APTOS MARINERS ROBOTICS, LLC.

Aptos High School • Aptos, CA 95003

-Experts in Deep Water Research, Repair, and Recovery-

*Featuring: "**Alien MKII**"*

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- **Isaac Cassar**: COO/Tetherman
- **Nathaniel Willy:** CFO/Assistant to the Pilot
- **Adam Simko**: Chief Engineer
- **Nick Davis**: Mechanical Engineer
- **Chris Randolph**: Chief Software Engineer
- **Breana Kostreba**: Electrical Engineer
- **Justin Lardinois**: Secretary/Treasurer
- **Mobin Skaria**: Chief Technical Officer/Graphics Designer
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- **Bob Goeckermann:** Faculty Advisor
- **Dan Atwell**
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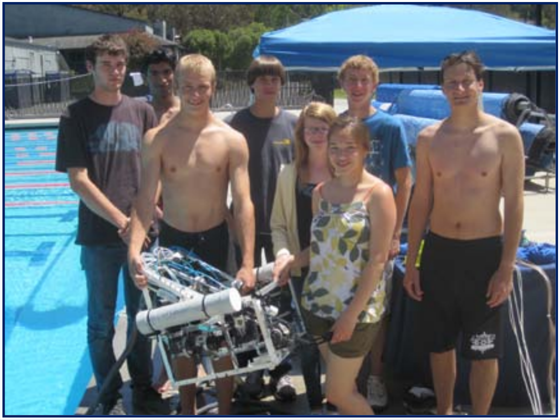

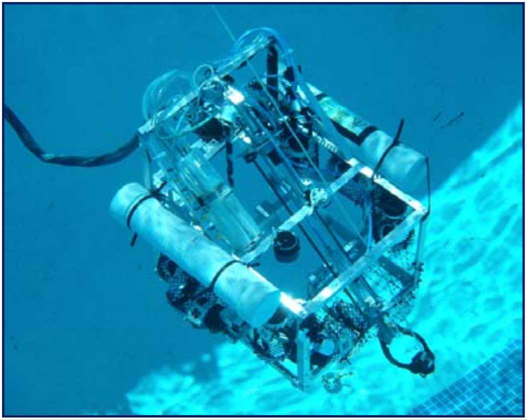

ABSTRACT

We are Aptos Mariners Robotics, LLC, and we are experts and innovators in deep water research, repair and recovery. Our diverse team of employees is proficient in engineering, software design, and deep water operations. The recent Deepwater Horizon oil spill disaster in the Gulf of Mexico validates the importance of being prepared to detect, prevent or rapidly repair a crippled deep water oil rig. We designed our ROV, the ***Alien MKII***, to demonstrate our capabilities with a simulated deep water oil rig disaster. Our ROV will repair, cap and shut off a simulated broken oil well, will gather samples of marine life, and will collect water samples at specific ocean depths. The primary elements of our ROV are speed, maneuverability, and our retractable mechanical arm and claw. To ensure maximum visibility under water, we installed four cameras located in strategic positions to facilitate our mission. To propel our ROV we installed eight 4,731 LPH bilge pumps with modified propellers for increased speed and maneuverability. To control our ROV, our software team designed a program that allows us to use an Xbox 360 game controller to operate and manipulate our ROV. The key feature of our ROV is our mechanical claw, which uses a solenoid controlled pneumatic actuator to extend, retract and grab targeted items. We developed an innovative suction device that is also operated by a pneumatic actuator to collect water samples. Our ROV will allow us to demonstrate that we are the best company to accomplish deep water tasks.

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COMPANY GOALS

When Aptos Mariners Robotics, LLC was challenged with developing an ROV that could perform deep water oil rig research and repair, the company established a set of clear and concise goals.

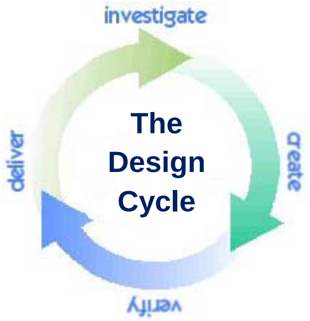
These goals included;

- Keeping the ROV size to a minimum
- Maximizing speed and maneuverability
- Minimizing cost through proper planning

We used these goals as our guiding principles to design and build our ROV. We believe that we accomplished all of our goals and look forward to demonstrating the capabilities of the Alien MKII.

DESIGN CYCLE

At Aptos Mariners Robotics, LLC, we utilized a simple design cycle to develop our ROV. There are four key components to this cycle;



Investigate, create, verify, and deliver. This process formed our approach to designing and building our ROV. It was critical that we investigated and fully understood the mission requirements before we began to design and create our ROV. As we began building each component of the ROV, we carefully verified through testing and the use of Failure Mode Effects Analysis that each part of the ROV was effective. Once verification was completed, we were able to finish and deliver each unique component and ultimately assemble a very effective and efficient ROV.

SAFETY

At Aptos Mariners Robotics, safety comes first! We follow a rigid code of safety that includes strict guidelines at pool side and in the workshop. In addition, we have included several key safety mechanisms on our ROV. These include cages on the motors, filed down edges, neatly tucked wires, pressure tested pneumatic cables, fuses and slightly positive buoyancy. The cages physically bar motors from harming wires, on-board devices, or team members working near the ROV. By filing down edges, we prevent undesirable cuts in wires, devices and skin. To make sure that the wires aren't the cause of a problem, we arranged them to fit snugly and tautly within our frame without having anything stick out. Our pneumatic hoses are safety checked to a degree much greater that what we require; while we need around 40-60 psi, the hose boasts a limit of about 150 psi. If anything does go wrong on the R.O.V. we have designed it with slightly positive buoyancy to ensure that it can surface on its own.

Off the R.O.V. we have several important safety elements. Our tether is wrapped in protective black conduit to protect our wires from external damage. To protect the wiring in our control box, we placed a fuse first in line on the positive line of power. If there is an undue fluctuation in voltage the fuse will blow before there is any damage to our equipment. A major safety innovation is in our software where we are able to monitor summary data of the entire R.O.V., including; functionality of software-hardware communication, temperature in the board and motor controllers, and ability of motors to move under command. We can use this safety feature to take preventative measures and resolve complicated and confounding hardware-software challenges without risking the opening of the control box.

DESIGN RATIONALE: ROV Components

Structure

Our primary focus this year was on speed and maneuverability. We knew that our ROV had to be compact and especially light. To reduce weight, we implemented a number of structural design elements, including:

- Making the frame out of 1.9 cm riveted aluminum angle instead of PVC piping.
- Cutting lightening holes in the aluminum to make the frame lighter and more hydrodynamic
- Replacing many heavy, steel parts with alternatives made of light aluminum metal.
- Rebuilding our motor shrouds out of lighter, thinner plastic webbing to cut down on weight.
- Using light, flexible Festo pneumatic tubing.

We favor 1.9 cm riveted aluminum angle over PVC pipe for a number of reasons: it is lighter, less expensive, stronger, and easier to work with, allowing us to customize many aspects of our ROV. In addition, aluminum angle has no internal volume, so while a wet PVC frame gains significant mass from filling up with water, aluminum angle has no such weight gain when underwater.

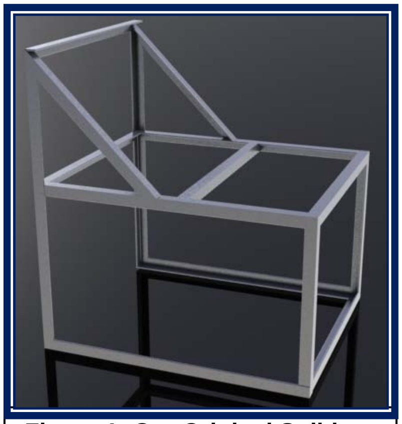


Figure 1: Our Original Solid Works CAD drawing

The shape of our ROV was designed for maximum efficiency in completing the mission tasks. Our goal was to minimize the size of our ROV this year, so we challenged ourselves to reduce the overall structural dimensions. Our frame this year is generally a cube. We needed this shape to house our eight propulsion motors and to hold them in their correct positions. We also needed the frame to enclose all of the ROV's components.

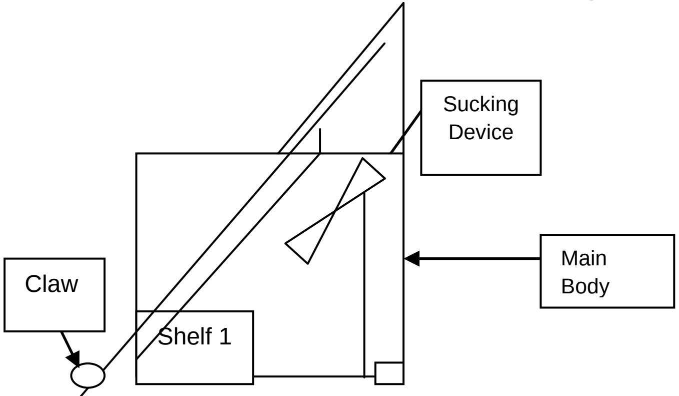
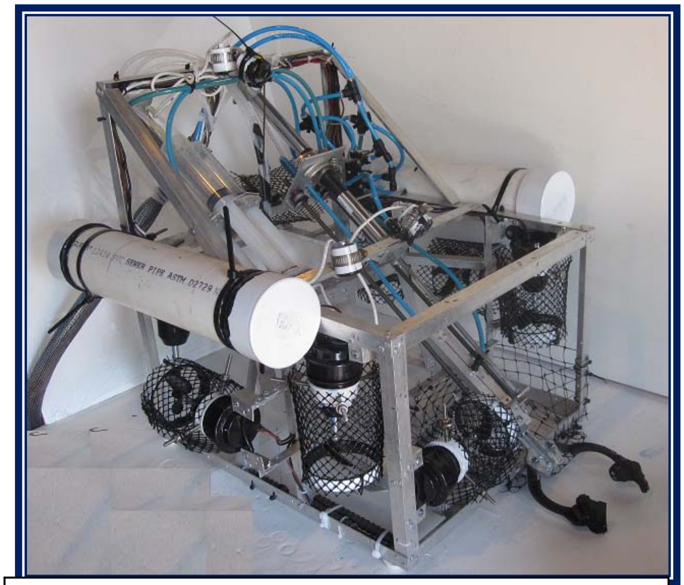


Figure 2: Line Diagram of ROV Structure

The main body of the ROV has been made so that all of the motors can be properly spaced out, and to allow room for all of the mission specific devices, or payload. The largest component of the ROV is the pneumatic claw extension cylinder, which spans the majority of the main body length. The main body is long and tall enough to enclose the cylinder in its entirety, and hold it



Complete Alien MKII structure with payload

at the correct angle for proper claw operation. We built a shelf which serves as the collection basket for the claw. It is lined with netting, and is positioned directly below the claw when it is in the position, so it can drop and store objects in the first shelf. We created a sucking device to collect oil samples and mounted it parallel to the claw on the left side of the ROV. We then mounted our pneumatic solenoids on the other side of the claw to maintain our center of gravity. The solenoids are extremely important, forming the heart of the pneumatic systems. They need to be well protected, and mounted in a stable position. In order to get everything built on schedule, we planned and tracked the build with Microsoft Project (see page 21).

Electrical

The electrical system of the ***Alien MKII*** is designed to be simple, easy to repair, and to minimize the possibility of electrical failures. The first thing on the positive line is an easily replaceable 25 amp fuse, so that even if a fuse on the battery somehow fails, there is still a fallback. After the fuse, the power splits to the motor control boards and the cameras. Power to the motor control boards is split among them, and they directly supply this power to our motors and actuators when activated by our software. In case of software or hardware failure, power terminals are installed between the boards and the motors so that we can easily switch over to a manual control box if necessary. Power to the cameras is supplied through the ends of the power cords that came bundled with the cameras, wired directly to our power supply. We have a separate switch for power to the boards and power to the cameras to avoid frying the cameras with any initial power spikes. There is a bit more wire for each connection in our box than necessary, this is so that we can easily open the box up to perform repairs. Our electrical schematic can be found on page 19.

Connor assisting with wiring

Propulsion

Being able to quickly descend and ascend is vital in deep water rescue operations. Our ROV is designed for both speed and maneuverability. For our motors we decided to use marine bilge pumps. These are optimum because they are already waterproofed and propellers can be attached relatively easily. We used eight 4,731 LPH bilge pump motors, versus the 3,785 LPH bilge pump motors on the ***Alien MKI***, because they gave more power but actually drew less current according to the manufacturer. Our motor configuration is two horizontal motors for forward/reverse functions, two horizontal strafing motors for left strafe/ right strafe, and a combination of all four for turning. For vertical maneuvering, we use four motors mounted along the outer corners of the frame for optimum stability.

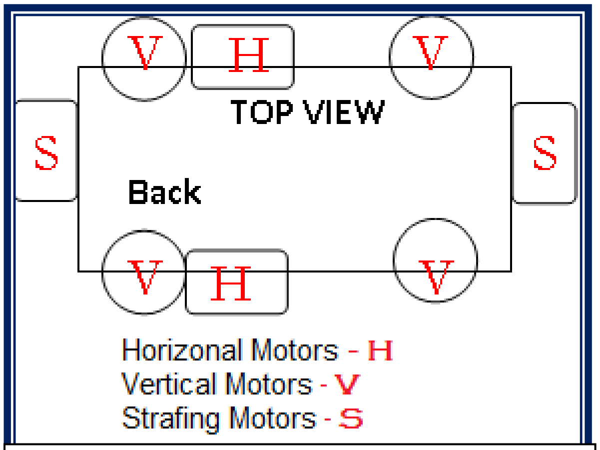
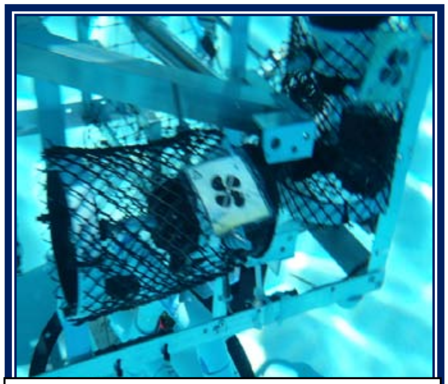


Figure 3: Motor Configurations

Our propellers are mounted 2.54 cm from the pumps using custom built prop-extensions to allow maximum water draw. We originally utilized three bladed propellers, but found that although technically they should have provided more thrust, they drew too much amperage thus reducing their total functionality. Instead, we found that using two standard bladed propellers improved our overall thrust by nearly fifty percent. A table of our propeller thrust test results can be found on page 14


Horizontal and Vertical Motors in use during practice

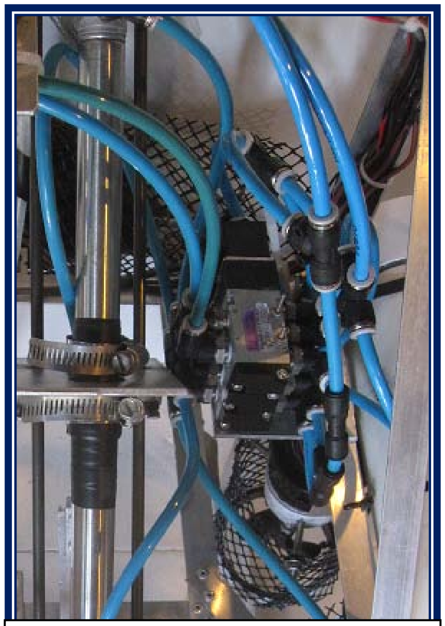
Cameras

The ***Alien MKII*** uses five 7.5 volt black and white security cameras to observe its surroundings for easier control and management of the ROV. All five cameras have been waterproofed by filling the camera enclosure with an epoxy solution. Each camera has a specific task. The first two cameras are positioned facing the claw. One of them is mounted behind the claw and faces forward, giving us a view of what is in front of the claw. The second is mounted at the front of our ROV, looking toward the claw at an angle. This allows us to have better depth perception when grabbing objects with the claw, because the first camera cannot display how close we are to the target. These two cameras give us a clear view of our claw workspace. The third camera is mounted facing downward at the pipe capping device. It allows us to have clear vision while capping a broken oil well, and also gives us a view below the ROV, which can be useful for spotting sample sites or creatures that are to be brought to the surface. The fourth camera is mounted facing toward the end of our Super Sucking Device tubing so we can easily get this tubing into the sample site, and keep it there long enough to obtain our liquid sample. The last of our cameras is mounted at the very top of the ROV, and gives us a visual on both our liquid sample collection chambers and our depth sensor. Using this camera, we can tell if we have finished collecting our liquid sample, and also check if we are at the correct sample station. By utilizing all five cameras together, we have full visibility of our entire work space.


Close up of our two top mounted cameras

Pneumatics

With the ***Alien MKII*** we decided to use pneumatics to power our Manipulator and SSD, as opposed to electric motors attached to worm drives. Pneumatics are very fast and have a great amount of power if used correctly, as opposed to slow electric gearboxes. We also found that pneumatics hold up very well underwater after very minor waterproofing methods. This was much easier than the extensive process of keeping water out of brushless motors. This year, we are currently using three pneumatic cylinders: two 25.4 cm and one 2.5 cm. Each of these are connected to a 5/2 solenoid valve so that we can remotely control the cylinder's actuation with our electronic controls. We chose solenoids over a manual valve because according to *Introduction to*



Pneumatic Solenoid Valves mounted in the structure.

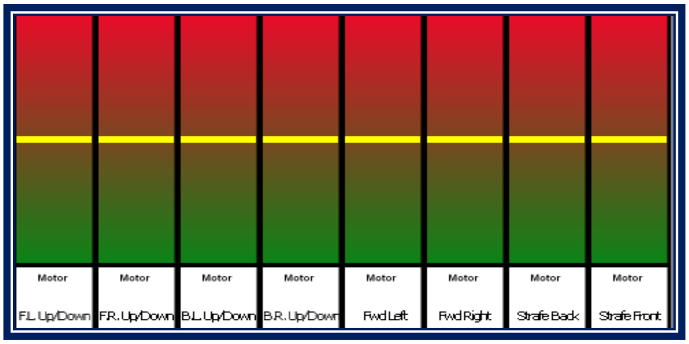
Pneumatics, by FESTO Didactic, this type of "Electrical actuation is usually selected when controls are located extremely long distances from the valves and where short switching times are required." This is optimum for us because we are both very far away from the ROV and we need rapid switching times. It is also advantageous because we only need to send one pneumatic air line down to our ROV and one exhaust line up to the surface instead of having to run separate lines from the surface for each cylinder. Each of our solenoid valves are 5/2s, which means that they have a default spring held in position A and then when given power, they switch over to position B, reversing air flow. When deactivated, the solenoid's spring returns it to its default position. The reason that we have 5/2 valves is so that if we have a power failure, all of our components will return to a 'safe' position. Our SSD will remain in its extended and fluid-holding position, our claw will remain firmly closed around whatever it was holding so we do not lose it, and our extension arm will remain extended so that if it is holding items too large to fit within our internal storage basket, it won't damage anything by attempting to retract it back in.

Motor Controllers and Related Software

On the ***Alien MKI*** we used an Xbox 360 control system that required the use of relay boards. We did very well at the International Competition during the pool mission using this system, but we were marked down in the Engineering Evaluation for using third-party software and programming. For the ***Alien MKII,*** we wanted to use a similar control system because of its success on the ***Alien MKI,*** therefore we made it a major team goal to write our own software. To accomplish this we created a Team sub-group dedicated to writing and building a functional, user-friendly, and reliable software and control system.

C# Programming

We had three main tasks in accomplishing our goal. First of all, we had to learn C#, a .Net Framework supported programming language, in order to use XNA Gaming Studio—an Integrated Design Environment (IDE). Being new to this language, we had to spend time learning its syntax while picking up methods to implement and integrate "keywords", or commands. Programming is many times a lone journey. To attain our level of understanding we had to individually put in at least 8 hours a week in addition to the progress we made during team meetings. We are all very proud of what has come of it, and we have all gained and will retain our newfound abilities well beyond the scope of this competition.

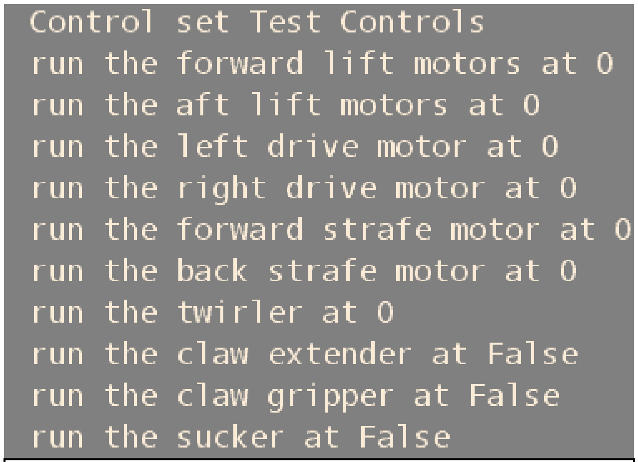


Visual Display Bar Graph showing all eight motors in the neutral position.

Bar Graph Development

The second key task in creating the programming was the display. The display is an overall visual that reflects on the activities of the ROV at any given time. Currently we have functioning outputs for motors and the motor controllers. The motors' rate of movement is visually displayed by its relative position on the red-to-green gradient. We calculated the position of the motors by relaying the messages from the Xbox controller to our PC interface. Because the motions of the motors are controlled by the thumb stick we can create a perfectly linear relationship with a relative point on the graph and the height of the graph. This acts as an intuitive display of the commands being given to the motors, as well as a check to see if the relays between the controller and the computer are functioning without error.

Motor Controls

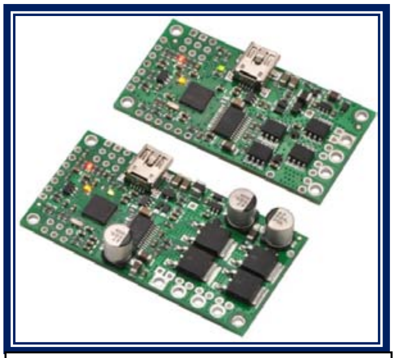


```
 Control set Test Controls
 run the forward lift motors at 0
 run the aft lift motors at 0
 run the left drive motor at 0
 run the right drive motor at 0
 run the forward strafe motor at 0
 run the back strafe motor at 0
 run the twirler at 0
 run the claw extender at False
 run the claw gripper at False
 run the sucker at False
```

Figure 4. Display created to communicate errors on the Motor Control boards.

The final task was to design a functional and efficient way to relay the commands of the Xbox controller to the motors. This part definitely took quite a bit of code and logic. In order to initiate the communication between the Xbox controller, the PC, and the motors, we had to purchase 9 of Pololu's Simple High-Power Motor Controllers. One of the pros of this component was its dual communication methods. It has both a USB interface for the computer, as well as a section for serial jumper jacks to allow connectivity between all the controllers.

We set up a port for the hardware, and created code to allow information exchange via packages of bits. We used several methods to store and modify this information into something that was useful to us. For example, we used the data from the motor controls to create a display of possible errors occurring in the board. This error message display capability proved essential when troubleshooting problems poolside. Another example is the input we put into the boards. We have to convert the Xbox controller's movements and actions into bytes of information in order to successfully create communication.



Motor Control Boards prior to installing in the control box.

We also created an intuitive control interface so that we could choose a favorite control scheme. We made a FPS (First Person Shooter) control scheme, a control scheme similar to last year's controls and finally we made a test control scheme for when we are chasing down bugs in the system. Our favorite was the FPS control scheme because it is designed so that the left thumbstick controls X and Y axis location, with the orientation of the ROV constant, the right thumbstick controls orientation of the ROV, both in left/right rotation and in ROV pitch, the right trigger has the ROV move up vertically, and the left trigger has the ROV move down vertically. Other operations such as the manipulator arm and the SSD are controlled via the 'a,b,x,y' buttons on the right side of the controller.

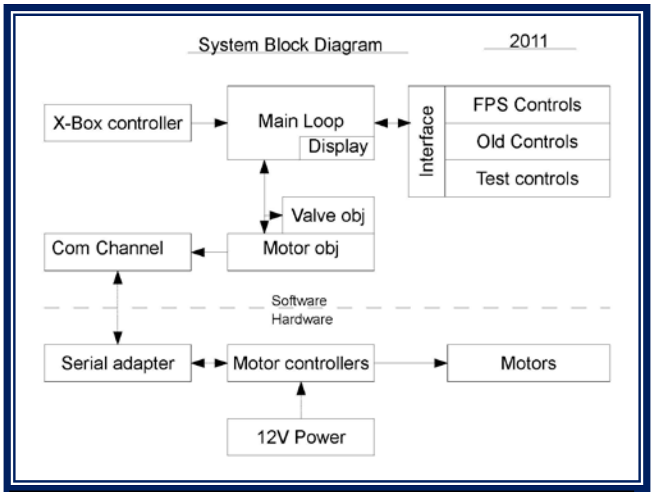


Figure 5. System Block Diagram

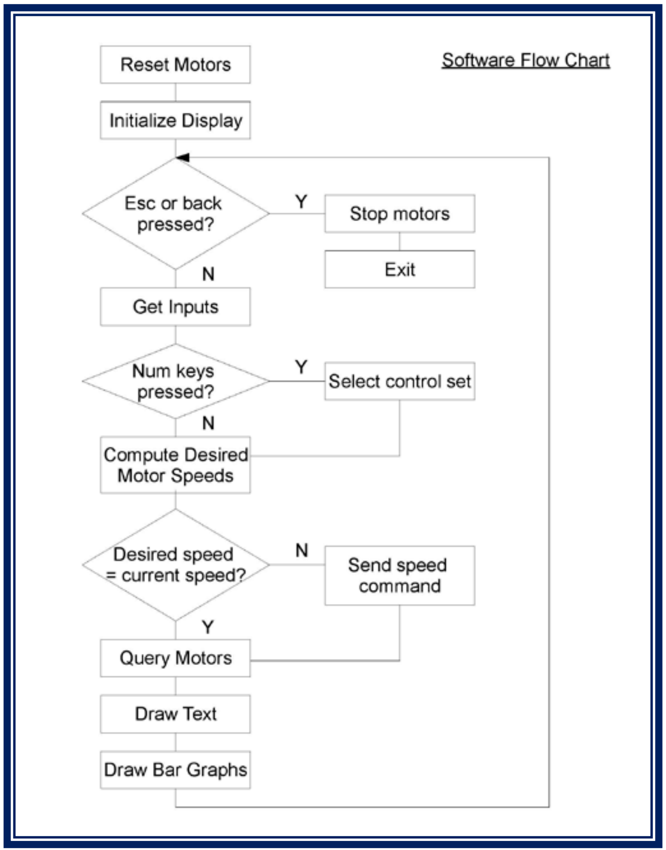


Figure 6. Software Flow Chart

DESIGN RATIONALE: Mission Tasks

Manipulator

The Manipulator on the ***Alien MKII*** is one of our most important payload tools, designed to allow us to accomplish a variety of necessary deep water tasks. We used the basic design principles from the ***Alien MKI***, and improved on them to make the claw smaller, stronger and more stable. There are two components to the Manipulator: the claw itself, which is modified from a simple trash picker-upper, and an extension cylinder, which allows us to extend and retract the claw.

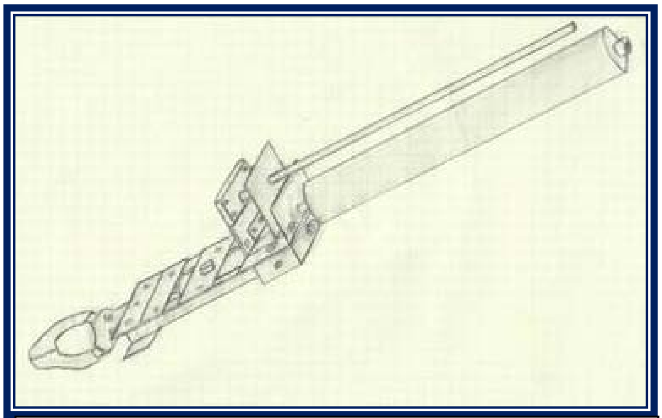


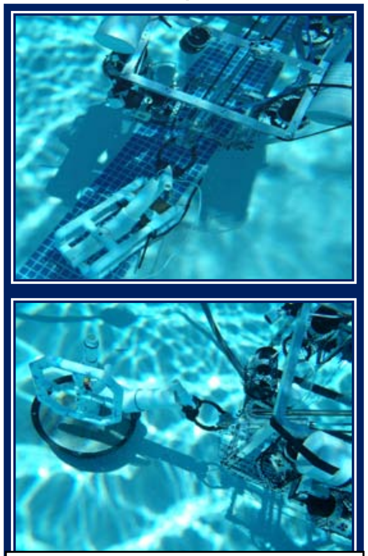
Figure 7. Original claw design.

The claw itself was designed using a common trash picker-upper, which we used because of its **simplicity** of operation and small size. It operates through a 5/2 solenoid-controlled pneumatic cylinder that pushes/pulls a teethed rod through the two arms of the claw, which contain gears. The result is that when the teethed rod is pulled, the arms close, and when the rod is pushed, the arms open. Using the formula $F_n = A' \times p - F_R$, where F_n is the effective piston force, A' is $(D^2 - d^2) \times \pi/4$, D is the piston diameter, d is the rod diameter, p is the operation pressure, and F_R is the frictional resistance, we found that our claw has a theoretical force of 131 N and an effective force of 118 N

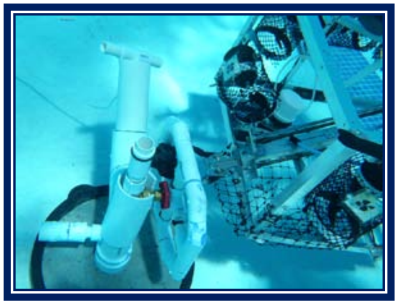
The manipulator cutting the pipeline.

when you subtract an estimated frictional resistance of 10%.

Several of the mission tasks involve carrying items, collecting samples, and turning valves, all requiring activity outside of the main ROV frame. For this reason, we designed our manipulator so that it would extend outside of the ROV to accomplish the tasks that require a claw, and then retract within the frame so as to deposit the samples into an internal storage basket. To accomplish this, we mounted the claw on the end of a 24.5 cm pneumatic cylinder, which allows us to extend and retract the claw through a 5/2 solenoid. We attached two stabilizing rods which connect the claw to the cylinder and thus help reinforce the entire unit. The result of the two stabilizing rods and the cylinder itself is a triangle shape, which is the most structurally sound of any shape.

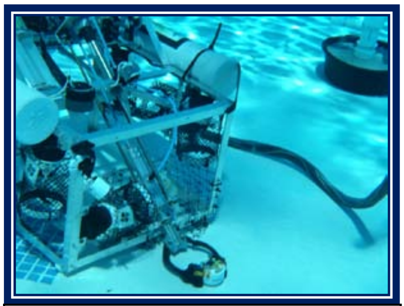


Removing the hose line from the top kill manifold and reinserting it into the well head.



Turning the valve wheel.

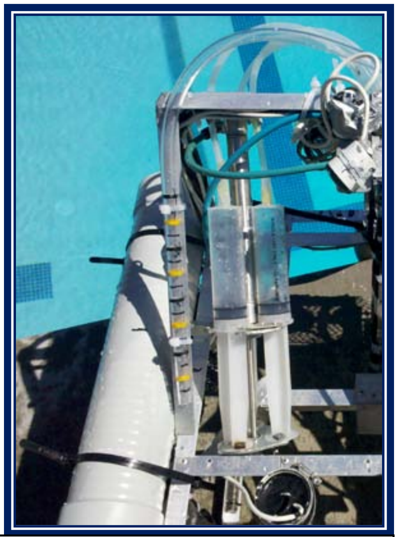
We put a lot of emphasis on keeping our manipulator functionally versatile and able accomplish a wide array of tasks. Because of this ability to perform multiple tasks, we were able to keep our ROV very simple and streamlined, not requiring a bunch of extra payload tools for every single task.



Collecting Biological Samples

Sucking Device

In any deep water oil disaster, it is vital that we understand the impact to the ocean environment. To sample the water for later testing, our ROV is equipped with a water collection apparatus, the Super Sucking Device (SSD). The SSD uses a cluster of three 60ml syringes attached to clear pneumatic line in order to extract the liquid sample from its container. The syringes are arranged in a triangular formation around a pneumatic cylinder, which when activated pulls the plunger on all three syringes. The three clear pneumatic lines are clustered together and are pointed directly downward through the recessed bottom of the ROV, so



The Super Sucking Device mounted inside the ROV structure.

the tip of the SSD is well within the sample pouch when the ROV sits on top of the container, thus stabilizing it when the sucking commences. As an added backup, we have built-in redundancy in that if one of our syringes happens to fail the remaining two still have a combined volume greater than the minimum 100ml that needs to be sampled.

The SSD docked and collecting sea water samples.

Depth Sensor

Throughout the year, one of our most difficult problems was the creation of a working depth sensor. Our first design was a pressure sensor based on resistance change. As there is more pressure the resistance will go down. We used conductive foam, one inch PVC pipe 1.9 cm, CAT-5, conductive cement, a multi-meter, and two pennies. We soldered the CAT-5 to each penny and sandwiched the foam between the two pennies within the PVC pipe. We connected the other ends of the wires to the two prongs on the multi-meter to measure the resistance as pressure changes. We water-proofed the pressure sensor in a balloon with zip ties and grey RTV. However, we found that this sensor just wasn't accurate enough for our specific use.

Our first attempt at a depth detector.

Our second design involved an electronic pressure sensor from Measurement Specialists, Model 4426 that measures sensed pressure in voltage, and uses 12V input. The specific part number is 4426-030A (0-30psi absolute). We soldered the electrical connections and then potted them to protect them from water. As a secondary protection from water, we used a hypodermic needle to inject an acrylic conformal coating product, HumiSeal, into the sensor port. Conformal coating is used on electronics boards to protect them from moist environments, but is not necessarily designed to protect against submergence. The company agreed to donate two sensors to the Team. However, once again this sensor just wasn't accurate enough for the range that we needed, it was meant to tell the change of depth between tens of meters, not one or two.

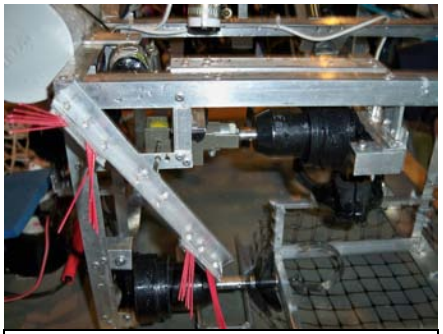
Our final Depth Sensor is mounted on the structure and based on air compression.

Our final and current depth sensor is based on air compression. A simple graduated tube sealed at one end shows the compression of air based on depth. Because there is a fixed amount of air within the tube, as the pressure increases the air will compress and cause water to rise into the tube. The amount of water in the tube is directly proportional to the depth and we have a camera on the labeled tube that allows us to see the change. This is a simple but efficient system that is less prone to damage or failure than our previous methods. The calibration marks on our tube are based on how many meters the ROV is below the surface.

CHALLENGES FACED

A major challenge we faced this year was developing a working depth sensor. We ran through many ideas and prototypes, and have had to go back to the drawing board several times in order to get the compression-based depth sensor we have today. Our initial idea was to have two metal plates attached to conductive foam, and the pressure in the water would compact the foam and make more contact points. This idea failed due to the variability in the foam's conductivity not being constant for each depth check, making it impossible to find a correlation between depth and resistance. Our next idea was to use an electronic board used to measure depth in dive watches. We waterproofed the board by encasing it with epoxy with only the pressure input exposed. This also had immense variation in output, which didn't work for our purposes. The current iteration of our depth sensor is a tube with graduations that is sealed on one side, which reads pressure based on the compression of the air trapped in the tube. As the air compresses, water rises into the tube and we can tell the depth based on the amount of water in the tube.

Another challenge faced was how to spin the valve the required 1080 degrees. We debated between a variety of methods, everywhere from air or water-powered fans to pneumatic rotary actuators. Eventually, we decided to go with a bilge pump attached to a gear reduction motor. The advantages of this design were that it was water-proofed, reliable, and relatively inexpensive. However, as we began testing the spinning mechanism device, we found that given the mounting location, there were very few possible camera angles to see the device, and it was very hard for the pilot to actually know when the prongs were within the wheel. As such, our pilot was forced to simply try turning the wheel with our manipulator, and, to our surprise, he found that he could turn the valve with the manipulator faster than with our low-geared spinning mechanism. As such, it was a simple choice for us to remove the spinning mechanism in its entirety and have the pilot turn the valve with the manipulator instead.


Original Spinning Mechanism

TROUBLESHOOTING TECHNIQUES

Although it is very important to solve problems after they occur, we actually put a lot of time into anticipating possible problems and then solving them *before* they occurred. To do this, we conducted a Failure Mode Effects Analysis (FMEA) on items that we felt had a potential for failure. What this did was determine: the overall risk factor of an item based off of the potential occurrence of a failure, the ability to detect the failure, and the severity of the possible failure. From these three values we came up with a Risk Priority Number (RPN), which if we felt was too high we had to implement some change in order to bring the number down to As Low As Reasonably Practicable (ALARP). On page 20 we have a sample potential FMEA on the risks of having our motor controllers on board the ROV in a special water-proof capsule. The result of this FMEA was that the RPN was too high, and as such we decided to have our electronics at the surface instead of on board the ROV.

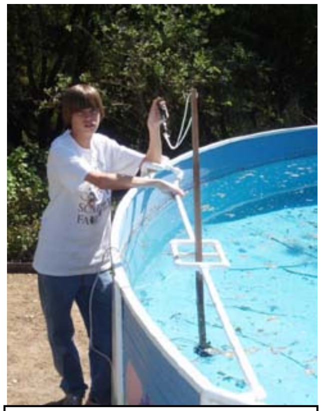
However, there are always unforeseeable problems that can occur. To troubleshoot the problems that arise during our mission runs, we usually begin with the same general methods. It is a three step approach that starts with the ROV and moves its way into the control system.

1. Our first step is to analyze the item in question on the ROV. From there we can usually determine what the problem is rather quickly. For example, if something is obviously broken then we know we must repair or replace it, or if propellers are rubbing against their cages we know that we must adjust the motor cages. The majority of our problems are solved in this manner.
2. If we are unable to solve our problem in Step 1, we then take a look at our computer display. Our display—initially an attempt at aesthetics—has transformed itself into a powerful tool of troubleshooting. From our bar graphs we can discern whether our signal is actually being conveyed through the Pololu motor controllers. Usually the obstacle is merely a bug between the software and the hardware, so we can fix it by resetting our power supply. The other components of our display are error messages. By communicating with the built in error detector in the motor controllers, we receive the list of items going wrong. From there, we can deduce a logical method to solve our problem. If the temperature is too high, we'd let it cool down. If we are drawing too much current, we would check to see if we have a short. Most of our software-hardware problems are solved this way.
3. If none of the previous strategies are able to find the problem, the next step would be to open the control box. Once inside, we would look for error lights on the motor controllers, faulty connections, or strained or loose wires. The error lights tell us if there is a problem with the motor controllers themselves, and from there we can plug into the motor controller in question directly via USB, and it can tell us what is wrong. If the problem is a bad connection, we can follow the pathways of the connections and solder or re-solder wires appropriately. If necessary, we could even make new pathways to maximize efficiency and minimize possible hazards.

DESIGN OPTIMIZATION: Propellers

For the Alien Mk II, we did a series of tests to decide which propeller we should use for our motors. We measured both the speed of the propellers and the thrust they provided. To determine speed, we measured the time it took for each motor / propeller combination to travel across a swimming pool. Fishing line was strung from one end of the pool to the other to define a path. The motor was attached to a wooden mount with two eye screws attached as guides. To measure the thrust, a wooden board was mounted on a pivot with the motor on one end and a force gauge attached to the top gives the actual thrust of the motor.

We tested a total of five propellers that were purchased from various hobby shops. None of the propellers came with specifications so we measured the diameter and pitch of each. After testing, it was clear that the standard two-blade props we used last year were the best out of the five that we tested. It had the highest average speed and thrust in forward and reverse by a long shot, and the amp draw was middling.



Nathaniel measuring propeller thrust

FUTURE IMPROVEMENTS

On future ***Alien*** models there are a variety of changes that we would to improve the overall performance of the ROV. The changes are all related to our motor control system, as this was this portion of the ROV that gave us the most trouble this year.

- We would like to add a trim control in the software so that the driver could set the trim and not worry about keeping the ROV still.
- To avoid shorting out the motor controllers we would institute an operations check and not touch them until wearing a grounding bracelet to prevent static from killing the board.
- We would double check the motor controllers before first powering them up so that we don't fry them before they are even tested.
- To avoid the chance of poor assembly on our part, we would either buy all the boards with the connectors preassembled or do a better job of quality assurance to avoid making mistakes in the assembly of the boards.

			Speed Test				Thrust Test			
			Fwd	Rev	Fwd	Rev	Fwd	Rev	Fwd	Rev
Prop Type	Diameter	Pitch	Avg Speed	Avg Speed	Avg Motor Amps	Avg Motor Amps	Avg Thrust	Avg Thrust	Avg Motor Amps	Avg Motor Amps
Blade Count	*(mm)*	*(mm)*	*(m/sec)*	*(m/sec)*	*(A)*	*(A)*	*(kg)*	*(m/sec)*	*(A)*	*(A)*
2-Aluminum	68	25	1.5	1.0	7.5	7.3	0.7	0.4	7.3	7.1
2-Standard	55	20	1.6	1.2	6.4	6.1	0.8	0.5	6.5	6.2
3-Standard	55	25	1.1	0.8	6.9	7.6	0.7	0.4	7.9	7.2
2-Rounded	45	18	1.6	1.0	5.3	5.3	0.5	0.4	5.5	5.4
3-Rounded	60	12	1.4	0.7	5.8	5.1	0.7	0.3	5.5	4.9

Figure 8. Propeller Thrust Tests

LESSONS LEARNED

This year we experimented and gained a solid grasp over applied programming. Though some of us had preexisting knowledge of programming, the scope of the project demanded a far larger vocabulary than we had at the time. However this year, because of our motivated mentors and members, we were able to develop programming to direct the movement of the R.O.V. in its entirety— including its motors and auxiliary tools—by manipulating an Xbox controller. Learning programming was definitely a highlight of the skills we learned working on the Alien MK II. We learned to upgrade from an analog board system—in which the boards relay on-off messages rapidly—to a digital motor controller that gave us the power to have a float (a variable) value assigned to the activation speed of devices (such as motors). This allowed us to have an immensely intuitive control system (F.P.S. Mode).

One of the most important things we learned this season, aside from our newfound technical skills, was our ability to function and work as a team. For many of us, this is our second year as a team competing in the MATE Center program. Prior to joining the team, most of did not know each other and we didn't socialize together. Over the course of the last two years, we have coalesced as a team. We have learned to respect each other for our unique strengths and our colorful personalities. We have become much more than teammates, we have become friends.

REFLECTIONS

I have enjoyed being able to build on each successive year competing in the MATE Competition. Each year I have learned more about leadership, delegation, and technical skills. This season, my senior year, has been the best. It's been rewarding to watch the entire team work together with focus and commitment. It's also been a great experience to challenge ourselves to design and implement a more complex ROV. We are doing things this year that would have been impossible for us to envision, let alone accomplish just a few years ago. ***Connor Munger – Senior (Fifth year MATE Competitor)***

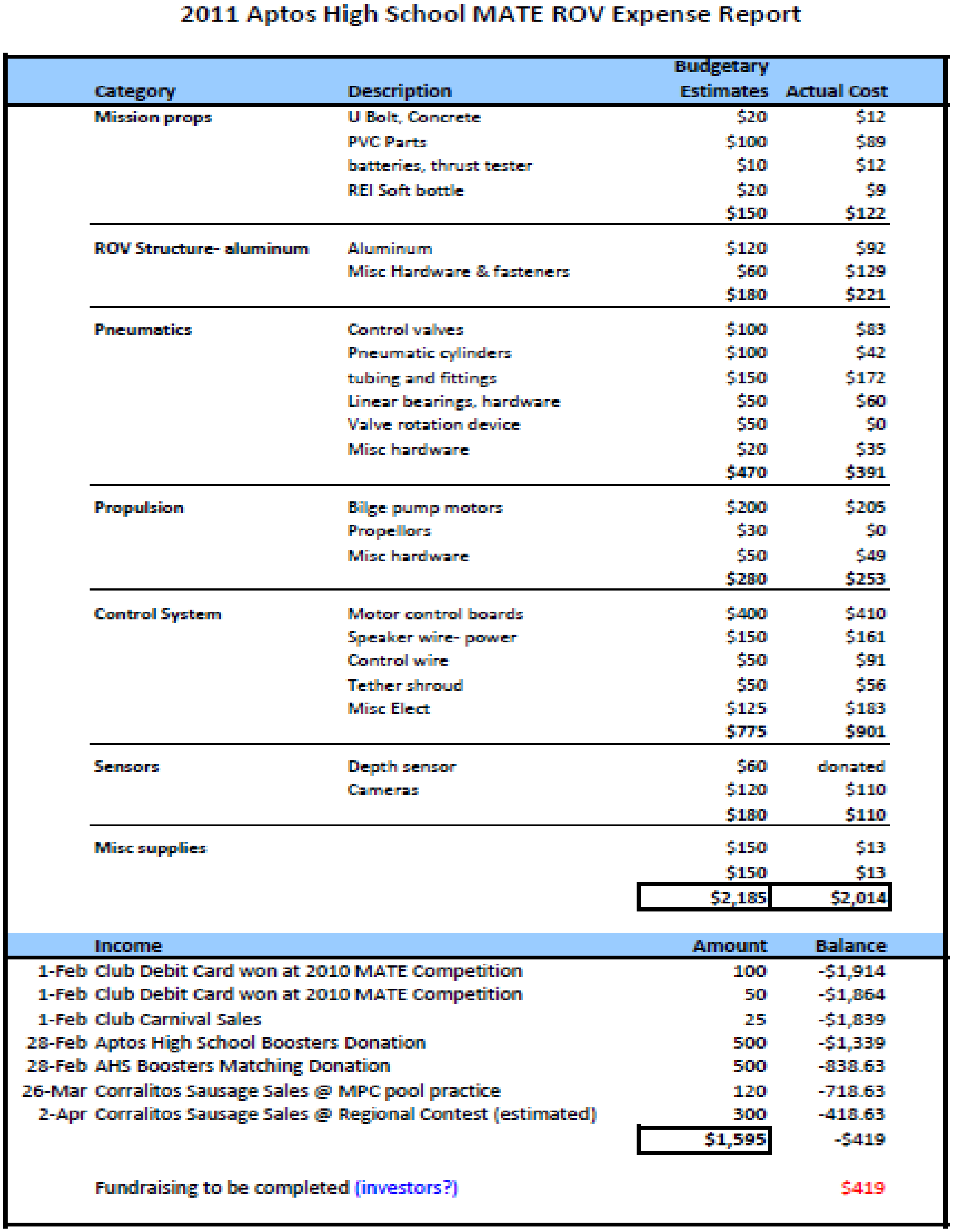
In previous years, I felt that there were a few of us that had to oversee every single project for anything to get done. However, this year our team really improved, and we were able to delegate tasks to team members, put our attention elsewhere, and then have those tasks completed to perfection. This is an awesome feeling, knowing that you have a terrific team behind you, each person with their own unique talents and areas of expertise, and everyone willing to put in the time and energy that's required to get the jobs done. ***Isaac Cassar – Senior (Fourth Year MATE Competitor)***

The most rewarding part of participating in the MATE Competition is the various skills I have acquired and knowledge I've gained. By working on an ROV from year to year, I have gained the experience necessary to work on various other projects of my own. I have learned how to correctly solder, work with aluminum angle, and utilize various other advanced construction techniques. Working on all sorts of mechanical/structural projects is a great passion of mine, and the experience I have gained by participating in the competition will prove invaluable and stay with me for the rest of my life. ***Adam Simko – Senior (Fourth Year MATE Competitor)***

THE BALANCE SHEET

One of our key goals this year was to accurately budget for and plan out our ROV to keep costs to a minimum. Our initial budget for the project was $2,185. The actual cost for our ROV was $2014. We are pleased to report that we completed our project $171 under budget. As of this report, we still need to raise $419 to cover our costs.

Based on our knowledge and experience, we feel that we could duplicate our ROV for a cost of $1,500.



2011 Aptos High School MATE ROV Expense Report

Category	Description	Budgetary Estimates	Actual Cost
Mission props	U Bolt, Concrete	$20	$12
	PVC Parts	$100	$89
	batteries, thrust tester	$10	$12
	REI Soft bottle	$20	$9
		$150	$122
ROV Structure- aluminum	Aluminum	$120	$92
	Misc Hardware & fasteners	$60	$129
		$180	$221
Pneumatics	Control valves	$100	$83
	Pneumatic cylinders	$100	$42
	tubing and fittings	$150	$172
	Linear bearings, hardware	$50	$60
	Valve rotation device	$50	$0
	Misc hardware	$20	$35
		$470	$391
Propulsion	Bilge pump motors	$200	$205
	Propellors	$30	$0
	Misc hardware	$50	$49
		$280	$253
Control System	Motor control boards	$400	$410
	Speaker wire- power	$150	$161
	Control wire	$50	$91
	Tether shroud	$50	$56
	Misc Elect	$125	$183
		$775	$901
Sensors	Depth sensor	$60	donated
	Cameras	$120	$110
		$180	$110
Misc supplies		$150	$13
		$150	$13
		$2,185	$2,014

	Income	Amount	Balance
1-Feb	Club Debit Card won at 2010 MATE Competition	100	-$1,914
1-Feb	Club Debit Card won at 2010 MATE Competition	50	-$1,864
1-Feb	Club Carnival Sales	25	-$1,839
28-Feb	Aptos High School Boosters Donation	500	-$1,339
28-Feb	AHS Boosters Matching Donation	500	-838.63
26-Mar	Corralitos Sausage Sales @ MPC pool practice	120	-718.63
2-Apr	Corralitos Sausage Sales @ Regional Contest (estimated)	300	-418.63
		$1,595	-$419
	Fundraising to be completed (investors?)		$419

DISASTER IN THE GULF


Deepwater Horizon before the explosion Source: Wikipedia

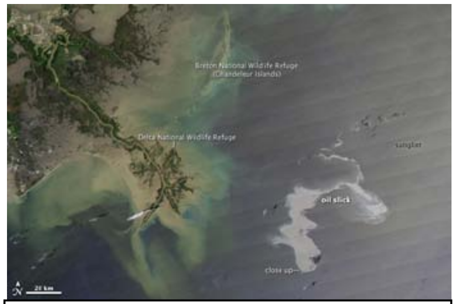
The United States is the largest consumer of oil in the world, using in excess of 21 million barrels of oil per day. Over 30% of the energy used in the United States comes from oil. As America's thirst and dependence on oil has increased, so has its dependence on foreign oil. In 1980, only 28% of oil consumed in the US was imported. Today, nearly 60% of the oil used in the US is imported. As domestic supplies of oil have diminished, domestic oil companies have been forced to seek oil in places once thought impossible. One source of oil has been found nearly 5,486 Meters below the Gulf of Mexico, where the water depth can exceed 1,524 Meters. These deep water oil wells are expensive to drill and potentially dangerous.


Deepwater Horizon after the explosion

The danger of these deep water oil wells was painfully demonstrated on April 20, 2010, when an explosion rocked the Deepwater Horizon oil rig, owned by Trans Ocean in the Gulf of Mexico. The new rig was preparing to pump oil in more than 1,500 M of ocean. The explosion killed 11 men and injured 17 others, and created an economic and natural disaster. According to the New York Times, "nearly five million barrels of oil flowed from BP's well, an amount outstripping the estimated 3.3 million barrels spilled into the Bay of Campeche by the Mexican rig Ixtoc I in 1979." The well was finally sealed nearly five months later after many efforts on September 19th 2010.


Ecological impact from the Oil Spill Source: UPI.com

The Deep Horizon oil rig demonstrated the vulnerability of these deep water oil rigs. Officials were not prepared to deal with a disaster of this magnitude and did not have an effective disaster plan in place. Remotely operated vehicles (ROV's) were vital to the success of the repair operations. ROV's were used to first diagnose and view the broken blow out preventers and were vital to the various repair attempts and eventual capping of the well head.



Deepwater Horizon oil slick from space Source: NASA

The impact of the oil spill will be felt for years. The spill caused extensive damage to marine and wildlife habitats as well as Gulf fishing and tourism industries. Over 320 miles of shoreline were impacted. Nearly a year after the disaster, tar balls are still fouling beaches, crude oil is still found along shorelines and marshes, and ROV's have detected large sheets of oil on the bottom of the sea floor.

The goal of Aptos Mariners Robotics, LLC is to provide a safe, reliable, inexpensive and speedy solution for problems such as these. It is clear that more deep water wells will be drilled and operated in our oceans and we need to ensure that oil companies have a safe and effective means of repairing and preventing disasters in the future. ROV's will continue to play a key role in the deep water oil industry for a long time to come.

ROV working on the blow out preventer Source: www.maddowblog.msnnbc.m

Workers cleaning oil on a Gulf beach. Source: www.aviewfromtheright.com

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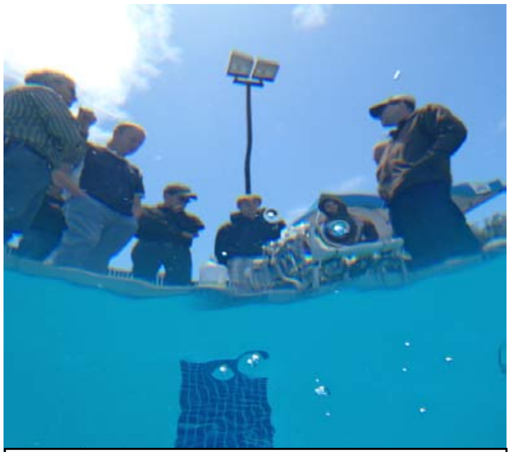
- Marine Advanced Technology Education Center (MATE)
- Mr. Casey O'Brien, our Principal, and Aptos High School for the use of the school pool and facilities
- Mr. Joe Manildi, our staff advisor, and the entire Aptos High Robotics Club
- Dan Atwell, retired engineer, for his feedback, donations, input and interest in our ROV!
- The Aptos Booster Club, for their financial support of our ROV
- Mr. Willy, Mr. Munger, Mr. Randolph, Mr. Pico and Mr. Cassar for their guidance and support throughout this project
- The Willy and Carlos Family for the use of their garage workspace
- Mr. Jim Triplett, the Aptos High School Swim Team Coach, for sharing the pool with our ROV
- Mr. Jamie Thompson, for his help in teaching us how to use SolidWorks
- All of our parents and families for their patience, encouragement and support for our Team and our ROV project. Thank you especially for feeding us during our long work sessions!!!



The Alien MKII keeps an eye on our Mentors!

APPENDIX

ELECTRICAL SCHEMATIC

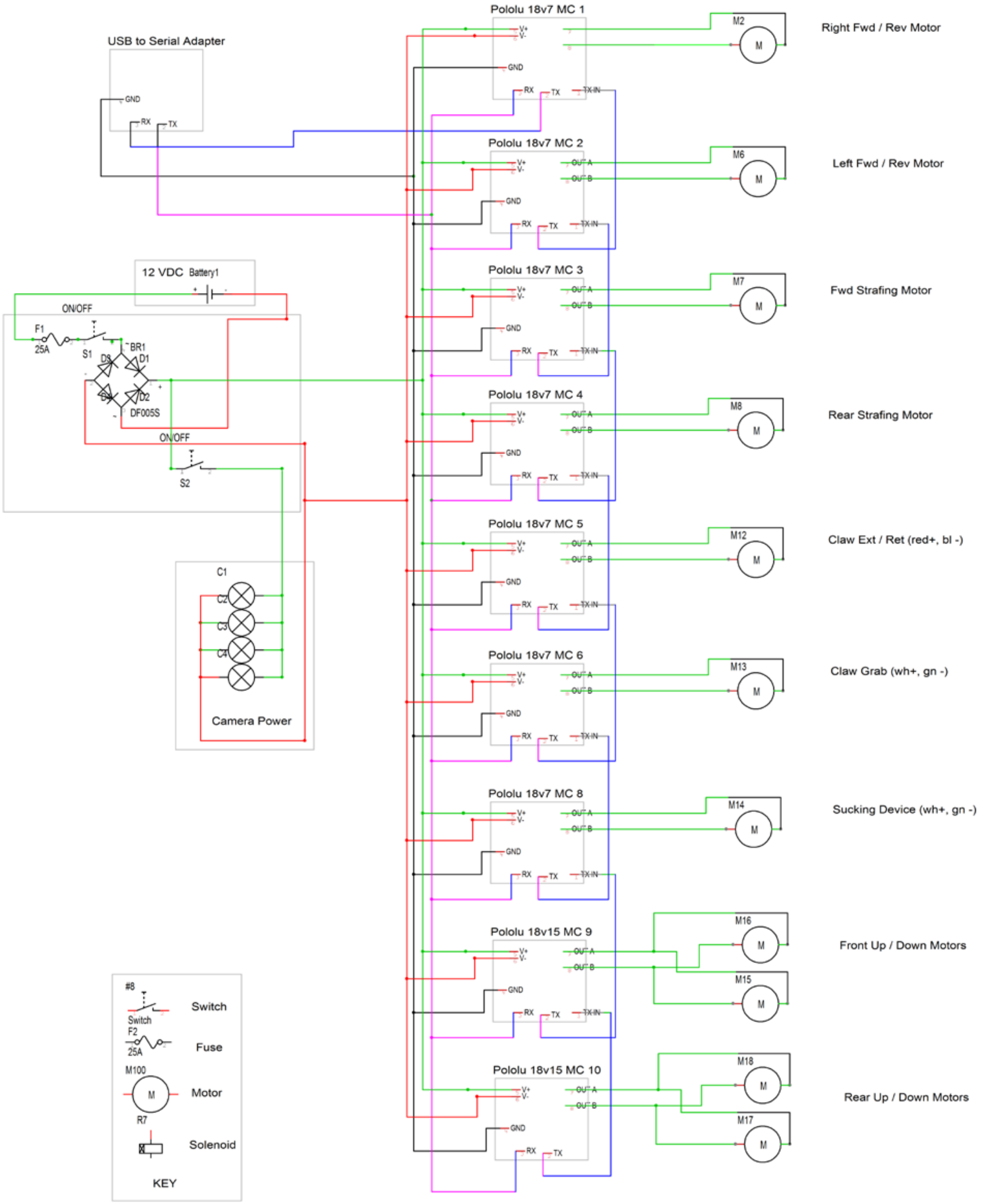
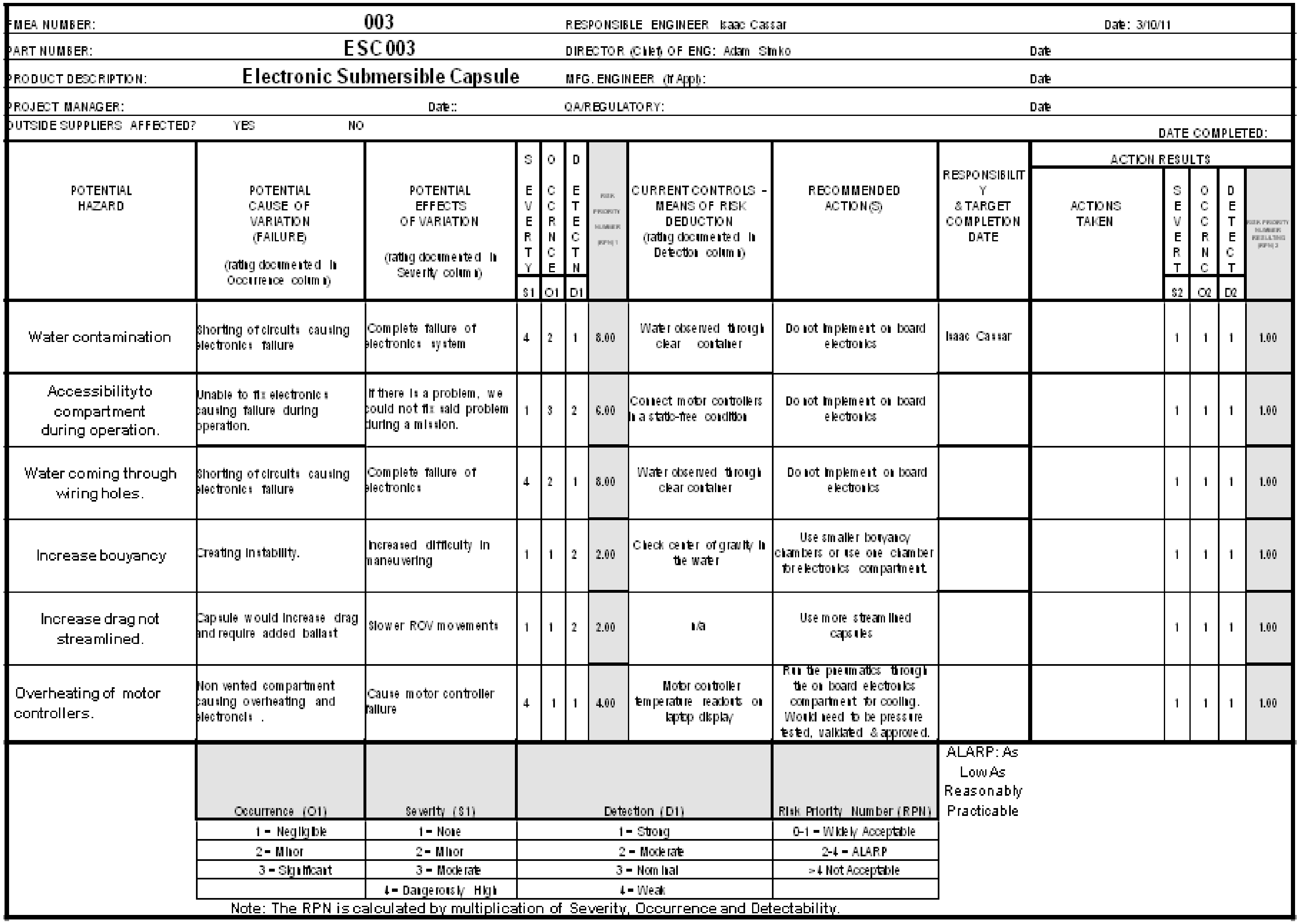


Figure 9: Electrical Schematics

FAILURE MODE EFFECTS ANALYSIS



FMEA NUMBER:	003	RESPONSIBLE ENGINEER Isaac Cassar	Date: 3/10/11
PART NUMBER:	ESC 003	DIRECTOR (Chief) OF ENG: Adam Simko	Date
PRODUCT DESCRIPTION:	Electronic Submersible Capsule	MFG. ENGINEER (If Appl):	Date
PROJECT MANAGER:	Date::	QA/REGULATORY:	Date
OUTSIDE SUPPLIERS AFFECTED?	YES NO		DATE COMPLETED:

POTENTIAL HAZARD	POTENTIAL CAUSE OF VARIATION (FAILURE) (rating documented in Occurrence column)	POTENTIAL EFFECTS OF VARIATION (rating documented in Severity column)	SEVERITY S1	OCCRNCE O1	DETECTN D1	RISK PRIORITY NUMBER (RPN) 1	CURRENT CONTROLS - MEANS OF RISK DEDUCTION (rating documented in Detection column)	RECOMMENDED ACTION(S)	RESPONSIBILITY & TARGET COMPLETION DATE	ACTION RESULTS				
										ACTIONS TAKEN	SEVERT S2	OCCRNC O2	DETECT D2	RISK PRIORITY NUMBER RESULTING (RPN) 2
Water contamination	Shorting of circuits causing electronics failure	Complete failure of electronics system	4	2	1	8.00	Water observed through clear container	Do not implement on board electronics	Isaac Cassar		1	1	1	1.00
Accessibility to compartment during operation.	Unable to fix electronics causing failure during operation.	If there is a problem, we could not fix said problem during a mission.	1	3	2	6.00	Connect motor controllers in a static-free condition	Do not implement on board electronics			1	1	1	1.00
Water coming through wiring holes.	Shorting of circuits causing electronics failure	Complete failure of electronics	4	2	1	8.00	Water observed through clear container	Do not implement on board electronics			1	1	1	1.00
Increase bouyancy	Creating instability.	Increased difficulty in maneuvering	1	1	2	2.00	Check center of gravity in the water	Use smaller bouyancy chambers or use one chamber for electronics compartment.			1	1	1	1.00
Increase drag not streamlined.	Capsule would increase drag and require added ballast	Slower ROV movements	1	1	2	2.00	n/a	Use more streamlined capsules			1	1	1	1.00
Overheating of motor controllers.	Non vented compartment causing overheating and electronics .	Cause motor controller failure	4	1	1	4.00	Motor controller temperature readouts on laptop display	Run the pneumatics through the on board electronics compartment for cooling. Would need to be pressure tested, validated & approved.			1	1	1	1.00

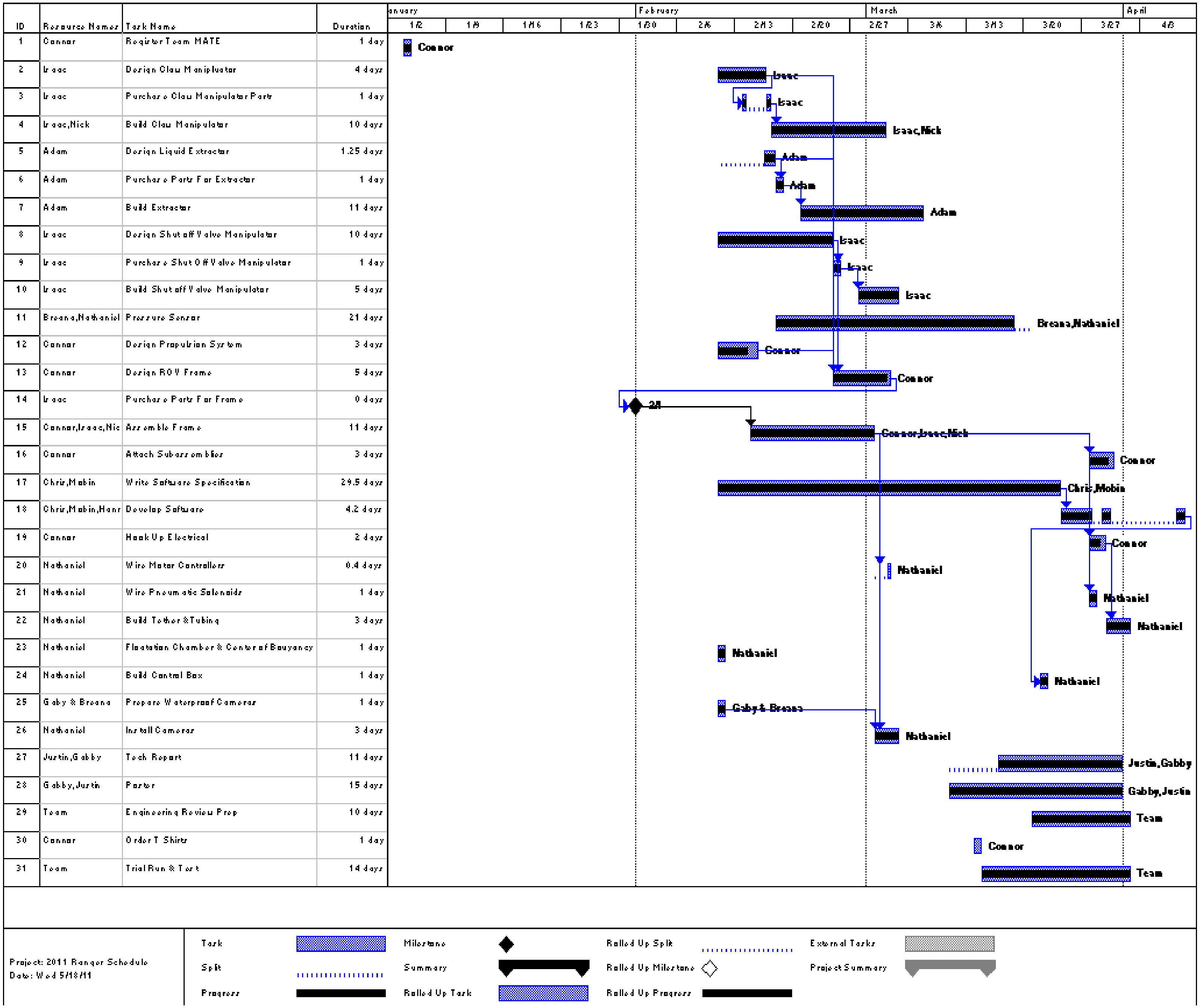
Occurrence (O1)	Severity (S1)	Detection (D1)	Risk Priority Number (RPN)
1 = Negligible	1 = None	1 = Strong	0-1 = Widely Acceptable
2 = Minor	2 = Minor	2 = Moderate	2-4 = ALARP
3 = Significant	3 = Moderate	3 = Nominal	>4 Not Acceptable
	4 = Dangerously High	4 = Weak	

ALARP: As Low As Reasonably Practicable

Note: The RPN is calculated by multiplication of Severity, Occurrence and Detectability.

Figure 10: Failure Mode Effects Analysis

MICROSOFT PROJECT OUTLINE



ID	Resource Names	Task Name	Duration
1	Connor	Register Team MATE	1 day
2	Isaac	Design Claw Manipluator	4 days
3	Isaac	Purchase Claw Manipulator Parts	1 day
4	Isaac,Nick	Build Claw Manipulator	10 days
5	Adam	Design Liquid Extractor	1.25 days
6	Adam	Purchase Parts For Extractor	1 day
7	Adam	Build Extractor	11 days
8	Isaac	Design Shut off Valve Manipulator	10 days
9	Isaac	Purchase Shut Off Valve Manipulator	1 day
10	Isaac	Build Shut off Valve Manipulator	5 days
11	Breana,Nathaniel	Pressure Sensor	21 days
12	Connor	Design Propulsion System	3 days
13	Connor	Design ROV Frame	5 days
14	Isaac	Purchase Parts For Frame	0 days
15	Connor,Isaac,Nic	Assemble Frame	11 days
16	Connor	Attach Subassemblies	3 days
17	Chris,Mobin	Write Software Specification	29.5 days
18	Chris,Mobin,Henr	Develop Software	4.2 days
19	Connor	Hook Up Electrical	2 days
20	Nathaniel	Wire Motor Controllers	0.4 days
21	Nathaniel	Wire Pneumatic Solenoids	1 day
22	Nathaniel	Build Tether &Tubing	3 days
23	Nathaniel	Floatation Chamber & Center of Bouyancy	1 day
24	Nathaniel	Build Control Box	1 day
25	Gaby & Breana	Prepare Waterproof Cameras	1 day
26	Nathaniel	Install Cameras	3 days
27	Justin,Gabby	Tech Report	11 days
28	Gabby,Justin	Poster	15 days
29	Team	Engineering Review Prep	10 days
30	Connor	Order T Shirts	1 day
31	Team	Trial Run & Test	14 days

Project: 2011 Ranger Schedule
Date: Wed 5/18/11

Figure 11: Microsoft Project Outline

MISSION CHECKLIST

Pre-mission setup

- ☐ Make sure the sucker rod is at the correct angle.
- ☐ Don't snag the line from the hook on the ROV.
- ☐ Actuate the sucker a few times to loosen it up.
- ☐ Calculate sample depth.

Remove the damaged riser pipe

- ☐ During descent, turn ROV so that it is facing the side with the Velcro ring.
- ☐ Put hook on the V-bolt and tell Mobin to put on tension.
- ☐ Remove the Velcro strip; be careful not to get the line caught on the ROV.
- ☐ Get out of the way and tell Mobin to pull off the riser pipe.

Cap the oil well

- ☐ Go grab the T -joint; be careful not to get the line caught and get a firm grip.
- ☐ Put the T -joint into the spire all the way before releasing the claw.
- ☐ Turn the wheel 3 times clockwise to close it, in>up>out>down.
- ☐ Drive to the top of the spire and install the cap; don't get tether caught.

Collect water samples and measure the depth

- ☐ Estimate which of the sample locations is at the depth we have to sample from.
- ☐ Go to the sample location and measure depth; put the tube level with the station.
- ☐ Blow out the air from the sucker; check the camera to make sure it worked.
- ☐ Drive over the bucket and get tube inside.
- ☐ Suck out the sample and check the camera to make sure it's full before leaving.

Collect biological samples

- ☐ Grab the pipe with screws first.
- ☐ Next get the crab.
- ☐ Last get the glass sponge, and hold it with the claw extended.
- ☐ Look around make sure none have fallen out, and return to the surface.
- ☐ Touch the side of the pool.

Post-mission collection

- ☐ Grab the animals from the basket before taking the ROV out of the water.
- ☐ Put the tubes into the sample collector and actuate the sucker.

Figure 12: Mission Checklist