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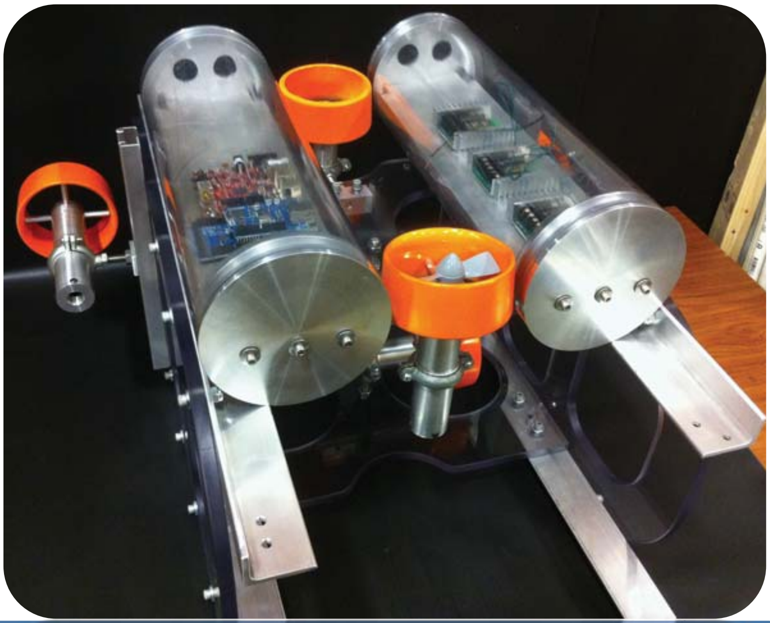

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Contents

Abstract ... 2
Design ... 2
Mission Tasks ... 2
Design Rationale ... 3
CHASSIS ... 3
CONTROLS ... 3
ELECTRONICS CAPSULES ... 4
THRUSTERS ... 5
CAMERAS ... 6
MANIPULATOR ARM ... 7
FUEL EXTRACTION ... 7
FUEL TANK CAPPING ... 8
LIFT BAG SYSTEM ... 8
SENSORS ... 9
Design Safety Features and Precautions ... 9
Budget ... 10
Electrical Schematic ... 11
Software ... 12
Flow Chart ... 12
User Interface ... 13
Trouble Shooting ... 14
Future Improvements ... 15
Reflections on Project Experience ... 16
Khanh Nguyen ... 16
Matthew W. Normandeau ... 17
Raymond Jones ... 17
Mathew Mazzola ... 17
Alexandra Washakowski ... 18
Mike LeVeille ... 18
Thomas Provencher ... 18
References ... 19
Acknowledgements ... 20

Abstract

An *Underwater* Remotely Operate Vehicle was designed, built, and tested by 2012's UNH ROV team. UNH ROV is a competition and research based interdisciplinary senior design project supported and funded by the University of New Hampshire and the NOAA Sea Grant. This year's ROV team has been built an ROV that will serve a dual purpose as a research and competition based vehicle. The vehicle has also been designed to support research in advanced 6 Degree of Freedom ROV Control Systems.

The UNH ROV (Remotely Operated Vehicle) team was tasked with surveying the *SS Gardner* shipwreck site using an underwater ROV. The team was first tasked to measure the length of the submerged PVC ship, determine its orientation, determine if debris piles near the ship were metal or nonmetal, and perform simulated multi-beam sonar scanning at three locations. The second task was to utilize a lift bag system to transport a fallen ship mast, transplant simulated coral from the ship to a designated area, use two simulated sensors to determine if a simulated fuel tank contained residual fuel, penetrate the tank and replace the fuel with saltwater and then patch the holes with caps.

An outreach system, website and sponsorship packet was developed in order to achieve the targeted budget to build the ROV. Design of the ROV was modular in order to incorporate instruments required to carry out the various tasks. An open design allowed for maximum water flow through the chassis and a safer environment for wiring. Six degrees of freedom were provided to the ROV using digital controls and specific thruster positioning. An inertial measurement unit provided data that was used to self-stabilize the ROV. Two capsules housed the electronics and were depth tested to 6.09m. An aluminum plate, spanning the length of the tubes, transferred heat from the electronics outward towards the ambient water. A control arm, camera system, metal sensor device, fuel extraction and capping systems, and simulated sensors were incorporated to help carry out mission tasks.

Design

Mission Tasks

The UNH ROV team was assigned to survey the *SS Gardner* shipwreck site using an underwater ROV. The vehicle would have to help measure the length of the underwater PVC shipwreck, provide data to determine its orientation, use a metal detector to determine if debris piles near the ship were metallic and perform simulated multi-beam sonar scanning at three locations. After performing these tasks the ROV had to utilize a lift bag system to move a ship mast, transplant simulated coral that was attached to the ship, use two simulated sensors to determine if a fuel tank contained fuel, penetrate and extract the fuel while simultaneously re-filling it with saltwater and finally patching the penetrated holes with caps.

Design Rationale

CHASSIS

The order in which the systems of the ROV were designed may be followed in the following paragraphs. The controls and chassis were developed simultaneously so that the controls could be tailored to the specific ROV design.

Maneuverability was a key factor in the design of the underwater ROV, which made the chassis a logical starting point for design. The main chassis, shown in Figure 1, was designed with the idea of it being modular, minimal, and open. Modularity would allow for the adaptation of devises required for mission tasks and any additional parts needed to be added for proper function of the ROV. In order to be modular, the chassis would have to incorporate rigid, easy to machine, and transferable pieces. It was originally conceived that the bulk of the ROV would consist of aluminum, but ultimately the material was chosen to be plate polycarbonate due to its weight reduction and lower cost. The targeted mass of the frame was 27.2kg for lifting safety and maneuverability purposes. A simple and open design was planned to reduce its drag and mass, both of which would decrease the vehicle's maneuverability. By having an open design, fluid flow would be less obstructed, thus reducing the power required by the motors. The open design would also help during wiring and reduce the risk of cross wiring. The size of the frame was based on the dimensions of the electronics capsules and a speculation for the different mission task components.

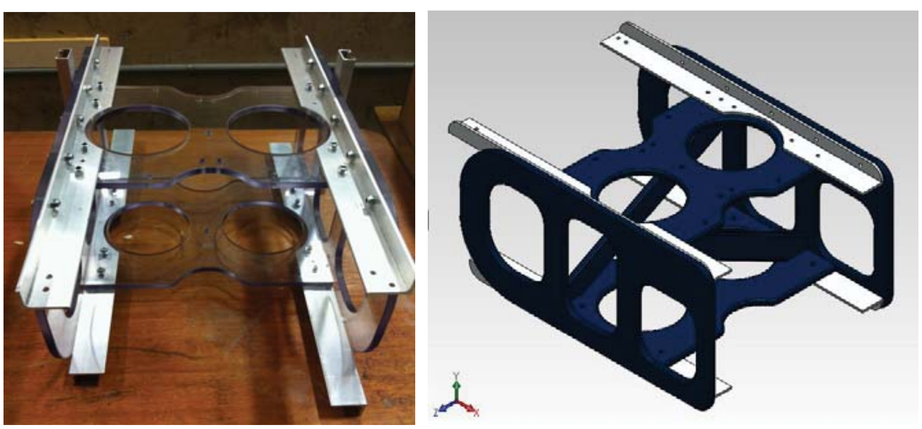

Figure 1: Fabricated chassis frame and SolidWorks frame model

CONTROLS

The ROV's feedback control system is based on a 6 degree of freedom dynamic model. Feedback is provided from the Inertial Measurement Unit (IMU), which includes an accelerometer, gyroscope, and magnetometer. Primary inertial measurements are taken by the IMU's accelerometer and gyroscope, which measure linear acceleration and angular velocity. The magnetic heading measured by the magnetometer is used to correct drift in the gyroscope [4]. Linear displacement is represented by the variables x, y, and z (surge, sway, heave) and angular displacement is represented by the variables φ, θ, and ω (roll, pitch, yaw). The angular displacement values are converted into Euler angles, which are required for kinematic and dynamic calculations.

The ROV's control system is based on trajectory flight path corrections. As the user decides where he or she wants to direct the ROV, the desired trajectory is updated and set for a small period of time. If the ROV were to perform all desired corrections within the time period, the control system will stop and wait for the next trajectory update. If the user updates the trajectory, the control system restarts with the new reference and continues to make corrections. Because this control system self corrects based on deviations from the desired flight path, the system is fundamentally autonomous. This can also be thought of as a drive by wire system because the pilot does not directly control forces and moments used to correct the ROV's inertial position. If all reference variables are set to zero, the ROV will perform self-stabilization maneuvers until the original inertial position is restored. This feature will allow the user to set the ROV to hold its inertial position, while performing required position corrections.

The current controller design is based on 6 Proportional-Integral-Derivative (PID) controllers, one for each Degree of Freedom (DOF). A PID control algorithm is commonly used for a wide variety of systems. All angles in the 6 DOF are converted Euler angles for calculations. Six degree of freedom based on Euler angles and he provides equations for transformation matrices used to perform mathematical operations such as rotations and integration of angular velocities to determine position.

ELECTRONICS CAPSULES

Two electronics capsules were designed to house almost all electronics onboard the ROV. The dimensions of these capsules dictated the main dimensions of the ROV frame and were based on the sizes of the electronic components inside. The selected tubing was a clear 3.175mm thick LEXAN cylinder to allow for easy viewing into the tubes. The aluminum end caps were fitted with bulkhead fittings, which allow for the electrical wires to pass through the sealed wall of the end cap without any water leakage. The end caps were fitted with large, 6.37mm thick, 146mm diameter O-Rings to completely protect against water seepage. The thick O-Ring was used to compensate for any variance in the inner or outer diameter of the LEXAN tubes. The end cap with O-Ring is shown in **Error! Reference source not found.**. Both end caps were connected by a 9.5mm thick aluminum plate that serves as the electronics tray. The plate and ends caps also serve as a heat transfer device, allowing for any heat produced by the electronics to be dissipate to the ambient water outside the tubes.

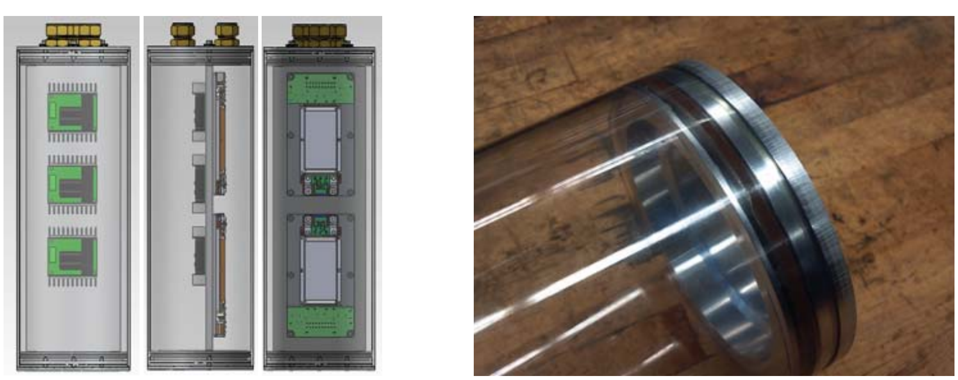

Figure 2: SolidWorks model of the motor control capsule which includes three motor controllers and two Vicor power converters (left). An end cap for the electronics capsule is shown with O-Ring and polycarbonate cylinder (right).

THRUSTERS

The ROV's propulsion system utilizes six thrusters. The thrusters were designed to utilize space effectively which resulted in a small overall package similar in size to a Seabotix thruster. Seabotix designs thrusters that are commonly used to propel ROVs of a comparable size to the UNH ROV. The UNH ROV thruster is shown in Figure 3.

Figure 3: UNH ROV Thruster partially assembled

The motor used in each thruster is a RS550 DC brushed motor with a long back shaft which could be used to attach an encoder later on if desired. The propellers used were originally designed to be placed on a large and slow park flyer remote control airplane. To use them on our thrusters, they had to be cut down to the desired outer diameter and the rotating speed had to be kept below 2000 RPM to reduce cavitation, a phenomenon which robs propellers of thrust. To achieve these speeds, a planetary gearbox with a 4.3:1 gear ratio was bolted to the front of the motors. The thruster housings were waterproofed using O-rings on both ends and the rotating shaft was sealed using a lip seal. The propeller was chosen by testing several different propellers and choosing one based its thrust and reversibility characteristics. The propeller cowlings themselves can increase thrust up to 50 percent if designed properly. The goal in creating the propeller cowlings was to create an airfoil shape; this actually helps create more thrust in the form of lift, similar to the lift from an aircraft wing. The design chosen was that of a MARIN 37 Kort nozzle profile, as shown in Figure 4. This profile was chosen for its good thrust and reversibility properties. The outer diameter for the propeller was chosen such that it would be about one to two millimeters away from the cowling to reduce tip losses while also preventing collisions between the two.

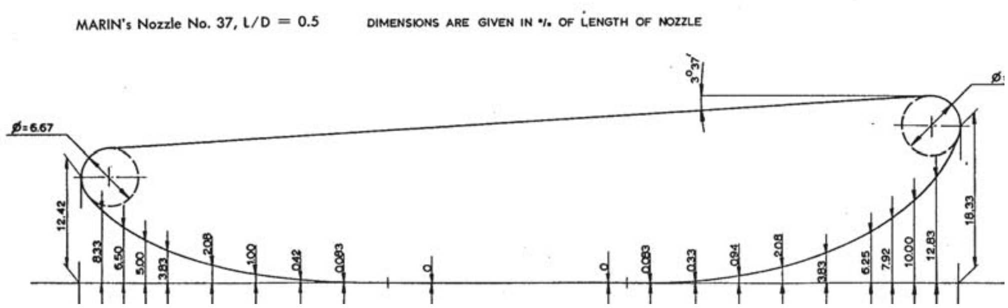

Figure 4: Profile of Kort nozzle used in thruster

Positioning of the thrusters was chosen such that 6 degrees of freedom could be achieved and that the flow stream through each thruster would not be obstructed. Four thrusters were placed in the center of the ROV to provide horizontal, vertical, pitch and roll movements. Positioning of these thrusters were such that the center of mass would lay between the vertical thrusters, but be above the horizontal thrusters. Having the center of mass in this position provides the ability for pitch and roll. The forward and reverse thrusters were place on the side of maximize the vehicle's stability and reduce the need for further pitch adjustment. The final position of the thrusters will be thoroughly tested before and after all the mission task components have been added. Figure 5 shows positioning of the thrusters.

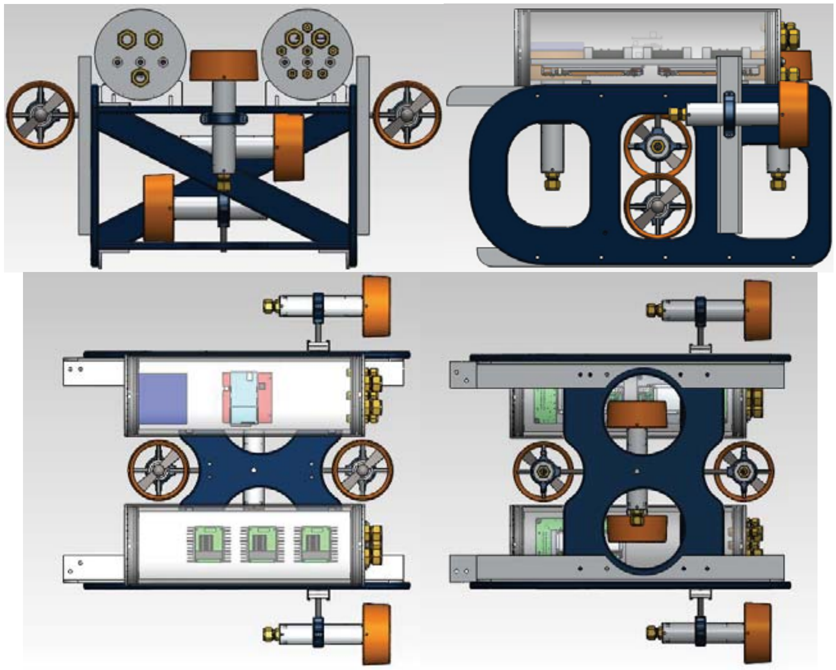

Figure 5: Top Left: Stern view, Top Right: Port view, Bottom Left: Top View, Bottom Right: Bottom View

CAMERAS

A single housing, with 180 degrees of vertical rotation, was designed to hold three cameras, as shown in **Error! Reference source not found.**. This camera housing was positioned at the very front of the ROV. With two forward facing cameras and one backward facing camera, this box allows for a full 360 degree view around the ROV. The housing was made from boxed aluminum with two clear polycarbonate windows for viewing. RTV sealant was used between the lids and the aluminum box for waterproofing. A dampening coupling was put between the servomotor, which is used to rotate the box, and the housing so that sudden rotational movements from the servomotor would be slightly damped. This would create a more pleasing viewing experience without jerking motions for the operator of the ROV.

The camera subsystem experienced many revisions throughout the design and testing process, however each iteration kept the camera components completely independent from the rest of the system. This is because the large bandwidth requirements of three high-definition uncompressed video streams could potentially interfere with other traffic in the data network.

To keep the system simple and reliable, three USB extender cables, one for each camera, travel through the tether to connect the cameras to the operator's computer. This approach also lowers power consumption when compared to another common technique, which plugs the cameras into an on-board computer and in-turn transmits the video data over Ethernet.

In addition to providing a 3D display to the operator, data from the two forward-facing cameras can be analyzed by software to approximate the distance of objects. This data can be important for autonomous operation. In the future, the software may be expanded to estimate the vehicle's position underwater similar to how a GPS provides cars with position information. The IMU alone is not accurate enough to provide position information, and these improvements to the software would allow the vehicle to be full-autonomous.

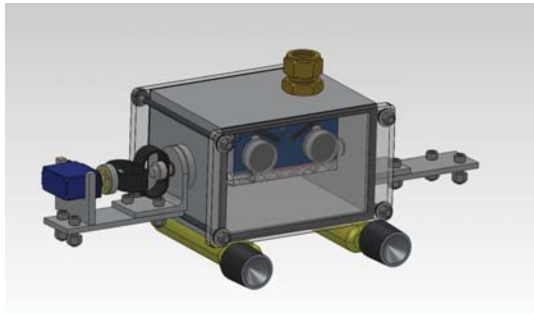

Figure 6: Front view of SolidWorks model of camera housing. Servo motor and damping coupling is shown on the left and two flashlights are connected to the bottom of the camera box. The two cameras facing forward are shown also.

MANIPULATOR ARM

A manipulator arm, shown in Figure 7, was purchased with 2 degrees of freedom. The arm is able to swing vertically and the claw can open and close. These degrees of freedom were chosen to reduce the need for whole vehicle movement during complicated grasping tasks. The control arm was tasked to transplant the PVC end caps with pipe cleaners, which simulate endangered coral on the *SS Gardner* shipwreck.

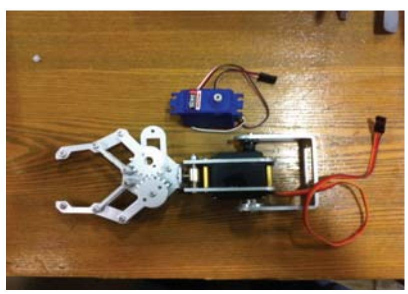

Figure 7: Manipulator arm with servomotor

FUEL EXTRACTION

The fuel extraction system chosen, shown in Figure 8, was easy to make and flexible. It consisted of two cones attached to hollow cylinders. The cones allowed the vehicle to descend onto the fuel tank without needing to do so extremely accurately. Sections of brass tubing were placed in the center of the hollow cylinders so that they could penetrate into the petroleum jelly while the vehicle was descending onto the fuel tank. The ends of the brass tubing were capped and holes were drilled into its sides so the jelly would not enter the tubes as easily while still allowing the fluid to enter or exit. Two 1.5 liter bladders will be stored on the chassis for the storage of salt water and fuel. A small pump was used to push the salt water into the fuel tank and force the fuel into the second bladder. By modifying the size of the tubing connecting the pump to the fuel extraction device, various flow rates could be achieved which allowed for a lot of tuning options so that the salt water would not flow into the fuel tank too quickly. The bladders chosen also had approximately three times the capacity of the fuel tank so that mixing

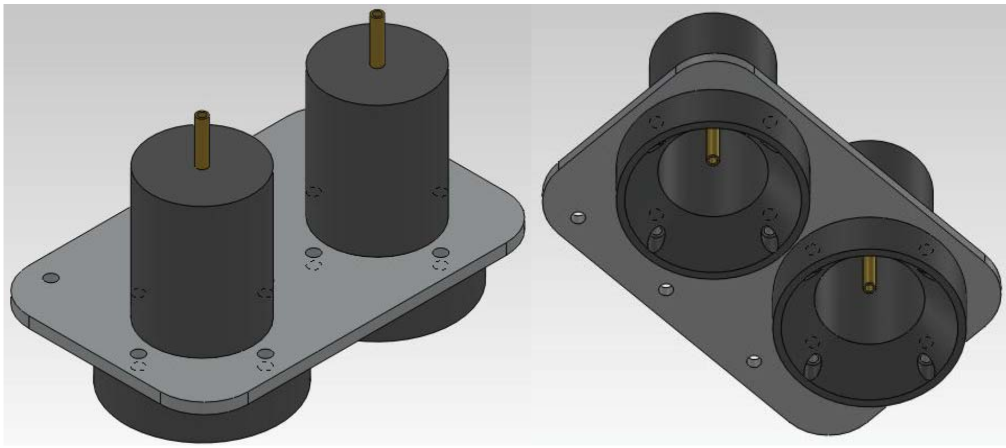

Figure 8: Top view (left) and bottom view (right) of fuel extraction device showing brass tubing used to penetrate petroleum layers. The cones are shown in the bottom view and are inside the hollow cylinders

FUEL TANK CAPPING

A system was designed to simultaneously cap both the inlet and outlet of the fuel tank, as shown in Figure 9. Two PVC pipes acting as guides and a metal bar were used to hold the caps in a fixed position on the end of the PVC pipes. The metal bar was used to keep the fuel caps from falling out of the PVC guides. When the fuel has been completely removed from the tanks, a pins on the front of the device will be pushed in, which will allow for the spring to push the metal bar away from the PVC guides. With the metal bar out of the way, the fuel caps will be released and able to attach to the end of the fuel tank inlet and outlet. The fuel caps will attach to the VELCRO on top of the fuel tank inlet and outlet, essentially sealing the fuel tank.

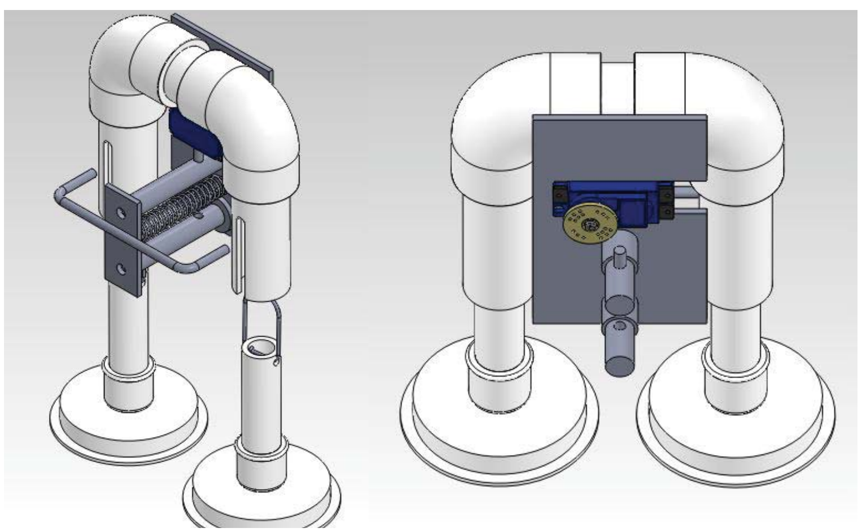

Figure 9: Front (left) and back (right) views of capping system, showing servo and pin system as well as spring to release sealing caps

LIFT BAG SYSTEM

The lift bag will be attached to the bow using a carabineer and pin release mechanism, as shown in Figure 10. The lift bag will be rigidly attached to the mechanism so that it is able to inflate vertically. The carabineer will be pushed against the U-bolt on the mast, which would lock the U-bolt to the carabineer. With the connection made, the ROV is able to maneuver the mast into its designated area. The carabineer will become detached from the ROV by using a servo to pull a pin. This mechanism was determined to be the safest way for the lift bag to detach from the ROV. This system allows the ROV to maneuver the mast without having to utilize the small control arm and allows for a way to easily detach the lift bag from the ROV. The servo motors on the control arm would not have been able to endure the stress of lifting the heavy mast without the risk of stripping their fragile gears.

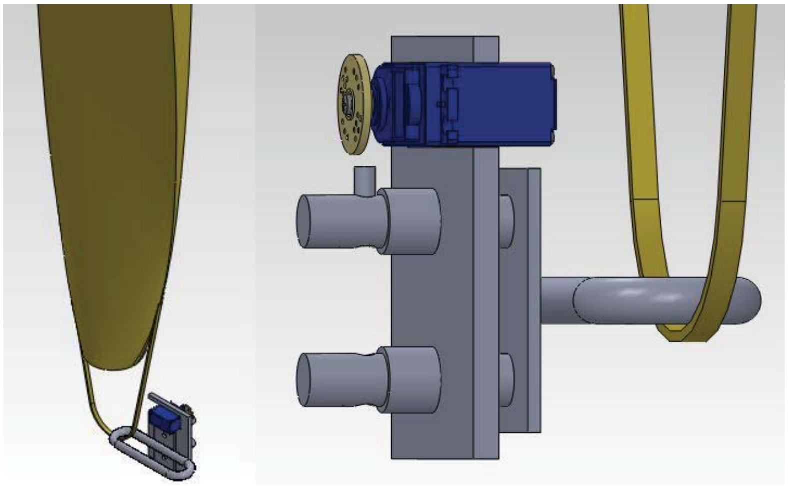

Figure 10: Lift bag system (left) and connection to ROV (right)

SENSORS

The simulated fuel tank sensors were designed using a 12.7mm diameter plastic, spring loaded, toilet paper roller and a 12.7mm x 31.75mm PVC slip bushing, as shown in **Error! Reference source not found.**. Attaching the toilet paper roll to the bushing allowed for an extended sensor when no force was applied. The spring allowed for the sensor to be in constant contact with the fuel tank in the event that the ROV became slightly perturbed during the testing procedure. The design of the metal detector was kept simple in order to increase reliability. Therefore, a strong magnet was hung from the simulated sensor such that it would be able to freely travel to a close by metal surface, alerting the camera operator that the debris being examined was metal. Orientation was simply determined using an analog compass. The compass was placed in front of the camera housing. This design was selected based on its simplicity and the projects time frame.

Design Safety Features and Precautions

- The entire frame is modular and may be disassembled bolt by bolt.
- Take care when lifting the entire assembled ROV due to a total mass of 36.3kg. Lifting handles provided.
- The tether may be completely disconnected from the ROV via the junction at the end of the tether line.
- Each thruster prop is covered by a bright orange cowling and can be detached by unscrewing the set screws.
- Quick disconnects for each thruster are behind their NPT fittings.
- Vertical height of the forward and reverse thrusters may be changed via the guide rails.
- Desiccant tubes are available in each capsule to collect moisture and can be oven baked to drive off the collected moisture.

- Each power converter and motor controller self regulates their power output in order to prevent electronics damage.

Budget

Item or System	Expense [USD]
Propulsion System (motors, speed controllers, waterproofing, propellers, gear drives, aluminum)	$1,356.76
Chassis (polycarbonate plates, aluminum stock, polycarbonate tubes, aluminum plates)	$1,152.80
Electronics and Controls (Beagle Board, Arduinos, IMU, Cameras)	$960.16
Tether Materials (Braided Sleeving, Wires, Cables)	$323.65
Mission Task Mock Up Course Materials (PVC, Hardware, etc)	$150.00
Travel (Flights, Hotel, Rental Car, Shipping ROV) ESTIMATED	$7,000.00
Miscellaneous (Fundraising Supplies, Team Shirts, Presentation Poster)	$300.00
Total Expenses as of 3/20/12	**$11,243.37**

Donations	Amount
OE Dept	2,000.00
CEPS Dean	2,000.00
Proffessor Thein	500.00
PNS	500.00
Vicor (Power Converters)	1,500.00
Burndy	7,950.00
Parent's Association	2,000.00
ME Department	900.00
Todd Gross	200.00
BAE	1,500.00
Jay S. Smith	500.00
NCMA	500.00
IFPTE	500.00
CACI	500.00
Total	**19,050.00**

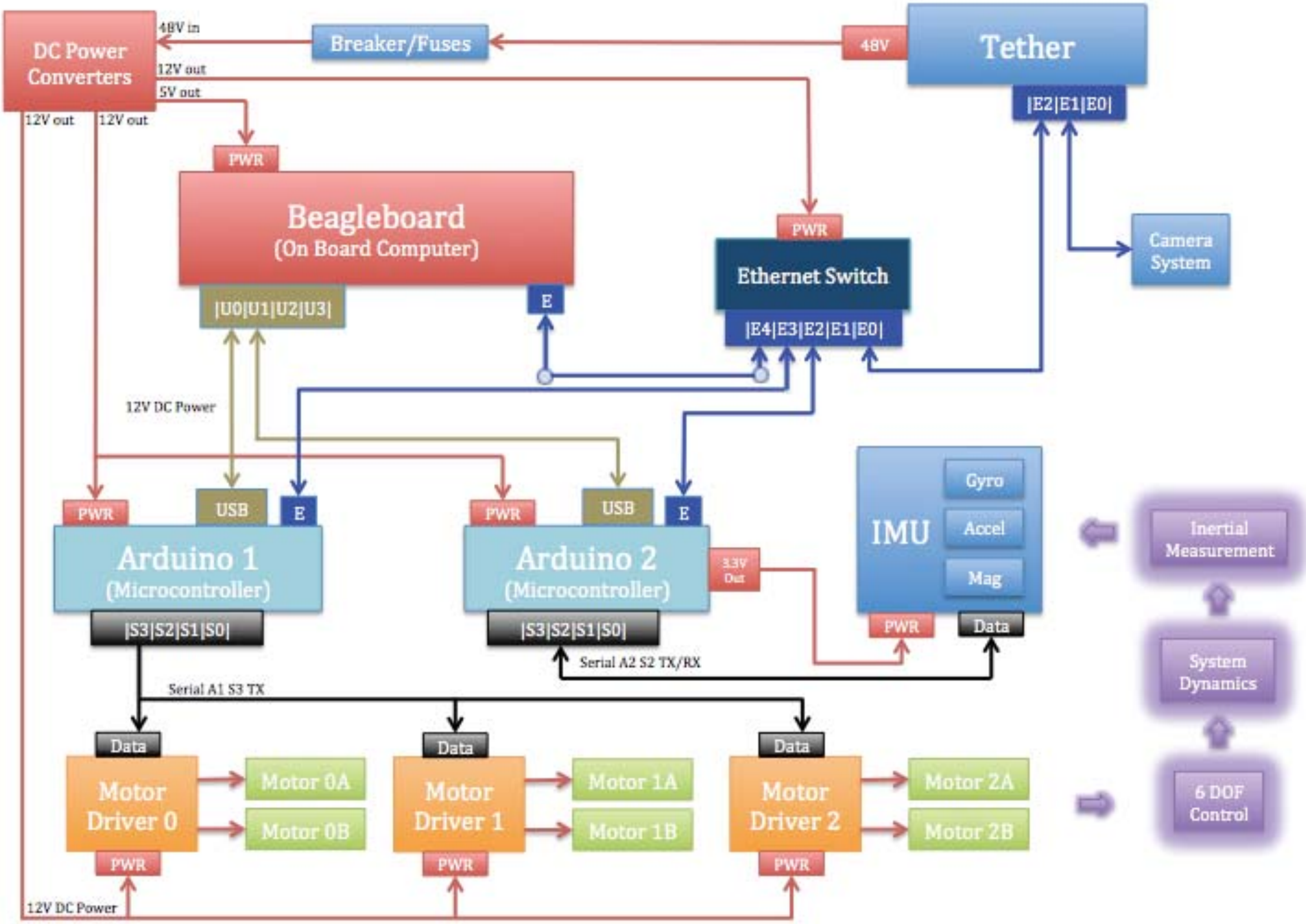

Figure 11 Electrical schematic showing connections between electronics.

The ROV's electronics system consists of two Arduino Mega Microcontrollers, 1 Beagleboard single board computer, 3 motor drivers, 6 thrusters, an Ethernet switch, and an Inertial Measurement Unit, which includes a Gyroscope, Accelerometer, and Magnetometer. Primary communications between Arduinos 1 & 2, the Beagleboard, and the computers at the surface is through the Ethernet network. The Arduinos can also communicate with the Beagleboard via USB connection. The Gyroscope, Accelerometer, and Magnetometer are integrated on the same circuit board along with a Microcontroller. Data from the sensors is read by the Microcontroller and then transmitted via serial connection to the Microcontroller at the other end. The motor drivers on the ROV use 4-byte packetized commands over a serial connection for setting motor speeds. Each motor controller has its own unique address, which allows the motors to be controlled by a single serial line.

Flow Chart

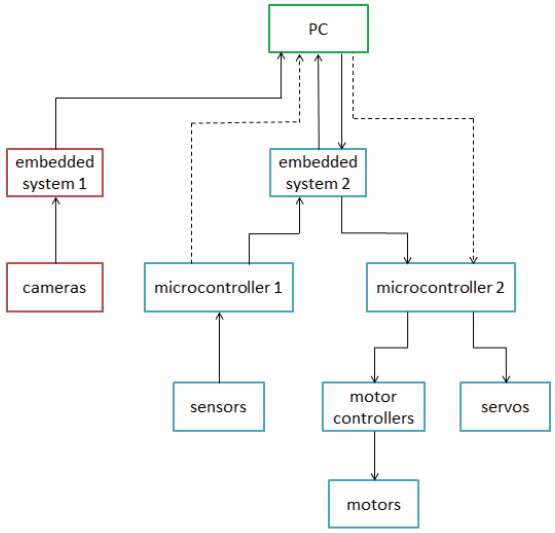

Figure 12 Software flowchart where solid arrows indicate primary data paths, while dashed arrows represent backup connections.

Due to the complexity of both the hardware and software on our ROV, we've included a chart displaying the flow of data between the many components (shown above) in addition to our wiring diagram. There exists two fully digital subsystems onboard our ROV: the camera subsystem, and the controls subsystem. We chose to separate the two because we didn't want the large bandwidth requirements associated with streaming uncompressed digital HD video to interfere with the controls.

In the camera subsystem, software we've written ourselves and installed on ES1 (embedded system 1) reads video data from USB webcams. The data is formatted and then sent to the operator using one of three Ethernet cables in our tether. Because of the large amount of video data (just under 125 MB/s), the only device we could find to fulfill the role of ES1 (and physically fit in our vehicle) was the Pogo-plug Series 4.

In our controls subsystem, microcontroller 1 gathers sensor data (IMU, temperature, etc.), and forwards it to ES2. The operator's desired thruster speeds are also sent to ES2 using another Ethernet cable in our tether. ES2 processes the operator's commands and IMU data to provide a complete drive-by-wire system with automatic stabilization. Additionally, ES2 periodically forwards sensor data to the operator over Ethernet. In the event our drive-by-wire system fails, we've provided backup data connections to provide full manual control. Again, all software running on the microcontrollers and ES2 was designed and written by our team. The microcontroller chosen for our design was the Arduino, because of its low power consumption and numerous I/O ports. The device that fulfilled the role of ES2 was a Beagleboard because of its small size and relatively high processing power.

Our electronics system is intended to be a reusable platform. Throughout our design, we chose to use standard, digital interfaces (USB, Ethernet) and simple, common software protocols (TCP, UDP, SCTP, etc.) to ensure our vehicle is flexible and extendable. It's a simple task to add additional sensors and software, and the platform can remain unchanged even if the chassis or propulsion systems are completely redesigned.

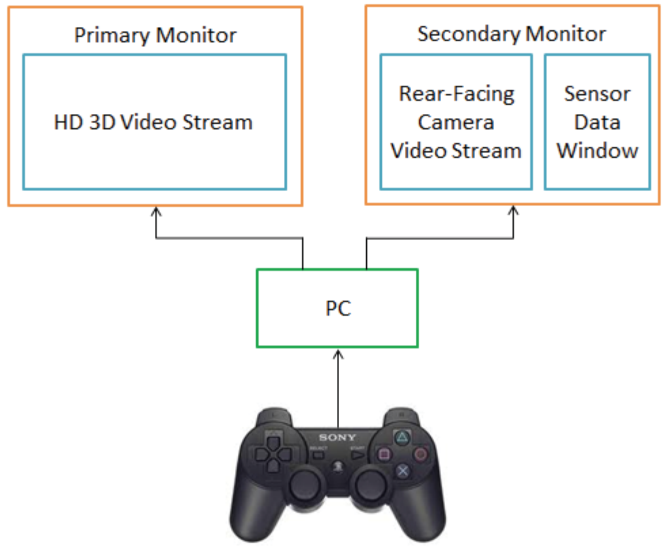

Figure 13 Digital user interface utulizing a PS3 controller and 3-D vision.

Our user interface consists of three main elements: two video display windows, a sensor display window, and a control interface. The primary monitor displays a video feed from the front of the vehicle. If the display is 3D capable, then the operator will be shown stereoscopic (3-dimensional) video from the ROV's viewpoint. This can help the operator judge the distance of objects which should be particularly useful when manipulating objects. A window on the secondary monitor will provide a 2D video feed which is used primarily for driving the ROV in reverse. Either video feed will display a warning if an impending collision is detected.

The sensor display window shows readouts from IMU, temperature, and any other sensors onboard the vehicle. Status indicators, representing the normal/abnormal operation of all onboard electronics are displayed in the same window. Various settings can also be changed using this window such as: enable/disable 3D, enable/disable drive-by-wire system, start/stop recording video, etc.

The control interface is not limited to a single device. A PlayStation 3 controller, keyboard and mouse are all available as control devices. Additional input devices, such as USB joysticks, can also be used, usually without requiring any software modifications.

The tether contained three Ethernet lines; two fully committed lines and one for back up and debugging. All of the written software contained debugging code so that errors, during the compiling process, could be traced back to their roots. The PID control was tested and debugged using a teeter-totter assembly. A motor was submersed in the water and had a rigid arm connecting it to the assembly. The motor was to provide enough force so that the rotating member in the center was perfectly horizontal. The motor also had to provide enough thrust in order to correct for any disturbances introduced at the other end of the member. Figure (13) shows the assembly. The IMU was set at the center of rotation in order to measure angular velocity and displacement. Feedback data from the IMU was used for the control system.

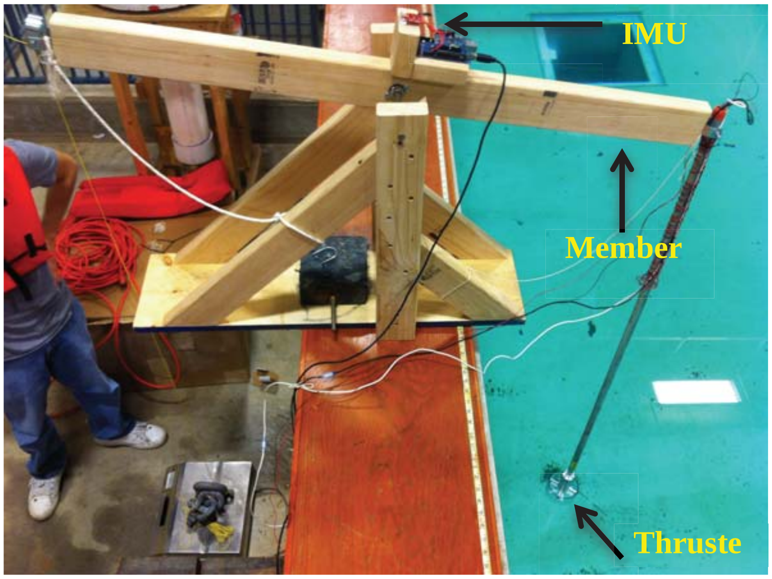

Figure 14 Teeter totter assembly to measure thrust and debug/develope PID control system. The IMU was located in the center of rotation.

Major future plans for the ROV include an increase in chassis size, use of lighter materials, higher output thrusters, a compact electronics capsule, a more maneuverable control arm, and more cameras and lights. A more rigorously testing of the control system could lead to greater insight and improvement of the ROV. The manner in which the ROV carried out its mission objectives were not as desirable based on the initial planning and designing of the vehicle. These suggested improvements would help to accomplish a much more desirable design and task execution.

The chassis design was able to incorporate all mission tasks, but space was very limited. While the chassis was originally being designed, room was left for manipulator arms and other devices. However, after the missions were revealed, it quickly became apparent that there was not quite enough room on the chassis. The fuel tank systems had to be placed in the bow so the cameras could see them, but their large size took up a lot of room and further increased the forward drag on the vehicle. A larger chassis with better space utilization would be more suited to handling unpredictable system integrations for the next generation ROV.

Use of lighter materials would help to improve maneuverability and reduce power consumption. A lighter ROV would require much less power from the thruster to move through the water. The rate of body roll and control would be carried out much faster due to a lower inertial mass. Lighter materials may help in these aspects, but an economical balance and production feasibility should also be taken into consideration when selecting building materials.

There is always room for further development of the control system. Because the system is software based, it can be easily modified. Software on the Arduino microprocessors can be reprogrammed, which is challenging because all electronics are sealed and cannot be easily removed. The ROV's on-board computer is Linux based and can therefore be used for many other applications. One improvement that should be made is the addition of direct feedback from the motors via an encoder. The current system relies on experimental data that correlates thrust to motor input voltage.

A more compact electronics capsule would help to consolidate wiring as well as reduce the overall footprint of the electronics. The current generation ROV has two large electronics capsules that were originally planned for housing many components. Although the large capsules provided excellent buoyancy, they did not use space efficiently. Future electronics housings could be improved by consolidating all of the devices into a single housing. The tube shape does not utilize vertical space efficiently due to the shapes of many electronic components. Perhaps a more rectangular housing could replace the current design.

The second generation ROV could implement a more rugged manipulator arm with greater degrees of freedom. An increase in material strength would help the arm be able to handle heavier objects and more degrees of freedom would allow it to perform more complex procedures while handling delicate and/or intricate objects. Having more cameras and lights would improve vision for maneuverability purposes as well as compliment the arm during mission tasks. The camera system used in the current ROV was adequate for performing all mission tasks, but more visuals could help to reduce mission time and provide greater spatial

The team faced and overcame many challenges in completing the vehicle, but the most difficult one to tackle was finance. The project started with no financial budget and no background or experience in professional fund raising. Motivation was the main component in mending the problem, but a strategic system was developed for finding potential sponsors. Continuous outreach and networking with recent and/or current employers and contacts made companies aware of the UNH ROV team. A sponsorship packet and website were then developed to physically and digitally market the team. The sponsorship packet and website emphasized the commitment of the team by showing the work and preparation completed prior to starting the project. Each member took part in providing any potential sponsor with a sponsorship packet. The team also made visits to companies. The team overcame all financial problems by systematically and continuously networking.

Design and execution of the ROV was technically challenging due to the ROVs operating environment. Team members had little experience in engineering and designing submersible components. Many of the technical challenges were overcome by researching underwater building materials and components. The team was also able to seek out advice from several ocean engineering professionals and machining experts. Safe practices for designing and machining submersible components were learned through such people. Communication became a key factor in finding appropriate solutions to our technical challenges and provided a valuable opportunity to communications with professionals.

There have been many opportunities throughout the academic years to practice teamwork, but none of these could have provided some of the experiences that this project has given. Team members constantly had to balance their weekly schedules simply because of how busy senior year schedules tend to be. Most arguments about design, finance and assigned workloads were resolved democratically. The team learned to not take these arguments personally and resolve issues outside of the work environment.

Khanh Nguyen

This project was challenging from the beginning and I am very proud of the overall work that the team has done. The ability to contact professionals and companies to sponsor the team and provide advice stands out as a personal and professional accomplishment. I believe that communication is a key attribute to the success of any engineering project and that this project has vastly improved my communication skills as an engineer. Another important skill gained from this project was the ability to practice engineering outside of academia. The MATE project was not course structured and the ROV design was nearly free to the interpretation of the team. This allowed for a practical way to apply engineering knowledge. It also allowed for practical engineering reports. Overall, the project provided personal and professional accomplishments in the areas of engineering communications and practice.

Matthew W. Normandeau

I have always been drawn to the technical challenges associated with the design and development of marine vehicles. I am most interested in the design of 6 degrees of freedom ROV control systems that are capable of implementing modern controls theory. From the beginning my “big picture” has been developing a platform for the research and development of advanced ROV control systems. The platform is based on a modular integration of the ROV’s Electrical, Mechanical, and Software systems. Without the collaborated effort of an interdisciplinary team (Mechanical Engineering and Computer Science), we would not have been able to produce a control system of this caliber. Without an ROV to control, designing this control system would be no more than an academic exercise. Teamwork and effective leadership is what built the ROV.

Raymond Jones

Participating in this project provided me with valuable knowledge and skills that simply would not be provided to me through my coursework. Working on a project with such little supervision really helped build my confidence as a leader. The greatest skill gained from this project however would by far have to be time management. This project taught me that things rarely go according to plan, whether it be key parts being delayed, or unforeseen problems arising and good time management helps to buffer these unanticipated issues.

Mathew Mazzola

By participating in the ROV challenge, it taught how important working with a team is. The ROV has so many intricate subsystems that could only be completed by splitting up the sub systems to different individuals of the groups. But by splitting up each individual subsystem to different individuals, everyone had to constantly be communicating with each other so that if changes to their subsystem had to made, corresponding subsystems could be changed accordingly. Another aspect of the ROV challenge was that the project had to be entirely structured by our team. Our team had to set our own deadlines for each aspect of the ROV so that the complete ROV will be ready in time for competition.

Alexandra Washakowski

Working on this interdisciplinary team of students has taught me a lot about working as a team and delegation of tasks. The ROV we designed is comprised of many intricate and complex parts, each requiring a specialized sub group for the design. The communication, cooperation, and integration of these groups were very important to produce a working ROV. I also gained a lot as the treasurer for the project. Working with sponsors and companies and organizing the income and expenses of the group was a very challenging yet rewarding. The team was able to purchase necessary materials to create the best ROV we could without worrying about depleting the budget. We also raised enough money to travel to National Competition, which UNH ROV teams have not been able to do in the past due to budget constraints.

Mike LeVeille

Coming from a Computer Science background, I looked forward to applying my programming and software systems skills to a robotics project. In no other projects I've worked on, have I needed to pay so much attention to bandwidth requirements, or integrate so many unique devices into a single system. I've also greatly expanded my knowledge of control systems, optics, and what the heck an O-ring is. Working with a team of engineers on a full-scale robotics project has only bolstered my interest in the subject. I encourage Computer Science majors to participate in ROV design and in MATE's ROV competition in the future.

Thomas Provencher

I was originally going to work on a different robotics senior design project until Khanh asked me to join the ROV team. I am extremely glad I decided to work on this project as I have never needed to make sure that what I was designing and building was not only functional, but also waterproof. Waterproofing everything was certainly the most difficult aspect of the design for this vehicle as the dimensions required by the available seals and raw materials greatly limited the space for electronics and increased the weight. The machining required to meet the strict tolerances of the seals also provided further challenges and increased production time which made time management even more important. I am extremely proud of all of the work the team has done and am confident that all of the lessons learned while working on this project will be applicable for years to come.

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