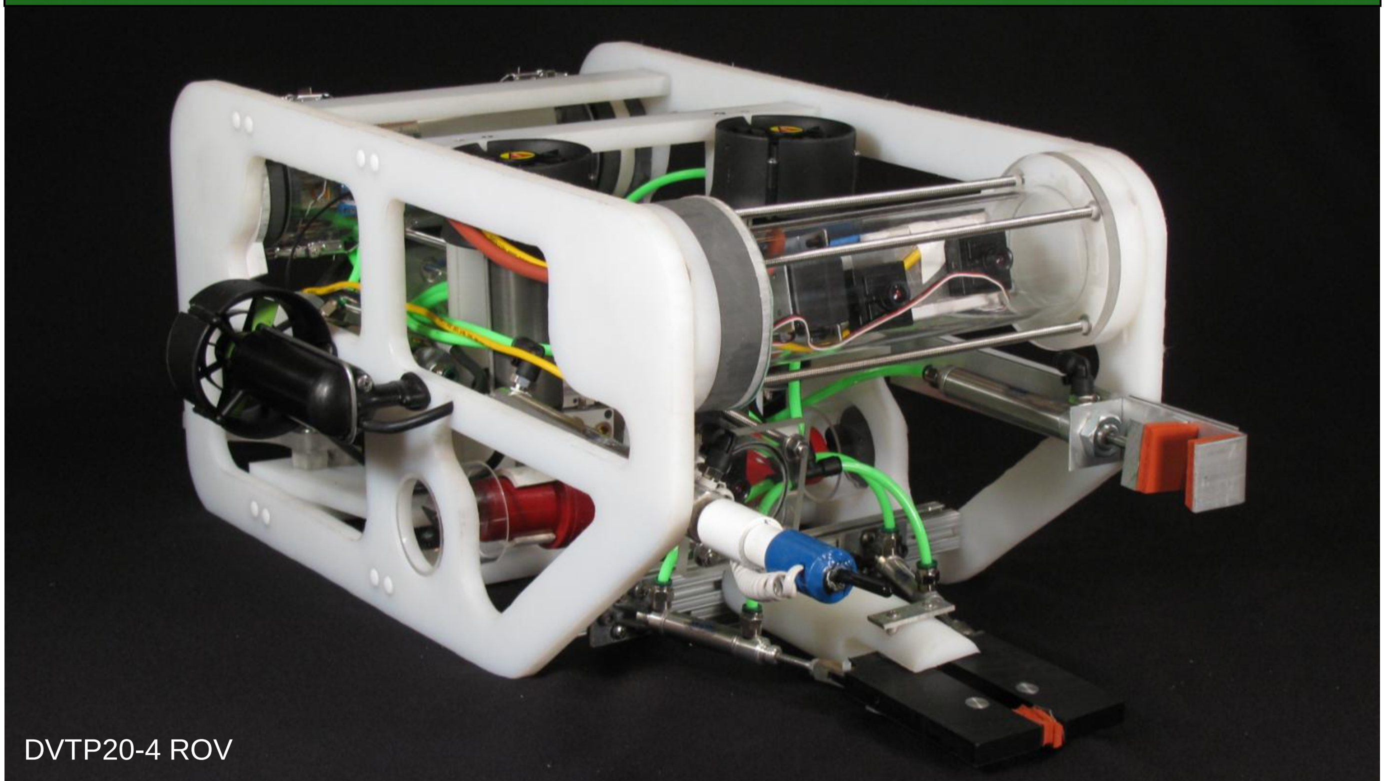
DeepView Technologies


DVTP20-4 ROV

Cornerstone Academy, Gainesville, Florida
Technical Report

Company Directory

Top row: Richard, Greg, Jacob, Timothy
Bottom row: Manuel, Emily, Timon

Manuel Angerhofer: CEO, Mechanical Engineer, Class of 2012.
Timon Angerhofer: Junior Software Engineer, Computer Science, Class of 2015.
Jacob Darbyshire: CFO, Journalism, Class of 2012.
Emily Davis: Media Specialist, International Studies, Class of 2012.
Timothy Davis: Video Specialist, Marine Biology, Class of 2014.
Richard Hurlston: Chief Design Engineer, Mechanical Science, Class of 2013.
Gregory Spencer: Chief Software Engineer, Electrical Engineering, Class of 2012.

Mentors

Jeffrey Knack, Alex Angerhofer, Connie Davis, George Edwards, Darell Taylor

Abstract

DeepView Technologies is a company based in Gainesville, Florida, that specializes in underwater robotics, particularly in submersibles that manipulate payload tools in severe environments. Our company has designed and fabricated a Remotely Operated Vehicle (ROV) to analyze and survey sunken World War II ships containing substantial quantities of fuel oil. A ROV is a machine capable of being controlled by a human pilot over long distances at great depths under water. Our ROV, the DVTP20-4, has been designed to quickly and effectively retrieve data from the shipwreck and surrounding site, and conduct fuel oil sampling, without causing undue damage to the ship or the environment. This mission is accomplished by the ROV's exceptional subsystems. The electronic and propulsion systems offer superior maneuverability and an innovative control interface allowing the pilot to precisely control the submersible. This precise control allows for optimal placement of custom fabricated payload tools and sensors that are used to survey the shipwreck site, retrieve oil samples, and collect other related data. All of these system controls and data are transmitted to and from the ROV across fiber-optic and digital data cables, allowing the transmission of complex data without interference. Another crucial system is the camera system, which gives the pilot a close-up view of the ROV and its payload tools while the submersible is in operation. All of these subsystems are mounted on our lightweight frame, which does not rely on any pre-manufactured parts, but is custom cut to our design.

Table of Contents

Company Mission

At DeepView Technologies, we strive for excellence and professionalism. Our mission is to provide the best product and service available to the industry. We developed our ROV, the DVTP20-4, specifically to inspect and aid in the clean-up of World War II shipwrecked oil tankers. DeepView Technologies recognizes the political and ecological sensitivity of the mission, and has paid specific attention to the environmental impact our ROV might have under operation. The DVTP20-4 delivers the most cost efficient solution without compromising quality.

Design Process

In order to complete all of the mission tasks in the most efficient manner, we had to develop systems and priorities for designing our ROV. When building the DVTP20-4, DeepView Technologies focused on three main criteria in the design process. All our decisions were based on time and cost efficiency, mission task integration, and safety. We designed the DVTP20-4 as a modular system that consists of a robust ROV base and multiple detachable payloads (Figure 1-1). The ROV base is composed of a frame, waterproof canisters, and navigation system. Since the missions involve sensitive environments, the most important function of the ROV base is maneuverability. Consequently our base was designed around an optimal thruster placement.

Figure 1-1: The Payload System.

DeepView Technologies went through two frame prototypes in order to test the design and ensure that all payload systems were detachable. Our engineers built these prototypes out of PVC pipe fittings because they are expendable and quick to assemble. Next, our design team developed the three waterproof canisters to fit inside the frame. When planning to fit these canisters, our priority was to ensure that our components remain safe and do not cause any harm to the environment. Each canister design went through three design steps: creating and testing a waterproof seal system, accommodating the canister to fit our components, and deciding on its placement on the frame as well as creating mounting hardware. Since two of our canisters contained cameras, DeepView Technologies oriented them in the stern and bow, which was advantageous to our navigation. While the ROV base was being built, another design team prototyped and tested the payloads. The team reviewed each mission carefully and designed each tool in order to successfully complete as many tasks as possible. During the design process, we asked two simple questions about each tool: "Does the tool complete its intended task successfully?" and "Does it integrate well with the frame?" One of the most important benefits of proper frame integration is a stable payload that contains and protects the tools. Since all of our tools are attached securely to the frame, the likelihood for malfunction or physical danger to anyone is drastically decreased.

Design Rationale: Research and Development

Frame

Because mission tasks are completed in a confined setting, our pilot required the need for a small, maneuverable, yet robust ROV. Our engineers researched several different frame materials and determined that PVC, although durable and easily assembled, did not fully meet our detachable design requirements. We chose UHMW (Ultra-high-molecular-weight polyethylene) because of its special properties and composition that make it an excellent underwater frame material. UHMW has a specific gravity of 0.94, which makes the frame slightly buoyant.

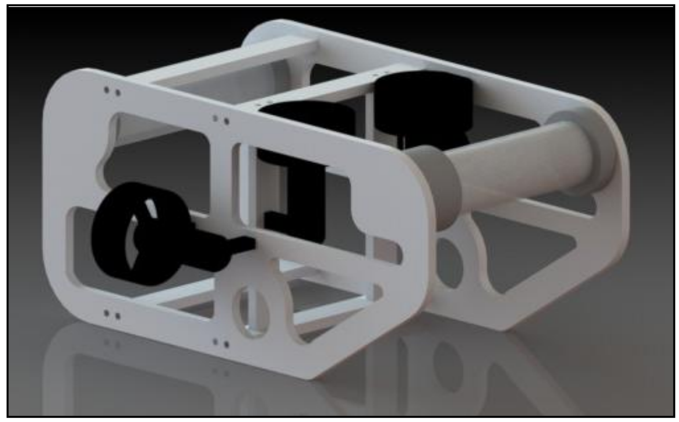


Figure 1-2: CAD Drawing of the UHMW Frame, Seabotix Thrusters, and Waterproof Canisters.

As a polymer, UHMW is easily machinable, yet rugged when assembled. To ensure that our UHMW frame would adhere to our standards, we made a prototype out of expendable PVC pipe and fittings as part of our design process. This allowed our frame engineers to quickly build a model with accurate dimensions of the frame (Figure 1-2), and helped our payload team test tool locations before mounting it onto the final product. The frame design is based on a modular system where almost all our tools and waterproof canisters can be quickly attached and removed. Our engineers achieved this by milling grooves into the UHMW and attaching moveable sliders that are secured by a setscrew. We are thus able to attach the payload, camera, and pneumatic systems to these sliders which provide a quick and easy way to mount and detach.

Even though we used UHMW, we still had to make minor adjustments to the weight of the DVTP20-4 in order to optimize its buoyancy. DeepView Technologies engineers used our proven system of placing four ¼-inch bolts on the inside corners at the bottom of the ROV on which we could add 9.6 washers for fine-tuning the weight distribution (Figure 1-3). The DVTP20-4's frame is composed of two ½-inch UHMW side panels that are connected by 30-cm UHMW spacer bars (Figure 1-2). Our engineers were able to design a compact ROV frame with the dimensions of 63 cm x 33 cm x 30 cm (LxWxH). DeepView Technologies was able to achieve this small and maneuverable frame size by mounting tools in both the bow and stern, and by integrating some of our cameras into our electronics cylinder. Forward thrusters are placed on the outside of the ROV to save space and produce the maximum turning torque. If for any reason the thrusters must be mounted inside the frame, the ROV width can be quickly extended by inserting 48-cm UHMW spacer bars.

Figure 1-3: Weight Tuning System.

Propulsion

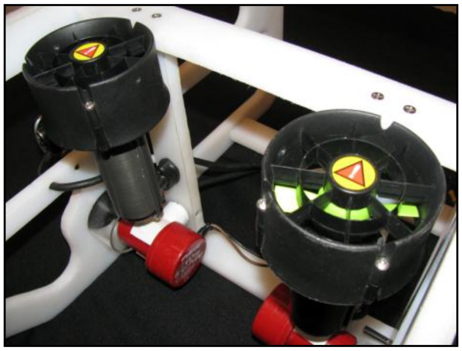


Figure 1-4: The Vertical Thruster Array.

The DVTP20-4 uses four Seabotix BTD-150 thrusters, two of which are for forward, reverse, and rotational motions. These thrusters are controlled by a differential drive propulsion system that relies on two independently controlled thrusters positioned on opposite sides of the ROV. Each thruster can run at different speeds and directions to move the ROV forward or make turns in the desired course. They provide about 9.6 newtons of thrust at 12 volts, and come pre-built with Kort nozzles around the propellers. For vertical thrust, we also use two Seabotix BTD150 thrusters that give us extremely responsive movement (Figure 1-4). Lateral travel is generated by two modified Rule 4150 LPH bilge pumps. These thrusters provide adequate force for our operators to effectively align the ROV with a mission task. To create a safe environment around our ROV, we built a custom cage for our bilge pumps that allows ample water flow, yet prevents any unwanted objects from striking the propeller.

Waterproof Canisters

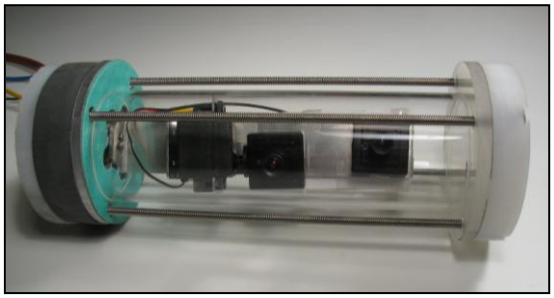


Figure 1-5: The Waterproof Camera Canister.

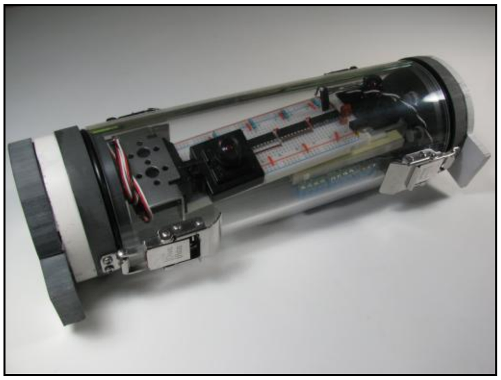


Figure 1-6: Quick Disconnect Electronics Canister.

To accommodate the electronics and cameras for the DVTP20-4's custom frame, DeepView Technologies created its own custom waterproof canisters. From the beginning, our design team knew we needed two canister designs: one with quick and easy access, and the other with semi-permanent mounting. When developing our own canisters, we had the freedom to build them to our exact requirements. Before making the final canisters for the ROV, we conducted extensive research and material experimentation. Our first priority was to find the best waterproof canister system. We examined commercial canisters used in past projects, consulted the MATE Underwater Robotics Science, Design, & Fabrication book, and searched Internet sources. We tested for the best combination of strength and thickness of the canisters, flat plate material and thickness, and gasket composition. Many prototypes were made to field test the different materials and our engineers were able to find a successful combination. All canisters are from cast acrylic tubing with a flat sealing plate on each end. On the camera canister, one of the flat plates is made of cast acrylic and is glued to one of the ends of the canister with Weld-On 3 plastic cement (Figure 1-5). The other end is sealed with a rubber gasket between the canister and an aluminum flat plate. Four Grade 316 stainless steel threaded rods are placed through holes on the four corners that tighten the aluminum plate and the acrylic plate together.

The other type of canister our company designed is similar, except the cap is held on with spring-loaded snaps, and the waterproof seal is an o-ring (Figure 1-6). DeepView Technologies uses glands to waterproof the cables and tubing that penetrate the canisters. All of the glands were drilled and tapped into the aluminum end caps. These custom-made waterproof canisters protect the ROV's pneumatics, electronics, and cameras from water; and fit perfectly into our custom ROV framework.

Tether

Our tether is composed of a variety of electrical and optical cables and pneumatic tubing (Figure 1-7). A single pair of #12 AWG wires carries 12-volt power from the surface battery to the ROV. Two four-pair Cat5e cables are used for sensor data and camera image transmission. Another important element of our tether is a pair of fiber-optic cables used for data transmission for precise positioning of servos and thruster speed control. The final addition to our tether is our pneumatic tubing. There are two tubes: one is pressurized to transfer pneumatic power to the ROV; the other vents the exhaust from the valve bank to the surface. This prevents dangerous pressure build-up in the pneumatic canister.

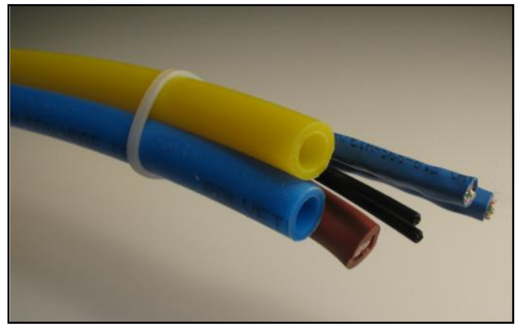


Figure 1-7: A Section of the Complete Tether.

Electronics

At DeepView Technologies, we have integrated fiber-optics technology and synchronous serial data transmission to be the foundation for communication between the pilot and the vehicle. Fiber-optics was chosen because it is able to instantaneously relay high amounts of complex data from one point to another. Using fiber-optics also eliminates the chance of electromagnetic interference affecting the signal. Fiber-optic technology combined with serial communication allows the transmission of complex data streams over long distance, providing optimal control of every system on the DVTP20-4. Data from a variety of sensor values generated from switches and potentiometers is transmitted through the optical fiber. To combine data from several sensor inputs, a PIC16F88 microcontroller is used as a multiplexer. It uses a fiber-optic transmitter to encode the digital signal into optical pulses. At the other end of the fiber-optic cable on the ROV, a fiber-optic receiver converts the light pulses back into an electrical signal that is sent to multiple PIC16F88 microcontrollers (Figure 1-8). Each PIC16F88 acts as a demultiplexer, retrieving only the control data for the device it controls. The mission tasks require the ROV to maneuver in environmentally sensitive sites. The pilot must have complete control to avoid a potential ecological disaster. For this reason, the DVTP20-4's hardware and programming offer the pilot proportional speed control to provide the maximum command of the ROV. The DVTP20-4 is equipped with four BTD150 thrusters controlled by Pololu 18v15 High-Power motor-drivers (Figure 1-9).

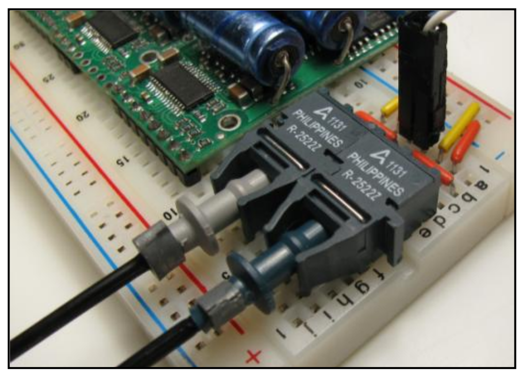


Figure 1-8: Fiber-optic Receivers and Cable.

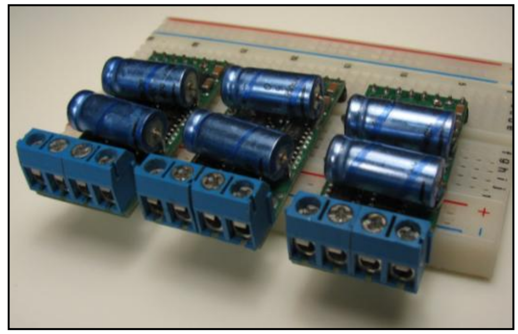


Figure 1-9: Pololu Motor Drivers.

These motor-drivers respond to Pulse Width Modulation (PWM) signals received from one of the ROV microcontrollers. The input voltage has a measured voltage range between 0 and 5 volts, which is created by varying the length of a 5-volt pulse at 20 kilohertz. The motor-driver uses this value to create a matching stream of 12-volt pulses that generate an average measured voltage in a range between 0 and 12 volts. The polarity of the thruster is controlled by a direction pin on the motor-driver. If a low is received on that pin, the thruster polarity is one way, and it changes polarity when the pin is flipped to high. These motor-driver inputs are determined by two potentiometers that are embedded inside two ergonomic joysticks. Each joystick controls one thruster, backwards and forwards. The two forward/backward thrusters form a differential drive arrangement where the turning motion is determined by the difference in the velocity between the two thrusters. By alternating these joystick positions the ROV will turn, move forward, etc. Pilots have commented that the differential drive system gives them a natural feel to the navigation, which provides superb control of the ROV in hazardous settings.

All payload tools on the DVTP20-4 are pneumatically powered, but they require electronics for control. Solenoids open and close valves that move each of the pneumatic cylinders. There are two solenoids per payload tool, allowing each tool to have two positions that include “open” or “closed” for the gripper, or “extended” and “withdrawn” for the calibration sensor. The 16F88 transmits inputs from several switches to the ROV to control each tool. Each switch has two positions to represent the position of the tool. An additional aspect of the electronics on the DVTP20-4 is DeepView Technologies' servo control of two video cameras. Using potentiometers, the microcontroller transmits the input values through the fiber-optic cable to the ROV and then to the servomotors. This process creates variable control over camera positioning, optimizing the use of each camera, and allowing for extremely precise positioning.

Pneumatics

Figure 1-10: Fabco-Air F-series Pneumatic Cylinder.

After an in-depth analysis of the mission tasks, our engineers realized that a simple linear motion was all that was required to operate our tools. For this reason, DeepView Technologies decided to use a pneumatic system to power our payload tools, since it offered the most effective and simplest mechanism. DeepView Technologies collaborated with Fabco-Air, Inc., a local pneumatic product manufacturer, in obtaining parts for the pneumatic system. With this equipment, our engineers designed their own custom built pneumatic system that can accomplish all of the mission tasks. The pneumatic system provides air pressure to several pneumatic cylinders onboard the ROV that apply a linear action to operate our tools. DeepView Technologies decided to use the Fabco-Air F-series pneumatic cylinders because they provided superior operation and compactness (Figure 1-10). To control all of these cylinders, we implemented five double-action pilot valves that receive control signals via one of the fiber-optic cables from the control panel.

Figure 1-11: Valve Bank with Manifold.

The double-action valves offer a superior response time and control over the single action-valves, which were smaller and cheaper (Figure 1-11). The DVTP20-4's pneumatic system is based on the pneumatic manifold that houses five separate valves. This manifold is placed inside a clear acrylic cylinder so that our ROV operators can perform a quick systems check before operation. DeepView Technologies uses two ⅜- inch polyethylene tubes to supply the entire pneumatic system with air. One tube supplies air pressure, and the other releases pressure from the cylinder to the surface. Our engineers designed the waterproof containers to be easily accessible, and chose to use hose couplings to attach the tubing to the cylinder because they handle more stress than normal push-to-connect fittings. To supply air to the onboard pneumatic cylinders, our engineers used ¼-inch nylon tubing because it safely supplies air and is quite flexible. In this case, we used push-to-connect fittings that work similarly to quick-disconnects, yet have no fitting attached to the end of the hose. Since customer safety is one of DeepView Technologies highest priorities, a mandatory pneumatics operations procedure has been established as follows:

- Make sure the supply air tank is filled up to its maximum capacity, and then turn the compressor off.
- Check all the airlines for leaks and ensure fittings are attached securely.
- Attach the ROV hose line to the tank.
- Slowly release air into the system until the gauge reads 40 PSI.
- Test all pneumatic tools before embarking on a mission.

The inclusion of a pneumatic system on the DVTP20-4 ROV has improved its versatility and reliability for all mission payload tools.

Sensors

Two Cat5e cables control the sensors on board the ROV. Both Cat5e cables go through the same gland on the main sensor canister. There are eight wires in each cable, making 16 wires in total. Three wires are used for the temperature sensor, and three wires are for three of the water sensors. Since the ROV has five cameras, ten of the wires connect the video signal of the cameras. Cat5e provides all the DVTP20-4's sensor wire needs while decreasing the tether size and eliminating electromagnetic interference.

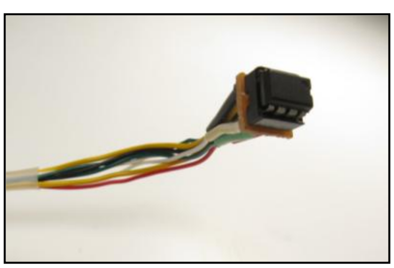


Figure 1-12: The Temperature Sensor.

To prevent the catastrophic failure of the waterproof seals, DeepView Technologies has installed water detection systems in all crucial canisters. The water detection circuit is a simple resistor and LED circuit. When water touches the two probes, connectivity is achieved, and the circuit is closed. The red LED lights up and warns of a water seal breakdown. A digital thermometer is housed inside the electronics canister to monitor heat buildup generated from the electrical components (Figure 1-12). This mechanism improves the safety of our system and can predict potential electrical component hazards.

DeepView Technologies' DVTP20-4 is equipped with five CM320 micro video color cameras mounted in custom waterproof canisters (Figure 1-13). Two of the video cameras are mounted on servo motors for tilting, and controlled by the pilot's assistant with two potentiometers on the control console. The pilot can view the onboard tools one moment, and then tilt the camera upward for navigation purposes. The other three cameras are in a fixed position for specific mission tasks. Because the tools are attached both in the bow and the stern of the ROV, we equipped both ends with cameras. The main camera canister serves as the central connection point for the camera network. All camera signals are sent through a pair of Cat5e cables to the surface. Our engineers decided that our technology for using fiber-optic cables with our cameras had not matured enough and was not ready for the ROV at this time. The wires to power each camera are connected together on a terminal strip that reduces the number of wires needed to carry power to the cameras from the surface. At the control center, the video signals feed into an eight-channel video multiplexer, then into a BNC-to-VGA converter that connects to the LCD monitor. This monitor displays up to eight clear images of the payloads and work environment.

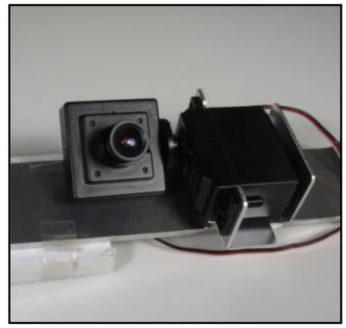


Figure 1-13: CM320 Camera with Tilting Mount.

Since visibility is key to successful navigation, DeepView Technologies created a camera tilting system. We designed two tilting camera setups, one for the electronics canister, and the other for the camera canister. The camera is mounted on a servo motor connected to a circuit board. A Pic16F88 is programmed to receive a fiber-optic signal from the control console. The values sent to the servo vary directly with the values of a potentiometer. As a potentiometer is turned, a signal is sent across the fiber-optic cable to operate the servomotor. The tilt system gives us a wide range of camera visibility in both canisters, and allows us to easily view a larger area.

Control System

DeepView Technologies has created an ergonomic console that houses all of the peripherals used to control the payload tools on the DVTP20-4 (Figure 1-14). The pilot's assistant operates these tools, which allows the pilot to focus on navigation. The two joysticks that navigate the ROV are attached to the console using one connector each. These joysticks include several switches and potentiometers that provide variable readings to control the thrusters. Each incoming fiber-optic and electrical cable has its own connector to minimize space inside the console. Moreover, the internal electronics and external connections are designed so they can be separated when opening the control box. Internally, each wire and component that connects the two halves has built-in connectors which can be easily separated for repairs.

Figure 1-14: Payload Console with Joysticks.

Payload Systems and Tasks

Measuring System

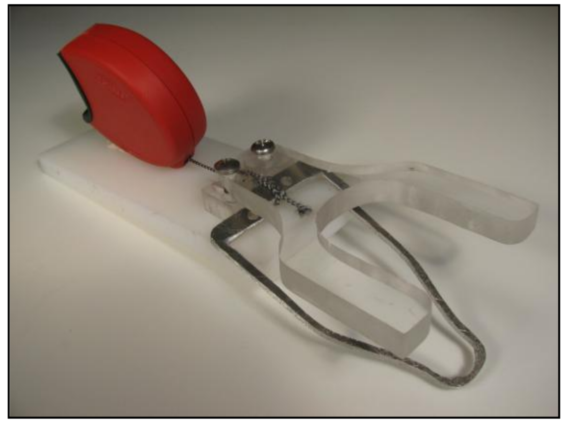


Figure 2-1: The Measuring System.

The most difficult mission task proved to be measuring the length of the shipwreck. In order to complete this task, our engineers developed an ingenious procedure utilizing a dog leash, a metal slip ring, and graduated markings on the leash (Figure 2-1). When considering a retractable, measuring device, a tape measure was instantly ruled out because it was bulky and contained too many metal parts. After exhaustive research, DeepView Technologies decided that a dog leash with accurate measurement markings would provide the best solution. In order to increase its visibility underwater, black graduations were created on a white nylon string. Having completed the actual measuring tape, an efficient method was needed for attaching the end of the string to one end of the shipwreck. Although there were many ways to accomplish this task, our engineers designed a simple solution of tying the end of the dog leash to a specially fitted slip ring. This metal ring extends out of the ROV and can be easily dropped over the half-inch PVC standpipe on the shipwreck. To see the measurement markings, a camera has been positioned to directly view the dog leash. Since the leash causes some opposing force when extended, the system is mounted on the stern of the ROV in order to take advantage of the extra thrust when traveling forward. This tool provides the most reliable and compact solution for this particular task.

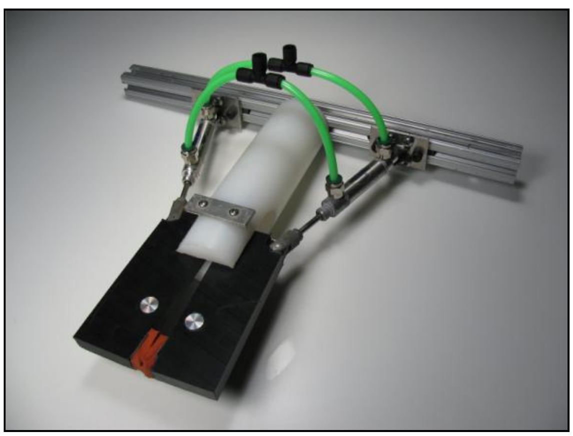


Figure 2-2: Main Gripper Assembly.

Primary Gripper

Accomplishing the many delicate operations in assessing a sunken oil tanker, such as removing and placing the corals, attaching the patch, and stabilizing the ROV on the shipwreck, required a strong and versatile main gripper that would not damage the objects being handled. To accomplish this goal, our engineers developed a gripper powered by two pneumatic cylinders with 25 millimeter stroke that gives a responsive and firm connection (Figure 2-2). These cylinders attach to the frame and the gripper plates, and pivot in the horizontal plane. The gripper mounts at a slight pitch to facilitate recovering objects on the seafloor. When the pneumatic cylinders activate, they push the gripper plates forward, closing them. To create a uniform angular displacement, both plates are paired by two gears. This ensures that both gripper plates will meet in the center and that the pressure provided by both pneumatic cylinders is equal. To prevent the gripper from damaging the objects being gripped, two foam pads have been attached to the insides of the gripper plates. The assembly was made out of UHWM to integrate the gripper with the frame and increase the overall buoyancy of the frame.

Lift Bag Gripper

An important mission task the DVTP20-4 must complete is attaching a lift bag to a fallen mast and inflating the device so the mast will rise to the surface. To complete this task our engineers have designed a second powerful gripper for the ROV that easily and effortlessly accomplishes this mission task (Figure 2-3). To inflate the lift bag, the ROV uses a long nylon tube that is inflated at the surface with a hand pump. The tube connects to the stern of the ROV with a loose cable clip and to the bow with a plastic strap. The tubing feeds into the lift bag so that when the hook is attached to the fallen mast, the hand pump on the surface can pump air through the tubing and into the lift bag. This process allows the fallen mast to rise to the surface. When the task is completed, the tubing is pulled until it slides right through the loose cable clips and up to the surface.

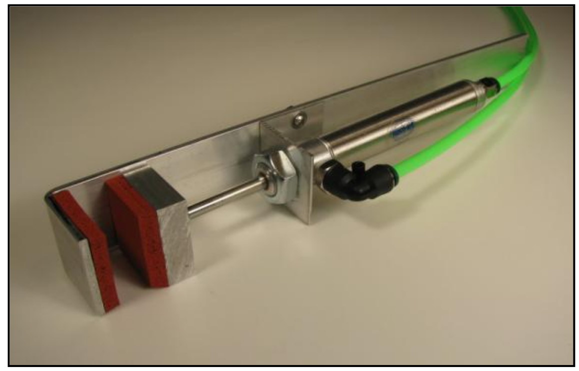


Figure 2-3: The Lift Bag Gripper.

Petroleum Probe

To successfully gauge the hull thickness and calibrate the neutron backscatter device, DeepView Technologies needed to create a unified petroleum probe (Figure 2-4). To maintain a safe and compact profile for the frame, the petroleum probe had to be retractable. The DVTP20-4 uses a 6-inch stroke pneumatic cylinder to solve this problem. The probe extends when needed and then is quickly retracted by the tool operator when other tools are in use. The calibrator is made of a ½-inch PVC cap attached to our pneumatic cylinder. To increase visibility, the PVC cap was spray-painted blue and includes a push button that lights an LED when activated.

Figure 2-4: The Petroleum Probe.

Oil Sample Retrieval

Collecting oil from a tank is one of the most important tasks in assessing the wreck. DeepView Technologies has designed a device that reliably collects the oil by using a syringe (Figure 2-5). The 100-milliliter syringe is mounted at the stern of the ROV with enough clearance to enter the hole. The syringe is powered by a 6-inch stroke pneumatic cylinder with a rubber piston that sucks the oil into the syringe. Our engineers have added nylon tubing to the end point of the syringe which makes the assembly long enough to penetrate the oil container. Once the sample has been collected, the piston can release the oil into another container for further inspection.

Figure 2-5: Oil Sample Retrieval System.

Metal Detecting Device

To successfully determine whether debris is metallic or not, DeepView Technologies needed a simple yet effective solution. Our engineers decided to use a set of magnets attached to a string suspended from the ROV. The metal detecting device is positioned so the device can be easily viewed, yet stays out of the way of other tools. When the magnet contacts the metal or PVC it either holds fast for a second or does not interact when the ROV pulls away. If the magnet stays connected, the material is a ferromagnetic metal, and if not, the material is PVC. This test lets the pilots easily analyze the samples and correctly label the debris.

Safety

Figure 3-1: Protective Bilge Pump Shroud.

Customer and product safety is one of DeepView Technologies' highest priorities, which is why our engineers have incorporated many features and procedures that ensure the secure use and operation of the DVTP20-4. When designing the frame, careful attention was given to make sure that all tools and thrusters were mounted out of harm's way. The main Seabotix thrusters all come preassembled with a Kort nozzle that covers the prop and efficiently directs water flow. However, for the custom bilge pumps our engineers provided a special cutout in the frame that encloses and secures the propeller (Figure 3-1). All payload tools of the DVTP20-4 are either enclosed completely within the frame, or can be retracted within the frame. Not only does this design make the ROV more maneuverable, it also decreases the chance of a tool causing accidental damage to the shipwreck or surrounding environment.

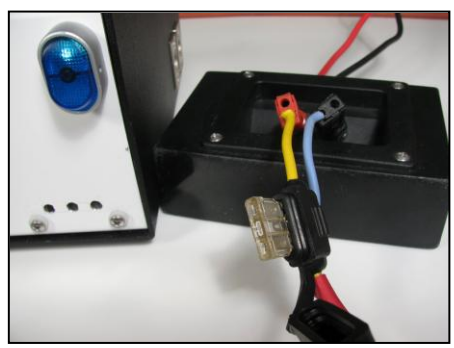


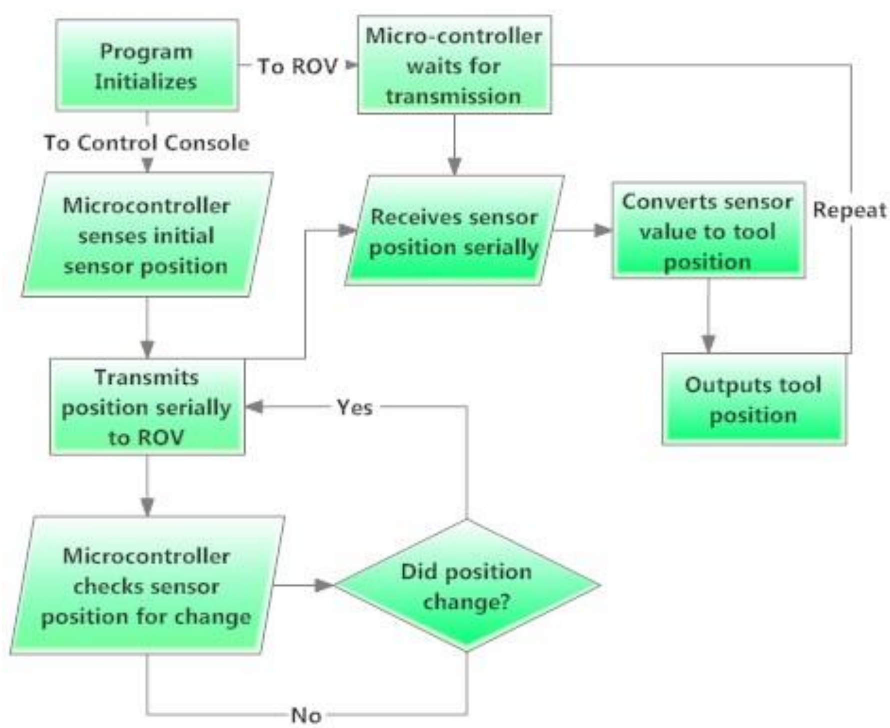
Figure 3-2: 25 Amp Fuse in Line with Main Power Switch.

For the two grippers, our engineers attached highly compressible rubber plates that ensure a secure and safe grip. All onboard pneumatic fittings and tubing are rated to at least 150 PSI, which is well above the maximum pressure limit of 40 PSI. Should a leak occur, the tool operator can immediately remove all air pressure to the ROV through a shut-off valve at the surface. To maintain safe pressures in the pneumatic canister for the valve bank, a second hose-line to the surface was added to relieve any excess pressure. All canisters on board are tested to be waterproof, and are easily accessible if any problem should arise. To ensure electronic safety, DeepView Technologies has included a 25-ampère fuse in line with all electronics. Another important safety aspect is the main power switch. It contains a power indicator light and gives the ability to quickly disconnect the electronics from the power source (Figure 3-2). DeepView Technologies treats employee safety as a high priority. Shop safety rules are constantly stressed by management, and personal protective equipment is required when working with power tools and hazardous chemicals.

Future Improvements

Although the DVTP20-4 accomplishes all mission tasks successfully, our engineers at DeepView Technologies have highlighted several future improvements that can be incorporated into the next generation ROV. We plan to introduce two o-ring grooves on the caps of our waterproof canisters. The grooves will allow for superior seals, and the second set of o-rings will serve as backups if the first seal malfunctions. This change will create a more streamlined canister that is also easier to access. A second improvement is a pan and tilt function on all video cameras. Some of the current cameras on the DVTP20-4 already support camera tilting; however including a pan will increase the viewing angle, thus reducing the number of cameras needed. This advancement will allow our pilots to view the tools and the environment, and reduce the number of cameras that impact vehicle weight and tether size. We also like to expand the use of printed circuit boards (PCBs). Although some of the DVTP20-4's circuits are on PCBs, the remaining circuits are wired on solderless breadboards. Using printed circuit boards produces a permanent circuit and makes circuit failure from vibration and transportation less likely, while allowing for smaller cylinders. DeepView Technologies is excited to announce that these improvements will be integrated into the DVTP30 series to be introduced in the fourth quarter of 2012.

Software Flowchart



The Software Flowchart

The software used and created by DeepView Technology has a specific flow. At the surface, a number of sensors, including switches, potentiometers, etc, are used to represent a specific position. The position of each sensor is then measured by a microcontroller. This data is transferred using serial communications and fiber-optics to the ROV. Once the microcontroller on board the ROV receives the data, the sensor position data is then converted to a similar value that controls a tool.

Troubleshooting Process

If a system fails during a mission, the engineering support team must troubleshoot the system malfunction. When attempting to find a solution, the engineers must identify the exact symptoms of the problem. A symptom is defined as an input that creates an undesired output, for instance incorrect positioning or failure to move. The team proceeds with the tedious task of determining why the output failed, and then solves the problem by following a specific procedure. First, check each component individually for failures that would affect the output. Second, attempt to fix each failure, if possible. Third, once a fix is completed, run the subsystem or ROV again to see if the fix works, or if any improvement was made. Finally, repeat as needed until no further improvement is realized. However, in the case that the issue is not solved by careful examination of each component, the engineering team enlists the help of the design team to find a new approach to complete the task. Once another system has been designed and fabricated to replace the failed one, it is tested and tried on the same task. If it fails, too, the troubleshooting process is repeated until a system has been created that works reliably. This process was applied to our measuring system and several problems that arose during its operation. First, the force required to pull out the self-retracting measuring line slowed down our ROV to a crawl. Additionally, the ROV was immensely difficult to maneuver and keep on a straight path while pulling the line. Thus our engineers broke both of these problems down by analyzing different systems of the ROV that had a negative effect. After close inspection, special modifications were made as follows, and the system was completely redesigned. The frame material and design was changed to allow the measuring line to be attached at the rear of the ROV, to ensure less drag and mass in the water, thus improving speed. The move to stern also allowed greater thrust to be used against the line because the thrusters have more power moving forward. Furthermore, due to our redesign, the ROV is easier to steer because the pilot has greater control navigating the ROV.

Description of Challenges

Non-Technical Challenge

The CEO of DeepView Technologies was tasked with creating team synergy, and needed to ensure the timely completion of the DVTP20-4. One of the major challenges this year was working with a larger team while still making sure that everyone was able to be productive and utilize his or her strengths. The solution was to efficiently allocate employees to specific tasks to maximize productivity in the design and construction of the ROV. Careful planning allowed the assignment of each project to qualified people who were able to drive the project without any issues. All senior members of the company were given major roles and were responsible for executing and completing tasks in a specific time frame. The newer employees were assigned to assist the senior members, provide support, and gain experience for future projects. The CEO gave advice to senior members and ensured that the entire project remained on schedule. His unique position allowed him to facilitate the smooth integration of the separate projects, and helped the company prioritize certain aspects on the ROV. He was able to keep everyone on task by maintaining and updating a task list for each employee that highlighted certain priorities and facilitated teamwork while decreasing downtime. He also organized meetings between different subproject groups to integrate space and control parameters. Through proper planning, DeepView Technologies was able to successfully accommodate a larger workforce.

Technical Challenge

Fiber-optics and serial communication have proved to be difficult and challenging technologies to apply to the DVTP20-4. In the research and development process, our engineers attempted to condense tether size and make our communications more efficient. Fiber-optics was the perfect solution. Our initial experiments involved simply connecting two PIC16F88 microcontrollers from the transmitting (TX) pin to the other's receiving (RX) pin. These attempts, however, were racked with failures because the software commands we used lacked the data structure to relay information reliably. By studying forums, particularly MELabs and Mods by Darrel, and a programming manual, we discovered a HSERIN / HSEROUT command that had the structure required to relay the data. Once this command was implemented, we met with limited success. The programs only ran once before stopping completely. Upon further research, we discovered that since serial transfer is synchronous and requires exact timing, each program must have very similar timing for it to work. This solution worked for a while, but was tedious, and required calculations of time per command to obtain accurate time measurements. Finally, we discovered that one bit of information could be included, and the receiving program could be set to wait for that bit. This process would automatically sync the two programs and allows for even more complex data to be transmitted.

DeepView Technologies overcame this challenge using the vast resources of the MELabs and Mods by Darrel forums, and other technical sources, as well as basic technical troubleshooting coupled with perseverance. Assimilating the know-how from these sources, our experience and success grew until we were able to effectively use fiber-optics in all of the programs.

Lessons Learned

Non-Technical Lesson Learned

This year our company added two junior members to our team. This created a challenge of learning to work together with less experienced members, and respecting them, even when they still needed training in certain areas. Our team learned leadership skills by teaching the junior members in areas of need. They were invaluable in researching and executing new technologies in which the company had no prior experience. Their fresh perspective on building ROVs often proved to be useful. Our junior members were able to gain firsthand experience in the ROV building process that has prepared them to take charge of DeepView Technologies' next generation of employees.

Technical Lesson Learned

In our quest to improve the quality and versatility of our ROVs, DeepView Technologies is constantly researching and testing new methods to provide cutting edge products. This year, our engineers began experimenting with pneumatics to supply power to the payload tools. Throughout this process, we learned about many different types of pneumatic fittings, how to repair and inspect pilot valves, and a variety of pneumatic cylinders and their appropriate uses. Our engineers were also able to master specific pneumatics terminology and discover when and where to use certain tubing materials and sizes. Learning how to design and build a pneumatic system has improved the reliability and responsiveness of the DVTP20-4's payload. The pneumatic system has made the construction and operation of the tools a much simpler and more reliable process. With a pneumatic system, our engineers have been able to spend more time improving other aspects of the ROV.

Reflections

Manuel Angerhofer, CEO

As CEO of DeepView Technologies, I guided the ROV design and construction, ensured that each team member knew his or her responsibilities, helped the team work together, and made sure everyone's ideas and concerns were heard. I also learned how to make difficult decisions, and guide a team under pressure. Since we had never used pneumatics before, I had to research, design, and test the system from the ground up. I learned how to complete difficult tasks without any outside help. My last year at DeepView Technologies has provided me with many skills I will need to lead engineering teams in the future.

Jacob Darbyshire, CFO

Working with DeepView Technologies this year was a great opportunity to participate in designing and constructing our ROV. As Chief Financial Officer, I created the budget and expense list. I was responsible for the sensors, as well as working with UHMW and other aspects of the frame. As a DeepView employee, I have learned how to speak up in an outgoing manner when I have an idea pertaining to the ROV. My time with the company has been an enriching experience, and will hopefully lead to greater career opportunities in the future.

Timon Angerhofer, Junior Software Engineer

As Junior Software Engineer at DeepView technologies, I constructed and programmed circuits for a number of sensors with limited assistance from others. As we neared the date of the competition, our Chief Software Engineer took over the main circuitry and programming, while I began working on various supporting tasks. From this experience I learned the importance of teamwork, listening, and following directions. My first year as the youngest member of DeepView Technologies has taught me valuable lessons I can use for future projects.

Richard Hurlston, Chief Design Engineer

This year, as the Chief Design Engineer of our company, I have been responsible for designing and building many components on our ROV such as the waterproof canisters that hold our electronics, pneumatics, sensors, and cameras. I also set up and positioned the cameras, and developed several generations of PVC prototype frames that ultimately led us to the final UHMW frame of the ROV. During the year, I have learned how to work more independently, yet at the same time teaching the junior members of the team.

Timothy Davis, Video Specialist

Early in the year, I was asked to join the DeepView Technologies because of my programming aptitude. As the year progressed, I learned many valuable lessons about teamwork, troubleshooting, and electronics. In addition to taking instruction from senior co-workers, I learned how to solve problems on my own. As a junior member, I had to learn programming and fiber-optic technology at a fast pace. Learning to work with a team while taking initiative on my own has provided invaluable experience for my future work as a research scientist.

Financial Report

2012 MATE ROV Budget/Expense Sheet

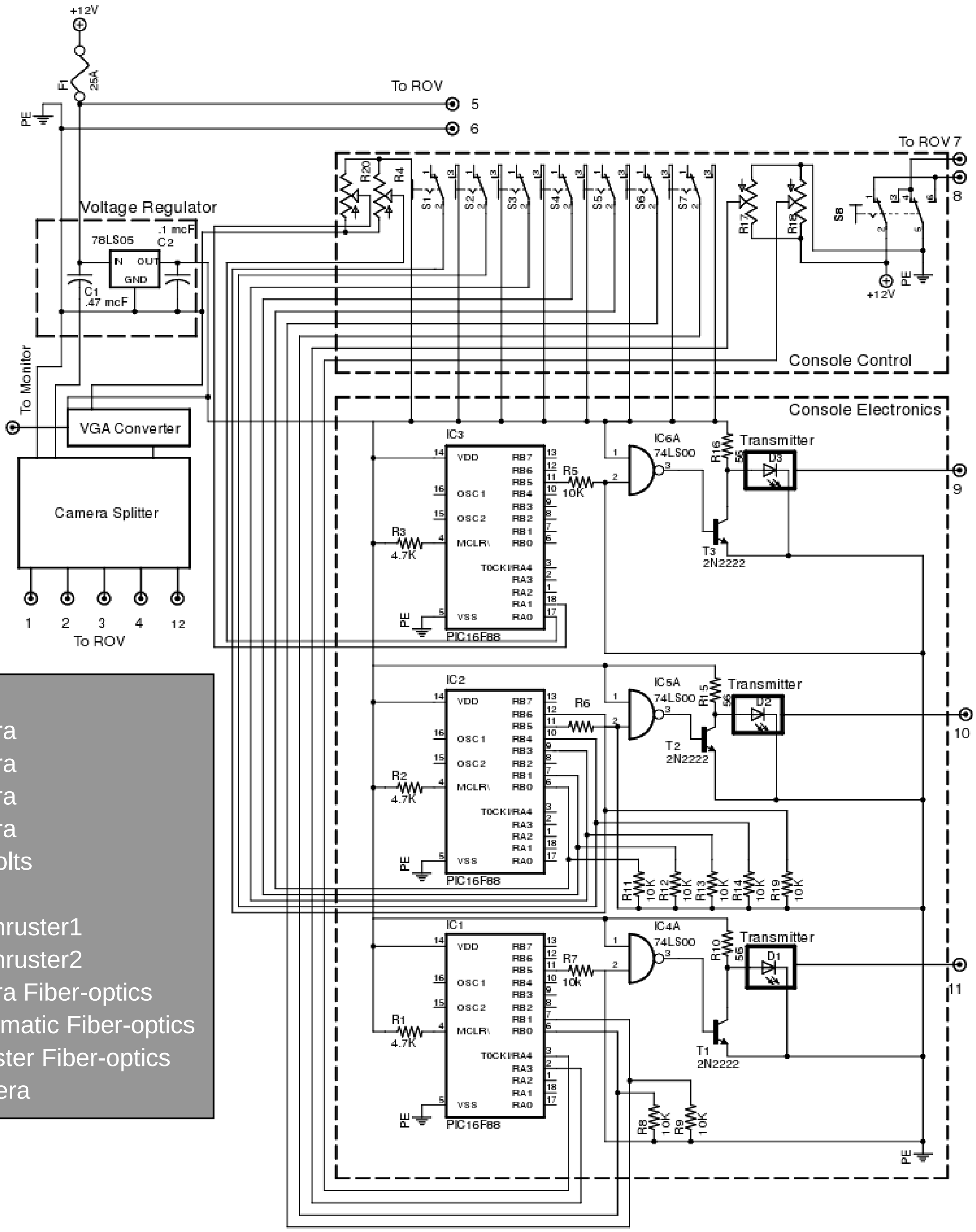
School Name: Cornerstone Academy — From: 8/1/11
Instructor/Sponsor: Jeffrey Knack — To: 5/14/12

Date	Deposit or Expense	Vendor	Description	Balance
8/1/11	$4,000.00	Team Parents	Parental Fees	$4,000.00
8/22/11	($65.25)	Industrial Fiber Optics	Fiber optic lab kit	$3,934.75
9/12/11	($19.75)	Home Depot	PVC, O-rings	$3,915.00
9/21/11	($119.62)	MSC Industrial Supply	NPT connector, pipe tap, O-rings, UHMW sheet	$3,795.38
10/6/11	$25.74	MSC Industrial Supply	Return	$3,821.12
10/9/11	($146.77)	Digi-Key Corporation	Fiber optic TX and RX	$3,674.35
10/10/11	($39.84)	McMaster-Carr	PVC sheet	$3,634.51
10/11/11	($12.73)	Radio Shack	TV-VCR impedance match	$3,621.78
10/11/11	($40.49)	Stock Drive Products	Gripper gears	$3,581.29
10/22/11	($54.26)	Skycraft Parts and Surplus	Fiber optic cable, 50A meter	$3,527.03
10/24/11	($32.99)	Amazon.com	Video to VGA converter	$3,494.04
10/24/11	($86.18)	Evertech USA Corp	Video quad splitter	$3,407.86
10/25/11	($10.61)	Sports Authority	Kickboard for ballast	$3,397.25
10/31/11	($123.65)	Computer Geeks	Video cameras	$3,273.60
11/7/11	($36.00)	Mouser Electronics	Connectors, cables	$3,237.60
11/8/11	($53.34)	Magnum Wood	Acrylic tubes	$3,184.26
11/15/11	($106.24)	Alllied Electronics	DPDT relays	$3,078.02
11/22/11	($294.09)	MSC Industrial Supply	Pneumatic tubing/connectors, Drill and tap	$2,783.93
12/1/11	($34.19)	MSC Industrial Supply	Pneumatic fittings	$2,749.74
12/8/11	($29.75)	Digi-Key Corporation	Depth sensors	$2,719.99
12/19/11	($88.45)	Home Depot	Props, epoxy, fuses	$2,631.54
12/19/11	($33.00)	BRAAS Company	Pneumatic fittings	$2,598.54
12/20/11	($23.01)	Magnum Wood	Acrylic	$2,575.53
12/22/11	($52.81)	McMaster-Carr	Acrylic tube, ABS sheet	$2,522.72
1/5/12	($17.42)	Home Depot	Props	$2,505.30
1/10/12	($84.87)	HPE Automation	80/20 extrusion, parts	$2,420.43
1/13/12	($29.98)	Parallax	Propeller QuickStart Board	$2,390.45
1/16/12	($49.93)	BRAAS Company	Pneumatic fittings	$2,340.52
1/18/12	($111.43)	Radio Shack	Gyroscope, compass, USB to serial cable	$2,229.09
2/4/12	($28.71)	Lowe's	PVC	$2,200.38
2/6/12	($23.60)	MSC Industrial Supply	Pneumatic fittings	$2,176.78
2/7/12	$26.81	MSC Industrial Supply	Return	$2,203.59
2/10/12	($20.41)	CustomMold	Brass plugs	$2,183.18
2/16/12	($50.00)	MATE Center	Registration fee	$2,133.18
2/20/12	($35.58)	Plastic Process Equipment	Brass plugs	$2,097.60
2/29/12	($77.55)	Microtherm	Fiber optic cable & fittings	$2,020.05
3/3/12	($46.94)	MSC Industrial Supply	Check valve, connectors	$1,973.11
3/14/12	($104.34)	Allied Electronics	Wxproof connectors, nozzles	$1,868.77
3/15/12	($46.67)	Zell's Hardware	Tap, grease, sandpaper, fasteners, brass tubing	$1,822.10
3/17/12	($169.83)	MSC Industrial Supply	PVC sheets	$1,652.27
3/19/12	($34.39)	Monoprice	Cat5e Cable	$1,617.88
3/19/12	($163.55)	McMaster-Carr	UHWM Side Panels	$1,454.33
3/23/12	($50.00)	Microchip Direct	Microcontrollers	$1,404.33
3/26/12	($612.46)	Seabotix	Thruster	$791.87
3/28/12	($214.55)	Digi-key	Switches/Fiberoptic TX/RX	$577.32
4/7/12	($10.47)	Amazon.com	Clothesline	$566.85
4/9/12	($10.58)	Pepboys	Compasses	$556.27
4/10/12	($23.28)	Ripley Retail	100 ml Syringes	$532.99
4/11/12	($80.00)	McMaster-Carr	4" Acrylic Tube	$452.99
4/14/12	($50.47)	Amazon.com	BNC-to-VGA Converter, clothesline	$402.52
4/17/12	($74.14)	West Marine	Compass	$328.38
4/18/12	($26.36)	NAPA Auto Parts	Hose fittings/fuses	$302.02
4/19/12	($15.89)	Office Depot	Foam Board	$286.13
4/20/12	($38.33)	Renaissance Printing	Florida Regional Poster	$247.80
4/24/12	($30.00)	MPH Industries, Inc.	Aluminum sheet	$217.80
4/25/12	($44.67)	Magnum Wood	Acrylic tubing and adhesives	$173.13
5/3/12	($82.71)	McMaster-Carr	Acrylic tubing	$90.42
5/14/12	($167.11)	MSC Industrial Supply	Pneumatic fittings, acrylic sheet, threaded rod	($76.69)

Corporate Donations:

Date	Deposit or Expense	Vendor	Description	Balance
10/21/11	$180.00	Fabco-Air, Inc.	Pneumatic cylinders	$180.00
11/4/11	$1,450.00	Fabco-Air, Inc.	Pneumatic valves and cylinders	$1,450.00
1/13/12	$700.00	DS SolidWorks Corp.	SolidWorks 2012 Student Edition	$700.00
5/8/12	$90.00	Fabco-Air, Inc.	Pneumatic cylinders	$90.00
	$2,420.00			$2,420.00

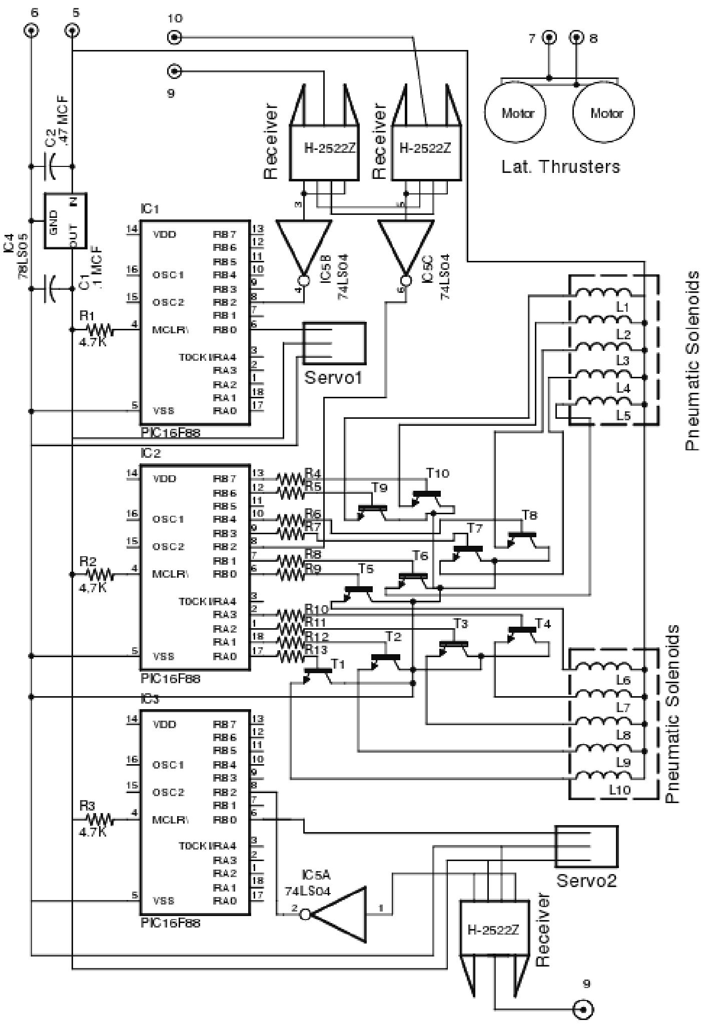
Electrical Schematics



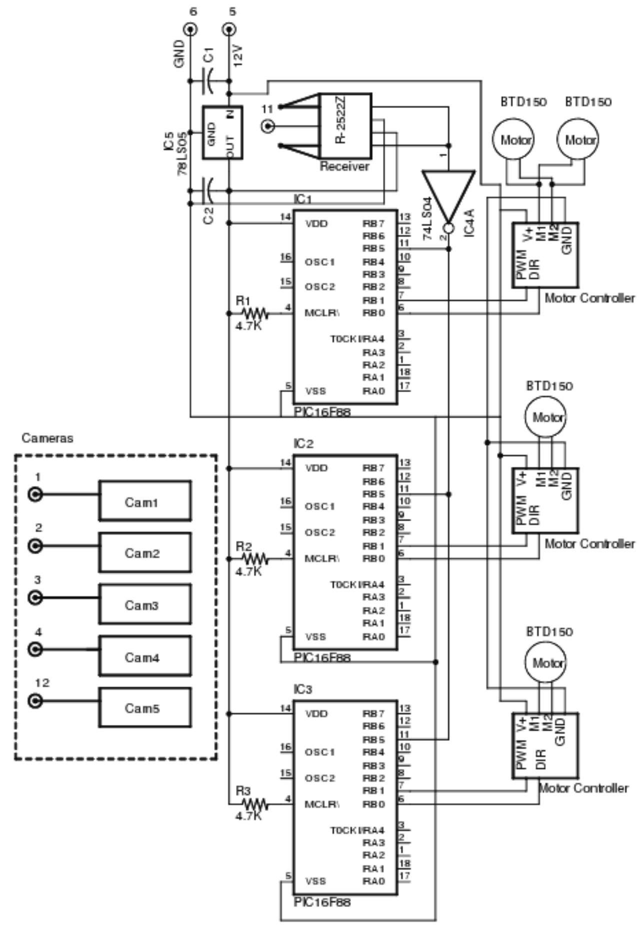
Legend:
1. Camera
2. Camera
3. Camera
4. Camera
5. +12 Volts
6. GND
7. Lat. Thruster1
8. Lat. Thruster2
9. Camera Fiber-optics
10. Pneumatic Fiber-optics
11. Thruster Fiber-optics
12. Camera

This schematic represents our control system at the surface. Included is every electrical aspect of control console and camera systems. Note the 25A fuse at the top of the schematic diagram labeled F1.

Pneumatics/Camera



Propulsion



Pneumatics/Camera:
Pneumatics and camera circuits. Signals 10 and 9 are the incoming fiber-optic signals for pneumatics control and servo camera control. IC3 is the microcontroller that controls all the pneumatics with transistor switches and electromagnets. The lateral thruster is displayed in the upper left, with signals coming from 7 and 8.

Propulsion:
Schematic representations of our propulsion circuit. The fiber-optic input is received at 11 by the H-2522Z receiver and is transmitted to the PIC16F88s. These microcontrollers take the information received and direct the four motors connected to the motor controllers.

References

1. Conversion of Measurement Units, http://www.convertunits.com/from/kg/to/N.
2. MATE Center, Underwater Robotics Science, Design & Fabrication, http://www.materover.org/main/.
3. Wolfram Alpha, http://www.wolframalpha.com/.
4. MeLabs Forums, http://www.picbasic.co.uk/forum/forum.php
5. Moore, Steven W. *Underwater robotics: science, design & fabrication*. Monterey, CA: Marine Advanced Technology Education (MATE) Center, 2010. Print.

Acknowledgements

Financial Sponsors:

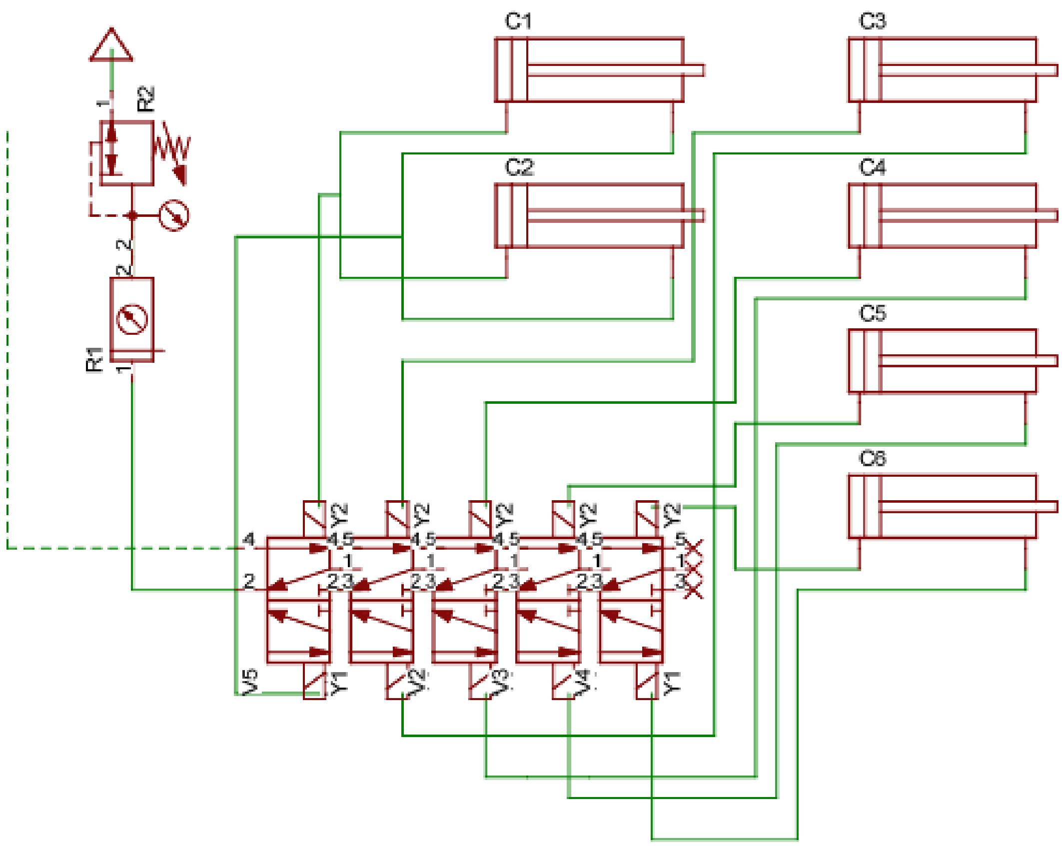
- Seabotix
- Dassault Systèmes Solid Works
- Fabco-Air
- Jeffrey Knack
- Parents of team members
- MATE
- Jim Carr

Local Team Supporters:

- Jeffery Knack – Team Mentor and Instructor
- The Administration of Cornerstone Academy
- Alex and Nadia Angerhofer, Buddy and Emily Hurlston, Sue Spencer, Kimberly Knack and Tim and Connie Davis

Appendices

Pneumatic Schematic



This schematic represents the airflow through our pneumatic system. R2 is the pressure regulator in line with the compressor, and R1 is our air preparation, which de-moisturizes the air. The line then feeds into the 5 double action solenoid valves. The output of the 5 values are then distributed to our various pneumatic cylinders. Note that C1 and C2 power the gripper and are both controlled from one valve. The dotted line is our air drain, which feeds back up to the surface.

Fiber-optics Software

Joystick Control Program

```
'-------------Variables------------
Switch1      VAR    PORTB.0
Switch2      VAR    PORTB.1
Switch3      VAR    PORTB.3
Switch4      VAR    PORTB.4
G            VAR    BYTE
H            VAR    BYTE
I            VAR    BYTE
J            VAR    BYTE
'----------Initialization---------
DEFINE OSC       8              'Oscillator is defined as 8 MHz.

DEFINE HSER_RCSTA 90H           'These are predefines for serial
                                'communication, defining the pin states of
DEFINE HSER_TXSTA 20H           'RB2(Rx) and RB5(Tx).
DEFINE HSER_BAUD 9600           'Sets Baud rate to 9600 symbols per second.
DEFINE HSER_BITS 8              'sets each data bit to an 8 bit value.

ANSEL = 0                       'Changes analog bits to digital.
PORTB = %00100000               'All PORTB pins are low except RB5(Tx)
OSCCON = $70                    'Oscillator is manually set to 8 MHz.
TRISB = %00011111               'All PORTB pins 7-5 are outputs,
                                'and 4-0 are inputs.
DEFINE CCP1_REG      PORTB      'Sets CCP1 register to PORTB
DEFINE CCP1_BIT      0          'Sets CCP pin to RB0
PAUSE 500                       'Pauses 500 to initialize program

'-------------Main Code------------
Start:
I = 0                           'Sets I and J = 0
J = 0
ADCIN 3,G                       'Read position of potiometer on RB3
ADCIN 4,H                       'Read position of potiometer on RB4
IF switch1 = 1 THEN I = 1       'Determines I and J value by measuring
                                'switch positon.
IF Switch2 = 1 THEN I = 3
IF Switch3 = 1 THEN J = 1
IF Switch4 = 1 THEN J = 3
HSEROUT ["B0",1,H,0,G,3,I,5,J]  'Serial output, B0 is start bit, 1,0,3,5 are
                                'spacer bits, such that microcontrollers
                                'receive the correct bits. H,G,I,J are data
                                'bits containing sensor positions.

GOTO Start
END
```

Thruster Control Program

```
'------------Variables------------
Switch1     VAR   PORTB.0
Switch2     VAR   PORTB.1
Switch3     VAR   PORTB.3
Switch4     VAR   PORTB.4
G           VAR   BYTE
H           VAR   BYTE
I           VAR   BYTE
J           VAR   BYTE
'----------Initialization---------
DEFINE OSC       8             'Oscillator is defined as 8 MHz.

DEFINE HSER_RCSTA 90H          'These are predefines for serial
                               'communication, defining the pin states of
DEFINE HSER_TXSTA 20H          'RB2(Rx) and RB5(Tx).
DEFINE HSER_BAUD 9600          'Sets Baud rate to 9600 symbols per second.
DEFINE HSER_BITS 8             'sets each data bit to an 8 bit value.

ANSEL = 0                      'Changes analog bits to digital.
PORTB = %00100000              'All PORTB pins are low except RB5(Tx)
OSCCON = $70                   'Oscillator is manually set to 8 MHz.
TRISB = %00011111              'All PORTB pins 7-5 are outputs,
                               'and 4-0 are inputs.
DEFINE CCP1_REG     PORTB      'Sets CCP1 register to PORTB
DEFINE CCP1_BIT     0          'Sets CCP pin to RB0
PAUSE 500                      'Pauses 500 to initialize program

'------------Main Code------------
Start:
I = 0                          'Sets I and J = 0
J = 0
ADCIN 3,G                      'Read position of potiometer on RB3
ADCIN 4,H                      'Read position of potiometer on RB4
IF switch1 = 1 THEN I = 1      'Determines I and J value by measuring
                               'switch positon.

IF Switch2 = 1 THEN I = 3
IF Switch3 = 1 THEN J = 1
IF Switch4 = 1 THEN J = 3
HSEROUT ["B0",1,H,0,G,3,I,5,J] 'Serial output, B0 is start bit, 1,0,3,5 are
                               'spacer bits, such that microcontrollers
                               'receive the correct bits. H,G,I,J are data
                               'bits containing sensor positions.

GOTO Start
END



        END SELECT                 'End Case Select, each Case ends at
                                   'this point.

    GOTO start
END
```