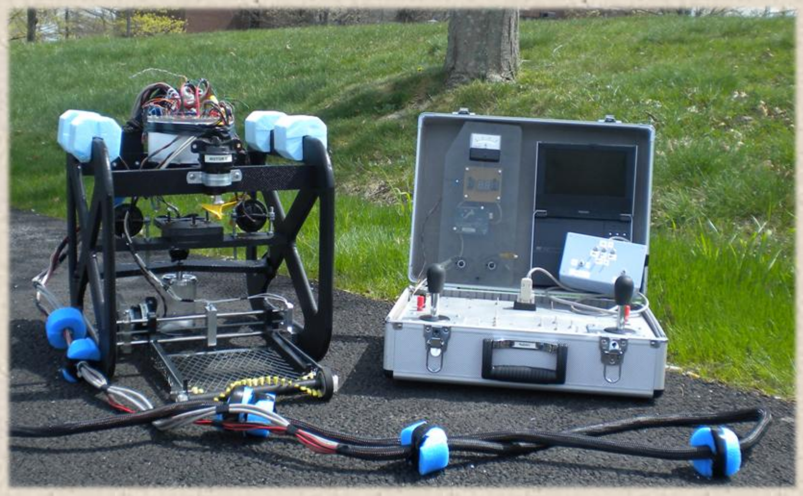
Team Tectonic Chaos

In Partnership with

BCC/UMD Engineering

Presents...

RaDAV



The Research and Data Acquisition Vehicle

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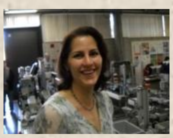

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NSF

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Abstract

Team Tectonic Chaos prepared this technical report to document our team's engineering process. We designed an ROV (Remotely Operated Vehicle) under strict budgetary and design limitations. The ROV we constructed has a lightweight plastic frame. It houses nine motors (including two motorized tools), lighting, four cameras, and multiple sensors. Our primary tool is a multipurpose fork that is designed to not only lift and pull objects, but also grab and release objects. A microcontroller was incorporated to control the temperature sensor and motor speeds. The electronics enclosure on the robot and our portable control box, with built-in control redundancy, are connected by a thirty-meter tether that disconnects easily. All of these systems come together to create RaDAV (Research and Data Acquisition Vehicle) our entry in this year's MATE 2010 competition.

Research

Figure R.1
HURL's ROV the RC-150

Figure R.2
Pogonophoran worm

The tasks given by MATE in this year's competition closely resemble real life research missions. The Hawaii Undersea Research Laboratory (HURL), a research station for the Western Pacific founded in 1980, has been studying the underwater environment at the Loihi seamount for the past few decades. The Loihi seamount, a recently active underwater volcano, has been of interest to the scientific community ever since a high volume of earthquakes hit the area in 1996. In one month the Loihi seamount was recorded to have experienced over 4,000 earthquakes.

As a result of numerous volcanic eruptions, the volcanic vent system formed a series of craters including Pele's Pit. Since then, HURL has been running missions in the area which are similar to the tasks in this year's M.A.T.E competition.

HURL has two submersible vehicles (Pisces IV & V) and a ROV (RC-150 Fig. R.1). These vehicles have been used to repair HUGO (Hawaii Undersea Geological Observatory) and collect crustaceans such as the pogonophoran worm (Fig. R.2) in compact locations. HURL has been checking water temperatures at numerous vents, collecting resources such as bacteria and sea life.

MATE Competition's second task is collect crustaceans like HURL has been doing. The third Task resembles HURL checking the water temperature at different vents. HURL's gathering of bacterial samples is imitated in the fourth task, where we have to scoop the agar sample. Since the danger of the underwater terrain makes it difficult for large submersibles to conduct these tasks an ROV is used to make it possible to reach many of these places safely. With an expertly designed ROV, we may facilitate the research of the scientific community at HURL.

With a broader focus the Marine Bio-products Engineering Center (MarBEC) researches bio-products including enzymes, antibiotics, anticancer agents, food additives, and pigments. Their mission being to finding means of helping mankind as whole, a mission we as engineers embrace and perform by creating the tools necessary for them to accomplish their job.

References

http://www.soest.hawaii.edu/GG/HCV/loihi.html

http://www.nsf.gov/pubs/2000/nsf00137/nsf00137c.htm

http://hvo.usgs.gov/volcanoes/loihi/

http://catalog.hawaii.edu/schoolscolleges/soest/facilities.htm

http://www.soest.hawii.edu/GG/HCV/loihi-summary.html


Rounding the corners on the frame

Frame

The frame of the ROV is made out of Black HDPE (High-Density Polyethylene). We initially narrowed down our choices of materials to extruded aluminum or PVC pipes, but with the limited budget as one of our main concerns, we chose to use black HDPE which was to be donated and therefore free. Taking advantage of this free resource became a priority as we recycled and found other uses for the scrap material. In addition to the budget advantage, we chose to use HDPE because it's easy to machine, strong, and fit for underwater environments which allowed us to produce the design that we wanted.

We chose a rectangular frame with rounded corners to ensure adequate surface area to mount the tools. The rounded corners will not catch on things when maneuvering in the cave or catch on the tether. There is an X pattern on either sides of the ROV for optimal motor placement and structural integrity. Additionally, the frame was designed such that it protects the tools, motors, and other systems from collision or interference. Team Tectonic Chaos chose to use this special kind of material instead PVC pipes for the previously mentioned reasons and because of the following advantages:

- Has buoyant properties that offset its weight in water
- Easily cleaned in case of contaminants.
- Lightweight meaning high speed ROV and less concern about buoyancy and easy transportation launch and recovery.
- Chemical- and corrosion-resistant for long-term service of the ROV in real life where it is used in very deep underwater condition.
- No moisture absorption means consistent buoyancy in the ROV.


PVC buoyancy chambers


Extruded Polystyrene block

Buoyancy

We originally attempted to use extruded polystyrene for buoyancy. After pool testing, we discovered that the foam was more porous than we had thought, and slowly absorbed water over the course of 10-15 minutes. We then decided to use two sealed 2"x50cm PVC sections for floatation to eliminate the issue. The PVC sections are mounted up top on both sides of the ROV to provide ease of modification and balance according to the design of the ROV. In addition to the PVC sections, the electronic enclosure provides more buoyancy. This is because the electronic enclosure has large quantity of air enclosed in it.

Tether wires with sheathing removed

Making the tether; running the connectors through the sheathing

View of wiring inside tether quick connect

Tether

A 30-meter tether connects the control station on the surface with the ROV underwater. The tether is detachable from the electronic control system topside using two connectors. The tether consists of four 2-conductor speaker cables and four stranded CAT5 cables all bound together within black, expandable plastic wire mesh sheathing.
Power is provided to the ROV by the speaker cables. The four 2-conductor 18AWG speaker cables are used in parallel as a 2-conductor power cable. This was done because we had the majority of the speaker cable available to us for free.

The stranded CAT5 cables are used for control and PWM (pulse width modulation), as indicated in the table below.

Wire #	CAT5 #1	CAT5 #2	CAT5 #3	CAT5 #4
1	Motor-1 forward	Motor-5 forward	PWM 1	CAM 1
2	Motor-1 reverse	Motor-5 reverse	PWM 2	CAM 2
3	Motor-2 forward	Motor-6 forward	PWM-1 bypass	CAM 3
4	Motor-2 reverse	Motor-6 reverse	PWM-2 bypass	Hydrophone 1
5	Motor-3 forward	Motor-7 forward	Lights on/off	Hydrophone 2
6	Motor-3 reverse	Motor-7 reverse	Extra	Temperature clock
7	Motor-4 forward	Motor-8 forward	Extra	Temperature enable
8	Motor-4 reverse	Motor-8 reverse	Extra	Temperature data

The flexible sheathing for the tether was chosen for a number of reasons. In contrast to zip ties, the sheathing bundles the wires together smoothly, with much less chance of snagging on anything in the pool. The mesh also protects the wiring from abrasion. The sheathing makes it easier to add or subtract wires from the tether. Without this sheathing multiple wire ties must be added or replaced every time the composition of the tether is changed.

Propulsion

RaDAV uses seven bilge pump cartridge motors for propulsion. There are two motors for forward and reverse motion, four for upward and downward motion, and one strafing motor for side to side motion. The choice to use bilge pump cartridge motors for propulsion was based on several factors: proven technology, reliability up to a depth of 76 meters, and low cost. The deciding factor was our ability to salvage bilge pumps off an old ROV and thereby reduce the impact to our budget.

Up and down thruster with shroud removed

The forward and reverse motors used are two 3,785 lph (liters per hour) bilge pumps, while the four up and down motors are 2,839 lph bilge pumps. The most thrust are being used for upward and downward motion for two reasons: to be able to lift the payloads, and to be able to navigate between surface and depth quickly. The strafing motor located at the center is a 1,893 lph bilge pump. The strafing motor used for turning and precise positioning, needs the least amount of power. All motors use an Octura 1270 propeller. The strafing motor generates an average of three Newtons, while the other four motors each generate an average of six Newtons. All seven motors together at full power draw about 20 Amperes of current.

Electronic Controls

RaDAV features a highly efficient electronic control system. RaDAV's Electronic Control features high end feature sets, redundant systems, and flexibility at an incredibly low cost.

RaDAV's controls can be divided into two basic sub-systems that make efficient control possible at low cost. The Sub-Sea Electronics Module (SSEM) and The Topside Electronic Control Interface (TECI). By dividing the electronic controls of RaDAV into a surface and a sub-sea system, it allows us to reduce costs, and integrate more control features at a low price. The SSEM, and the main power connection are the only two components of the system controlling currents over 10 Amperes, Therefore the vast majority of tether conductors, switches, and control circuitry can be downsized, and controlled by low power digital logic and component based circuitry. This reduces cost, and allows for multiple control options with minimal modification to the core systems.

Design Rationale

Sub-Sea Electronics Module with relays exposed

The SSEM contains an electronic system capable of controlling all payload and propulsion systems via low current control signals. SSEM contains eight NEC-H Bridge Relays, utilized to control propulsion and payload tool motors. The relays are divided into two separate banks of four, directly connected to two PWM controlled Power Busses.

The SSEM utilizes PWM (Pulse Width Modulation) to vary the power output of each bus. The PWM circuitry is comprised of two MOSFET driven Solid State Relays. Each SSR receives a PWM signal from the Arduino and amplifies it to sufficient amperage to supply multiple motors. In the unusual occurrence that the PWM circuitry should fail, The PWM system contains a Bypass Relay capable of directing the flow of current around the SSR, directly to the tether's power source.

Topside Electronic Control Interface

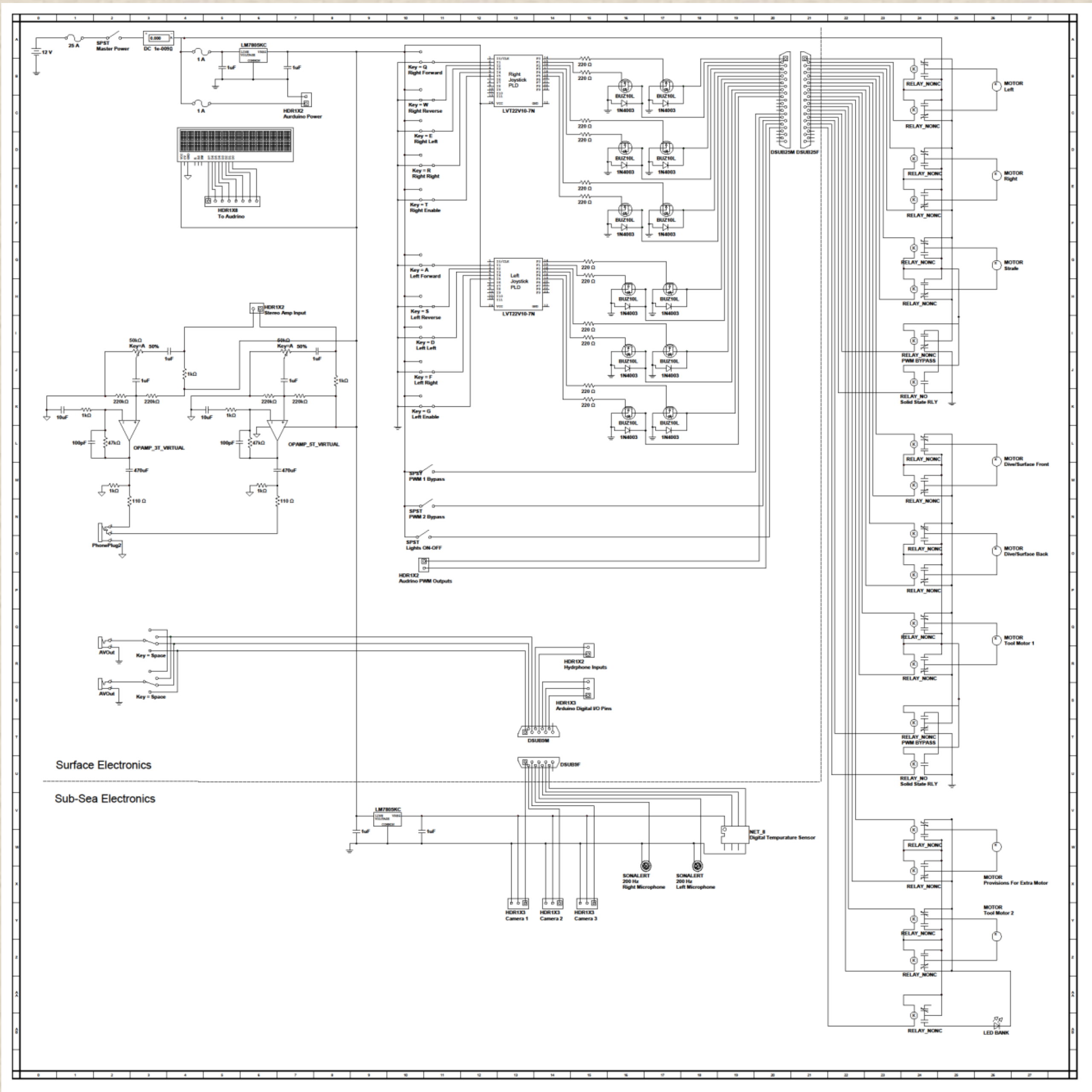
The TECI is the heart of the control system. TECI is packaged in a portable and easy to set up attaché case containing all components required to operate RaDAV. The top portion of the case contains

- 7" LCD Video Display
- Panel Ammeter
- LCD Temperature Readout Display
- Camera System A/V Patch Panel

The bottom portion of the case contains all ROV control elements including…

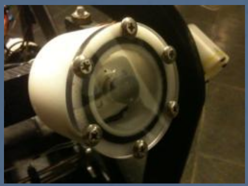
- Two Programmable Logic Device (PLD) controlled Joysticks
- Redundancy Control Panel
    - PWM Bypass Switches
    - Directly Relay Control Switches
    - System Kill Switches
- Lighting Control Switches
- System Fuse Panel
- Removable Tether Connector
- Copilot Tool Remote Control Connector

Electrical Schematics




Making the delrin enclosures


Hydrophone enclosure


Camera enclosure


LED spotlight

Sensors

When manufacturing our sensors, we chose to use one enclosure design; a piece cylindrical delrin stock turned on a lathe with a lexan cap bolted onto it. We did this because the materials were readily available and cheap, and the same design could be easily scaled for the size of each sensor.

- *Hydrophones*

We used a pair of hydrophones at equal distance in order to take advantage of our inherent ability to detect sound direction, and thus making detecting the seismic activity in task 1 easier. Additionally, the kit needed to assemble the stereo audio amplifier board was cheaper than that for a mono system.

- *Cameras*

Our ROV has 4 mounted cameras, one for guiding the agar tools, one for the fork tool, one focused on our temperature sensor, and one dedicated to the field of view of the ROV. We used all color cameras so we could easily distinguish between objects in the water opposed to having to tell between different shades of grey.

- *Temperature Sensor*

We considered using several different styles of thermometers including a meat thermometer, a thermistor and an alcohol thermometer, but decided to use a digital chip wired to an Arduino that uses code to test the temperature every cycle. We used this method because we were able to send the temperature signal to the top rather than use a camera to read the temperature. The temperature sensor was also available to us for free.

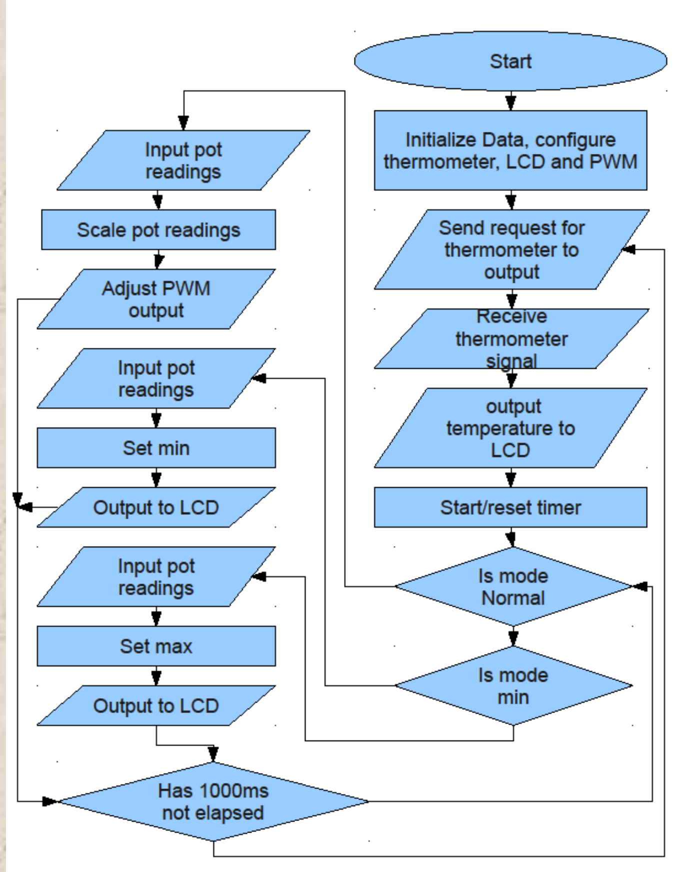
Programming

The Arduino was chosen for having the best benefit-cost ratio. The Arduino is one of the few microcontrollers that cost less than a quarter of the total budget. It is also one of the most flexible, being open-source and multi-platform, where most other solutions only worked on Windows. Its wide use also enables documentation to be easily obtained.

Design Rationale

Arduino code originated as a template from the manufacturer. The code was modified to perform two functions. The first and primary function is the potentiometer driven pulse width modulation to control motor speed. It does this by taking a reading from a potentiometer scaling the values, and then outputting the motor speed by the built in Pulse Width Modulation. The secondary function is temperature readings. The Arduino sends a serial signal to the thermometer IC for the thermometer to send a serial signal with the temperature reading with a half degree Celsius of accuracy. The Arduino then outputs the reading to an LCD. This LCD is also used to display instructions for calibrating the PWM.

In order to improve multithreading, the required delay for the thermometer in the main loop was replaced with a sub loop to run the PWM adjustment segment for a total of the amount of time needed for the delay, about 1,000 milliseconds. This attribute results in the temperature sensor being updated every second, and the PWM being adjusted for any other time. At most, the PWM will have only a 400µs delay every second between updates, with an insignificant delay for the remainder of the time.



Motor and chain assembly used to move the forks in the tool

Prototyping the Fork Tool

Payload Tools:

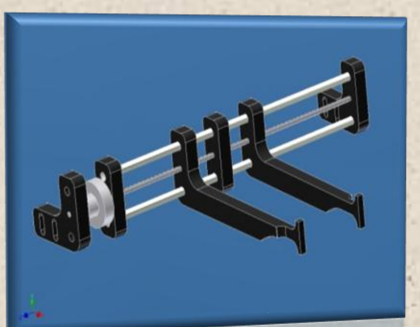
- *Fork Tool*

In order to complete the first and second tasks, we needed to be able to pick up, hold and move a variety of objects from one location to another. This problem essentially broke down into two categories: Lifting and grasping.

We researched existing grasper and lifting mechanisms to see how previous teams had accomplished these tasks. One of our main concerns when designing the tools was the need to accomplish the largest number of tasks with the least number of tools possible. We considered making static grippers, forks, and hooks, but the variety of things we needed to grab lead us to the conclusion that a variable, or powered, gripper would be best.

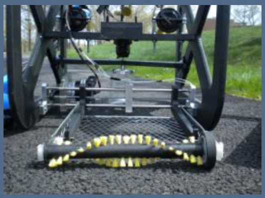
The fork tool consists of two L-shaped HDPE forks with hooked ends. The forks slide on two steel guide rods and are moved by drive shaft that consists of two co-linear, oppositely threaded rods. Each fork has a small magnet recessed into the side to allow it to easily grip any ferrous metals. Each fork also has multiple steel pins protruding from its outer face, and foam lining the inside of it. This combination of features allowed us to combine many tools into one multi-purpose tool that could complete multiple tasks as well as interface with our other tools, such as the crustacean rake.

The entire tool, with the exception of the guide rods, was CNC machined because the design required accurate and precise manufacturing in order to minimize the chances of the forks binding during operation, especially under load. Additionally, limit switches were installed in order to prevent thread stripping when the forks reach the limits of their position.



Inventor 2010 drawing of the fork tool

Actual tool after manufacture prior to being mounted to the ROV



Original Crustacean Sweeper tool

- *Crustacean Rake*

The Crustacean Rake was designed to work in conjunction with the Fork Tool to complete Task 3, as well as serve as a containment tool to hold the other mission materials. The original tool, the Sweeper, was designed to replicate a mechanical carpet sweeper, with the intent that it would sweep crustaceans into a basket as it rolled along the pool bottom. The tool was designed to be detachable from the rest of the ROV, and is picked up and held by the Fork Tool. This freed up space within the confines of the ROV itself and provided us with a container to place the other mission objects so that they may be carried to the surface.

In testing, we discovered that the tool was unable to pick up crustaceans if they were too close to the back wall of the cave. We redesigned it as a rake which allows us to pick up crustaceans from the floor and the wall. We also added a flexible net to the back of the basket, which gives us more carrying capacity and will also trap objects inside. Additionally, the side walls have been heightened and made to slope from front to back, and "flyby wires" have been added. This has a number of advantages: It decreases the risk of objects falling out, makes the basket easier to pick up, and, when picked up, causes the basket to tilt up, causing objects inside to fall toward the net.

Agar Auger

- *The Agar Auger*

This powered agar removal tool that was designed to handle a variable consistency of agar. Inspired by the Archimedes Screw, the tool consists of an angle cut, spiral piece of delrin that will cut into the agar and move it up the spiral into a clear plastic containment tube as it spins.

Agar Removal Tool

- *ART (Agar Removal Tool)*

This tool consists simply of a PVC tube fitted with an end cap with a check valve in it. The ART works by inserting the tube into the agar and then removing it. The Automotive PCV Valve allows any water in the tube to exit as the tool fills with agar, but prevent it from coming back in as the tool is removed, creating a vacuum and preventing the agar from falling out. ART is our backup tool to be utilized in case a problem arises with the agar auger. ART is balanced with weight and buoyancy so it can be thrown into the water by the poolside crew, and sink to the bottom where RaDAV can retrieve it.

Troubleshooting Techniques

- Electrical Systems

When testing our electrical systems, we work to isolate the problem. If we encountered a problem where a part, such as a motor, was not working, we would remove the motor from the system and then battery test both the motor and the system separately. If the part was found to be faulty, it would be replaced. If the part worked with direct power, we would re-install the part in the electrical system to see if it was receiving power. The wiring would be traced back to the electronics enclosure or the control box to test if either the relays or the physical switches were the problem. From there we would attempt to fix any faulty wiring, replace any damaged equipment, or try to bypass the problem through another system.

- Camera System Calibration

During our pre-mission set up time, when setting up the control box for the mission task, the pilot checks each different camera feed to ensure they are provide the desired view. For any camera feed that is not properly positioned, the pilot communicates with the launch and recovery team to reposition the cameras into proper viewing angles using simple directional commands.

- Temperature Sensor and Microcontroller Code

When testing our temperature sensor, we encountered problems getting a reading on our seven-segment display that matched any realistic approximation of the surrounding temperature. To troubleshoot the temperature sensor we had a laptop with a USB cable that we could plug into the microcontroller inside the control box. The code could then be tested by isolating the sections of code for the temperature sensor and PWM control from each other and running each to see if one interfered with the other. The next step was to run alternate code to make the microcontroller display randomly generated numbers to determine whether the display was connected correctly and receiving the correct signals from the microcontroller. Changes to our code may then be made to attempt to fix the temperature sensor readings before declaring the temperature sensor to be faulty.

Lessons Learned

We learned that it is very important to communicate, early and often. This became especially obvious when we tried to organize for meetings. Our team has eight members, almost all of whom have different class schedules as well as jobs outside of class. Finding one time when everyone could meet was nearly impossible, and the problem was only exacerbated by our failure to communicate early on. One thing that drove the lesson home was an attempted scheduling of a meeting on a Sunday. An email was set out early in the week that no one responded to until the day of the meeting. Predictably, the meeting did not go as planned, with only four people showing up and only limited work being accomplished.

On a more technical note, this experience has taught us the importance of accurate modeling. When we were trying to test tool ideas for the retrieval of agar, we attempted to use JELLO as the test medium as it was readily available. We did this because we did not have agar readily available. What we found was that it did not work at all as a substitute. Its cohesive and adhesive properties differed significantly from that of real agar. This lead us to making two tool designs, one that is motorized and intended to deal with almost any consistency of gelatinous media, and another that is designed to work with the apparent properties of agar we observed in videos.

Team Tectonic CHAOS at the New England Regional Competition

Reflections

"A true leader needs to be independent, but is dependent on his team."
-Derek

"I don't need to have my hands on everything in order to have it done right."
-Ben

"I'm a bit impatient; I'm more of a doer than a dreamer."
-Peter

"Engineering is eating your cake and building a machine to make you another one so you can have it too."
-Matt

"It's all about seeing what needs to be done, dividing it up, and assigning tasks."
-Nick

"I'm interested in things on a systematic level"
-Lauri

"We are equal, but we are not the same."
-Alex

"I loved learning how other people do things, their strengths, and their weaknesses."
-Thuba

Teamwork

Every member of Team Tectonic Chaos collaborated as a unit to complete this ROV. Although our individual expertise is unique we managed to work on and learn from the strengths of each other. Our teamwork has been one of our greatest strengths throughout this whole process and is largely responsible for the final product.

Acknowledgements

Team Tectonic Chaos would like to acknowledge the following people and organizations for their indispensible support and contributions that made this team's progress and accomplishments possible.

- **The MATE Center** - *for organizing this competition*
- **Massachusetts Maritime Academy** - f*or hosting this year's regional competition*
- **University of Hilo** - *for hosting this year's international competition and providing discounted lodging*
- **CoCo Engineering** - *for supplies materials, time, work space, and facilitating the manufacturing process*
- **Fall River Boys and Girls Club** - *For providing facilities for pool testing*
- **The Southeastern Massachusetts Achievement and Retention in Technology Program** - *for financial support*
- **Bristol Community College** - *for providing work space, time, and instruction*
- **UMass Dartmouth** - *for all their support*
- **Salt Marsh Pottery** - *for financial support*
- **Dr. Robert Powel** – *for assistance in acquiring travel accommodations*
- **Dr. Meyers** - *for his technical and moral support*
- **Al Censorio** - *for permission to us use lab and aid in the manufacturing process*
- **Meghan Abella-Bowen** - *for her time and patience as our SMART grant proctor and team mentor*
- **The Autodesk Corporation** - *for use of the Inventor software providing a visual aid to RaDAV's design process*
- **The Adobe Corporation** - *for use of the Photoshop CS3 software used for all photo and design editing*
- **Family and Friends** - *for their constant moral support*
- **Team Tectonic Chaos Members** - *for all of the hard work, long hours put into this project*

Future Improvements

In the future we would like to incorporate a second Arduino micro-controller on-board the ROV to reduce the number of wires in the tether. Additionally we would like to incorporate separate PWM control for the tool motors, so that we do not have to reduce thrust while making precise tool movements. We would also replace the 7-segment displays with a single LCD display, which would allow us additional accuracy in making readings, as well as using fewer pins.

In terms of improving our tools, we would consider replacing the basket tool with a motorized vacuum for catching crustaceans, as this seems more likely to be successful in a real world environment. The fork tool would have better bushing and bearings to reduce backlash in the thread. Also a larger diameter threaded rod, stronger motor, and better gear reduction to increase gripping capabilities.

Other improvements we have considered making are: the replacement of the navigational controls with a single multi-axis joystick or video game controller; the addition of a compass read out and an artificial horizon to aid in piloting when no visual frame of reference is available; and lastly additional, stronger thrusters for better control of the ROV.

Challenges

Our team encountered numerous challenges, technical, financial, communicative, and otherwise. Overcoming these challenges was one of, if not the, most important parts of this competition. Following are a few of the challenges we experienced.

- Financial: With a very tight budget, (only $500.00 total allotted) our entire design process was limited from the beginning. We made sure we got the biggest bang for our buck. Almost half of the value of our ROV consists of donated and salvaged material.

- Trust: "I don't need to have my hands on everything in order to have it done right." In order to get everything done, we needed to rely on people we did not know well and hope they would not fail us. Trusting one another took time and also it helped when we began to understand that we were all equally skeptical of each other.

Budget

Purchased Materials

Item Description	Retailer	Quantity	Price Per Unit	Price Total
	Frame			
Washers 1/4-20	Home Depot	10	$0.18	$1.80
Nuts 1/4-20	Home Depot	38	$0.06	$2.28
Threaded Rod 1/4-20	Home Depot	1	$3.31	$3.31
			Total	$7.39
	Propulsion			
Mayfair 500 GPH Bilge Pump Motor	West Marine	1	$24.99	$24.99
Mayfair 750 GPH Bilge Pump Motor	West Marine	2	$24.99	$24.99
Mounting Brackets (pipe clip)	Home Depot	3	$0.82	$2.46
			Total	$52.44
	Tether			
500 foot box of Stranded Cat 5 Cable	Tiger Direct	1	$64.99	$64.99
100' 16 AWG 2 Conductor Wire	Home Depot	1	$13.00	$13.00
50' Wire Sheathing	McMaster Carr	2	$20.39	$40.78
			Total	$118.77
	Electronic Controls			
Solid State Relays	Futurlec.com	3	$21.00	$63.00
Joystick	All Electronics	2	$11.95	$23.90
SPDT Switch	All Electronics	10	$0.90	$9.00
SPDT Switch (momentary)	All Electronics	10	$0.50	$5.00
Audrino Microcontroller	Amazon.com	1	$29.00	$29.00
12 VDC SPDT 40 A Relay	You Do It Electronics	2	$1.35	$2.70
30 A DC Panel Meter	Futurlec.com	1	$9.90	$9.90
30A Meter Shunt	All Electronics	1	$10.00	$10.00
15A Power Diode	Futurlec.com	3	$0.75	$2.25
SPDT (On)-Off-(On) mini toggle switch	All Electronics	10	$1.05	$10.50
Hitachi LCD Display	All Electronics	1	$6.00	$6.00
Banana Plug, Red	All Electronics	2	$0.50	$1.00
Banana Plug, Black	All Electronics	2	$0.50	$1.00
Binding Post, Red	All Electronics	1	$0.85	$0.85
Binding Post, Black	All Electronics	1	$0.85	$0.85
DB-9 Hood	All Electronics	1	$0.39	$0.39
D-Sub Connector, 9-pin male	All Electronics	1	$0.45	$0.45
D-Sub Connector, 9-pin female	All Electronics	1	$0.49	$0.49
1A 100v Rectifier Diode	All Electronics	100	$0.03	$3.00
N-Channel MOSFET, 55v 22A	All Electronics	16	$0.50	$8.00
8-Position Dual-Row strip, 20A	All Electronics	2	$2.66	$5.32
2-Position Dual-Row strip, 30A	All Electronics	1	$0.80	$0.80
SPDT On-On Mini Toggle Switch	All Electronics	10	$0.90	$9.00
			Total	$203.60
	Camera System			
O-rings, 5" OD	McMaster Carr	15	$9.67	$9.67
O-rings, 1' OD	McMaster Carr	15	$5.70	$5.70
Kinnamax Color CCTV Camera	Amazon.com	3	$17.00	$51.00
Rotary Switch	"You-Do-It"	2	$4.17	$8.34
			Total	$74.71

		Tools		
Velleman Super Stereo Ear	Amazon.com	1	$10.00	$10.00
Two Part Epoxy	Home Depot	1	$4.81	$4.81
PVC Fittings	Home Depot	1	$0.92	$0.92
5 gallon bucket Painter's screen	Home Depot	1	$2.28	$2.28
Mayfair 500 GPH Bilge Pump Motors	West Marine	1	$16.99	$16.99
Spiral Point left hand thread 10-24	McMaster Carr	1	$16.96	$16.96
			Total	$51.96
			Purchased Materials Total	$508.87

Donated Materials

Item Description	Source	Quantity	Price Per Unit	Price Total
		Frame		
HDPE Plastic (scrap)	BCC Labs	4 $ft.^2$	$65.08	$65.08
Marine Foam	Dr. Michael Meyers	144$in.^3$	$1.00	$1.00
Stainless Steel Deck Screws	Derek Lagasse	16	$0.10	$1.60
			Total	$67.68
		Propulsion		
Mayfair 1000 GPH Bilge Pump Motors	Salvaged From Old ROV	2	$18.00	$36.00
Mayfair 750 GPH Bilge Pump Motors	Salvaged From Old ROV	2	$16.00	$32.00
Mayfair 500 GPH Bilge Pump Motors	Salvaged From Old ROV	1	$14.40	$14.40
Propeller Adaptors	Salvaged From Old ROV	6	$4.00	$24.00
Marine Propellers	Salvaged From Old ROV	6	$4.99	$29.94
			Total	$136.34
		Tether		
300' 18 AWG 2 Conductor Wire	Salvaged From Old ROV	1	$20.00	$20.00
			Total	$20.00
		Electronic Controls		
7 Segment Display	Dr. Michael Meyers	2	$0.50	$1.00
NEC H-Bridge Relays	Dr. Michael Meyers	8	$0.50	$4.00
Husky Tool Case	Derek Lagasse	1	$20.00	$20.00
Logitech PC Steering Wheel	Nick Powell	1	$10.00	$10.00
7447 Integrated Circuit	Dr. Michael Meyers	2	$0.20	$0.40
Temperature Sensor	Dr. Michael Meyers	1	$5.00	$5.00
Aluminum	Ben Whittaker	1	$18.00	$18.00
			Total	$58.40
		Camera System		
LED Flashlights	Derek Lagasse	1	$5.00	$5.00
7" Portable DVD Player	Derek Lagasse	1	$10.00	$10.00
8/32 Stainless Steel Screws	Derek Lagasse	18	$0.09	$1.67
Delryn Stock	Coco Engineering	1	$15.13	$15.13
Lexan Lens	Coco Engineering	4	$8.56	$34.24
			Total	$66.04
		Tools		
Mayfair 500 GPH Bilge Pump Motors	Salvaged From Old ROV	1	$14.40	$14.40
Asssorted gears and belts	Nick Powell	1	$1.00	$1.00
6061 Aluminum	Coco Engineering	1	$1.00	$1.00
Vaccumm Brush Assembly	Salvaged From Dump	1	$2.00	$2.00
Polycarbonate Tube Stock	Coco Engineering	1	$2.43	$2.43
PVC pipe	BCC Labs	1	$9.83	$9.83
Mineral Oil	Ben Whittaker	1	$6.00	$6.00
			Total	$36.66
			Donated Materials Total	$385.12

Travel Expenses for 8 Team Members

Expense	Budget Allocated	Cost Per Person	Total Cost	Surplus Funds
Airfare	$5,460.00	$682.00	$5,456.00	$4.00
Shipping	$800.00	$777.00	$777.00	$23.00
Food	$800.00	$88.00	$704.00	$96.00
Room and Board	$1,300.00	$160.50	$1,284.00	$16.00
Baggage Fees	$400.00	$50.00	$400.00	$0.00
Rental Car	$360.00	$90.00	$360.00	$0.00
Rental Car Gas	$80.00	$20.00	$80.00	$0.00
Totals	$8,760.00		$8,621.00	$139.00

Donations

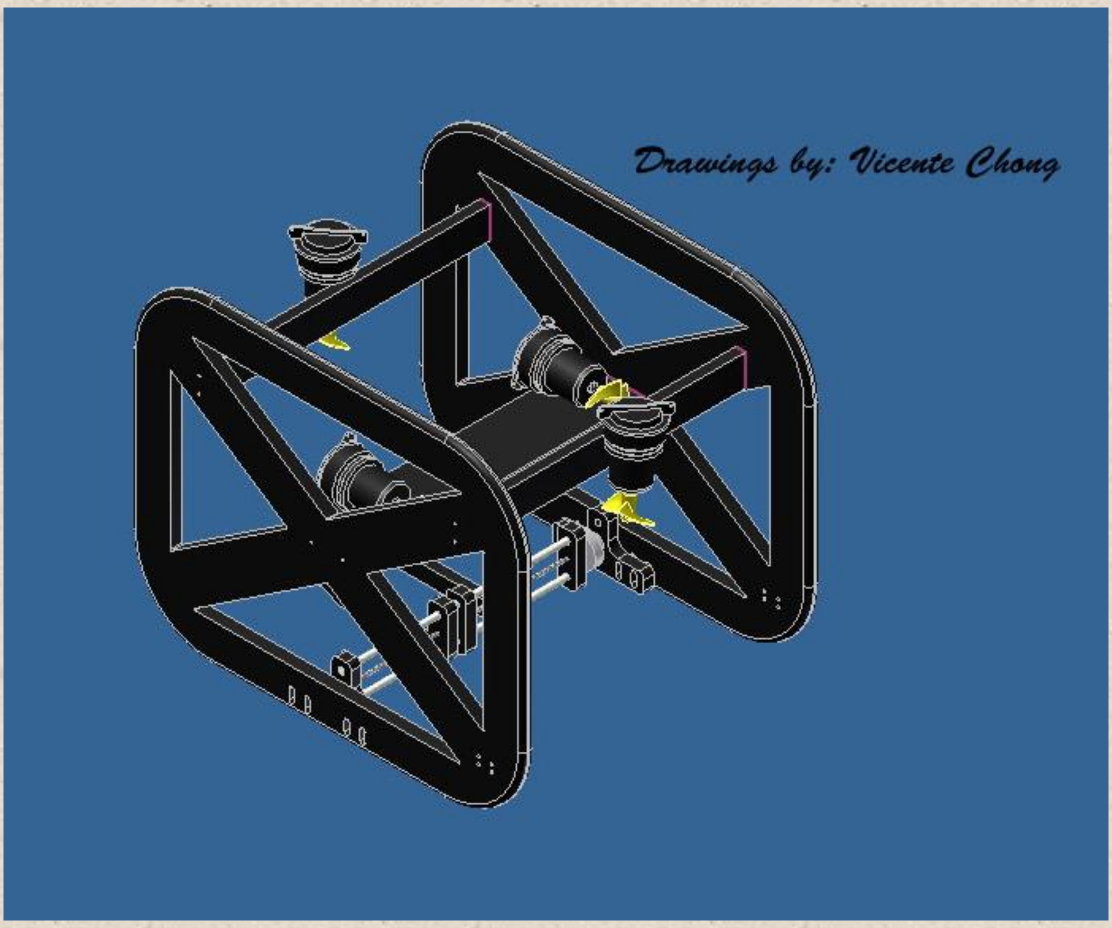
Source	Amount
MATE Travel grant	$500.00
Team Pledges	$1,000.00
Bill Lagasse Donation	$700.00
Dr. Meyers Donation	$100.00
Team Fundraisers	$311.00
Ben's Donation	$1,000.00
MATE Regional Travel Comp	$1,000.00
Bake Sale	$667.00
Ted Shwartz's Donation	$200.00
Charles Saltsman Donation	$250.00
Robert Powel Donation	$500.00
Salt Marsh Pottery	$150.00
Sam Powel	$50.00
Ellen J Langer	$100.00
New Orleans Neurotology	$250.00
Rene Moira	$100.00
Rick Semels	$250.00
Student Senate Donation	$2,300.00
Megan	$100.00
SMART Grant	$500.00
Total	$9,928.00

Financial Totals

ROV Purchased Materials	Travel	Total Expenses	Total Funds Raised	Surplus
$508.87	$8621.00	$9129.87	$9,928.00	$798.13

ROV Purchased Materials	ROV Donated Materials	Total Value
$508.87	$385.12	$893.99

Appendix 1



2010 Autodesk Inventor Drawing of ROV Assembly In Its Early Phase