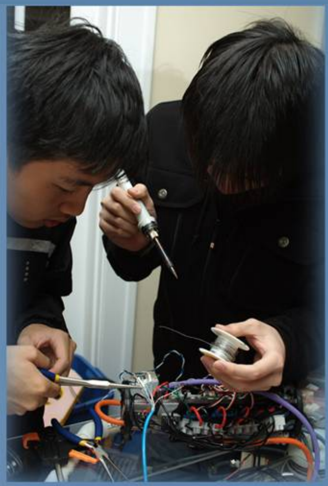
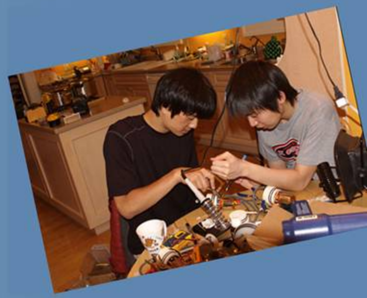
Saint George's School

SGS Robotics





Team Members: Collin Shuen Albert Chiang Harrison Fan Ray Yu Tim Wai Eric Huang Rich Hong

S.G.S. DEFIANT

Mentor/Sponsoring Teacher: Mr. Andrew Kay

NX-05

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1. Abstract

This year’s project marks the culmination of five years of experience in the MATE ROV Competition. The SGS Defiant is the largest ROV that SGS Robotics has made to date and is by far the strongest. All construction, including lathing and milling, was carried out by the team. Each part of the robot was carefully planned out before execution and issues were resolved as they became apparent. We set a budget this year of $2000USD, forcing us to design and purchase our parts carefully. We chose to build our own major systems, including the electronics, control bay, and four horizontal thrusters. We have utilized microcontrollers programmed by members of our own team, thus reducing costs. Our ROV is controlled by a PC joystick which communicates with the microcontroller via a computer. The signal is transmitted to this onboard microcontroller by a pair of RS-485 transceivers. All of the motors are controlled by ESCs (electronic speed controllers). The thrusters are constructed with cast acrylic tubing, polyester resin end-caps, shaft seal O-rings, and brushless motors.

2. The Team

Our collective comprises of seven members, each with a different area of expertise but all contributing to the greater whole which is SGS Robotics.

Albert Chiang Grade 12

Albert has been part of the robotics program since grade 8 and has competed in Scout, Ranger, and Explorer class competitions on both the regional and international level for the past five years. The central management of the team, Albert keeps everybody busy and coordinates the construction of the ROV.

Harrison Fan Grade 12

Harrison has been involved in our school’s robotics program for five years, making his mark as the chief electrician since his first. From power connectors to circuit boards, he has wired and soldered dozens of connections, sometimes the same ones twice. Harrison allows us to control the SGS Defiant with more than on and off switches.

Collin Shuen Grade 10

Collin joined the robotics team in his grade 8 year but was by no means an amateur. By far the most resourceful person on the team, Collin represents an integral asset and will lead his peers to success in the years to come. Collin provides the team the means of building an ROV with his tools, random materials in his basement, and experience.

Rich Hong Grade 12

Rich is the resident expert on programming in most language known to computers. He joined the team two years ago and since then, our control system has been complemented with microcontrollers, graphic user interfaces, and various programs for an array of uses. Rich makes our ROV move fluidly and gives us the capability to use a joystick.

Eric Huang Grade 10

Eric is a new member of the St. George's robotics program and has greater potential than any other member. Already doing grade 12 math and science, his intelligence will comes in handy when troubleshooting a wiring issue or coming up with new methods of accomplishing our goals. Eric will prove to be vital in years to come.

Tim Wai Grade 10

Tim is also a new member of the program and has shown great interest in the field of robotics. Though inexperienced, he is progressively learning the methodology behind the building process and the workings of an ROV. Tim represents a continuation of the St. George's robotics program.

Ray Yu Grade 10

Ray is the final member of the robotics team and is also the most eager to learn. By pitching in where he can, he is learning the basic skills of cutting, lathing, and painting. His dedication is shown through the fact that he refuses to get changed out of his uniform before beginning to work, even on weekends. Ray's future is still to unfold.

3. SGS Defiant

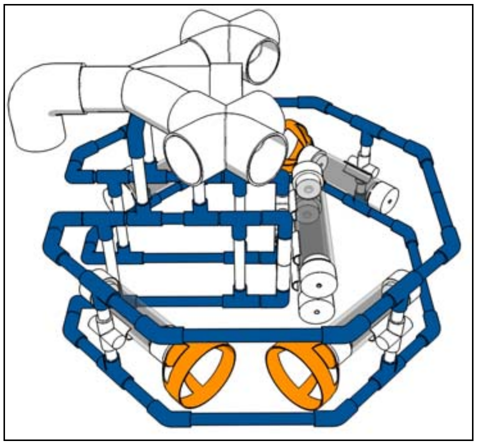


Figure 1 - 3D render

Figure 2 - Isometric view

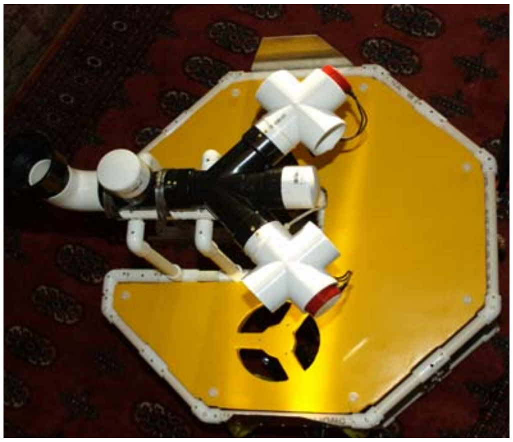


Figure 3 - Top view

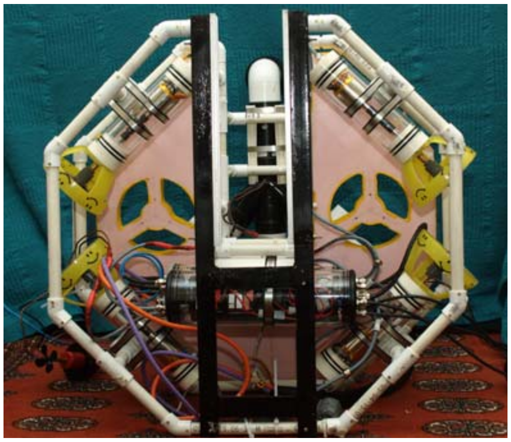


Figure 4 - Bottom view

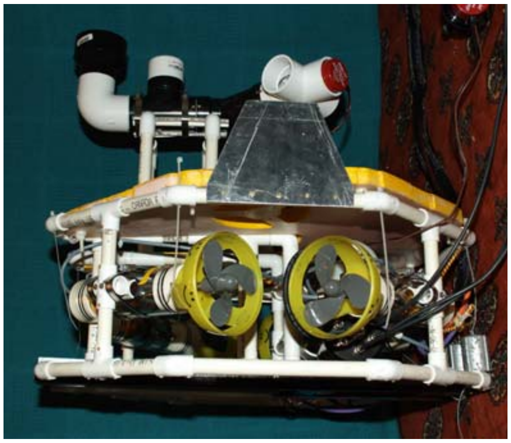


Figure 5 - Side view

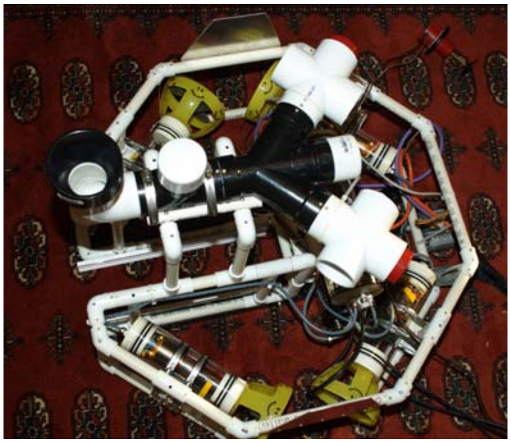


Figure 6 - Top view with float removed

3.1 Rationale

In the industry, engineering projects have budgets, deadlines, and specific client needs. Our general goals when building the SGS Defiant were:

- Budget under $2000USD
- Keeping to our budget by custom manufacturing our own thrusters and control system from scratch
- Center of mass at a constant location, regardless of the addition of the PAS*
- We may have a basic looking ROV, but it is geared towards completing the required tasks. That is why we did not include anything that is not required (superfluous sensors, fiber optic communications tether, manipulator arm).

Our individual mission rationales were:

Mission 1:

- Water current is countered with a heavy and sturdy ROV with powerful thrusters, capable of propelling the ROV in any direction
- Using an arm or even two arms is neither easy nor cost effective
- A simple mechanism (no electronics) that will be triggered automatically upon correct orientation of the robot will more or less guarantee success

Mission 2:

- The frigid waters must be taken into account when dealing with waterproofing; only O-rings rated for extreme cold can be used
- Take advantage of the cold by using the water to cool our thrusters and electronics
- Task 1
  - Simplest solution: get a finger to poke the O-ball
- Task 2
  - A solid surface like the ice makes it hard for a net to scoop up ping pong balls
  - Suck up the ping pong balls with a powerful on/off suction device that could be used for other tasks later on
- Task 3
  - PAS is heavy, greatly affecting ROV balance
  - Keeping it in the center of gravity will keep the ROV from tipping
  - A dedicated downward-looking camera is essential for targeting

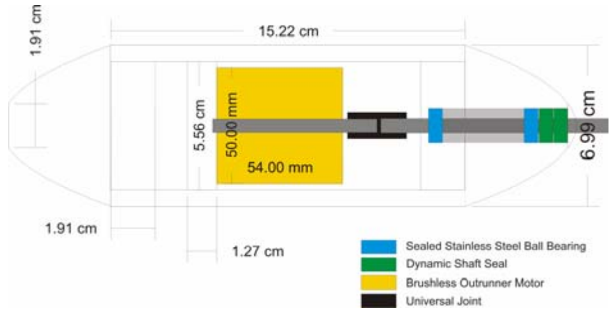
Mission 3:

- Suction is re-used for cap, special auto-dropper for gasket
- Hot stab should require an arm for the axes of motion required
- A solenoid is a cheap and very effective actuator

* Passive acoustic sensor

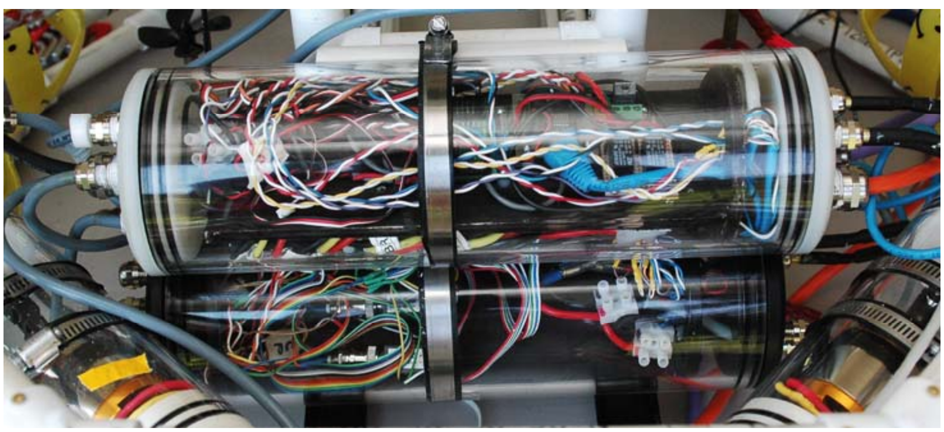
3.2 Vehicle Systems:

Thrusters



Explorer class thrusters are quite often the most expensive part of an ROV. Our thrusters are comprised of brushless out-runner motors as they are more efficient, require less maintenance, and provide more torque than brushed motors. They are housed in cast acrylic tubes with double static radial O-ring seals, while the shaft is sealed with double dynamic shaft seals. All O-rings being used are Buna-N (nitrile) rated down to a temperature of -40°C. Universal joints are installed to overcome any shaft misalignment due to mounting variations. Two ball-bearings are placed directly behind the shaft seals to minimize rotational out of round.

Electronics Bays



Our electronics are housed in cast acrylic 4” (10.16cm) tubes capable of withstanding more pressure than Schedule 40 PVC. The end-caps are sealed with a triple static O-ring system: two radial and one axial. IP-68 rated cord grips are installed into custom drilled and tapped holes in the end-cap for cable ingress.

PVC frame

As with most of our previous ROVs, we decided to construct the frame of the SGS Defiant with PVC pipe. It is cheap, widely available, and can be constructed and deconstructed quickly for transport.

3.3 Electrical Systems:

Communication

Our control system incorporates a Basic Atom 28 microcontroller, RS-485 (Cat5) communications protocols, relays, servo controllers, and electronic speed controllers (ESCs). Our video signals are transmitted by video baluns connected by twisted pair Cat5 cables. This method greatly increases the range of the video and reduces the size of the tether. The schematic of our communications network can be found in **Appendix A**.

Power

We utilize 24V power to not only increase available power at any give current draw, but also to reduce voltage drop through the tether. Our fuses ensure the safety of our power systems. A power schematic with inline fuses can be found in **Appendix B**.

Programming

The Basic Atom is custom programmed by two of our team members. A graphic user interface (GUI) was created for testing purposes and a single joystick controls all of the axes of motion on the ROV. A flowchart of this program can be found in **Appendix C**.

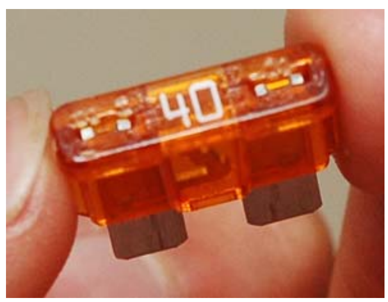


Figure 7 - 40A fuse that is installed in the topside power distribution box

3.4 Budget/Expense Sheet:

Items	Source	Cost	Donations
Brushless motors (4)	eBay	$200.00	
Brushless controllers (4)	eBay	$120.00	
Brushed controllers (2)	eBay	$60.00	
Rule 1100gph (1.156L/s) bilge pumps (4)	Wal-Mart	$120.00	
Sevyler SBM props (4)	Sevyler Canada		$32.00
Graupner props (2)	Hobby Shop	$6.00	
Traxx props (2)	Hobby Shop	$6.00	
Basic Atom 28 and Mini Atom Bot Board (2)	Lynxmotion	$110.00	
RS-485 (SN75176) transceivers (2)	HVW Technologies	$24.00	
Parallax servo controller	HVW Technologies	$45.00	
Igus Cat5e Cable 50' (15.24meters)	Igus		$250.00
Power cord 16 gauge 50' (15.24meters)	Home Depot	$15.00	
Miscellaneous wire	McMaster	$15.00	
2.75" (6.985cm) clear cast acrylic tubes (4)	McMaster	$76.00	
4" (10.16cm) clear cast acrylic tubes (2)	McMaster	$48.00	
Cord grips (12)	McMaster	$48.00	
Acetal 4" (10.16cm) diameter 6" (182.88 cm) length	McMaster	$35.00	
6mm diameter 318 stainless steel rod	McMaster	$21.00	
PVC pipe and fittings	Home Depot	$80.00	
Cameras (3)	Supercircuits	$60.00	
Video baluns (3)	eBay	$30.00	
Saitek joystick	Fry's	$39.00	
Electric solenoid	Electronic Goldmine	$3.00	
Scrap metal and plastic pieces	Mr. Kay's basement	$0.00	
Misc. items (screws, connectors, o-rings etc.)	Various sources	$200.00	
Total		$1,361.00	$282.00
Grand Total including donations		**$1,643.00**	
Budget (funding from Saint’s Auxiliary)		**$2000.00**	
Surplus		**$639.00**	

All costs are in USD and rounded up to the nearest dollar.
Items purchased online include shipping and handling costs.

4. Challenges:

Challenge 1
We are students in a school where there are countless activities in which we all take part in. As such, our main problem is getting the team members together to gather every day and give their best effort. Some days, our meetings only consist of two members, although there is a lot to accomplish. On other days, we are waiting for parts, yet all of our members are present. This problem is not limited to the members of our team; our teacher sponsor is not always on time to meet us on weekends.

Solution 1
In any engineering project there are the engineers and designers; however, there must always be at least one person managing the schedule. Proper team management is the key to solving this problem. Thinking ahead of time, checking on the stock of resources, and checking the availability of the pool are some menial tasks that are just as important as the actual building of the ROV. We must even make sure that our teacher knows exactly what we want to accomplish and that he has to put some effort into being on time. We did not start as the most organized students in the school, but this robot has forced us to deal with scheduling and timing.

Challenge 2
Though we have a relatively large amount of human resources, this cannot be said about our material resources. We did not purchase $750 commercial thrusters because not only do they cost an unreasonable amount for an ROV of this scale, but also because buying pre-made components is not in the spirit of the competition as it does not teach us about the internal processes. That said, we did encounter many problems with this approach. Mainly, our custom made components tended to not work periodically due to unexpected issues.

Solution 1
We did not plan our custom made systems overoptimistically. We expected issues to arise and such we incorporated a design that would allow testing of subsystems and constant opening and closing of the housings. Instead of sealing the thrusters with marine sealant to ensure a secure and permanent seal, we used a number of O-rings so that anything airtight can be opened if the need arises.

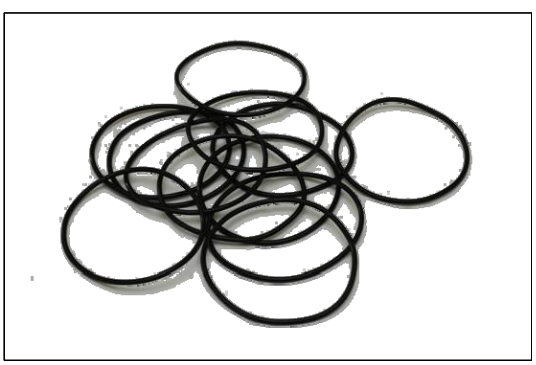


Figure 8 - Using O-rings allow us to be able to open and close our watertight housings

5. Troubleshooting:

Definition: Troubleshooting is a form of problem solving. It is the systematic search for the source of a problem so that it can be solved. Troubleshooting is often a process of elimination - eliminating potential causes of a problem.[1]

> *It is the SGS Defiant's maiden test day. The pool is warm after swim team practice has ended. Placing the robot in the water, we fire her up. All systems are normal. With sweat rolling down our brows, we push the joystick upwards. She stutters, and moves to the left. Then, we push up-left, hoping to induce a forward-left movement. Instead, the renegade robot surges backwards, then left, then we see a prop loosening and we lose one of our thrusters. We abort and retrieve the ROV. The affected thruster feels warm*

Panic ensues.

What went wrong?
The process of troubleshooting this issue not only tested our powers of deduction, but many of the safeguards and precautions we had designed into the Defiant.

1. With an underwater robot, the first fear is always a leak in the waterproofing. Thankfully, we designed and built all electronics housings out of transparent material. Thus, a quick peek into the transparent acrylic tube containing the main electronics housing revealed that waterproofing was not the problem.

2. We go through the checklist of possible ailments: RF interference, crosstalk, loose screws, and damaged thrusters. Our attention was finally pointed to the actual cause of the issue; a pair of wires was connected incorrectly. We now have two options. As our control system operates off a software-controlled microcontroller, we can simply switch two numbers in the coding and everything would be fine. However, we can also attempt to keep things consistent and physically fix the issue.

3. After thoroughly drying the robot, we pull out the electronics housing – time for disassembly. Here, we now experience the full benefits of an organized, "plug-and-play" design as a result of terminal blocks, as opposed to hardwiring through soldering. Removing the electronics, we now have to disassemble it into various subsystems for testing. Thankfully, good labeling of components and wires makes this part a cinch. We easily locate the crossed wires and with four turns of a screwdriver, the wiring is repaired. We now reseal the electronics housing carefully as not to damage the O-ring seals and do a quick test to ensure that it is fully sealed by dunking it in a sink and watching for bubbles.

4. We are now ready for another test.

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[1] "Troubleshooting." *Wikipedia, the free encyclopedia.* 23 May. 2007. <Reference.com http://www.reference.com/browse/wiki/Troubleshooting>.

6. Future Improvement

Though three of the team's seven members are graduating and will not be constructing an ROV next year, the future of SGS robotics cannot be considered bleak. We now know that we can construct thrusters typically worth over a thousand dollars each for only a few hundred. The next ROV will follow roughly the same rationale as this year, custom designed to accomplish the tasks as quickly as possible.

A notable improvement that could be made would be to the ROVs vertical propulsion system. Currently, we are using two modified bilge pump motors installed vertically on a fiberglass foam float to provide upward or downward thrust. Not only does this provide barely sufficient thrust, it also limits our ability to submerge down to 70meters. These bilge pumps are only sealed with basic grease boxes and would definitely give out when under excess pressure. Next year we may construct custom motors for the vertical thrusters similar to the lateral thrusters. This would require reversible 24V brushless ESCs. These are nonexistent and we would have to take up the difficult task of building and programming them ourselves.

Figure 9 - One of the two vertical thrusters installed in this year's ROV

7. Lessons Learned

In many ways, this experience has been about far more than just a mere robot. Firstly, it is about the education. We have acquired a myriad of technical skills, ranging from hands-on experience with the lathe and mill, to salvaging useful parts from old junk computers. From the Dremel to the belt grinder, we have become proficient at wide range of tools. And of course, we know to always put safety first.

Secondly, it is about the mistakes. We learn best by making mistakes, and thus we have learnt a lot. From lathing too much off to drilling the wrong sized hole, all of us have made mistakes and learnt from them. We have become better for having been worse.

Lastly, and most importantly, it is about the team. Some of us started of as classmates, others two grades apart. After having worked non-stop for almost a year, we have grown to be far more than that. We have become a synergetic group that works together and gels. We pass tools without calling for them; we know when to pitch in and when to stand back. Whatever the end result, it is the memories we will treasure most.

8. International Polar Year

The International Polar Year is a large scientific programme focused on the Arctic and the Antarctic from March 2007 to March 2009. [It] will involve over 200 projects, with thousands of scientists from over 60 nations examining a wide range of physical, biological and social research topics. It is also an unprecedented opportunity to demonstrate, follow, and get involved with, cutting edge science in real-time.[2]

8.1 The Arctic

One of the few comparatively clean parts of the world, the Arctic, is facing the effects of pollution from around the globe. One may wonder why this is important, as nobody would consider living in this area. However, there are many small communities which live in the Arctic regions of Canada, some of which have electricity, schools, police, stores, etc. The largest group, the Inuit, live along the coast and still hunt seal, caribou and whales.

Due to the pattern of worldwide sea and air currents, the Arctic has become the dumping ground for airborne pollutants from urban areas. This will soon affect the local populations as their primary source of food is the wildlife tainted with the pollutants. We may soon cause irreversible damage to the ecosystem of the pristine Arctic as a result of everyday exhaust and contaminants.[3]

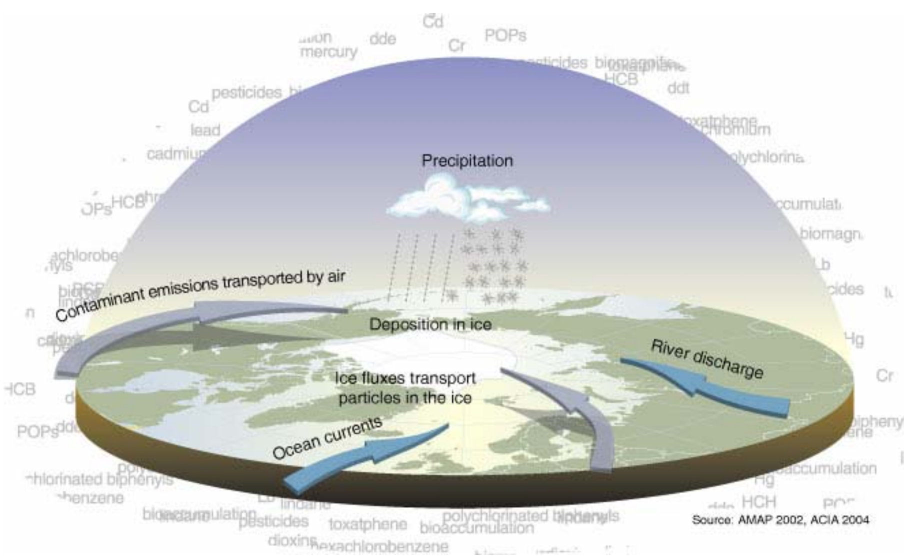


Figure 10 - Pollutants in the air travel to the Arctic

[2] "About IPY." IPY 2007-2008. 23 May 2007 <http://www.ipy.org/index.php?/ipy/about/>.
[3] "Canadian Arctic Contaminants Assessment Report II." Indian and Northern Affairs Canada. 28 June 2006. 24 May 2007 <http://www.ainc-inac.gc.ca/ncp/pub/physum_e.html>.

8.2 The Antarctic

On the other end of the world, Antarctica seems to have suffered little from the effects of global warming. It is the coldest place on Earth due to its geographical location and high altitudes. Regardless, there are over one thousand inhabitants of Antarctica doing various research assignments at the moment. As can be imagined, the low temperatures in conjunction with extreme variations in day length make living in Antarctica quite difficult.

In reality, the inhospitable and uncivilized world of the South is perfect for a very wide field of research. Many scientists are housed in the famous McMurdo Antarctic outpost where they can study organisms adapted to extreme cold, study sky untouched by light pollution of cities, or study some of the world's oldest ice.[4]

In contrast to the relatively more primitive life of the Arctic communities, those living in Antarctica are fortunate enough to have relatively decent living conditions. Massive air transports are capable of bringing necessities to McMurdo multiple times a year and immense heaters coupled with cosmic bowling adds a touch of home to the world of ice.

Figure 12 - A weather station being set up[5]

Figure 11 - A C-141 transport being refueled

[4] (June 2002) in Stonehouse, B. (ed.): *Encyclopedia of Antarctica and the Southern Oceans*. John Wiley & Sons. ISBN 0-471-98665-8.

[5] Pictures of Antarctica courtesy of *Origins Exploratorium Antarctica*

9. Reflections

We started off as seven very different individuals with a single goal; we are now a group of highly focused individuals with the skills to go into the industry and make a difference in the world.

> *"Where are you guys? You need to get cracking on the robot!"*
> *"We've been at Collin's house until midnight for a week now working on it."*
> -Conversation between Mr. Kay and the team

Looking back, all the sleepless nights have paid off. We now know how to lathe and mill a multitude of different materials, how not to drill holes randomly, and most importantly, how to work as a group on a single project. We have worked with electronics and programming at a level most post-secondary students cannot grasp (though sometimes we were distraught ourselves), familiarized ourselves with the tools and resources available to us, and applied the seemingly useless science of high school in a practical setting.

After this year's competition, some of us will stay to fight another year, but some of us will move on and leave the school that we have been almost living in for five years. However, we will all be able to walk away one day, knowing that a competition such as this one taught us more than any class or teacher could ever teach.

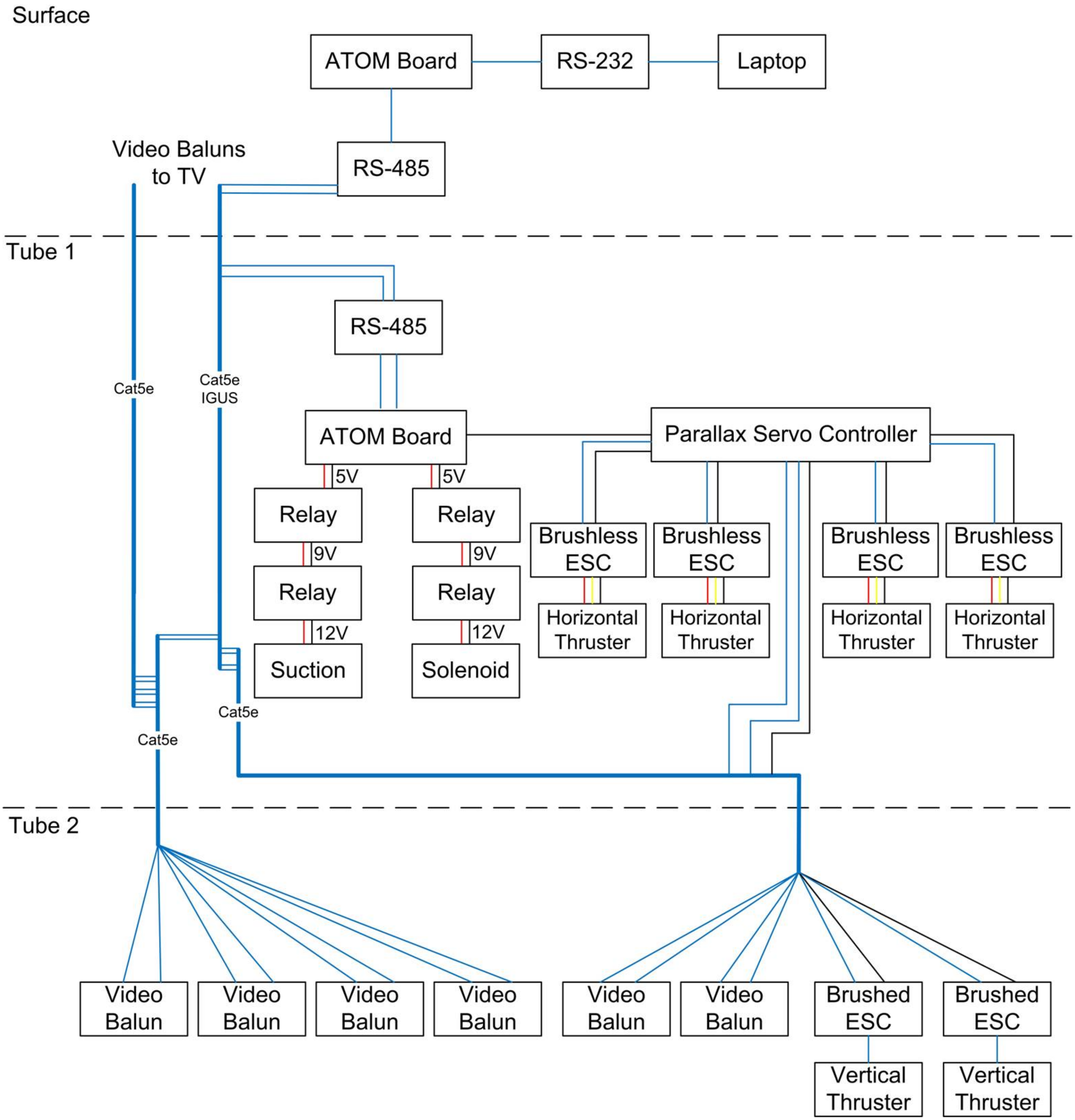
10. Acknowledgements

SGS Robotics would like to thank:
Dr. Donald Shuen for his time, financial contributions, and mentoring,
Mr. Andrew Kay for enrolling us in this year's competition,
St. George's Auxiliary for the financial support of our club,
McMaster-Carr, RP Electronics, Lee's Electronics, and Home Depot for supplies,
Memorial University of Newfoundland for hosting, and
The MPC Foundation, MATE, judges, officials, and pool staff for making this year's competition possible

11. Appendices

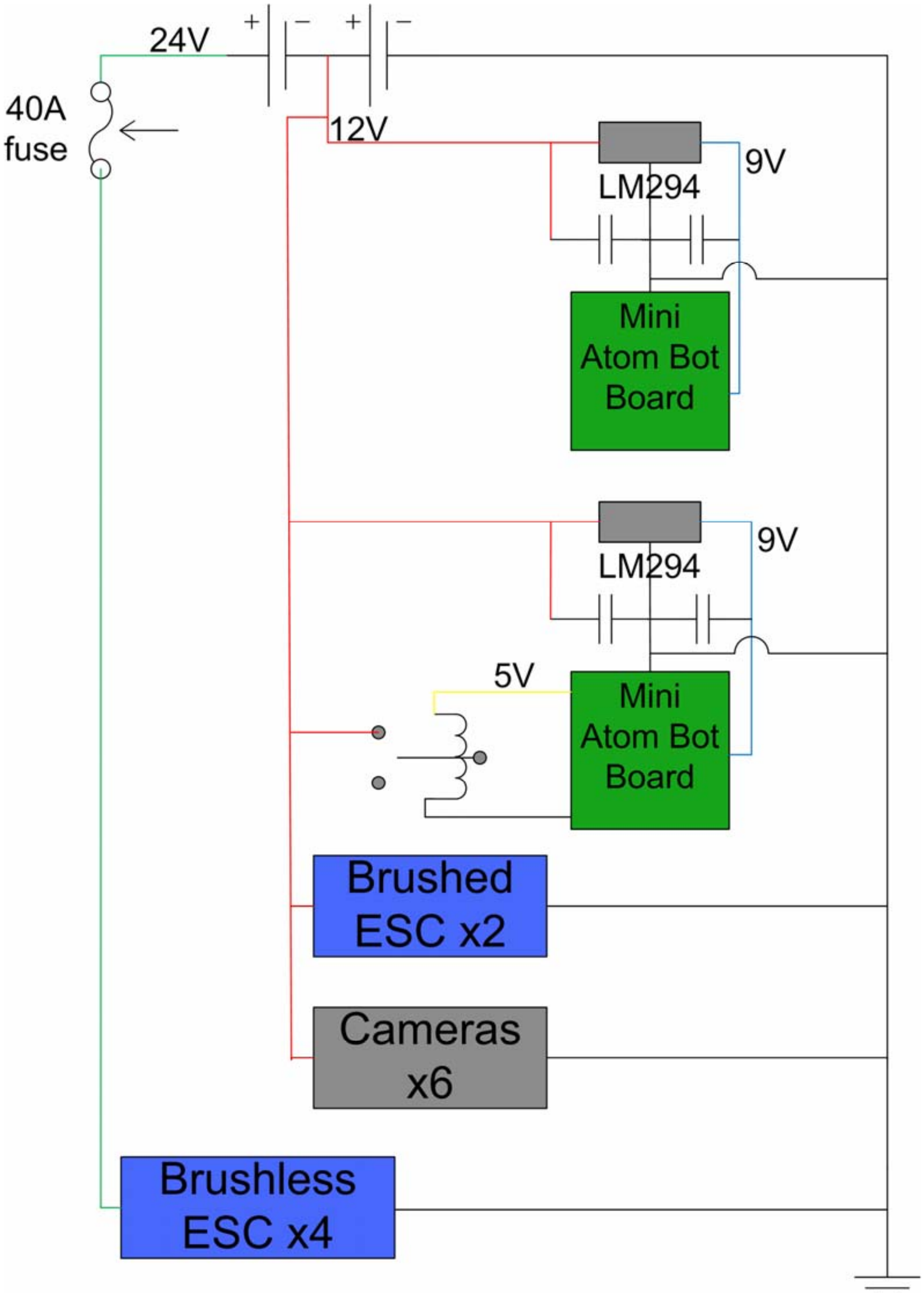
Appendix A

Communications Schematic



Appendix B

Power Schematic



Appendix C

Programming Flow Chart