Sea-Tech 4-H

Skagit Exploration And Marine Technology 4-H Club

Skagit County 4-H Program – Washington State University Cooperative Extension Office

R·O·V ECLIPSE

Trevor Uptain

Joe Thieman

Benjamin Janicki

Keegan McAdams

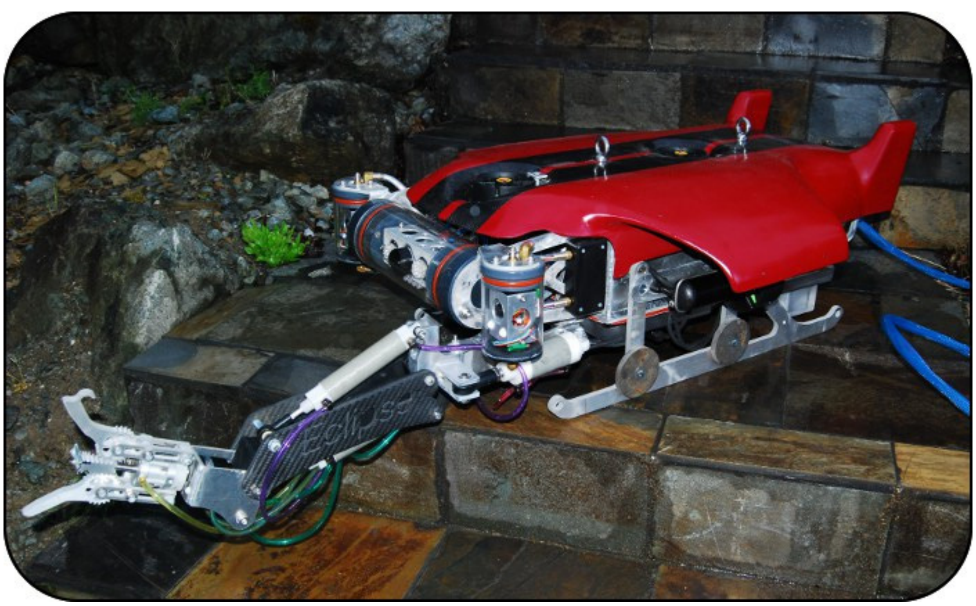
Stanley Janicki

Heather McNeil

Miranda Uptain

Peyton Hasenohrl

Team Mentor: Lee McNeil



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Abstract

The Eclipse ROV is Sea-Tech 4-H Club's entry into the 2010 International ROV Competition, hosted by the Marine Advanced Technology Education (MATE) Center.

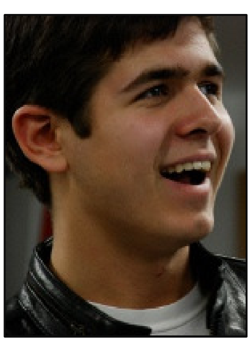
A team comprised of eight members designed and built a Remotely Operated Vehicle (ROV) capable of performing the mission tasks published by the MATE Center. The ROV was designed in UGS NX6 before construction to eliminate as much trial and error as possible. The design utilizes a break-form aluminum frame to mount cameras, thrusters, an electronic and hydraulic pressure housing, a pressure-resistant mission package and a carbon fiber shell. Four high-quality, 24-volt thrusters provide vertical and lateral thrust. A hydraulic power system operates a five-axis manipulator arm with a powerful gripper that is used to manipulate or retrieve objects under water. The main camera assembly tilts through 360 degrees of vertical rotation to allow for a comprehensive field of vision. On both sides of the main camera is a secondary camera that rotates 360 degrees horizontally. High-density polyurethane foam is mounted to the top of the pressure hull for flotation.

The ROV systems were designed and assembled by the team, using student-made custom parts and electrical components, hydraulic systems, sensors, and a limited set of donated parts. The competition theme, "ROVs in Treacherous Terrain: Science Erupts on Loihi, Hawaii's Undersea Volcano" provided an opportunity for the Eclipse team to experience the challenges of working in a real-life environment and applying real-world challenges to the design and construction of their machine.

1. Team Eclipse

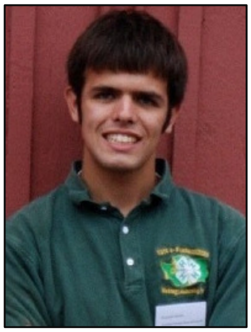
Trevor Uptain
Team Role: Team captain, arm controller, engineering facilitator
Competition Role: Mission Commander

Trevor has participated in Sea-Tech for seven years. He has worked on six different ROVs, and led the team to a third place victory in the 2009 International MATE ROV competition. With a focus on the competition's engineering logistics, he spearheaded the technical report and worked on a variety of systems on the ROV. He is graduated and aspires to achieve a Master's degree in Business Administration.



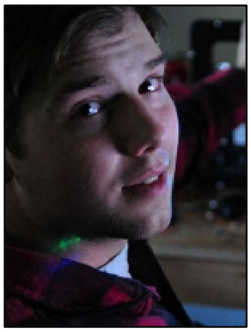
Stanley Janicki
Team Role: Co-captain, sensors, CAD model, carbon fiber shell
Competition Role: Co-Captain

With three years of experience building ROVs in Sea-Tech, Stanley is a task-orientated leader with schedule efficiency as his top priority. Proficient with CAD modeling, he accomplished the goal of creating a detailed, accurate and precise model of the entire ROV. He is currently is in the ninth grade as a home-schooled student.



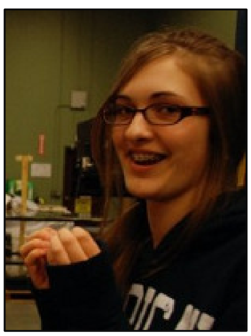
Benjamin Janicki
Team Role: Mechanic, general assembly, poster display
Competition Role: Tether Manager

Benjamin, 18, is a focused member of the team who enjoys mechanical work and learning about new technologies. He attends Skagit Valley college as a Running Start student, and is transferring to the University of Washington this fall to obtain a degree in Engineering.



Joe Thieman
Team Role: Electronics
Competition Role: Pilot

Joe Thieman found a keen interest in electronics at a young age, and built his first robot from scratch at age 12. At 14, he began programming, and has continued to expand his knowledge of electronic and microprocessor control systems ever since. Joe has achieved his goal this year of building the most complex control system ever installed in a Sea-Tech ROV.

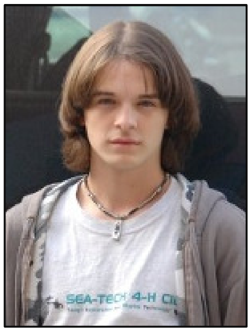


Heather McNeil
Team Role: Cameras, lighting, front chassis
Competition Role: Mission Specialist

Heather, 15, is a home school student and fortunate to be the mentor's daughter. This has given her the opportunity to learn about engineering first hand. She enjoys math and has been able to apply those skills to real-life applications on Team Eclipse. This is her fifth year in Sea-Tech, and her fifth ROV project. Three of those years have been spent participating in the MATE competition.

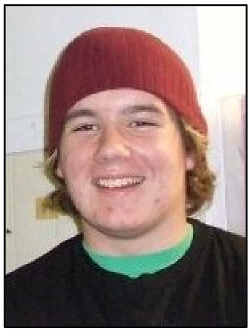
Miranda Uptain
Team Role: Technical compilation, general assembly
Competition Role: Engineering Specialist

Miranda is a new addition to the Explorer Team, but has participated in building Ranger Team ROVs for the past three years. She is interested in writing and used this interest to help compile and write the technical report. She also contributed in the mechanical construction of the ROV. Miranda is currently a home schooled student in the 11^{th} grade and intends to further her career in music and writing.



Peyton Hasenohrl
Team Role: Mechanic, general assembly, general construction

Peyton is on his way to a mechanical engineering degree, inspired by his 6 years of working on ROVs in Sea-Tech**.** He is 18 years old and has recently graduated high-school. Peyton enjoys spending time in the shop doing construction on the ROV.



Keegan McAdams
Team Role: Mechanic, general assembly, general construction

Keegan attends Skagit Valley College, where he is in the final quarter of completing his Associate of Arts Transfer Degree. This will be the fourth year Keegan has been participating with the MATE competition through Sea-Tech, and he has been building ROVs in the club since 2004. He has had the opportunity to experience many different jobs this year on the team, including the construction and layup of the carbon fiber shell, hydraulic plumbing, and construction of the arm and claw.

2. Design Rationale

2.1 Mission Oriented

Design Goals
ROV Eclipse is designed as a working platform capable of specific tasks. At its core, the ROV is constructed of a break-form, aluminum frame, to which is mounted propulsion, cameras, payload tooling, sensors, and covered by a hydrodynamic, carbon fiber shell. All of the tooling attached to the machine was designed to complete a set of mission guidelines published by the Marine Advanced Technology Education (MATE) Center for their 2010 ROV Competition. This tooling includes:

- A hydraulic-powered arm capable of performing every mission task
- A hydrophone to measure sound
- A sensor to measure temperature under the water
- A set of three cameras for navigation, as well as to view and record the missions as they are completed

2.2 CAD Modeling

From previous experience building ROVs, the team realized at the beginning of the year that designing the ROV in a CAD modeling program before construction would greatly increase building efficiency. They made it their goal to design the entire machine and its subsystems in CAD. The team had access to UGS NX6 for mechanical design, and utilized 3D Studio Max for photorealistic renderings.

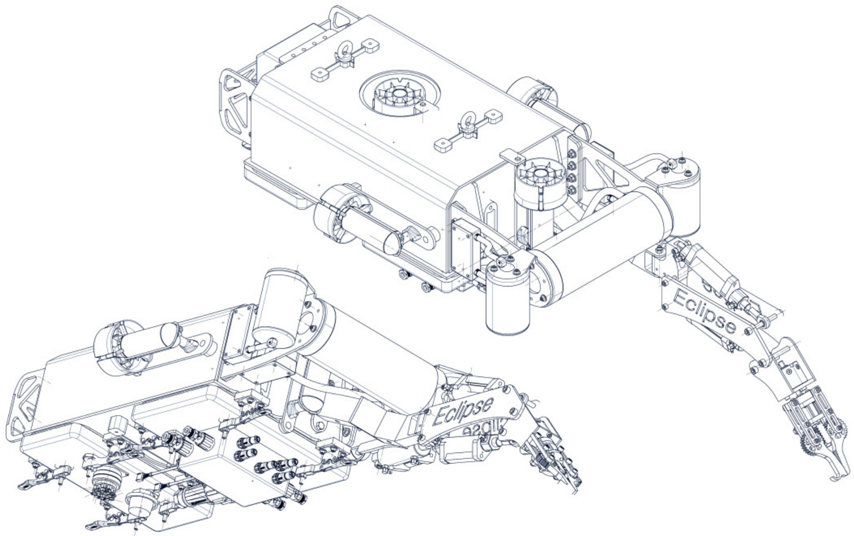


Figure 1 – A perspective view of the ROV designed in UGS NX6

To date there are over 350 hours into the CAD model. It contains over 1200 solid bodies and over 200 part files. Its extreme accuracy was important for various subsystems such as the shell, which was machined on a CNC mill per the design of the model.

Utilization of the model was very successful, not only in increasing design efficiency, but in allowing each member to add input to and understand every design aspect of the vehicle.

2.3 Mechanical Structure

Pressure Hull

The structure of ROV Eclipse is a welded, aluminum pressure hull. The 3/16” aluminum was cut to fit, then secured with a marine-grade weld. An aluminum cylinder is welded in vertically to provide a duct for the rear vertical thruster, while the second thruster is attached to the front of the hull to eliminate the need for a duct. The box is separated into two separate compartments. The front compartment houses the electronics, and the rear houses the hydraulic system. The bottom of the box has two rectangular openings cut out of it for access to the compartments. Each one is sealed by a cast acrylic lid fitted with an O-ring and four over-center toggle clamps. This design provides easy access to the electronics and hydraulic systems and support to the various subsystems on the ROV.

Figure 2 – Pieces of the pressure hull before being welded

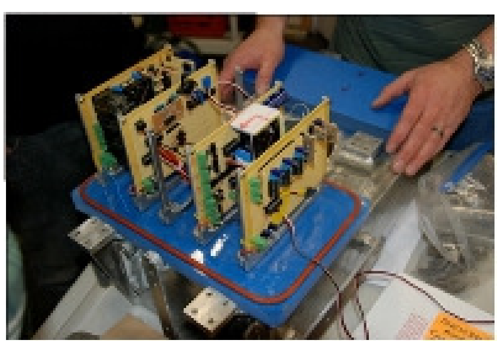


Figure 3 – The electronic boards mounted to the card holders

All of the electronics are mounted to the underside of one acrylic lid. Four boards, which include the control system, the fly-by-wire systems, and the sensor control circuitry, are mounted vertically by custom-designed, sliding card holders. Communications to the cameras, lights, thrusters, and surface are routed out of the lid into a housing which contains removable, waterproof connectors. The housing was made by bonding a stack of three pieces of acrylic, with holes drilled and tapped for the connectors. The housing was then machined to create an opening on one end, forming a box-like shape. After the connectors were fitted inside, the opening was filled with a potting compound to seal the connections. The housing was then bonded to the lid.

Flotation

The ROV is designed to be neutrally buoyant with a strong righting moment. A 12.5mm layer of foam mounted to the top of the ROV, as well as the camera and hydraulic housings, are positively buoyant. The payload tooling, shell, and pressure housing are close to neutrally buoyant. Skids mounted to the bottom of the ROV are negatively buoyant. In case of modifications, an attachment is bolted to the rear of the ROV allowing for the attachment of foam for additional flotation. This basic concept of flotation on top and weight on bottom provides the very essential, yet often overlooked righting moment necessary for stability.

Shell

This year, due to a generous donation of materials and workspace from a local company, the team had the opportunity and ability this year to create a resin-infused, carbon fiber shell to encase ROV Eclipse. The shell was built for hydrodynamics as well as aesthetic value. Before designing the shell, the team visited the company to do a carbon fiber layup test. The successful test determined that carbon fiber would be an excellent material to use due to its strength, light weight, and ease of machining.

Figure 4 – The team wraps plastic sheeting around the mold to create a vacuum

The shell was designed completely in a CAD modeling program by a team member. It is designed in two halves, top and bottom, that fit one over the top of the other. The side fairings were machined separately. The mold pieces were cut out in high-density polyurethane foam on a CNC mill. Team members actively participated in writing the executable file for the machining of the foam. These molds were then inlaid with a release agent and sheeting, followed by sheets of carbon fiber. They were then placed in a vacuum and injected with resin. After the resin hardened, the shell was removed by cutting the foam block in half and separating the pieces. Resin-soaked carbon fiber sheets were used to attach the side fairings and repair any inconsistencies in the shell. After the shell was sanded, it was painted and finished with a clear coat. These processes were all done with little or no assistance from the company employees. Team members put a combined total of over 300 hours into the construction of the shell.

Figure 5 – The finished carbon fiber shell

2.4 Tooling

Arm Structure

Eclipse bears a bilateral, hydraulic powered arm with a specialized manipulator attached to the end. The arm was cut from carbon fiber and aluminum, using the water jetting service graciously provided by Janicki Industries. However, the CAD modeling required for the process was done entirely by Eclipse team members. Access to this technology allowed the design to integrate a more elaborate shape and unique features, such as the cutout of the team's name in the arm pieces.

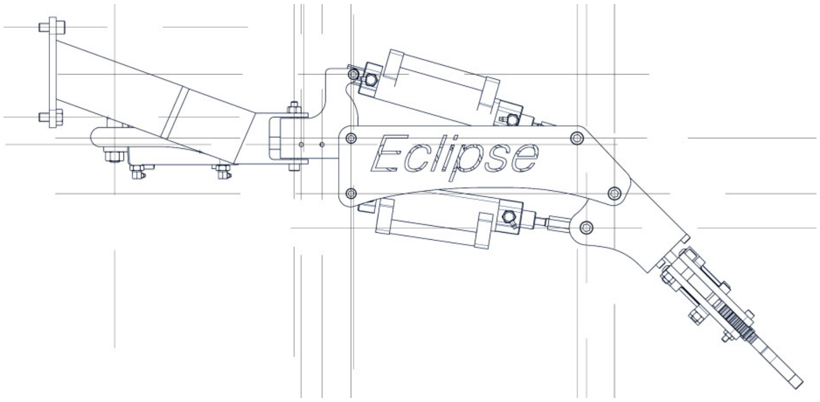


Figure 6 – A CAD model of the hydraulically powered arm

On previous Sea-Tech ROVs, the standard design incorporated two robotic arms with limited functionality in order to accomplish the missions. This year, due to the size of the hydraulic valves, the team decided to build a single, more dexterous arm. The arm uses three hydraulic actuators to achieve three movements. The first actuator provides side-to-side movement from the shoulder joint. The second actuator controls the vertical motion of that same shoulder joint. The third actuator controls the extension and flexion of the lower arm section. Fitted foam is sandwiched between the upper and lower arm pieces to achieve neutral buoyancy. This prevents the ROV's center of gravity from being affected by the movement of the arm.

Payload Tooling

The missions for the 2009 competition require specialized manipulators in order to complete the specified tasks efficiently. The challenge was to tailor the manipulator to perform the missions while still maintaining adaptability and versatility for generic use. A revolving hydraulic cylinder provides 270 degrees of rotary motion, while a single-acting cylinder provides lateral movement. The claw is machined from ½" and 3/8" aluminum and utilizes a gear system to shut the claw, and a tension spring acting in the opposite direction, to open it. A hook is incorporated on one claw to complete Task #1, Mission #1, *Remove two pins to release the High Rate Hydrophone (HRH).*

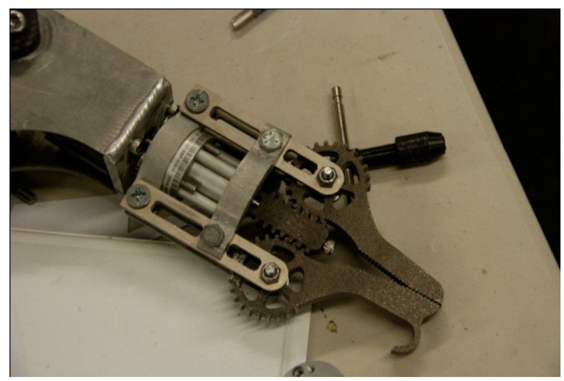


Figure 7 – The finished claw

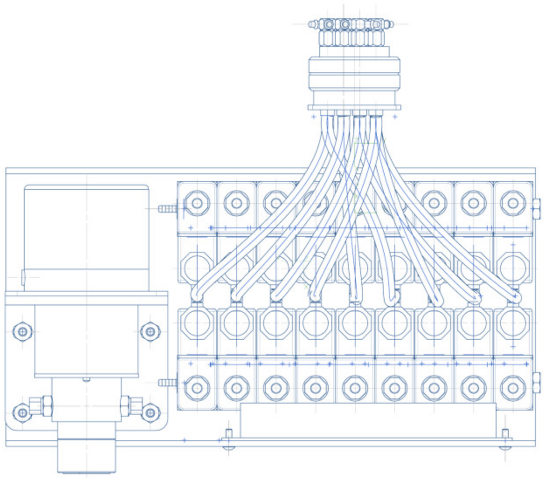


Figure 8 – A CAD model of the layout of the hydraulic box

Although the tooling on ROV Eclipse is built specifically to perform the published competition missions, it is designed so that claw pieces can be easily swapped without re-building the entire arm. This is useful in future projects, where we might wish to accomplish a task that the current manipulator cannot accommodate.

Hydraulic Systems

The arms utilize a low-pressure, water hydraulics system. The system is powered by a miniature, stainless steel pump, which can develop 115 PSI. The design uses 2-way, normally closed, isolated valves rated for air, oil or water. Four valves power each actuator for discreet positioning. The entire hydraulic system, including its control circuitry, is mounted to an aluminum platform which is sealed inside the pressure hull. A Twintec connector provides a quick disconnect from the system, enabling the removal of the robotic arm.

Arm Controller

A sensor is attached to each lateral actuator to measure the extension of the shaft. This allows for exact positioning, which opens up the opportunity to explore a variety of options to control the arm. The team opted to build a 50% scaled, bench-top model of the arm which they could operate in real time to control the movement of the robotic arm. The controller operates a set of potentiometers and switches that provide feedback to the control system, which relays the information to the ROV. In case of failure, a backup system controlled by rocker switches is installed in the control console.

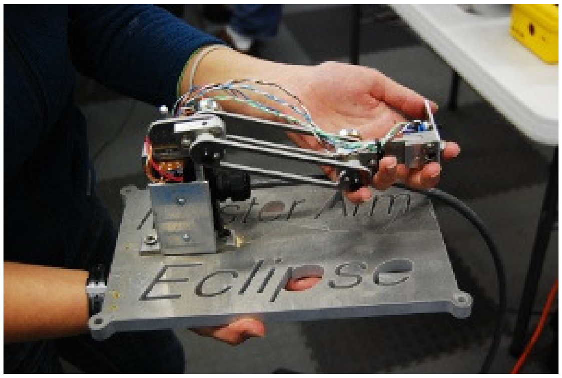


Figure 9 – The arm controller

2.5 Propulsion Systems

Motors

ROV Eclipse is outfitted with a set of four Seabotix thrusters made specifically for ROVs. Each thruster outputs 2.2 kg of thrust. The configuration sets up one thruster on either side of the machine for forward and backward thrust and yaw control. The two vertical thrusters produce ascent, descent and limited pitch control. The thrusters are equipped with a brushed DC motor and housing, end caps, propellers, and kort nozzles, so no modifications were necessary to integrate the thrusters with the system.

Attachment

The thrusters are attached to the ROV by a custom-made plate fastened to two welded bosses on the pressure hull. This allows for quick removal in case of repair or modification. The motor mount also provides support for a set of skids which are attached to the bottom of the vehicle.

2.6 Cameras

ROV Eclipse has three cameras. One is for navigation and the other two are for observing the peripheral surroundings. All three have a similar design in that they are all encased in cast acrylic tubing, with LED lights, slip rings, and stepper motors. Although the cameras are similar they differ slightly to meet their individual and specific purposes.

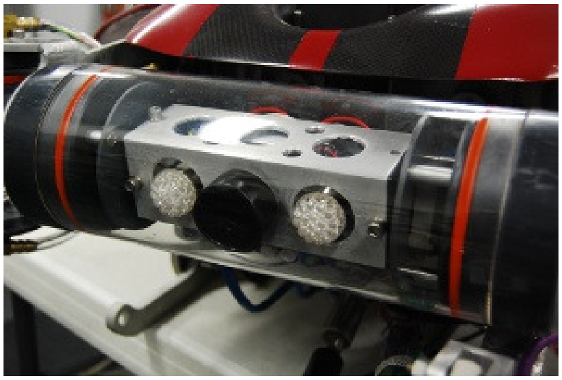


Figure 10 – The main camera assembly

The primary camera is positioned horizontally in clear, cast acrylic tubing on the front-center of the ROV. Positioned on either side of the camera lens are LED Bayonet Lamps, 48,000 MCD single contacts. The lights were included in the design for visual indication. A 6-circuit, 2 amp, 300 RPM slip ring enables the camera to rotate continuously, powered by a 400mA stepper motor. This assists in each of the missions, allowing each camera to be positioned as needed while performing each mission task.

The team selected a Sony 3/8" CCD color camera as the primary camera because of the wide-angle view, which enables the viewer to see a wider picture. The camera was also available from a previous ROV project, which eliminated the need to purchase a new camera and increased cost efficiency.

The two secondary cameras are very similar to the primary camera, but with specific alterations. Like the primary camera, the secondary cameras are mounted inside of a clear, cast-acrylic tube. They also incorporate slip rings and stepper motors. But unlike the primary camera, the secondary cameras are vertically oriented. Beneath the camera lens, on the aluminum tube, two 10mm lamps are placed for navigating in dark environments. These lights are crucial to complete Task #2, *Collect samples of a new species of Crustacean,* since the task requires entering a dark tunnel.

For the secondary camera assemblies, the team chose two Sony ¼" CCD color cameras. These cameras are beneficial in navigating the tunnel during Task #2. To complete the mission, the pilot must navigate around a corner of the tunnel. The cameras can be positioned to look around the corner while turning. After the corner is rounded and the crustaceans are collected, the cameras can be positioned to look behind the ROV, allowing the driver to proceed in reverse out of the tunnel.

2.7 Electrical Systems

The electronic control system for ROV Eclipse is the most advanced to date on an ROV built by Sea-Tech. It boasts 14 microcontrollers, a fly-by-wire system, selectable PWM frequency, feedback-loop hydraulic actuator control, and the ability to access debug data on the fly. It has 11 sensors, 4 thruster outputs, 3 stepper motor outputs, 10 solenoid valve outputs, and two 24 volt auxiliary outputs. The system is also comprised of smaller modules, each capable of operating independently of the rest. This allows the system to be re-configured in the case of a single modules' failure.

Power Control

Eclipse' system has multiple operating voltages: 3.3, 5, 12, 15, and 24 volts. A breakdown of the uses of each voltage is as follows:

- 3.3v: Used for the 3-axis accelerometer chip
- 5v: Used for all microcontrollers, binary systems, and the pressure sensor
- 12v: Used for the stepper motors, MOSFET gate drivers, actuator position sensors, and the hydraulic sensor
- 15v: Used for the thermocouple amplifier
- 24v: Used for all thrusters, solenoid valves, auxiliary functions, and in the form of +/-12 for the hydrophone

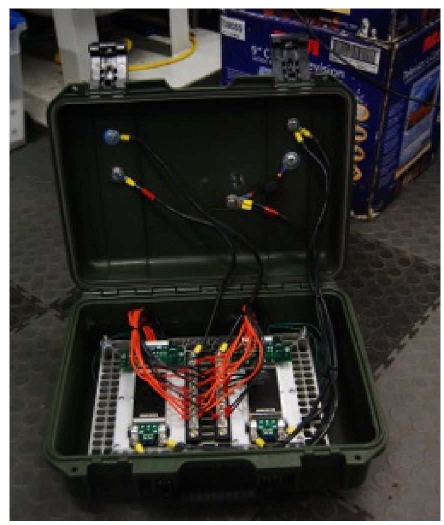


Figure 11 – The step-down converter unit

The 24 volt power is supplied by a pair of DC-DC converters generously donated to the team by Vicor.

Computing Systems

As mentioned above, the system contains 14 microcontrollers overall: 9 in the ROV, and five in the console. They all work simultaneously, some in parallel, and others processing information and distributing it to other processors down the chain.

Communications

The ROV Eclipse communications system is a continuation of Sea-Tech's 2009 system. It utilizes a CAT5E cable, and transmits using a 12 volt version of RS485. The system has proven itself rugged and reliable.

Control Console

The body of the control console is constructed of a Pelican case containing multiple sub boxes for the pilot, manipulator operator, and for the sensor readouts. It contains 5 microcontrollers. Four of them work together to take data from the 16 switches, 5 potentiometers, and three-axis, hall-effect joystick. The last microcontroller is used for driving indicator LEDs, and displays for the temperature and frequency taken from the sensors.

Audio

The audio system consists of a hydrophone generously made by and donated to the team by Aquarian Audio. It runs through a 10X pre-amp in the ROV, then sent through a twisted pair in the tether to the console. Once in the console, the signal is run through another 10X amplifier, through a 1^{st} order adjustable high-pass filter, then through a 1^{st} order adjustable low-pass filter. These filters can be adjusted as to pass only the desired frequency on to the microcontroller, giving a cleaner reading. After these filters the signal is fed through a variable-gain amplifier, the output of which is sent to a microcontroller through a Schmitt trigger, and a class-B amplifier to drive headphones.

Fly-By-Wire

The fly-by-wire system has 3 parts. The first is a function to auto-level the ROV along the pitch axis. This system is useful when lifting objects with the arm. It also helps to stabilize the ROV when driving at full-speed forward.

The second part is the heave dampering. It takes the analog output from the depth pressure sensor and runs it through a low frequency, high-pass filter. This creates a rate-of-change output. When this function is active, the vertical heave control sets a target rate of change. The ROV will then try to accomplish that specific rate of change.

The last function of the fly-by-wire system is depth hold. This function is becoming more and more common on ROVs today. It is very useful, especially during Task #2, *Collect a new species of crustacean,* when the ROV is being driven inside of the cave.

Feedback-loop Hydraulic Control

The ROV's arm is actuated by hydraulics, but the team incorporated a unique feature to the arm system by incorporating a set of position sensors on the elbow and shoulder joints. This allows the control circuitry to be given a target position. It will then move the arm to match that position, much like a servo. This allows the team to use many types of intuitive input devices - from a computer mouse, to an Xbox controller, to an analog of the arm kept in the computer control console – to control the arm.

2.8 Tether

The ROV is equipped with a 15.6 meter tether. Power is sent from the poolside batteries to the ROV via two lengths of marine-grade, 8 gauge power cable. Communication to and from the ROV is accomplished by two lengths of stranded CAT-5 communication cable. As a whole, the tether is encased in an expandable PET plastic sleeving that is both light and flexible.

At the surface, the tether terminates in a strain relief connector that is threaded into the back of the control station. On the other end, the tether terminates at a connector terminal (see 2.3, Design Rationale, *Pressure Hull*) Strain relief at the ROV is provided by a compression fitting mounted to an aluminum bracket.

2.9 Safety Features

Several members of the Eclipse team were recipients of a safety award at the 2009 MATE International ROV competition. With safety in mind, several features are incorporated into the design of the ROV for safety while building, handling and testing:

- All thrusters are protected by guards and ducts
- Warning labels are placed near any moving parts
- A handle is attached to the rear of the ROV for safe launch and retrieval
- A safety protocol is always followed during testing of the electronics

3. Expenditure Summary

The following is a summary of the project expenses. While the team has created a detailed budget sheet, for the sake of space in this report it has been condensed to a price for each category.

Category:	**Total Cost:**	**Donated Amount:**	**Team Expenditure:**
Camera Assemblies	$510	$0	$510
Sensors	$225	$0	$225
Control System	$1,130	$225	$905
Hydraulic Power System	$1,220	$500	$720
Pressure Housing	$1,270	$1,270	$0
Tether	$230	$0	$230
Connectors	$320	$0	$320
Manipulator/Arm	$445	$400	$45
Thrusters	$1,560	$780	$780
Composite Shell	$2,730	$2,730	$0
Grand Total:	**$9,640**	**$5,905**	**$3,735**

4. Troubleshooting

In the past, Sea-Tech has wrestled with the challenge of tight quarters for control components. Our designs inhibited troubleshooting because access to the circuitry meant disconnecting it from the entire system. The Eclipse design team solved this problem by designing the ROV to feature removable circuitry. All of the components of the electronic control system are mounted to the lid of the pressure housing, which can be detached from the main box. This allows the control system to be removed from the ROV while still keeping it intact.

Figure 12 – Testing the ROV in a small tank

Most importantly, removable circuitry allows the team to troubleshoot the logic circuits from one end to another, the control station to the output. Critical connections between the electronics on the lid and the various powered devices of the ROV—including the thrusters, cameras, and lights—are made with connectors that allow the components on the lid to be entirely detached. Thus, most trouble shooting of the electronics can be conducted without the presence of the ROV itself. This protects sensitive powered devices, such as the camera, from exposure to unforeseen, critical failures in the electronics system. Once problems are identified and solved in the electronic control system, the system can be reattached to the ROV to test the machine as a complete unit.

5. Challenges Faced

5.1 Time

"You come to compete with teams from all over the world, but your greatest competitor—greatest foe—is time itself." No statement can better describe Team Eclipse's biggest struggle than this one by Lee McNeil, the team mentor for the project. Sea-Tech only meets once a week, which does not allow adequate time to produce a quality machine of this magnitude. One of the team's solutions was to take initiative to meet independently outside of club hours. This allowed the team to complete the more time-consuming projects, such as the resin-infused carbon fiber shell and the pressure hull.

Another solution was the allocation of tasks. During one of the first team meetings of the year, the team listed the various tasks to be accomplished this year and allowed each member to express his or her areas of interest. This allowed the tasks to be divided according to the interests and skills of each team member. Thus, the tasks were completed enthusiastically and in a timely manner.

5.2 Carbon Fiber Shell

On a project of this magnitude, it is very important to plan ahead so that precious time is not wasted. This lesson was never clearer than when the team attempted to remove the carbon fiber shell from its mold. Because of the design of the shell, there was no taper added to the fins at the back of the shell. This made it very difficult to remove the shell from its mold as planned. After much deliberation, the team decided to slowly remove the foam from the outside of the shell with cutting tools. This was disappointing, since the initial plan was to keep the mold intact in case of damage to the shell. De-molding the shell was an extremely long process, during which the team experimented with every tool available, from diamond-bladed cutters to hammers and chisels. Finally, the mold was removed with no damage to the shell itself. Through patience and diligence, the team overcame the challenge with success to produce a useful shell.

6. Lessons Learned

6.1 Hydraulic Systems

As described in previous sections, the team opted this year to power their robotic arm with low-pressure water hydraulics. This seemed like the ideal solution after the team's previous, and often negative, experience with pneumatics. Pneumatic systems require running an air compressor whenever operating the arm, an unwieldy and often impractical requirement. They also require routing an air line down the tether, nearly doubling the tether size and adding stiffness which influenced and restricted the movement of the ROV. Hydraulics circumvented both of these problems. The hydraulics system uses ambient water from the pool and ejects it back, leaving no mess behind and inflicting no damage to the environment.

The team also added sensors to the hydraulic actuators. These sensors provide high-resolution positioning feedback to the system, allowing us to position the arm discreetly. This allowed us to explore a variety of controls for the robotic arm, including a scaled, bench-top model of the arm. The arm mimics the movement of the scaled model with real time feedback. This would not have been possible with pneumatics because the speed is unpredictable due to variations caused by condition or PSI. Due to all of these reasons, the team concluded that hydraulics provide a distinct advantage over pneumatics, and considers the system a success on the ROV Eclipse project. The team plans to utilize hydraulics on any further ROV projects.

6.2 Teamwork

An important lesson learned by the team this year was that each member could not focus on their own ideas and inspiration, but must depend on everyone's success. The team realized early on that it was necessary to delegate tasks to each team member in order to complete the project in budget and on time. Tasks were distributed based on interest and skill level in particular areas. This process works very well in theory, but the team soon found out that while some individuals completed their tasks quickly and ahead of schedule, others were falling behind. It became apparent that individuals on the team needed to cross over into other areas of expertise. While this caused some friction at first, it was actually very important in order for the team to work together as a group. Even the conflict of ideas can lead to new ideas, which in turn lead to an improvement on the project. Late-night work parties taught the team to help one another with ideas and construction, which led to increased turnaround time from idea to final product. The invaluable experience gained on this project has taught the team to be greater leaders and problem-solvers in the future.

7. Future Improvement

7.1 Saltwater Capable

ROV Eclipse is a brilliant working platform capable of a variety of tasks. However, there is room for improvement on any project, and Eclipse is no exception. Sea-Tech has always dreamed of building an ROV capable of operating in a saltwater environment in real-world conditions. Many of the components for marine exploration are already in place. For instance, because of the competition guidelines, the ROV is already outfitted with cameras, a hydrophone, and a temperature sensor. In order to operate the ROV in a hostile environment and at a reasonable depth, several modifications would be necessary. The main task would be to modify the pressure hull to be non-corrosive in saltwater. This would entail rebuilding the pressure hull from a new, non-corrosive material or hard-anodizing the aluminum. Furthermore, the acrylic lids for the pressure hull would need to be replaced or reinforced in order to protect them from high water pressure when operating in depths greater than the competition swimming pool.

7.2 Tether Length

The length of tether currently used for ROV Eclipse is not long enough to accommodate the deep diving that the team has purposed for this machine. Therefore, to prepare Eclipse for deeper dives, a future project will include lengthening the tether. Since the tether is designed to be removable from both the control station and the ROV itself, it is possible to replace the tether with any length desired without extensive rewiring.

8. Loihi Seamount

The Loihi seamount is an undersea mountain rising more than 3000 meters above the floor of the Pacific Ocean. The youngest volcano in the Hawaiian chain[1], the seamount provides a unique opportunity to explore the interesting and often mysterious processes surrounding hydrothermal vent sites.

History of the Seamount
Once thought to be a 'dead' volcano, the Loihi Seamount was largely ignored until an intense swarm of earthquakes led researchers to the site in 1996[2]. Between July 16 and August 9, more than 4,000 earthquakes were recorded, some with an intensity of up to 4.0 on the Richter scale. A rapid-response cruise vessel was dispatched almost immediately, but visibility was greatly impaired by floating mats of bacteria and displaced minerals. When additional cruises were dispatched in September and October of that same year, it was discovered that a row of vents along the southernmost portion of the seamount had collapsed and formed a crater 600 meters in diameter and almost 300 meters deep.[3]

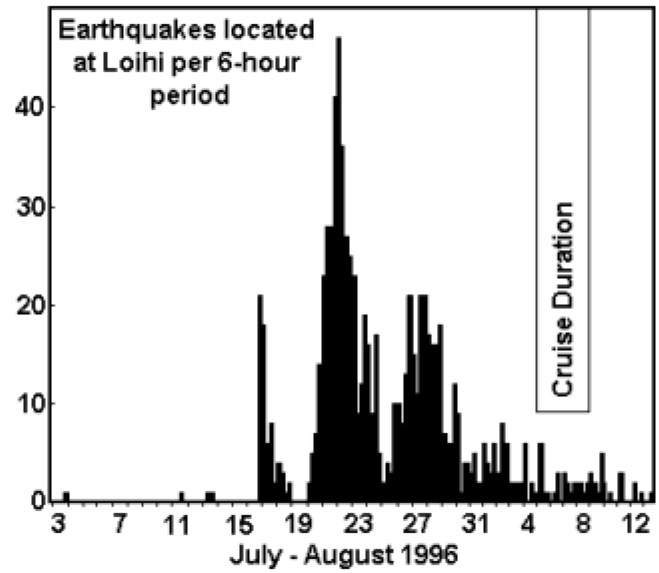


Figure 13 – A graph of the earthquake swarm at the Loihi seamount (Image courtesy http://www.volcano.si.edu /world/volcano.cfm?vnum=1302-00-&volpage=var)

Hydrothermal Vents and Biology
A new series of hydrothermal vents began to form very soon after the swarm of earthquakes. Hydrothermal vents are geysers on the seafloor. They continuously gush super-hot, mineral-rich water that supports a diverse community of organisms. Although most of the deep sea is sparsely populated, vent sites teem with a fascinating array of life, from tubeworms taller than human beings to ghost-white crabs.[4] The temperature of the vents at the Loihi seamount ranged from 200 to over 400 degrees Celsius. Heavy amounts of carbon dioxide[5] and iron emitted from the vents provided an ideal environment for an array of bacteria to form, including a high temperature bacteria which was the first to have its entire genome sequenced.

Marine life around the Loihi seamount, although not as diverse as the life found among other seamounts, include Monkfish, bresiliid shrimp, members of the cutthroat eel family, and tube worms.[6]

Study of the Seamount
Exploration of the Loihi seamount is conducted by the Hawaii Undersea Geological Observatory (HUGO). The observatory was established in 1997 in response to the earthquake swarm, which made apparent the need to further study the Loihi seamount and the processes and life surrounding it.[7] HUGO is an undersea volcano

[1] http://www.soest.hawaii.edu/GG/HCV/loihi.html
[2] http://www.soest.hawaii.edu/GG/HCV/loihi_j_a_1996.html
[3] http://hvo.wr.usgs.gov/volcanoes/loihi/
[4] http://www.ceoe.udel.edu/extreme2004/geology/hydrothermalvents/index.html
[5] http://www.soest.hawaii.edu/GG/HCV/loihi-summary.html
[6] http://en.wikipedia.org/wiki/Loihi_Seamount
[7] http://www.soest.hawaii.edu/HUGO/deploy.html

observatory, incorporating a series of hydrophones and sensors to observe and record any occurrences on the seamount. The observatory is linked to the shore by a 40 kilometer fiber-optic cable. Due to damage to the cable in 2002, it is no longer operational.

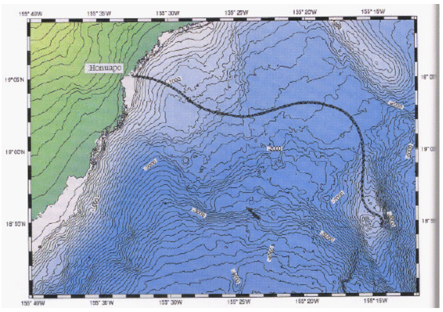


Figure 14 – The cable linking HUGO to the shore

The Hawaii Undersea Research Laboratory (HURL) provides regular research and monitoring of the Loihi seamount. The laboratory equips and operates two submarines, as well as a Remotely Operated Vehicle (ROV). HURL has made over 50 dives to Loihi, collecting data, sampling organisms, deploying instruments, and repairing HUGO.

MATE ROV Competition

The 2010 ROV competition hosted by the Marine Advanced Technology Education Center (MATE) has provided the ROV Eclipse team the opportunity to explore the challenges of working in a real life environment. The competition theme, 'ROVs in Treacherous Terrain: Science Erupts on Loihi, Hawaii's Undersea Volcano', is directly tied to the Loihi seamount and has given the team an opportunity to research the processes surrounding hydrothermal vents, underwater earthquakes, and the field of study surrounding them.

9. Reflections

The year of 2009-2010 has been a rewarding one, riddled with unique, but rewarding, challenges. From brand new systems, unique design, and the most advanced control system to date, Team Eclipse has created an amazing machine capable of not only diving and operating, but of completing a specific and difficult set of mission tasks. We have set new standards for Sea-Tech, with design innovations such as water hydraulics and unique camera systems. We have raised the bar for new technology at the competition, with additions such as the bench-top arm controller and fly-by-wire systems such as pitch compensation and depth hold. And, most importantly, we have grown from a group of individuals to a unified team with purpose.

As individuals, the team has learned to take ownership of different aspects of the project and see them through to completion. As a group, they have discovered that they really are capable of seeing through a project of this magnitude. Through demanding time constraints, they learned to improvise when the ideal solution was not attainable. The team has been challenged to share and meld their ideas to create something amazing. As with any group the team faced the challenges of disagreements, personality conflicts, and simple differences in opinion. But in the end, they learned how to rise above these challenges and work together for a greater purpose than individual self. Several team members worked night and day to complete individual sections of the project. Yet, in the end, the success of the project as a whole was equally dependent on every smaller aspect, and no task was insignificant. An ROV is not complete without a camera, tether, control system, pressure hull, or control console. By themselves, no one individual could have completed this project. As a group, the team discovered their capability.

The 2010 MATE International ROV Competition has motivated and inspired the team to greater things. Without the MATE Center's technical specifications and thought-provoking ideas, many of the innovations on ROV Eclipse would never have been considered. In less than a year, the team has successfully accomplished the daunting task of building, from scratch, an ROV to be very proud of. She is the product of experience, through both weaknesses and strength.

10. Acknowledgements

Team Eclipse would like to recognize the companies, organizations and individuals who made this year possible. Without their support, the completion of this project would have been impossible:

- Lee McNeil, our mentor and advisor, for your expertise and dedication to the team members as well as the project
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- Janicki Industries, for your generous sponsorship of this project through financial and service contributions
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- Clippard Minimatic for discounts on the hydraulic valves
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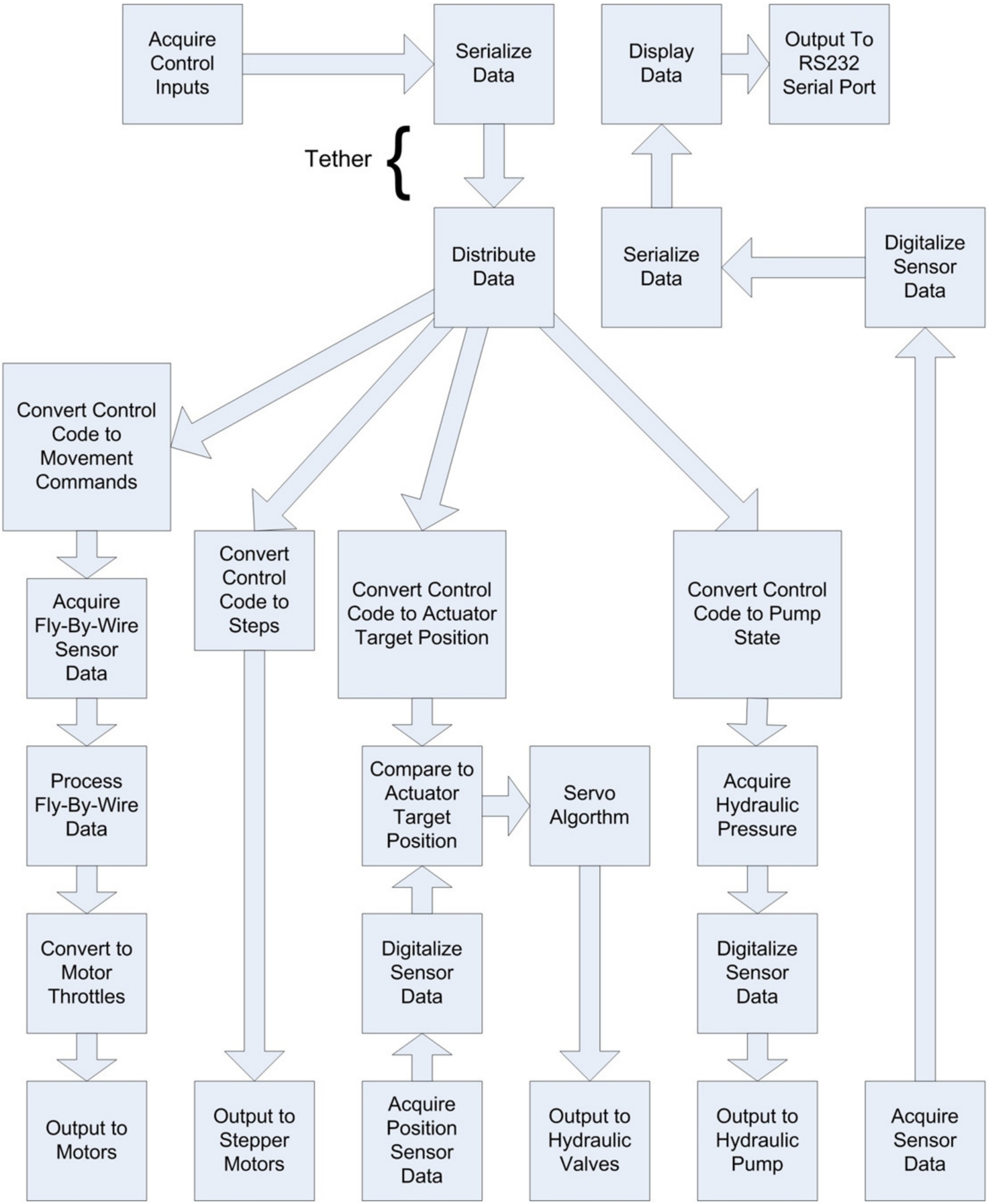
- Orbex Group for donating the camera slip rings
- Exact Scientific for their generous money donation
- MicroPump for donating the hydraulic pump
- SeaBotix, for discounts on the thrusters

11. Appendix

Appendix A – Flow Chart



Appendix B – Electrical Schematic