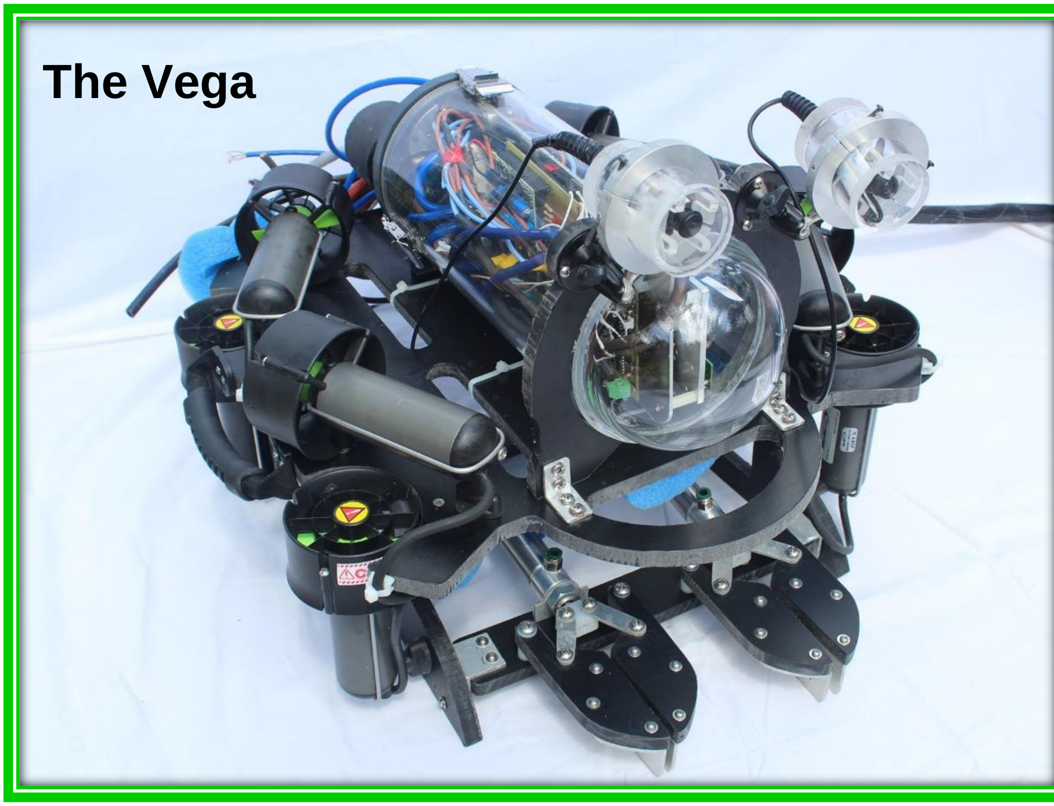
# DeepView Technologies




**Cornerstone Academy, Gainesville, FL**
**Technical Report**

## Company Directory

Noah Goodall: Senior Team Member, CEO and Chief Design Engineer

Timon Angerhofer: Senior Team Member, Chief Software Developer

Timothy Constantin: Optical Systems Engineer

Pierce Tolar: Optical Systems Engineer

Oscar Witte: Canister Specialist, Tether Manager

Tirza Angerhofer: Electrical Engineer

Will Hodik: CFO and Design Engineer

Carter Wyatt: Payload Tool Specialist

(Left to Right) Top: Alexander Angerhofer (mentor), Oscar, Carter, Noah, Timothy, Pierce
Bottom: Timon, Tirza, Will

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## Abstract

At DeepView Technologies, we strive to provide the best product for our customers at the most affordable price. As a company with ten years of experience, we constructed the Vega, an ROV designed and built for missions in the Arctic environment. The Vega is capable of collecting data on marine life found in the arctic region under the ice, of which there is a severe need. It was also constructed to examine and restore corroded sections of underwater oil pipelines, as well as maintain and test these pipelines. To do this, our talented team of engineers designed and constructed unique subsystems. These subsystems, which are mounted on a custom UHMW frame, are all controlled by a single USB Xbox 360 controller running through an Arduino microcontroller. The use of a single pilot allows for precise movements and quick responses. The seven cameras arranged around the Vega provide a clear field of view of the surrounding area. A 25 meter tether carries power and air down to the waterproof canister on the ROV, which houses the electronics as well as other sensitive equipment. The tether also takes signals and exhaust from the Vega up to the surface. Our ROV, named after the SS Vega, the first ship to sail through the Northeast Passage, is equipped with all the necessary tools it needs to accomplish its Arctic mission.

## 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 a combined 12 years of competition experience and has constructed multiple unique ROVs built according to MATE standards. DeepView's latest creation, the Vega, has been manufactured with careful attention to detail and with safety as its highest priority. We recognize the importance of the task given to us, and firmly believe that the Vega is best suited for this mission.

## Design Rationale and Vehicle Systems

### Frame

The frame of any ROV is one of the most important aspects of the vehicle. It is the first step of the manufacturing process and its design takes into account every other tool and system. For DeepView's latest ROV model, our design team focused on attention to detail and automated manufacturing.

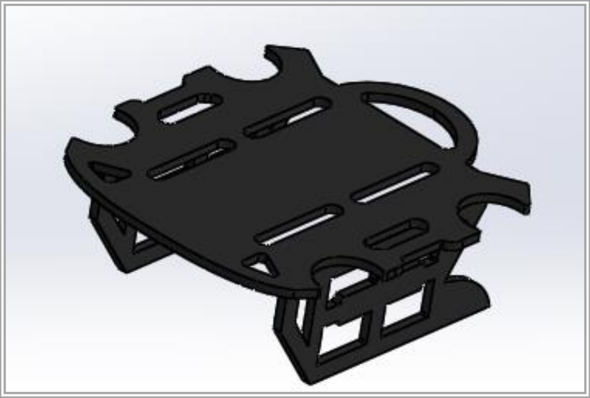


*Figure 1: A CAD drawing of the frame made in SolidWorks®*

This year's frame took on a new and interesting shape. Most ROV frames, such as our previous models, consist of two side faces, combined by center crosspieces. Tools, cameras, thrusters, and other components are mounted within this box-shaped vehicle, a simple and fairly universal design. This presents a few problems, however, as servicing and adding components within the tight confines of this frame is difficult, and mounting space is limited. With this in mind, our team devised a unique new layout that solved these issues. At its core, our "open" frame design starts with a horizontal center plate. The waterproof canister, horizontal vector thrusters, and other tools can be mounted atop this plate. Underneath, two parallel "skids" support the center plate, much like a sled. Between these skids sit grippers, cameras, other tools, and plenty of open space for additional floatation, if needed. Mounted on the outside faces of the skids are four vertical thrusters which direct thrust through circular holes in the center plate. To protect sensitive tools from damage and prevent the ROV from getting snagged on outside surfaces, the center plate is shaped so that most tools are within its confines.

*Figure 2: The Design team assembles the frame.*

Our entire frame was assembled in Solidworks® prior to its construction (Figure 1). This allowed for more precise construction as well as increased creativity. Being able to visualize and change the frame on the computer before building it allowed for quick adjustments to the design. Having a 3D model helped us to predict future issues and correct them digitally. After we were satisfied with a final design, the frame was manufactured using a CNC mill. Thanks to this automated process, assembling the frame was as easy as connecting the center plate to the skids with stainless steel sheet metal screws.

### Buoyancy

Buoyancy aids in the stability of the ROV and allows for precise and accurate movements when submerged. With this in mind, DeepView Technologies carefully chose which materials to use in construction. The frame and most of the tools were manufactured from ultra high molecular weight polyethylene (UHMW) because of its specific gravity of 0.94, which is close to that of water with a specific gravity of 1.00. Thus the material is almost neutrally buoyant. This year our goal was to streamline the manufacturing process by minimizing additional attachments. We distributed the weight of two grippers, eight thrusters, and seven cameras in such a way as to balance the vehicle underwater. The majority of the vehicle's floatation comes from the main waterproof cylinder. This year's acrylic cylinder is slightly smaller than the model from the previous year to keep the ROV compact; however, we lost the extra flotation we could have gained from a bigger canister. We decided that keeping the vehicle compact, maneuverable, and intuitive to work on was a higher priority than convenient buoyancy. To balance the lack of positive buoyancy, space beneath the Vega's center plate was allocated for additional foam floatation.

*Figure 3: Noah and Carter test buoyancy.*

To adjust the buoyancy, we first placed the ROV in the water to determine if it would sink or float and to determine the pitch and roll. Once these factors were determined, we then added weight or flotation as needed. To easily balance weight we use an adjustable washer system. We mounted two bolts to the front of either frame skid beneath the center plate of the ROV so that when needed, we could add stainless steel washers to correct the problem of pitch and roll. This system will also be helpful to adjust buoyancy to the different conditions that will be encountered at the competition. Sea water and cold water near its freezing point are denser than freshwater. These conditions will lead to a higher buoyancy than freshwater at 20ºC and the buoyancy will have to be adjusted by adding additional stainless steel washers.

### Canister and Cap

On the Vega, a single waterproof canister is used to house electronics and provide buoyancy. On this year's ROV model, our team was able to reduce the size of the main canister, as well as improve its effectiveness. The canister is made from a translucent acrylic cylinder, which is 6" in diameter with ¼" thick walls, and is 25.4 cm long. At the end of this canister is a clear acrylic dome, which we mounted with a combination of silicon sealant and acrylic glue #3. This dome provides a clear, uninhibited view for our forward navigational camera. We prevent condensation in the canister by using an anti-fog spray used for scuba divers' goggles. Wires enter the canister at the rear through a custom designed endcap made from PVC. Like the frame, the endcap was first designed in Solidworks®, which allowed us to pinpoint potential errors and correct them digitally

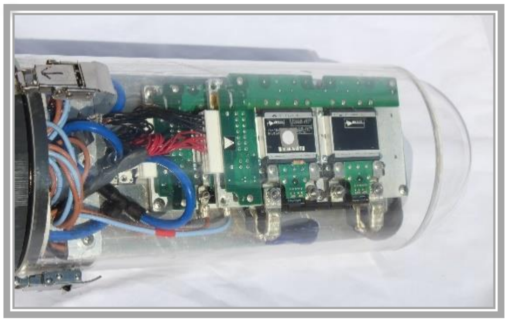


*Figure 4: Canister with voltage regulators housed inside.*

before going into production. Once the design was finalized, it was professionally manufactured by the machine shop of the Chemistry Department at the University of Florida.

A 5 ½" o-ring, compressed by three Dive-Rite clips, was the first layer of waterproofing. Seated in a groove is an additional o-ring, which presses against the last ½" of the canister's inside walls. For tether entry, individual holes were sized for each wire, and holes for six pneumatic fittings were drilled and tapped. Our team used a virtually fail-safe system for waterproofing these wire connections. A shallow basin was milled into the inside of the cap around the wire and pneumatic holes. Once the wires were inserted through their respective holes and the pneumatic fittings had been screwed in, we then filled this basin with marine epoxy. The epoxy dried, confined to its basin among the wires, resulting in a solid and tidy waterproof seal.

*Figure 5: Oscar sands the bottom of the canister to provide a better seal.*

Also included in the cap design is a method for heat dispersion. One of the challenges of this year, described in detail in the Challenges section, was converting from 48V to 20V for the thrusters and 12V for the electronics, and distributing power to various systems around the ROV. We placed power converters inside the main waterproof canister, generously donated by the Vicor Corporation, to convert from 48V to 20V and 48V to 12V. These converters, along with other electronics, generate a significant amount of heat within the canister that has to be removed. Our team devised a simple and compact system to accomplish this. All on-board electronics are mounted to either side of a 3.18mm thick aluminum board. At the rear of the canister, the end of this board extends through the PVC cap. This extrusion is waterproofed in the same way as the wires. Because these aluminum endings extend into the cold waters outside our canister, heat from the electronics is conducted away.

## Propulsion

For the purpose of navigation, eight Seabotix BTD-150 thrusters are used. Two were purchased specifically for the Vega, while six of these were reused from last year, since eight new thrusters would put us over our budget. Also, building custom thrusters would be less reliable and very time consuming. Four horizontal thrusters were placed in a diamond-shaped orientation 30 degrees away from the direction of forward motion on the top of the central plate (Figure 6). This allows us to use them as 'vector thrusters' where the direction of thrust can be controlled by adjusting the thrust of the four units in a

*Figure 6: Configuration of the thrusters. The four thrusters on top are the vector thrusters and the four thruster sat the bottom (only two visible in this figure) are used for vertical movement.*

concerted manner. Vector thrusters improve the range of motion and have more precise movements when underwater, which makes tasks requiring accuracy easier. Forward power is generated at $4 \cdot \cos(30^\circ) \approx 3.5$ times the thrust of one unit while sideways thrust is generated at a power of $4 \cdot \sin(30^\circ) \approx 2.0$ times the thrust of a single unit. Speed is important primarily for forward motion, while sideways motion can still be facilitated in this arrangement eliminating additional lateral thrusters. The four vertical thrusters were placed at each corner of the ROV to balance out weight. They were screwed into the side skids and the kort nozzles were fitted into circular grooves on the central plate. The kort nozzles, which are standard on the Seabotix thrusters, improve thrust as well as ensure the safety of the ocean environment. Caution stickers have been placed on the thrusters to warn about the presence of moving parts. The thrusters, rated by Seabotix, produce 2.2 kilogram-force bollard thrust continuously at 19 V which corresponds to a force of 22N.


*Figure 7: A Seabotix BTD-150 thruster*

## Pneumatics

*Figure 8: Pneumatic piston*

This year pneumatics were used to power only two grippers, which allowed DeepView Technologies to simplify and condense the pneumatics system. The pneumatic cylinders and valves were generously donated to us by Fabco-Air Inc., located in Gainesville, FL. We decided to use a fully closed pneumatic system consisting of pistons and ⅜” and ¼” pneumatic tubing. We used double-action pistons with bidirectional U-cup seals on the shaft. The seal is located on both sides of the piston shaft. As the water pressure builds, it pushes the external seal down. On the other hand, increasing air pressure, seals the internal U-cup tightly, thereby maintaining a positive seal on the shaft. This seal ensures no water leakage through the pistons. The pneumatic tubing is connected to the outer sides of the valves and then connected to the pistons by means of waterproof push-to-connect pneumatic fittings. Instead of using the bulky manifold, as in previous years, we used two valves connected by a Y splitter. This splitter connects the two pneumatic valves to one main flow of air. The same pneumatic tube brings down compressed air from the surface, while another pneumatic tube brings up exhaust air from the ROV. The tubes are rated at 1 MPa (150 psi) and the pistons are rated at 100 psi.

## Tools

### *Payload System*

The ROV is equipped with a single payload system which consists of two vertically oriented grippers. Our payload specialist used UHMW to manufacture these grippers, which are used to

Figure 9: Vertical grippers with pneumatic pistons

manipulate mission items. The grippers are driven by two double-action lateral pneumatic pistons, powered by compressed air at a pressure of 276 kPa (40 psi). The air propels a piston rod forward, which pushes two aluminum arms forward. These arms open the grippers. The base of the claws was manufactured from UHMW using a band saw and belt sander. The aluminum L brackets on each side of the gripper were attached by means of stainless steel screws to the UHMW piece. The two grippers are padded with sponge nitrile rubber for improved grip. Custom made aluminum brackets attach each piston to a UHMW brace, which is then bolted to the frame. They are attached to the front right and left side of the ROV.

*Measuring System*

For this year's mission we needed to measure the dimensions of an iceberg, measure the length of a pipeline, and determine the height and angle of a wellhead. After brainstorming and discussion, we decided to create a scale system on the monitor to measure the required objects. The thickness of PVC pipe is used as the standard because it a known factor that is present in all the missions requiring measuring. Once the pilot orients the camera facing the object that needs to be measured, the copilot freeze frames one of the cameras and measures both the length and width of the pipe with a ruler before unfreezing. Then, the pilot continues the mission while the co-pilot calculates the length by means of proportionality. With this system we are easily able to figure out lengths, widths, and heights in less time than using a simple measuring tape as in previous models. When determining the angle of the wellhead, however, we need to find the height and length first, and then use trigonometry to find the angle. One of the co-pilots calculates the angle while the pilot continues the mission.

*Vacuum Pump*

Figure 10: Vacuum pump and rubber fitting

The Vega is equipped with a specially designed vacuum pump which collects algae samples from beneath the sea ice. A 2200 GPH bilge pump was sealed at its intake end by a 90 degree PVC pipe fitting, and extends vertically from the horizontal frame plate 28.8cm. The exhaust end of the bilge pump extends off the starboard side of the ROV. This end can be used to inject water through pipelines to test water flow. Since a ½" PVC pipe can be difficult to maneuver into a small pipe, our design team devised a simple method of guiding the exhaust pipe. A rubber fitting is attached to the inside of a plastic guide cone. This assembly sits at the end of the exhaust tube. With this addition, the ROV pilot can now guide the exhaust tube over a pipeline with relative ease. The vacuum pump is located at the back of the vehicle and is easily detachable when it is not needed. Two cameras inside the main canister face the pump so that the pilot can easily collect algae samples or inject water into a pipe.

*Figure 11: One of the clamps that make up the lift line. This holds the 1-1/2" PVC pipe.*

*Lift Line*

The lift line is designed to aid in pipeline maintenance by removing damaged sections of pipe. It is composed of two claws, designed and manufactured by our own engineers. These claws are connected by an aluminum rod, by which the Vega can securely hold the entire assembly. Each claw consists of two halves, made from UHMW, which when placed together form a circle large enough to fit snugly around a 1-1/2'' PVC pipe. This circle is lined with rubber padding to prevent the pipe section from sliding out. Both halves of each claw are held together by springs, so that when the ROV pushes against the PVC pipe the claws will open and guide the pipe within their grip. Once the pipe fits securely within both circular openings, these springs snap both claws shut around the pipe. In the initial testing phase, the claw would fold inward when it was opened, because only the springs were keeping the claws together. We added a pin between the two ends of the claw, where the springs were attached, thus solving the problem. A rope is attached to the rod that connects the two claws so that the corroded pipe can be pulled to the surface.

*Claw*

The rotary claw, located beneath the Vega's center plate, is used to turn pipeline valves with ease. It is powered by a high-torque servo, which has been thoroughly waterproofed by our design team. The circuitry has been coated in rubberized plastic and the inner motor coated in a marine grade anti corrosion agent, all of which is sealed in a plastic covering waterproofed by an o-ring and rubberized plastic coating. Attached to this servo is a four pronged nylon claw that extends beneath the Vega's lower skids. When a valve needs to be turned, the Vega simply lowers the four-pronged claw onto the cross shaped valve head, and activates the servo. A lower camera facing the claw ensures easy placement for the pilot. The signal of the hacked servo is connected to the surface through the pneumatics board.

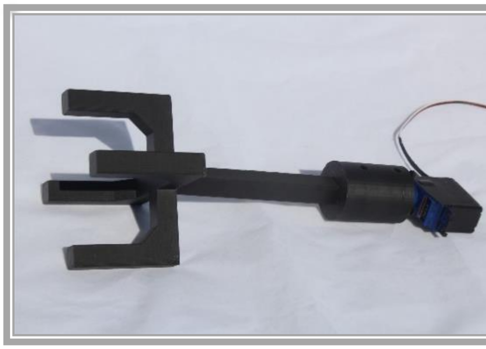


*Figure 12: The claw is used to turn the valves.*

The first step in making the claw was brainstorming and designing. The team decided collectively that turning the valves with the grippers would be too time-consuming. Instead, they decided to use a servo with an attachment that would allow the valves to be turned with no extra motion of the ROV. We also wanted a method of removing the claw quickly once it had completed its task. A simple system of quick-release pins allows the extended claw to be removed from the servo mid-mission. Once the idea was decided upon, the claw came to life in Solidworks®. This model was then sent to be 3D printed. Our first prototype was too brittle and broke easily because it had only a 75% fill factor. The second time, however, when the model was made of solid plastic and printed with added reinforcement, the claw came back strong enough for the job.

**Tether**

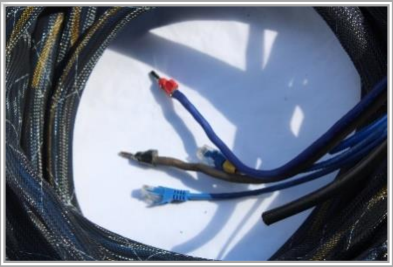


*Figure 13: Tether and surface connectors*

The tether on the Vega, developed by Deep View Technologies, includes two CAT-5e cables, a pair of stranded 8 AWG cables, one ¼" pneumatic tube, and one ⅜" pneumatic tube. The cameras and communications between onboard and shore-side Arduino boards are run through the CAT-5e cables. The stranded 8 AWG cables are used to carry 48V and up to 40A down to the ROV. We chose this stranded gauge as it was an optimal balance for our amperage draw, tether flexibility, and tether length needs. Over the course of the 25m long tether, there are only 55 milliohms of resistance which creates a negligible amount of voltage drop. The ¼" pneumatic tubing is used to supply the pressurized air (40psi) to the ROV in order to power the valves and cylinders. The ⅜" pneumatic tubing is utilized for the exhaust from the cylinders and valves back to the surface. The cables and tubes are held together by a flexible mesh sheath, making tether management simple and organized. Deep View Technologies has kept the tether as thin as possible to avoid creating undesired drag. The final diameter of the tether has been designed at a minimal 2.7 cm. The tether is connected to the ROV by means of a custom-engineered PVC end cap. Strain relief at the ROV is implemented by a piece of UHMW attached at the back, on which a part of the tether is securely attached. When the ROV is jerked or makes a sudden movement, the tether will be pulled from where it is attached to the UHMW piece rather than the connections. At the surface, the tether cables are connected to the pelican case housing the monitor and controls.

**Electronics**

Electronics are an integral part of any robotic system. At DeepView Technologies, we strive to use the most efficient but affordable electronic components to accomplish our objectives. This year the main components integrated into the Vega were Arduino microcontrollers, Vicor power converters, and home-made printed circuit boards.


*Figure 14: Arduino Uno and Arduino Mega used for programming.*

After achieving great success with Arduino microcontrollers on the Hydrus, DeepView's competition model from last year, we knew that we could rely on these chips again for the Vega. Three Arduinos are used in our ROV system. One Arduino Mega 2560 is located inside the control box, while two Atmega328 chips on board the ROV communicate signals from the surface Arduino to the components and send back signals to the pilot as well. We used the Mega 2560 inside the control box because it has four serial ports compared to the one port found on the more popular Arduino Uno. These extra ports allow for communication between the microcontroller and a computer while the entire system is running for troubleshooting purposes. The two Atmega328 chips onboard were chosen due to their small size. The microcontrollers this year also run at a higher speed with a baud rate of 115,200, which is twelve times faster than the rate used in last years' product.

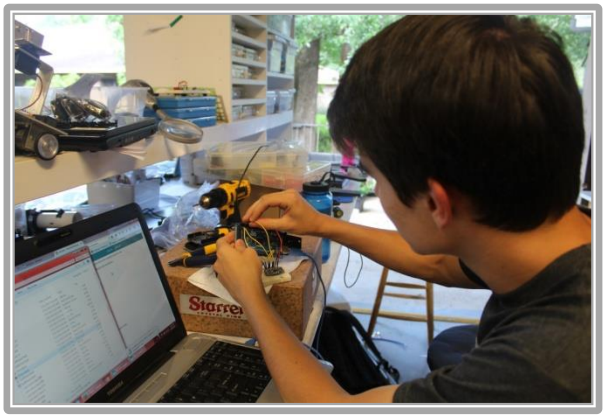



*Figure 15: Timon programs the Accelerometer with Arduino.*

All three of the microcontrollers communicate with each other through their serial ports. The Mega 2560 in the control board receives data from the Xbox controller and then packages the information into arrays. These arrays are sent out through the transmitting serial port and then go directly through the tether and into the receiving serial port of the first Atmega328 chip. This chip extracts the data it needs for its systems and inputs extra data it receives from sensors into the stream. This modified stream of information is then sent to the second Atmega328, where the process is repeated and all sensor data is sent back up the tether to the Mega 2560, which displays the sensor data accordingly and then repeats the cycle. By using this method, all of the microcontrollers have communication with each other, allowing for expedient data transfer.

As a team new to the Explorer class, one of the big challenges we faced was learning how to deal with the increased voltage supply. Our team of engineers had never dealt with any voltage higher than 12 volts, so learning how to step down from 48 volts became a formidable task. We looked forward to running our thrusters at 20 volts instead of the previous 12 volts, but knew we would have to design our ROV to fit a power converter and to dissipate heat (see Canister section for more detail, pg. 3). We did some online research and asked teams from previous years what they had done in order to get an idea of the type of product we ought to obtain. We even briefly considered to make our own converters but decided against it because we lacked the time, expertise, and technology to create a dependable system. After thorough research and with help from application engineers from Vicor Corporation, we received the VICOR VA-A2962649 and the VA-E2962613 models, which were donated to us free of cost by Vicor Corporation. These models fit our needs perfectly because they output both 12 and 20 volts, fit snugly inside our canister, and are very efficient, dissipating less heat than home-made converters. The VA-A model provides one 20 volt output that can pull up to 20 amps, while the VA-E model provides a simultaneous 20 volt output with 20 amps and a 12 volt output at 10 amps. Because only the thrusters require 20 volts and they each draw about 3.75 amps, the workload is split between the two models with four thrusters running off one converter. A 10 amp max current is more than enough at 12 volts as the only notable current-drawing loads are the seven cameras at a maximum of 800 mA each.

The Printed Circuit Boards (PCB), located in the canister on the ROV, house the electronics that make the components work. PCBs, although they are hard to modify, are very compact. Every year DeepView Technologies designs and makes their own boards. This year, double sided PCB's were used as an improvement from previous models. This reduced the size of the boards even further and allowed the ROV to have a smaller canister. The PCBs are located on the aluminum plate in the main canister and are attached with spacers and stainless steel screws.

First, The PCBs were designed using the CAD program, Eagle, version 4.16, by CadSoft. The design was then printed out on a transparency and placed on a precut positive presensitized copper clad board. This board is coated on both sides with a thin layer of copper and a green laminated sheet containing the positive photoresist layer. After illumination with a UV lamp the exposed parts of the photoresist become soluble in the developer solution and wash off. The underlying copper layer is thus exposed and can be etched away using ferric chloride. To prepare a double-layer PCB the design was irradiated onto one side of the copper clad board first using UV light. The irradiated photoresist layer was then washed. Then, two holes were drilled in opposite corners so that when irradiating the second side, the design could be more easily matched up. Using the same steps as before, the transparency with the design was placed onto the other side of the board, irradiated and developed. At this point the board had two matching designs on opposite sides with the copper tracks still covered in unexposed photoresist while the exposed areas showed the blank copper layer. The board was now placed in a solution of ferric chloride which etched away the exposed copper that needed to be removed. Care had to be taken not to leave the board too long in the etching solution in order not to undercut the conducting tracks, yet long enough to remove the copper between them. Holes were now drilled where the electronic components were to be mounted followed by soldering them to the board.

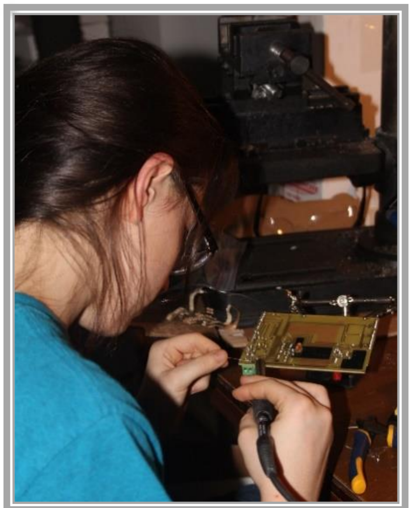


*Figure 16: Tirza solders components onto the Propulsion PCB.*

**Control System**

The control system of the Vega is greatly streamlined compared to previous models in order to facilitate transportation and to achieve greater overall simplicity in the on-shore systems. It consists of an Xbox 360 controller and a monitor which are housed inside a control box, a modified pelican case, along with all above-ground electronics. Two joysticks, two analog switches, and fifteen digital switches on the Xbox controller provide input for the Vega, while camera and sensor data are displayed to the user via the monitor, an LCD screen, and four programmable LEDs on the controller. The control box


*Figure 17: Pelican Case with connectors*

is also highly modifiable, meaning that extra LCD screens, LEDs, switches, or other components can be integrated into the system with relative ease.

We decided to rethink our control box because previous control systems were too bulky and not easily transportable. Now, one box houses everything a user needs to operate the Vega. This is not only simpler and more efficient, but it is also safer, as less cables are exposed. We purchased a 56x23x35 cm Pelican case to be the base of our control box because it is robust and lightweight. We chose this size specifically because it was as small as possible while still holding all of the electronics necessary. In order to modify this case to fit our needs we had to mount an LCD monitor in the lid of the pelican case, this required us to drill four holes in the lid of the case to utilize the universal mounting holes of the monitor. We also had to buy commercial 90 degree VGA and power cord connectors in order to fit in the limited depth of the case. Next we had to modify the bottom half, which would contain the electronics. Since our on-shore electronics, were housed inside we had to provide connections to the tether as well as 110v for the display electronics. We were able to reuse the costly CAT5e female connections from the previous years in order to save money. We used a hole-saw to drill holes for mounting all of these connections to the Pelican case. Next we provided connections for the cables in the tether which included the main power supply. We were able to mount these connections directly to the case via machine screws. We used this same connector for the connections to the flow sensor which has a separate tether. Lastly the male 110 volt connector was mounted. All electronics are mounted securely and safely inside the Pelican case.

*Figure 18: Xbox 360 controller*

At the heart of the control system is the Xbox 360 controller. This controller was chosen because of its intuitiveness, its reliability, and our previous experience with the product. ROV control is made easy with this controller because all buttons and joysticks are within easy reach of the user’s hands. This allows the pilot to focus more on the monitor because they do not have to constantly look at their controls to operate the vehicle. Thousands of hours were spent by other companies to make this controller feel comfortable and easy to use, so we decided to take advantage of this well-designed and affordable product. We also used this controller on the previous ROV model to great success and felt that reusing it would be a wise choice.

### Cameras

Angle of view, compactness, and quality are all important factors in the construction of effective cameras for the ROV. Without well-made cameras, an ROV is essentially useless in the water. For the Vega, Deepview Technologies looked to previous models for inspiration. The cameras on our 2014 model, the Hydrus, had many useful features, but also several shortcomings. We created similar cameras while improving upon the design.

*Figure 19: The Vega's camera and clamp*

The first step in creating waterproof cameras for an ROV is choosing a commercial camera, as cameras are difficult and time consuming to make. Our Optical Engineers chose the Fisheye FPV cameras due to their low cost and 170 degree angle of view, as well as their 1280x960 resolution. We bought five of these cameras and use two bought last year, which had not been opened. The next step in production was waterproofing the camera. Two U-shaped acrylic brackets, made in shop on a band saw, were attached to each side of the camera. The four legs of these brackets were glued to an acrylic circle with a 5 cm diameter, which we cut and sanded. A 6.35 cm long acrylic canister with the same diameter was then glued to the end cap with acrylic glue #3. The ends of the canister had been sanded so that there would be no gaps in the seal. The camera wires were soldered to a longer wire that led to the ROV through the tether. A second endcap, featuring a hole for the wire to exit, was used to seal the other end. As on the previous side, the canister and the endcap were sanded and then glued with acrylic glue #3. A gland and epoxy, which was carefully placed at the inside and outside of the seal, ensured that no water would leak in from the point of entrance for the camera wire. In order to mount the camera, two aluminum half circle rings were used to form a clamp. Holes were drilled into the faces of the two half-circle rings, so that when the holes lined up a full circle was created. A third hole was drilled on the outside of the ring so that a mounting bracket could be screwed on. The two half circles were attached by means of a number 2 machine screw, forming a ring clamp around the camera canister, while the mounting bracket was screwed into the ring on one end and attached to the ROV on the other in specific locations.

*Figure 20: Timothy attaches the two front cameras to the Vega.*

There are seven cameras strategically placed on the ROV to maximize viewing angles. Three cameras were placed inside the main canister, which reduced construction time and preserved mounting space, because they did not need to have separate waterproof canisters. One camera faces the front of the canister, giving a general view of the surrounding area. Another looks upward to help position the suction tube of the vacuum pump. The third camera faces the side for orientation while pushing water out of the pump. The remaining cameras were carefully attached to the frame of the ROV. Each gripper has a camera mounted above it facing down. These camera views overlap, providing a large amount of coverage for the grippers. The third and fourth cameras were mounted on the bottom of the frame plate, with the third camera looking down on the claw and the fourth providing a clear view of the back, when we use our inversion feature.

**Sensors**

The Flow Sensor is an Adafruit liquid flow meter. Water goes into one end of the sensor and spins a fan in the middle of the apparatus. The sensor then measures the speed of the fan and in so doing calculates the current of the water, which leads up to the control system where it is shown on an LCD screen.

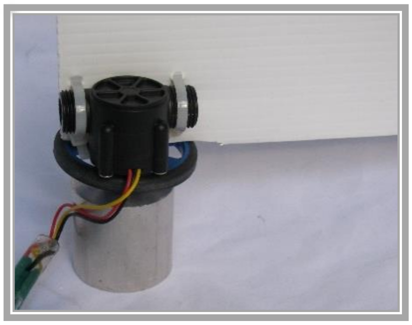


Figure 21: Flow Sensor

In order to keep the flow sensor on the ground and always pointing in the right direction, it was attached to a base and whee (Figure 21). A circular aluminum base with a 5cm diameter was cut to a length of 4.8cm. Then a small hole was placed in the center of the base and tapped, so that it would fit a number 2 machine screw. The top half of the screw was filed down so that the bottom half could be screwed into the base securely while the top half would allow a wheel to spin freely. The wheel, which was made of plastic, was zip tied to a corrugated piece of 12 by 38 cm white plastic in a way that it would not interfere with the spinning of the wheel. A 2 ½" wheel with a hole through the center was attached to a servo piece. The screw was placed through the hole in the wheel and the servo piece and finally screwed into the aluminum base. The plastic was placed so that one edge lined up with the wheel and the other end flowed back behind. This created a pivot point which reliably turns the wheel when there is a current. Finally, the flow sensor was attached to the wheel by means of zip ties.

Also attached to the ROV are a 3-axis accelerometer, a 3-axis gyroscope, and a temperature sensor, all housed on the Adafruit LSM9DSO chip inside the canister. Combining the accelerometer and gyroscope readings allow us to accurately determine the ROV's speed and direction in all three axes. With this information, the microcontrollers can determine how closely the ROV is following the navigation instructions given by the control system. A few possible reasons for the Vega not following these instructions perfectly are current pushing the ROV, a load attached to one side of the ROV, or one thruster possibly not working as efficiently as another.

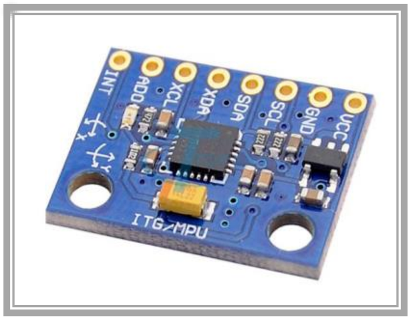
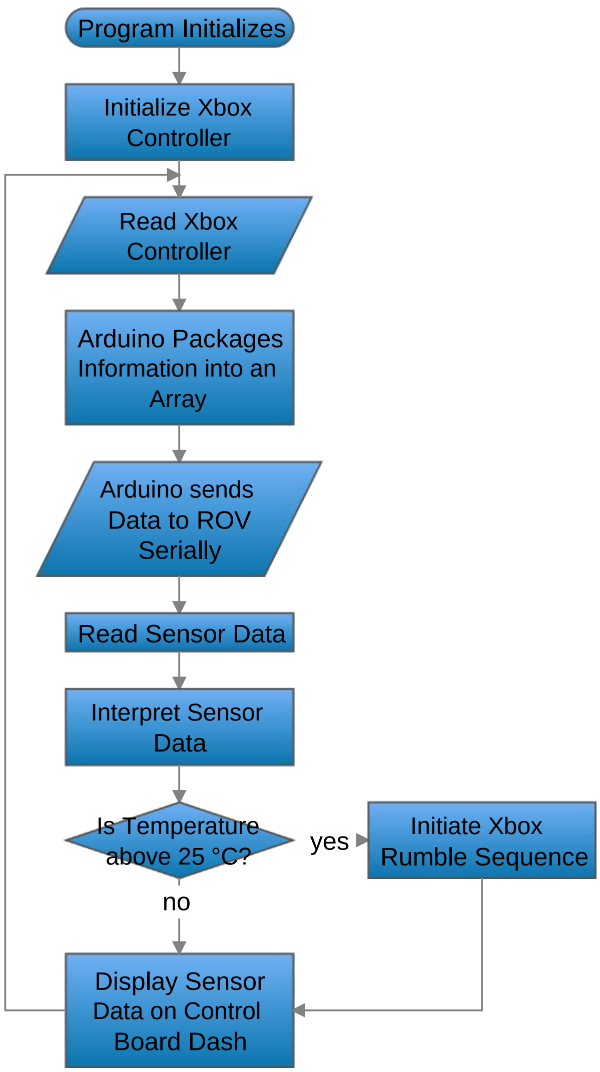



Figure 22: Adafruit LSM9DSO

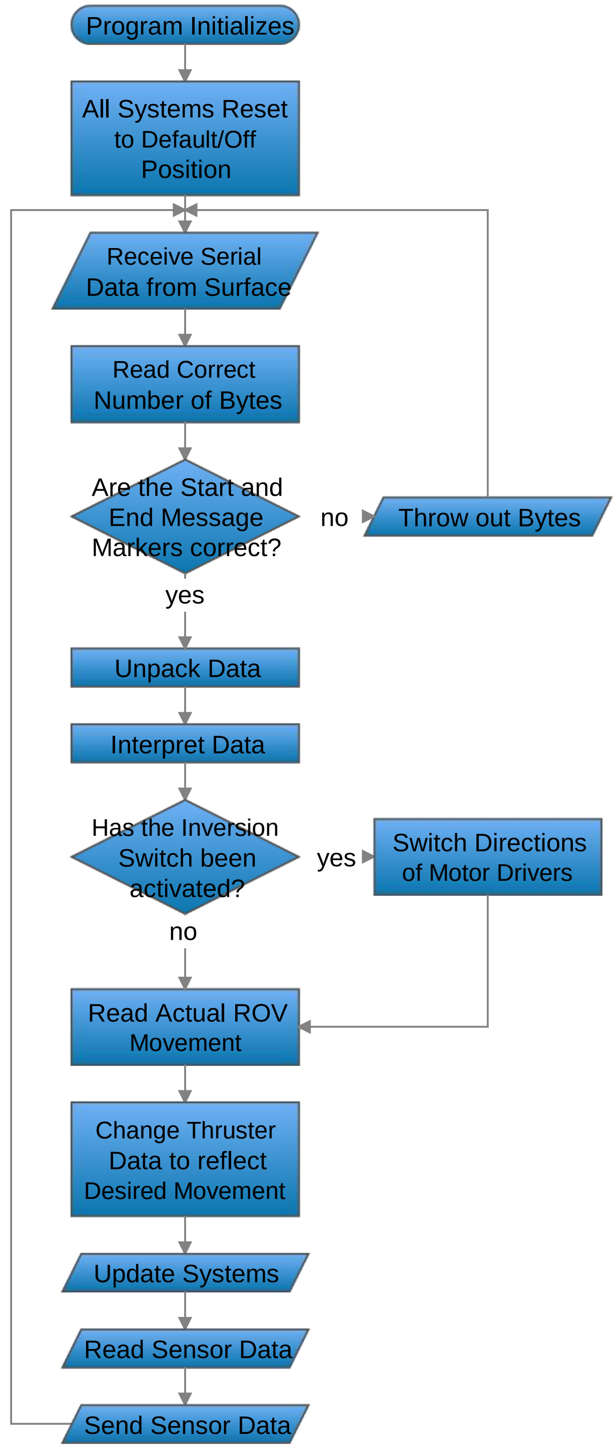
The microcontrollers take all of this information into account and then adjust the thruster outputs until the actual movement of the ROV matches the desired movement. This creates a control loop which helps to stabilize the ROV especially during the mission with water currents in the pool. The pilot can also press a button on the controller to turn off the accelerometer/gyroscope system if they desire only manual control over the vehicle. The use of these sensors is a brand new innovation for DeepView Technologies, and we were excited to start using it because of how it affects the fluidity of movement in our products.

## Software Flowchart

### Control Box




### ROV



## Troubleshooting Techniques

With such complexity on the Vega, an effective troubleshooting technique is crucial. We want to ensure that if a problem occurs, a user can quickly rectify the situation and return to running missions. 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.

One hypothetical example of this process comes in the possibility of the Vega's failure during a mission run. Operators should try finding a solution before pulling the Vega back in by its tether and possibly damaging it. To isolate the problem, operators would first check to see whether there was power inside of the control box. If there was power, the problem could be narrowed down to either the tether or the ROV. In this case, the entire system would be turned off and back on to see if it was a momentary lapse. The ROV, however, would most likely have to be brought up for further testing. If the control box had no power, then operators could narrow down the problem to the control system and would test the connectors to further isolate the problem. A typical problem is that the power got unplugged, the battery might have run out, or the fuse could have blown. Once the problem has been found, a solution can be implemented and with some success the Vega will be up and running within a few minutes.

This process was used to great success to fix our cameras. When we started practicing at the Florida Regional Demonstration, we began to notice that our cameras had started becoming very blurry and had some static problems. We tried to isolate the problem in the few hours we had before the demonstration by looking at the battery levels and doing a cursory check of the wiring, but we were unable to find the problem and used our backup cameras instead. When we came back from the demonstration we isolated the problem and found some water leakage inside some of the cameras. To fix this problem, we took the affected cameras out of their canisters, dried them, and tested them separately to see if they still worked. However, when we implemented all of the working cameras along with some new replacements, they were still not working effectively. We had to try a different solution and found a new problem when we looked closely at the wiring. We discovered that the ground wires from the cameras and the ground on the camera splitter had not been connected together to a common ground. When we connected these grounds, the cameras began to work as we knew they ought to and we confirmed that our troubleshooting process had been successful.

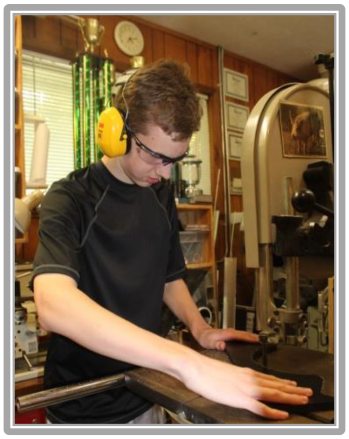


*Figure 23: Pierce cuts a piece of UHMW, while wearing PPE.*

## Safety

Safety is of the utmost importance in the DeepView Technologies Laboratory. By following a company made safety checklist and holding each other accountable, company members have received no major injuries that required medical attention. Even so, a licensed driver is required to be at the work site whenever people are working in case of accident. It is the responsibility of each team member to ensure that the safety procedures are followed in their own work and the work of others. This includes reminding others to wear personal protective equipment (PPE), telling others when a power tool is being used, and training to work with the different tools safely. In the DeepView Technologies program, experienced members train junior members in the safe handling and use of power tools and pneumatics. Every member is required to use correct PPE for a specific task, such as goggles to shield from projecting particles and ear protection when cutting aluminum on the band saw. Also, company members are required to wear closed toed shoes and tie back long hair to prevent injuries. Each member is in charge of keeping their work site neat and orderly and open electronics are always kept far away from water.

The Vega was built with safety in mind. All components of the ROV are enclosed and fastened tightly onto the frame. It is slightly positively buoyant so that in the case of a power failure the ROV will float to the surface, where it can be collected. Handles have been added to the ROV to permit easier transportation and to reduce the risk of dropping the vehicle. All the edges are rounded and there are no protruding bolts to prevent injury. The grippers are lined with rubber so that the objects the ROV picks up are not crushed. The ROV contains no harmful materials so as to protect the ocean environment. The tether has strain relief on both ends so as to not damage the wires and connections if pulled. There is also a temperature sensor in the canister to warn the pilot if the electronics are getting too hot. The pneumatics system is rated at 100 psi and is checked regularly to ensure it stays at 40 psi. A 40 amp fuse is on the positive side of the power supply.

## Challenges

### Technical

Although we faced many challenges, we were able to conquer them with determination, hard work, and teamwork. This year, because we are competing at the Explorer level for the first time, we faced the challenge of using a 48V power supply rather than a 12V marine battery. Because all our components used either 12V or 20V, we needed to find a way to convert 48V to the power we needed onboard the ROV, in a way that was compact and affordable. They had to be compact so that they could fit into the main canister of the ROV, but also affordable so that we could adhere to our budget. At first, we contacted experienced explorer teams and online forums. We bought three power converters which had been recommended to us, but were bulky and required a large box to contain. After further research, however, we discovered better power converters, namely the VICOR VA-A2962649 and the VA-E2962613 models, which were donated to us by Vicor Corporation. The original power converters were relegated to backup duty in case the newer ones failed. Next came the challenge of incorporating the power converters into the electronic system. This process took painstaking research and conversations with Vicor Corporation Application engineers, but finally the power converters converted 48V to 20V for the thrusters and 12V for the electronics. To compensate for the extra weight of the power converters, we added extra flotation to the bottom of the ROV. Now the Vega is equipped with an effective and efficient method of converting its voltages.

### Non-Technical

Mr. Knack, our team mentor of seven years, retired this year. Our new mentor, Dr. Alexander Angerhofer is very knowledgeable with regard to robotics but due to his work schedule, he was not always able to be involved. This forced the senior members to take on additional leadership roles such as enforcing the schedule and encouraging teammates to stay focused on their work. We faced this challenge by planning more carefully and researching our projects in more depth. As a team, we realized we could also work independently and effectively.

*Figure 24: Team mentor, Alexander Angerhofer, advises Carter and Noah.*

## Lessons Learned

### Interpersonal

Company members learned to manage time better with each other throughout the year. At first, the team struggled to accomplish their work on time. Many members were either waiting for parts to arrive which had been ordered online, or waiting on other teammates to accomplish their work before they could finish their own. After a few late nights at the shop, we made a detailed schedule and planned out the next few weeks. Every company member was required to adhere to their deadlines and, if needed, work outside of the normal meeting times to complete their tasks. Having a schedule allowed the team to organize their time and work more efficiently. Communication also improved between the team members, who worked on different aspects of the ROV, such as electronics, programming, and mechanical. By making a schedule, the company was able to emphasize their goals and focus more of their energy on what had to be done. This schedule is found on page 20.

### Technical

A technique we attempted to incorporate in our ROV design this year was 3D printing. This was a challenge for us, because we had never used the 3D printing process before. Therefore, we did not leave space in the schedule for reprinting, if there were problems. Since we had a deadline to meet, we attempted to finish the pieces in Solidworks® quickly; however, this led to faulty designs in some of the parts. We were able to overcome this problem by carefully creating the pieces, when we allotted more time to it in the schedule. While some pieces were not completed for 3D printing in time, we were able to modify them in other ways to fit our needs. Next year we hope to use 3D printing again, but complete the Solidworks® files in a more timely and precise manner and always have another option if this technology is not viable.

### Teamwork

Figure 25: Junior members, Oscar and Will, receive advice from senior members, Timon and Noah about the pelican case.

An important goal of this year's building process was to ensure that each member of the team participated in and learned from the construction of the ROV. At the beginning of the year, we established a schedule and assigned projects to each team member. These projects fell into the category of either mechanical engineering, or electronics and software design. Our two senior members, Noah Goodall and Timon Angerhofer, took charge of each category respectively. Noah's design team was composed of Pierce Tolar, Timothy Constantin, Oscar Witte, Carter Wyatt, and Will Hodik. They took charge of the physical aspects of the ROV by designing the ROV and constructing its frame and mechanical components. Pierce and Timothy designed and constructed all the cameras. Pierce also designed the measuring system and they both designed the frame in Solidworks®. Oscar constructed the new control box which utilizes a Pelican case. He also designed the Canister cap and assembled the acrylic canister. Carter made the payload systems. Will created many of the various attachments needed for the missions. For the electronics and software design, Timon wrote all of the programming and advised Tirza Angerhofer in the construction of the double-sided printed circuit boards. These two groups interacted with each other on a regular basis to make sure that the individual projects would be seamlessly aligned into the Vega. The other competition requirements, such as the technical report, engineering evaluation, and poster, were a team effort in that each person wrote the sections that pertained to the work they did. The overall product was then edited by a small group of chosen team members. For example, Pierce, Timothy, and Tirza were in charge of overseeing the technical report.

Our mentor, due to his work schedule, was not able to attend all of our team meetings, because they took place throughout the week as well as on Saturdays. The senior members, therefore, took on more responsibility and were the main advisors for the junior members.

### Future Improvements

After building the Vega, we discovered many things that we could improve or even completely revolutionize. In future years, we hope to incorporate a multiplexer for the video and electronics system. Multiplexing consolidates all the electrical signals into one signal by assigning each electronic signal a certain wavelength. At the surface control system, these signals would be split and analyzed. Single mode fiber optics, which we hope to use, have very high bandwidths of data transmission and can send terabits of data in seconds. They also have less signal attenuation than the bulkier multimode fibers. These advantages would allow for high definition video signals on the monitor and multiple video streams at the same time. Because they have a diameter of around 8.3 to 10 microns, the single mode fiber only allows for the propagation of one pulse of light at a time which reduces the risk of overlapping light pulses and distortion of data. These fibers would also replace the Cat-5e cables, which are currently being used, allowing us to have a thinner tether. This new thinner tether would provide less drag and allow for easier tether transportation and management.

## Project Management

### Planning

*Figure 26: The team assembles for a planning meeting at the beginning of the year.*

At the beginning of the year, a planning meeting was commissioned where all the DeepView members assembled and discussed scheduling, strategy, and brainstorming for different mission tasks. The senior members presided over the meeting. We decided to meet every Monday to build the Vega. The next phase of the ROV building process, was research and development. Team members, each of whom had been assigned a task, were overseen and advised by the more experienced members, who ensured they adhered to the predetermined schedule and encouraged them to finish their projects. During each meeting, the team would have a shared fifteen minute break, where the members could relax and recharge themselves for the tasks that lay ahead.

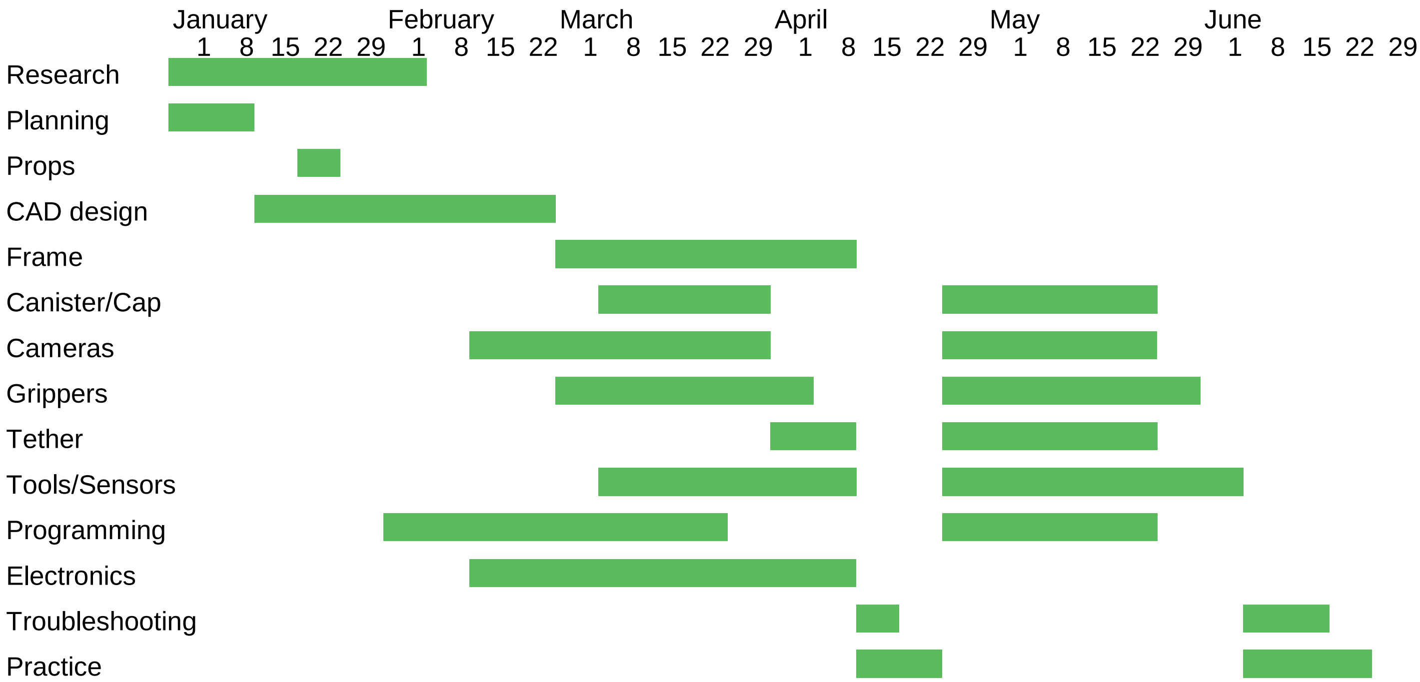
When any team member needed to purchase a component for their project they were required to alert their team leader and the CFO and explain why they believed it was necessary. Then the purchase was made by the team mentor or the senior team members. There are also plenty of tools and resources, such as screws, Aluminum metal, resistors, LEDs, etc., in the shop, which were free to use for each member. These resources would be checked often and replaced if they were running low.

The team held each other accountable to follow DeepView's protocols and procedures, including but not limited to, the Safety Protocol and the Troubleshooting Procedures. Senior members would often check the work of the junior members to ensure that they were following procedures and help them through difficult processes. When a problem occurred, the team leader would walk the junior member through the troubleshooting procedures, encouraging them to do most of the work themselves. In this way, the team was able to effectively and efficiently solve problems.

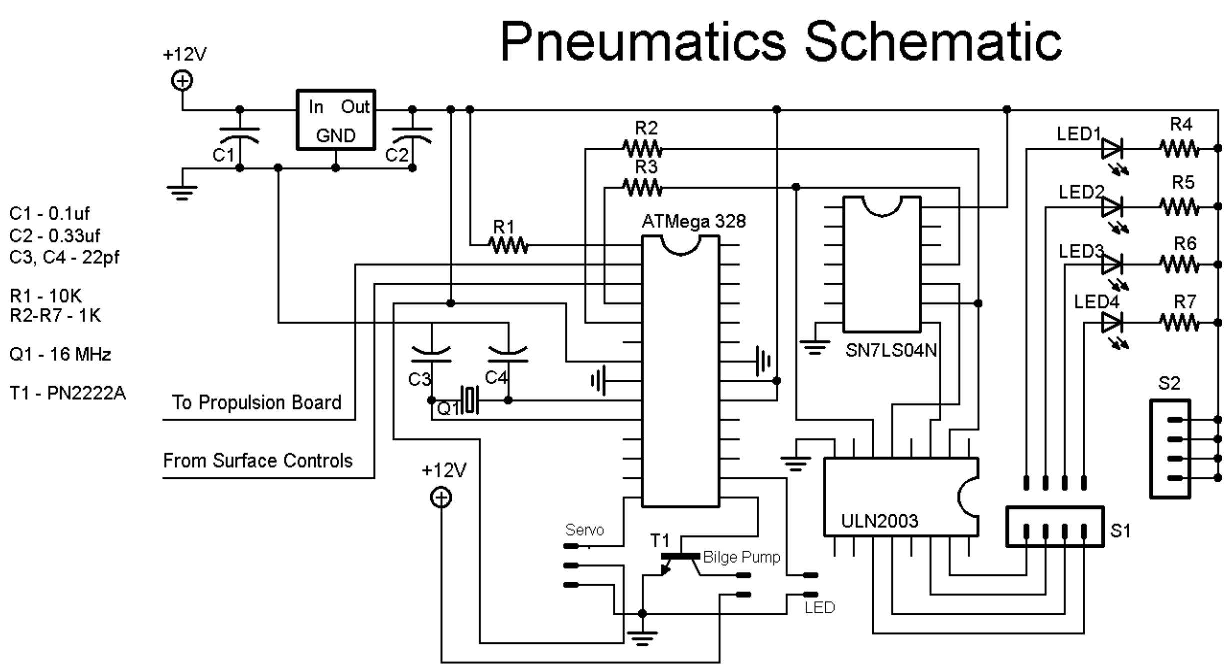
## Reflections

DeepView Technologies took on new challenges this year with a move to the Explorer class, along with a tight schedule and new leadership. At times, our members needed to work long hours in order to complete the ROV. The dedication and hard work of DeepView employees helped to keep the team moving forward. Our company members have become more proficient with their technology skills as they worked with new projects. This has been beneficial to the team as a whole and encouraged DeepView Technologies to accomplish our goals even in the face of adversity.

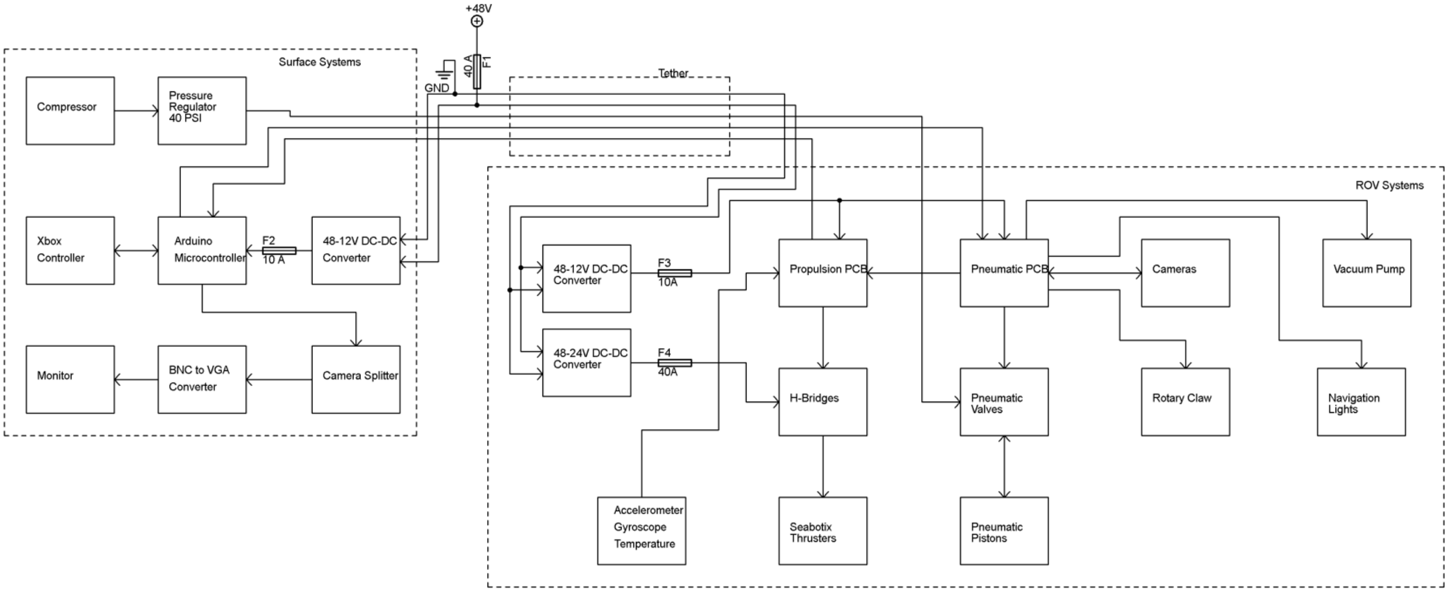
## Schedule



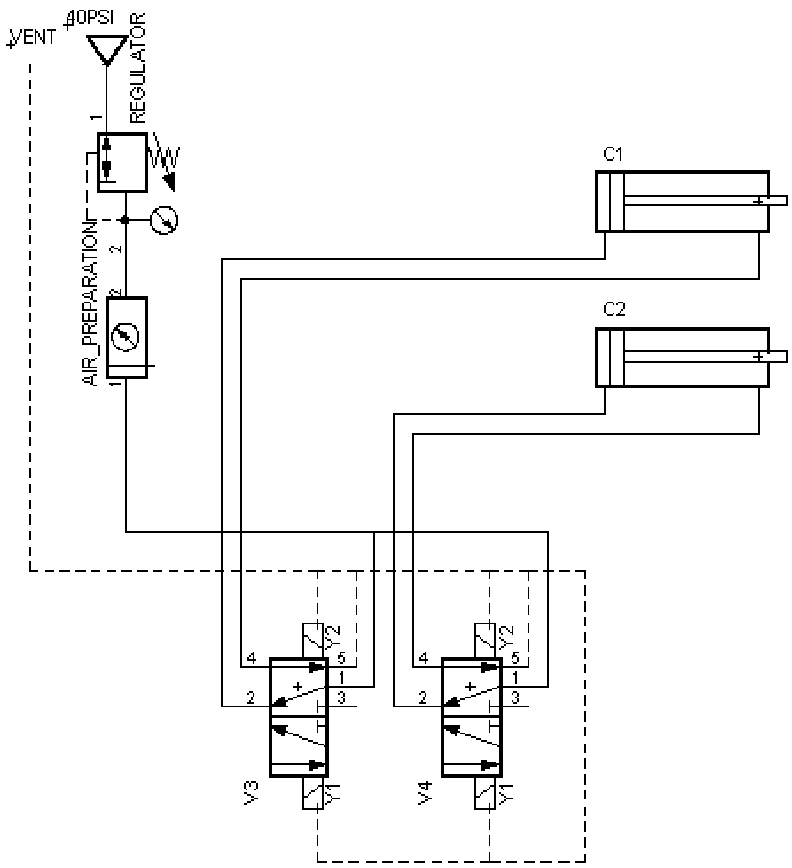

## Schematic Example



## System Interconnection Diagram




## Pneumatic System Interconnection Diagram



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## Acknowledgements

**Financial Sponsors:**

- Seabotix
- Dassault Systèmes SolidWorks®
- Vicor Corporations
- Fabco-Air, Inc.
- Parents of team members
- Pamphalon Foundation Inc.
- MATE

**Local Team Supporters:**

- Alex Angerhofer - Team mentor and Instructor
- Jeffery Knack
- The Administration of Cornerstone Academy
- Bernice and Sharon Constantin,
- Team Parents, Kimberly Knack, and Sam Hurlston

## Budget

The team began the year with $8000 that was given to us by team parents and sponsors. The team spent approximately $5610.10 on the construction of the Vega. Donations included two power converters worth $1109.10 and pneumatic pistons and valves from Fabco-Air worth $124.08, which brings the cost of the ROV to $6843.28. The rest of the money, was divided equally among the remaining team members for travel purposes.

| | Amount | Vendor | Description | Balance |
|---|---|---|---|---|
| | 6000 | Team Parents | Parental Fee | 6000 |
| | 2000 | Pamphalon Foundation | Donation | 2000 |
| **Props** | -368.99 | Home Depot | Prop PVC | 7631 |
| | -8.46 | Advance Auto Parts | Prop | 7622.55 |
| | -7.41 | Toys R Us | Prop | 7615.14 |
| | -95.11 | Home Depot | Prop | 7520.11 |
| | -11.61 | Lowes | Prop | 7508.5 |
| | -4 | Amazon | Ping Pong Balls | 7504.5 |
| **Electronics** | -200.61 | Adafruit | Accelerometer/Gyroscope | 7303.81 |
| | -763.45 | Pololu Corporation | H-Bridges/Motor Driver | 6540.36 |
| | -116.21 | Digi-Key | Various Electronic Parts | 6424.15 |
| | -280.8 | Zhan Electronics | 4x 48V to 12V Converters | 6143.35 |
| | -19.95 | Amazon | Hossen DC/DC | 6123.4 |
| | -71.25 | Amazon | Copper Clad Boards | 6052.15 |
| | -717 | Amazon | 48V/40A Battery | 5335.15 |
| | -454.44 | Amazon | Power Supply | 4880.71 |
| **Cables and Connectors** | -75 | Ebay | Power Cable | 4805.71 |
| | -34.61 | Amazon | Cat5e Ethernet Cable | 4771.1 |
| | -154.99 | Amazon | Pelican Case | 4616.11 |
| | -49.76 | MSC Industrial Supply | Pneumatic tubing | 4566.35 |
| | -28.95 | Ebay | CCTV Cables | 4537.4 |
| | -3.39 | Amazon | 10 pair T- Plug connectors | 4534.01 |
| **ROV Materials** | -251.38 | McMaster-Carr | Screws, Nuts, Rods, etc. | 4282.63 |
| | -278.31 | McMaster-Carr | UHMW Sheets | 4004.32 |
| | -31.68 | Amazon | 2x Seaflo Bilge Pump | 3972.64 |
| | -45.49 | Digi-Key | Aluminum Box | 3927.15 |
| | -131.16 | McMaster-Carr | Acrylic Tube and Dome | 3795.99 |
| | -1414.14 | SeaBotix | 2x Thrusters | 2381.85 |
| | -177.37 | Dx.com/Grainger | 5x Cameras and Brackets | 2204.48 |
| | -60.54 | RubberSheetRoll | Rubber sheet | 2143.94 |
| | -36.17 | H.A. Guden Inc. | Hinges | 2107.77 |
| **Miscellaneous** | -18.88 | Amazon | Double Sided Tape | 2088.89 |
| | -27.66 | Amazon | Safety Items | 2061.23 |
| | -14.78 | Amazon | Plasti Dip | 2046.45 |
| | -9.06 | Publix | Testing Materials | 2037.39 |
| **Services** | -58.3 | Astronaut Studios | CNC job | 1979.09 |
| | -84.77 | Astronaut Studios | 3D Printing | 1894.32 |

## Appendix A

### Safety Checklist

### Company

- Always wear PPE when working with the ROV
- Long hair must be tied back
- 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 shroud 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