Sea-Tech 4-H

Skagit Exploration And Marine Technology 4-H Club

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

Trevor Uptain

Joe Thieman

Peyton Hasenohrl

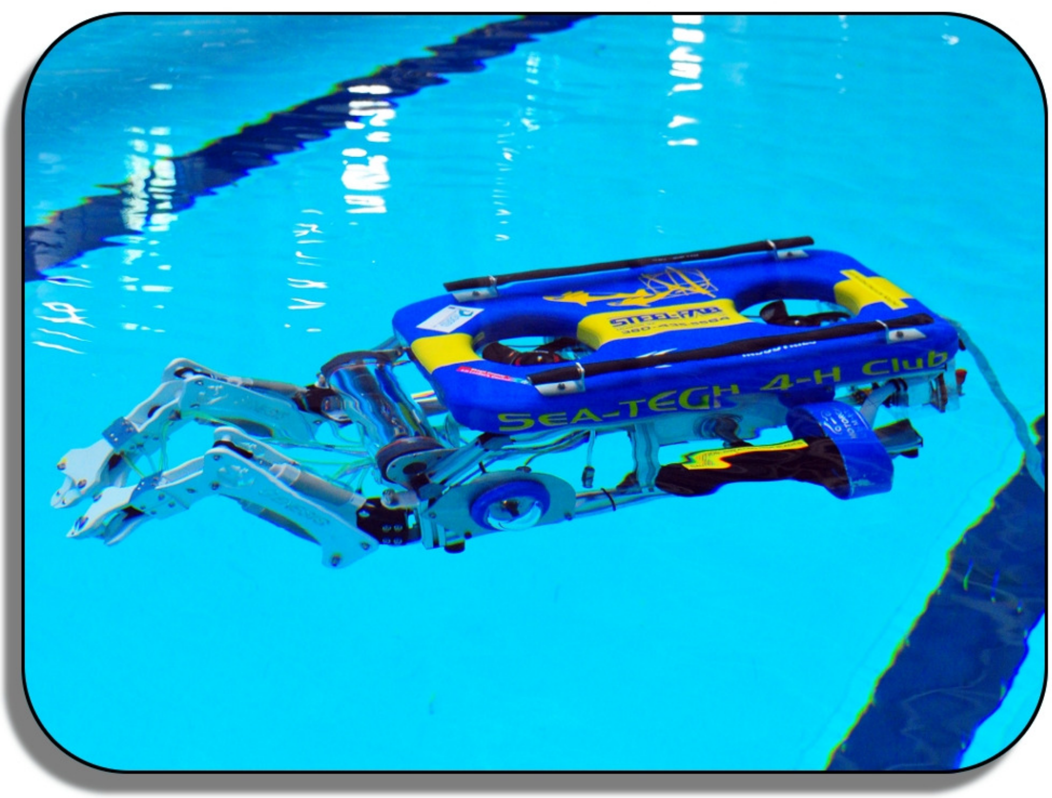
Jacque McNeil

Lee Thieman

Keegan McAdams

TEAM GENESIS

Team Mentor: Lee McNeil



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Abstract

ROV Genesis was built in 2008 by members of Sea-Tech 4-H Club of Skagit County. The machine was designed to function as a highly adaptable, underwater work platform that can be tailored to accomplish any specified mission.

For entry into the 2009 Marine Advanced Technology Education (MATE) Center International Competition, the students of team Genesis designed and constructed various adaptations to optimize ROV Genesis for the new mission tasks. These alterations included adding a step-down converter to comply with power requirements; adding a secondary camera to optimize mission time; redesigning the robotic arms and manipulators for greater functionality; and upgrading the electronic control system. These tasks were initiated, designed, and accomplished by students with occasional input and advice from the team advisor. They presented intrinsic challenges that generated both personal and team growth in various technical and interpersonal skills.

The theme of the 2009 MATE International ROV Competition is "ROV's: The Next Generation of Submarine Rescue Vehicles." Sponsored by OceanWorks International of Vancouver, British Columbia, the theme presents concepts from the company's latest submarine rescue technology. Thus, the mission tasks emulate some of the operations and capabilities of the Remotely Operated Rescue Vehicle (RORV) designed and manufactured by OceanWorks.

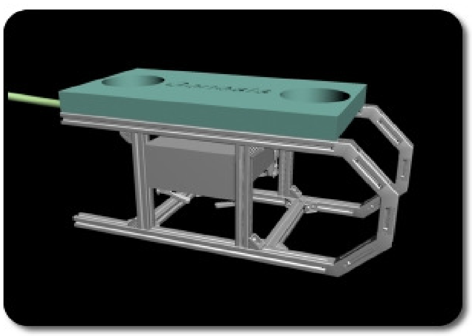


Figure A.1 – Early concept art of Genesis

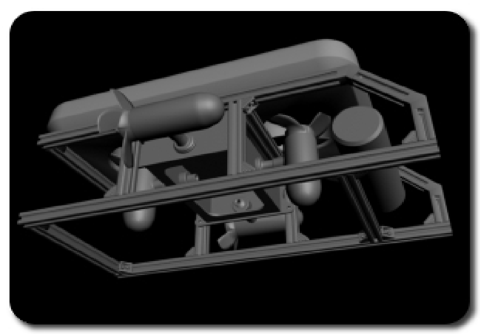


Figure A.2 – Genesis comes to life in 3D

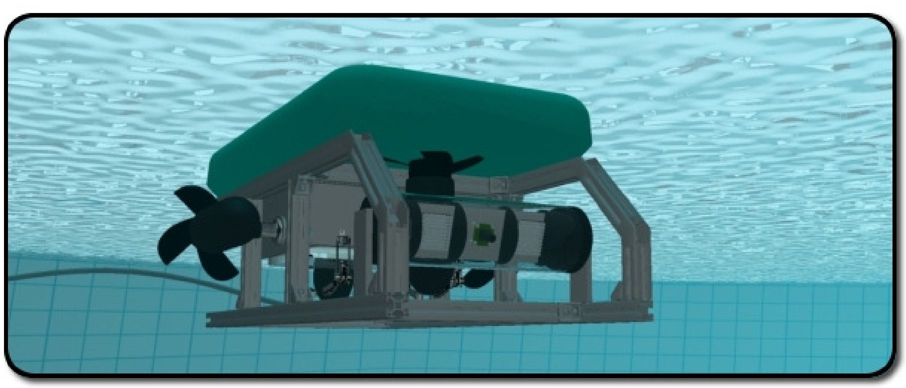
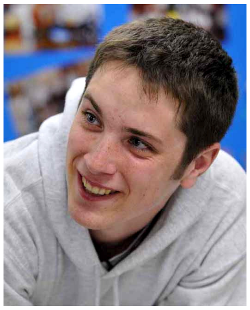


Figure A.3 – A photo-realistic rendering of original Genesis design

1. Team Genesis



Trevor Uptain

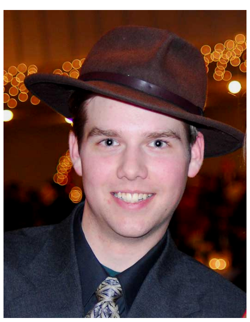
Team Role: Team captain, pneumatics, arm and manipulator assemblies, technical report support
Competition Role: Mission Commander

With six years of experience building ROV's in Sea-Tech, Trevor is a big-picture person with the overall design in mind. He is a natural leader, having the self-appointed task of keeping the team on schedule. He currently attends Skagit Valley College through the Running Start program and just finished his freshman year.

Jacque McNeil

Team Role: Technical report, step-down converter box, arm and manipulator assemblies, written documentation
Competition Role: Missions Specialist

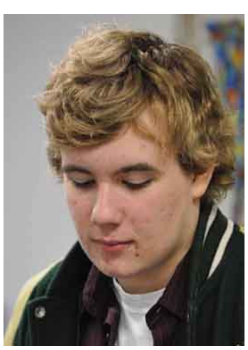
Jacque is a founding member of Sea-Tech, having participated in the club since it began in 2000. She is a focused and driven participant of the Genesis team, with a special talent for technical writing and documentation, as well as a knack for designing and building any ROV part that comes her way. She recently graduated with a General Associate of Arts University Transfer Degree from Skagit Valley College in June of this year, and is planning to graduate in 2011 with a Bachelors in nursing from Washington State University.



Joe Thieman

Team Role: Electronics, control system, step-down converter
Competition Role: Pilot

Joe Thieman has been building ROV's in Sea-Tech 4-H club since 2001. Having found an interest in electricity when he was 6, and taught the fundamentals by his dad, he has made designing and building electronic control systems for Sea-Tech ROV's his club specialty. He is dedicated to improving his electronics knowledge and skills through ample experience. Recent accomplishments include learning 5 computer languages and upgrading the Genesis control system, his most complex system to date.



Keegan McAdams

Team Role: Mechanical refitting, frame system reinforcements, side scan camera
Competition Role: Manipulator Operator

Keegan is a very focused member of the team. His mechanical proficiency is an invaluable asset as are his excellent skills as a machinist. Keegan has been building ROV's in Sea-Tech for five years, and just completed his sophomore year at Skagit Valley College.

Peyton Hasenohrl

Team Role: Mechanical refitting, side scan camera
Competition Role: Tether Operator

Having been in the club for four years, Peyton is a home schooled student of seventeen. He offers a variety of skills that he contributes to the team, including drawing, designing, and coming up with creative solutions to problems. He plans to begin attending Skagit Valle College as a Running Start student in the fall quarter of 2009.

Lee Thieman

Team Role: Arm assemblies, photographic documentation
Competition Role: Photographer

A new addition to the Genesis team, Lee is an idealist with careful attention to detail. Besides mechanical design, he enjoys documenting the team's progress through photography. Lee is considering attending college within the next few years with the goal of taking his photography professional.

2. ROV Genesis Design Rationale

2.1 Mission Oriented

Design Goals

Team Genesis began this year with a previously completed machine, which competed in the 2008 MATE International ROV Competition. The objective of the original design was to create a highly adaptable work platform that could be tailored to any specified mission. This year's competition provided the team with the opportunity to demonstrate the original design intent. The team approached the completed Genesis design with new ideas that would optimize the ROV for the specific mission requirements of the 2009 MATE competition. Our specific goals were:

- Add local frame reinforcements to strengthen the system
- Redesign robotic arms for greater functionality
- Design and build manipulators specific to the mission
- Add a stationary side scan camera
- Solve the existing electronic challenges in the control system
- Design and build a step-down power converting system to comply with the new MATE competition standards

2009 Missions

The missions for this year's competition are designed to simulate a generic submarine rescue operation that could be performed by a Remotely Operated Rescue Vehicle (RORV). Thus, they require very specialized features to perform these tasks well.

Task #1: The first task is to survey and inspect the outer hull of the disabled submarine and report areas of damage.

Task #2: The second task is to provide survivors in the submarine with ventilation from the surface. To accomplish this, the ROV must carry a nozzle attached to an airline from the surface to the submarine. It must also open the compartment in the conning tower and insert the valve into a receptor. After the simulation of airflow has been established, the ROV must close the hatch and return to the surface with the airline.

Task #3: The third task is accomplished in three parts. First, the ROV must retrieve the Emergency Life Support System Pods (ELSS) from the nearby carousel. Next, the ROV must first open the open compartment at one end of the submarine and insert the ELSS pods.

Task #4: The final task requires the ROV to descend onto the escape hatch and connect to it with the mating skirt.

2.2 Mechanical Structure

Platform Framework

ROV Genesis is structured in a very traditional style with an outside frame, foam floatation, and self-contained pressure housing. The frame was constructed using Bosch-Rexroth aluminum framing members, which were generously donated by Pacific Integrated Handling. These pieces uniquely interlock and can be securely fastened in place while still allowing for future adjustment of the frame and mounting hardware. Thus, the frame can accommodate nearly any spatial need. This innate adaptability allowed the team to easily attach this year's modifications without rebuilding the entire frame. These specific modifications will be discussed in detail in the following sections.

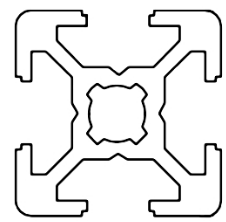


Fig. 1 - Bosch Tubing Cross-Section

Float

Atop Genesis is a float constructed of hydrostatic-proof polyurethane foam. In accordance with the design theme of adaptability, this float is multifaceted in its functionality. Its primary function is to counteract the negative buoyancy of the dense frame components. The density of this material resists water retention but still efficiently maintains positive buoyancy, thereby producing a stable, upright orientation. The float also functions as the shroud for both vertical thrusters. In the middle of the foam block is a pair of 18-centimeter holes functioning as propeller ducts (see section 3.4 on the propulsion system).

Pressure Housing

The central pressure housing of ROV Genesis was constructed to be robust and durable and functions to safely contain the electronic system that controls the ROV. The box is constructed from a section of aluminum C-channel with two custom plates welded—using a marine weld—to either end that also serve to mount the box to the Bosch frame. Each of the four sides of the box has a port to which a motor is mounted. This housing is consequently the foundation of the frame system.

Figure 2 - Testing seal on housing lid

The housing is sealed by a cell cast acrylic lid fitted with an O-ring and four over-center toggle clamps. Each of the four clamps exerts 450 kilograms of pressure on the lid sealing it to the box. The quality of the seal is aided by a Schrader air valve on the box, which can release the internal air displaced by the compression of the O-ring in the seal.

The top of the box is wide to allow easy access to the components mounted within. However, the majority of electrical components are mounted to the lid, which can be completely detached from the box. This design feature allows nonrestrictive access to certain components that may require troubleshooting or maintenance. This advantageous design feature is discussed further in section 4.1 on troubleshooting.

Step-down Converter Box

One component system that was added to the Genesis design this year was a second pressure hull designed specifically to house the new step-down converter (described in section 3.6). This box is considerably smaller than the initial pressure hull but utilizes the same design concepts as the original housing. On one face of the aluminum box are four ports that accommodate separate primary power feeds, one to each of the four motors. The lid is cell cast acrylic and attaches to the box using four over-center toggle clamps which exert 250 lbs of force each.

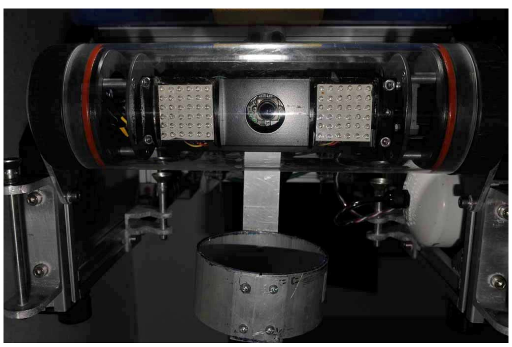


Figure 3 - Transfer skirt under primary camera

Transfer Skirt

Mission task four requires the addition of a transfer skirt that would interface with a port on the mock submarine. Due to budget and time constraints, Team Genesis produced a low-cost, simple solution to this challenge. The resulting design is a stiff aluminum ring suspended from the frame by a long metal bracket. The apparatus is strategically located under the main camera housing (discussed further in section 3.5), which can rotate to look straight down through the ring at the docking port.

2.3 Robotic Arms

Arm Structure

Genesis bears a bilateral pair of pneumatically powered arms with specialized manipulators attached to each end. The original arms built for ROV Genesis were constructed using the Bosch material used to construct the frame, along with custom fittings and ball joint bearings. The resulting structure was not as robust and dexterous as desired. One of the more significant challenges of this old design was the weight that resulted from the aluminum components.

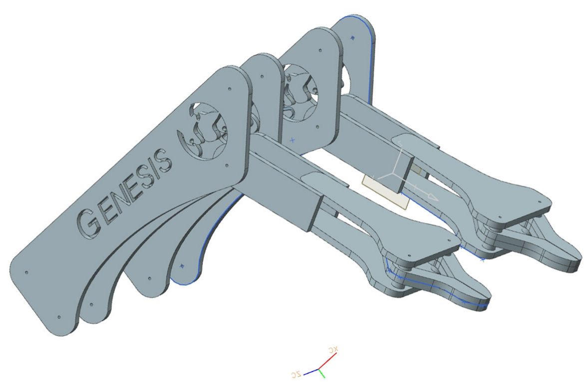


Figure 4 - Solid model of maniupulator arms

Team Genesis completely redesigned the arms entirely from scratch for this year's competition. Instead of aluminum, the new arms are constructed using Seaboard, a high density polyethylene plate with a specific gravity very close to that of water. Thus, the ROV's center of gravity is not affected by extending the arms as much as with the original design. The Seaboard arm pieces were all cut using a water jetting process graciously provided to the team by Janicki Industries. 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 and logo in all four upper arm pieces. Due to the need for professional experience to run the water jetting system, this was not *directly* done by team members. However, the team members were involved as much as possible including being present when the pieces were cut.

Just as in the previous arm designs, each arm functions using three pneumatic actuators. 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 retraction of the lower arm section.

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. The optimal solution was to build several interchangeable manipulators each specialized and tailored to a specific need.

Like the arms, each manipulator is constructed using Seaboard, which was also cut by Janicki Industries using a water jetting process. Each manipulator is also designed to function using one pneumatic actuator. The first two manipulators are generic claws, which improved the design of one of the previous aluminum manipulators. The claw pieces are L-shaped and function as class one levers with a sliding cam interface where the clevis of the actuator is attached. Like the arms, all of these pieces were cut from Seaboard using a water jetting method that followed a computer-generated model.

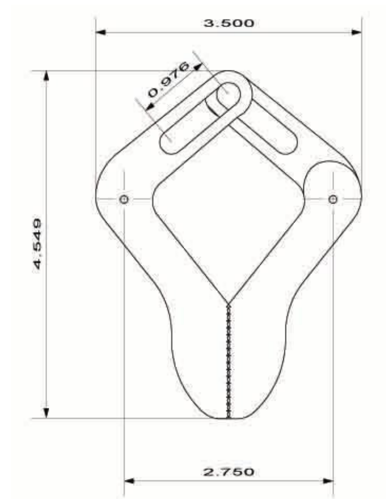


Figure 5 - Manipulator end effector layout

This design allows for generic use, but it also functions to accommodate the specific mission tasks. The ridges on the end effectors of each gripper are designed to securely grip the life support nozzle that must be carried to the submarine mockup. Furthermore, the size of each gripper will allow easy insertion into the handles atop the life support pods that must be lifted out of the crate.

Figure 6 - Hatch rotating end effector

A third manipulator, which can readily be swapped with one of the generic ones, is specifically designed to open the submarine hatch quickly. It presents a four-pronged effector that fits freely between each bar atop the hatch. The single actuator functions to rotate the base of the assembly, thus spinning the hatch into an open position.

Pneumatic Control System

In order to function with accuracy, precision, and dexterity, the robotic arms require intermediary positioning. Each actuator is controlled by a four-way, five-port pneumatic solenoid valve, which allows for discrete positioning functions. In contrast, actuators that work the manipulators are controlled by three-way valves, which stroke the actuator fully in or out only. To eliminate a significant amount of plumbing, all of these control valves are miniature cartridge valves mounted on a common manifold. Each valve has an LED, which indicates proper performance of the specific valve.

All of the pneumatic tubing is connected through one of two multi-port connectors located on the forward face of the housing. These ports connect the control valves to the actuators, facilitating rapid disconnection for the easy removal of the arms from the machine. The tubing for the pressure lines to and from the actuators is color-coded and the diagram is included in.

To conserve space, the valves are exhausted directly into the pressure housing. The exhaust air pressure is unloaded overboard through a pressure relief valve fitted in the housing. The valves are protected from debris by a 10-micron filter.

One of the flaws of the previous housing design was that it attached to the frame in a cantilevered mount. This made the box precariously vulnerable to damage. Thus, the team machined two aluminum braces that anchor the free end of the box to the frame thereby increasing its stability and durability. This activity was part of the local frame reinforcements

2.4 Propulsion System

Motors

The original Genesis design included all four motors, one 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. These thrusters are large, 12-volt trolling motors each mounted directly off the main pressure hull by a custom strut. The custom struts were designed by one of the team members, but machined and donated by Diversified Machining Inc. They replace the manufacturer's tiller shaft that comes standard with each motor. One end of the strut is threaded to match the motor, while the other is threaded and connected to the pressure hull using an aerospace style jam nut. Each strut is also bored out to create a pass through for wires that run from the motor directly into the control system in the pressure hull.

Two of the motors have been modified to accommodate a pressure compensation system for deep-water diving, which is discussed further in section 7.1 on future improvements.

Propellers & Shrouds

Each motor is fitted with a 7-inch, four-blade propeller and a custom built shroud. The two outboard thrusters are shrouded by aluminum rings that are mounted to the outside of the ROV's frame. The two vertical thrusters are mounted within the midsection of the ROV and protrude through two openings in the float. The holes in the foam function adequately as shrouds, and therefore, eliminated the need for aluminum ones.

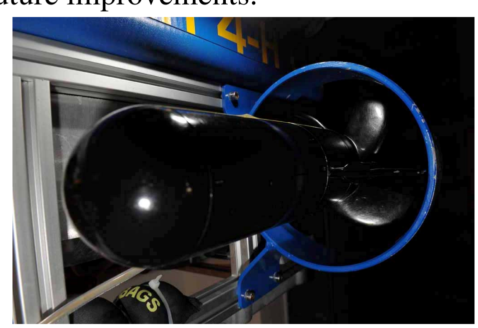


Figure 7 - Side thruster with propeller shroud

2.5 Cameras

Primary Camera
The navigational camera was part of the original Genesis design. The color camera is a board-mounted, 1/3-inch CCD Sony chip set with a 92-degree field of vision (FOV). It has 0.5-lux rating that automatically adjusts the shutter for light levels. A baffle is also installed on either side of the camera to prevent adjacent light from reflecting back into the camera.

The camera and two LED arrays are symmetrically mounted to a rotating aluminum plate, which spans the length of a cast acrylic tube pressure housing. Two plastic end caps are mounted on either end of the tube to create a watertight seal. A stepper motor is installed in one of the end caps and functions to rotate the aluminum plate to which the camera and lights are mounted. This assembly allows the camera and lights to continually rotate concurrently around a horizontal axis, thereby providing the operator with the capability of a complete view of the ROV's surroundings. The other end cap contains a mercury trace slip ring to interface the coax and camera power through a rotating joint.

Secondary Camera
One of the mission tasks requires the ROV to survey the entire submarine mockup for points of damage. Rather than try to use one camera and maneuver between navigation and the damage survey, the team decided to add a secondary camera that could be used simultaneously with the main navigational camera. Thus, the main camera could still function for navigation around the submarine, while the secondary camera could be devoted to surveying the damage.

This secondary camera along with its sealed housing had been previously assembled—according to the Sea-Tech club standard configuration—and set aside as a spare part for the Ranger class ROV's. Thus, the camera was readily available, and its addition to ROV Genesis was inexpensive. The standard Sea-Tech configuration includes a ¼-inch CCD camera with a 90-degree FOV. It is securely mounted to a board which is mounted in a 3-inch PVC fitting and sealed with a compass dome port.. The entire assembly is potted and permanently sealed to ensure that it is watertight.

To attach the camera to the side of the ROV, the team machined a simple aluminum plate that was mounted to the ROV frame in the lower right corner of the forward section. Unlike the primary navigational camera, this camera is stationary and has no light assembly.

2.6 Electronic Control System

This year, the electronics of ROV Genesis have been completely redesigned from the original 2008 system. Using information gathered from the last system we proceeded to design a control system incorporating all of the best features of the last system while redesigning the weak points.

Features of the Original Design
One of the most stable and reliable features of the original 2008 system was the reliance on relays in the motor controllers. Not only was this feature robust, but it also served as an electrical-mechanical redundancy factor in case of an unforeseen failure of the MOSFET controllers. Furthermore, the programming was composed from scratch and therefore, tailored to the specific needs of the ROV.

These desirable features had proved effective for ROV Genesis and were thus incorporated into the new design.

However, other features required fine-tuning. The most significant problem with the original control system design was that the motor driving circuitry was not electrically isolated from the computing system. Thus, the two systems shared noise that interfered with the quality of the output signal and the overall stability of the system. This interference degraded the performance of special features such as variable speed control.

Computing Systems

For the sake of efficiency, Team Genesis opted to redesign the entire control system while simultaneously eliminating to bugs of the original system. The new design shifted from the previous centralized processing unit (CPU)—which had been the original approach—to a new, parallel processing system. This new system is composed of six microprocessors that work simultaneously in separate master-slave sets. Furthermore, these processors run, in the new system, at twice the clock speed of the previous design.

This change in processors provided a new challenge for programming. Instead of a design that employed one program to coordinate all of the CPU functions in sequence, the new design utilizes six different micro-controllers that, like the processors, operate asynchronously and simultaneously. The previous design placed the PWM in the hardware, whereas the new design has achieved greater stability by anchoring it within the software itself.

Furthermore, the new control system allows the motors to be controlled at variable speeds. The shifted architecture of the computing system allowed for an efficient reconfiguration of the circuits in a manner that reduced the amount of shared noise. Specifically, the high power circuits were opto-isolated from the low power circuits. Thus, the system was able to retain stability while optimizing the desired performance of the machine.

Flow Sheets of this system can be found in **Appendix A.1.**

Communication

Communication from the poolside control box to the electronic components on board ROV Genesis is conducted via a CAT 5 communication cable included in the tether. The original design utilized RS232 serial lines for communicating down this cable. However, the new system has been revised into a modified, 5-volt version of RS485. This alteration provides the control system with a much stronger signal and increases the level of noise immunity. Furthermore, the new communication system now allows for two data lines running down the umbilical as opposed to the original single line.

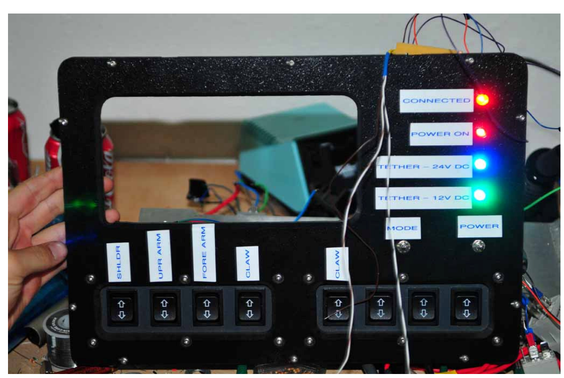


Figure 8 - Control station consol board

Control Station

The Genesis control station is housed in a Pelican brand, watertight case. A flat screen monitor is mounted into the lid. The main box cover contains eight momentary rocker switches for actuating the manipulator arms. The piloting controls are contained in a palm-sized controller that contains three controls. A hall effect, three-axis joystick controls ROV movement. A momentary two-position rocker switch controls camera tilt. The third feature is a potentiometer that can set control bias on the vertical thrusters to trim ROV pitch.

A flow chart of this system can be found in **Appendix A.2**.

Power

As a Sea-Tech standard operating specification, all of the systems of ROV Genesis were designed to operate on 12 volts. However, 48 volts is standard for the 2009 competition rules. To bridge this disparity, Team Genesis designed and built a Buck-type switching regulator to reduce the voltage for the ROV. This initial design of this regulator delivered catastrophic, unforeseen challenges that are discussed further in section 5.2.

Nevertheless, the final stage of the design includes protection features to buffer the delicate microprocessor systems from the brutality of complete regulator failure. Subsequently, Team Genesis created a unit that protects the circuitry from reverse polarity, over voltage, and short circuits. This protection circuit consists of a diode, two 15-volt Zener diodes, two 12-volt linear regulators, a 100-microfarad capacitor, and a 5-amp fuse. The intent of this design is to prevent such a catastrophic system failure from being repeated.

Schematics of control systems can be found in **Appendix B**.

2.7 Tether

As part of the original design, ROV Genesis has a 50-foot tether that feeds power and communication from the control station to the ROV. Power is sent from the poolside batteries to the ROV via a 10-gauge, duplex, finely stranded, copper power cable. The camera is powered using its own supply, a tandem coax cable with power. Communication between the control station and the ROV is conducted using a CAT 5 communication cable (for more information see section 3.6). A ¼-inch, urethane air hose delivers pressurized air to the pneumatic valves and doubles as a flotation device within the tether casing. 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 stainless steel strain relief fitting at the rear of the machine. This connection is further protected and reinforced by a polyurethane, watertight insert.

2.8 Expenditure Summary

Because Team Genesis began the year with a completed machine, the budget was significantly minimized. The goal was to make the necessary repairs and modifications while spending about three hundred dollars. The team laid out a projected expense sheet, which is included in **Appendix C**.

Manipulator Arms: $61.60
Step-Down Converter Box: $0.00
Manipulators: $12.00
Miscellanious Improvements: $41.70
Electronics: $374.16
Total Cost: $489.60

3 Troubleshooting

Figure 9 - Team Genesis performing neutral buoyancy check

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 Genesis 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 provides easy access to the control system as well as the ability to remove it from the ROV while keeping it intact. Most importantly, it 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 actually 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, then the system must be reattached to the ROV to test the machine as a complete unit.

4 Challenges Faced

4.1 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 Genesis's biggest struggle that 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. This year, Team Genesis had the advantage of working on a completed machine. However, the lack of time still proved difficult.

One of the team's solutions was to take initiative to meet independently outside of club hours. This allowed the team to complete time-consuming projects such as the various modifications to the control system.

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.

4.2 System Failure

At the 2009 Pacific Northwest Regional competition, the team experienced a catastrophic system failure. The team had designed and constructed a power converter (discussed in section 3.6) to adjust for the differences in power requirements between Sea-Tech club standards and the 2009 MATE competition standards. The system had been successfully tested, under relatively short durations of operation, prior to the competition day.

The night before the regional competition, a last-minute addition was made: a 30-amp fuse installed on the input side of the buck-type switching regulator. As the throttles were opened, the input fuse blew. Genesis had a 30 amp fuse on both sides of the power converter, the 48-volt side and the 12-volt side. Theoretically, the 48-volt side should have been drawing ¼ the current that the unit was outputting, but the fuse on the 12-volt side was unaffected. Through careful analysis, the team discovered that the problem was that the switching frequency of the regulator was too low for the inductors and launched massive current spikes into the output capacitor.

An attempted solution included winding an inductor, using a 12-guage wire and a large chunk of steel. Nevertheless, without a free-wheel diode across the inductor, the inductive spikes passed the rating of the switching circuit's filter capacitor. The capacitor exploded. This essentially allowed the spikes to thrust 48 volts through the entire system, causing the linear regulators fail. Thus, only hours before the critical proving run, the entire Genesis control system was destroyed in a cloud of sparks and smoke.

Over the next four hours, the team worked furiously and courageously to revive the controls enough to conduct the proving run. Despite the impossible odds, the team managed to accomplish this task through the support of fellow club members, leaders, parents, and two trips to the local hardware and auto parts stores. ROV Genesis indeed qualified for the international competition, but that accomplishment gave rise to another challenge: only four weeks to reconstruct the electronic controls system.

5 Lessons Learned

Through the catastrophic system failure at the regional competition (discussed in section 5.2), Team Genesis learned that troubleshooting and fail-safes are critical to maintaining a reliable and functioning machine.

One of the flaws in the design of the control system was no safety net to protect the sensitive components from being destroyed by an overload of power. When the control system experienced catastrophic failure during the regional competition (see section 5.2), the power surge damaged the entire system, including some expensive components such as the hall-effect joystick. The system had been designed to rely entirely on the pair of fuses at the step-down converter. However, in this incident, one of those fuses failed, and there was no backup. This situation clearly demonstrates the need for protection redundancy within the system.

Furthermore, careful testing and troubleshooting can reveal major problems and prevent disaster. Troubleshooting can often feel repetitive, tedious, and even pointless. Nevertheless, it ensures that the systems are in good condition and prevents disaster. Thus, tests of the entire system should be conducted methodically and in the same manner in which the machine will be operated.

6 Future Improvement

6.1 Pressure Compensation System

One future goal for ROV Genesis is the ability to dive much deeper than competition depth. Because the trolling motors that provide thrust for Genesis were designed for shallow water, this would require some modifications. Much of the design and construction process has been completed for such a system due to work on a previous Sea-Tech project that was ultimately abandoned.

The problem is that, in their unmodified state, the motor seals would leak under significant pressure. In 2003, Sea-Tech designed a system that would compensate for significant water pressure by pushing oil into the motor casing. The concept was simple: oil needed to be pushed into each motor in amounts that were proportionate to the ambient pressure as the ROV descended or ascended.

The oil would reside in a small, cylindrical, aluminum reservoir with a rubber membrane on one side. Attached to the outside of the ROV, the reservoir would be exposed to the ambient pressure. Thus, as the ROV descended, the membrane would act like a diaphragm, responding to the pressure to force proportionate amounts of oil into each motor at ambient pressure. Furthermore, Sea-Tech 4-H Club is currently in possession of the completed pressure-sensitive oil reservoir.

The dielectric oil of this system has two functions. First, it functions as a corrosion inhibitor, and therefore functions to protect the structures within the motors. More critically, however, the oil fills the motors under pressure to eliminate air voids. Air pockets in the motor casings, when compressed by the pressure of deep water, would cause the casing to cave and render the seals ineffective. Oil, unlike air, is incompressible. Thus, it would work to maintain the structural integrity of the motor and attains a zero pressure differential between the motor seals.

The motor struts and two of the motors on ROV Genesis were customized with this specific pressure compensation system in mind. The two modified motors were each drilled and fit with a stainless steel fitting that would allow the flow of oil into motor case. This fitting can be attached to the oil reservoir via a single, narrow piece of tubing.

The custom-machined struts were designed with a robust seal that can withstand pressure. A flange at one end of the shaft facilitates an o-ring face seal. The shaft itself has a gland seal that acts as an auxiliary seal. The strut is hollow to provide a pass through for the control and power wires. However, within the shaft is a lip that accommodates a plug to prevent oil from traveling up the strut. Although these struts were designed and modeled by a member of Team Genesis, they required specialized machinery and experience that Sea-Tech did not possess. Thus, they were graciously machined according to the CAD model by Diversified Machining Inc., who donated time and resources in addition to the struts themselves.

6.2 Tether Length

The length of tether currently used for ROV Genesis is not long enough to accommodate the deep diving that the team has purposed for this machine. Therefore, to compliment the pressure compensation system and prepare Genesis for deeper dives, a future project will include lengthening the tether.

7 Submarine Rescue

Submarine rescue systems are critical to the existence and operation of submarines, whether for military, commercial, or private use. Over the last seventy years, the United States military has used several rescue systems, from the original McCann system to the latest developments from OceanWorks International.

McCann Submarine Rescue System

In May of 1939, The U.S. submarine, *Squalus*, sank to the sea floor more than 240 feet below the surface.[1] The aft section had flooded, killing 26 of her crew, but the other 33 survived in the sealed forward compartment.[2] This incident initiated the first submarine rescue in naval history.[3] This first rescue employed the first rescue system, which included the McCann Submarine Rescue Chamber (SRC). This bell-shaped chamber was designed to attach to the escape hatch of a submarine to allow sailors from the disabled to sub to be ferried safely to the surface.[4] The bell was limited in its capacity, so the rescue efforts took four separate trips to get all 33 survivors to the surface.[5]

Figure 10 - McCann Submarine Rescue Chamber

(Photo courtesy of MATE)

The Squalus rescue was a defining moment in the rapidly growing submarine division. The incident had refuted the notion that no submarine crew could survive a sinking, and demonstrated that submarine rescue was indeed possible and necessary.[6] The McCann SRC had accomplished the supposed impossible, and a modified version of the original design is still in use by various submarine navies today, including the U.S. and the Italian navies.

Figure 11 - DSRV atop an SSBN

(Photo courtesy of MATE)

Deep Submergence Rescue System

Over the next three decades, as submarine capabilities grew, so did the demand for a more robust system that could match those capabilities. In 1970, the Navy launched the first of a new class of Deep Submergence Rescue Vehicles (DSRV), the DSRV-1 *Mystic*.[7] This new design was a free-swimming submarine itself, small and battery-powered.[8] Like the McCann design, the DSRV also had a mating skirt that allowed the rescue submarine to attach to the escape hatch of the disabled sub.[9] This mini submarine required the assistance of a special transport submarine to

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1 Cecchetti, "History of Submarines and Submarine Rescue," 6.
2 Ibid.
3 Ibid.
4 Ibid., 7.
5 Ibid.
6 Ibid.
7 Ibid., 10.
8 Ibid.
9 Ibid.

transport it to the rescue site.[10] This system was the working standard in U.S. submarine rescue for nearly forty years, until it was replaced in October of 2008.

Submarine Rescue & Diving Recompression System

In 2000, the U.S. Navy contracted OceanWorks International to construct an efficient, compact, and robust rescue system to replace the cumbersome DSRV.[11] For over twenty years, OceanWorks International has been at the forefront of diving technology.[12] As stated in a press release July17, 2008, OceanWorks is "an internationally recognized subsea technology company specializing in the design and manufacture of manned/unmanned subsea systems and specialized equipment" for a variety of markets.[13] The Navy contract requested a complete Submarine Rescue & Diving Recompression System (SRDRS) that is currently close to completion.

Figure 12 - ADS2000

(Photo courtesy of MATE)

The first of this three-piece system was certified for operations in 2006. This is known as the Advanced Underwater Work System and is essentially a one-man submersible in the shape of a full-body suit.[14] These sophisticated suits are fitted with special joints that can withstand immense pressure, and thus, the suits are rated for 2000 feet.[15] The four suits owned by the United States Navy function concurrently with the Navy's Launch and Recovery locating equipment.[16] Together, these two devices can accomplish the first task of a submarine rescue: locating the submarine.

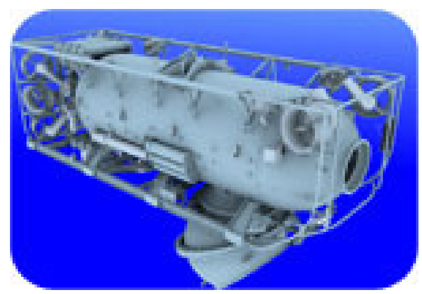

Figure 13 - OceanWorks PRM

(Photo courtesy of OceanWorks International)

The second piece of the rescue system is the Pressurized Rescue Module (PRM), which was officially completed in October of 2008.[17] The body of this module is a watertight cylinder encased by a rectangular, metal cage.[18] The size of the frame is 24 feet long and 8 feet wide.[19] Mounted to the frame, the submersible's thrusters can swivel to provide precision steering.[20] The articulated skirt on the bottom of the machine is capable of docking with any submarine escape hatch. The skirt can also swivel to align it with the sloping angle of the downed sub, up to 45 degrees.[21] Furthermore, the transfer skirt can

[10] Ibid.
[11] Grob, "Sea Trials on the New US Navy Submarine Rescue System," www.oceanworks.com.
[12] OceanWorks International, "OceanWorks Submarine Rescue Sytem is an Operational Success at the NATO 'Bold Monarch' Exercise," www.oceanworks.com.
[13] Ibid.
[14] Cecchetti, "Worldwide Submarine Rescue & Escape Today " 17.
[15] Ibid.
[16] Ibid.
[17] Cecchetti, "Worldwide Submarine Rescue & Escape Today " 18.
[18] Faram, "Lifting Lives from Down Under," 14.
[19] "OceanWorks Announces Launch of New US Navy Submarine Rescue System," www.oceanworks.com.
[20] Ibid.
[21] Ibid.

equalize the pressure between both the downed submarine and the PRM.[22]

One of the most striking features of this particular submersible is that it is not a submarine, but rather a Remotely Operated Rescue Vehicle (RORV).[23] Thus, it has a tether that is connected to the machine's controls on board the surface rescue vehicle. The tether dramatically improves the functioning of a rescue because it allows the attendants within to communicate much more clearly and effectively with the surface. Unlike with the DSRV, the PRM can convey communications in real time, which increases the efficiency of rescue efforts.[24]

Figure 14 - Antanov 124 heavy lift transport unloading PRM

(Photo courtesy of OceanWorks International)

The design of the PRM has several advantages over the DSRV and McCann systems. The first is rapid deployment. The rescue vehicle is stationed at the Naval Air Station o North Island in San Diego.[25] Its size and weight allows it to be transported by air using a heavy lift transport airplane.[26] Thus, the PRM can be onsite, anywhere in the world, in less than 72 hours. In the way of passenger capacity, the OceanWorks' PRM is the largest existing rescue vehicle, accommodating two attendants and sixteen passengers.[27] Thus, the PRM functions effectively for the second stage of submarine rescue: retrieval of the surviving crew.

The piece yet to be completed is a pair of thirty-two-man decompression chambers that contribute to the system's Transfer Under Pressure (TUP) capability.[28] These two decompression chambers are designed to reside on the deck of a rescue ship and interface directly with the Pressurized Rescue Module (PRM).[29] This piece of the system will allow rescuers to transfer pressurized survivors to safety at the surface, while maintaining the pressure of the disabled submarine.[30] Once at the surface, survivors would be transferred to the decompression chambers to become acclimated to atmospheric pressure. Thus, the chambers function in the final stage of submarine rescue: treatment of survivors.

The 2009 MATE Competition mission tasks emulate standard rescue functions and capabilities of OceanWorks' PRM. The initial survey of damage is critical to inform rescuers of any unforeseen hazards that could complicate the mission. It also informs rescuers concerning the details of the situation that disabled the submarine. In a real situation, the task of providing ventilation for the trapped crew could mean the difference between life and death as they wait to return to the surface. The third task, posting the ELSS pods inside the open compartment, provides extended life support for sailors trapped in the submarine while they await transport to the surface. The final task,

[22] Broz, "Deep Sea Savior," 14.
[23] Cecchetti, "Worldwide Submarine Rescue & Escape Today " 18.
[24] Faram, "Lifting Lives from Down Under," 14.
[25] "OceanWorks Announces Launch of New US Navy Submarine Rescue System," www.oceanworks.com.
[26] OceanWorks Submarine Rescue Sytem is an Operational Success at the NATO 'Bold Monarch' Exercise," www.oceanworks.com.
[27] "OceanWorks Announces Launch of New US Navy Submarine Rescue System," www.oceanworks.com.
[28] Cecchetti, "Worldwide Submarine Rescue & Escape Today " 18.
[29] Ibid.
[30] Faram, "Lifting Lives from Down Under," 14.

attaching to the escape hatch using the transfer skirt, is the pinnacle of the PRM's mission. This is the final stage wherein the submersible can finally ferry survivors to the ship waiting at the surface.

8 Reflections

Overall, the year of 2008-2009 has been rewarding, though riddled with unique challenges. From budget constrictions to interpersonal conflict, Team Genesis has grown from a group of individuals to a unified team with a purpose.

As a team, we have discovered that we are capable of refitting and improving an existing project. Our budget constraints demanded frugality and prioritizing in order to accomplish what was necessary. Thus, we learned how to improvise when the ideal solution for a given situation was not attainable. As a group, we have been challenged to share and meld our ideas to create something amazing. As with any group the team faced the challenges of disagreements, personality conflicts, and simple differences in opinion. In the end, we learned how to rise above these challenges and work together for a greater purpose than individual self. As individuals, we have learned that no project can be completed satisfactorily without a significant amount of collective dedication and hard work. 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. By ourselves, none of us could have completed this project.

The 2009 MATE International ROV Competition has motivated and inspired us to greater things. In fact, without the MATE Center's technical specifications and thought-provoking ideas, many of the improvements on ROV Genesis would never have been considered. In less than a year, we have successfully accomplished the daunting task of refitting our ROV to not only meet the mission requirements, but to perform significantly better as a machine. With such additions as variable speed, power adaptations, a side camera, improvements in pneumatics, and a redesign of the arm and manipulator systems, the ROV functions more smoothly, is more robust, and can accomplish more much faster. She is the product of experience, through both weaknesses and strength.

9 Acknowledgements

STEEL-FAB, INC.

Team Genesis 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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- Stanley Janicki a fellow club member, for his 3D models of the arms and manipulators
- Janicki Industries, for your generous sponsorship of this project through financial and service contributions, including allowing us to water jet parts using your equipment.
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- Trish Barnes, English instructor at Skagit Valley College, for advising us on technical writing techniques.
- The friends and family of the team members, whose support, encouragement, and understanding made possible each team member's dedication and perseverance.

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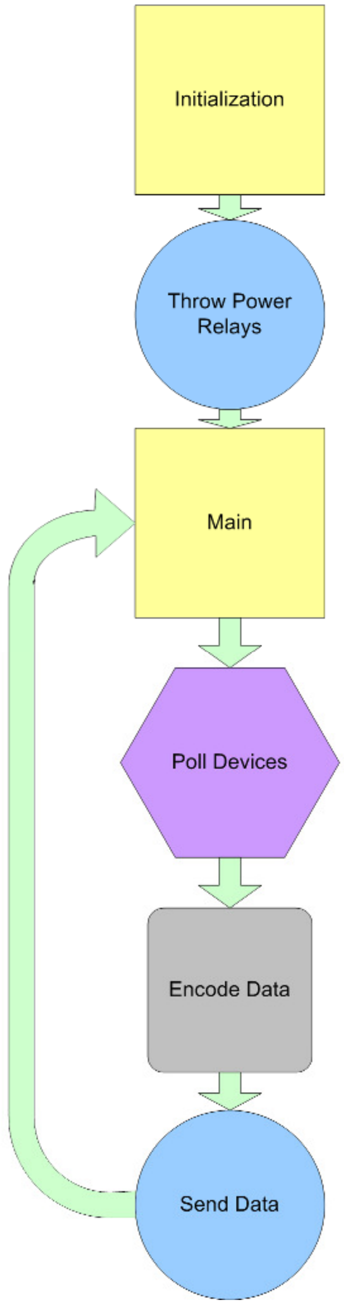
11 Appendix

Appendix A – Flow Charts

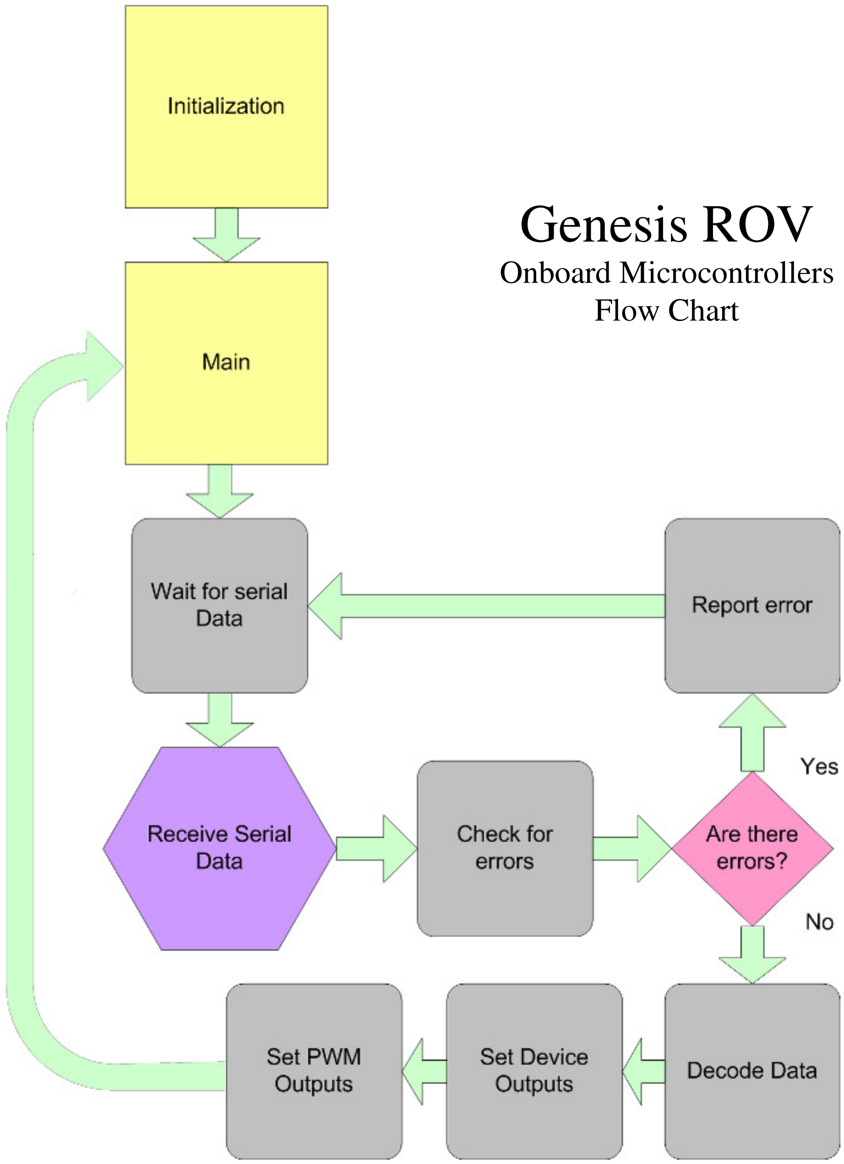
A.1 Genesis Control Console Flow Chart

Genesis ROV

Control Console Flow Chart

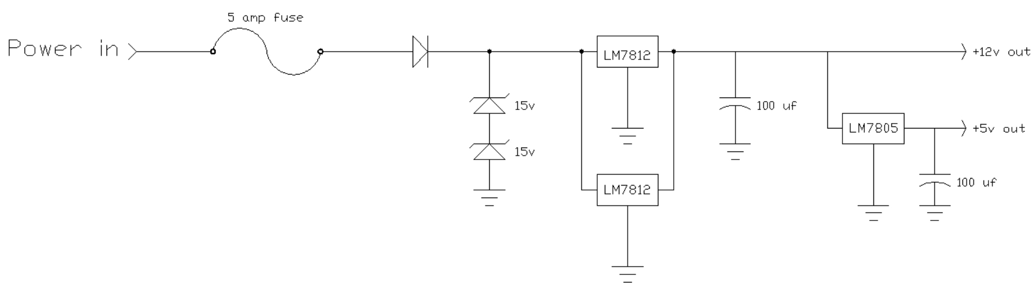


A.2 Genesis Onboard Microcontrollers Flowchart

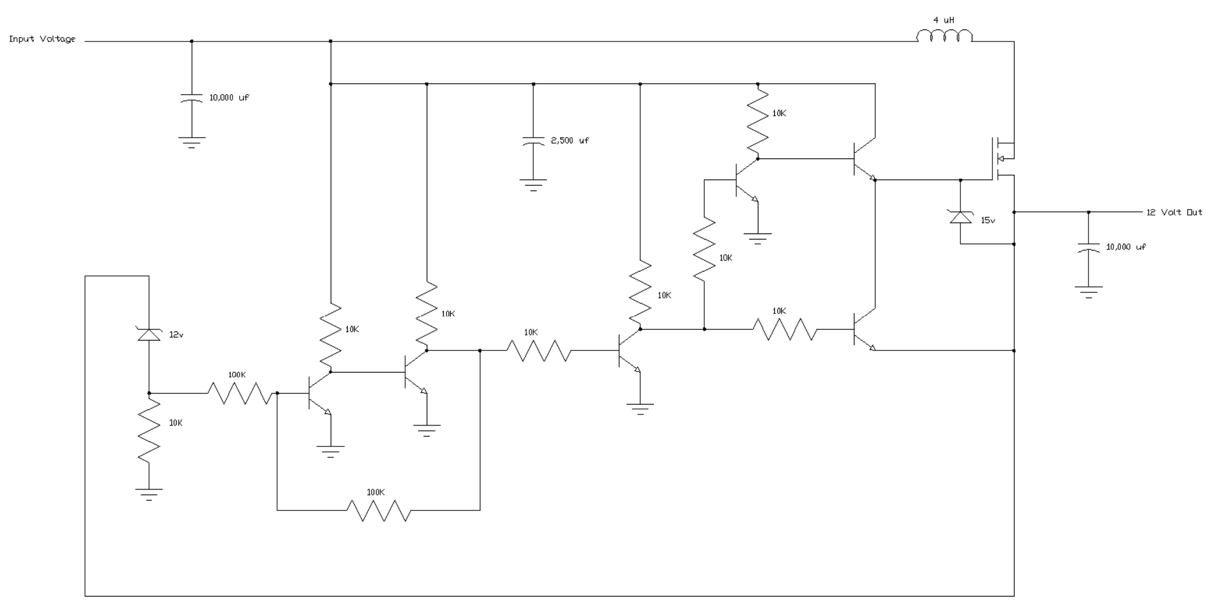


Appendix B – Electronic Schematics

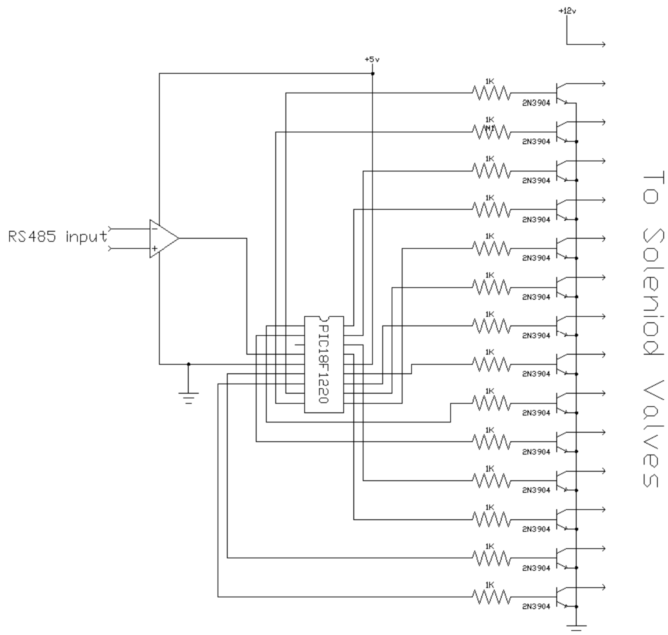
B.1 – Power Supply Circuit



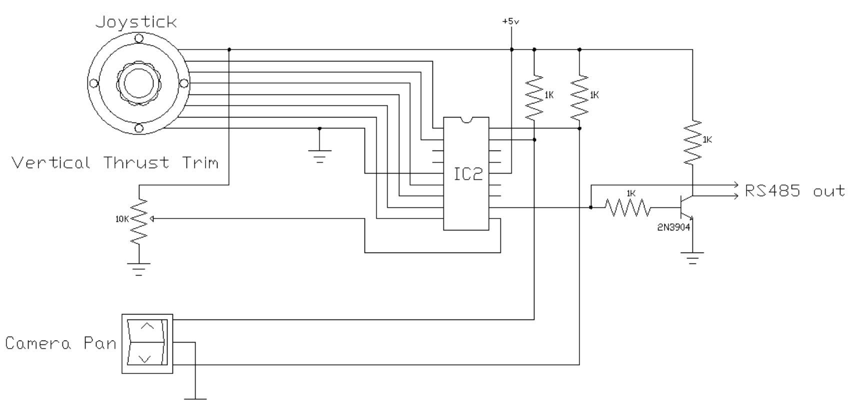
B.2 – Step-Down Regulator



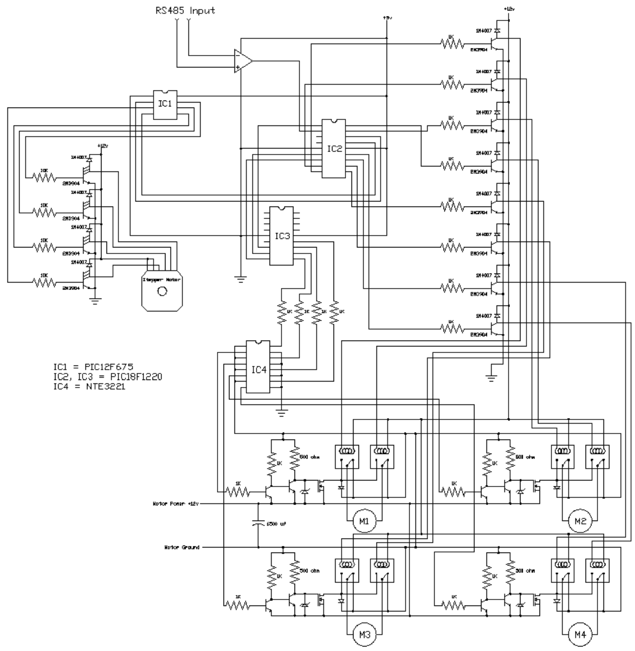
B.3 – Onboard Solenoid Valve Circuitry



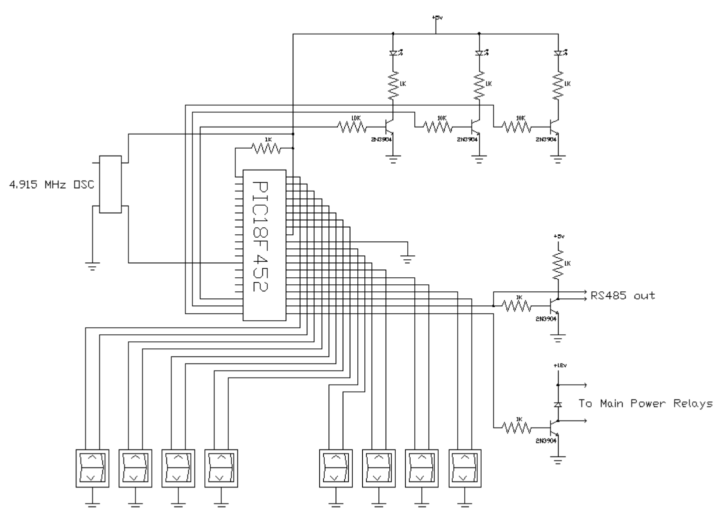
B.4 – Console Motor Driving Circuitry



B.5 – Onboard Motor Driving Circuitry



B.6 – Console Manipulator Driving Circuitry



Appendix C – Expenditure Spreadsheet

Item Description:	Source:	Cost:	Donation:
Manipulator Arms:			
1/2" Seaboard, 2' x 1.5' plate	Tap Plastic		$15.37
Mounting hardware	Ace Hardware	$61.60	
Pneumatic fittings		Owned by club	
Waterjetting	Janicki Industries		Labor donated
	Sub-total:	$61.60	$15.37
Step-Down Converter Box			
1/4" aluminum plate	Lee McNeil		Material donated
3/4" acrylic lid	Lee McNeil		Material donated
Welding	Janicki Industries		Labor donated
	Sub-total:	$0.00	
Manipulators			
1/2" Seaboard, 2' x 1.5' plate	Tap Plastic		$5.13
Mounting hardware	Ace Hardware	$12.00	
Waterjetting	Janicki Industries		Labor donated
	Sub-total:	$12.00	$5.13
Misc. Improvements			
1/4" aluminum plate	Lee McNeil		Material donated
1/4" O.D. x 1/8" I.D. urethane tubing x 25'	Airtronics	$41.70	
	Sub-total:	$41.70	
Electronics			
ETI hall effect joystick	ETI Sytems, Inc.	$270.00	
10,000 micro-Farads capacitor		$40.00	
PIC18F452 processor chip		$20.52	
PIC18F1220 processor chip		$18.60	
PPI 82C55A		$11.08	
Analog Comparator LM339		$1.80	
NPN Transistor 2N3904		$7.00	
Diode 1N4007		$1.00	

5 Volt Regulator LM7805		$1.66	
15 Volt Zener Diode 1N4744		$0.76	
10uf 63V Aluminum Electrolyctic Capacitor		$1.74	
	Sub-total:	$374.16	
	Grand total:	$489.60	$20.50