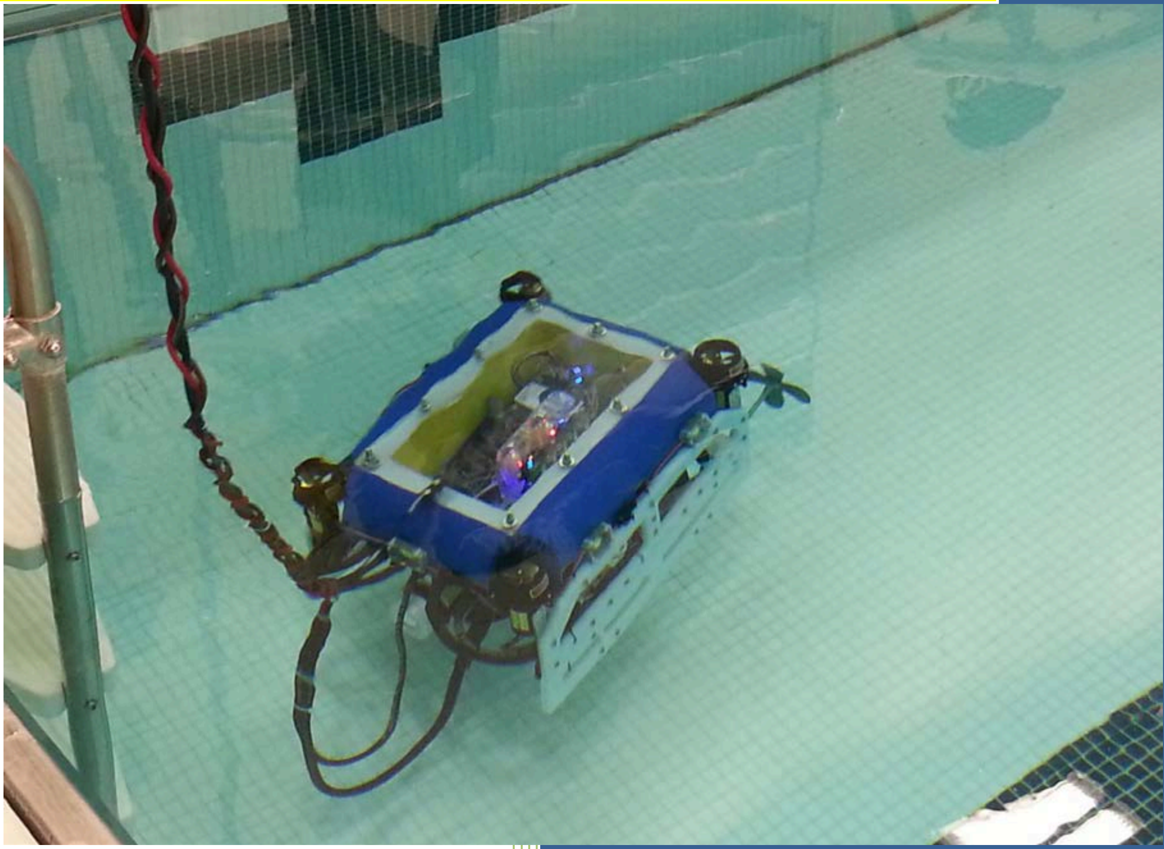
University of Massachusetts - Dartmouth International MATE ROV Competition



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University of Massachusetts DROVE

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Intro

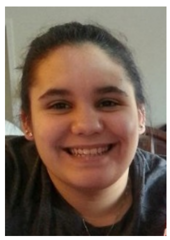
Company Abstract

The IDEA Club has participated twice before in the Explorer class of the International MATE ROV competition. We have competed in Houston, Texas and Orlando, Florida. Two of this year's team members, Steven Brown, and Brandon MacDonald, are returning to the competition along with four others who will be experiencing it for the first time.

Company Member Info

Steven Brown
CEO, Pilot and Computer Engineer
(Senior)

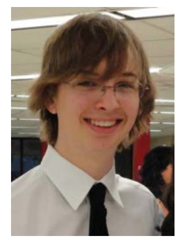
Brandon MacDonald
Mechanical and Design Engineer
(Junior)



Stacy Correia
Electrical Engineer
(Junior)

Richard Bellizzi
Mechanical Engineer
(Junior)

Hugo Quezada
Mechanical Engineer
(Sophomore)



Edward Purtell
Computer Engineer
(Freshman)

Design

Overview

For this year's competition we really had to change the way we have built our previous ROVs. In order to build a competitive ROV, it was unanimously decided that we needed to make DROVE as compact, modular and high-quality as possible. We also decided to purchase professional thrusters, professional waterproof connectors and have a solid stainless steel electronics box. These decisions have corrected issues which have led to our biggest struggles and issues in previous years. Also, when building tools we also realized that we needed to keep them as simple as possible. As the saying goes, "keep it simple stupid." The more complex that the tools are, there are more problems that can go wrong with them during the competition. Another goal of ours was to build DROVE so that the main body unit can be reused in future competitions, only requiring new tools to be built later on for future tasks.

Electronics

Main Control Unit

For the main control unit (MCU) at the ROV, it was decided to use the versatile Arduino Mega 2560. This is a cheap and flexible microprocessor, which has ample processing power, IO, and communications for the requirements. The Mega (as it will be referred to from now on), has 54 digital IO ports, with 15 providing PWM output. Additionally, 16 pins which are tied to an ADC can also be used as digital IO. The Mega also has support for 4 simultaneous serial port connections, something which gives a great advantage for debugging. The Arduino platform also facilitates rapid prototyping, as the ATmega chip which is at the heart of the Mega allows reprogramming without penalty. That is, programs can be written, uploaded, and tested in a matter of minutes, with the ability to change the code at a whim without costly hardware changes. This makes the Arduino a hacker's favorite among many. As such, the Arduino Mega2560 was chosen as the main control unit.

Microcontroller	ATmega2560
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	54 (of which 15 provide PWM output)
Analog Input Pins	16
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	256 KB of which 8 KB used by bootloader
SRAM	8 KB
EEPROM	4 KB
Clock Speed	16 MHz

Table 1 - Arduino Mega2560 Summary - From ***http://arduino.cc/en/Main/ArduinoBoardMega2560***

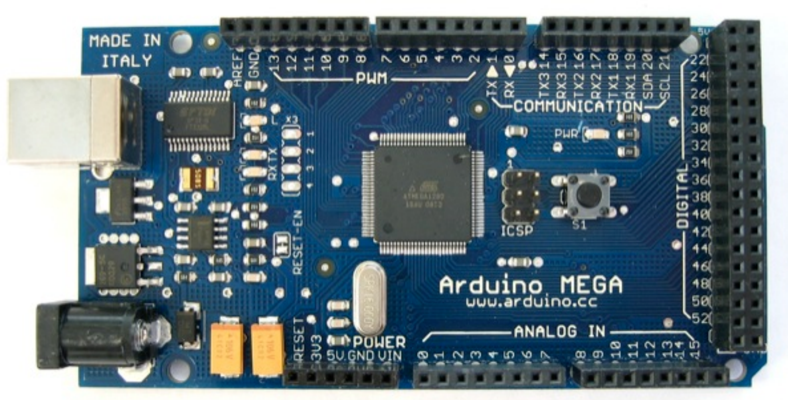


Figure 1 - Image of Arduino Mega2560 - Via arduino.cc

A PCB was designed to breakout all the pins on the Arduino, and to group them according to function and destination. These functions are:

- Thruster control (each addressed as a servo, needs 1 signal pin and a ground pin)
    - Twelve groups of three pins (one for signal, one for ground, another NC) allowing for up to 12 thrusters to be controlled. As the ROV currently only supports 6, this allows room for expansion.
- Tool control (two pins necessary, one GPIO for direction and one PWM for speed)
    - Two groups of 10 pins (5 groups of the two pins per tool) allowing for independent control of up to ten separate high-current tools.
- Camera switching (9 total pins, 3 selection pins for each of 3 feeds)
- Sensor input (one ADC pin per sensor, also Vcc and GND)
    - Sixteen groups of these three pins, allowing 16 analog sensors to be read from.
    - A 75A current sensor occupies one location, allowing the operator to determine what amperage the ROV is drawing.
    - Pressure transducer for accurate depth readings is attached to a second location to allow the operator to determine the current depth of the vehicle.
    - Conductivity sensor is attached to one of these pins.
    - Additional sensors such as leak sensors may be attached.
- I2C breakout pins (SCL, SDA, Vcc, GND)
    - Used for various sensors utilizing the I2C bus. Sensors include
        - Accelerometer & Compass for the operator to know current heading and angle
        - Pressure & temperature sensor for indicating to the operator a fault within the electronics case.

Additionally located on the PCB is a RS232 circuit, which converts TTL level signals (0V - 5V) from the Arduino into RS232 level signals (up to +/- 15V), allowing for longer cable length with lessened signal loss. The output from this circuit is connected to a header to allow easy connection to the tether wires.

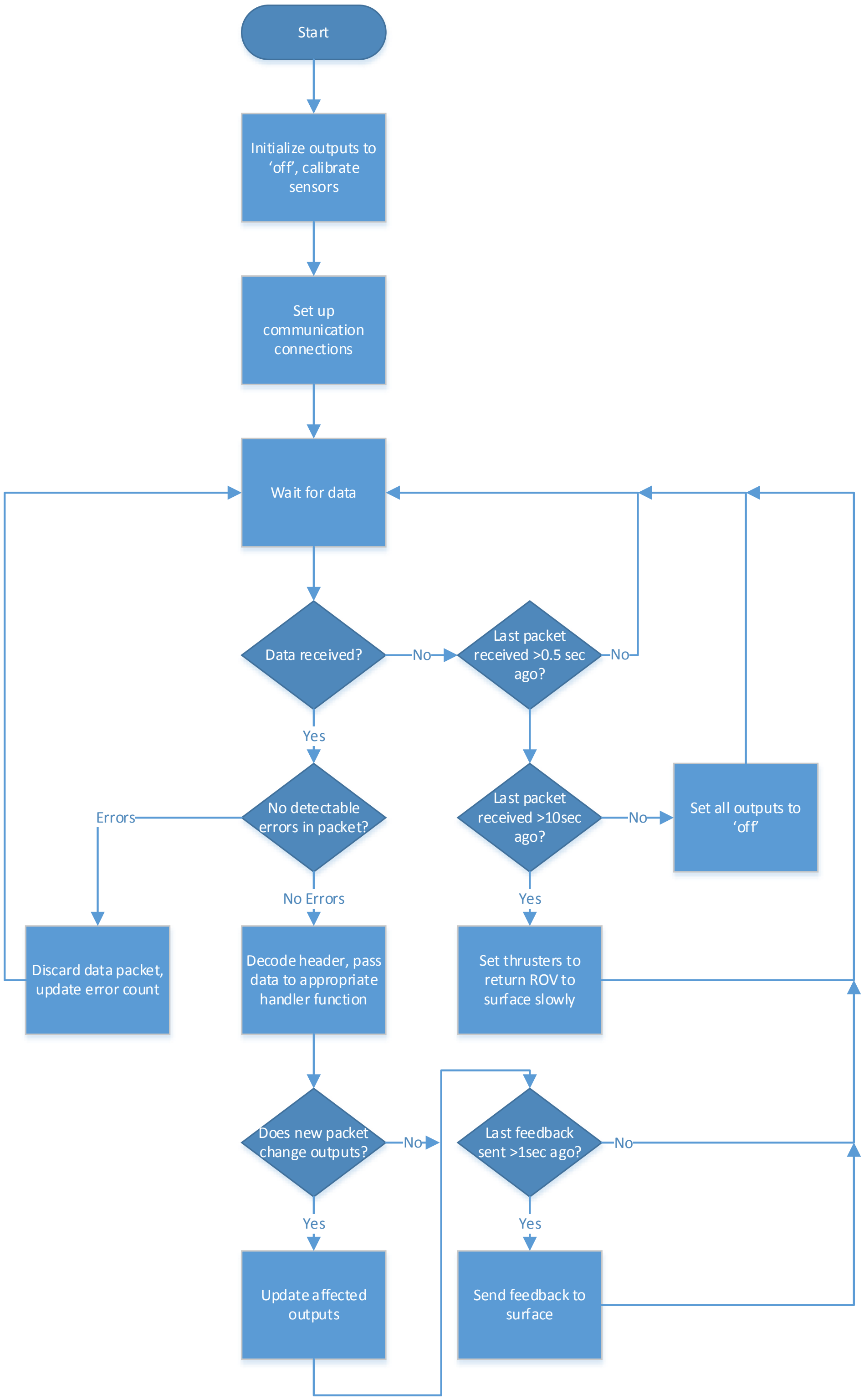


Figure 2 - Master Control Unit software flow

Camera Selector Module

The Camera Selector Module (CSM) was derived from the need to transmit eight video signals over three wires. Previously the IDEA Club's ROV required two Cat5 cables for the tether - one for data and low-current power (to power the surface electronics) and one for the eight camera feeds, which would be selected from at the surface. After examining this system, it was determined that the past systems wasted much. Eight signals were sent to the surface yet only one or two could be viewed at any one time, wasting all those wires in the tether. Since one Cat5 cable can support data communications and power with only using four wires (Vcc, GND, TX, RX), it was decided to use the remaining four wires as camera lines (Camera Ground, Feed1, Feed2, Feed3). Since the operators likely won't have more than three displays to use at one time, this was considered the best mode of operation, as it did not waste any unnecessary wires, leaving the tether with a single cable for both communications and cameras.

This board contains one circuit replicated three times. The circuit simply takes eight analog inputs, routes them to two 4x1 analog switches (each switch has 4 circuit inside, each consisting of 1 analog input, 1 analog output, and 1 switch controlling whether the input is connected to the output). Deconstructed, this is akin to placing eight analog inputs to eight switches, with a selector on each switch. The outputs are all tied together to form a bus, which is sent up the tether. It is important therefore to only allow one switch to be on at a time, otherwise there will be two cameras at once on the output bus, and the resulting video will be unusable.

To accomplish this, a 1-of-8 decoder is used. This decoder takes three inputs, representing a number between 0 and 7 in binary, and activates the corresponding output, making sure to keep the other 7 outputs in the 'off' state. This ensures that only one of the analog switches will be outputting to the bus at any one time. The three selection lines into the decoder originate from the MCU, where the user can command a different camera be viewed.

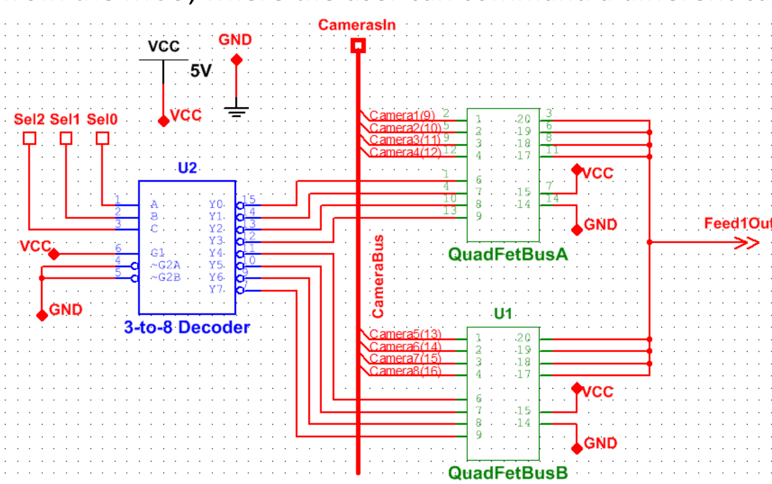


Figure 3 - Circuit diagram of camera selector circuit

Tool Control Board

The Tool Control Board (TCB) is a board allowing bi-directional control of a brushed DC motor, providing 30A max continuous current, when adequate cooling is supplied. This is achieved through 5 discrete circuits on the PCB. Each circuit consists of a surface mount integrated H-bridge motor driver (VNH2SP30-E). This small chip utilizes PWM and direction pins to provide power to a brushed DC motor. See Appendix [datasheet] for more information about this chip.

Input to the TCB is the 2x5 connector cable from the MCU board. Two pins, one for speed (PWM) and one for direction (GPIO) are used to control each discrete motor driver circuit. The speed pin is tied directly to the PWM pin on the H-bridge chip. The direction pin is routed to a hex inverter and to one IN pin on the H-bridge chip. The inverted direction output from the hex inverter is tied to the other IN pin on the H-bridge chip. This is required for correct operation of the chip, as outlined in the table below:

Table 2 - Truth Table for Operation

IN_A	IN_B	Input	Operating Mode
1	1	--	Brake to V_{CC}
1	0	PWM	Clockwise
0	1	PWM	Counter-Clockwise
0	0	--	Brake to GND

Figure 4 - VNH2SP30-E Chip

This chip can allow a maximum continuous output current of 30A with proper cooling. Most tools that have been previously designed for the ROV have drawn a maximum of around 9A, so these chips have plenty of overhead. Without proper cooling, these chips are rated for 14A continuous, still more than enough to satisfy the current requirement by most of the ROV's tools. Still, to be safe, two 80mm fans were mounted to provide airflow across these chips to allow for higher current draw, if the need arises.

As a fault monitor, a simple LED was tied to the 'Fault' pin of the H-bridge chip. This pin needs to be pulled high to enable the chip, and when it encounters a fault, the chip pulls the pin low. This allows us to put a LED (with current limiting resistor) in parallel with a pull-up resistor, tied to the Enable/Fault pin such that the LED lights up when the chip faults.

Main power to the TCB is provided through a large terminal block rated for 30A continuous. Since it is highly unlikely that any more than one of these tool circuits will be on and providing max allowable current to its respective tool, 30A was considered a safe rating for the input terminal block. The +12V power provided by this is routed to the V_{in} pins of the H-bridge chips, as well as to a voltage regulator, which provides +5V for use with the hex inverter and the +5V levels required on the enable pins of the H-Bridge chips.

Surface Control Board

For a user interface, the Raspberry Pi is used with a custom Linux image. The modified ArchLinux image boots into a Python script to provide user control of the ROV via joystick. The Raspberry Pi is an open-source, low-power and cheap computer on a chip. This was chosen again due to its low cost, as well as its size. The same approximate size of a credit card, the low-power Raspberry Pi is still fast enough to process user input while being compact to better integrate with the portable ROV control system. Two models of the Raspberry Pi exist, the Model A & B. Model B is identical to the A, save for two USB ports whereas the A has one, and the inclusion of an Ethernet port. The Model B was selected for use, mainly due to USB requirements (one USB port for communication with the Arduino, one for the joystick).

System on a Chip	Broadcom BCM2835
Processor Speed	700MHz (O.C. to 1Ghz)
Memory	512MB
Connectivity	2xUSB2.0; 100Mbit Ethernet
Video	Composite; HDMI
Power	MicroUSB, 5V

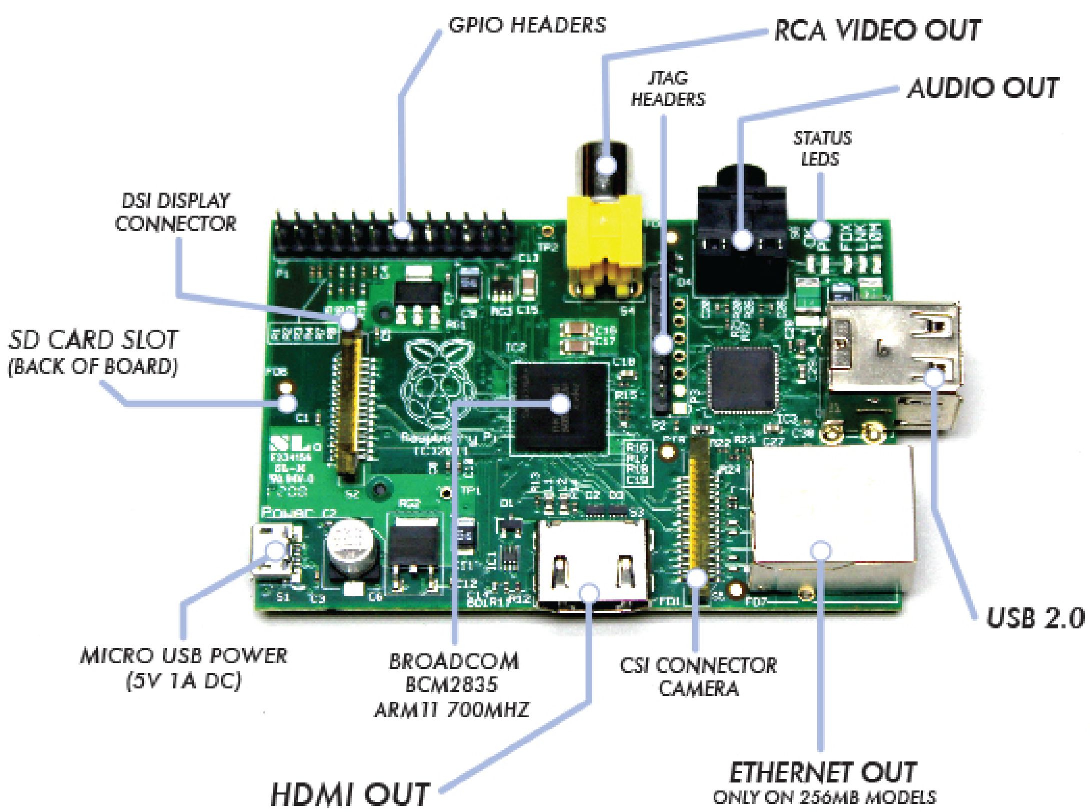


Figure 5 - Image of Raspberry Pi Model B - Via pcmag.com

In addition to the Raspberry Pi, the Surface Control Board (SCB) integrates with another Mega, which provides communications from the control system, and links to the tether for communications with the MCU on the ROV. On the left side of the board is the tether input. This provides +12V power from the ROV to power the SCB. Also on this connector are Tx and Rx for communications, and the three camera feeds from the CMUX on the ROV. The three camera feeds are simply routed to three 1x2 pin male headers (signal and ground each) to be plugged into a monitor. The Tx and Rx lines are routed to a RS-232 chip for decoding, and the output of this chip is tied to Tx1 and Rx1 of the Mega. Again, Tx1 and Rx1 were chosen to allow Tx and Rx to be used for USB communications with the controlling computer. The +12V power input from the tether is tied to the V_{IN} pin of the Mega, as well as an LED to provide a visual indication to the pilot that the board is receiving power from the ROV. An additional LED provides a visual indication that the surface Mega is operating correctly and is stepping the incoming +12V to +5V levels for use with any digital or analog sensors to be used on the surface.

Ten analog input pins are broken out to ten 1x3 pin male headers on the PCB to be used for any control that cannot be achieved through our joystick attached to our control system. Uses for this include the output of potentiometers which control the position of the robotic arms on the ROV. This allows a modular approach to control of the ROV, instead of having one joystick control everything. Further, 12 GPIO pins are broken out into 12 1x2 pin (GPIO and ground) male headers to be used as inputs or outputs for items such as pushbuttons (for example, for our camera selector). All of the Mega's PWM outputs are also broken out into male headers to be used as necessary. The initiative to provide a platform which can be reused year after year, while incorporating future expandability was the motivation to breaking out various pins that may not have a specific purpose at this point in time.

Buoyancy Package

The buoyancy package was hand cut and formed from Divinycell H80 syntactic foam blocks. This foam has a density of $0.211\ kg/m^2$ and allows for a maximum tool capacity of 9.072 kilograms. The package houses DROVE's electronics box and is mounted to the top of the frame.

Thrusters

Six 400HFS-L hi-flow thrusters from Crust Crawler supplying a maximum of 22.24 Newtons of thrust each are used to propel DROVE through the water. Four of the thrusters are used for vertical thrust and two are used for horizontal thrust, as well as turning DROVE. Having 4 vertical thrusters gives many advantages to DROVE. With each vertical thruster positioned on a corner it allows for DROVE to be able to lift uneven loads that may be difficult to others by adjusting the speeds of the thrusters to keep it level when lifting. It also allows for the pilot to be able to control pitch and roll which can be helpful in accomplishing tricky maneuvers.

Frame

The frame of DROVE consists of two parts made using High Density Polly Ethylene (HDPE) because it is lightweight in water yet strong. The first part of the frame is the body carriage. This is the part of the frame that is connected to the buoyancy package. It is where the horizontal and vertical thrusters are mounted and contains all of the exterior wiring and a series of DC to DC converters. The second of the frame is the tool carriage. This is attached to the bottom of the body carriage and is where all the tools are mounted. The tool carriage can be removed from DROVE while loaded with tools by unplugging the wired tools from the body carriage and unscrewing the mounting brackets. This helps when removing and adding different tools to the tool carriage. Both carriages also have a large number of equally spaced holes to make tool mounting easy.

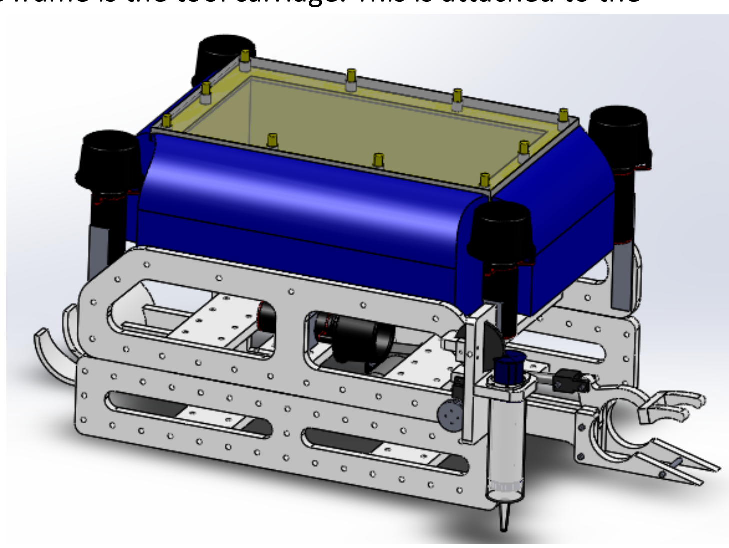
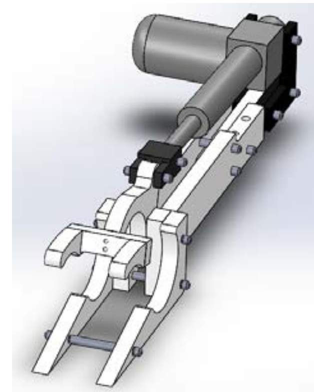


Figure 6 - Complete ROV model

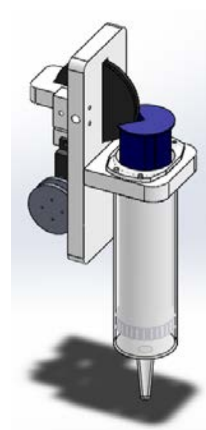
Main Tools

Multi-Use Claw



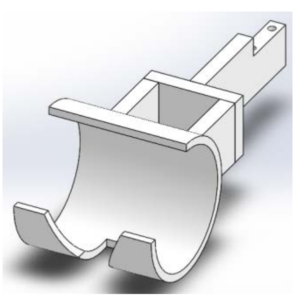
The multi-use claw featured on DROVE is a simple yet effective one function claw that is located in the front, center of DROVE. The opening and closing function is produced by a powerful electric linear actuator that has been modified slightly to make it waterproof. The mouth features two different clamping points. The larger is perfect for removing different materials and debris, such as bottles from the bottom of the ocean, while the smaller located at the front of the mouth is for removing small or flat materials from the oceans depths. This will come in handy when picking up a plate from a shipwreck. The front of the mouth also features an angled wedge that makes it easy to get under an item that is flat on the floor of a ship wreck or the sandy/rocky bottom.

Microbial Sample Collector



The microbial sample collector is perfect for collecting samples up to 150ml of microbial mat from the ocean floor. This tool works by using a waterproofed continuous rotation servo that winds up a wire on a spool that goes up over a pulley and is connected to the bottom of a plunger in a 150ml syringe, which gets lifted. This pulls in the microbial mat to the holding tube where it is stored till removed at the surface. The frame of this tool is also made of HDPE like the multi-use claw.

Bull Horn Hook



The bull horn hook is another simple effective tool that may be overlooked if looked at quickly. This was specifically created in order to aid in the retrieval of the old sensor and deploying the new sensor but also is capable of other uses. This hook can also be used as a ram to push and move debris out of the path of DROVE. This tool was made using 4in. PVC and HDPE.

Cross Hook

The cross hook tool was created in order to open latches and doors, to gain access to different rooms in the ship such as the cargo hold. Each end has a slight bent and was coated in rubber to help grip the latches. This tool can also be used to pull and push debris in order to help clear the path of DROVE. This tool was made from steel and is attached to DROVE using threaded rod.

Cameras

A total of 8 cameras will be utilized and integrated into the design. The system has power provided from the main hub along with the data transfer from the cameras. The mounted cameras are high quality color CMOS Camera Modules. The camera specs consist of a vivid color video with a 640x480 resolution. The circuitry outputs an RCA signal which is what input the hub receives from the ROV. The cameras themselves are not waterproofed so each one is encased separately. The casing includes a flat sheet of plastic to provide a base, which the camera is secured to using epoxy. This support is placed into a PVC cap and then secured by a PVC connection behind the mounted camera. A glass panel is place between the camera and the opening of the PVC cap.

Figure 8 - CMOS Camera Module

Every connection between the PVC and the glass or between the PVC and the connected piece of PVC is sealed using silicone filler. The original idea to create a molding of the cameras in a clear epoxy was adjusted when the visual output was blurry. Each camera is positioned to provide a maximum visual of the tools and the placement of the ROV itself. The main camera is positioned underneath the nose giving a view of the tools in the front such as the claw which can be used to grab or push objects.

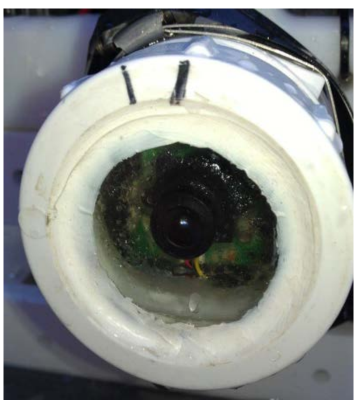


Figure 7 - CMOS Camera Module in PVC Encasement

Other positions of the cameras include one underneath the ROV at the tail end for reverse functions as well as on the side of the ROV. The side camera is aimed perpendicular to the ROV to be utilized in the scanning tasks which can work in tandem with the stabilizing aspects of the ROV. Cameras mounted at the nose, on the top of the ROV on both the right and left side to be used as a way to provide a wider view of the nose end of the ROV.

Two other cameras are placed at the tail end of the ROV facing forward but aimed at an angle out to provide a visual of the sides of the ROV and the tools mounted there. The last camera is used to project a view of the underside of the ROV to help in analyzing how far from the surface of the ocean bed the ROV is located as well as to view the wreck from an aerial view. This view can be utilized when counting the mussels for that task. The idea is to have everything that is being used for a task in a line of sight of a camera to make sure each action is performed as is desired. To increase success of each task having a visual of every tool in action can provide a more accurate account of what is occurring allowing the pilot to have less room for error.

Safety

Workshop Safety

When building DROVE safety was of utmost importance to the team in our workshop. We created a series of agreed upon safety guidelines in order to keep safe in order to keep team members from being injured by things such as tripping over cords, flying partials from cutting, electrical shock etc. These guidelines are as follows:

- Safety glasses must be worn when using any type of power tool or if in the vicinity of these tools in use by team mates.
- Closed toed shoes must be worn in workshop.
- Buddy system, no one works alone
- Keep workshop and work station clean.
- Keep wires and extension cords out of walkways and away from water.
- Make members aware of hot soldering irons in use and check twice to make sure they are unplugged before leaving.
- Make team members aware of live wires and electrical systems testing.
- Think before you do.

During testing of robotics, things don't always respond to inputs in the way the developers expect; motors may turn on unexpectedly, other tools may refuse to turn off, or other stray electrical pulses may otherwise cause undesired behavior. Whenever plugging in the ROV to test, the area surrounding the ROV was clear of any parts, and everyone working in the shop was made aware that the power was being applied. This ensured no one would reach into the props, try wiring anything, or otherwise modify the ROV while it was powered on.

DROVE Safety Features

Drove was also created with safety in mind. A heavy duty stainless steel electronics box was made to house the electronics to ensure no leaks would occur or a failure under pressure. The wires leave and enter the electronics box through custom made professional waterproof connectors to ensure tight sealed wire connections. Wires are routed tightly along the body carriage to keep them from getting loose and snagging on things. The thrusters are equipped with shrouds to keep people from being injured by the propellers.

DROVE's electronic systems employ a slew of safety features which should aid in the event of a failure of any kind. Much of the communication is check-summed, and all commands sent to the ROV are passed through rigorous error detection algorithms to filter anomalies, such that they don't ever get passed onto the rest of the system, causing erroneous outputs. For example, packets of incorrect length, packets whose data does not match the header, and packets with invalid headers are immediately discarded and made note of. Packets which pass this initial test go on to analysis, where the supplied checksum is validated, the data is compared against the previous received values, and if they are within a threshold, the data is considered successfully received and the ROV acts on the command. If, however, the data has changed drastically since the previous transmission (for example if the requested motor speed goes from 100% reverse to 75% forward), the new value is stored (but not acted upon), until the next data packet arrives. If the new data packet contains roughly the same value as the stored value, we assume the data is valid. If the new data is not close to the stored data, we assume the stored data is invalid, and is discarded, while the new data is acted upon.

In addition to the communication safety features, sensors deployed in the electronics box provide helpful feedback to the pilot, which can alert them to problems. A 75A current sensor allows the operator to view the amperage through the system, and can modify his piloting accordingly. If a short in a module occurs, an unusual spike in current should alert the pilot to the situation. Feedback relating to the communication link quality, depth from surface, and motor outputs all provide real-time data to the operator regarding the status of the ROV.

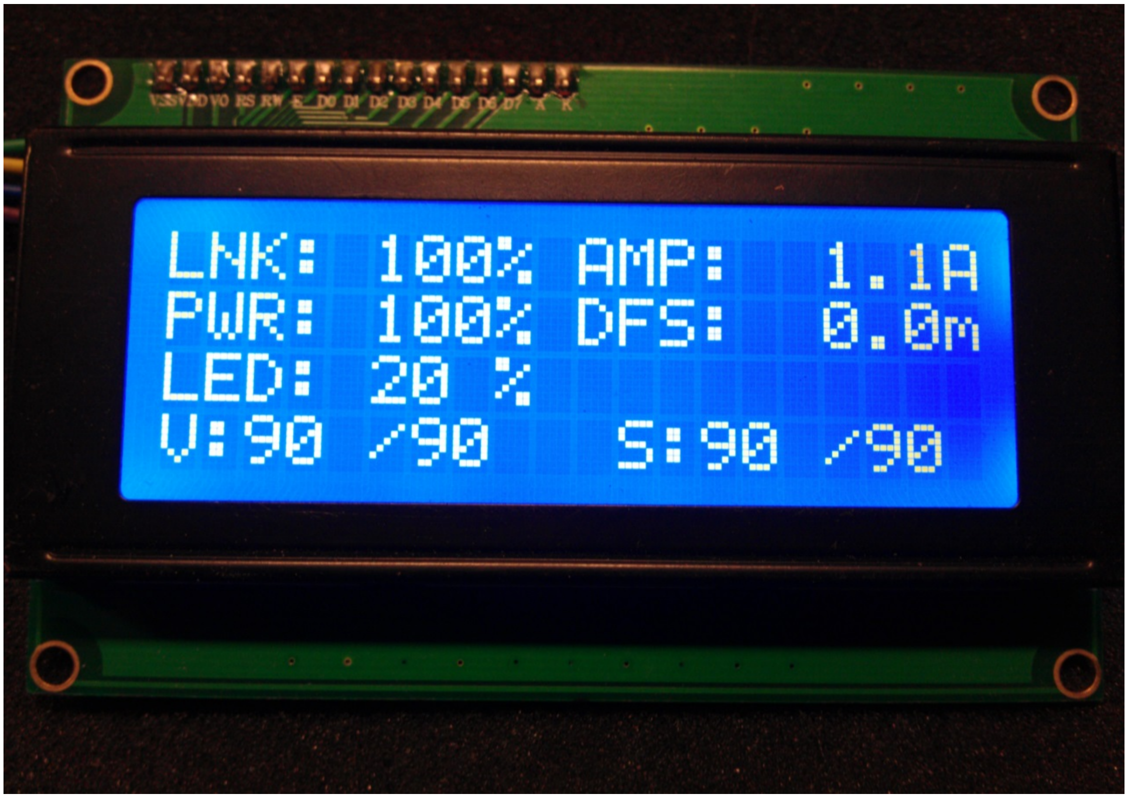


Figure 9 - Feedback from ROV displayed on LCD screen

Logistics

Budget

Income	Amount Given
UMass Dartmouth SGA	$8,000.00
ECE Department	$500.00
College Engineering	$1,000.00
PEP	$500.00
Gibson	$900.00
Pololu	$100.00
SMAST	$300.00
Total Income	$11,300.00

Project Expenses	Cost
Hardware	$111.69
Cables and Wires	$490.53
Thrusters	$3,594.00
Miscellaneous	$673.82
Electronics	801.74
Total	$5,671.78

Project Donated Expenses	Projected Cost	Cost to Us
Foam	$500	$0.00
Electronics Box	$300	$0.00
PCB Manufacturing	$1300	$0.000
Water Proof Connectors	$1600	$800.00
Tether	$630	$0.00
Total	$4,330.00	$800.00

Transportation	Projected
Gas (Driving)	$1,000
CRTC	$650
Total Income	$1650.00

Total Income & Expenses	Actual Cost	Production Cost
Construction	$5,671.78	$5,671.78
Donated Expenses	$800	$4,330.00
Transportation	$1,650.00	$1,650.00
Income	$11,300.00	$11,300.00
Remaining	$3,178.22	$351.78

*Production cost is the cost that the ROV project would have taken on if we had not been given any donations.

*Red Text indicates that our account would have been in the red or over drawn by the amount.

Our company had an abundant amount of funds this year, due to the fact that we could not attend last year's competition. This resulted in us receiving a budget last year for the ROV and working on it all year and this year we got a similar budget; however, we had already made some large purchases last year which did not need to be made again this year. Also, with the larger budget this year we were able to make a large purchase for the water proof connectors. This will highly advance our ROV and is what we thought was the best use of our extra budget this year. For the rest of the allocation of the money, we decided on the most important aspects that would improve the basic body of the ROV that we already had designed. In addition, donations and sponsorships are always important and we cannot forget that we would have been over budget if we did not receive the donations that we did.

Conclusion

Challenges

Over the past year our company has overcome different kinds of challenges while working on this ROV project. The first challenge that we had to overcome was that a lot of our company's members that had experience with the competition from previous years were not able to dedicate as much time to the ROV this year. This resulted in a company of with more underclassman then upperclassman. Although, that is not completely bad for our company because fresh minds bring new ideas, it hurt us in that they weren't as educated on the topic.

Another challenge that we conquered was that for the first time we had an abundant budget; however, not the same drive and will power we have had in previous years with less money. This was a biggest challenge for us because the most dedicated members of the company seemed to be upperclassman and they had the least amount of time due to work responsibilities and school work outside of the club. The last predominate challenge that our company faced this year was meeting time. We work on this ROV project outside of all our school work and sometimes priorities were set and it was not the ROV. In addition, with many new members working on the project it was more important to meet as a whole group so they could be caught up to speed and more hands on with the project.

Lessons/Skills Learned

This ROV project has taught our company a lot of different lessons both in life and in our career. The most relevant thing to everyone in the company is that it gave each of us hands on experience with many different things. This includes and is not limited to working with power tools, learning to solder and program chips. Also, the project heavily relies on problem solving, which can be a life lesson and a career lesson. Not everything will work on its first try and sometimes troubleshooting becomes the most important part of a project. Problem solving is used not only in the previous examples but also in the decision of tools to complete the task. The lesson of problem solving also in most cases mirrors teamwork.

In our company like others, I'm sure there were fights about the best tools and what was the best way to complete a task. For us we learned how to overcome that by using teamwork. The lesson of teamwork allowed us to learn how to hear everyone's point of view and make decisions based off of what the group concluded as whole. Last but not least, at lot of the company learned how to prioritize this year. A lot of us our upperclassman and although it might have been more fun and interesting to work on the ROV, sometimes we needed to focus on our school work instead. All of these lessons being important to how each of us hopefully thrive in our careers in the future.

Reflection

Brandon MacDonald

This is my second time participating in this competition and it has been a very beneficial experience for me. Through the building and designing of the ROVs I've worked on it has helped me to become a better CAD designer by providing me with many things to model, serving as a great form of practice. Through the building and testing of tools I have designed in the CAD program, it has helped me to see what is possible when designing parts. This will help me greatly in the job world in the future. This project has also helped me to gain confidence in myself when designing and building items as well as helped to improve my teamwork and communication skills. These are a few important things that employers like to see in a person. In fact, participating in this competition has already helped me to gain a paid internship with Boston Power. I included it in my resume and when I was interviewed by them, they were very happy to see that I was a part of something like this competition. I have no doubt that this competition has been anything but beneficial to me.

Acknowledgements

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Appendix: Systems Interconnection Diagram