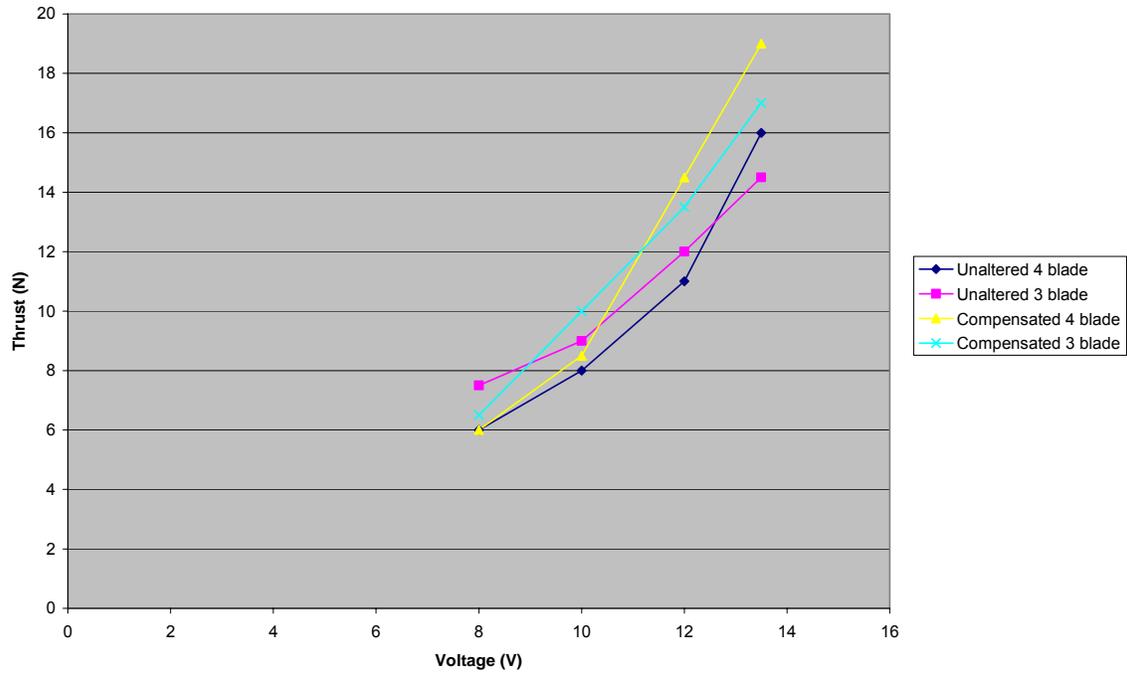
Appendix 8. Logic chart: Digital / Analog Controls

```
                    ┌──────────────────────┐
                    │   Laptop running     │
                    │   Visual Basic 6.0   │
                    └──────────┬───────────┘
                               │
                               ▼
┌──────────────┐    ┌──────────────────────┐
│  Logitech    │    │    Analog Inputs     │
│ 3-axis USB   │──▶ │   Phidgets 8/8/8     │
│  Joystick    │    │     Controller       │
└──────────────┘    └──────────┬───────────┘
                               │
                               ▼
                    ┌──────────────────────┐
                    │      Phidgets        │
                    │  4 Servo Controller  │
                    └──────────────────────┘
```

PWM 1	PWM 2	PWM 3	PWM 4

2 PORT Thruster Motors	PORT Vertical Thruster	STBD Vertical Thruster	2 STBD Thruster Motors
	PORT Vertical Thruster	STBD Vertical Thruster	
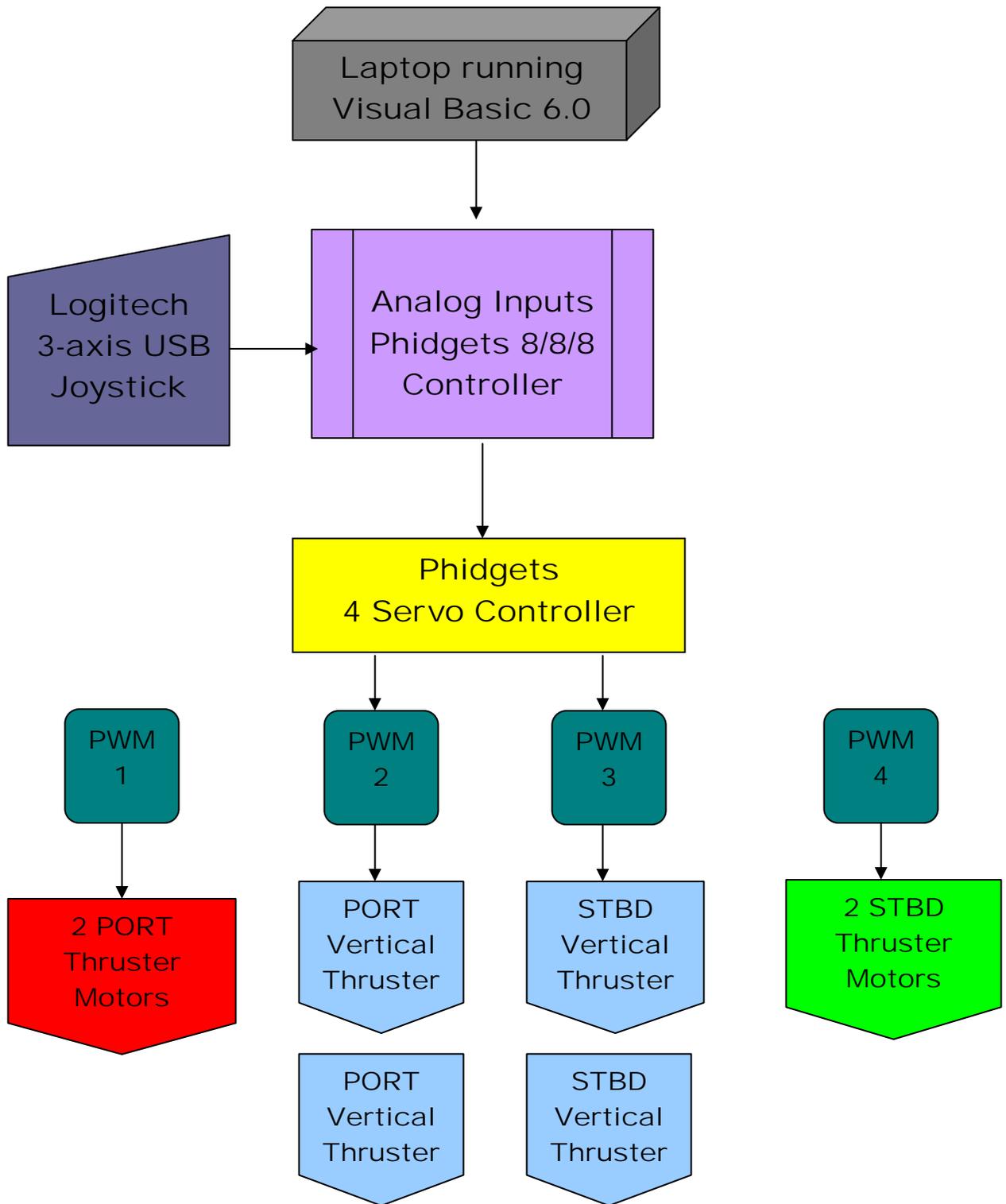
Wiring Schematic for ROV using eight (8) thrusters
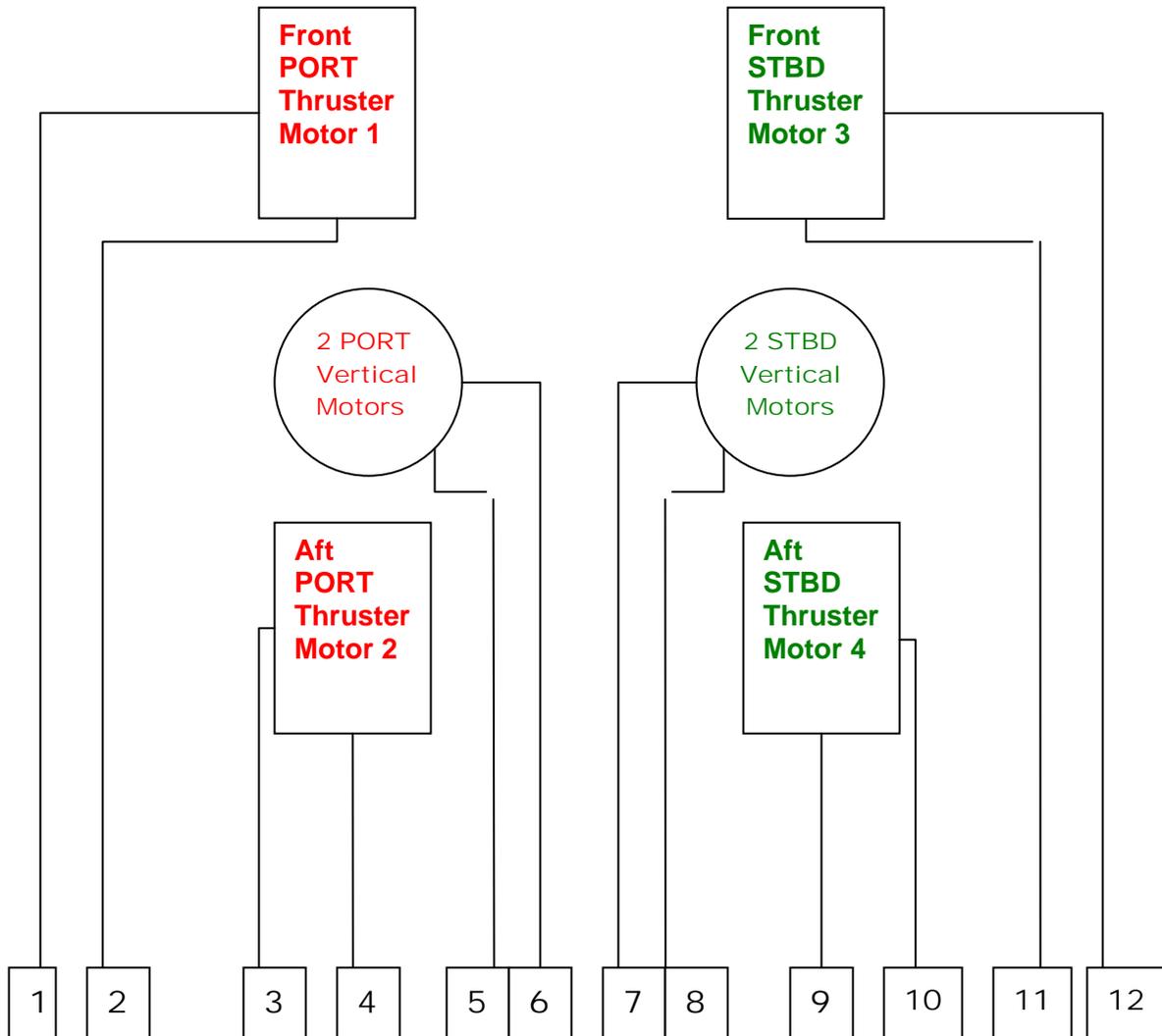
C1	1,3	2,4	5,7	6,8	9,11	10,12

1. This is the wiring configuration on the ROV, with 4 vertical thrusters.
2. The wires in the same block are joined before connecting to tether.
3. There are four pairs of power wires from the thruster array, each pair of wires powering two (2) thrusters and controlled by one Pulse Width Modulator, in the topside controller.

Software Logic Diagram

Visual Basic 6 programming is designed by the team to control thruster power.

Joystick input is analog and translated by Direct X to digital input values which are readable by Visual Basic 6. The joystick input is in two directional axes X (in the axis of the ROV) and Y (perpendicular to the main forward axis of the ROV). The horizontal twisting action of the joystick directs the sway (sideways) movement, enabled by switching the polarity of power to the alternate vertical thrusters

The twinned Port and Starboard thruster operations are straightforward. Both pairs of horizontal thrusters pushing in the same direction results in movement forward (or reverse) in the opposite direction. Turning is achieved by having the pair of vectored thrusters on one side of the ROV operating in a reverse direction to the alternate side.   Sway (sideways) motion is achieved by having the vectored, vertical thrusters on one side of the ROV operate in opposite direction from the alternate side.

The logic for the programming of these operations is illustrated below.