



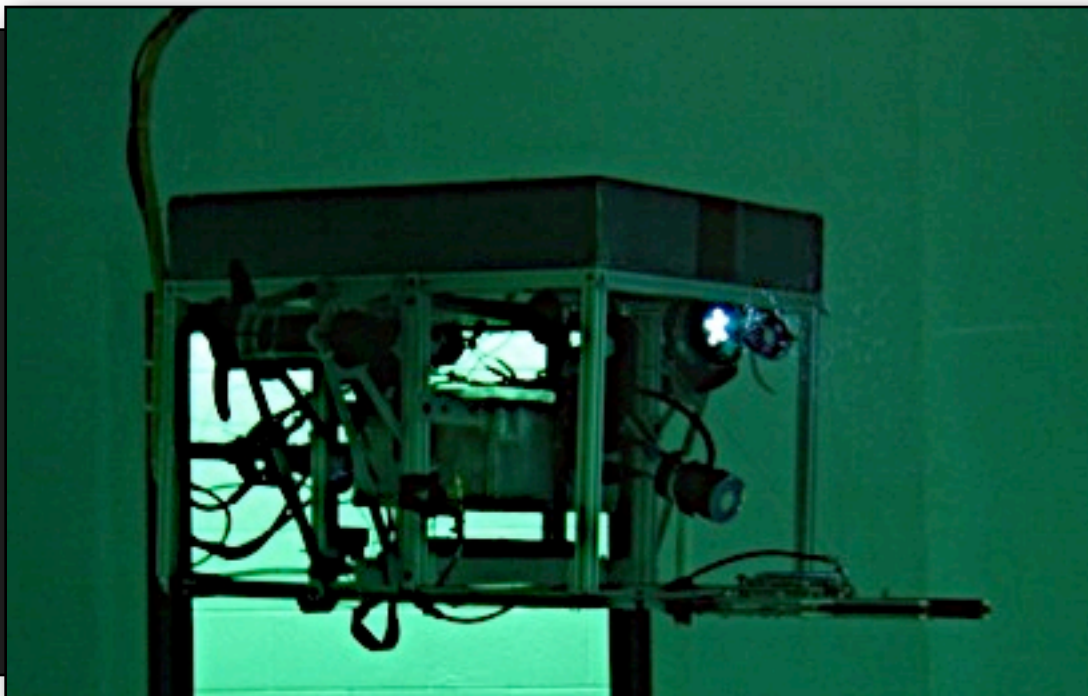
UNDERWATER ROBOTICS AT THE UNIVERSITY OF WASHINGTON

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CASUS



A stable, intelligently designed underwater vehicle built for success - even in the harshest environment



Trevor Uptain, CEO/
Mission Commander

Scott Daley, Electrical
Engineer/Pilot

Colin Katagiri, Test
Engineer/Copilot

Tysen Mulder, Electrical
Engineer

Matt Bolte, Research and
Development/Mission Control

Nate Evans, Design Engineer/
Mission Specialist

Matthew Rasmussen, Design
Engineer

Kevin Quinn, Research and
Development

Jake Dosset, Marketing
Director/Tether Manager

Ryan Cox, Control Systems
Engineer/ Mission Run Tech

Taylor Juve, Electrical Engineer

Kira Homola, Payload Systems

Emily Cyr, CFO/Mission
Specialist

Brian auf der Springe, Software
Analyst/Mission Run Tech

Nate Steinbock, Mechanical
Engineer

Casey Hearn, Tooling
Development

Team Mentors: Rick Rupan, Miles Logsdon

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Casus is an underwater Remotely Operated Vehicle (ROV) operated by students at the University of Washington. It was created for entry in the 2012 International ROV competition hosted by the Marine Advanced Technology Education (MATE) Center, as well as for use in the field by researchers affiliated with the university.

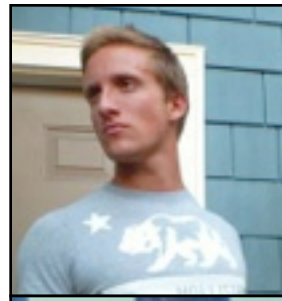
A team composed of sixteen members, known as 'Team Casus,' have designed and constructed an adaptable, intuitively controlled ROV. All machine systems and subsystems were created to perform a specific set of tasks published by the MATE Center. ROV Casus acts as a versatile platform, with a frame constructed of adaptable aluminum channel. A waterproof pressure vessel constructed of aluminum houses electronic controls, and provides additional structural support for the frame. Four 12 volt thrusters provide propulsion. These, along with a 30 foot tether, terminate at the pressure housing using wet mateable connectors. Neutral buoyancy and stability are achieved by the addition of a high-density float. A pneumatic control system powers a manipulator used to accomplish the mission tasks. Three cameras positioned strategically on the machine encompass all mission-specific tooling in their field of view. Tooling and propulsion systems are controlled by a student-designed electronic system, which utilizes an Arduino microcontroller.

Team Casus shares a common goal with the MATE Center, which is to interest students in marine technology careers. The ROV competition will allow students to utilize their machine in a high stakes, realistic environment to simulate real-world experience.

Name/Mission Role/ • Team Responsibilities/Expected Graduation Year



Trevor Uptain
Mission Commander
 • Scheduling
 • Design collaboration
 • Technical report
 • Pressure hull/float
 2014



Matt Bolte
Mission Control
 • Group coordination
 • Troubleshooting
 • Machinery operation
 • Hull/frame/float
 2014



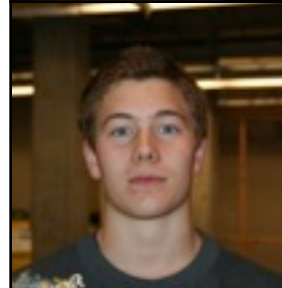
Jake Dosset
Tether Manager
 • Design
 • R&D
 • Frame Assembly
 • Vehicle Construction
 2014



Emily Cyr
Mission Specialist
 • Finances
 • Tech report
 • Documentation
 • Travel coordinator
 2014



Scott Daley
Pilot
 • Electronics
 • Software
 • Connections
 • Control interface
 2014



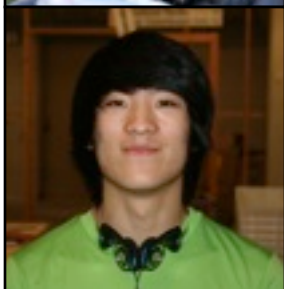
Nate Evans
Mission Specialist
 • Pneumatic controls
 • Manipulator
 • Tooling coordination
 • Pneumatic interface
 2013



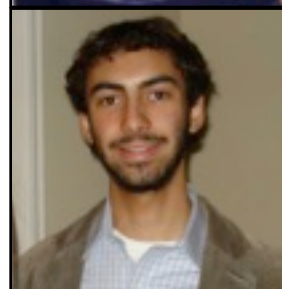
Ryan Cox
Mission Run Technician
 • Electronics
 • Software
 • Tether
 • Control interface
 2014



Brian auf der Springe
Mission Run Technician
 • Electronics
 • Software
 • Connections
 • Control interface
 2014



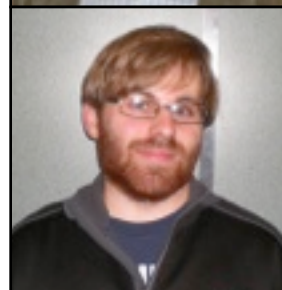
Colin Katagiri
Copilot
 • Electronics
 • Software
 • Connections
 • Control interface
 2014



Nate Steinbock
 • Cameras
 • Lights
 • Vehicle assembly
 • Vehicle construction
 2015



Taylor Juve
 • Software diagrams
 • Vehicle construction
 • Electronics
 • Schedule updates
 2015

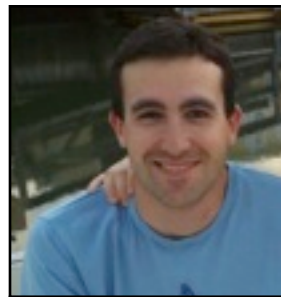


Tysen Mulder
 • CAD modeling
 • Waterproofing methods
 • Design and interface
 • Vehicle construction
 2015

**Kira Homola**

- Payload interface
- Oil extraction method
- Lift bag tooling

2012

**Casey Hearn**

- Payload interface
- Oil extraction method
- Lift bag tooling

2012

**Kevin Quinn**

- Electronic components
- Arduino installment
- Software input
- Controls input

2014

**Matthew Rasmussen**

- Electronic components
- Arduino installment
- Software input
- Controls input

2014

DESIGN RATIONALE

2.1 Logical Design Process

Design Collaboration

When the company began regular meetings in January of this year, they quickly recognized that the design process would require both cooperation and flexibility. This necessity was caused in part by funding uncertainty, which meant that no definitive plans could be immediately made for the purchase of certain components. Another factor was the large size of the Casus team. It was realized that poor coordination between sixteen people could pose a risk for conflicting design ideas, including the possibility of a member working on a task without realizing that another has already accomplished it. Recognizing that such an issue could cause a loss in money and time, the company created a process for planning and design efficiency:

- A list of tasks was created, and each one was assigned to an individual or group. Although the list was far from exhaustive, it included major components of the vehicle and any subsystem that could be foreseen as important at the time. The list was updated whenever a new task came to the team's attention.
- Team Casus realized that many of these tasks would be completed outside of scheduled club days and times. Meetings were held twice a week for about three hours, but constantly changing school schedules controlled whether certain members could even make it to group meetings as the season progressed. It became important for the team to utilize a simple, utilitarian method of communication to promote a step-by-step planning and design process. The team chose to utilize an internet forum for discussions related to the ROV, as well as a Facebook page to quickly collaborate with and get advice from their teammates.
- Each person or group of people assigned to a task was held accountable not only to a deadline for their project, but to the rest of the group for a scheduled completion. Recognizing that they would only be successful as a unit, the team fostered a sense of

responsibility without stifling the creative design process.

These methods proved effective as the year progressed. Although the process experienced some confusion when several members left the club early on, the gaps were quickly filled by available team members. The system allows individuals and small groups to work on their assigned tasks without the entire club present. The design and planning process was practiced and streamlined throughout the year, and will be implemented in future company projects.

CAD Modeling

The Casus project is supported largely by donated parts, which eliminated the company's possibility of building a machine directly from a computer designed model. Flexible design was crucial, since it was impossible for the company to predict when a simpler or more affordable solution would present itself. This type of construction has its own benefits, often promoting simple and creative solutions that might never have been considered otherwise. However, the team recognized the importance of CAD models, and created several of them throughout the year.

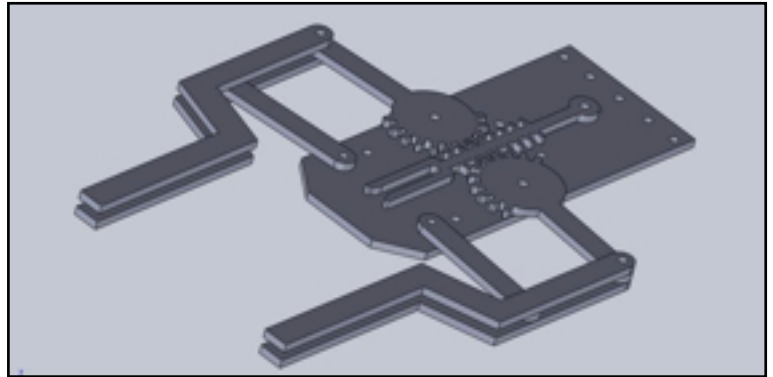


Figure 1 - A CAD model of the manipulator demonstrating the mechanics of the design

The company was given several copies of SolidWorks, and used it to model various subsystems. Implementation of the modeling process was important to the success of the project. The company found that the creation of CAD models helped not only to forecast design, but allowed for the use of water jetting services. Various CAD models are shared between team members, fostering interpersonal communication and promoting a complete understanding of the vehicle.

2.2 Science and Technology Emphasis

It takes a project like Casus to appreciate the role that science and technology play in the design and construction of an ROV. The Casus team, recognizing that science and technology are often taken for granted, placed an emphasis on the incorporation of intelligent, methodical design processes into their project. The team embraced the idea that science and technology should be pursued instead of ignored, and although budget constraints prevented the team from purchasing expensive parts, each member was encouraged to pursue creative avenues, solving problems that led to their own technological and scientific breakthroughs.

2.3 Mission Specificity

The design of ROV Casus is tailored to meet the specifications published by the MATE Center for the 2012 International competition, as well as the real-life missions the company will encounter diving in the Puget Sound next year. Versatility was a priority throughout the design process. The frame of the vehicle is the most important aspect of that versatility, with sliding mounting slots available along the entire length of every frame piece. This structure lays an

adaptable foundation for every other system attached to ROV Casus, including a set of mission specific, detachable tooling and sensors. These are designed to accomplish the 2012 mission tasks at the international venue. To perform a successful mission run, the company drafted a strategy for each task to be accomplished. The Casus design team referred to those strategies as construction proceeded, developing tools and accommodating needs within the constraints of the mission strategies. Mission specific tooling includes:

- A pneumatically powered gripper to retrieve and manipulate objects underwater, which is vital for the completion of several components of mission task number two
- A set of three cameras to provide a comprehensive field of vision, as well as to monitor mission tooling
- An air-powered assembly to fill a lift bag, which is used to move a fallen mast
- An extraction tool to remove oil from a vessel and simultaneously replace it with ambient seawater
- A high-intensity LED array used to simulate a sonar scan

2.4 Mechanical Structure



Figure 2 - A section of the extrusion used to construct the frame

Frame

The structural support for the ROV consists of extruded aluminum channel manufactured by 80/20 Inc. Recognizing that the channel was easily adapted to support system change, the company designed the frame to promote versatility for every other vehicle component. The frame measures 46 x 76 x 61 cm, providing a large area for the incorporation of future improvements. It supports the pressure hull, three cameras, the LED array, payload tooling, the float, and four thrusters. The frame was designed, cut, and assembled by Team Casus. Hardware specific to the channel is used to support every subsystem securely. The company considers this design to be a successful example of simple ingenuity.

Pressure Housing

The ROV's control systems and solenoid valves are housed in a pressure vessel designed to keep electronics safe from soaking or moisture. The pressure vessel is constructed of 1/4" aluminum plate. It is essentially a metal box, sealed to be water tight on one side by a rubber sheet attached to an acrylic lid. The lid is sealed firmly to the lip of the box using two ratchet-lock spring clamps, although design modifications in the near future will incorporate toggle clamps and an O-ring seal. Six connectors are mounted to the face of the pressure hull, two on one side and four on the other. These connectors are a point of contact between the electronics system and the surface controls, protecting the inside of the box from water even if the surface side of the connector is detached. The pressure hull design incorporates four mounting posts, which mount directly to the frame. The pressure hull was designed by team members, while the aluminum and welding service was donated to the company.

Flotation

A 15 x 76 x 61 cm piece of high-density polyurethane foam is mounted to the top of the ROV. The company designed Casus to operate as a moving platform, its stability unaffected by the addition of tooling or the retrieval of heavy objects. With the ROVs center of mass concentrated

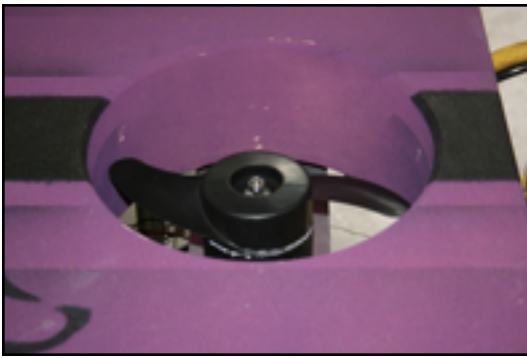


Figure 3 - The surface of the float with the thruster duct cut out

at a very low point, the addition of the foam provides neutral buoyancy and a strong righting moment. The team received the foam as a roughly shaped, unpainted block. The buoyancy of the material was calculated before the company modified it, and compared to the current weight of the ROV. It was determined that two, 23 cm diameter, circular ducts would be cut into the foam to accommodate the vertical thrusters. This was a precise calculation, but the team allowed for a margin of error when calculating the buoyancy. This decision was made to allow for the addition of unforeseen equipment, recognizing that it is more simple to add weight to the bottom of the machine than to put foam back on the float.

The foam was machined at the Mechanical Engineering shop at the University of Washington. With some initial assistance, several team members learned to program a Bridgeport mill. The foam was first trimmed to be level and square. Once this had been accomplished, it was possible for the thruster ducts to be removed from the block, again with the use of a programmable mill. A router was used to bevel the edges of the float for aesthetic value. The foam was painted and attached to the ROV with four 18 cm bolts. During initial practice runs, the company quickly came to appreciate the stability provided by the addition of the polyurethane float.

2.5 Payload Tooling

The MATE Center publishes a Missions Document outlining specific tasks to be accomplished by competing ROVs. To facilitate the successful completion of the mission within the allotted time slot, the company constructed a set of comprehensive tools to accomplish the missions with efficiency.

Manipulator

A versatile, utility-sized manipulator tool is mounted to the front of the ROV. The gripper was designed in SolidWorks to minute specifications and cut out from 1/4" aluminum plate on a water jet. The manipulator is built for function, with the capability to grasp large, heavy objects. Linear action is provided by a one-way actuator, which is controlled by a solenoid valve in the pressure hull. The linear motion of the actuator is turned into horizontal motion by a linkage system. A second linkage directs the gripper to open in parallel.



Figure 4 - The pneumatically controlled gripper

Oil Extraction Tool

To extract oil from the ship in task #2, a two-part system was created that attaches to the oil tank and detaches from the ROV. To achieve this, the company constructed an apparatus consisting of two rigidly connected insertion pipes. These pipes are housed as a floating body, held gently in place by rubber gaskets, within a pair of funnels that act to guide the ROV down onto the Inflow/Outflow ports on the oil tank. Once a mate has been achieved, the funnels clamp onto the tank while the pipes within the funnels slide down, penetrating the Vaseline layer and allowing fluid to be pumped into and out of the reservoir. Upon reaching the terminal extent of insertion, a trigger is activated that releases two clamps providing attachment points to the ROV. The entire two-part system then detaches from the ROV, enabling the vehicle to complete other tasks while fluid is extracted. To avoid an underwater reservoir and provide power to the pump, a long, thin tube wound with a power line will be connected to the surface, allowing the fluid to be pumped out of the pool. The pump needs a 12V power source, originating from the step-down converter on the ROV, then routed back to the surface and down the thin tube to the pump. Once all of the oil has been extracted, the ROV will be piloted back to the tank to pull out the insertion pipes and the pump, leaving behind the funnels clamped onto the tank. To use the provided Velcro patches, we will cut a slot for the pipe to slide through and house the patches within the funnels ahead of time. The Velcro patches will be in place, completely covering the inflow and outflow ports. The clamped funnel portion will be left behind providing an additional layer of protection beyond the Velcro patches.



Figure 5 - The oil extraction tool

Lift Bag Tool

The team will attached a carabiner to the lift bag, holding it with the ROV's arm. A large plastic ring will be inserted into the opening of the lift bag, providing a large hole for air to enter the bag from below. The ROV will hook onto the mast and fill the lift bag through a small air hose that runs along the arm of the ROV, while still holding the assembly. Once the lift bag is full, the mast will be raised and moved to the designated drop site. The ROV arm will release the carabiner, allowing the mast to settle to the bottom within the boundary of the drop site, where it will remain attached to the lift bag for the duration of the exercise.

LED Array

An array of mini LED lights are mounted in a waterproof housing and fixed above the front facing camera. The array produces a high-intensity beam which is used to simulate a sonar scan. The housing is a simple design, constructed from a small length of PVC fitting and capped with a clear acrylic lens.

Compass

A compass is mounted in full view under the forward facing camera. It is used to determine the orientation of the ship on the seafloor in Mission #1.

Ship Measurement Device

A simple device was constructed to measure the length of the ship as specified in Mission #1. A tape measure is mounted to the front of the ROV in view of a camera. The metal lip of the tape measure was removed, and was replaced with a hook to grasp the edge of the ship. The ROV pilot simply needs to position the hook over the edge of the ship and drive backward, drawing the tape out until the opposite side of the tanker is reached. The readout is visible on a surface monitor.

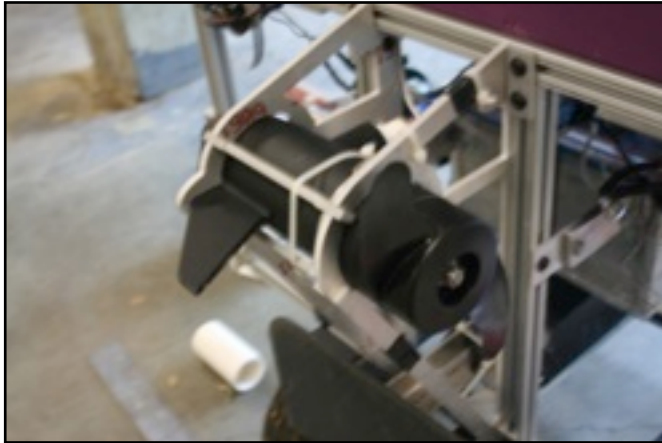


Figure 6 - A thruster attached to its custom-designed aluminum mount

2.6 Propulsion

Thrusters

The design of ROV Casus incorporates four large thruster motors. Two horizontally mounted thrusters are used for forward and reverse thrust and for steering. Two vertical thrusters, one mounted in the front and one in the back, equip ROV Casus with vertical ascent and descent capability. The thrusters were originally designed as trolling motors, producing 13.6 kg of thrust apiece. The steering attachment for each motor was mechanically removed. This left a gap in the motor casing, which was filled with a marine epoxy to waterproof it. The

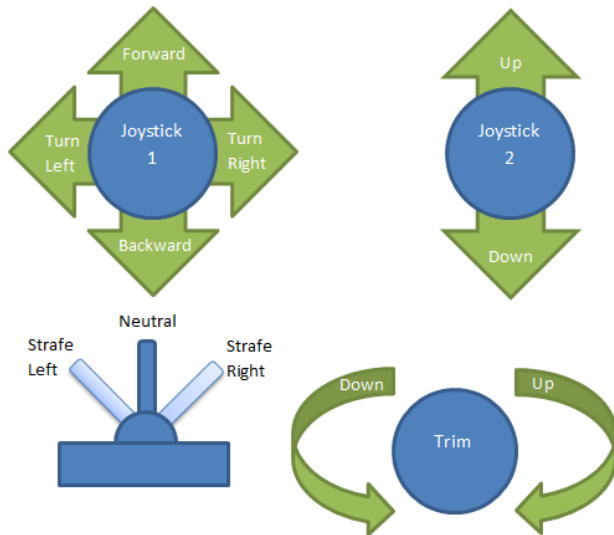
motors run on 12 volts, and are powered from the surface through the tether. The thrusters are mounted to the frame of the ROV using custom-designed motor mounts, which were modeled in a CAD program and water jetted to specification from 1/4" aluminum sheeting. Each thruster was equipped with a waterproof connector manufactured by Seacon, which allows for rapid connection to the pressure hull.

Propeller Safety

As with all of their ROV subsystems, Team Casus prioritized safety in the construction and operation of their thruster motors. The vertical thrusters are completely encompassed by the thruster ducts in the polyurethane float, and pose little to no risk of unintentional injury. To completely ensure safe operation, safety stickers are placed in plain view to warn operators of spinning propeller blades. The horizontal thrusters are encircled by externally mounted propeller shrouds made of heavy duty plastic. Additional warning stickers are placed externally around the rim of the shroud.

2.7 Cameras

ROV Casus is equipped with a set of three cameras, positioned strategically around the ROV to provide a comprehensive field of vision. They were manufactured by Armelectronics, originally designed to be security cameras. The team removed the camera units from their housings, placing them into simple waterproof casings which were constructed from PVC fittings. The electrical connection terminates at the back of the fitting using a marine epoxy.



2.8 Electrical Control System

Control

The control system of the Casus ROV is designed to be simple, robust, and practical. The team chose to utilize an Arduino microcontroller as the basis for the control system. The Arduino interface is flexible, allowing for easy programming and customization without compromising quality.

The majority of the ROV's movement is controlled with two joysticks. One is for all translational and rotation movement. The other joystick is used to control the depth of the ROV. In addition, a potentiometer is used

to set a trim for the vertical motors so that the ROV can be held at a constant depth. A 3-position switch which is used for left and right strafing movement.

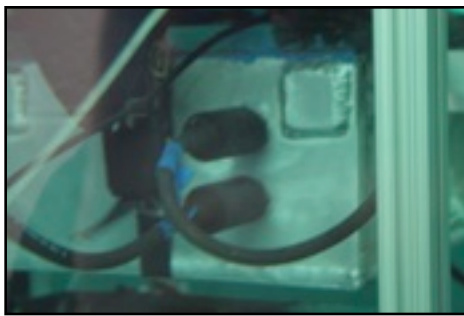


Figure 7 - The Seacon connectors attached to the pressure hull

The joysticks and potentiometer are connected to the tether, running from the surface controls to the pressure hull onboard the ROV. Once inside the ROV, the two translational signal wires run to one Arduino UNO microprocessor, which is connected to a motor controller, and finally to two motors outside of the pressure hull. The vertical and vertical trim signal wires are connected a second Arduino UNO, a microprocessor, and a pair of motors. The microprocessors interpret the control signals and tell the motor controllers how to adjust the speed of the motors. The 3-position switch is wired directly to 12 volts inside the pressure hull, as well as 4 small motors located around the ROV. When the

switch is in the neutral position, the motors will not spin. When the switch is in either the left or right position, the motors will all spin to push the ROV to the left or right respectively.

Connectors

All four motors and the tether terminate at the face of the pressure housing with underwater wet mateable connectors. These connectors, manufactured by Seacon, are easily installed and put into use without compromising the watertight housing. The use of the underwater connectors provides the company with a pressure vessel that can quickly be detached from its connections in the case that quick repairs are necessary.

Surface Controls

The ROV is controlled at the surface using a modified Pelican case, equipped with joysticks and switches. These are mounted to an acrylic lid, which is fitted to the inside dimensions of the case.



Figure 8 - The surface controls

2.9 Safety Features

The company recognizes that safety during the design and construction process is very important, and the everyday practices of the Casus team members reflect a high degree of thoughtfulness. Before construction of the vehicle began, a list of shop rules was posted on the wall in the company garage. The list was meant to reinforce the importance of workplace safety, giving practical reminders for the safe operation of equipment in the shop. That action set a precedent for the rest of the year, promoting a safe work environment for each student. Although the club has many safety standards for testing and operation, some of the most important are:

- Safety glasses must always be worn when working with power tools
- No one can work in the shop or run the ROV without another member present
- A safety protocol is always followed during testing of the electronics
- All propellers are guarded by thruster ducts or sturdy shrouds
- Warning labels are placed near moving parts

BUDGET AND EXPENDITURES

Donations	Dates	Amount
Rick Rupan	13-Feb	\$ 250.00
Miles Logsdon	7-Feb	\$ 250.00
Deborah Kelley	21-Feb	\$ 500.00
Barbara Way		\$ 50.00
Williamson and Associates	15-May	\$ 300.00
Greg Cox	22-Apr	\$ 50.00
Kathryn Mulder	23-Apr	\$ 10.00
Jeremy Lehner	24-Apr	\$ 5.00
Taylor Juve	26-Apr	\$ 50.00
Rebecca Bolte	30-Apr	\$ 100.00
Bolte	30-Apr	\$ 100.00
Kathryn Mulder	23-Apr	\$ 10.00
Mulder	30-Apr	\$ 55.00
Rita Peterson	8-May	\$ 100.00
Susan Hautala	8-May	\$ 300.00
Jennifer Auf Der Springe	14-May	\$ 20.00
Russ McDuff	8-May	\$ 500.00
Julie Uptain	15-May	\$ 50.00
Nancy Cox	15-May	\$ 100.00
John Deleany		\$ 1,000.00
Harlan Johnson	24-May	\$ 100.00
Richard auf der Springe	24-May	\$ 50.00

Inkind

Video Cameras	\$	600.00 AVX
Marine epoxy	\$	20.00 UW Ocean RECYCLING
Tether	\$	500.00 Sound Ocean Systems
Pressure Hull	\$	400.00 B&B Fabricators
Foam	\$	400.00 Janicki Industries
Connectors	\$	1,000.00 UW Ocean RECYCLING
Soldering supplies	\$	30.00 MTS
Shrink wrap	\$	15.00 MTS
Frame alluminum		
Small motors	\$	80.00 Rick Rupan
Control Case	\$	100.00 UW Ocean Recycling
Total Donations	\$	7,095.00

Description	Location	Date	Amount
Trolling Motor	Walmart.com	10-Feb	\$ 109.47
Soldering Supplies		4-Feb	\$ 34.53
Hrdware		23-Feb	\$ 33.84
Guitar Pick up		20-Feb	\$ 2.89
Motor Shields		16-Feb	\$ 133.85
3 trolling motors	Walmart.com	23-Feb	\$ 328.40
Arduino Board		18-Mar	\$ 37.05
Acrylic for Control box	Home Depot	20-Apr	\$ 20.24
Aluminum Plate	ThyssenKrupp		\$ 181.27
Controls			\$ 44.25
Power Plug			\$ 5.85
Plastic foot and check valves	Lowe's		\$ 23.56
Hardware			\$ 47.05
Hardware	Hardwicks		\$ 27.96
Checks			\$ 14.51
Actuator			\$ 59.00
Matt			\$ 68.70
Acrylic for Pressure Hull	Tap Plastics	7-Apr	\$ 37.64
Hardware for Arm			\$ 29.14
Hook-up wire and multiplexer	Vetco	11-May	\$ 48.19
Metal Krob	Radioshack	8-May	\$ 3.27
2 Joysticks		11-Apr	\$ 8.99

D sub 25 pin connector		20-Apr	\$	7.00
Measuring Tape	Hardwick's	9-Apr	\$	2.29
4 hose clamps	Hardwick's	9-Apr	\$	9.16
Lubricant	Hardwick's	8-May	\$	8.90
Hardware (nuts, bolts, washers)	Hardwick's	8-May	\$	19.34
Rubber gasket	Hardwick's	8-May	\$	10.25
Dual Heat Soldering Gun		18-May	\$	32.99
10 LEDs	superbright leds.com	29-Mar	\$	11.89
5 Resistors	Radioshack	2-Apr	\$	1.30
Power transformer 12v to 5v step down		30-Mar	\$	6.79
Prototypingboard	Radioshack	16-Apr	\$	3.98
4 standoffs	Radioshack	17-Apr	\$	3.19
2 solenoid valves			\$	26.00
Arduino Uno board	NKC Electronics	3-Apr	\$	21.95
Connectors	Wenow	6-Apr	\$	5.85
Air Hose	Hardwick's	11-May	\$	11.27
Wire ties	Hardwick's	4-May	\$	3.59
PVC	Hardwick's	19-May	\$	10.00
PVC Pipe fittings	Hardwick's	18-May	\$	20.00
Epoxy	Hardwick's	4-May	\$	19.48
Hardware	True Value	23-Apr	\$	5.46
Silicon Glue	Ace Hardware	7-May	\$	4.37
4 Toggle Clamps	McMaster-Carr	24-Apr	\$	140.46
Silicon O-ring	McMaster-Carr	1-May	\$	16.17
Dc-Dc Converter 48-12v step down	eBay	5-Apr	\$	69.99
Shipping			\$	410.00
Total			\$	2,181.32

TROUBLESHOOTING

Troubleshooting Technique

No matter how much careful planning goes into a project, human or machine failure is always a possibility, and it is to be expected that troubleshooting techniques will need to be used to solve the problem. Team Casus utilized such techniques several times throughout the year when faced with unexpected failures in equipment. In such cases, it is usually necessary to embrace a methodical approach in solving the problem. Troubleshooting is an often underutilized process that can be applied almost immediately to identify a problem, or at least to eliminate what the problem might *not* be.

Identification and Solution

One example of a troubleshooting method used on the Casus ROV involves an apparently faulty connector in the pressure hull. Six connectors were installed, but only five of them worked properly at first. The thruster matched with the bad connector would not run. To identify the core problem, the company created a list of components potentially at fault. One possibility was that the connector itself was faulty, which was a possibility since the part was donated and had been used previously. A second was that a motor controller had somehow been damaged during the installation of the connectors. The third was that the controls had been wired up incorrectly. To solve the problem, the careful troubleshooting methods described in the previous section were applied to remediate the situation.

Component Testing

Since the connector could not be uninstalled from the box without unsoldering the connections, it was decided that the problems would be addressed in this order:

- The control box would be opened, and the motor controllers would be inspected visually for damage. If this proved to be the problem, a new controller would likely need to be ordered.
- If no faults were spotted, the wiring configuration in the pressure housing would be compared against previously drawn diagrams to ensure their completeness.
- If neither of these methods solved the problem, the connector would be desoldered to test continuity.

No damage was to be seen anywhere in the housing, so the team moved on to step two. At first glance, everything looked perfect. However, upon closer inspection, it became clear that the wire contact to the fixed half of the connector had been soldered on incorrectly. After comparing the wiring to the diagrams, the team realized that a documentation mistake had caused the wiring interface to the connector to be mirrored. Fortunately, no permanent damage had been done, and the problem was quickly remediated.

This is a simple example of troubleshooting and component testing. Similar techniques were applied to other parts of the control system and ballasting issues.

CHALLENGES

Team Management and Task Allocation

There are many benefits that come with having a group as large as the Casus team does, but there are also a few downsides that can lead to frustrating, and sometimes even demoralizing experiences. One aspect of team management proved difficult for the company this year, caused by the large number of members involved in the project. With so many people working on the ROV, it was often difficult to allocate tasks to keep everyone engaged. This proved to be a problem more than once during the year, especially when funds were low and meeting attendance was high.

To overcome this challenge, the team acknowledged that there was nothing any one person could do to allocate tasks to every individual. Each member of the team was responsible for the ownership of his or her own part of the project, and needed to pursue their own design

goals on their own terms. As the year progressed, team members discovered for themselves how their time could be better used to further construction of the ROV.

Waterproofing the Pressure Housing

The pressure hull was originally designed to be sealed by an acrylic lid with an O-ring gland, held in place by four high-strength toggle clamps. The team had attempted to seal the lid on, but discovered that the O-ring that had been purchased to seal the box was about an inch too long to fit snugly around the gland and properly seal the hull. The team placed an order for a new O-ring, but there was a strong chance that it would not arrive for weeks, and the company realized that sealing the pressure hull was essential if they wanted to qualify.

To solve the problem, the team sought out the advice of a University of Washington faculty member with the oceanography department. He suggested that the O-ring be replaced with a rubber gasket as a temporary solution, held in place by the lid and secured using ratchet-lock spring clamps. Although several team members were hesitant to take the suggestion, the necessary materials were purchased and the idea implemented. The new design quickly proved itself effective in keeping water away from the inside of the pressure hull.

These are only two of many challenges the team has faced over the course of the Casus project.

LESSONS LEARNED

Interpersonal Information Sharing

Interpersonal communication amongst members of team Casus was vital in order for the project to be finished within budget and on time, and poor methods of communication become very obvious when used in a group the size of the company. For our group specifically, it became quickly apparent which methods of communication were most effective. Email, for example, did not prove to be an effective method of conversation for many team members, causing a break in the team's communication network. Conversely, utilization of a Facebook page for group communications was surprisingly successful. The lesson learned was not only the value of communication, but that the medium used for that communication can make a big difference.

Camera Waterproofing Methods

ROV construction poses a challenge not often faced in other branches of robotics: the mixing of water and electronics. Casus supports three cameras, a necessity for the completion of every mission task. While the team has refined their methods of creating waterproof housings in the last few months, they have learned that there are better methods out there than the ones they are currently using. The company learned that lesson the hard way when the main camera flooded during the ROVs first dive. The company will focus much of its future research and development on alternate camera waterproofing methods.

FUTURE IMPROVEMENTS

Saltwater Capability

Casus is designed to be operated in the Puget Sound by faculty members at the University of Washington. With that goal in mind, the team hopes to spend this summer equipping the ROV to run in saltwater. While many of the ROVs components are rugged and well designed, there are many parts that simply could not withstand the harsh environment of the sea. Here are some steps the team needs to take to accomplish this drastic improvement:

- The current electronics housing would be replaced by a cylindrical pressure hull
- All aluminum onboard the ROV would be hard anodized
- Stainless-steel hardware would replace the current set
- An oil pressure compensation system would be incorporated into the thruster design
- The tether would be lengthened to 100 meters

TEAMWORK

The company considers this year's ROV project to be a success. Team Casus recognizes that their ROV could never have been completed in such a short amount of time without a strong sense of teamwork within the group. Each aspect of the project, from the design and construction of the vehicle to the technical report, was facilitated by a group of individuals who were determined to succeed. Each member of the group proved their commitment through hard work, dedication, and thoughtfulness in the design and construction of their vehicle. Every team member contributed to the overall success of the group, a success that involved building every component onboard the Casus machine from scratch. This includes a very reliable working platform, an intelligent controls system, and reliable software. Specific tasks were developed at the beginning of the year to create a system of accountability, holding each team member accountable for their part of the project. A system of deadlines was created to keep the project on schedule, a task that wasn't easy when working with so many other teammates. Team Casus pulled through even that challenge, emerging to travel to the international competition in Florida, even after they were told it wasn't possible. It's just a little something this company likes to call 'teamwork.'

PROJECT REFLECTIONS

2012 is not only our company's first year competing at the international level, but is the first year of ROV construction for most of our team. Inspired by the success of the MATE program, the overarching goal of our organization is to promote the values of creativity and innovation as they apply to ROV design, recognizing that an interest in marine technology will almost certainly follow. Casus is the product of that idea, an ROV built in less than five months by students with a passion for success. A few of the skills our team has acquired include software coding, CAD modeling, and a strong sense of teamwork. Our group synchronized almost immediately, with every student finding a common interest in ROVs. Our achievements have been remarkable, and our efforts have been noticed. Several articles about ROV Casus,

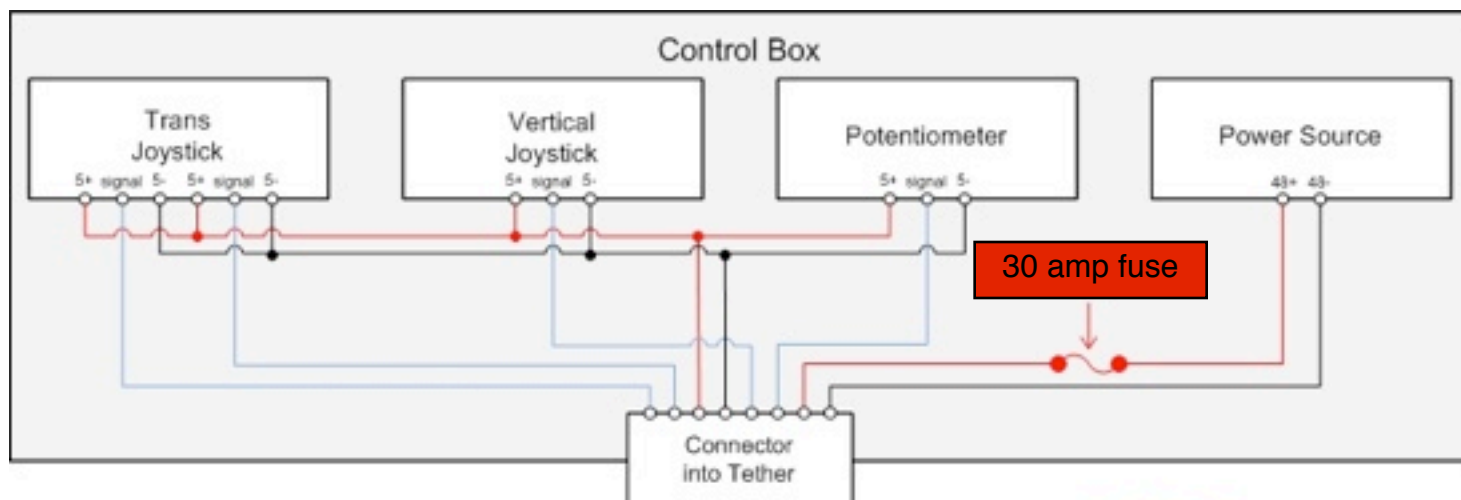
overwhelming assistance of faculty from the UW School of Oceanography, and donations from supportive friends and family members are the most obvious indicators of our success.

Our company is confident that our unique approach to problem solving has prepared us well for the international venue. Just as we have accomplished so much throughout the construction process, we expect to produce results in Orlando. The focus of the team, our comprehensive building process, and the surprising dexterity of an ROV as large as Casus all lend to a big potential for success. Better yet, we plan to use the lessons we learn from this competition to make modifications to Casus so that it can be used by our school. When it comes down to it, our team doesn't measure results based only on how many points we accumulate in Orlando, but also by the impact we make to the research community at our university. We know that whatever we learn along the way will increase our value as students and employees, and help Team Casus to realize that, together, anything they set out to accomplish is possible. We look forward to seeing you in Orlando.

Acknowledgements

We would like to thank the following people and businesses for their financial, moral, and technical support. Without you, nothing we did this year would have been possible.

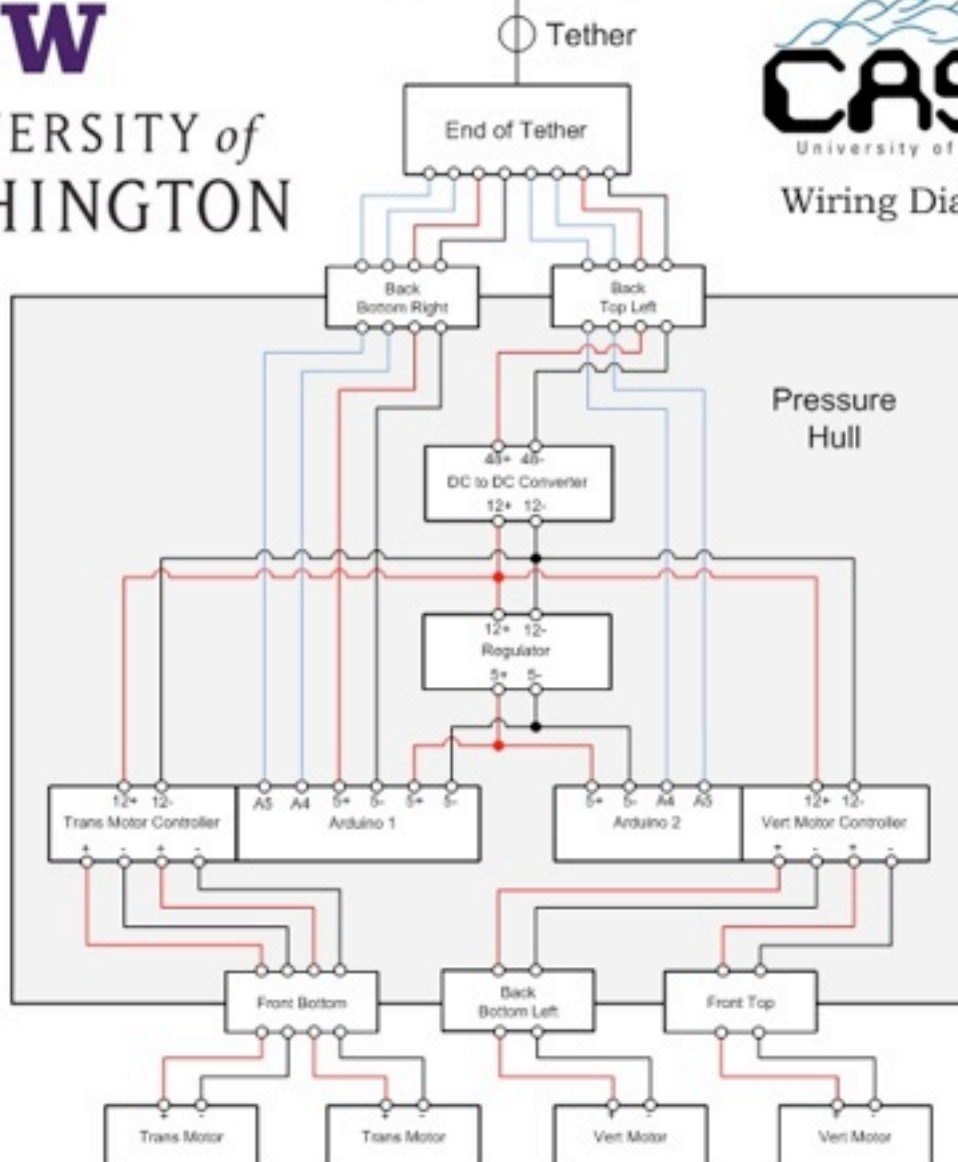
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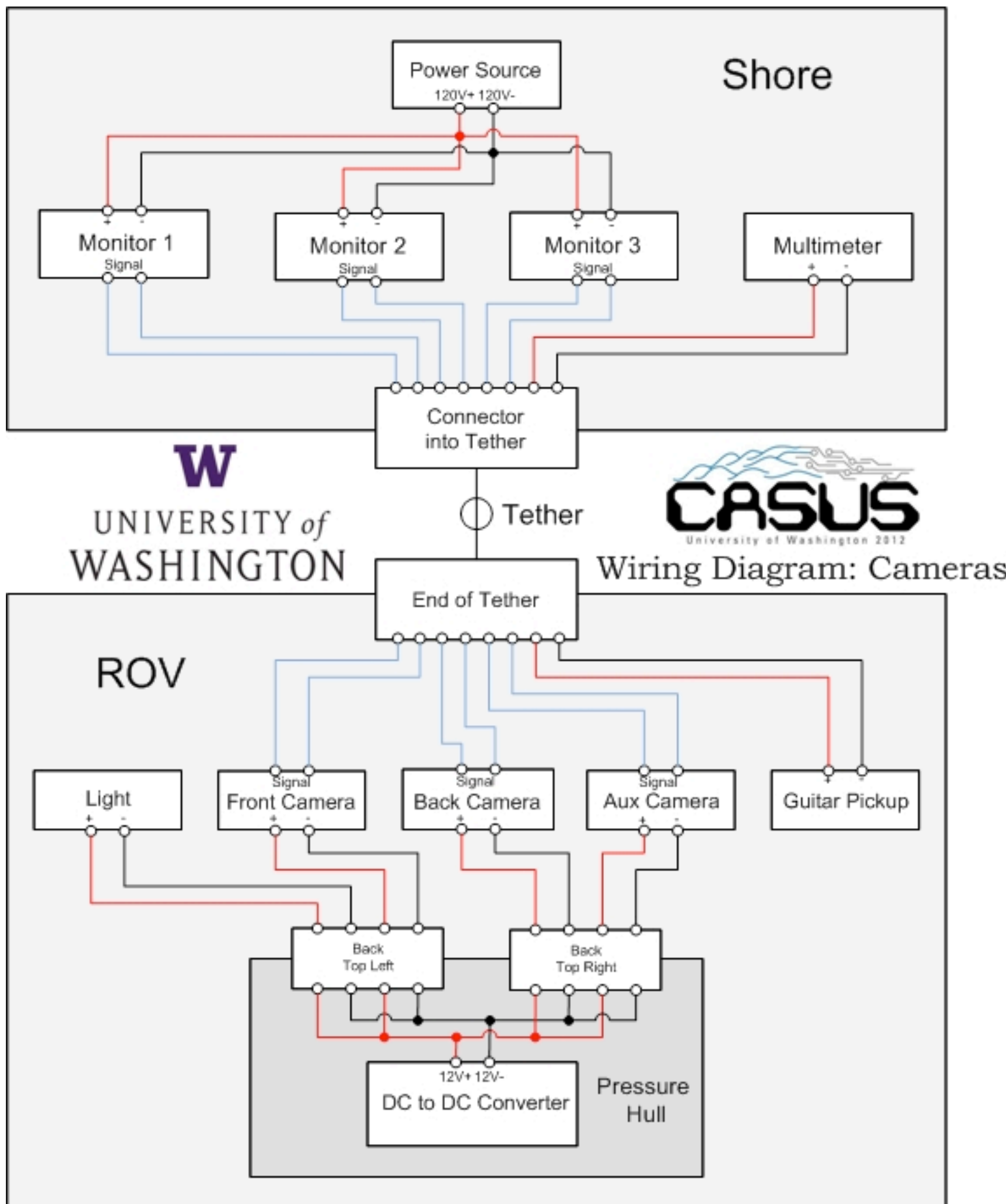


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Wiring Diagram: Motors





Casus ROV

Onboard Microcontrollers
Flow Chart

