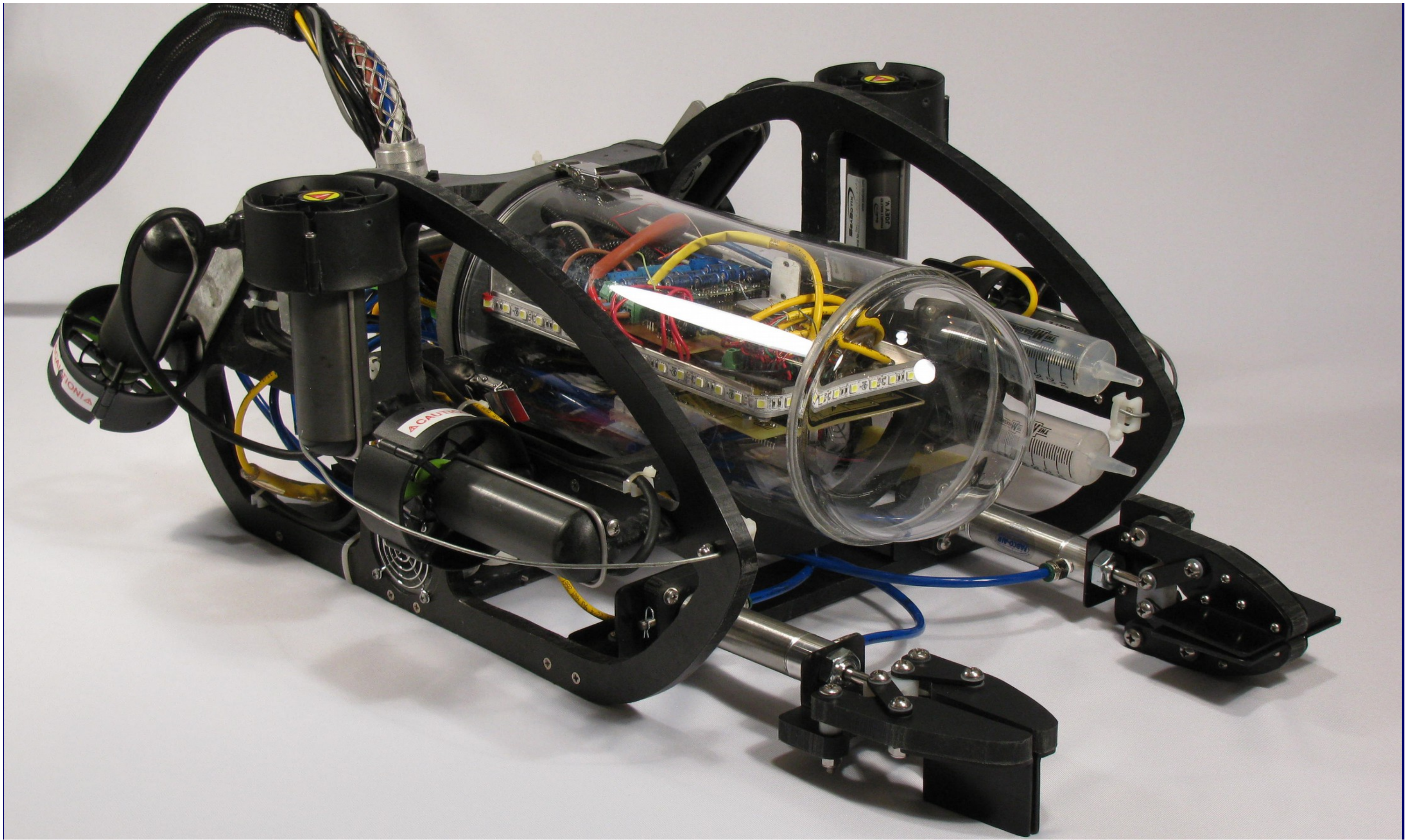
DeepView Technologies



Cornerstone Academy, Gainesville, Florida
Technical Report

Company Directory

Andrew Maule: CEO and Payload Tool Specialist, Class of 2014.
Timon Angerhofer: Chief Software Developer, Class of 2015.
Noah Goodall: CFO and Chief Design Engineer, Class of 2015.
Timothy Constantin: Optical Systems Engineer, Class of 2016.
Pierce Tolar: Optical Systems Engineer, Class of 2016.
Oscar Witte: Design Engineer, Class of 2016.
Tirza Angerhofer: Electrical Engineer, Class of 2017.
Will Hodik: Design Engineer, Class of 2017.
Carter Wyatt: Design Engineer, Class of 2017

(left to right) Top Row: Pierce, Carter, Noah, Oscar, Jeffery Knack (Mentor)
Bottom Row: Timothy, Andrew, Will, Timon, Tirza

Mentors

Jeffery Knack, Alex Angerhofer, Samuel Hurlston, Gregory Spencer

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Abstract

At DeepView Technologies, customer satisfaction, safety, and environmental protection are our main priorities. With seven years of experience in the ROV (Remotely Operated Underwater Vehicle) industry, our vehicles are some of the most versatile and resilient products on the market. Each of our products is capable of performing a wide variety of tasks. The Hydrus, our latest ROV model, is specifically designed to identify, explore, and assist in the salvage of shipwrecks. DeepView's talented team of engineers designed and manufactured unique subsystems to aid in each step of the shipwreck recovery mission presented by MATE. The Hydrus makes use of a USB Xbox 360 controller operating through an Arduino microcontroller, to put control of the ROV and all of its subsystems in the hands of a single pilot. This speeds up reaction times, increasing the pilot's precision and making fine movements easy. An 18 meter tether sends electrical signals and compressed air to the ROV to power its electric and pneumatic tools. On-board the Hydrus, an acrylic waterproof canister safely houses sensitive electronics, and contains wide-angle cameras for navigational purposes. Outside the canister, an array of waterproof cameras provides clear views of the tools to the pilots above. All subsystems are mounted on a custom-made UHMW Polyethylene frame designed and manufactured in-house by DeepView.

Company Mission

DeepView Technologies is a company dedicated to providing the finest in marine ROV systems. Our skilled team of design engineers is backed by seven years of experience, as well as the construction of multiple unique ROVs according to MATE standards. DeepView's latest creation, the Hydrus, has been manufactured with impeccable precision and careful attention to detail. We recognize the importance of the task given to us, and firmly believe that the Hydrus is best suited for this mission.

Design Rationale and Vehicle Systems

Frame

DeepView Technologies decided to take a bold step in a new direction with this year's ROV frame. With a sleek hydrodynamic look and greatly reduced size, Hydrus is the most maneuverable and compact DeepView vehicle ever produced.

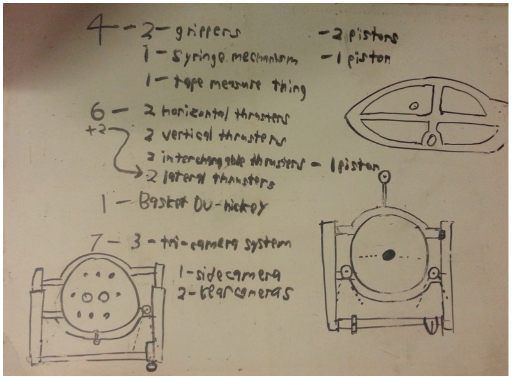


Figure 1: Side view sketches of the Hydrus with a checklist of all pistons, thrusters, and cameras.

The first step in designing a frame is to consider the systems that the ROV will hold. To efficiently perform the missions, the Hydrus needed two separate grippers and a double syringe with a ram. Pistons are needed to operate these tools. We also needed to consider space for the thrusters - two horizontal, two vertical, two lateral, plus two that can be rotated between horizontal and vertical positions to allow for additional thrust when needed. Of course, water-tight enclosures were necessary to house

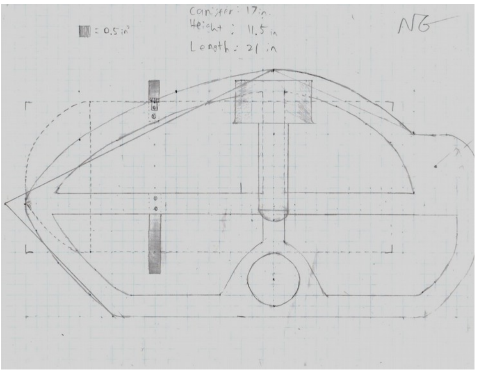


Figure 2: The original design draft of the Hydrus.

the electronics, the pneumatic valves, and the various cameras. Our design team settled on a rough draft that came out of our first brainstorming session (see figure 1). We then drafted a 2D drawing that established the placement and spacing of all necessary tools (see figure 2). The largest parts of the frame are the two side faces, to which all other components are attached. Instead of going with the typical one-size-fits-all rectangular shape to which many ROVs are bound, we decided to specifically shape our frame to fit only the tools necessary for this year's mission while keeping with a more hydrodynamic drop shape. This allowed us to dramatically reduce the ROV's size and shave off unnecessary weight. The Hydrus is expected to fit into tight spaces during shipwreck recovery missions, a task which requires the vehicle to be compact and maneuverable. As an added bonus, it is much more aesthetically pleasing.

Figure 3: Noah using a jigsaw to cut out the frame.

Our engineers now had the task of choosing the frame's material. While aluminum has the advantage of providing a rigid support structure, it adds a tremendous amount of mass to the ROV. PVC is another common choice in frame construction, with interconnecting pipes that allow for simple assembly. However, they also make precise placement of tools and thrusters more difficult, and are somewhat unsightly for use in professional ROVs. Given the positive experience DeepView Technologies had with Ultra-High Molecular Weight Polyethylene (UHMW) in the past several years, our engineers once again settled on this material. This thermoplastic is highly durable, yet easy to manufacture into any desired shape, and is fairly inexpensive, making it perfectly suited for our needs. Most importantly, UHMW has a specific gravity of 0.94, which means it is neutrally buoyant.

With schematics drawn and materials chosen, construction commenced. We started with 4'x4'x½" sheets of UHMW, as we found that ½ inch of material was the least amount of thickness necessary to provide the structural stiffness we needed. Next, the design team carefully sketched the outline of each frame section onto the plastic sheets. Then, after cutting around each piece with a jigsaw and a steady hand (see figure 3), our team painstakingly sanded away imperfections to reveal the finished product.

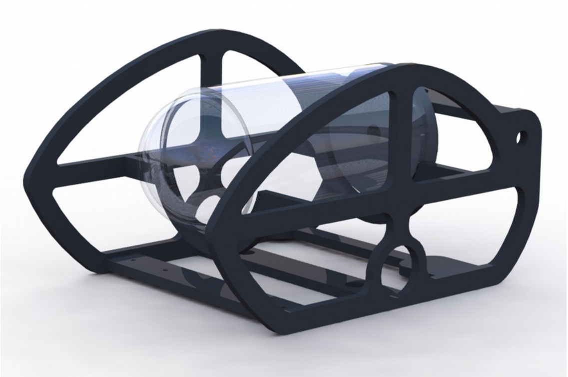


Figure 4: Mechanical CAD drawing of the Hydrus' frame and canister

The frame (see figure 4) was assembled using stainless-steel sheet metal screws, which hold each piece firmly in place while still allowing disassembly if needed. The ROV's main electronics canister sits atop two U-shaped braces spanning the width of the frame. Our two pneumatic grippers are mounted at the bow of the vehicle beneath the canister on a 5 cm wide UHMW brace. At the stern, our measuring device is fixed upon a similar brace. Just above, cables entering the canister are fed through another brace and are mounted with a strain relief grip. This wire mesh grip absorbs and relieves tension from the electrical connections to the canister. The pneumatic piston controlling DeepView's own Dynamic Thruster System is attached to the frame with a specially designed aluminum bracket, and runs through a hole cut in the rear canister brace. Each of these UHMW braces make up the Hydrus' frame structure, connecting the two side faces and providing space to mount the ROV's tools. The entire frame was manufactured in-house by DeepView engineers.

Buoyancy

Buoyancy was a crucial factor in the Hydrus' design process. ROVs require steadiness at varied depths and perform substantially better when their floatation is tuned correctly. DeepView's design team kept this fact in mind when choosing the craft's materials. As already mentioned, the Hydrus' frame is manufactured from UHMW polyethylene with a specific gravity of 0.94, which means that the frame itself has a negligible effect on buoyancy. Weight attached to the frame mainly consists of tools, cameras, equipment within the waterproof canister, and thrusters. These were placed along the frame in such a way as to evenly distribute weight and maintain balance. Our engineers found that the large acrylic canister housing the on-board electronics would provide the lift necessary to counteract the now substantial amount of equipment sinking the ROV, and little additional floatation was needed to achieve neutral buoyancy. In fact, without the bulky foam that is common on many similar crafts, the Hydrus suffers from far less drag than a typical ROV. A transparent dome seals the front end of the cylinder, providing clear views for internal cameras and adding to the vehicle's hydrodynamic design (see figure 5).


Figure 5: The waterproof canister that contains the electronics and pneumatic manifold.

The canister was produced in-house by cutting an acrylic tube and attaching the dome to it using acrylic solvent cement. A detachable cap seals the canister at its base, and is kept waterproof using a nitrile rubber O-ring. It is fixed to the canister by three Dive-Rite snaps, which are anchored to the acrylic cylinder. The length of the canister is 28 cm, while the inside diameter measures 16.5 cm. For calculation of the canister's volume, the inside radius of the dome is assumed to be the same as the cylinder radius, although it is a bit smaller. That leads to a displacement volume of around 7 L. This allows for 7 kg of heavy payload tools, thrusters, and cameras. From this, approximately 2 kg needs to be subtracted to account for the equipment inside the canister.

Propulsion

The Hydrus uses six Seabotix BTD-150 thrusters for navigation (see figure 6): two for horizontal movement, and two for vertical movement. Additionally, to provide ancillary thrust, DeepView developed a Dynamic Thruster System using pneumatic pistons to rotate two thrusters at the rear of the ROV to either vertical or horizontal positions. This was done when we realized that we

needed more powerful vertical thrust in order to carry the 10 kg anchor line to the surface, the heaviest payload of the mission. Also, when rotated into the horizontal position, the Dynamic Thrusters provide increased forward and reverse thrust. We decided to mount the thrusters on the ends of an aluminum axle across the frame which can be rotated by 90º using a pneumatic piston and a folding bracket mechanism (see figure 7). The thrusters were connected to aluminum plates on either side of the Hydrus and then were welded to the aluminum axle. The axle connects to the bracket folding mechanism on the leftmost part of the bar.
The folding mechanism is then connected to a pneumatic piston which is attached to the side of the frame. The piston controls whether the thrusters are facing vertically or horizontally, if the shaft is in, the thrusters face horizontally and if the shaft is out, the thrusters face vertically. The BTD-150 thrusters are equipped with Kort nozzles to improve thrust and are rated by Seabotix to produce 2.2 kgf bollard thrust continuously at 19 V which corresponds to a force of 22 N. However, our ROV is restricted to 12 V maximum voltage and our tests revealed a thrust of approximately 9.6 N under realistic conditions. We therefore realized that two vertical thrusters would not provide sufficient thrust to lift the anchor.
The forward/reverse thrusters are controlled by a differential drive system. This means that the two thrusters are independently controlled and can run at variable speeds, enabling the Hydrus to make tight turns determined by the difference in the motion of the two independent thrusters. This system gives the Hydrus a zero turn circle, allowing it to rotate in place. The thrusters were placed on the outside of the ROV in order to maximize leverage for tight turns. Additionally, the Hydrus was outfitted with two modified Rule 4160 Lph (100 gph) bilge pumps for precise lateral movement. This additional movement allows the Hydrus to make small corrections and reposition itself when needed.
In order to keep both operators and the marine environment safe, the propellers of the thrusters needed to be well shielded. The Seabotix thrusters come with their own commercial enclosure while the bilge pump thrusters were custom-fitted with enclosures using acrylic cylinders and metal grates (see figure 8). These protect the propellers and prevent damage to systems outside the ROV. Commercial thrusters were used because DeepView Technologies currently does not have the expertise to build their own thrusters from scratch. We chose Seabotix Thrusters because of their excellent price to performance ratio.

Figure 6: A Seabotix thruster. These supply the majority of the thrust for the Hydrus.


Figure 7: The Dynamic Thruster System.

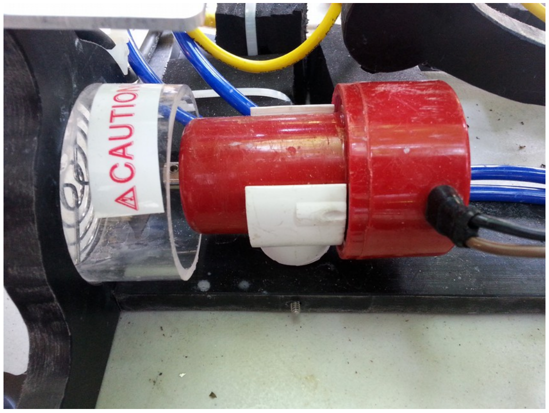


Figure 8: A lateral thruster made from a modified bildge pump.

Pneumatics

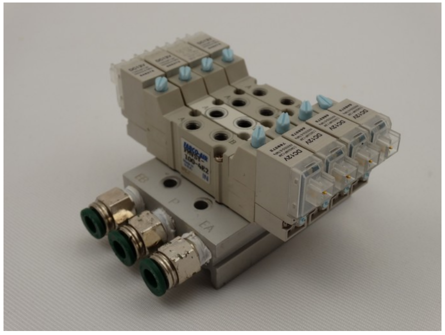


Figure 9: The Pnuematic manifold.

When designing the pneumatic system we knew that we needed an arrangement that was both compact and able to power two grippers, a dual syringe ram, and the Dynamic Thruster System. After experimenting with many different pistons, we decided to use double-action pistons with bidirectional U-cup seals on the shaft. The seal strengthens as water pressure increases on the external seal and as air pressure increases on the internal seal, thereby maintaining a positive seal on either side of the shaft. We decided to use a fully closed pneumatic system consisting of four pistons of different length, ¼” OD pneumatic Polyurethane tubes, and a 4-station pneumatic manifold (see figure 9). The manifold was secured to the bracket inside the canister, and the tubes were connected to valves in the end cap. More pneumatic tubing was connected to the outer sides of the valves and then connected to the pistons. These valves keep the end cap waterproof and allow us to be able to swap out tubes if they become damaged or in the case of switching channels to adjust to new hardware.


Figure 10: The three types of pneumatic pistons used on the Hydrus.

Two of the tubes that come out of the end cap go into the tether and reach up to the surface, with one tube going into a compressor and one being used for exhaust. The tubes are rated at 1.2 MPa (175 psi), the manifold is rated at 0.7 MPa (100 psi), and the pistons are rated at 1.7 MPa (250 psi). The pneumatic pistons and manifold were purchased commercially because we do not have the technology to make our own and also because they were offered to us at a substantial discount.

Tools

All payload tools and the measuring device were designed and manufactured in-house by DeepView Technologies.

Payload Systems

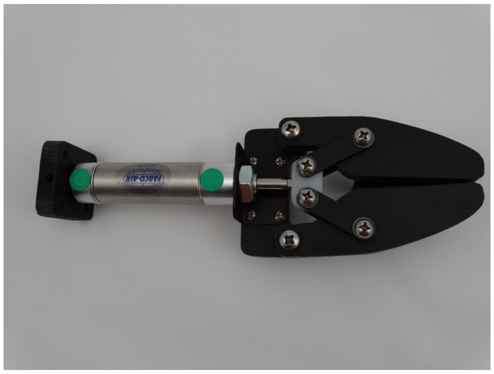


Figure 11: The vertical gripper.

In order to complete the mission tasks, DeepView Technologies developed the Hydrus with three payload systems. They are actuated by double-action, lateral pneumatic pistons powered by compressed air, at a pressure of 276 kPa (40 psi). The payload systems include two nearly identical padded grippers, one oriented vertically and one oriented horizontally, and a dual syringe mechanism.

The gripping surfaces are made from UHMW claws, aluminum L brackets (one for the vertical gripper surfaces and two for the horizontal gripper surfaces), and square rubber pads. Using a band saw and a belt sander, we then built pivoting aluminum arms that would connect the surfaces to the pistons for each of the grippers. These arms are connected to a small UHMW joint using stainless steel screws. The joint was then screwed into the shaft of the piston, and an aluminum bracket provides additional stability to the claws. When they were complete, the vertical gripper and the horizontal gripper were attached to the starboard and port side of front of the ROV, respectively.

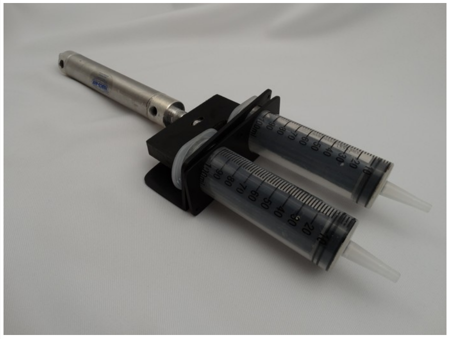


Figure 12: The dual syringe system.

The dual syringe ram was built from a U-shaped section of UHMW, two 100 mL syringes, and a plastic tube that connects the two syringes. We connected the tube to a splitter which created two ends of the tube to attach to the two tips of the syringes. We attached O-rings to the tops of the UHMW section to act as shafts for the syringes. We also screwed the UHMW section into the shaft of the piston. The entire mechanism was attached to the inner port side of the Hydrus where the piston and syringes could be protected and the tip of the tube could extend outward (see figure 12). The mission requires us to extract a sample of at least 150 mL from the microbial mat. Because 100 mL syringes were the largest size readily available to use, a dual syringe setup was employed.

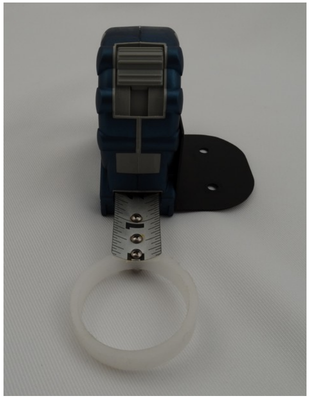


Figure 13: The measuring device.

Measuring Device

One of the tasks in the mission requires measuring and documenting the dimensions of a shipwreck. To do this, we came up with the idea of mounting a stainless steel tape measure to the stern of our ROV on one of the frame’s cross braces. We moved the belt clip and re-used the holes of the belt-clip mount in order to mount the L shaped bracket (figure 13). The bracket is made from an L-shaped piece of aluminum which was cut to size with a bandsaw, then rounded out with a belt sander. Two holes were drilled into the bottom of the bracket for mounting the tape measure to the cross brace on the ROV, and then one hole was drilled on the side of the bracket for mounting the bracket to the tape measure. The UHMW ring on the end of the tape measure was designed to hook onto the screws on the corners of the shipwreck. After attempting the mission, we realized that the tape measure needed to be angled farther downward in order to attach to the shipwreck more easily. To solve this issue, a sloped piece of UHMW was cut down to the exact shape of the aluminum mounting bracket and fixed underneath, providing the tilt we needed.

Tether

The tether used by Deep View Technologies includes a pair of #12 AWG wires, a pair of #16 AWG copper wires, two Cat 5e cables, two fiber-optic cables (1 mm fiber diameter), and two ¼” pneumatic tubes (see figure 14). The pair of #12 AWG wires, protected by a 25 A fuse, provides 12 V and ground to the electronic systems of the Hydrus. We used #12 AWG wires for main power because they have very low resistivity. This leads to a combined resistance of only 0.19 Ohm over 36.5 meters of wire, which results in a total resistance of only 0.095 Ohm over 18 meters. At maximum allowable current (25 A) this corresponds to a voltage drop of about 2.4 V, which is still tolerable for powering the ROV. The pair of #16 AWG wires is used to supply power directly to the two lateral thrusters.

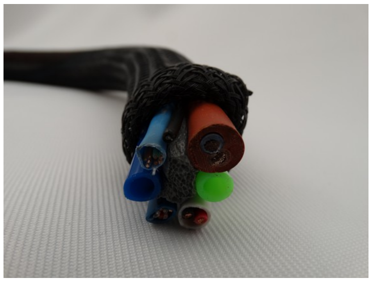


Figure 14: A cross-section of the tether.

Two CAT5e cables are used to carry the video feed. These cables are beneficial because the twisted-pair wires inside reduce interference. One fiber optic cable is used to carry information to control the thrusters and pneumatics, a second cable is in place as a backup if the first fiber optic cable were to become damaged. There are also two pneumatic tubes within the tether. One tube is pressurized, transferring air compressed to 40 psi to the ROV's valve bank which controls the pneumatic tools. The other tube is for exhaust, venting air from the valve bank back to the surface. Our tether uses ¼ inch pneumatic lines which are flexible and reduce drag, making the tether easier to manage and less prone to affect the overall handling of the ROV. To ensure that the tether remains neutrally buoyant, a ½ inch foam backer rod is inserted within the middle of the wires. The cables and tubes are held together by a flexible mesh sheath, making tether management simple. This tether is durable, easy to handle, and features a relatively thin diameter of approximately 3.5 cm.

Electronics

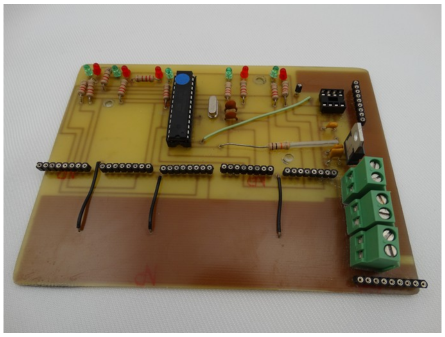


Figure 15: The Hydrus' navigation board with Arduino microcontroller.

Electronics are an integral part of any robotics system. At DeepView Technologies, we are constantly improving our electronic systems so our ROVs can be more efficient and use a smaller footprint. What sets us apart from the competition are the use of fiber-optic communication, Arduino microcontrollers, and home-made printed circuit boards (see figure 15).

Fiber-optic communications have greatly improved the quality and speed of our signals since we introduced the technology to our ROVs in 2012. We decided to use fiber-optics as opposed to a CAT-5E cable to transmit our signals because fiber-optic cables are much more reliable over long distances. Normal wires do not work well for transferring data over long distances because of the voltage drop that occurs and because they are more prone to outside interference. Fiber-optic cables use light to carry digital signals across the cable. The light can travel for very long distances without experiencing significant loss in intensity and it does not suffer from electrical interference.

Our fiber-optic setup utilizes a transmitter, a receiver, and a 60 foot fiber-optic cable. In order for a signal from the control board to be transmitted by the fiber-optic transmitter, the signal has to be taken from one of the TX pins of the Arduino, and is then sent through a NAND gate in a 74LS00N chip. The fiber optic transmitter takes this transformed signal and sends it through the tether to the fiber optic receiver. The on-board Arduinos use the signal from the receiver to execute their tasks. We anticipated problems from switching our microcontrollers from PIC16F88 to Arduinos, but the fiber-optics could be interfaced with the microprocessors just as before. The challenge was getting the software to work, which required some more complex coding, as will be discussed later in this section.

A significant improvement this year to our ROV compared to previous models is the implementation of Arduino microcontrollers. Arduinos use the widely distributed C++ programming language and have more processing power than the PIC16F88 chips we used in previous models. Although C++ was a new language to our software developers, our talented team was able to quickly learn the required commands by collaborating and using outside sources such as *Programming Arduino* by Simon Monk. In order to learn how to use Arduinos, our programmers set aside the month of January for research. After gaining a basic understanding of the language, the team began writing the basic code needed to control the main systems (see figure 16). 467 lines of code were written. It was fairly straightforward and contained mainly 'if' statements. The most challenging part was getting the serial communication to work through the fiber optics. We finally succeeded in packaging the control information into arrays and correctly sending it over the fiber-optic cable. However, the receiving Arduino was not using this data correctly and seemed to be getting random variables. After some research, we discovered that adding message markers to the beginning and end of each package of data would provide the solution to this problem. The receiving Arduino would then check each package to make sure that both message markers were there before beginning to use the data. We found that this method worked very well, and it is still being employed on the Hydrus. To describe this process in more detail, the transmitting chip packages all the information into a simple array, which is then sent serially to the receiving chip. This chip then reads the required number of bytes and checks to see that they are the correct ones. It does this by ensuring that the start and end of message markers are correct. If these markers are not correct, the chip throws out that string of bytes and looks for a new one. The chip then unpacks the correct arrays and uses the bytes to carry out its code.

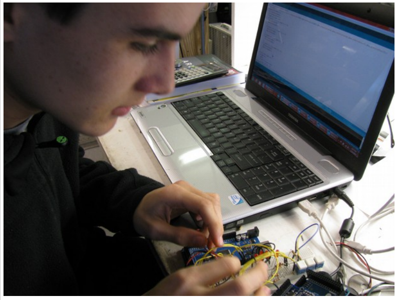


Figure 16: Timon programming an Arduino microcontroller.

The Hydrus uses one Arduino Mega 2560 inside the control box and two Arduino Uno’s on-board the ROV. A Keyes USB Host Shield is attached to the Mega 2560 so that the Xbox controller signal can be sent to the Arduino. In order to use this signal, we found an Arduino library, created by users felis and Lauszus (github.com) which attributes custom commands to all the functions of the Xbox controller. These custom commands allow the Arduino to check whenever the state of a button or joystick is changed on the controller. They can also tell the controller when to rumble or change its LED settings.


Figure 17: Tirza drilling holes in one of the PCBs.

A valuable feature of the Hydrus is our home-made PCBs (Printed Circuit Boards). These boards make the Hydrus' electronic systems more reliable and simple. PCBs are very beneficial because they are compact and provide solid support and connections for the electronic components. They are also aesthetically more pleasing than messy bread-boards. After we test a circuit using breadboards, a PCB is designed using the program Eagle by CadSoft. The program places the pads and necessary connecting wires into the 2D working area. It is then printed out on a transparency film, on which the lines show up black for positive photoresist boards. A single-side copper-clad board from MGChemicals is then prepared by cutting it to size, and removing the protective film from the photoresist layer. The printed film is placed on top of the board and irradiated with a UV lamp (MGChemicals Exposure Kit) for 8 minutes. The exposed board is then dipped into a developer solution of 20 mL of MGChemicals positive developer with 200 mL of water. Now the developed photoresist can be brushed off with a foam brush. The copper is exposed where the UV-exposed photoresist was washed off while it still protects the copper layer where the black circuit drawing prevented the UV to reach the photoresist. Now, the board is placed into a container with a 39% ferric chloride solution (MGChemicals) which dissolves the copper and exposes the underlying substrate. This process typically lasts between 30 and 45 minutes, but the PCB has to be checked frequently to confirm that the ferric chloride does not etch the copper making up the circuit that needs to remain. After the copper is removed the board is rinsed with water and dried, and finally holes are drilled where the components are to be connected, and the components are soldered on.

In total, four different PCB boards are used on Hydrus – one for propulsion/navigation, one for control of the pneumatics, one for the cameras, and one for the control board. An example of a circuit schematic made by DeepView Technologies is shown on page 22.

Control System
The control system of the Hydrus includes the main control box (see figure 18) and the Xbox controller (see figure 19). The control box houses all of the surface electronics and has ports for connecting the different components of the tether as well as the Xbox controller. Not only does the control box take the inputs from the pilots via the Xbox controller to send to the ROV, it also receives important sensor data from the ROV to display on two LCD screens, and an LED on the front of the control box.

Figure 18: The control box.

Figure 19: The Xbox controller.

The Hydrus' control box has been re-purposed from last year's ROV model. To create the control box, our engineers drafted a design which was sent to Tel-Test, who manufactured it according to our specifications. This was done because we do not have the necessary tools for bending metal required to produce a professional-looking box. Employees of DeepView Technologies added all other components to the control box, including electronics, connector housings, switches, LCD screens, etc., and a few slots for future expansion. While the Hydrus does not use the switches or sliders on the control box required for last year's ROV and relies solely on the Xbox controller, our engineers decided to keep these components on the box because they could serve as a backup control system in case of electrical malfunctions.

We decided to use an Xbox controller as opposed to the traditional joysticks because it is much easier for the main pilot to control everything with the Xbox controller. It controls all thrusters, pneumatic pistons, and lights on the ROV by connecting to the Arduino inside the control box. With previous ROVs, we found it difficult to communicate effectively when the pilot was focusing on the joysticks, while the co-pilot was focusing on all of the switches. With an Xbox controller, all the commands are consolidated onto one device, and the pilot can control everything without having to waste time telling the co-pilot which switch to flip. This allows the co-pilot to stay focused on the cameras and on conveying important information to the pilot such as what task needs to be completed next or which direction the ROV is heading.

Cameras

Camera selection, positioning, and functionality are paramount for the pilot to be able to effectively accomplish the project missions. This year, Deepview Technologies experimented with several new types of cameras and two encasement designs.

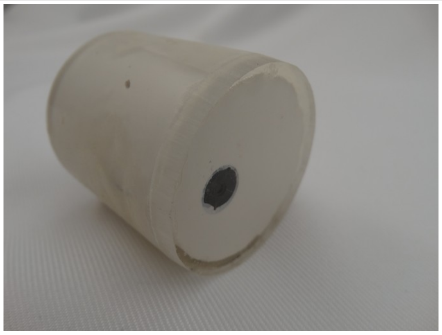


Figure 20: The old camera design.

The Mini Video CCTV Pinhole security camera was the first type of camera we used. Because this camera is not waterproof, we had to create our own canisters to keep water from getting inside the camera (see figure 20). We started by gluing a transparent acrylic circular plate to the end of an acrylic cylinder. A camera was placed onto the bottom of the cylinder, lens against the transparent plate. We stripped the connecting wire of each camera and soldered it to another 18 gauge wire, heat shrinking it to insulate the connection. This additional wire was extended from the encasement to the ROV. The camera and its original connecting wire were secured inside the cylinder by filling the cylinder with epoxy, creating an entirely waterproof unit. We epoxied a swivel bracket to the back of the cylinder, thus providing enhanced flexible camera positioning. Two cameras were mounted, each fixed to view both grippers, as each gripper required a camera to view horizontal location and vertical depth. We also mounted one camera to view the ROV’s measuring system, and one rear view camera. Additionally, two cameras were placed inside the ROV’s canister, allowing forward and side vision of the vehicle.


Figure 21: An outer camera, kept waterproof by the canister.

While operating the ROV, it was discovered that the first waterproof camera design had an unstable wiring connection due to the soldered joint being crammed too tightly into the canister. The cameras turned out to have an insufficient field of view. Rather than adding more cameras at additional cost, we decided to experiment with alternative camera types and a different waterproof encasement method (see figure 21).

A FishEye camera and a Mini Spy Board CCTV camera were ordered. The FishEye camera has a field of view of 170 degrees, outstanding for such a small camera, and boasted a resolution of 1280 x 960 pixels. We replaced the two cameras inside the main canister of the ROV with the FishEye FPV cameras. The Mini Spy Board CCTV cameras were purchased because they also provided a wider field of view. We developed a new encasement method which was more effective. A longer acrylic cylinder was used so there would be less stress on the wiring connection. Instead of filling the cavity of the cylinder with epoxy, we placed hard foam around the camera to hold it in place. This reduced the time needed to dry epoxy, and eliminated the possibility of getting epoxy on the camera lens. Holes were drilled into a second acrylic plate for the wire and the mount. The plate was permanently secured to the cylinder using marine glue. Finally, we used epoxy to seal the container where the wire exited. Improving the cameras equipped the pilot to better perform the missions. In total, 6 cameras provide a complete view of the tools and the ROV's surroundings. We decided against purchasing commercial waterproof cameras because by building our own waterproofing systems we had more flexibility, we could tailor them to suit our needs, and we saved money.

Sensors

One of the tasks in this year's mission required our ROV to locate a source of venting groundwater and then to compare the conductivity of the groundwater compared with that of the lake water. This process is simulated by two cups, one with saltwater (the venting groundwater) and the other with freshwater (the lake water). To complete this task, Deep View Technologies engineers created a conductivity sensor made up of two electrical probes soldered onto a 60 foot pair of #16 AWG copper wires (see figure 22). We inserted the soldered connection into the acrylic tube and used epoxy to waterproof the connection and to provide stability while the probes were inserted into the vents. The remaining copper wire runs up to the control box where the voltage drop between the two probes is measured by the Arduino inside the control box and then displayed onto one of the LCD screens. The voltage drop is measured by using a voltage divider where the sensor acts as the resistor that connects to +5 V, and the resistor going to ground is 10 kOhm (see figure 23). The Arduino measures the potential voltage between these two resistors, which corresponds to the voltage drop of the conductivity sensor. The more conductive the water, the lower the resistivity between the probes. The wires for the conductivity sensor are separate from the main tether to enable the pool-side assistants to easily remove the sensor from the water after the conductivity readings have been taken.

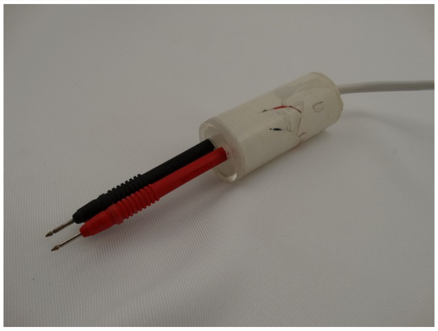


Figure 22: The conductivity sensor, used to measure the venting water.

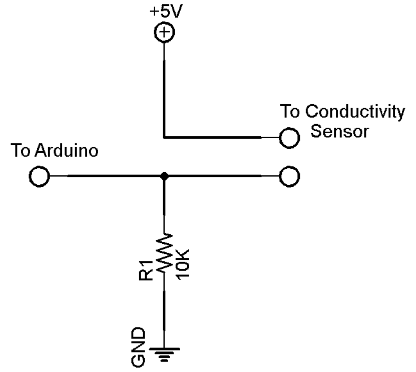


Figure 23: The conductivity sensor's circuit diagram.

Although not necessary for mission completion, a temperature sensor (see figure 24), water leakage sensor, and a waterproof analog compass were implemented on the Hydrus so that users can have access to important information about the vehicle while it is in use. The temperature sensor (a thermistor) is located in the main canister of the ROV to alert the pilot of overheating circuitry. The thermistor is connected to one of the CAT5e cables, which carries the signal to the control board. To read the output of the thermistor, we use the same method as the conductivity sensor, using a voltage divider. Because the relationship between the change in voltage drop and the change in temperature is linear, we created an equation by recording the voltage drop when the thermistor was placed in two different baths of known temperature and then solving for y=mx+b. This gave us accurate temperature displays for all ranges of temperatures the Hydrus may experience. The Arduino in the control box displays the correct temperature on the LCD screen, which updates every time the main code goes through a loop. In addition to the warning on the LCD screen display, when the temperature inside the ROV gets above thirty degrees Celsius, the vibrators inside the Xbox controller are programmed to activate every minute to let the operator know about dangerous temperature levels. This allows the pilot to quickly take action whenever the electronics overheat and avert further damage to the ROV.


Figure 24: The thermistor in the temperature sensor.

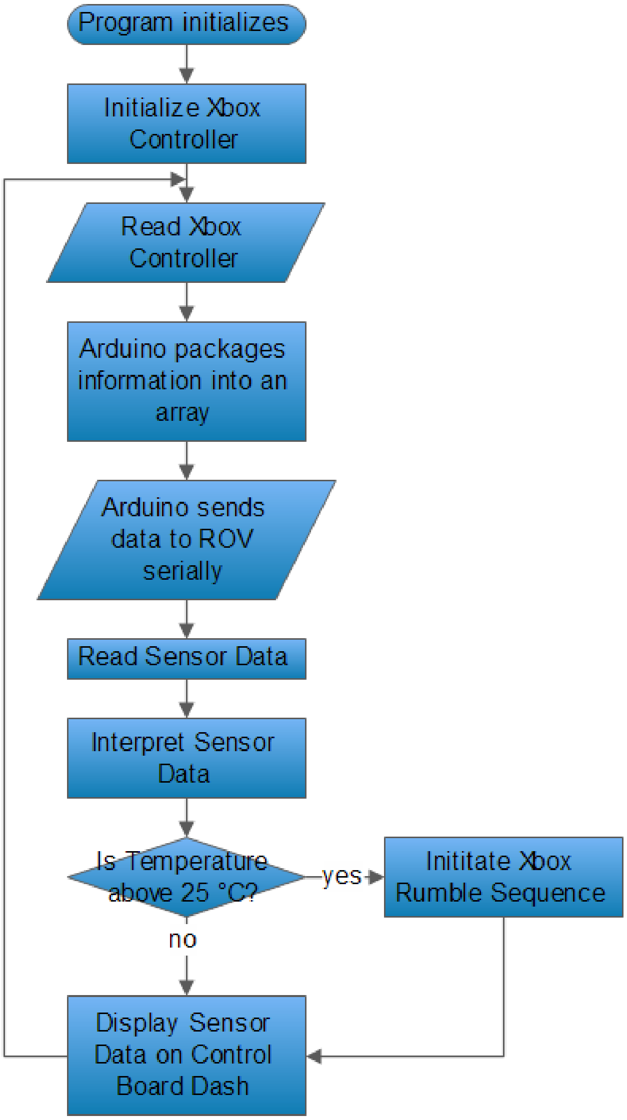
Another sensor located in the canister is the water leakage sensor. True to its name, this sensor alerts the pilot to the presence of water in the canister. This is important, because it allows the pilot to bring up the ROV before the circuit boards housed in the canister are ruined by being submerged. The sensor is placed in the bottom of the canister where the water is most likely to collect and consists of two copper wires. When the bottom of the canister fills with water, the copper wires are submerged which closes an electrical circuit and causes an LED to turn on alerting the pilot of the situation.

Another important sensor is a waterproof analog compass (see figure 25). This compass, which is mounted on the bow of the Hydrus can be clearly seen by the front camera, allowing the pilots to orient themselves if they get lost. Creating the small compass presented several difficulties, namely: the loss of time, effort, and the difficulty of making a workable compass that is waterproof and small enough to complement our ROV. Because of these difficulties, Deep View Technologies elected to use a commercial compass. The compass was attached securely to the frame of the ROV in plain view of a camera. To mount the compass on the Hydrus, we drilled a small hole just wide enough for the compass to mount into one of the side panels of the frame. The compass mount fits snugly into this hole and can only be pulled out intentionally. These sensors allow the ROV to be safer and more reliable.

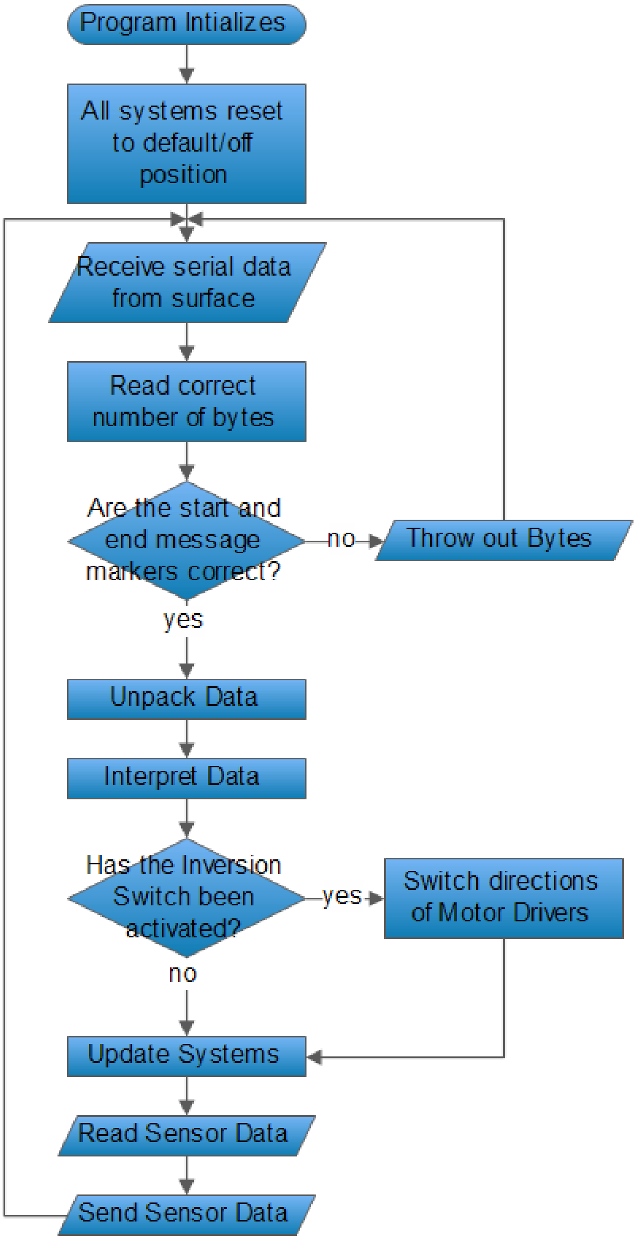
Figure 25: The analog compass.

Software Flowchart

Control Box



ROV



Troubleshooting Techniques

With so many complex systems on the Hydrus, we realize that there will be times when the ROV malfunctions. Knowing this, our engineers have outlined a detailed troubleshooting process to allow users to swiftly restore the Hydrus' functionality should something go wrong. The main steps in our troubleshooting process are: Isolating the Problem, Implementing a solution, Checking the solution, and then Trying a different solution if the problem has not been resolved.

An example of this troubleshooting process could be a situation where the Hydrus suddenly stopped functioning while offshore. Before pulling the Hydrus back in by its tether and possibly causing damage, operators could check the control box on the surface to see if it has power. If it does, then the problem could be narrowed down to the tether or the ROV. If the control box does not have power, then operators could narrow down the problem to the surface systems and possibly get the ROV operational again without having to remove it from the water. A typical problem might be that the power was unintentionally unplugged, the battery might have run low, or the fuse could have blown.

Our team had to use this troubleshooting process at the Florida regionals competition. In the middle of the first run, disaster struck and all of the pneumatic tools stopped functioning. We had already completed some tasks and our time had almost run out, so after checking that the thrusters still functioned, we attempted some other missions that did not require the pneumatics to be functional. After the mission, we removed the canister and diagnosed the pneumatics board to isolate the problem. After checking that there were no loose wire connections on the board and that the valves switched manually, we turned the ROV on again and the board worked. However, the power would only stay on when the board was held in a certain position. We looked closer and noticed that one of the solder joints had become loose. The obvious solution was to resolder that joint, and then after checking all pneumatic systems, we were able to confirm that this had been the problem and that our troubleshooting process had worked.

Safety

Safety is DeepView Technology's highest priority. Our products were designed specifically to be safe to manufacture and safe to use. Fortunately, this year no major accidents have occurred. There were a few minor injuries, ranging from cuts and scrapes to solder burns. More serious accidents were avoided in part due to our safety practices, which have kept our members safe and our machines working properly. Each company member must be trained and certified in the use of power tools and pneumatics before being allowed to operate machinery. We were required to wear personal protective equipment (PPE), including eye and ear protection, face masks or safety glasses to protect against flying projectiles. Protective gloves had to be worn when sanding so that hands would not be burned or shaved. A licensed driver always had to be present while we were working on the ROV or with power tools to transport teammates to the hospital in case of major accidents. Safety precautions when operating/handling the ROV included long pants, closed toed shoes, and tying long hair back into a knot. We made sure the electronics / electrical power connections were far from the water and always checked to make sure the pressure in the air compressor was always regulated to 0.3 MPa (40 psi) or less. When transporting the ROV, it must be carried by a minimum of two people, although usually three people assisted in its transport.

The Hydrus included the following safety design features: We sanded down all sharp edges on the ROV and placed caution stickers on potentially hazardous devices, such as the thrusters. We also added fan kort nozzles to the thrusters and bilge pumps to protect people and the lake environment from spinning propeller blades. All loose connections were secured and every component was attached securely to the frame. All the electronics can be powered-down within five seconds by a switch controlled by the pilot, in case of problems. A 25 Amp fuse is on the positive side of the power source of the battery in the event that a short circuit occurs. The pneumatic tubes and fittings are rated to 1 MPa (150 psi), although the normal operating pressure is around 276 kPa (40psi). A temperature sensor and a water leakage sensor located in the main canister of the ROV alert the pilot of overheating circuitry or a leakage of the canister which could harm the electronics. A compass also helps the pilot to orient the ROV.

Safety Checklist

Company

- Always wear eye and ear protection when working with power tools
- Long hair must be tied back into a knot
- Wear correct safety apparel including long pants, closed toed shoes, and safety goggles when on deck
- No loose clothing

Physical

- The ROV has no sharp edges or exposed harmful materials
- All items are connected securely to the ROV and will not fall off
- All connections have strain relief
- Caution stickers are placed on any possible hazard (thrusters, grippers, etc.)
- Every propeller contains its own covering to protect wildlife and pool managers
- Tether is properly secured at surface and in ROV
- The ROV must be carried by at least two people when moved

Electrical

- 25 Amp fuse on the positive side of the main power source
- All electrical wires and parts are kept away from water
- All wiring and electrical parts are properly sealed
- All electrical components are enclosed in a box at the surface
- Check all connections before turning on power
- Make sure the compressor’s pneumatic pressure is lower than 40 psi before turning on the ROV

Challenges

Technical Challenge

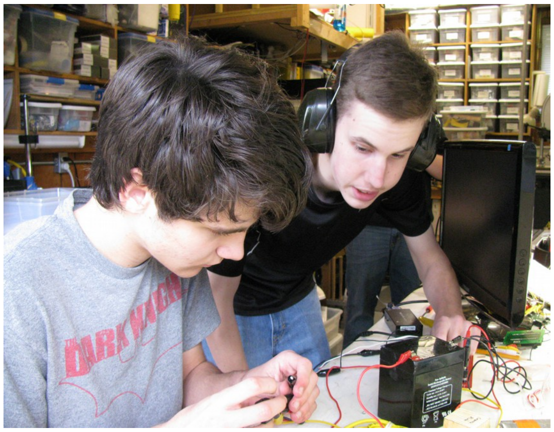


Figure 26: Timothy and Pierce working on camera functionalities.

This year's major technical challenge was the cameras. We strove to create smaller waterproof housing for the cameras outside of the main waterproof canister. In order to do this we experimented with waterproofing various mini security cameras in a small canister (see figure 26). The company created a one-ended cylinder without any complications. The connection between the camera and the wire was coiled inside of the canister, and it was filled with epoxy. Initially, this setup proved compact and efficient. However, prolonged use caused the camera feed to flicker and give out. To temporarily fix this, we used Harbor Freight Underwater cameras and used tape and zip ties to attach them to our pre-determined camera mounts. These worked well as a temporary fix to this major issue. We were forced to keep these cameras in place for the regional competition as we had no time to create another solution. After regionals these were replaced by a camera setup which included a one ended canister much like the original. The camera was placed lens down and surrounded with hard foam to solidify its position. As opposed to using epoxy to fill up the entire canister, another acrylic plate was glued to the other end of the canister. This plate had two holes in it: one for the wire running to the main canister and one for the mounting bracket. In order to fully waterproof this new component, epoxy was applied to the two holes in the end cap. This design successfully functioned as a compact waterproof unit that could easily be positioned at useful angles around the ROV.

Non-Technical Challenge

One of the greatest challenges our team faced this year was an inadequate amount of work space. With six additional team members, there often wasn't enough room for everyone to concentrate on their specialized projects at the same time. Everyone took turns using the shop areas, which sometimes reduced daily productivity. This sometimes led to a lack of focus, causing distractions to other members, or led to rising frustration as team members waited for a chance to develop their particular task. Clutter was also a result of having a congested work area. Our team overcame this dilemma by creating a good team chemistry and working together to complete individual assignments more quickly, thereby freeing up work space for the next group. We also organized and centrally located all the tools and parts so they were easily accessible to everyone.

Lessons Learned

Interpersonal

This year Deepview Technologies team members learned to develop patience with each other. As we worked, numerous instances appeared which required team members to use a tool or work space which someone else needed. These instances came throughout the year because of our small workshop and increased number of members. One example was during the process of epoxying the camera canisters. Due to the nature of epoxy, one team member had to hold the entire system without moving in order for it to dry properly as other team members operated around them. This process used up valuable work area which was needed by other members. Through this opportunity and many others, we all learned to respect our fellow co-workers and to be patient when they needed something we also needed, because we would want to be treated with the same respect and patience.

Technical

Understanding the programming language for Arduinos was possibly the most helpful and useful skill learned by our programmers this year. Even during the development phase, we knew that we wanted to use Arduinos on the Hydrus. This meant that the software developers and electrical engineers had to get started right away on learning the new language and understanding the new microcontrollers. This team learned many skills, including how to use basic if statements, arrays, serial commands, and the most important skill of all, knowing how to troubleshoot. The many important lessons learned during that process are what allow the Hydrus to dive today.

Teamwork

The team was composed of nine members this year: three senior members and six junior members. The senior members consisted of Timon Angerhofer, Noah Goodall, and Andrew Maule, The junior members consisted of Tirza Angerhofer, Timothy Constantin, William Hodik, Pierce Tolar, Oscar Witte, and Carter Wyatt. Each member was assigned to a specific system of the ROV with Timon overseeing the electronics development, Noah overseeing the design of the frame and how other systems fit into it, and Andrew overseeing payload systems. The junior members worked on systems under the guidance of the senior members. The mentors gave advice along the way but did not build any systems contained in the Hydrus nor program any of the electronics. As development went on, we devised several schedules to keep the ROV's construction moving and give us enough time to practice with it. We originally planned to have three weeks of practice time but due to delays on the completion of systems and troubleshooting we only had one and a half week to practice before regionals. Likewise, changes made to the Hydrus' systems in preparation for Internationals has cut down on our practice time significantly.


Figure 27: Oscar helping Timothy with Cameras. Oscar's main job was the canister.

Future Improvements

DeepView Technologies is always looking for new technologies and improvements to implement in our products. Although the Hydrus is already very advanced and includes technologies which very few competitors have, we know that there is always room for improvement. On next year's model, we hope to include an accelerometer and a gyroscope. An accelerometer will allow us to measure the different accelerations our ROV is producing and experiencing, while a gyroscope will give us information as to how much the ROV is tilting. With this information navigation can be improved greatly because we will be able to program thrusters to automatically adjust depending on the readings from these two sensors. For example, if we wanted the ROV to remain stationary in the water but there was a slight current, we would have to constantly monitor the cameras and the controls in order to prevent movement. With an accelerometer, the thrusters could be programmed so that whenever the joysticks are in zero-position, the thrusters would automatically turn on and off to account for the current and keep the ROV stationary. A gyroscope could function in the same way but would keep the ROV from tilting too much if, for example, a heavy object was attached to one side. To implement these sensors, we would have to find suitable microcontrollers to use, and then figure out how to integrate them into our programming. We are looking forward to discovering how an accelerometer and/or a gyroscope can be integrated into our future models.

Reflections

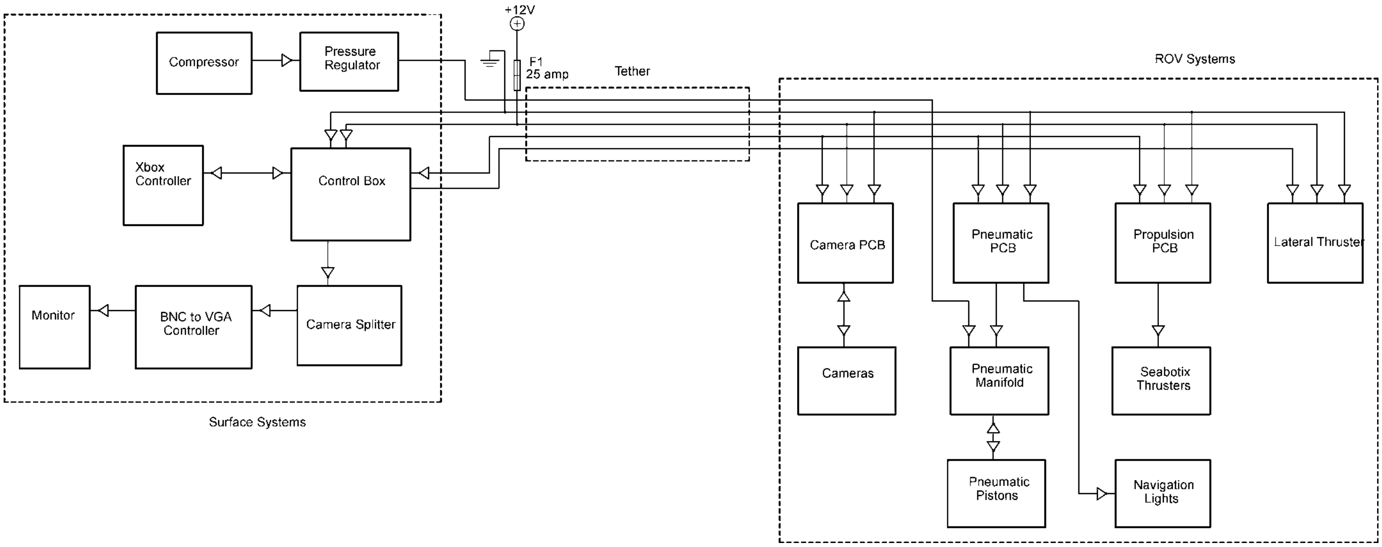
As we reflect on this year, we realize that Deep View Technologies has seen improvement in not only the ability and talents of its company members, but also their teamwork when working together. Late nights spent working on the ROV and quick troubleshooting before the competition have forced us to rely on each other. Through a positive attitude and a hard work ethic our team has been able to accomplish more than we thought we could and has pushed us to our limits. Through this project our members have gained confidence in themselves and the team as a whole. This year has challenged us and although we had new leadership and mostly new team members, we were able to overcome our difficulties to become a functioning company.

Financial Report

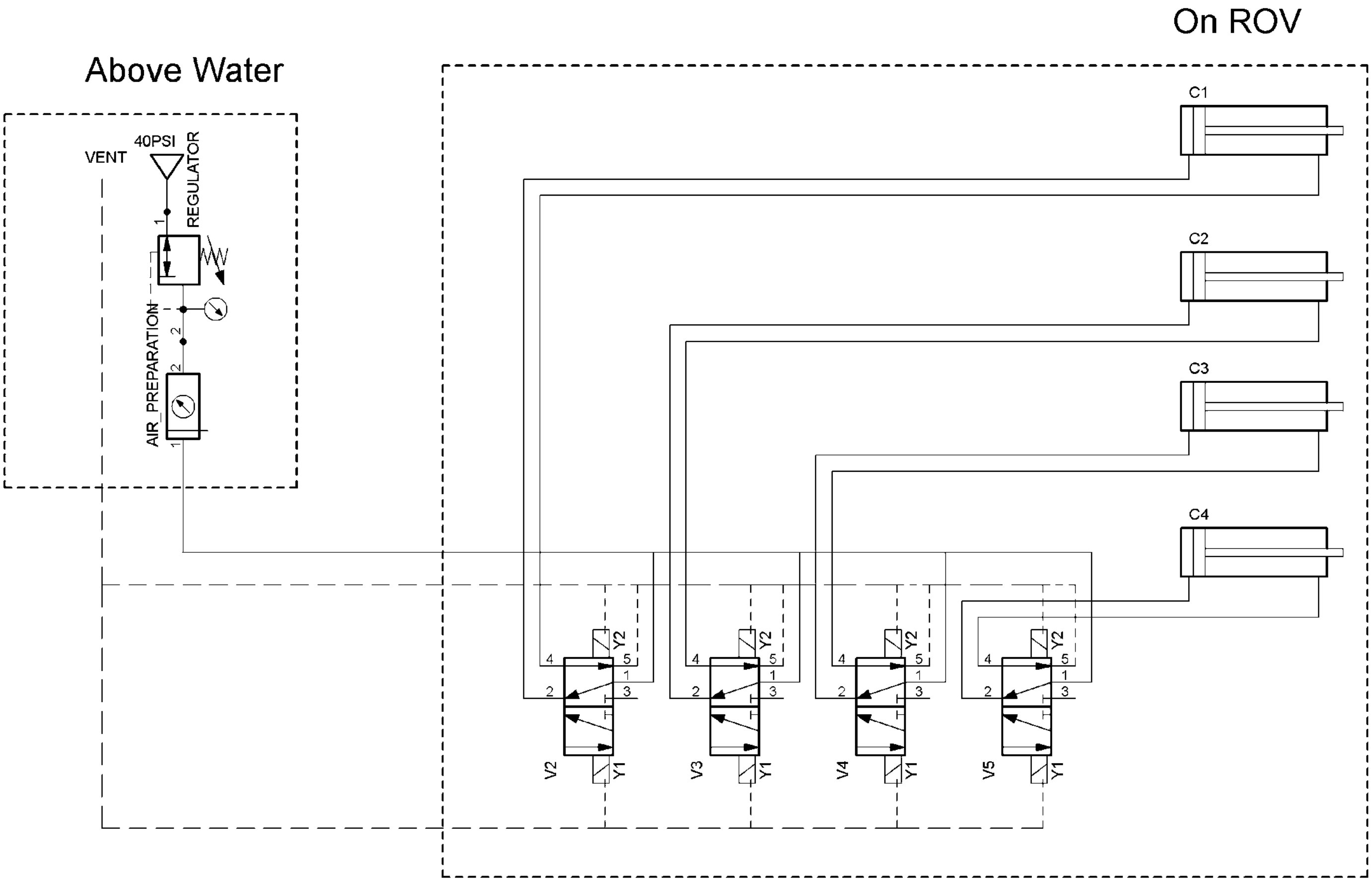
Date	Deposit or Expense	Vendor	Description	Balance
Donations				
9/1/13	$8,000.00	Team Parents	Parental Fee	$8,000.00
2/19/14	$1,000.00	Pamphalon Foundation	Donation	$9,000.00
11/20/13	$0.00	Fabco Air	Pneumatic Pistons	$9,000.00
Props				
11/4/13	($91.53)	Home Depot	Props- PVC and bolts	$8,908.47
11/4/13	($16.77)	Lowe's	Props- PVC	$8,891.70
11/4/13	($26.50)	The Creative Workshop	Props- plastic sheet	$8,865.20
11/13/13	($2.96)	Publix	Props- plastic cups	$8,862.24
11/13/13	($4.54)	Lowe's	Props- pipe	$8,857.70
12/6/13	($4.44)	Home Depot	Props- PVC cement	$8,853.26
3/11/14	($2.70)	Home Depot	Props- Clothes line	$8,850.56
R&D				
11/22/13	($26.95)	Mouser Electronics	Gyroscope	$8,823.61
12/9/13	($112.89)	Ebay	Cameras	$8,710.72
4/21/14	($63.10)	Light in the Box	Cameras	$8,647.62
5/9/14	($29.99)	Amazon	Camera	$8,617.63
Other				
11/29/13	($52.87)	Home Depot	Air compressor	$8,564.76
3/6/14	($22.03)	Harbor Freight Tools	Flex drill extension	$8,542.73
3/13/14	($75.00)	Active.com	Team creation fee	$8,467.73

Date	Deposit or Expense	Vendor	Description	Balance
ROV				
2/18/13	($2,106.19)	Seabotix	Thrusters	$6,361.54
10/14/13	($106.16)	Jameco Electronics	Assorted electronics	$6,255.38
10/31/13	($84.16)	Jameco Electronics	Arduino	$6,171.22
11/2/13	($6.34)	Zell's Hardware	Silicone Grease	$6,164.88
11/12/13	($120.97)	Mouser Electronics	Assorted electronics	$6,043.91
11/14/13	($33.39)	Lloyd Bailey's S&W	Lead weights	$6,010.52
11/14/13	($39.44)	Jameco Electronics	Assorted electronics	$5,971.08
12/3/13	($117.41)	McMaster Carr	UHMW	$5,853.67
12/3/13	($40.50)	EZ Tops World Wide	Acrylic dome	$5,813.17
12/3/13	($36.02)	Jameco Electronics	Flash Microcontroller	$5,777.15
12/11/13	($26.95)	Mouser Electronics	Arduino	$5,750.20
12/13/13	($140.68)	Allied Electronics	Epoxy	$5,609.52
12/13/13	($13.90)	Dipmicro Electronics	PCB header	$5,595.62
1/19/14	($35.04)	MSC Industrial Supply	Acrylic tube	$5,560.58
1/20/14	($63.12)	123 Security Products	Camera brackets	$5,497.46
1/21/14	($71.06)	Seacon Global	Nuts and bolts	$5,426.40
1/22/14	($24.93)	Boone Welding	Welding	$5,401.47
1/23/14	($35.04)	MSC Industrial Supply	Polycarbonate Tube	$5,366.43
1/24/14	($31.70)	Lowe's	Epoxy	$5,334.73
1/30/14	($112.22)	Fabco Air	Pneumatic valves	$5,222.51
2/3/14	($32.94)	Superbrightleds.com	LED strip	$5,189.57
2/7/14	($47.64)	Home Depot	Aluminum	$5,141.93
2/19/14	($93.93)	McMaster Carr	UHMW and screws	$5,048.00
2/28/14	($20.55)	MSC Industrial Supply	Fan guards	$5,027.45
3/6/14	($21.12)	Lowe's	Epoxy	$5,006.33
3/7/14	($37.18)	Sfcable.com	USB cable w/mount	$4,969.15
3/10/14	($225.14)	Boone Welding	Welding	$4,744.01
3/10/14	($21.12)	Florida Fasteners	Fasteners	$4,722.89
3/11/14	($31.80)	Boone Welding	Welding	$4,691.09
3/13/14	($66.16)	MSC Industrial Supply	Screws and nuts	$4,624.93
3/13/14	($43.19)	McMaster Carr	UHMW	$4,581.74
3/14/14	($33.20)	Jameco Electronics	Assorted electronics	$4,548.54
3/14/14	($87.51)	MSC Industrial Supply	Pneum. tube, screws	$4,461.03
3/14/14	($26.38)	Digi-Key	Washers, heatshrink	$4,434.65
3/14/14	($42.52)	Jameco Electronics	Arduinos	$4,392.13
3/24/14	($30.65)	Dipmicro Electronics	PCBs	$4,361.48
3/24/14	($102.00)	Allied Electronics	Assorted electronics	$4,259.48
3/31/14	($373.10)	Pololu	Motor drivers	$3,886.38
4/5/14	($42.32)	Home Depot	Epoxy	$3,844.06
4/8/14	($9.53)	Ace Hardware	Plastic dip	$3,834.53
4/25/14	($35.04)	MSC Industrial Supply	Polycarbonate Tube	$3,799.49
5/5/14	($45.60)	DealExtreme	Cameras	$3,753.89
5/12/14	($63.12)	123 Security Products	Camera brackets	$3,690.77
5/25/14	($217.72)	Amazon	Cameras	$3,473.05

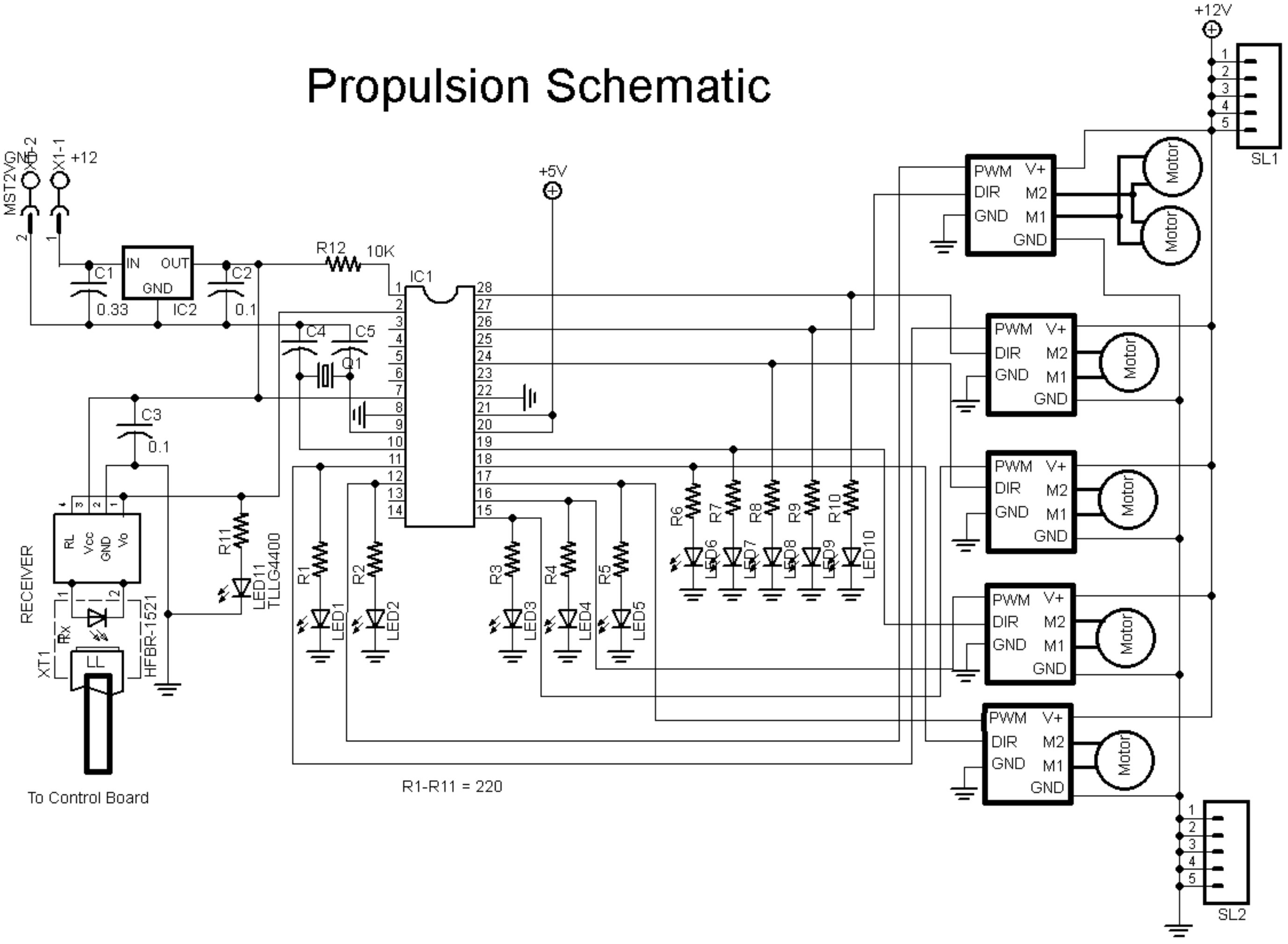
System Interconnection Diagram



Pneumatic SID



Schematic Example



Propulsion Schematic

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