Spartan Scuba Squad

Presents "Maurice"

Stephenville High

Stephenville, Newfoundland

Left to Right: (Back) Adam White, Patrick Aucoin, Chris McDonald(mentor), Matthew Tabor(captain), Hillary Stacey, Tom MacIsaac(mentor), Chantal MacIsaac, Hannah Bennett, Thomas MacIsaac

(Front) Thomas Ford, Bree Besaw, Travis Marche, Steven Smith, Laura Alexander, Allan Sutherland

Abstract

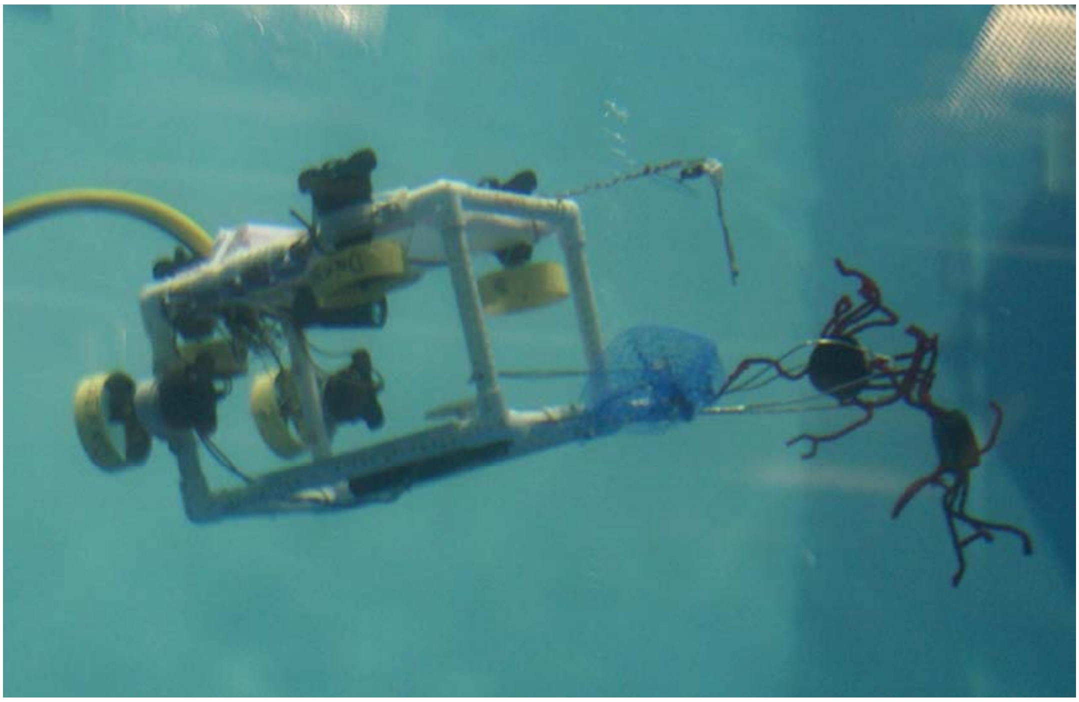
Spartan Scuba Squad is a team made up of approximately fourteen students and two mentors from Stephenville High in Stephenville, NL. In September of 2007, the team devoted themselves to the International ROV competition directed by the Marine Advanced Technology Center.

It is mandatory for all competing teams to design and build a remotely operated vehicle (ROV) that can properly complete three specifically outlined missions in efficient time. We organized our team to find ways to solve the three missions. Our team's main priorities were the functionality and maneuverability. To achieve this, we decided a rectangular CPVC frame and a hand like claw would work the best. The hand-like claw was very efficient and helped us pick rocks off the black smoker and props off the bottom of the tank. The PVC pipe is an easily accessible and inexpensive material that we already had. It is light weight and it doesn't resist the water due to the open framed shape.

Within our team it was strategically done that each member of the team has a specific task to complete. These groups came together and produced one very impressive R.O.V, and one very fun experience!

Table of Contents

Our ROV "Maurice" Figure 1



Design Rationale 1.0

Our ROV was built to be lightweight, hydrodynamic, and highly maneuverable. We had a camera that we received last year, so we had to focus on building around its field of view, which limited the size of our ROV. The tether had already been supplied so we had to work within its limits,

In order to make room for tools to be built, we had to keep a space that would allow for a motor or other objects to be attached. To do this, we left a bare spot in the ROV near the front. This was all taken into consideration as we also had to keep the cost at a minimum.

Our design was also built around achieving neutral buoyancy, so we had to incorporate foam into the project. The foam displaces water without adding any significant mass. Our ROV ended up being extremely compact, which allowed us to increase the maneuverability and speed in completing our missions.

We wanted to achieve all three tasks in one dive, so we created three different tools to help us complete in the fastest time possible. To achieve this, we used a claw, a net, and a temperature probe. We originally attempted to use a multi-tool, but realized it was not practical without design and goals.

Frame 1.1

Our frame consists of 1 inch CPVC (Chlorinated polyvinyl chloride) pipe constructed into a rectangular frame. CPVC is very easy to work with and can be easily drilled, fitted, cut and tapped. The frame has holes drilled in it to reduce air bubbles and mass. We used this design because it was very simple, and just worked. Also it fitted our budget, as all pieces were found around our shop and cost us nothing.

Thrusters 1.2

The motors used to maneuvered our ROV are 5000 L/H Johnson Bilge pump motors. These motors draw 5 amps maximum and average around 3 amps. These motors drive a 70mm propeller. They are attached by 3mm of PVC pipe and PVC bracket. The shrouds are made from a hard plastic bottle and attached with a V shaped piece of plexi-glass.

The thrusters were strategically placed on the frame of our robot to achieve maximum speed and maneuverability. Three motors were place along the top of the robot, two in the front at both the left and right corners, and one in the rear, place in the middle. These motors give us the ability to tilt, rise and sink. We placed more motors on the front then back to give us better lift when carrying objects underwater. The other two motors were place in the rear of the robot and were used to give us forward, backward and left and right thrust.

Buoyancy 1.3

Our design was also built around achieving neutral buoyancy, so we had to incorporate foam into it. The foam displaces water, without adding any significant mass. The foam used on our ROV is Owens Corning Celfort 300 polystyrene foam. It has a compressive strength of 210kPa and the hydrophobic properties are 0.7% water absorption kPa. Having strong foam is important because if it is not strong enough when we descend into the pool the foam will compress, lose volume and buoyancy that we need to be able to resurface. Pa stands for pascal which is a SI derived unit to measure pressure or stress. kappa is used to measure air-pressure and it is most commonly used. We will have around 20.9 kPas of pressure above us.

Tether 1.4

The tether we used was measured at 11.27m long; it is neutrally buoyant and contains ten sixteen gauge wires, a coaxial cable and a shielded twisted pair. The tether is covered with protective polyurethane coating to prevent damage and electric shock.

Eight of the ten sixteen gauge wires power the five thrusters. The remaining two wires power the tool motor. The shield from the twisted pair provides power to the camera and temperature sensor. The coaxial carries the video back to the surface. The shield of the coaxial is the ground wire for the camera power and the sensor.

Camera 1.5

On the ROV we used the LCA 7700c. The camera uses a 12 volt DC power source. The camera has a 3.6 mm 192 degree lens. The LCA 7700c is able to give us great picture underwater while doing our missions. The camera is completely waterproof, lightweight, has a wide angle view and is specifically designed for ROV use. We placed the camera on the rear, looking over our tools and the front of our ROV.

Tools 2.0

We used multiple tools to complete the missions assigned to us for this year's competition. The tools used include a working claw, an attached net, and a temperature probe. The temperature probe allowed us to measure very accurate temperatures for that particular mission. The net is very simple, and allows us to complete the collect the black smoker mission. The claw is the most impressive tool on our robot, and is made to work by a power window motor and some simple cables and piping.

The Probe-2.1

The temperature probe is designed to measure the temperature of the water being ejected from the pipe. To achieve this we use an AS35 temperature sensor, which has a linear voltage output proportionate to the temperature. The voltage drop across a silicon diode changes linearly with a change in temperature. This chip uses this principle to measure temperature. The chip amplifies and shifts this voltage drop so that 0 degrees Celsius will output 0 volts, and will increase 10mV for every degree Celsius. Using this formula we can accurately measure temperature

Figure 2 “The Probe”

The Claw-2.2

The claw was designed to complete the task of picking up crabs from confined spaces, and also from open spaces. After a lot of discussion, we came up with the idea of coat hangers and a PVC pipe. They were attached to a power window motor, which rotated, causing the claw to expand and contract, like that of a fish's jaws. The claws design has been tweaked many times, for instance once in St. Johns after a test run we decided we needed better grip on the crabs, so we added electrical ties. We believe that now we have the best design possible.

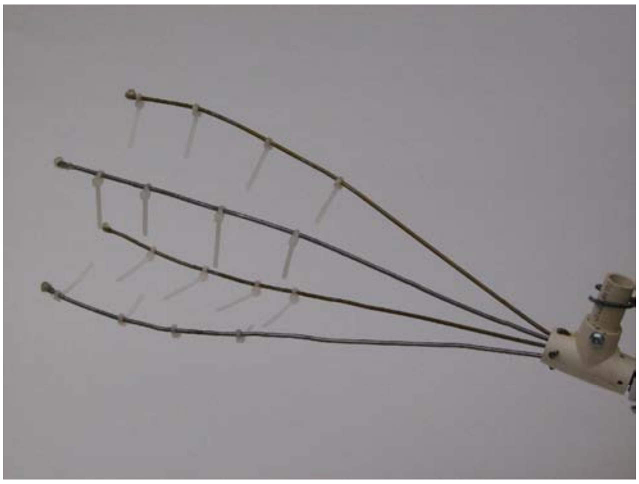


Figure 3 "The Claw"

The Net-2.3

The net is a simple tool attached to the robot by a bent clothes hanger. It is curved to the shape of the stack to better grasp the rocks. Underneath the frame is a simple net designed to catch rocks knocked off by the frame of the net.

Figure 4 "The Net"

Control System-3.0

When deciding on the control system for our ROV, we had to take multiple things into consideration. Important aspects such as high accuracy, low latency, low cost, and availability of products influenced what options were realistic to us. The electronic control system we chose is simple, accurate, and well-suited for our needs in this competition.

Commands are sent from a game controller to the laptop user interface where they are processed and forwarded to the micro-controller. The micro-controller then sends control signals to six different motor drivers, while a voltage is measured from the temperature probe.

We decided to use an ATMega32 8-bit micro-controller for our control system because it has multiple peripheral features that benefit our ROV. We use analog to digital conversion for our temperature probe when measuring voltage in relation to temperature. Timers and PWM enable us to control the speed of our motors. To convert our data from the parallel bytes of the laptop to serial forms of the micro-controller, we use a universal asynchronous receiver/transmitter.

Electronics-3.1

Electronics used include a microcontroller, 3 motor driver boards, fuse block, voltage regulator and a USB (universal serial bus) to serial converter. The Microcontroller communicates with the PC via the USB to serial board. It generates signals to control the motor control boards, and measures the temperature sensor output voltage.

Fuse Block-3.1.1

The fuse block distributes power to the various electronics. Power enters through a main 25A fuse, which is split through three 10A fuses and one 1A fuse. The 10A supplies power to the motor driver boards and motors. The 1A fuse powers the microcontroller, camera and sensor.

USB To serial Converter-3.1.2

The USB to serial converter consists of a FT232 integrated circuit(IC). This IC provides us with a transistor to transistor logic (TTL) level serial port to match the microcontroller, and presents windows with a virtual commport (VCP) that acts as a regular serial port.

Micro-controller-3.1.3

The Micro-Controller we used for this project was the Atmega 32 micro-controller from Atmel. This is a high performance, low power board. The chip offers four PWM Channels, 32 programmable I/O lines and programmable serial USART. The chip operates between 4.5 – 5.5 volts. The Chip works extremely well and is very easy to program and work with.

Motor Drivers-3.1.4

The motor drivers used were two Pololu dual motor driver carrier boards based on the fully integrated H-bridge motor driver chip the VNH2SP30. Each board has two of said chips to power two motors per board. These drivers require three wires per motor, one PWM (pulse width modulation) and two direction inputs. The chips used in this board were originally designed for power windows and other automotive applications. They can handle 30A and have a very low on resistance which gives them very little heat dissipation.

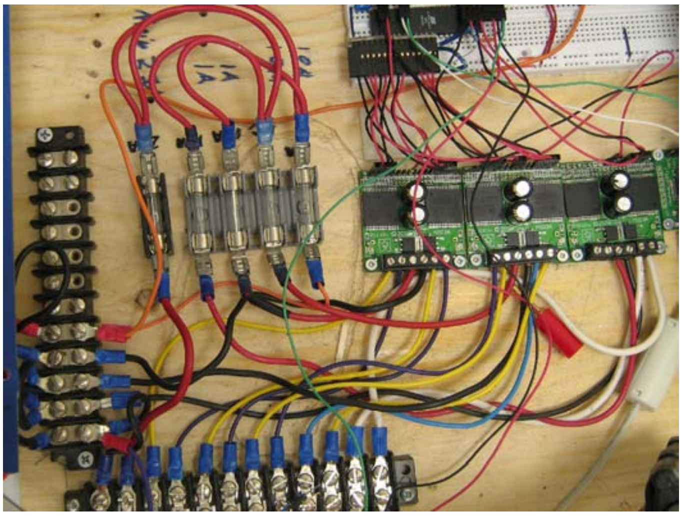


Figure 5 “The Electronics”

Software-3.2

The software of our robot acts as the virtual medium between our physical controller input and the robot itself. As explained in the next two sections, portions of visual basic and assembly code we wrote act to interpret, receive and send information from our controller, microcontroller, and temperature probe.

Visual Basic-3.2.1

Visual Basic interacts with the direct input to receive axis information from the joystick. The various axis values are then mixed to produce the motor directions and speeds. These speeds and directions are then sent as a frame via MSCOMM DLL (dynamic link library) to the micro-controller.

The first task of the visual basic program is to set up data structures for the DirectX and initialize the joystick and Serial Port. When changes in the joystick occur, a function is called where we read in the joystick axis and buttons.

The joystick axis's return a value from 1 – 10,000 and a little math is required to calculate the motor speeds and directions. After we read in the values we subtract 5000 to get a vector of the joystick position from center. We then mix the x and y axis for the forward and back and left and right thrusters. This is done by having the primary axis control the speed of both motors while the secondary axis is the difference of speed between the two motors. We then scale the magnitude of the value after mixing down to a range of 0-254 for the PWM motor speed. We also calculate the motor direction byte by checking if each motor speed is greater or less than zero. Each bit corresponding to motor directions are logically OR'd together to complete the motor direction byte. Finally we transmit a frame of 6 bytes starting with the start byte (0x55) followed by 4 PWM motor speeds and the motor direction byte.

We have to check the joystick buttons one by one. The buttons return a value corresponding to how long the button has been pressed. Anytime a button has been pressed for a value of 10 we consider the button to be pressed, and send a command to the microcontroller corresponding to that button. Button X starts our claw motor, A stops it, B also allows us to run the motor the opposite way of X.

The other major function of our software is the receiving of the temperature from our probe. On the MSComm event we check for the successful reception of three bytes. The first byte is a start byte, followed by a high byte and a low byte which contain the temperature reading. We multiply the high byte by 256 and add it to the low byte to obtain our ten bit value. We have to then multiply this by our volt per step which is the reference voltage divided by 1024 steps. Since our temperature probe outputs 10mV per degree Celsius we simply multiply the voltage by 100 to get temperature. This value is then displayed in a text box.

Assembly-3.2.2

The first step in our microcontroller program is to set up the peripherals that are being used with our micro-controller. Once this is completed, we enter the main loop. In the main loop, we continuously check to see if an analog to digital conversion is in progress. If so, we then wait until the conversion has been completed, and read in the results. Next we check to see if the universal asynchronous receiver transmitter (UART) is clear. This enables us to transmit the analog input number, low byte, and high byte. Once these bytes are transmitted, we repeat the main loop process.

When a byte is received, an interrupt occurs. When an interrupt occurs the current program state is stored to RAM and the interrupt sub routine (ISR) is executed. The ISR reads in the byte from UART. First ISR checks to see if we are receiving a frame. If we are receiving a frame, the counter will be non zero, and will indicate which byte we are on. If the counter is zero, we look at the content of the byte for a command.

There are five different commands. The command 55 hex indicates the start of a frame, and it then sets the counter to 5. The command 54 hex starts an A2D conversion. The command 53 hex stops the tool motor. The command 52 and 51 hex turn the motors left or right respectively.

Describe One Challenge 4.0

During our building process we have encountered several obstacles. However, one comes out into the forefront, the temperature probe. Originally we used a Thermistor. However, this was inadequate and did not operate well underwater. So we changed direction. We used the AS35 chip connected to wires which led to our main system. The AS35 is a highly precise temperature probe. This worked much better, for a time. However misfortune was on the horizon. We used an improper capacitor. It was too large. Consequently, we switched it out for a smaller one. Also, we had some problems with wires corroding around the joints around the AS35. So, we re-soldered the chip and covered the joints in epoxy. This resolved the issue.

Trouble Shooting 5.0

As a team we all followed a set of simple steps to trouble shoot. First we would look at what the problem was, and then isolate it. Next we decide on what the problem was how we can fix the problem. We then execute our final decision on the problem. If these steps don’t work, we return to step one and start again

During the testing of our first prototype the motors weren't working properly. One motor didn't work at all while two motors were not functioning properly. First we had to determine if it was a problem with the wiring, coding/programming or if the motors could be faulty. After looking over the wiring and programming we found some minor errors in the coding/programming. We fixed these bugs and motors functioned better then ever.

Lessons Learned 6.0

During the course of this endeavor we learned many, many lessons. One of the big lessons the team learned is how computer systems worked. We learned that processors and many other chips inside computers store addresses in areas called registers. Also that serial communications can be used to communicate between different systems. The team also learned that testing is the only way to really determine if something is going to work. There was as much, if not more testing than actual building. However, the best lesson we learned is how to work as a team.

Future Improvements 7.0

A problem that seems to happen every year is running out of time to design and fabricate all the tools and attachments that we need to have the best run. We need to start planning for next year as soon as we get back! The plan for next year is to make a set plan and schedule for all to follow. In that schedule we need to add in time to fundraise and seek financial aid. As we got closer to the date of the competition in St. Johns, we found that we didn't have enough time in the pool and practice, next year we want to start earlier and get more practice with the ROV in the pool.

Reflections on the Experience 8.0

Joining the Stephenville Robotics team has been a rewarding and educational experience for all of our members. Our team was composed of students with some knowledge about robotics to students who had previous experience in the field. This proved to be a challenge our team had to overcome but with the determination of our members and the guidance from our mentors, our team was able to overcome many challenges that faced us along the way.

Members of the team found niches within the group during the year. Some members discovered their skills suited to the design and fabrication area while others enjoyed the electronic aspect. Overall our team developed teamwork skills and a knowledge base about the field of ROV.

Acknowledgments 9.0

Spartan SCUBA Squad would like to thank the many people and organizations that helped us make this all possible for our team.

-Abbott and Haliburton

-Canadian Tire

-The local Lion's Club

-Second Stage Players

-Marine Institute

-Callahans Contracting

-Wal-mart

-Bynes Shoes

-Scotia Recycling

-Town of Stephenville

-Town on Kippens

-Town of Port aux Port

-Price choppers

-CO-OP Stephenville

-HM Audio

-Stephenville Aquatic Center

-Western School District

-Tech Oil

-Stephenville High

-Western Petroleum

-Blue Bird Taxi

-Rotary Club

-Comeplex Minerals Corporation

-The Georgian

References 10.0

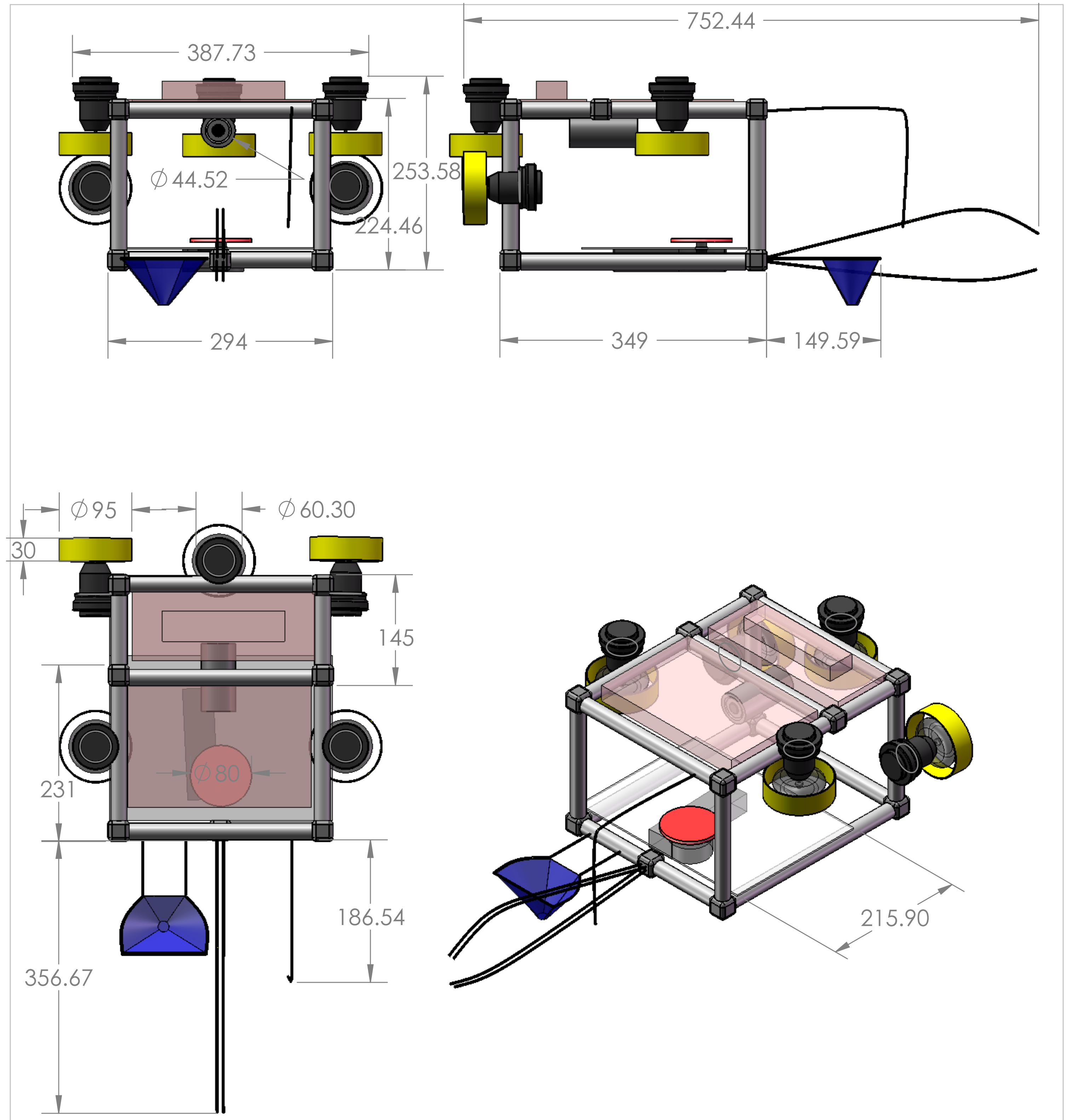
Pololu Motor Drivers http://www.pololu.com/catalog/product/705/resources
VNH3SP30 motor driver data sheet (228k pdf)

Atmel ATmega32 http://www.atmel.com/dyn/Products/Product_card.asp?part_id=2014
ATmega32(L) Summary (20 pages, revision M, updated 5/08)

AS35 Temp Probe http://www.alldatasheet.com/datasheet-pdf/pdf/165266/AOSMD/AS35.html

Johnson Thrusters http://www.johnson-pump.com/JPMarine

Foam www.tlpinsulation.com/datasheets/celforthd.pdf

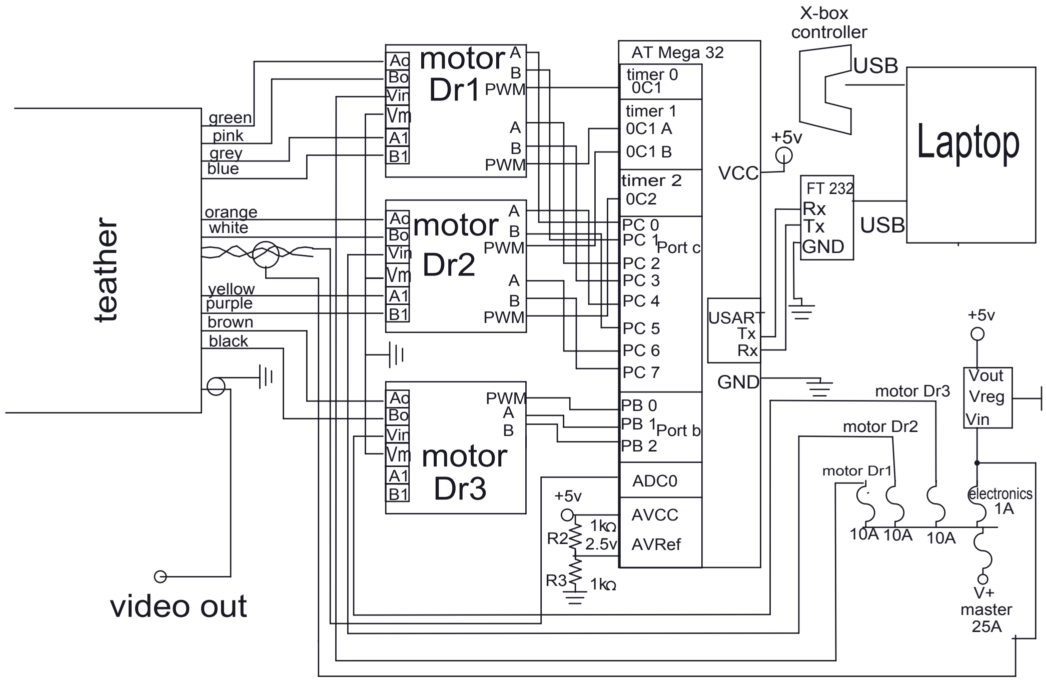


PROPRIETARY AND CONFIDENTIAL

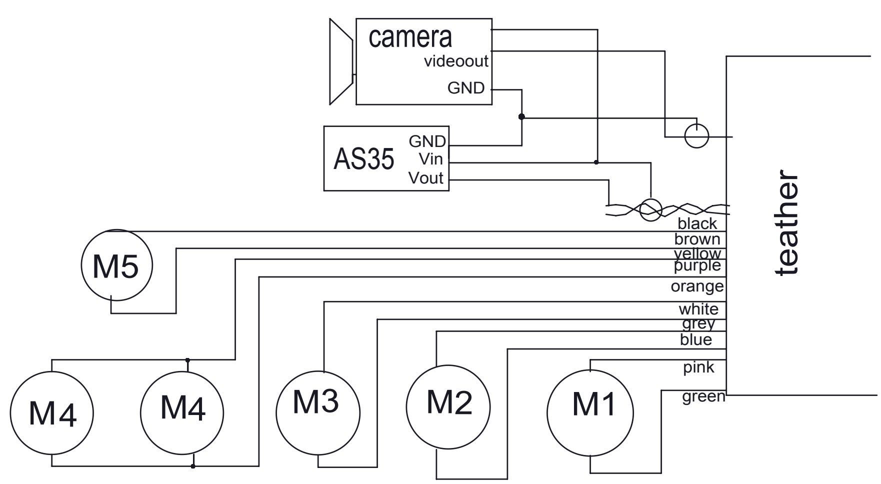
DIMENSIONS ARE IN METRIC	SCALE DRAWING		NAME	DATE	Name.	Maurice	17
		DRAWN	Stephen.s	June 04, 08	SCALE:1:7	WEIGHT: 4100G	SHEET 1 OF 1

Appendix B - Electronic Schematics

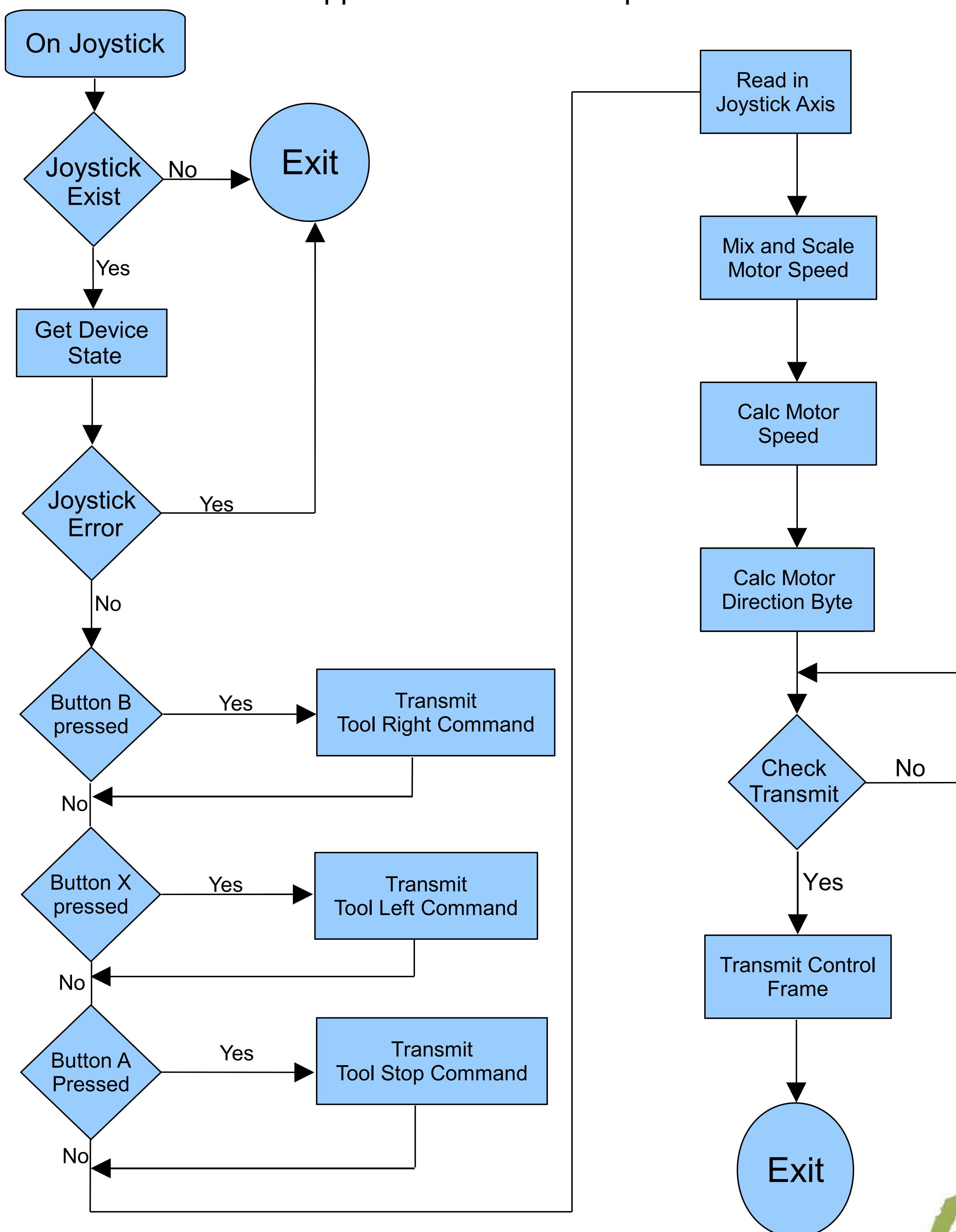
Surface Electronics



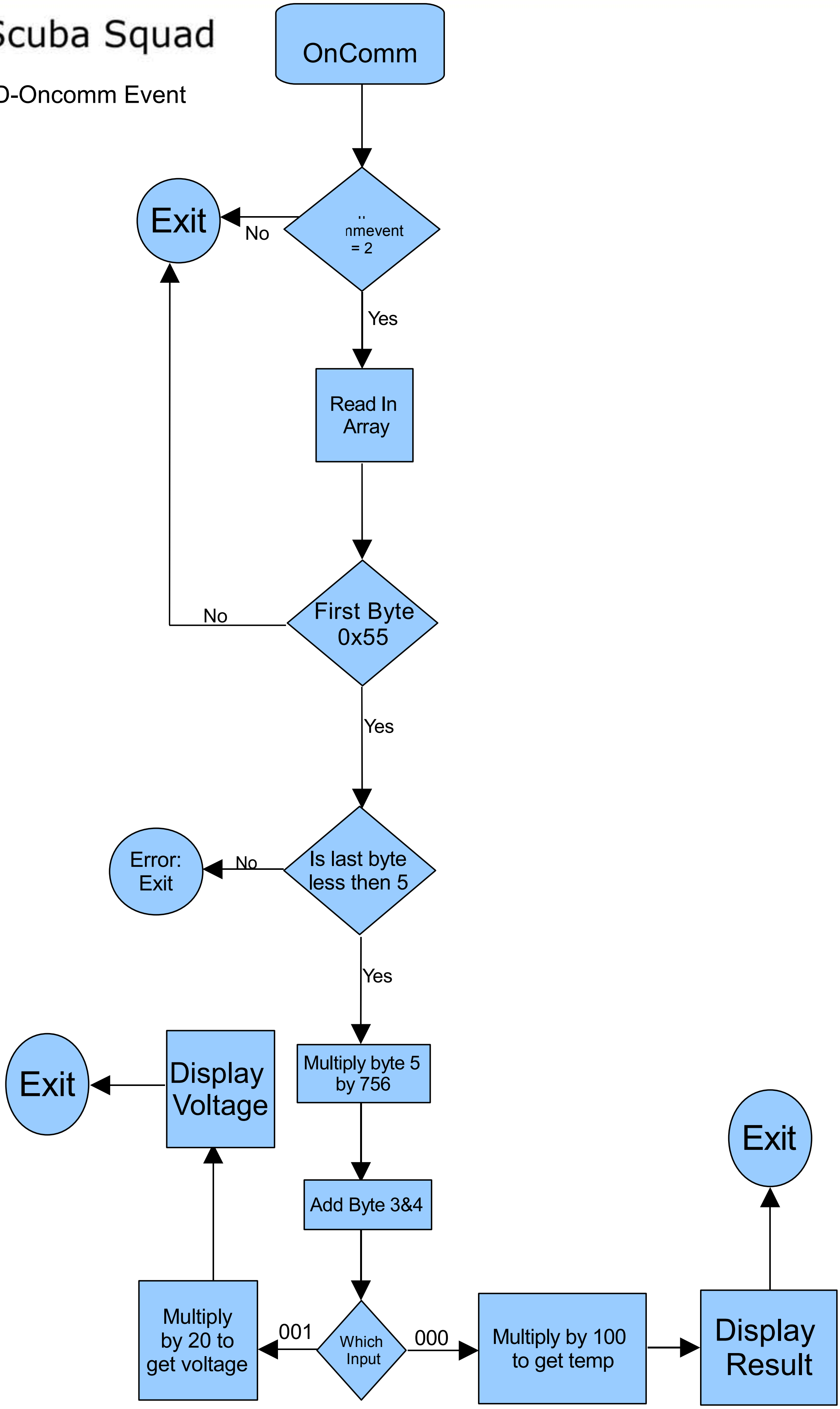
Subsea Electronics



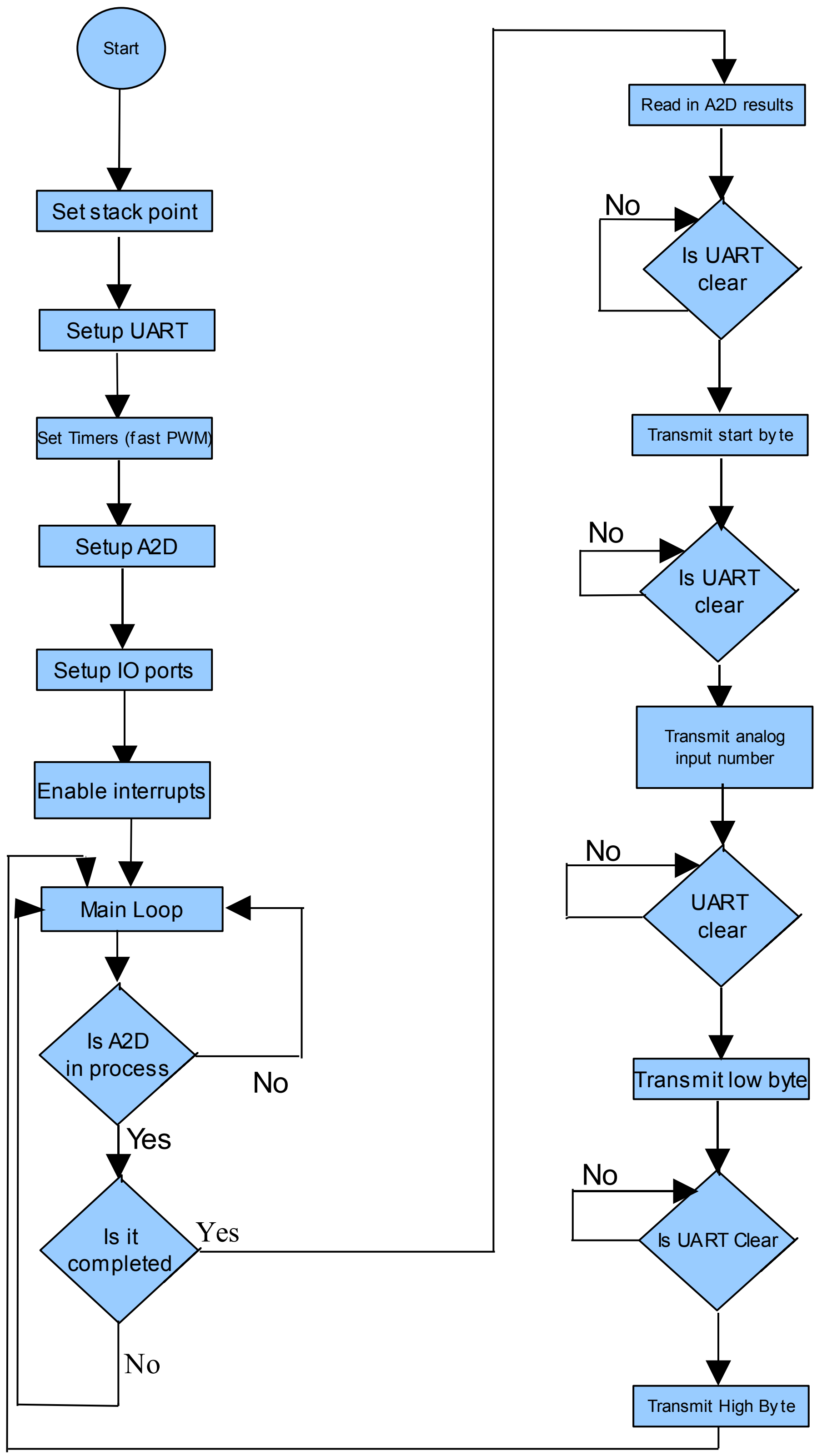
Appendix C - DirectX Input



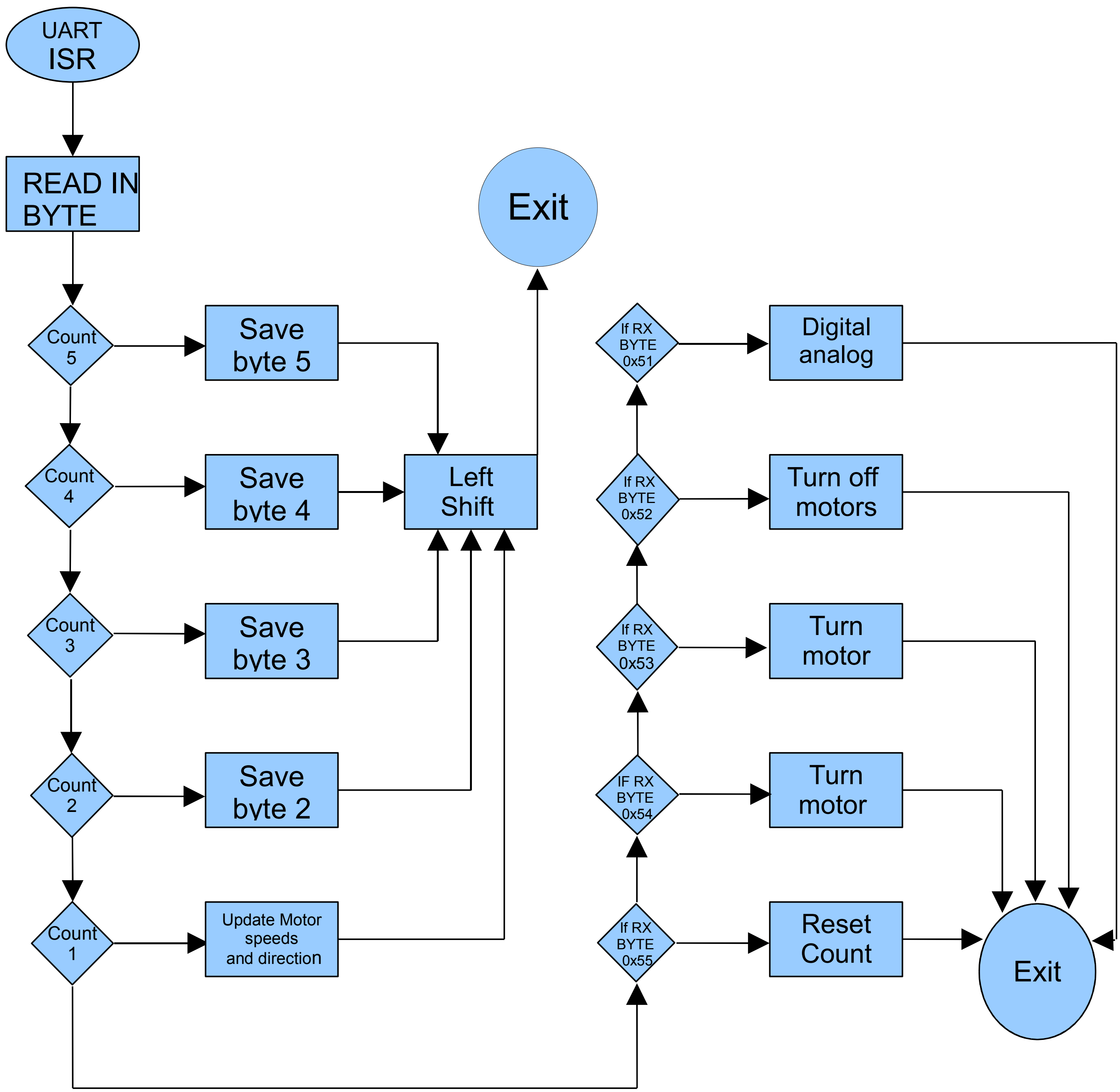
Appendix D-Oncomm Event



Appendix E - Assembly Main Program



Appendix F - Assembly Subroutine



Appendix G

Structure				
Description	**Quantity**	**Price**	**Total**	
PVC Pipe 3/4"	10 ft	$1.20/ft	$12.00	
PVC 3-way fitting	8	$.91	$7.28	
PVC T	3	$.31	$.91	
Total			**$19.28**	
Buoyancy				
Description	**Quantity**	**Price**	**Total**	
High Density Foam 2"	4 x 8 Sheet	$29.95	$29.95	
Total			**$29.95**	
Control				
Description	**Quantity**	**Price**	**Total**	**Comments**
Tether	32 ft	$12.00 ft	$384.00	Donated
Xbox Controller	1			Donated
Pololu VNH2SP30 Motor Controller Boards	3	$54.94	$164.82	
Atmega 32 MicroController	1	$9.00	$9.00	
Total			**$173.82**	
Camera/Propulsion				
Description	**Quantity**	**Price**	**Total**	**Comments**
Motors	6	$114.00	$684.00	Donated
Brass Hubs	6			Donated
Propellers	6	$14.00	$84.00	Donated
Underwater Camera 7700-C	1	$269.00	$259.00	Donated
Total			**$1,027.00**	
Tools				
Description	**Quantity**	**Price**	**Total**	**Comments**
Clothes Hangers	4	$0.25	$1.00	
Onion Bag	1	$1.25	$1.25	
Aluminum Stock 1"	3ft	$3.40 /ft	$10.20	
1/4" Aluminum	1' sq	$3.15 sq/ft	$3.15	
Power Window Motor	3	$42.00	$126.00	
Small Circular mirror	1	$3.00	$3.00	
Small Rotational Mount(for mirror)	1	$2.00	$2.00	
Thermal Chip	1	$0.65	$0.65	
Total			**$146.25**	
Bulk Materials				
Description	**Quantity**	**Price**	**Total**	**Comments**
Self Taping Screws 1/2"	1 PKG	$2.39	$2.39	
Electrical Ties 3"	1 PKG	$1.29	$1.29	
Liquid Electrical Tape	1 PKG	$3.29	$3.29	
Misc Wire	10 ft			**Donated**
Solder	1 Roll	$5.39	$5.39	
Epoxy	1 PKG	$4.29	$4.29	
Total			$16.65	
Overall Total			**$1,412.95**	

Appendix H

Item	Amount	Comments
Marine Institute	$6,500.00	Donation
School Board	$3,000.00	Donation
Town of Stephenville	$800.00	Donation
Town of Kippens	$500.00	Donation
Tech Oil	$500.00	Donation
Safe Grad	$400.00	Donation
Dance	$400.00	Fund Raiser
Canteen	$863.22	Fund Raiser
ROV Day(Bake sale)	$627.00	Fund Raiser
COOP	$500.00	Donation
Western Pet	$100.00	Donation
Price Chopper	$1,000.00	Donation
Xtra bakesale	$55.45	Fund Raiser
Blue Bird Taxi	$80.00	Donation
Rotary	$1,000.00	Donation
Tufting (Tickets)	$5,000.00	Fund Raiser
Painting (Tickets)	$1,000.00	Fund Raiser
Comaplex Minerals Corp	$500.00	Donation
BBQ (price Choppers)	$300.71	Fund Raiser
Donation (Personal)	$65.00	Donation
Bake Sale	$13.00	Fund Raiser
Town of Port au Port	$200.00	Donation
Georgian Newspaper	$250.00	Donation
Spa Getaway (tickets)	$1,000.00	Fund Raiser
Total	**$24,654.38**	To Date 06/06/08

Appendix I

Travel & Accommodations				
Description	**Quantity**	**Price**	**Total**	**Comments**
Coachline		$2,700.00	$2,700.00	
Shuttle Bus		$200.00	$900.00	
Airline Tickets	15	$990.51	$14,857.65	
Accommodation		$4,425.00	$4,425.00	
Freight		$200.00	$200.00	
Meals		$1,800.00	$1,800.00	
Total			**$24,882.65**	