Technical Report

2009 MATE International ROV Competition

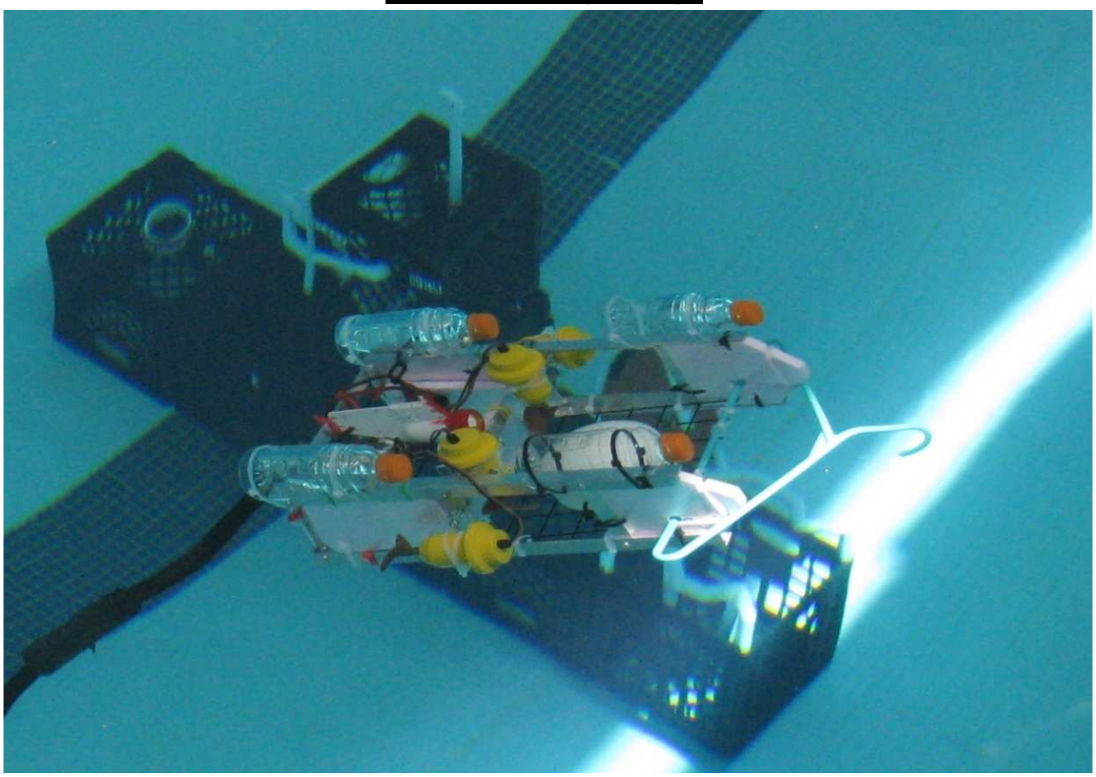
ROVs: The Next Generation of Submarine Rescue Vehicles

Purdue University IEEE ROV Team

West Lafayette, Indiana, USA

Explorer Class

ROV *Osprey*



Position	Team Member	Major
Team Captain	Seth Baklor	Industrial Engineering
Electronics	Dustin Mitchell	Computer Engineering
Thrusters/Research	Clement Lan	Computer Engineering
Cameras/Research	Kuan-Po Chen	Electrical Engineering
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Instructors/Mentors: None

Abstract

ROV *Osprey*, the first creation of the new Purdue University IEEE (Institute of Electrical and Electronics Engineers) ROV Team, has been built to accomplish and exceed the 2009 MATE International ROV Competition mission requirements. The vehicle was designed with a focus on overall reliability, design simplicity, and speed/agility. All of these goals were to be accomplished within a predetermined final vehicle cost of approximately $2,000 (not including the cost of research/testing or the cost of going to the competition).

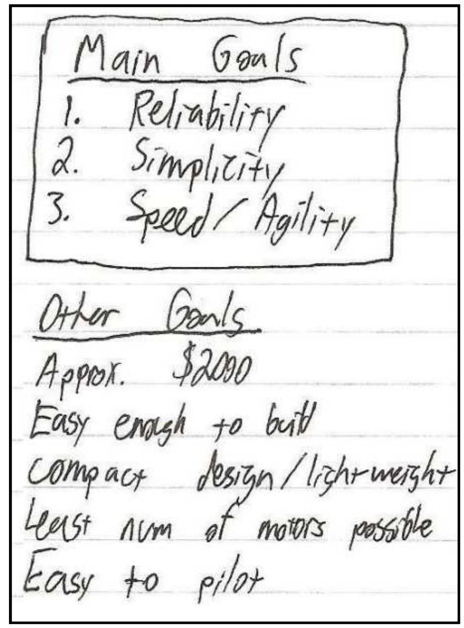

Figure 1 - Original goal setting

The vehicle is designed to aid crippled submarines by surveying them for damage, delivering Emergency Life Support System (ELSS) pods, delivering fresh air, and rescuing crew in the extreme condition that it becomes necessary. Designing submarine rescue vehicles is a crucial and exciting part of the ROV world the team is proud to have experienced.

This report will present the creation and evolution of ROV *Osprey* and the Purdue team as a whole. Having just been formed, the team has overcome a lack of knowledge, experience, available tools, and support to become better engineers.

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1. Design Rationale

1.1 Structural Frame

The team knew from the beginning that the frame on ROV *Osprey* had to be extremely innovative. The tools necessary to construct the vehicle using conventional high-grade materials were not available. The construction process could only require simple, inexpensive tools such as a corded drill and a rotary tool. The team also needed materials that could help it achieve the main goals of reliability, simplicity, and speed. This led the team to three potential solutions: all foam construction (using home insulation foam supported by carbon fiber rods), traditional Polyvinyl chloride (PVC) construction or a daring frame design made of oxidized aluminum bars. After testing and comparing the durability, weight, strength, and ease of construction of the three materials the choice was to use the aluminum. The design called for 1.9 cm wide, 0.32 cm thick flat and 'L' shaped bars to be bolted together. The use of these thin bars created an extremely strong vehicle that could be made with a household power drill. The hydrodynamic drag created by these bars is extremely low, allowing the vehicle to move swiftly through the water.

Some major decisions were made early on about the shape of the frame. It was decided that, to achieve our goal of speed and agility, the vehicle's height would be kept at a minimum. The electronics box would be placed in the back of the vehicle to provide easy tether access and leave room for mission tools up front. The mating skirt (a simple PVC end cap) would be as close to the center of the vehicle as possible to make remaining stationary while mated much easier. The thrusters would be placed far outside to allow greater yaw and roll control. The manipulator would be placed front and center as it is the easiest location for the pilot. After those decisions were made, the shape formed itself. The vehicle stands just 18 cm tall without its buoyancy system and is just 22 cm tall with the system.

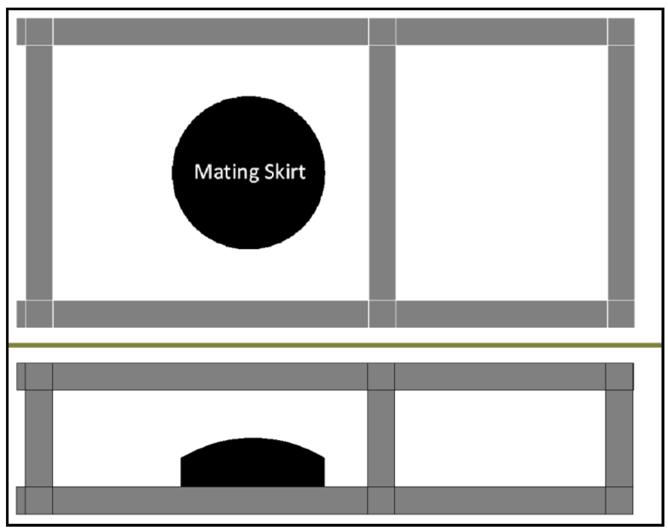

Figure 2 - Top view (top) and side view (bottom) of frame shape

To make maintenance and repair easier, the team decided on a standard bolt size. Everything on ROV *Osprey*, except the Pitch Control System drive shaft due to strength concerns, is size 8-32. Because nothing is glued to the vehicle, just attached using these bolts or cable ties, anything can be removed and repaired if needed.

1.2 Manipulator

It was challenging to find a system to power the manipulator that fit within our original goals of reliability and simplicity. After researching the technical reports of explorer and ranger teams from the 2008 and 2007 MATE competitions, only two common sources of power were found. Pneumatic power was ruled out quickly as being too heavy in the tether and too complicated. The other common method was gearing motors (often converted bilge pumps) to have enough torque to open and close a manipulator. This also seemed too heavy and complicated. Both of these ideas were discarded. Research of potential sources of power led to possibly using electromagnets. There would be a spring to hold the gripper closed at all times (basically a spring clamp). Whenever the gripper was to be held open, an electromagnet mounted inside the handle would simply be turned on and attract a piece of steel on the other side of the handle. This system does not depend on any moving parts to function besides the grippers themselves. The lifespan of the magnet when used underwater was the only issue in question.

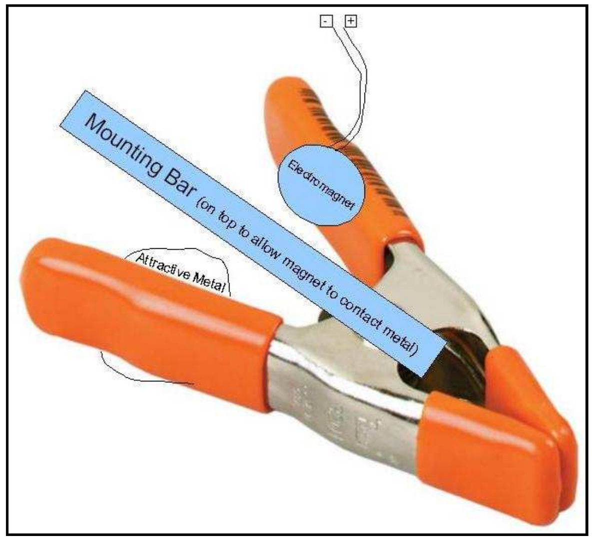

Figure 3 - Electromagnet powered manipulator concept

Because this system required many of the other systems to be built first, it was not tested until very late (two weeks before the planned vehicle construction deadline) and found not to work. There are no available electromagnets that can work at the distances required. To make a temporary working manipulator, the team has decided to use a pre-existing gripper. In the past, a few MATE teams modified handheld trash collectors. Researching similar systems brought the team to something called the 'PikStik.' The grippers open wide enough to open the hatch for delivering the ELSS pods, are strong enough to hold the ELSS pods in transit, and have the precision to hold the insertion point. The team will cut it in half and not use the handle side. This manipulator has a wire inside that, when pulled, closes the grippers. A system is yet to be built to pull on this wire, but it will be powered by a modified 63.1 LPM (Liter Per Minute) bilge pump motor.

Figure 4 – 'PikStik' trash collector (Courtesy of Amazon.com)

1.3 Propulsion

ROV *Osprey*'s propulsion system focused on three of the team's original goals in a specific order: reliability, simplicity, and speed. The team originally thought of creating custom brush-less thrusters based on remote controlled car motors that would be encased in an air tight chamber. There would then be a drive shaft with a magnetic coupler allowing connection to a separate drive shaft and propeller outside the air tight chamber without much friction. This was determined to be too far from the original goal of simplicity and potentially a reliability risk. The team then decided to interview an experienced custom remote controlled aircraft designer and builder to come up with more ideas. He suggested that the team try using a remote controlled car brushed motor directly attached to a propeller without any waterproofing and just purposely flood it. This design required no waterproofing (leaving no concern of accidental flooding), was incredibly streamlined because there was no outer casing, used slightly less power than expected, required no special electronics to run, and produced an unexpected 20 N of pushing force in testing. It fit all three original goals, but was soon deemed unsafe.

Figure 5 - Brushed motor that works underwater (Courtesy of TowerHobbies.com)

The decision was then made to use a propulsion system that was known to be reliable, simple, and within our budget; bilge pumps. The team was concerned for the potential lack of speed and opted to test bilge pump sizes that are larger than that of conventional, store-bought pumps. The pumps were stripped of their outer casing to make them more streamlined and provide access to the drive shaft. These pumps were then outfitted with brass propeller shafts from Octura Models and given remote control boat propellers of similar pitch and shape. Testing with 233.4 LPM (Liters Per Minute), 126.2 LPM, and 63.1 LPM led to a surprising conclusion. The immense weight of the 233.4 LPM and 126.2 LPM made the vehicle slower than the 63.1 LPM bilge pump. The 63.1 LPM pump was very similar in weight and size to the next smaller pump, 47.3 LPM, and was therefore deemed the best balance of power and size.

Figure 6 - Process of converting bilge pumps to thrusters (Courtesy of Edgewater High School 2008 Technical Report)

The number of motors was determined by the requirements of the mission. ROV *Osprey* required two motors for control in the x-y plane. It was deemed necessary to also have two vertical motors to allow full maneuverability while the Pitch Control System is in use (and the vehicle is pointed straight down). Much debate took place as whether or not to include a sway (or side strafe) motor. It was known that the vehicle would use a side watch camera for the

1.3 Propulsion (cont…)

survey which would utilize the two main x-y plane motors, so the sway motor would only be used for small corrections while doing the rest of the mission. This benefit was not deemed greater than the drawbacks of added weight, added drag, and added overall height (as the only location available was above the vehicle).

The type of propellers to use was chosen based on previous research done by one of the team members. As part of a 2008 MATE ranger class team, this team member went through a testing process using the same exact model of bilge pumps. This testing included different materials (plastic and beryllium), different number of blades (two, three, and four), different size blades, and different pitches. Each propeller was attached to a motor then the motor was run and force was measured using a spring scale. While there was a definitive answer as to the pitch, size, and number of blades the two materials had equal performance. The plastic propellers were therefore chosen as they are safer and lighter than the beryllium propellers.

1.4 Cameras

The original design for ROV *Osprey* had two cameras: a main camera facing forward and another side watch camera. The main camera would provide a direct, first person image for the pilot to see ROV *Osprey*'s front view. The purpose of this view would be for most movement and viewing the manipulator when in use. The side watch camera would provide another view, perpendicular to the direction of forward movement, for the pilot during the survey mission. The pilot could then survey a submarine for damage without incorporating a sway (or side strafe) motor or turning ROV *Osprey* each time the pilot wanted to face the submarine for closer inspection. These cameras would be fixed on the vehicle (not able to pivot or pitch independently of the ROV's movement) in order to hold with the team's goals of reliability and simplicity. Non-fixed cameras also add another element of things to manage and are not human-factors friendly.

IP (Internet Protocol) cameras were originally chosen over analog cameras for two reasons: IP cameras are often lighter weight than analog cameras and can have multiple cameras that share the same Ethernet cable back to the surface while each analog camera requires its own cable. Having such a crowded, heavy tether would negatively impact one of the key focuses of ROV *Osprey*: speed/agility. However, during the research process, the team found that the price of IP cameras was far beyond their expectation and that there were no available waterproof IP cameras. The team could not afford to risk using such expensive cameras with a custom waterproof enclosure, so the team decided to try using USB webcams. USB webcams are usually light weight and cost much less than IP or analog cameras. The most suitable camera that the team found was Logitech's Quickcam Messenger webcam. It weighs 1.9 gram and costs just $6.99. While an old model, the webcam meets all quality and size goals the team looked for.

1.4 Cameras (cont…)

To waterproof the Logitech Quickcam Messenger, the team sealed the webcam in a custom waterproof enclosure. First, because the focus of the camera is fixed, five minute epoxy was used to keep the camera from going out of focus during the waterproofing process. The enclosure was made from PVC fitting with a 1.9 cm inner radius expanding to a 2.5 cm inner radius attached by epoxy to a 4 cm radius, 32 cm thick disk of acrylic (rated at 250 times the strength of glass). The webcam's lens was then secured using silicon inside the enclosure up against the acrylic disk. This kept the lens from being damaged by the next step which actually made the enclosure waterproof. The entire enclosure was then filled with epoxy. While this method meant not being able to fix the camera if anything went wrong, it was only a loss of a $6.99 webcam and the team is more confident in the reliability and simplicity of this than if an airtight chamber was attempted.

Figure 7 - Logitech Quickcam Messenger (Courtesy of Amazon.com)

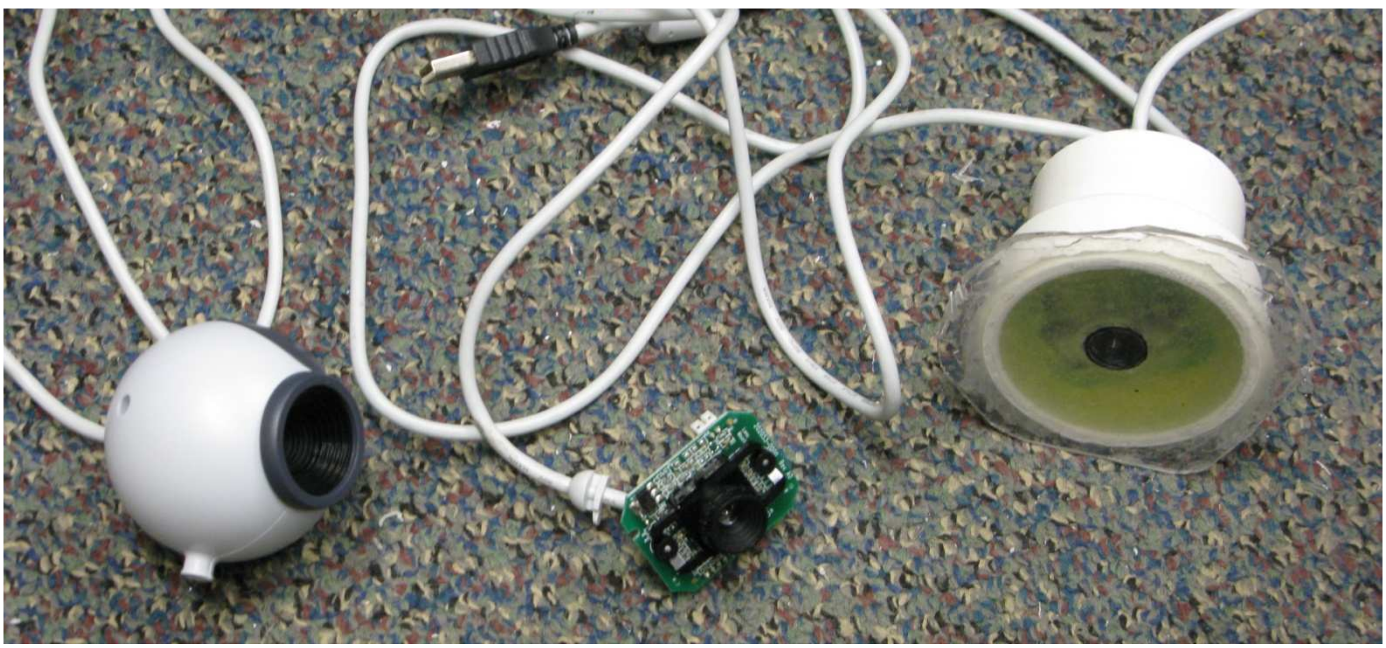

Figure 8 - The stages of waterproofing a webcam; from factory (left), to stripped (Middle), to sealed in epoxy (right)

1.5 Buoyancy

The buoyancy system was originally before the Pitch Control System was considered. Using two 591 mL Gatorade bottles placed on top of the frame on each side of ROV *Osprey*, it would neutralize buoyancy. The buoyancy system would be easily adjusted by adding or removing the amount of water in each bottle. The strength of these bottles was tested and proved sufficient at depths beyond our needs (4.3 meters). However, after several trials of underwater testing with ROV *Osprey*, the team found a serious issue with the vehicle's roll and pitch stability. While practicing the mission, the vehicle often had an unintentional 35 to 45 degree downward pitch, which made using the manipulator difficult. Moving the bottles farther back temporarily fixed this issue slightly, but not completely.

Figure 9 - ROV *Osprey* with two Gatorade bottles

To entirely resolve the issue, the team redesigned the buoyancy system by having four 335 mL Gatorade bottles on each upper, corner of ROV *Osprey*. The new buoyancy system aimed for two major criteria: stabilize its horizontal motion and create a strong righting force in a situation where the pilot become disoriented and would need the vehicle to level itself out. The purpose of having the four Gatorade bottles on top of the vehicle was to create a high center of buoyancy, which created a strong righting force that kept the vehicle stable.

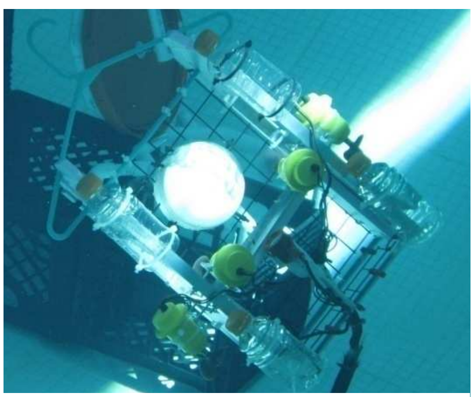

Figure 10 - ROV *Osprey* with four smaller Gatorade bottles

The vehicle is yet to be tested with a new electronics system enclosure in the rear of the vehicle that is positively buoyant and the new Pitch Control System that will be part of ROV *Osprey* in time for the competition. The new enclosure may be buoyant enough to eliminate the need for the rear Gatorade bottles. While this streamlines the ROV further, it also lowers the center of buoyancy reducing stability. If this is found to be a serious issue in testing, the team plans to add weights on the bottom of ROV *Osprey* and keep the rear Gatorade bottles with enough buoyancy to counteract these weights. This would lower the center of gravity and raise the center of buoyancy to increase stability. The Pitch Control System could be negatively affected by such a stable ROV design, keeping it from changing pitch enough to complete the mission. Testing will be the only way to determine if the center of buoyancy needs to be lowered to give more authority to the Pitch Control System. The design makes changing the center of buoyancy easy as it is simply a matter of moving the Gatorade bottles.

1.6 Pitch Control System (PCS)

Immediately after completing the regional demonstration, the team decided to test ROV *Osprey*'s ability to complete the ELSS pod transfer task. It was the first time the vehicle had an opportunity to be in the water with an entire set of mission props and the team was curious how the propulsion system would perform picking up the heavy pods. The test result found that the motors were strong enough, but the weight of the pods significantly lowered the pitch of the vehicle (beyond 45 degrees) any time the ROV tried to move. This gave one of the team members, Dustin Mitchell, an idea: design the vehicle to purposely look straight down. Thus, the pitch control system was created to control the center of gravity of ROV *Osprey*. Two 1.3 cm radius PVC pipes where attached to the bottom of each side of the vehicle. Multiple fishing weights weighing a total of 255.1 grams were placed inside each pipe. The fishing weights would be tied together by fishing line with the strength to hold 13.6 kg (about five times the actual weight it would pull) for guaranteed strength. PVC end caps with small holes at their tips were then put on these pipes to keep the weights from falling out. Holes were placed every 3 cm on all four sides of the pipe to make sure no trapped air bubbles affected the buoyancy of the vehicle. The fishing line would then pass through a 2 cm radius pulley wheel at each end cap to reduce the force needed to move the weights. They reduce the force needed by taking the fishing line away from the end cap and reducing friction against the cap itself. A motor then rotates a large wheel that the fishing line is wrapped around in the center which pulls the fishing weights either direction inside the pipe. For example, when ROV *Osprey* performs tasks requiring downward pitch, the PCS pulls the fishing weights to the front end in order to force the vehicle to pitch forward.

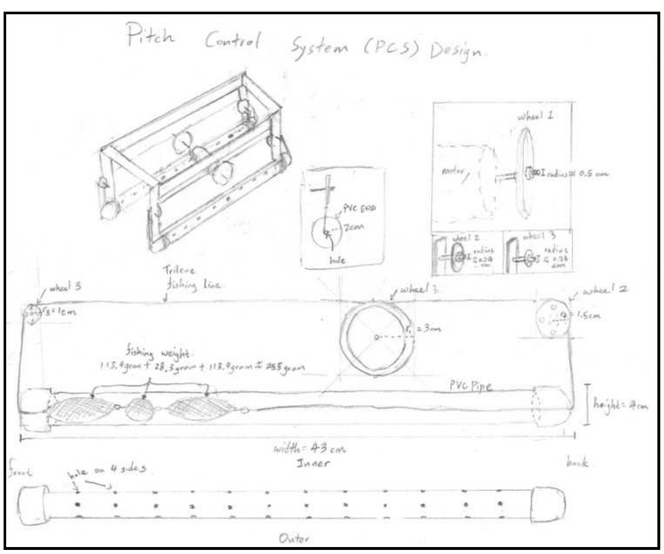

Figure 11 – Pitch Control System concept drawings

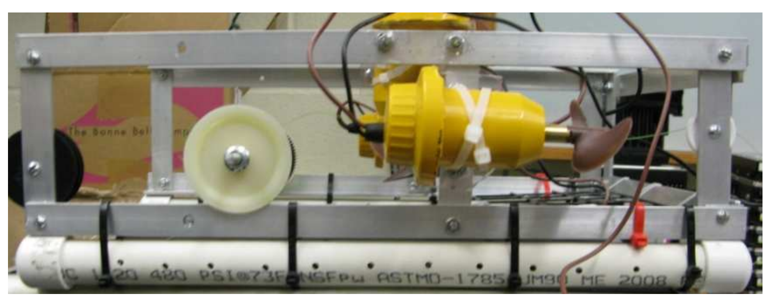

Figure 12 – Pitch Control System mounted on ROV *Osprey*

2. Electronics System

2.1 Base-Station Hardware

The base-station system is responsible for regulating the necessary voltage levels as well as handling all user interface required to control the vehicle. The base-station power supply is a DC to DC, 48 Vdc input, 500W ATX power supply capable of supplying the 35A @ 12 Vdc and 50A @ 5 Vdc voltage levels that are more than necessary to power the on-board electronics. Both voltage levels are delivered separately through the tether to the ROV. The team chose to do all voltage regulation at the surface mainly to reduce the amount of electronics contained in the on-board enclosure. By regulating all voltages, any heat generated in the process is dissipated at the surface rather than inside the on-board enclosure. This also gave us the opportunity to use a power supply which provided both levels we require in one package, reducing the amount of hardware fabrication on our part. See appendix B for a complete power distribution diagram.

The user input and output is handled by a PC running Windows .NET2.0 framework, in our case a Lenovo laptop running Windows XP Pro. The UI (user interface) software, which will be discussed later, takes care of all communication between the base-station and on-board system over a standard Ethernet LAN (local access network) as well as displaying the camera feeds received from the on-board computer. A LAN was chosen because it has a possible length which is more than enough for the tether, the standard TCP (transmission control protocol) transport layer allows for reliable, in-order packet delivery, and it has a high maximum transfer rate of approximately 11MBps. The complete tether will include this Ethernet cable as well as a 12 Vdc (for powering most systems), a 5 Vdc (for powering the on-board electronics), and ground power cords. Because there are so few cables, the tether is light and easy to manage.

2.2 On-Board Hardware

The on-board systems are divided into two separate components: the on-board computer and the control board. The on-board computer is a Gumstix Connex 400xm running an embedded Linux 2.6 kernel with an Ethernet daughter board. The main job of the on-board computer is handling and routing all communication between the control board, on-board USB webcams, and base-station computer. The control board is responsible for controlling all real time systems such as propulsion and the manipulator. A circuit diagram of the control board can be found in Appendix A. The control board is based off of the atmega32 and attiny2313 microcontrollers from Atmel. These were chosen because they have a very strong and well supported open source envelopment environment allowing for rapid development without the need to purchase development software.

The control board was designed to facilitate later expansion with minimal hardware redesign. This was achieved by splitting it into a main controller and daughter boards. The main controller handles all communication with the Gumstix and forwards all commands to the relevant daughter boards. Communication with the daughter boards is done using a two wire interface with a custom protocol to assign dynamic addresses to the daughter boards. With this system, adding additional functionality to the on-board system only requires designing a new daughter board and

2.2 On-Board Hardware (cont…)

adding the support into the firmware. This removes the need to redesign the hardware that is already in place when additional features are added. A standard protocol for reading and writing data to daughter boards was also developed to make communication uniform across all daughter boards. Each daughter board presents read and write ports which the control board may use. The meaning of each port will vary depending on the daughter board.

The thrusters are driven using Dual VNH3SP30 Motor Drivers from Pololu capable of outputting 30A continuous current on each channel. The boards are controlled using three inputs for each channel, two high/low signals for controlling thruster direction and one PWM (pulse-width modulation) signal for controlling thruster speed. The drivers are controlled by a PWM daughter board. The daughter board presents a port for each PWM channel. Writing a value will cause the thruster speed and direction to change based on the new value. The direction and speed are both encoded into the value written to the port.

2.3 Base-Station Software

All software running on the on-board as well as the base-station computers was written in a modular fashion to allow future expansion as well as to ease the debugging process. The base-station software is a multi-threaded application written in C# and is linked against the SlimDX library for controller input. There are three main threads: the networking, joystick, and GUI (graphical user interface) thread. All inter-thread communication is done using an event driven programming model. A dataflow diagram of the major components of the base-station can be found in Appendix C.

The networking thread is responsible for communication with the on-board computer. After receiving a packet and reforming it from the data stream, an event is fired and all other listening threads are informed and allowed to handle the incoming data as each requires. The joystick thread is responsible for periodically polling the status of the user input device and firing an event. The periodic polling is done using a timer which wakes up the joystick thread once every 20ms. The joystick interface class was written as an abstract class allowing support for many user input devices. Currently an Xbox 360 and RealFlight Simulator controller are supported. Lastly the GUI thread is responsible for updating the display. This is the thread which is automatically spawned by the .NET framework to handle GUI related events in any application. This thread is also responsible for "wiring up" all of the events and event handlers for the rest of the application's worker threads.

Figure 13 - Xbox 360 controller (Courtesy of Microsoft.com)

2.4 On-Board Software

Since the on-board Gumstix runs a Linux kernel, a threaded programming model was again used for the routing software running on the Gumstix. The routing software running on the on-board computer was split into separate modules with each module controlling one point at which data can enter or leave the computer and one control module which spawns and destroys all others. A dataflow diagram in Appendix D shows graphically how the modules are connected together. This programming approach allows for the routing software to be easily extended in the future as new components are added. Currently there are modules written to handle serial communication, network communication, and USB camera input using the video4linux driver. All modules communicate to each other using POSIX (portable operating system interface for Unix) message queues. One benefit to using POSIX message queues is that each module can utilize the Linux select() system call. This allows a module to multiplex its CPU time between various I/O sources reducing the total number of threads created in the routing software.

The cameras used were the internal components of a Logitech Quickcam Messenger webcam. One major reason for choosing these cameras was that support was already available for them in the Linux kernel version which came shipped with the on-board Gumstix computer. Each camera has its own module running in the routing software which is responsible for capturing each individual frame, compressing it using an open source JPEG library, and handing it off to the network module so it can be transmitted to the base-station. Initially the frames were transmitted without any compression, in their raw form, but it was found to consume too much LAN bandwidth, approximately 2MBps per camera. After JPEG compression the bandwidth usage was reduced by 90% with minimal loss in image quality.

3. Reflection

3.1 Challenges

The original design of the electronics system was much more complex than the final product and incorporated many more features the team would have liked to have. The team quickly ran into two limiting factors that required a change of focus to the core, necessary functions of the electronics system. These factors were time and manpower. The electronics group started the construction process with three team members. As time went on, as with every division of the Purdue University ROV team, team members decided that this competition wasn't for them. This left only one team member with the necessary computer experience. Due to delays caused by being a new team and our lack of experience with scheduling, this major issue was not truly considered until one month before the regional ROV demonstration. The team had to make a few tough decisions. It was assumed that the electronics system would not be ready in time for the demonstration. The team decided to find an alternative control system for the demonstration. A computer controlled electronics system would still be used at the international competition, but without the complete set of sensors or capabilities as originally planned.

3.1 Challenges (cont…)

The challenges that these decisions created became magnified by the fact that the team also decided to work only two of the available four upcoming weeks due to semester finals. One of the team members had built and still had access to the control system of a ranger class team from 2008, Edgewater High School of Orlando, Florida. It was determined that this control system would work with ROV *Osprey*'s propulsion system. The system was obtained just a week before the competition, connected, tested only once, and proved an effective substitute.

Although this allowed the team to qualify, it created some major concerns. The original plan was for the vehicle to be completely operational by the regional competition. This would allow complete focus on the report, presentation, poster, and mission practice. Using the alternative system left most of the vehicle yet to be completed such as the final camera system, manipulator, Pitch Control System, electronics system and user interface.

The only way to overcome these challenges is with continued determination to finish ROV *Osprey* which the team is committed to.

Support, both financial and physical, was a major issue this year for the team. Without any history or previous record to prove our determination in the competition, many companies and organizations were hesitant to sponsor us. Because of the state of the economy, most of the organizations that initially showed interest in sponsorship had to decline once it came time to actually deliver the donation. With so many organizations on the Purdue campus, it was a challenge to gain any attention when the team needed aid. While there are over five machine shops that are well equipped on campus, none were made available to the team because of other organizations having already been given priority. For the same reason, the team could not find anyone interested in becoming a mentor or instructor to the team who wasn't already helping someone else.

Knowing our financial limitations, we had to design our vehicle accordingly. The team did not know how it was going to afford the trip to Boston though as it had run out of funds. Thankfully, Lockheed Martin was able to give a second donation that was not expected. The team cannot truly overcome its lack of a mentor. However, there has been little interpersonal conflict.

3.2 Troubleshooting Techniques

Because the team had little experience, it ran into many cases that required trouble shooting. The capabilities of the electronics system have been changed multiple times. The manipulator has had to be completely redesigned because the original design did not work. The original buoyancy system was extremely unstable. The team used the same method for troubleshooting all of these issues. Find at least two alternative solutions by brainstorming as a group that remains within our design goals of reliability, simplicity, and speed/agility.

3.2 Troubleshooting Techniques (cont…)

The team expected systems not to work the first time. While at least one team member had some experience in each system, there were no experts. When systems failed, a brainstorming session was held with all available team members. Every member with an idea would present their idea to everyone else. Usually this gave another team member an idea that was a variation of the original idea. At least two solutions had to be found this way before we would stop brainstorming. These solutions would be examined based on the original design goals. This process was one of the few areas where having a smaller team was a benefit, and it usually ran very smoothly.

The idea not chosen would not be scrapped however. If the available time and funds would allow, both ideas would be built to give us a chance to compare in person. If the team did not have the resources to build both, the idea would be written down in detail to make sure it would not be forgotten. This was in the expectation that the new idea might also fail. This proved a valuable process with the manipulator as we now have to use that secondary idea.

Because the software was written in a modular fashion it made debugging much easier. As each component of software was finished it was tested for correct behavior. After that was verified it was then added into the rest of the system and all bugs as a result of any interactions with the new component were resolved. This made isolating and fixing bugs much easier.

Since the on-board computer runs a Linux kernel, that allowed the team to prototype the on-board Linux software using a regular PC desktop. Due to limited resources on the on-board Gumstix, it lacked essential development tools such as a debugger and compiler necessary for any software development. By prototyping on a PC, the team was able to utilize the extra resources to find and fix bugs in the software.

3.3 Lessons Learned/Skills Gained

The members of the team have learned how to work together as a team. From discussion to design and then design to construction, the team had overcome several issues such as debating on different design ideas or unexpected experiment results. The troubleshooting techniques the team implemented helped keep up productivity and was the first time for most of the team members to be in such a professional environment.

However, the most difficult challenge that the team faced was resource limitation with time and finance. Most of the team members were busy throughout the semester and the team's budget could not afford much. Thus, time had to be used wisely and every purchased material in experiments had to be used carefully. The team learned to effectively make a schedule, create due dates, and plan ahead for experiments before just doing them. It sounds simple and easy, but these practical applications of organization minimized the wasteful use of resources effectively.

Most of the team members had never used any construction tools such as power drills or rotary tools. While they were taught in engineering courses how to design something, they couldn't actually make it. They have learned how to safely use these tools. This is something that is also taught conceptually, but is never fully understood until a practical application is presented.

3.4 Future Improvements

ROV *Osprey* is far from finished.

The electronics system was originally planned with a number of sensors, none of which we now have. An attitude sensor could be used to give the pilot a horizon indicator on the laptop, which would make re-gaining orientation easier in case of an emergency. The team knows that a horizon indicator could be beneficial with the Pitch Control System and with a vehicle that has such great roll ability. A depth sensor would also be nice for the pilot as another indicator of where the vehicle is in space. The team also plans to research a system that would indicate how far from the closing point of the grippers any object is. This would be presented on the graphical user interface as a moving vertical bar moving closer to a fixed bar of another color. When the moving bar is on top of the fixed bar the operator closes the manipulator. Another, similar distance measurement system could also be used while operating the mating skirt.

The camera system did not turn out as high resolution as the team would have liked. The solution, however, is not as easy as switching to different cameras. Using webcams with higher resolution begins to reach the bandwidth limit imposed by the USB specification. This improvement is thus still in question.

The team was hoping, from the beginning, to use an active buoyancy system. A system that could automatically add or remove air inside a compartment and keep the vehicle neutrally buoyant no matter what it is carrying would make the pilot's job much easier. This system could hurt the design goals of reliability and simplicity, but would greatly add speed because of the extremely short time it would take to surface from the bottom when given a large amount of added buoyancy. It could also make delivering heavy ELSS pods much easier as it would give enough buoyancy to counteract the downward force of the pods.

The team itself will continue to need future improvement. While all of the team members have grown from the experience, there is more experience to be gained to make us better engineers. The team is also still looking for more team members who can be beneficial.

3.5 Individual Reflections

Seth Baklor - Having competed in a ranger team, I expected the experience to be different. I expected a greater sense of professionalism, which I did find, and greater access to resources, which I did not find. The thing that surprised me the most initially working with this team was the lack of creative, new ideas. Many of them did not have an experience similar to what I had and only knew what was taught in class. Never had they had to design and build such an open ended project. As time went on, the entire team became much more creative and effective.

3.5 Individual Reflections (cont…)

Kuan-Po Chen - It was my first time working on a real engineering project, and I gained a lot of practical experience that could not be learned in a classroom. In the competition, I found the diversity of competitors to be surprising; from elementary to university students. Even the elementary school students had amazing ideas for the design of their ROV. Throughout the competition, I have learned that there are many different ideas that can be incorporated in to a design that can perform just as well and have learned how teams perform during a troubleshooting period. It was a great experience to be involved in the Purdue IEEE ROV Team.

Clement Lan - Up until my involvement on this team, my engineering experience has been limited to theoretical projects and class material. This competition has given me much more insight on how to work with a large team on a real project, with set deadlines and constraints, although the team slowly whittled down to a smaller group. I learned many practical things that I would never be able to learn or experience through normal coursework, such as troubleshooting a non-ideal design or discovering alternative methods to accomplish the same thing, or even incorporating a flaw to be an integral part of the design. Despite a few of the setbacks we encountered, I found this to be a positive and infinitely helpful learning experience.

Dustin Mitchell - With this being my second to last semester until I graduate from Purdue, I used this project as an opportunity to put into practice all of the knowledge that I have accumulated over the past 3-4 years while taking classes. This was the first ROV that I had worked on but I was able to fall back onto previous skills I had learned developing an autonomous helicopter to design and implement the electronics system. Overall I learned a lot about the ROV industry and ROVs themselves. I feel that the ROV industry has a lot of room to grow in the area of electronics and control systems and consider it as a future career path for myself.

Joe Pelletiere – Having a lot of hands-on engineering experience, the design process was what was new to me. I have never worked on a team from a brainstorming phase all the way through to a construction phase. The experience has been very educational and has taught me about the ROV industry which I knew little of.

4. Budget Report

Table 1 – Budget Report

Item	Cost ($USD)	Donations ($USD)
Research Costs (No parts in this section are recounted in the vehicle costs section)		
Large bilge pumps to test with	$90.79	
Webcams for testing	$153.63	
Waterproof electronics enclosure (from manufacturer Pelican Case)	$38.50	
Frame materials (originally PVC and foam)	$130.77	
Waterproof power connections (didn't end up using them – 50% off)	$277.68	$138.84
Lynxmotion manipulator	$109.97	
Electromagnet	$40.57	
	$841.91	**$138.84**
Vehicle costs		
Wired USB Xbox 360 Controller	$41.98	
Logitech Quickcam Messenger webcam	$28.76	
Webcam waterproofing materials (epoxy, silicon, PVC fittings, acrylic sheet)	$77.98	
Frame Materials (Aluminum bars and bolts)	$96.03	
Gatorade Bottles	$4.00	
Waterproof electronics enclosure (from manufacturer Underwater Kinetics)	$32.92	
Underwater Ethernet cable from Subconn (discounted at 50% off)	$300.00	$175.00
Tether power cords	$132.06	
Fishing weights and line for pitch control system	$18.78	
PVC and pulley wheels for pitch control system	$7.77	
1” X 1” grid cage to protect propellers and mount mating skirt	$4.00	
PikStik Pro Manipulator	$19.99	
Bilge pumps for thrusters	$98.86	
Prop shaft adapters and propellers from Octura models	$37.00	
Gumstix Computer (donated by team mate)	$130.00	$130.00
Motor Controllers	$150.00	
Lenovo XP Laptop (donated from Purdue IEEE Aerial Robotics team)	$1,300.00	$1,300.00
Waterproof power connections	$100.00	
Other electronics	$100.00	
	$2,680.13	**$1,605.00**

4. Budget Report (cont…)

Competition Expenses		
Parts of insertion point prop	$14.02	
PVC and other parts to make mission props	$216.82	
U-Haul trailer to transport ROV	$342.00	
Transportation cost (gas)	$521.25	
Flights for some team members	$300.00	
Hotels en route	$300.00	
Housing in Buzzards Bay	$320.00	
Team T-shirts and polos	$242.95	
	$2,257.04	**$0.00**
Donations		
Lockheed Martin		$3,250.00
Northrop Grumman		$250.00
Purdue Engineering Student Council Merit Fund		$1,500.00
	$0.00	**$5,000.00**
Summary		
Research Costs	$841.91	$138.84
Vehicle Costs	$2,680.13	$1,605.00
Competition Expenses	$2,257.04	$0.00
Donations	$0.00	$5,000.00
Contingency Funds**	$964.76	$0.00
Total	**$6,743.84**	**$6,743.84**
Balance	**$0.00**	

**Any leftover funds will be used to compete in the 2010 MATE Competition

5. Description of an Existing Submarine Rescue System

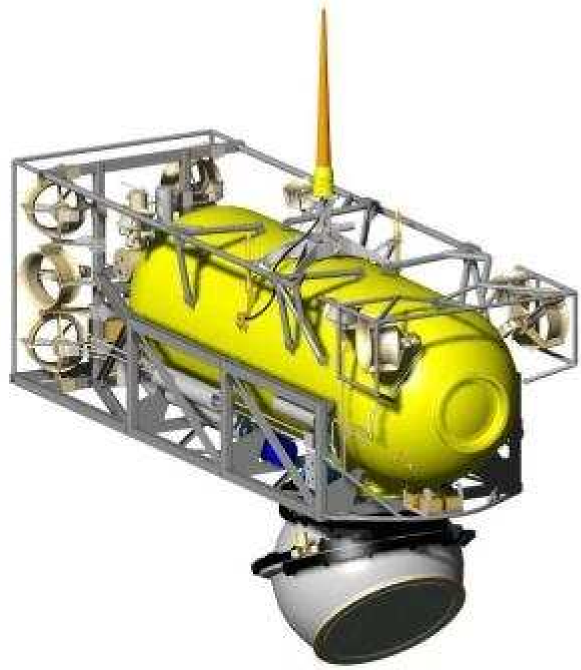

Figure 14 - SRDRS Pressurized Rescue Module (Courtesy of Phoenix International)

The USS Thresher (SSN-593) was a nuclear submarine built, launched, and lost in the 1960's. Although it passed multiple trials and participated in the Nuclear Submarine Exercise as well as a few weapons tests, on April 10th, 1963 the Thresher suffered damage during a deep-diving exercise and was lost. It was determined that the cause was due to some form of failure with the casting, welding, or pipes which caused the engine room to flood and the submarine's systems to shut down, consigning 129 people to their deaths. This event can be said to have motivated the world to begin developing a submarine rescue system to prevent a similar tragedy from occurring again.

The Submarine Rescue Diving and Re-compression System (SRDRS) is the Navy's current submarine rescue system, developed to replace the old system consisting of a Deep Submergence Rescue Vehicle (DSRV) and a mother submarine with recompression capabilities. The SRDRS is made up of four elements - the Assessment/Underwater Work System (AUWS), Submarine Decompression System (SDS), the Pressurized Rescue Module System (PRMS), and the PRMS Mission Support Equipment, which can include such elements as the Launch and Recovery System (LARS). The system, when needed, will be transported to and installed on a vessel of opportunity (VoO).

5. Description of an Existing Submarine Rescue System (cont…)

The AUWS is the first system to be utilized in the event a submarine is disabled, and is made up of manned atmospheric diving suits, which will inspect the downed submarine and stabilize the downed submarine through use of ELSS (Emergency Life Support System) pods or the decompression-ventilation system. The AUWS is also responsible for clearing debris from the vicinity of the disabled submarine. The SDS consists of two re-compression chambers and any needed support equipment. Crew members from the disabled submarine can be placed in the re-compression chambers and be readjusted to atmospheric pressure aboard the vessel of opportunity. The PRMS consists of the Pressurized Rescue Module (PRM) and support equipment, including supply vans, transfer skirts, umbilical winch, LARS, and deck cradle. The LARS is an A-frame from which the PRM will be launched and recovered.

The PRM (see right) is the actual ROV around which the SRDRS is centered. The design is of a cylinder with hemispherical ends, in which personnel rescued from the disabled submarine will sit, surrounded by a cursory frame. The Horizontal Manway on the bottom of the PRM allows for transfer of personnel to the PRM by mating with the deck hatch. All sensors and equipment are mounted on the exterior of the hull. The PRM is controlled exclusively by crew members in a control van aboard the vessel of opportunity, with the sole exception of two attendants inside who control and monitor the life support systems. The PRM, if needed, will go down to the disabled submarine, mate with the submarine hatch, take up to 16 personnel from the submarine aboard, and return to the surface, where the rescued personnel will be re-compressed by the SDS.

Figure 15 - PRM Module being recovered from rescue exercise (Courtesy of Navy.mil)

ROV *Osprey*, developed in 2008/2009 by the Purdue University IEEE ROV team, performs many of the same tasks required by the SRDRS. Namely, being able to inspect a disabled submarine, stabilize the submarine using ELSS pods and ventilation, and having the ability to dock with the submarine. At 18 cm tall, 30 cm wide and 58 cm long, the ROV we designed has the capability to perform the tasks of the AUWS and the PRMS, with the exception of crew member rescue and re-compression, since we are performing on a far smaller scale. If ROV *Osprey* were brought to full scale, it could accomplish every task of the entire SRDRS system.

For a complete list of references, see section 7: References/Works Cited

6. Team Safety

From the beginning of construction, the team was determined to be as safe as possible. OSHA approved safety goggles and closed toed shoes were required to be worn by all team members while power tools were in use. All power tools were connected through a surge protector that was switched off whenever a tool was not in use. The design of the vehicle does not require any tools considered extremely dangerous such as power saws, mills, or lathes of any kind.

ROV *Osprey*'s design includes few components that could be dangerous to itself, a user, or the environment. The four on board motors have a relatively low maximum current draw of 6 amps each. These motors are all fitted with plastic propellers that pose less of a threat than metal propellers. The vertical motors are placed out of reach within the main frame. The two outside motors are covered by a cage to prevent any mishaps. There is no pneumatic or active buoyancy system which would require containment of high pressures that could potentially burst. While the competition allows a 48 Vdc power draw at 40 amps, our vehicle uses 12 Vdc at a maximum current of 30 amps. The team agrees that this power rating is significantly safer.

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7. References/Works Cited

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8. Acknowledgments

Sponsors

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To the MATE Center for giving the team this incredible opportunity

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Purdue University Athletic Center Pool
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Purdue Student Paul Rosswurm for contributing ideas
Expert remote controlled plane designer, David Bucknell
All the friends and family who proof read this report

APPENDIX A - Electrical Schematic

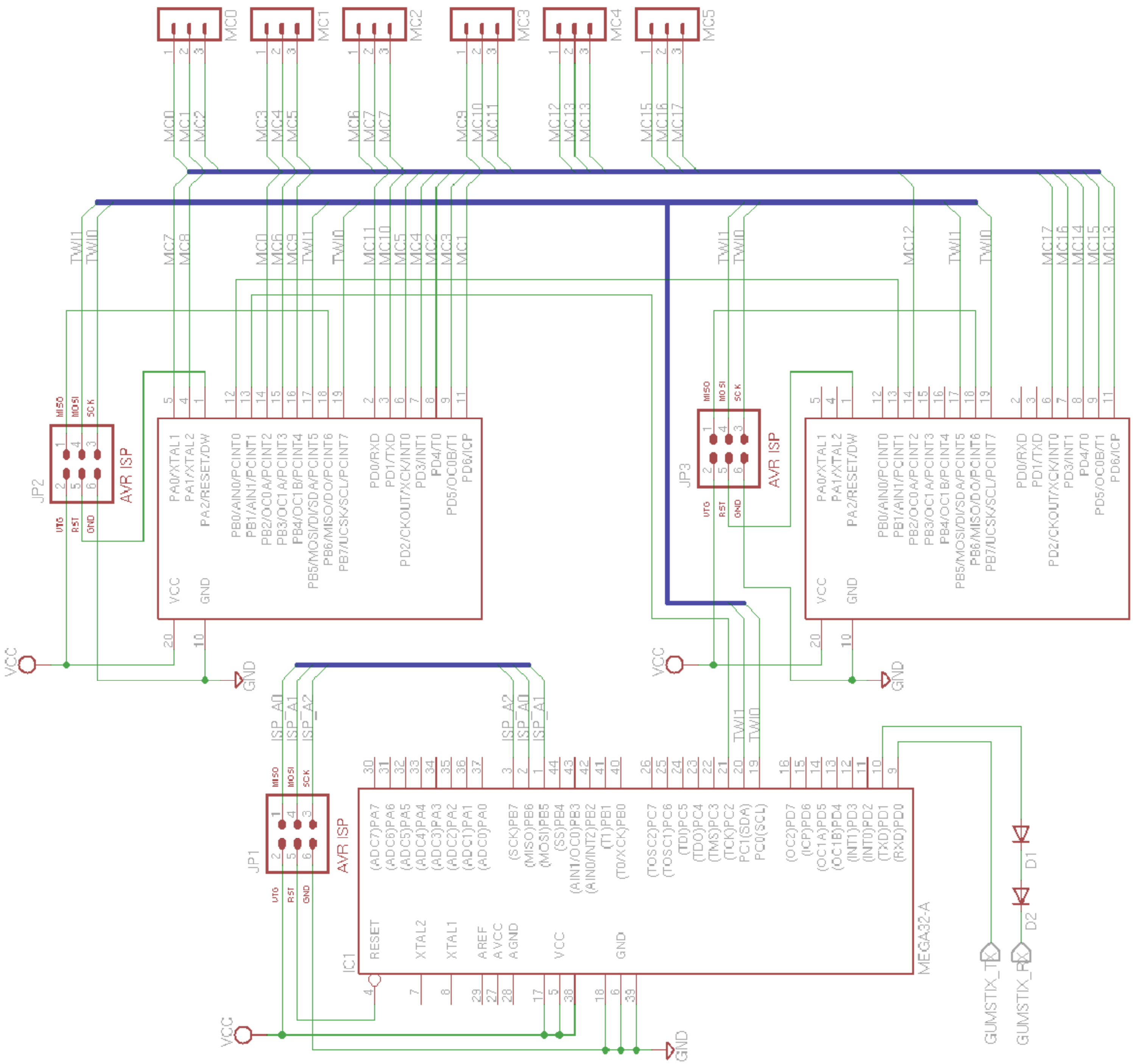

Diagram 1 – Electrical Schematic

APPENDIX B – Power Distribution Diagram

NOTE: Common Ground Isn't Shown

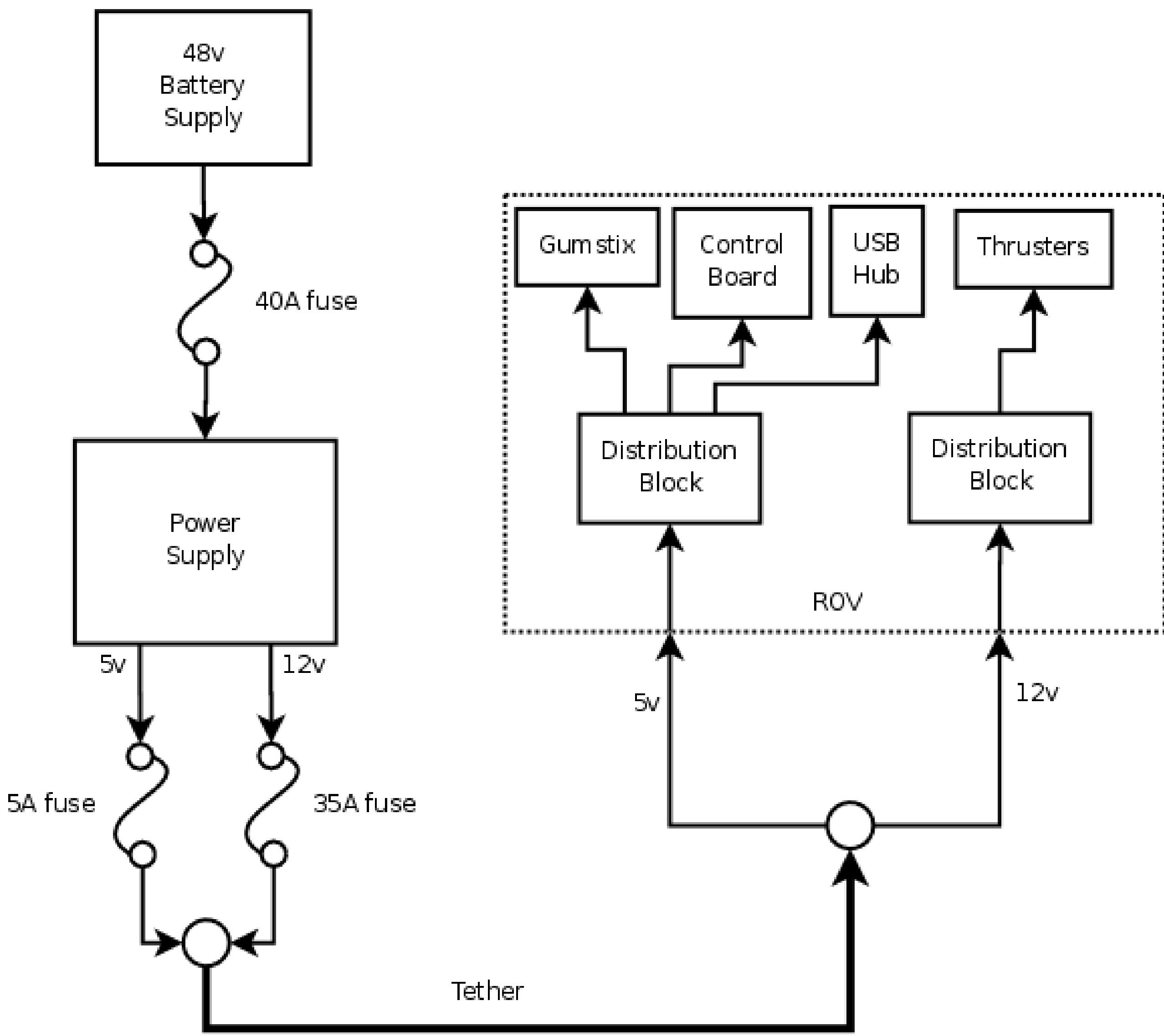

Diagram 2 – Power distribution

APENDIX C - Base-Station Dataflow Diagram

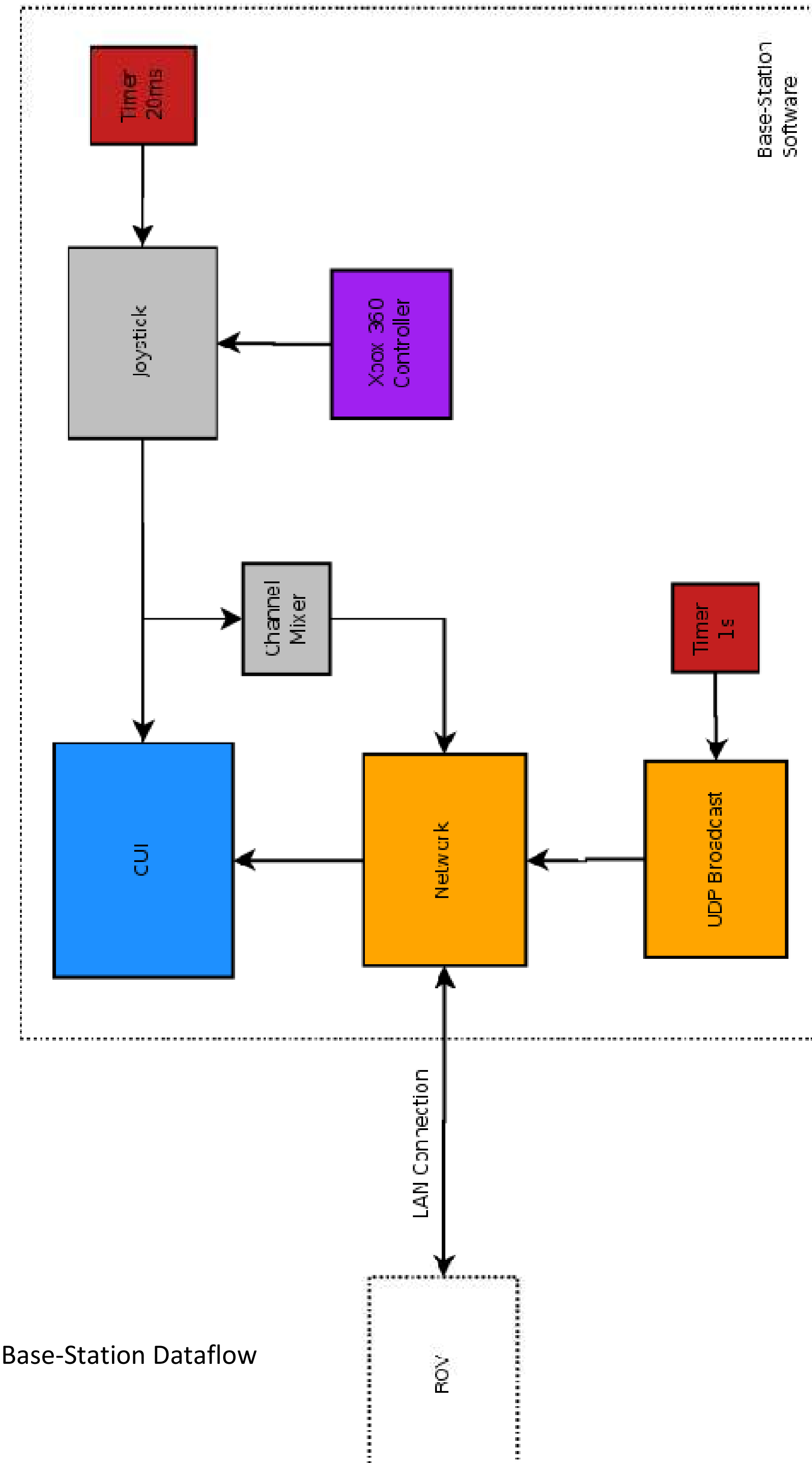

Diagram 3 – Base-Station Dataflow

APPENDIX D - On-Board Dataflow Diagram

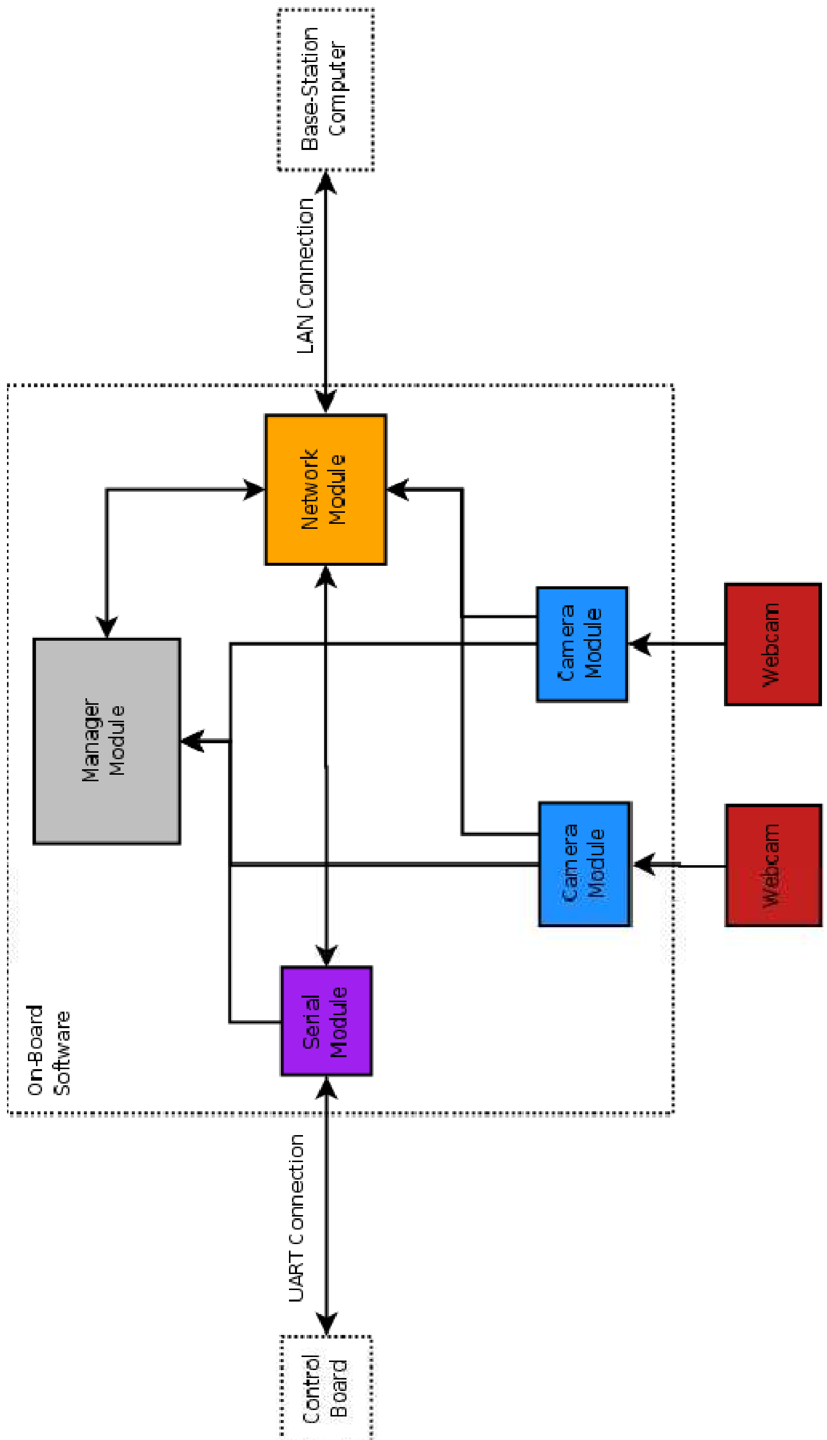

Diagram 4 – On-Board Dataflow