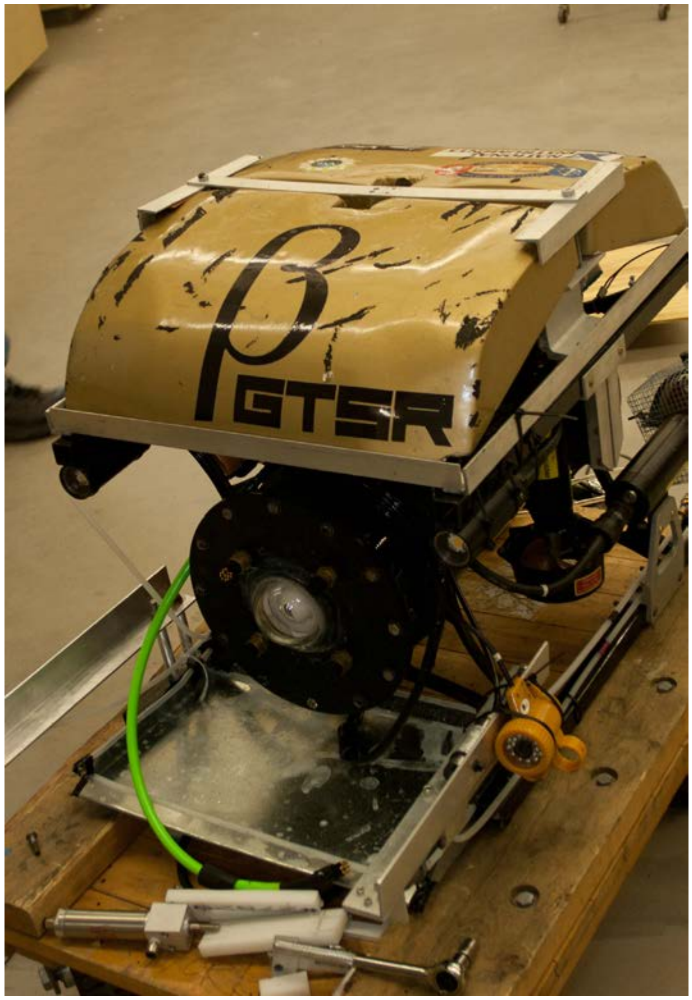
Georgia Robotics Technologies



Georgia Institute of Technology
Savannah, Georgia

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Note from the CEO

Although Georgia Robotics Technologies is only in its third year, as the new CEO of GRT, I'm excited to bring the newest in GRT's robotics lineup to the market - the ROV Beta II.

For three years GRT has brought the newest in underwater robotics technology to the market - introducing new systems like wireless control systems, intuitive joystick control, flight safety envelopes, onboard control interpretation, fail safe modes, and the best in structural foundations. As the new head of GRT I promise to continue delivering the front line technology you've come to trust and depend on.

This year's ROV Beta II (ROV Beta Mark II) offers additional redundancies, simplified control systems, easy to maintain manipulators, and highly efficient power systems for prolong runtime. As always the ROV Beta II continues to be built with top of the line components from National Instruments, National Semiconductor, Texas Instruments, Castle Creations, SeaCon, and Crust Crawlers. GRT products sacrifice nothing for the very best.

As always - Georgia Robotics Technologies and all of the employees here wish you the very best with our new ROV Beta mark II.

The leading wave - Georgia Robotics Technologies

Michael Tam
Chief Executive Officer
Georgia Robotics Technologies
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As the foremost underwater robotics venture in the southeastern United States, Georgia Robotics Technologies is located in Savannah, Georgia. With easy access to oceanic fronts, and other testing facilities, our products undergo constant testing and improvement in order to bring you the pinnacle of underwater robotic technology.

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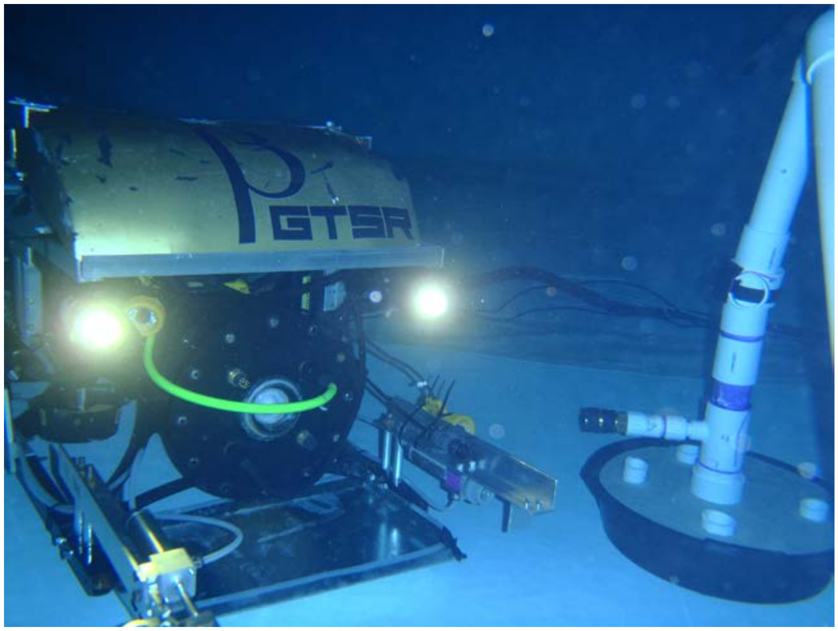
Savannah EST. 2009 Georgia

Photo on cover:
Image of ROV Beta during completed testing stages.

Abstract



Georgia Robotics Technologies introduces ROV Beta as a new mobile oil spill emergency response platform. Leading the response to the Deepwater Horizon Oil Spill, ROV Beta leverages new technologies to remove damaged riser pipes, cap oil wells, collect samples, and perform other underwater scientific and engineering tasks.

Now in its third year of continual development, ROV Beta represents the lessons learned from previous MATE International Competitions in the design and manufacture of this third generation ROV. Replacing the previous universal manipulator design comes new customized manipulators modified for the specific task at hand, increasing efficiency and ease of use.

The newly designed onboard power regulation allows the system to harness the new 48 volts power supply while providing protection from transient voltage drops.

With continued developments in mechanical design, electrical systems, and software programming, Georgia Robotics Technologies proposes ROV Beta as this year's new platform for underwater research and repair operations.

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Introduction

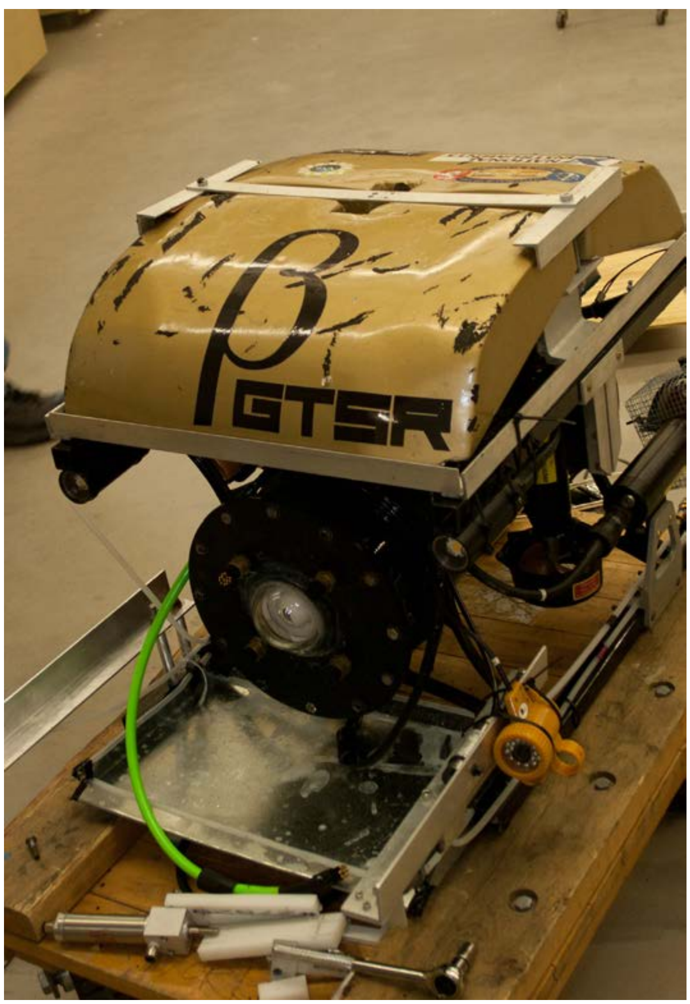
Improving on the original ROV beta, the ROV Beta Mk II provides enhanced thrust, redundant control systems, simplified control systems, improved reliability, simplified maintenance, ease of use, and lower cost.

As a second generation product the ROV Beta Mk II improves on many of the features in the original ROV Beta while eliminating many of the problems. The Mk II also inherits many of the features on the original ROV Beta you've come to learn and love such as wireless controls and on board software.

Gone are the complex manipulators from the first generation ROV replaced with easy to use and replace manipulators designed for specific tasks. The previous cameras have been replaced with a new multi view point camera system which now includes a pan and tilt camera with 90 seconds of power backup for full thruster manipulation. The bilge pump has been reduced to half the power consumption.

The power system has been completely replaced to operate on 48 volts improving power transfer efficiency, and also a flexible power input from 24 volts up to 48 volts.

Overall the Mk II provides many enhancements, details of which are covered in this document. Georgia Robotics Technologies wishes you the best of luck with our newest underwater robotics platform.

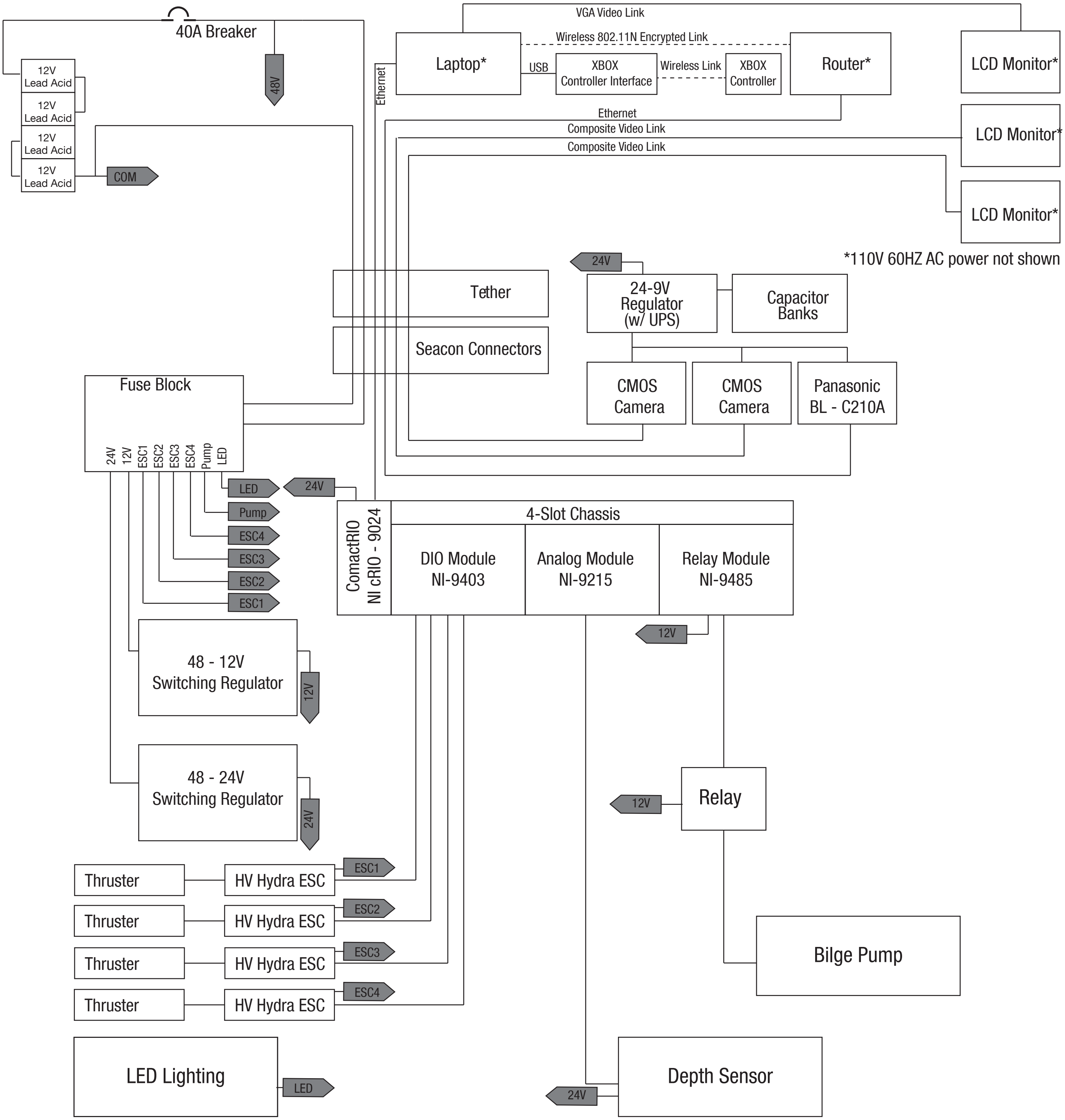


Budget and Expenses

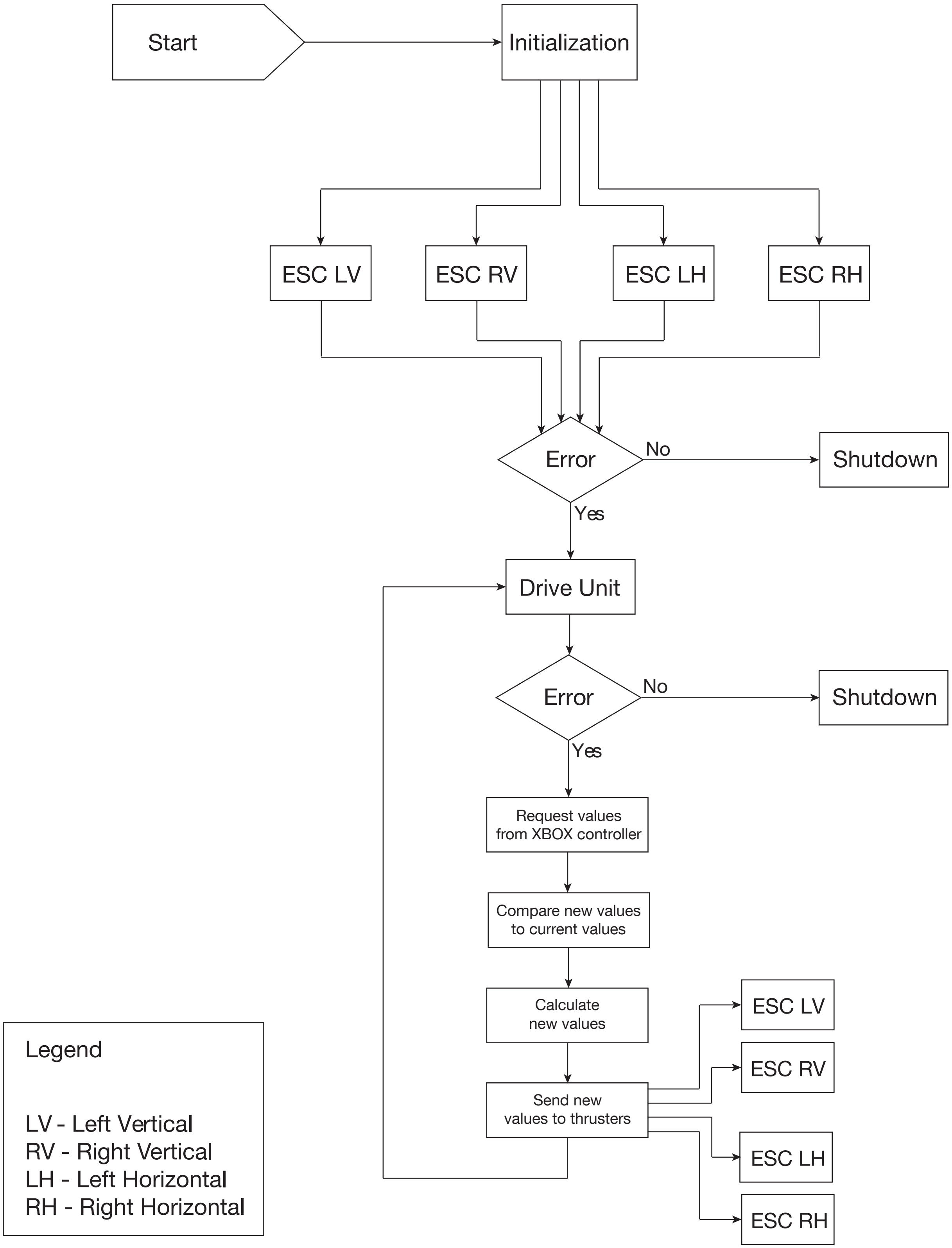
Distributor	Product	QTY	Cost	Discount
National Instruments	NI cRIO-9014	1	$2,429.00	$1,700.30
National Instruments	NI CVS-1456	1	$3,779.10	$2,645.30
National Instruments	NI 9403 DIO module	1	$332.10	$232.40
National Instruments	Ni 9485 8-Channel Relay	1	$287.10	$200.90
National Instruments	NI 9870 Serial Module	1	$521.10	$364.70
CrustCrawler	600HF Thruster	4	$6,396.00	$800.00
SEA-CON	Waterproof Through-hull connectors	8	$2,500.00	$1,000.00
Outland Tech	UWL-401 LED Light	2	$2,600.00	$2,600.00
Castle Creations	Hydra HV-60 ESC	4	$1,440.00	$796.00
VICOR	24VDC-12VDC Converter	1	$189.00	
Metals Depot	Material (steel)		$400.00	
Cales to go	Tether (VGA)		$110.00	
Bulkwire	Tether (Power)		$390.00	
Monoprice	Standed Cat5e 1000ft		$80.92	
Depco Pump Co.	In-Line Pump	1	$57.34	
Keller America	Depth Sensor	1	$300.00	
Bimba	Manipulators	2	$90.00	
HP	dm1z Notebook	1	$500.00	
Amazon	BL-C210a Security Camera	1	$150.00	
Amazon	RT-N12 Wireless Router	1	$40.00	
Dell	20" LCD	1	$120.00	
McMaster-Carr	Pneumatic Lines and Fittings		$200.00	
	Total Expense		$22,911.66	
	Discounts/Donations			$10,339.60
	Net Expense		$12,950.13	

*Expenses covered by NSF grants obtained by Dr. Fumin Zhang

Electrical Schematic



Software Logical Flow Diagram

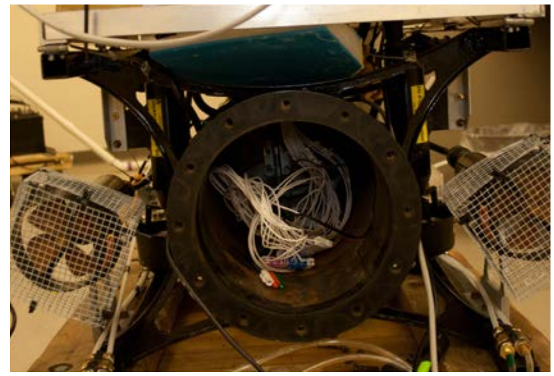


Design Rationale

With every piece of machinery proper design and manufacture is key. While each device may be built with care and from quality components, they can only function well in concert when an overall design solution is implemented. Rather than completely redesigning the hull and structural mounts from the previous generation we focused on the components that went into the ROV to complete this year's design parameters.

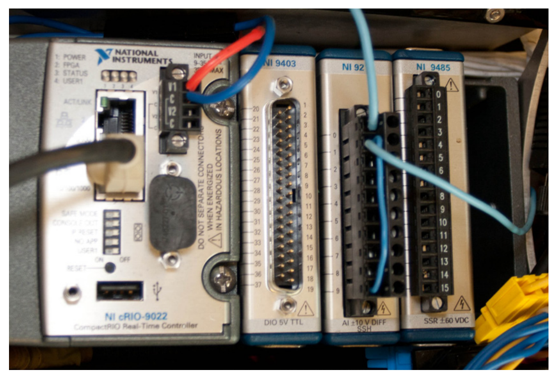
Hull

The hull is largely retained from the last generation of ROV Beta allowing simple replacement of parts and accessories. This hull design has been proven to be highly reliable and pressure sealed in testing and usage. Connections remain the same, with the key being simple replacement using standardized Anderson Power Pole connectors which can be quickly reconfigured. The hull is composed of cast iron with two end caps which allow for easy internal access. The circular design of the hull also increases strength without needing additional weight. Four mounting structures are provided outside the hull, with an additional block of molded syntactic foam for buoyancy control and hydrodynamic streamlining.



Control Systems

The control systems comprise of a wireless XBOX controller, a laptop, and pneumatic switches coupled to a National Instruments compactRIO. This setup allows us to control the robot using a set of pneumatic lines and an ethernet network. With the power of the compactRIO's onboard processing we were able to setup a flight safety envelope to avoid overcurrent scenarios. Additionally the compactRIO allowed us to program the thrusters to be more intuitively controlled utilizing joysticks and triggers on a familiar control surface. Using the analog, relay, and digital IO modules the compactRIO interfaces with all of the electrical systems to provide a unified control system. Each of the joysticks control and individual pair of thrusters, either vertical or horizontal. The triggers allow for rotation by individually controlling the horizontal thrusters.



(top) Hull design (bottom) National Instruments compactRIO with modules

Tether

The tether has been vastly improved from the previous generation design with new twisted pair ethernet data communication which eliminates interference and improves reliability. The 32 meter long tether consists of 2 sets of power cables, 3 Cat5e lines, and 4 pneumatic air lines. The tether has also been wrapped continuously in nylon spiral wrap allowing for a smoother exterior. Floats allow the tether to be neutrally buoyant decreasing drag on the ROV. Air lines running through the tether are wrapped individually decreasing the likelihood of a pneumatic pressure loss due to punctures, kinks, and bends.

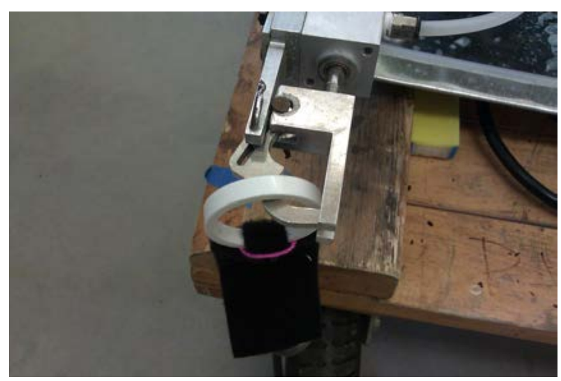
Design Rationale (continued)

Bilge Pump

For the third mission, the robot needed to take a sample of "oil" to bring back to the surface for testing. The compartment that holds said oil is composed of an outer bucket and an interior bladder. Our robots objective was to abstract a sample from a small tube approximately 1 inch wide. To do so, we implemented a bilge pump system with a hose attached to the front end that would suck up a sample of the oil and deposit it into a compartment via connected tubing. The bilge pump system is located on one of the robots manipulators to allow for easy viewing and control over where the system is placed. A simple depth sensor interfaces with he compactRIO to relay the current ROV depth to the pilot on the surface

Manipulators

This year's manipulators have been modified to be mission specific rather than to use manipulators that emulated gripping tools with multiple axis of freedom. While manipulators with multiple degrees of freedom were flexible in application, the complexity of the design resulted in many usage difficulties and mechanical faults. Rather than attempt to rebuild the manipulators to correct for these problems, it was decided to build simpler pneumatic manipulators that performed a single customized task.



(top) grabber manipulator
(bottom) claw manipulator

The basic manipulators installed on the device are a grabber, and a claw. These manipulators can be easily replaced for your specific application. The head for the grabber was made from a rubber block and used a peace of angle aluminum to press against allowing it to hold things. The components for the claw where created from Delrin and ABS plastics because there was a readily available supply of each. Both manipulators were attached to the vessel using both threaded aluminum rods and aluminum tubing to support the pieces of angle aluminum that both manipulators were a part of.

The construction of each manipulator consists of a single double acting pneumatic actuator for power and control with different "heads". Each head can be replaced easily on site to allow for a variety of different tasks. Control for each manipulator is from the surface via a simple three way pneumatic toggle valve, this allows us to simplify the on board electronics and provide a degree of fault tolerance. If a problem occurs with the valve, the system can be disconnected and replaced easily.

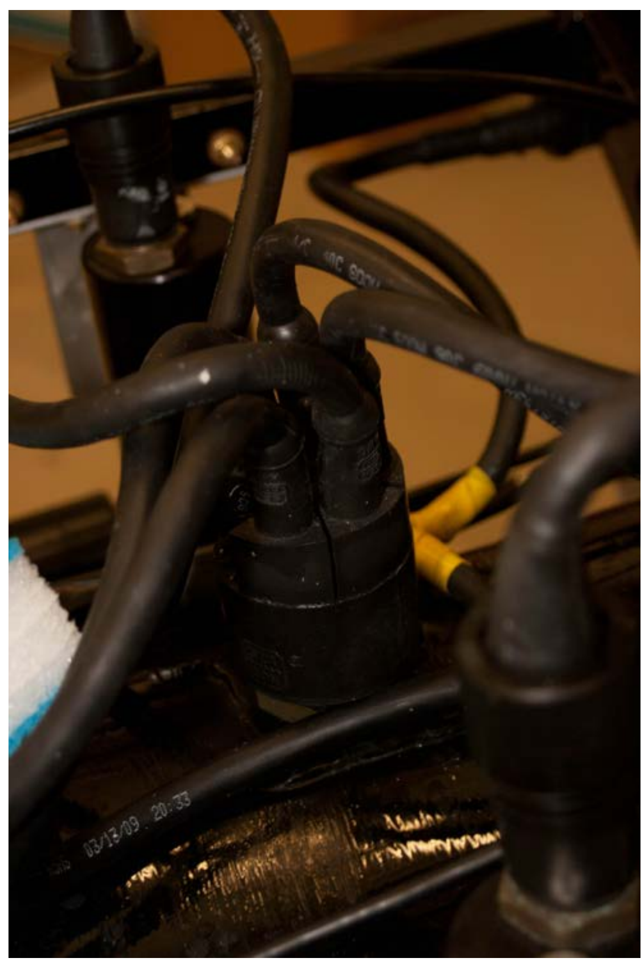
Design Rationale (continued)

Waterproofing

Waterproofing on the ROV Beta II is focused on three different points, waterproofing connections, main hull waterproofing, and waterproofing individual components. While much of the components purchased were waterproof to begin with - not all were designed for depth of up to 12 meters. To allow for full immersion or simply to improve a depth rating (lower depth or no depth rated devices are less expensive) silicone caulk and silicon lubricant were used in concert with epoxy and epoxy putty.

Waterproof connectors were purchased from SeaCon to allow for underwater connections to be made quickly and easily while still maintaining depth rated connections. While prebuilt connectors are more expensive - they are more reliable and easier to replace in case of a failure.

The main hull is constructed from steel, but the end caps are sealed with both silicone caulk and a large rubber gasket as well. Using several hex head bolts a positive seal is created on the vessel. The dome for the camera is sealed on the front hull end plate using epoxy and rubber caulk. Epoxy alone provides and excellent seal, but with continued use sometimes some hairline cracks or small separations occur, using silicone caulk helps with flexible sealing while the epoxy provides the majority of the rigidity required for pressure resistance.



(left) tether connections (right) SeaCon pie connector

Design Rationale (continued)

Camera Systems

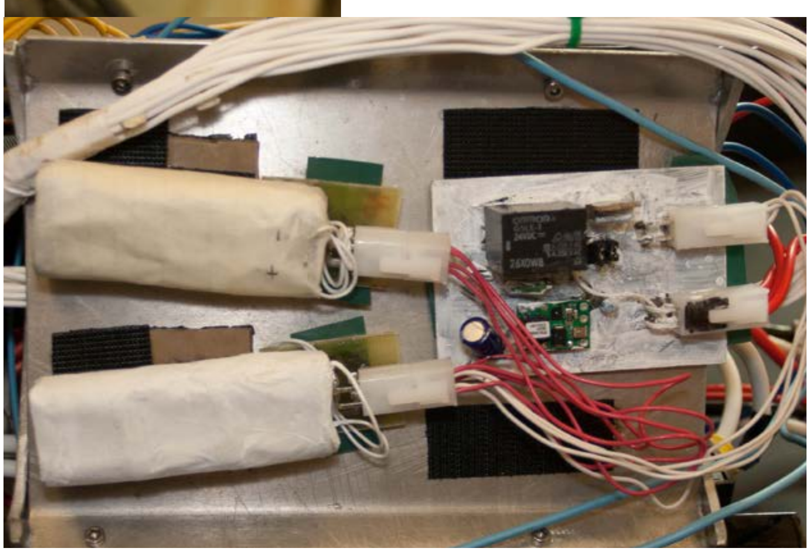
The camera systems in ROV Beta II are unique in that they comprise of three separate cameras each with their own monitor. The pinnacle of the three cameras is the Panasonic BL-C210A which is a home network enabled pan and tilt security camera. The pan and tilt function allows us to use the camera not only as a navigation aid but also as a visual aid for each of the manipulators. The additional fixed analog CMOS cameras allow us to provide an alternate view of the manipulators and tether.

This dual view of the manipulators provides a redundant visual system in case of a power failure for up to 90 seconds on the pan and tilt camera. However, the pan and tilt camera is powered off an uninterruptible power supply (using capacitors as charge storage) due to the large current drain from the thrusters.

To compensate for poor lighting conditions LED lights are installed on the front of the ROV. These provide the main lighting for the Panasonic pan and tilt camera. These lights are aimed forward of the ROV, and provide 1700 Lumens each. The CMOS cameras have their own built in LEDs.

Images (CCW from top)

BL-C210A, CMOS Camera, LED light, 24V-9V regulator with capacitor bank backup, control systems



Challenges Encountered

Last year while operating the thrusters on full throttle during combined ascent and forward motion the cameras would cut out constantly and leave the ROV with no visual guidance. The problem was quickly isolated to a current drain issue related to multiple thrusters being actuated simultaneously. To mitigate the issue after experiencing problems last year – a thruster current limit was utilized in the thruster software, however the current drops continued to affect the system even when thruster current could not be sacrificed further.

After reaching this stalemate between system functionality and guidance, a new camera was installed with the hopes of reducing current requirements. To power the camera a 24 volt to 9 volt linear regulator was used as it was cost effective and appeared to satisfy all the requirements. Soon after installation however we found that while the regulator did perform at a higher than desired temperature, the current loads continued to cause voltage drops that even the new camera could not handle.

The final solution to the problem was to install a 24V to 9V switching regulator with 95% or greater efficiency coupled with a charge controlling diode and capacitor bank for power storage. With the 24V charge storage in the capacitor bank the camera is able to withstand up to ninety seconds of power, with pan and tilt power backup sustained for fifty seconds. Additionally the new switching regulator is able to supply up to 1.5 amps with minimal heat buildup, this allows us to power not only the pan and tilt network camera but also the backup analog cameras which can during normal standby usage, provide a second field of view, and tether view.

Troubleshooting Example

Our main camera is a standard home internet security camera that transmits video over ethernet and has pan and tilt capabilities. The original plan was to wire 33 meters of Cat5e directly to a SeaCon connector and back to Cat5e inside the hull and have the camera directly connect to a routing device on the surface. This method worked well for a minute but slowly degraded to the point where latency and dropped frames became unacceptable for piloting the ROV. We attempted to troubleshoot it by checking continuity through all 4 pairs of wires in the Cat5e to both ends. A short was found between two lines and we began checking the line. Initially we pointed fingers at a bad splice between the SeaCon and Cat5e allowing water to intrude and cause a short. Despite resplicing and doing a better watertight seal and fixing the short, the camera remained inconsistent. Our next troubleshooting step was to drop the data transmission rate from 100Mbps to 10Mbps however by that time the packet loss had become so great there was no connection at all. Unfortunately, even with the camera's H.264 video compression, the 10Mbps was not enough bandwidth for smooth video regardless so that would not have been a viable alternative. After trying another SeaCon connector and 100 new feet of Cat5e, one of our mentors pointed out that the SeaCon connector we were using was untwisted and could possibly be introducing too much noise into the line. This turned out to be the case and after sourcing a twisted pair SeaCon connector, all our issues with packet loss was resolved.

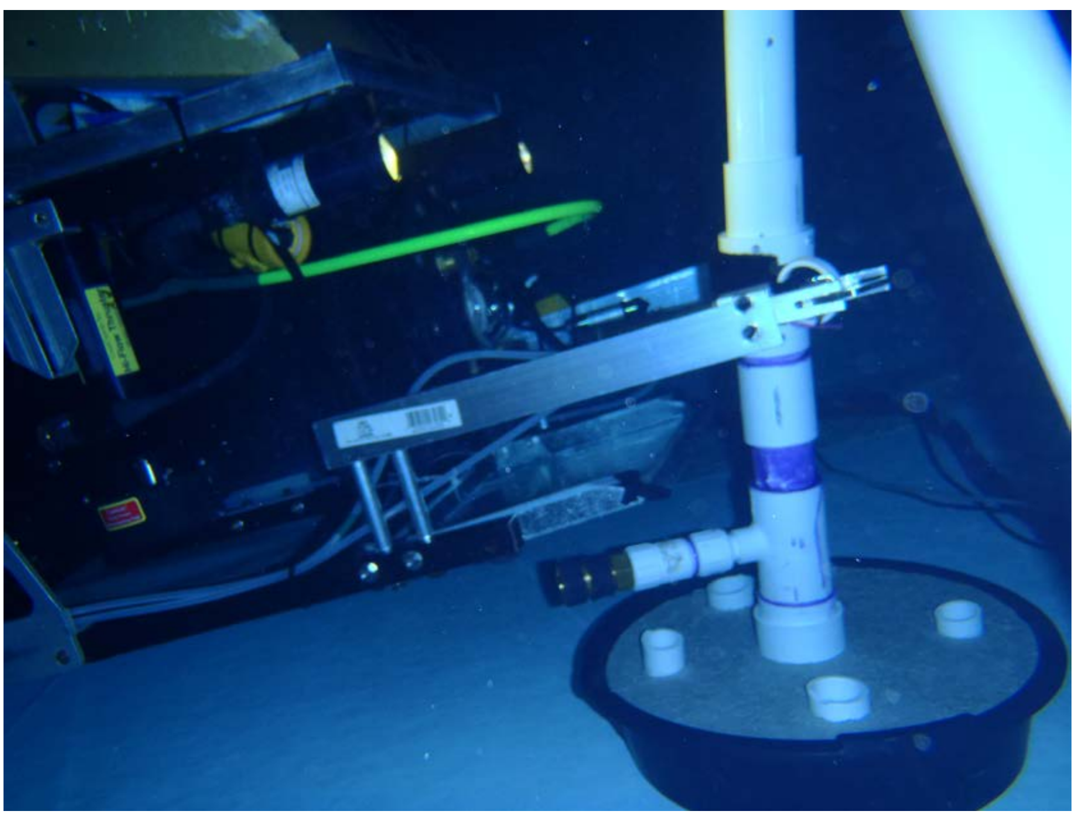
Lessons Learned

Throughout the build process we learned numerous skills including properly crimping RJ45 heads without untwisting too much length of wire. During the pneumatics system assembly we also learned that push to connect pneumatic fittings do not work with vinyl tubing due to its malleability which resulted in some redesigned fittings. We learned that the barb connectors with hose clamps work best for the vinyl tubing and the compression fittings with Delrin sleeves work best with rigid wall tubing. We also learned that whether or not something is rated for water resistance is important especially in regards to adhesives as seen with the disintegrating foam insulation tape used on the tether for buoyancy.

Improvements in New Generations

While ROV Beta is an advanced underwater robotics platform, future improvements continue to be proposed and considered. Future improvements in consideration include a larger rectangular hull, a new tether, onboard pneumatics, adjustable lighting, task specific manipulators with additional degrees of freedom and azipod thrusters. Azipod thrusters would provide greatly improved maneuverability along with strafing capabilities.

New improvements to ROV Beta will ensure continued support of technological advancements in the underwater sector – keeping your deep sea operations at the forefront, improving research and engineering productivity.



Reflections

“As a member of team, I have come to be a part of a group and have been given new inspiration for success. I have also learned to appreciate the fine points of group dynamics as a whole and to work with each of the members shortcomings as well as their strengths to the full advantage of the team.”
–Michael Tam

“Collaborating with the team has opened my eyes to the vast world of engineering. With my time on the team, I feel as though I have a better understanding of mechanical engineering and also a passion for it. But more than that the team has given me new insights in group dynamics and life skills.”
– Evelyn Kim.

“Diving with the team has been a unique experience. Diving with a robot requires a unique set of skills, instead of talking to someone 3 feet away, hand signals to a robot’s cameras require an interpretation of a limited set of movements to communicate the same things.”
– Patrick Lizana

“Piloting the ROV has been absolutely amazing, orchestrating complex movements remotely, a real life action happening just a few feet away.”
– Brian Redden

“Designing and implementing electrical systems on the ROV off site and delivering all parts through the mail was a unique experience. Without direct access and with remote video chat being the only option for support, pretesting, and proper design became a fascinating, but sometimes frustrating experience.”
– Phillip Cheng

Working together as a team, each of us contributing our own skills, and drawing on the strengths of others to fill the valleys of our weaknesses, the experiences and memories of this year will truly be an experience to remember, and will never be replicated. But those of us who can will be returning next year to repeat the frustrations, but also the joys of underwater robotics.
- Georgia Robotics Technologies

Acknowledgements

We would like to thank SeaCon for their discounts on their great watertight connectors. CrustCrawler for their powerful thrusters. MATE for hosting this competition and giving us this great opportunity. Castle Creations for the high voltage electronic speed controllers. Vicor for the high efficiency 48VDC to 24VDC regulators. National Instruments for the expandable compactRIO system. National Science Foundation for the funding to do everything here. The mentors for dedicating the time and effort to provide us with useful advice. Armstrong Atlantic State University for the use of their new engineering lab and excellent pool. Georgia Tech Savannah for the facilities to house and work on the ROV.

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