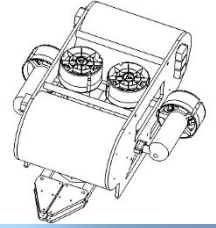
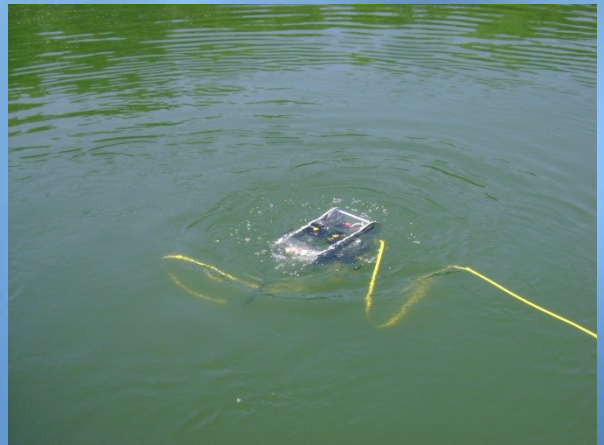


Missouri State University ROV Team



and ROV *Benthic Bear*



Team members:

Luke Waier - Team captain - Mechanical Engineering
Jeremy Clemens - Electrical Engineering
Tommy Tran - Mechanical Engineering
Zac Slaughter - Mechanical Engineering
Brian Olle - Mechanical Engineering

Mentor:

Dr. Pawan Kahol - Dept. Head of Physics, Astronomy, and Materials Science

Table of Contents

1. Abstract.....	page 3
2. Benthic Bear.....	page 3
3. Design Rational.....	pages 4-5
4. Vehicle Systems.....	pages 6-7
5. Budget/Expense Sheet.....	page 8
6. A Challenge.....	page 9
7. Troubleshooting Technique.....	page 9
8. Lessons Learned.....	page 10
9. Future Improvements.....	page 10
10. Reflections.....	page 10
11. MBARI Hydrothermal Research.....	page 11
12. References.....	page 12
13. Acknowledgements.....	page 13
14. Appendices.....	pages 14-16
- Appendix A - Electrical & Com. Schematic.....	page 14
- Appendix B - SolidWorks Assembly.....	page 15
- Appendix C - Buoyancy Calculations.....	page 16



1. Abstract

This year's project is the application of all our team has learned from participating in the MATE competition the past two years. This year we decided that most of the problems we faced in the previous projects could be solved by simplifying the ROV design and manufacturing process. This year we also decided to spend much more time designing to ensure any potential design problems were solved before parts were ordered or machined. During the design stage we used CAD software to analyze and adjust our design. This design tool proved very effective as it enabled us to better visualize the individual parts and the assembly of those parts.

2. Benthic Bear

Figure 2.1



Benthic Bear



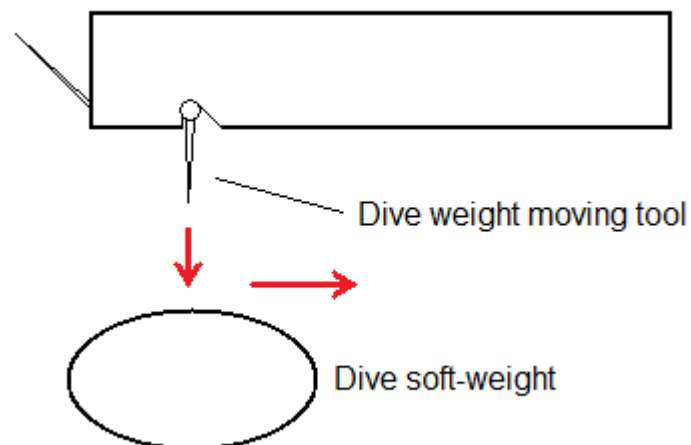
3. Design Rationale

We began our design process by listing our technical challenges. We relied on our experiences during the past two years of designing and building ROVs for the MATE competition to design solutions to the problems associated with building an ROV and completing the missions assigned by MATE. We created our original ROV design using the guideline of keeping it simple. That design went through a few modifications on paper; each change in the design reduced the number of parts, reduced the cost, and simplified the manufacturing process. We created the final design in SolidWorks, and used this to analyze any additional design problems. Here are the solutions we designed to complete the mission tasks we will encounter at the MATE competition.

Task #1 - Freeing the OBS from the seafloor

As with our team's ROV, our methods for completing the missions are very simple. We built a tool that can move and pick up specifically light weight soft dive weights. This tool works by poking between the fibers that hold in the lead weight with a needle. This needle is the same used to sew clothing and is small enough that it does not damage the cloth dive weight. To free the OBS from the seafloor we use a needle that is pointed down. We thrust the ROV downward slowly, poking into the weight, then thrust reverse. This pulls the weight off of any simple structure it is resting on.

Fig 3.1

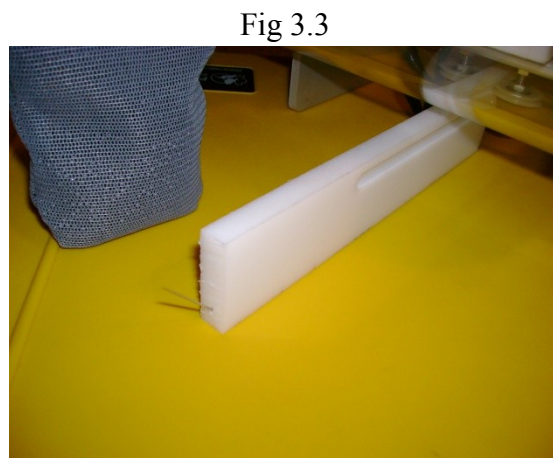
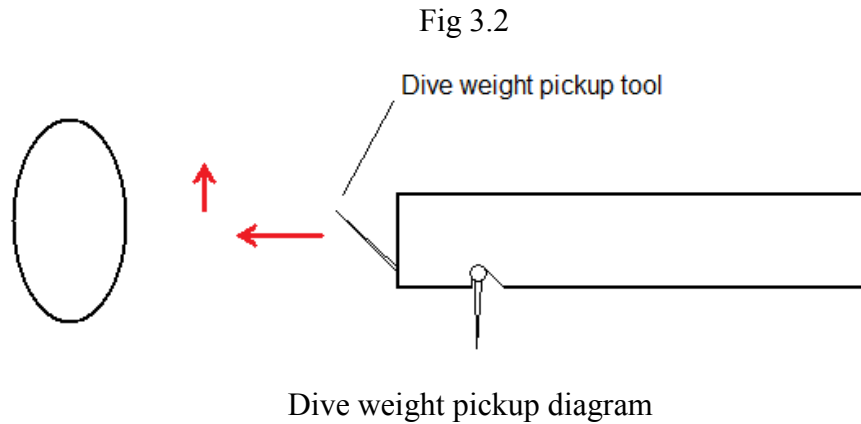


Weight moving diagram



Task #2 - Collect up to three samples of lava

For this mission we use the front needle of the dive weight tool. This needle is angled upward so it holds onto the dive weight. To use this tool we thrust forward into the weight and thrust upward to the surface for retrieval. We extensively tested this method of extracting the dive weights and it performed well in most situations.



Dive weight tool

Task #3 - Measure the temperature of hydrothermal vent fluid

For this mission task we simply attach a small digital thermometer to the end of our dive weight tool. The display on the thermometer is in view of the camera, and an attached probe extends into the stream of flowing fluid.

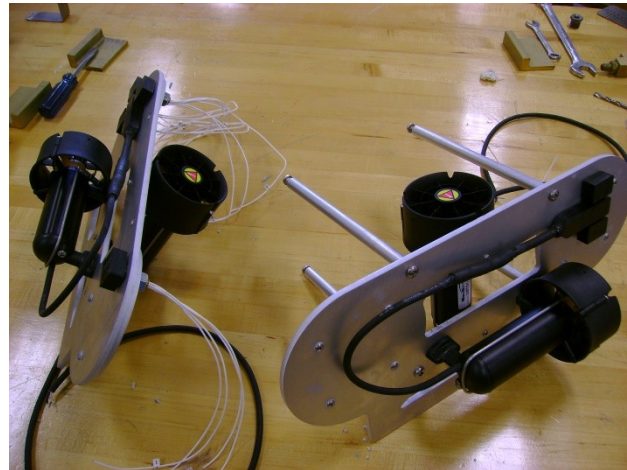


4. Vehicle Systems

Structure

The main structure of Benthic Bear was built from one plate of 1/4" 6061 aluminum and a tube of acrylic. The aluminum plate was laser cut into two main pieces that hold everything together, and four pieces that hold the o-rings and acrylic tubes in place. There are no permanent enclosures on Benthic Bear. Everything is easily accessible and can be replaced if necessary.

Figure 4.1

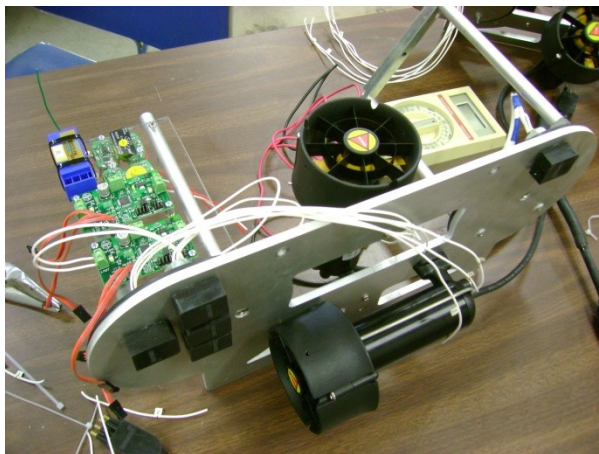


Assembling ROV

Electrical

Our vehicle uses a six channel Airtronics RC transmitter and receiver as the interface for communication to the ROV. Two onboard dual-channel motor controllers connect to the RC receiver and control each thrusters speed and direction. All connections made from outside the vehicle to both enclosures use SubConn connectors, which can be easily disconnected at any time.

Figure 4.2



Wiring the Electronics



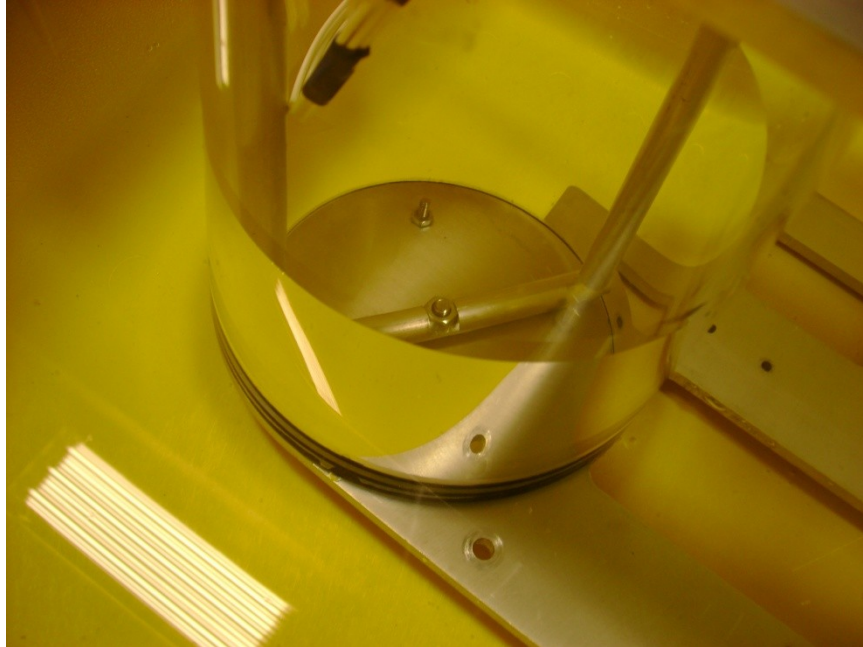
Video

The pilot operating Benthic Bear sees the mission through a high resolution camera mounted on a tilt motor within the front acrylic tube. This camera can be tilted from the surface a full 360 degrees up and down. Video is transmitted through a twisted pair of 16 AWG wire connected to a passive video balun at each end.

Waterproofing

The entire design of Benthic Bear was mostly based on an idea for a simple and reliable way to seal the ROVs dry compartments while providing quick access to the components within each compartment. The basic idea is to “sandwich” together the outer plate, and o-ring, on each side of an acrylic tube. A cross bar on the inside of the tube pulls the two outer plates together, effectively compressing the o-rings. To gain quick access simply back out the bolt that holds it all together. The bolt itself is counter-sunk into the aluminum plate and is sealed with a smaller o-ring.

Fig. 4.3



Waterproof testing - Shallow water test



5. Budget/Expense Sheet

School Name: Missouri State University

Instructor/Sponsor: Dr. Pawan Kahol

Deposit or Expense	Description	Amount	Balance
Deposit	Student Organization funding	\$5,000.00	\$5,000.00
Expense	Four SeaBotix Thrusters	\$1,593.50	\$3,406.50
Expense	SubConn Connectors	\$785.04	\$2,621.16
Expense	24vdc motor	\$30.25	\$2,591.21
Expense	Cast acrylic tubing	\$135.75	\$2,455.46
Expense	Laser cut aluminum	\$279.51	\$2,175.95
Expense	Motor controllers	\$247.27	\$1,928.68
Expense	High resolution camera	\$130.97	\$1,797.71
Expense	Digital thermometer	\$33.66	\$1,764.05
Expense	Two 24 - 12v DC/DC converters	\$31.86	\$1,732.19
Expense	O-rings	\$23.89	\$1,708.30
Expense	Pelican Case	\$153.78	\$1,554.52
Expense	48 - 24v DC/DC Converter	\$304.30	\$1,250.22
Expense	Electronics assortment	\$22.22	\$1,228.00
Expense	Misc. hardware	\$65.00	\$1,163.00
Expense	Five airline tickets to San Diego	\$1,420.00	-\$257.00
Expense	Five rooms for four nights at UCSD	\$875.00	-\$1,132.00



6. A Challenge

One challenge our team faced was fixing a design flaw that caused our ROV to leak water during our first water proof test. The problem was caused by the design of having the force on the o-rings applied on just one side of each o-ring. The original design required stainless steel, but we switched to aluminum to save money. The softness of the aluminum caused an uneven distribution of force on the o-rings. We solved this by fabricating interior cross pieces that applied force to the o-rings from the center of the o-rings which naturally caused an even distribution of force on each o-ring. This proved to be a successful design modification as we have not had any moisture in the enclosures since then.

7. Troubleshooting Technique

When we realized that one of our motor controllers did not power on when it was connected to a power supply we went through a quick troubleshooting process to see if it was due to an error we made. We started by gathering information about our setup. We had two identical controllers connected in parallel to a 12v battery, and one consistently would not power on. We noticed that each controller had a high voltage jumper for use above 16v, and both jumpers were not removed. We also noticed that the controller was unresponsive to control signals and both its LEDs did not light up, which differed from the working controller. We double checked our input power polarity. We then started eliminating possibilities of the cause through experimentation. First we disconnected the “good” controller to see if the controller would work by itself. Then we removed the high voltage jumper and connected a 24v battery. Finally we consulted technical support from both the company that made the motor controller, and the company that we purchased the controller from. After all of our troubleshooting we concluded that the controller must be faulty or somehow had been damaged. We were able to send the controller back to the supplier and received a new one.



8. Lessons Learned

We consider this year's project more of an application of all the lessons we learned last year, but there were a few things we did learn this year. First, we learned that we should always test all our electronic components when we first receive them. We learned this because one of our motor controllers did not work when we first connected it to power, and like many of our parts it had been sitting in a box for a few months until we were ready to use it. We had to send the controller back to the company and order a new one, and this put us behind our schedule. Another lesson we learned is that o-rings don't always work so well if they don't have an equal distribution of force compressing them. We realized this when our first waterproof test resulted in an ROV full of water. We learned that this problem could be fixed by either using more rigid material which better distributes force on the o-ring, or applying the force from the center of the o-ring.

9. Future Improvements

There is always room for improvement, and next year we could improve in the overall organization of the project. We did every thing we could do to make the project go as smoothly as possible to limit the amount of time we needed to take away from our normal classroom studies, but there were set backs to our schedule. To improve this we need to create ways to better plan and organize team meetings and schedules for working on the ROV. Also we need to find ways to spread out the individual member responsibilities to lessen the work load of a small number of dedicated members.

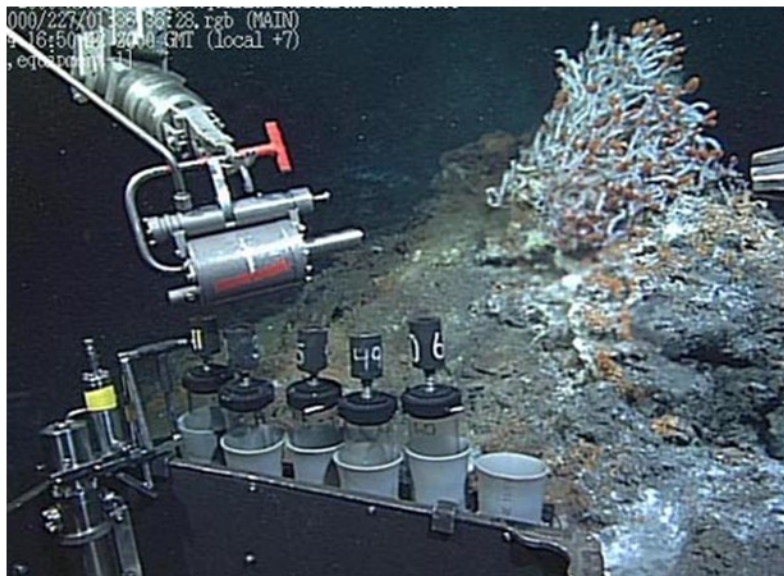
10. Reflections *by Luke Waier - Team Leader*

As the veteran of the MSU ROV Team I can look back at our past projects and say that this year's project is a major success. Our ROV this year is just built to work, and I feel comfortable knowing we will enter the competition this year with an effective vehicle. Throughout this project we encountered a few problems worried us, but each team member was able to put their mind into some of our biggest challenges, and this was a good experience for those new to the team.



MBARI Hydrothermal Research With ROV Tiburon

Since black smokers were first discovered in 1979 along the East Pacific Rise they have been a subject of research among many ocean scientists. MBARI (Monterey Bay Research Institute) started sampling hydrothermal vent fluid from the Gorda Ridge in 1988 and has since returned using the ROV “Tiburon” to conduct research at this site. The Gorda Ridge is a “tectonic spreading center” west of the Gorda Plate and south of the Juan de Fuca Plate. MBARI used Tiburon to sample fluids from the active hydrothermal system in Escanaba Trough in Gorda Ridge in 2000 and 2002. The region is considered relatively stable as the composition and temperature of the vent fluid samples are fairly identical to the samples first extracted in 1988, although the temperature of the more recent samples had increased.



ROV Tiburon sampling vent fluid at Gorda Ridge in 2002

Although surface samples show a stable environment, the pore water data taken after drilling at Gorda Ridge suggest that the chemistry under the sediment cover is more complex than was originally expected.

Like MBARI’s expeditions with Tiburon at a real mid-ocean ridge, we will be using Benthic Bear to extract samples and data from a simulated active hydrothermal zone and mid-ocean ridge.



12. References

MBARI Research & Development

<http://www.mbari.org/volcanism/Ridge/R-Hydrothermal.htm>

NOAA Vents Program

<http://www.pmel.noaa.gov/vents/geology/gorda.html>



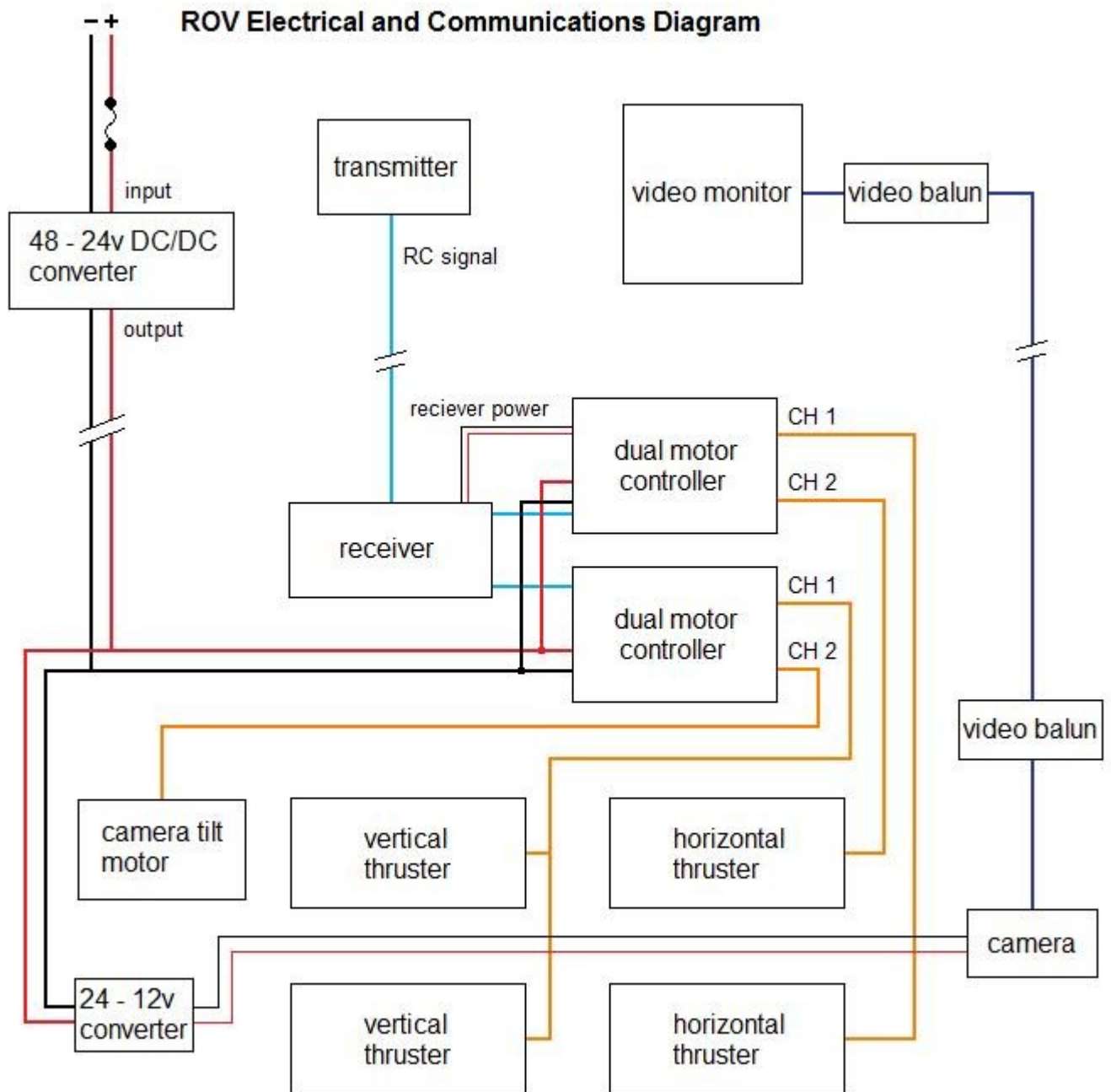
13. Acknowledgments

We would like to thank SOFAC, SeaBotix, SubConn, VideoRay, and Trossen Robotics for their generous contributions and support for our project this year.

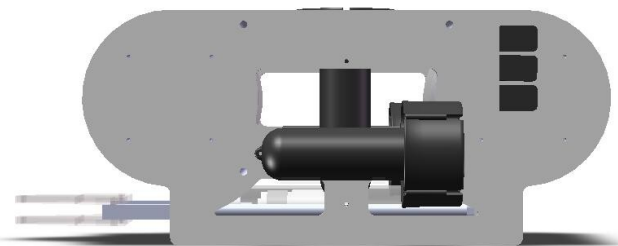
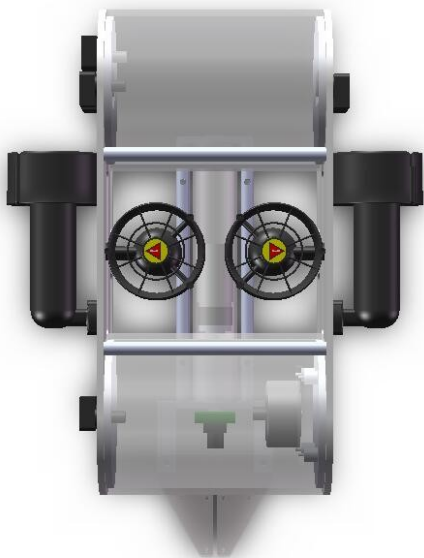
We would also like to thank MATE and all the competition sponsors for making this experience possible.



Appendix A - Electrical and Communications Schematic



Appendix B - SolidWorks Assembly



Appendix C - Buoyancy Calculations

When designing Benthic Bear we needed to know what adjustments to the vehicles buoyancy would need to be made in order to get the ROV close to neutrally buoyant. We were particularly uncertain whether the acrylic tubes would displace too much water. Here are our calculations and results which were used during the design process.

To find the buoyancy of a single object we simply subtracted the density of water from the density of the material, keeping units consistent, multiplied by the object's volume, and then multiplied by G to get the result in Newtons. To get the total buoyancy of Benthic Bear we added the buoyancies of the individual parts as necessary.

$$\begin{aligned}\text{Density of water} &= 997 \text{ kg/m}^3 \\ \text{Density} &= \text{mass/volume} \\ \text{Force} &= \text{mass} \times \text{acceleration of gravity}\end{aligned}$$

$$\begin{aligned}\text{Volume of Aluminum side plate (provided by Solidworks)} &= 426 \text{ cm}^3 = 4.26 \times 10^{-4} \text{ m}^3 \\ \text{Density of 6061-T6 Aluminum} &= 2700 \text{ kg/m}^3 \\ \text{Buoyancy of side plate} &= ((2700 \text{ kg/m}^3) - (997 \text{ kg/m}^3)) \times (4.26 \times 10^{-4} \text{ m}^3) \times (-9.8 \text{ m/s}^2) \\ &= -7.1 \text{ N (Negatively Buoyant)}\end{aligned}$$

$$\begin{aligned}\text{Volume of Acrylic tube wall} &= 592 \text{ cm}^3 = 5.92 \times 10^{-4} \text{ m}^3 \\ \text{Density of Acrylic} &= 1.2 \text{ g/cm}^3 = 1200 \text{ Kg/m}^3 \\ \text{Buoyancy of tube wall} &= ((1200 \text{ kg/m}^3) - (997 \text{ kg/m}^3)) \times (5.92 \times 10^{-4} \text{ m}^3) \times (-9.8 \text{ m/s}^2) \\ &= -1.18 \text{ N (Negatively Buoyant)}\end{aligned}$$

$$\begin{aligned}\text{Volume of Sealed Acrylic Tube} &= \pi \times \text{radius}^2 \times \text{length} \\ &= \pi \times 3^2 \times 8\text{in} = 226.19 \text{ in}^3 = 3.70 \times 10^{-3} \text{ m}^3 \\ \text{Displacement of sealed Acrylic tube} &= (3.7 \times 10^{-3}) \times (997 \text{ Kg/m}^3) \\ &= 3.69 \text{ Kg} = 36.16 \text{ N (Positively Buoyant)}\end{aligned}$$

$$\begin{aligned}\text{Buoyancy of SeaBotix Thrusters (given by SeaBotix thruster specs)} \\ &= -3.43 \text{ N (Negatively Buoyant)}\end{aligned}$$

$$\begin{aligned}\text{Net Buoyancy of ROV} &= \text{Buoyancy of 4 thrusters} + 2 \text{ side plates} \\ &\quad + 2 \text{ tube walls} + \text{displacement of tubes} \\ &= 4 \times (-3.43 \text{ N}) + 2 \times (-7.1 \text{ N}) + 2 \times (-1.18 \text{ N}) + 2 \times (36.16 \text{ N}) = \underline{\underline{42.04 \text{ N Positively Buoyant}}}\end{aligned}$$

