Aggie Deep ROV

Sponsored by
UC Davis MAE Dept. & College of Engineering

Faculty Advisor
Professor Roger L. Davis, PhD

TECHNICAL REPORT

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ABSTRACT / EXECUTIVE SUMMARY

The project objective of the Aggie Deep ROV team is the design and manufacture of a remotely operated underwater vehicle. This vehicle is to be controlled remotely by an offshore pilot using solely the aid of onboard watertight cameras for guidance. The vehicle is tethered to the shore by a multiple wire electrical cable carrying power, control and video signals. The vehicle gets its maneuverability from 5 mounted electrical thrusters. The ROV will compete in the 2008 MATE International ROV competition consisting of several scored tasks which the ROV must complete.

The ROV must be able to free an obstructed scientific device from a pool floor by removing randomly placed weights off of the device. The device has positive buoyancy, so the task will be complete when enough weights have been removed for the device to float to the surface. The vehicle must also have the ability to collect up to 3 of these weights and bring them to surface for retrieval. These weights will each be 2lb bags of lead shot with no handles or tabs for easy holding. Once this portion of the competition is complete, the vehicle is required to hover over a vertically mounted hydrothermal vent and obtain a temperature reading within 6 degrees of the actual water temperature.

TABLE OF CONTENTS

FINAL LAYOUT DRAWINGS OF SYSTEM AND SUBSYSTEMS

Figure 1 – Completed Vehicle (ISO Side)

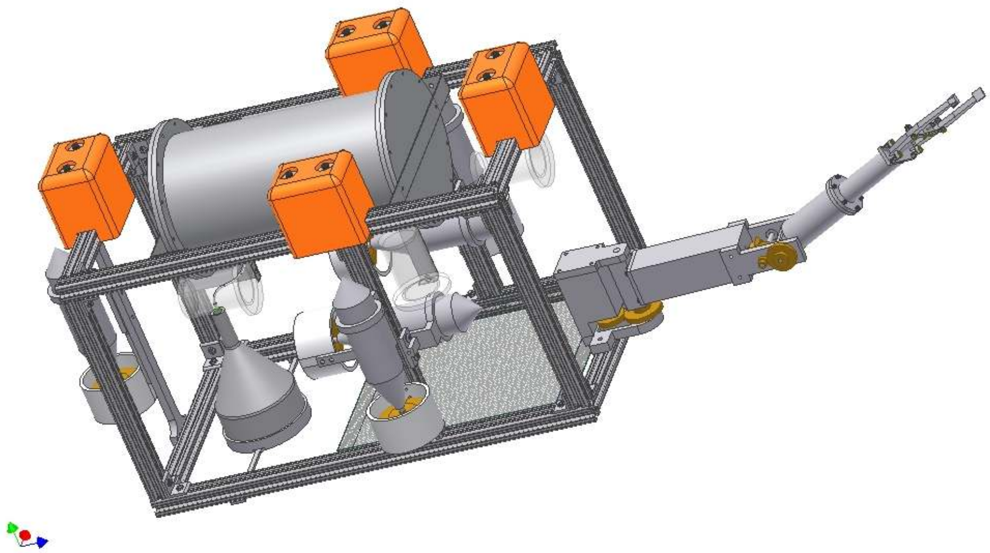


Figure 2 – Completed Vehicle (ISO Rear)

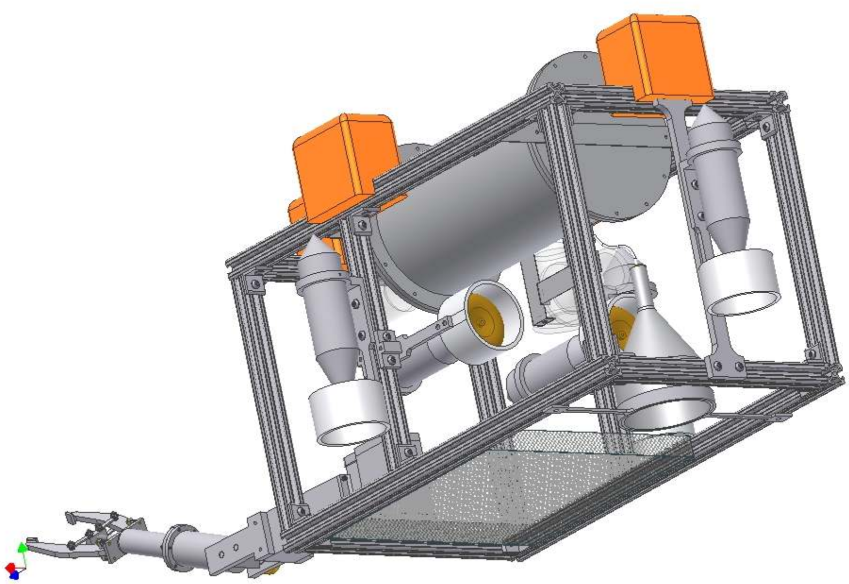


Figure 3 – Vehicle Thruster, Flow Concentrator, Collection Bin and Camera Systems

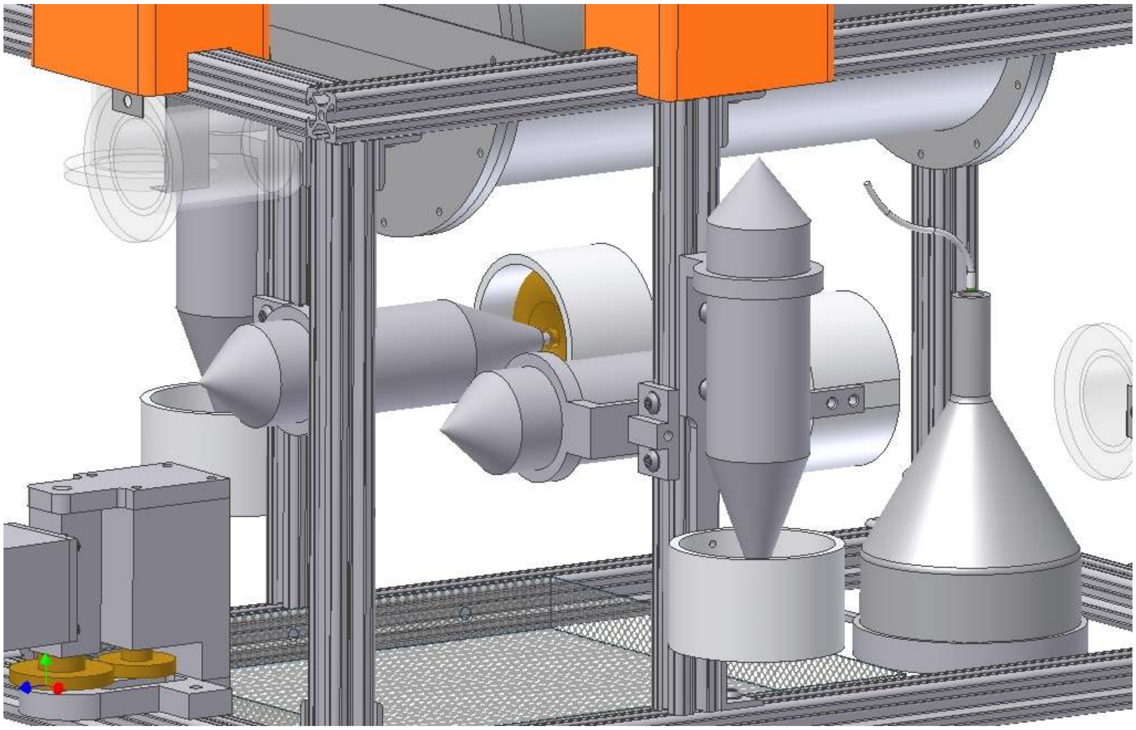


Figure 5 – Vehicle Top View

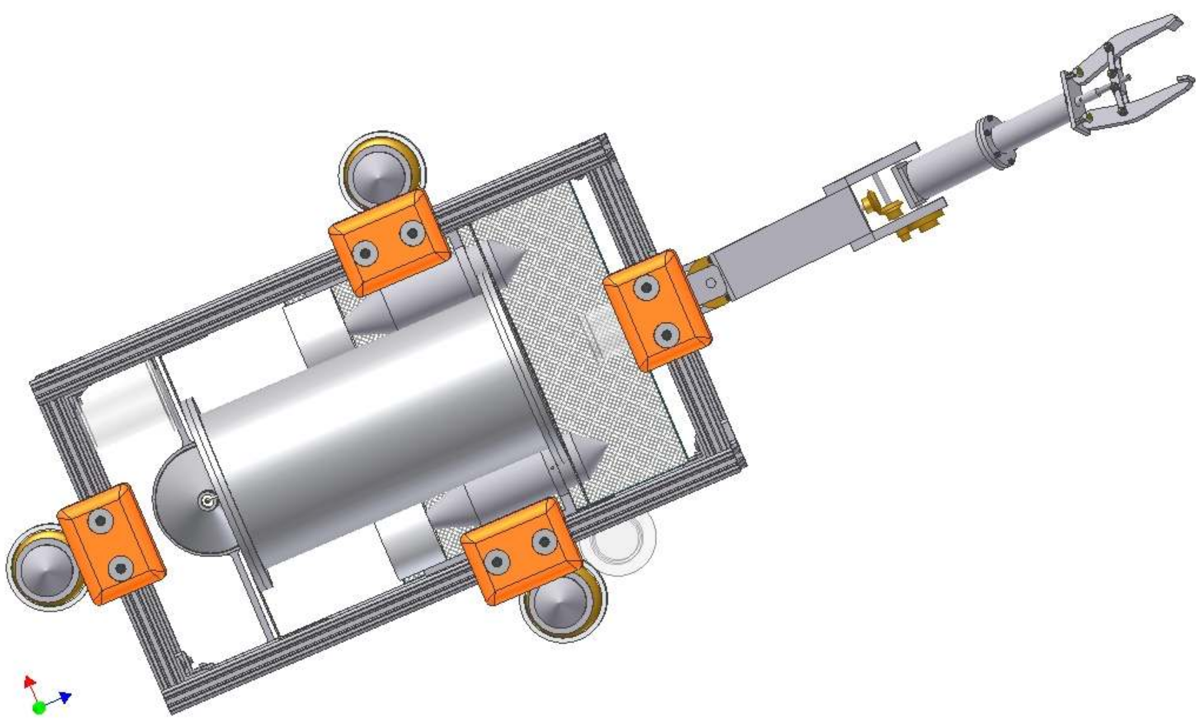


Figure 6 – Manipulator Arm

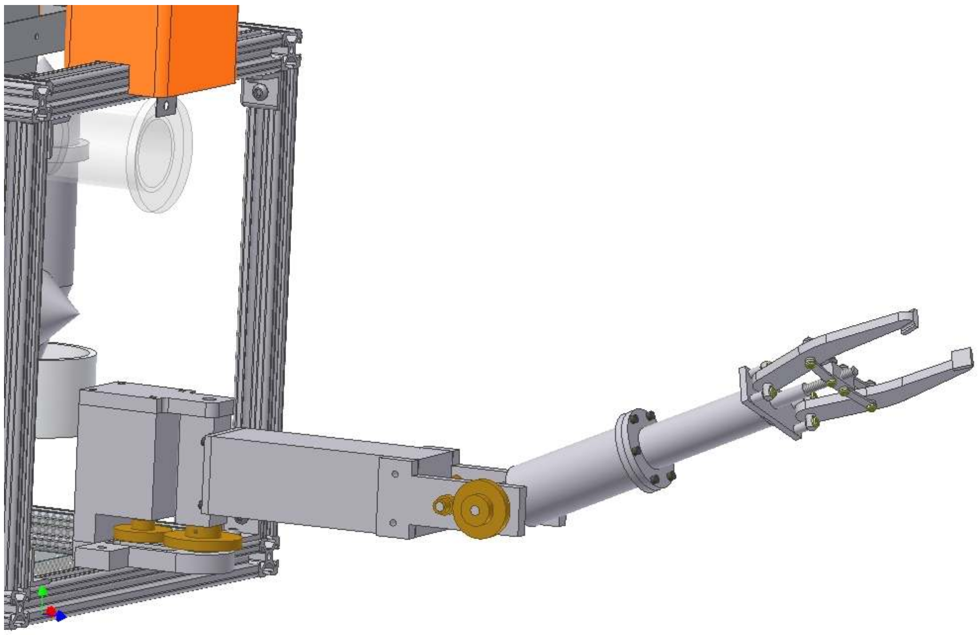


Figure 7 – Vehicle End View

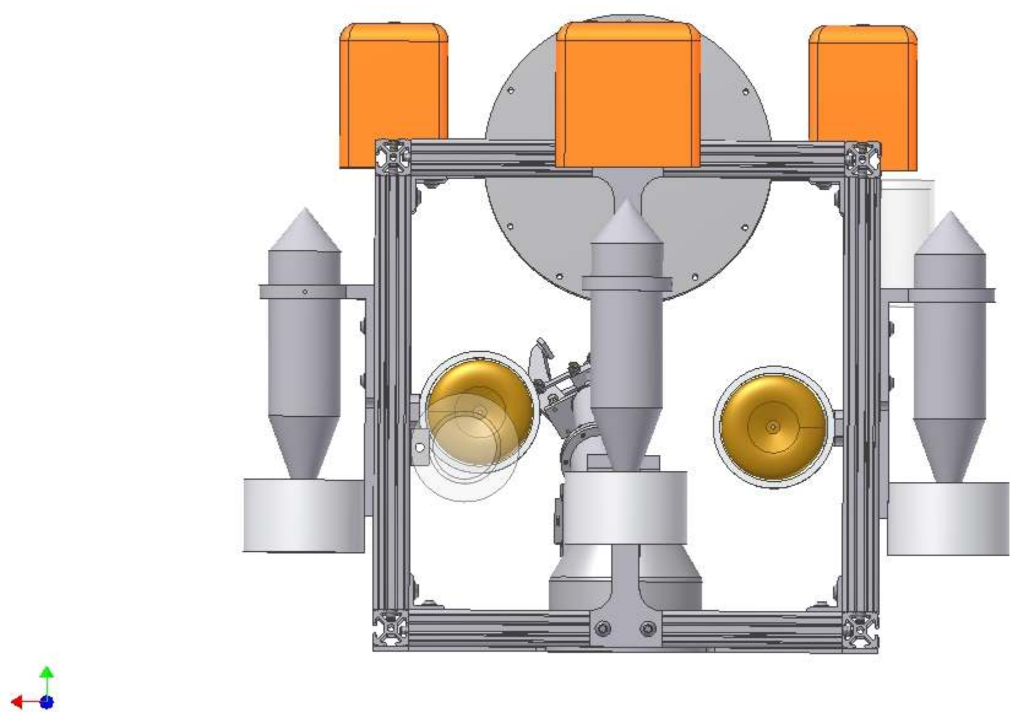


Figure 8 – Upper Manipulator Arm Exploded View

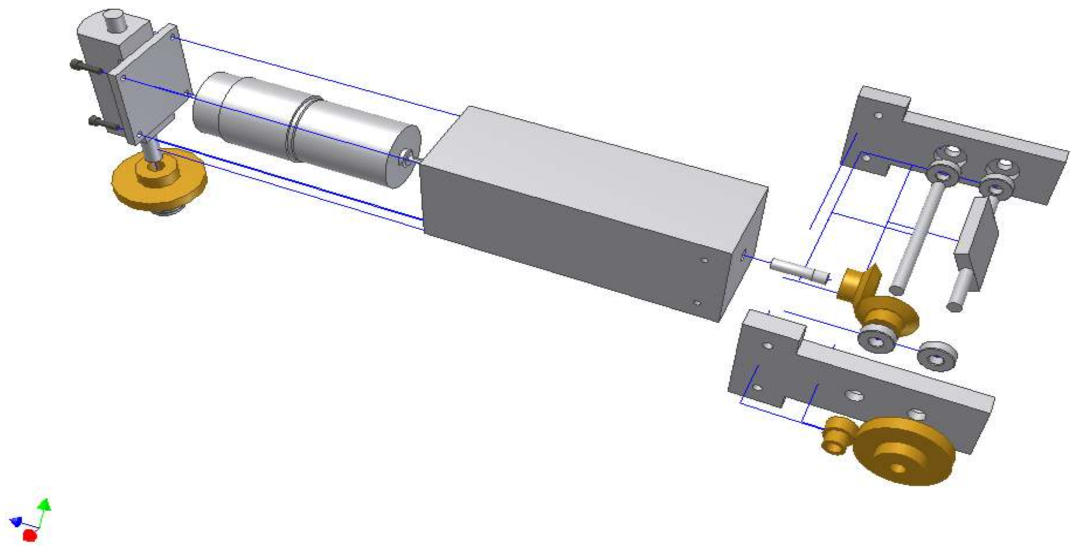


Figure 9 – Lower Manipulator Arm Exploded View

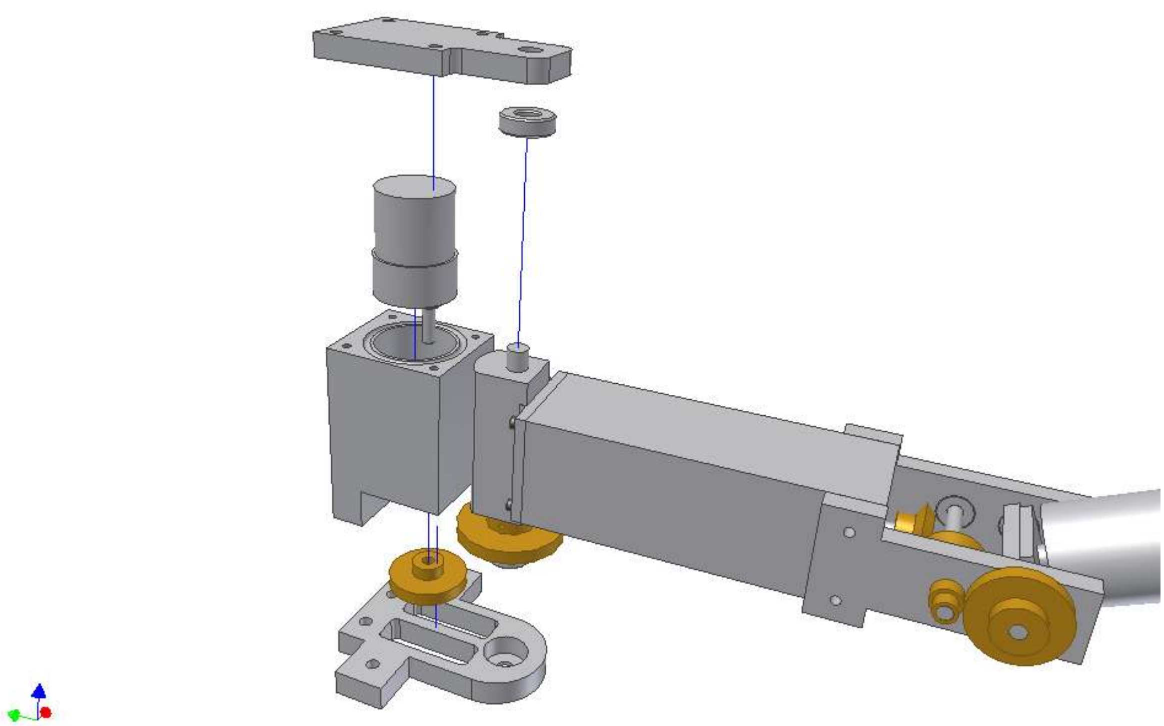
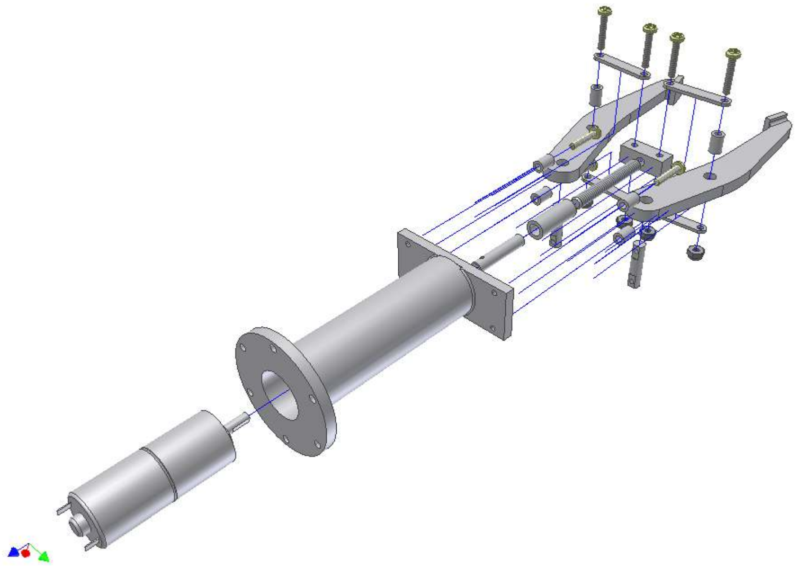


Figure 10 – Manipulator Arm Claw and Wrist Exploded View



BILL OF MATERIALS

PART	Manufacturer	Unit Price	Amount Needed	Total Cost	Part Number
Frame					
Extruded Aluminum*: 80/20 Brand*	G.A. Wirth	$2.76	20	55.2	1010
Cutting Fee		$1.95	5	9.75	7905
Brackets					
1.5x1.5x0.125 Angle 6061 T-6	Metal Craft Warehouse	$1.75	48	84	A62AE1215
Nuts					
T-slot Economy Nuts	G.A. Wirth	$0.21	100	21	3382
Socket Cap Screws; L=3/8" Thread=1/4"-20	McMaster- Carr	$12.91	1	12.91	
Controls					
Batteries	2006 ROV team				
Wiring, *10 gage, 20 ft*	Home Depot	$16	1		
Tether, *75 ft*	2006 ROV team		1		
Industrial Potentiometer Joystick	Bargain Barn	$4	1	4	
Standard Nylon Cable Ties	Machine Shop	0		0	
Electric Slide Terminals	Napa Auto Parts	$7.95	2	7.95	784391
100 Ohm Resistors	Digi-Key	$0.018	10	0.18	CF1/41005 RCT-ND
4.7K Ohm Resistors		$0.054	20	1.08	4.7KQBK-ND
10K Ohm Resistors		$0.016	50	0.82	CF1/410K5 RCT-ND
47K Ohm Resistors		$0.018	10	0.18	CF1/22K5 RCT-ND
Polyfilm Box Capacitor 10nF 63V		$0.085	10	0.85	478-3373-ND
Ceramic Radial Capacitor 100nF 50V		$0.157	10	1.57	399-4264-ND
Electrolytic Capacitor 100µF		$0.245	10	2.45	565-2029-ND
Diode GP 1A 400V DO-41		$0.041	10	0.41	1N4004-E3/73GI-ND
Switching Diode 75V 300MW DO-35		$0.12	20	2.4	1N4148DICT-ND
Transistor BV547 45V 100MA TO-92		$0.11	20	2.2	BC547BTACT-ND
P-Channel Mosfet 55V 74A TO-220AB		$2.20	20	44	IRF4905PBF-ND
N-Channel Mosfet 55V 49A TO-220AB		$1.215	20	24.3	IRFZ44NPBF-ND
Quad Operational Amplifier LM324		$0.42	10	4.2	296-1391-5-ND
12K Ohm Resistor 1/4W		$0.054	10	0.54	12KQBK-ND
33K Ohm Resistor 1/4W		$0.054	10	0.54	33KQBK-ND
220K Ohm Resistor 1/4W		$0.054	10	0.54	220KQBK-ND

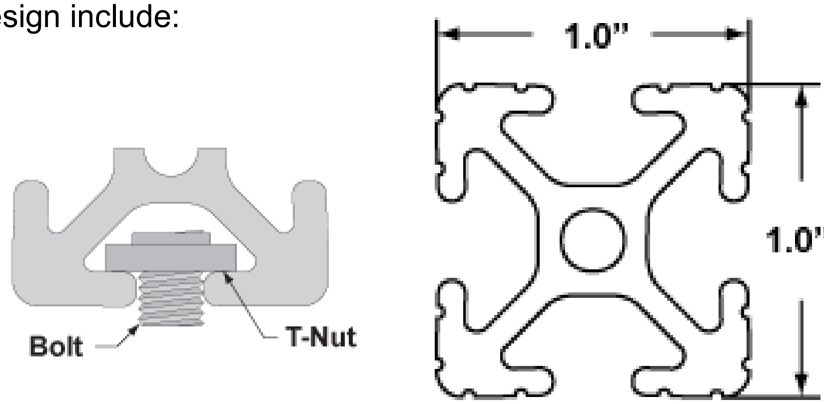
470K Ohm Resistor 1/4W		$0.054	10	0.54	470KQBK-ND
Tax and Shipping				19.21	
IC Transceiver LP R5485 8-DIP		$2.90	2	5.8	DS1487N-ND
IC AVR MCU 16K 20MHz 28-DIP		$4.11	4	16.44	ATMEGA 168-20PU-ND
Shipping & Handling				9.6	
USBtinyISP AVR Programmer Kit	Adafruit Industries	$22.00	1	22	
Thrusters					
Thrusters	2006 ROV team	0	5	0	
Rivabo 5-blade Propellers 65 MM, 3/16mm shaft dia, type right	Harbor Models	$25	4		555-065*
Ducts/Cylinders: PVC Pipe, 3" dia, 4.5' long	Ace Hardware	$5	1	5	
JB Weld	Home Depot	$4	2		
Aluminum (Thruster supports)					
0.25x1 Flat Bar 6061 T-6	Metal Craft Warehouse	$1.10	72	79.2	A61FL2510
2 Dia x 0.25 RD Tube 6061 T-6			12	0	A61RT2520
Underwater Silicon Sealant	Tap Plastics	$4.50	1	4.5	
O-ring Lubricant	Machine Shop	$0.00		0	
O-rings	2006 ROV team	$0.00	5	0	
Waterproof Cameras					
Mini Wired Color CCD Camera	2006 ROV team	$0	3	0	
Triax Cable, 10 ft	Machine Shop	$0.00		0	
Heat Shrink Tubing		$0.00		0	
Foam Padding		$0.00		0	
Acrylic tubing, assorted sizes	Tap Plastics	$8.10	3	8.1	
Acrylic caps, assorted sizes		$11.85	9	11.85	
Acrylic cement		$10.50	1	10.5	
Multi-view soft/hardware	TBD				
Waterproof Thermocouple					
MSI Sensors: Relative Humidity/Temperature Module	Mouser.com	$65.50	1	65.5	824-HTM2500
18” Long-Necked PVC Funnel, 5” dia mouth	Harbor Freight	$2.49	1	2.49	90468-3VGA
Cross Brace: Miscellaneous Aluminum	Machine Shop				
Buoyancy Devices					
TAP X-30 Polyurethane Foam, 1/2 gallon kit	Ty Nowotony’s Personal Supply	$0.00	1	0	
Dry Box					
Aluminum Pipe- Schedule 40; 6" 1 ft	ABC Supply	$39.90	1	39.9	640P63
Aluminum Flat Bar- 8x8x1/4"		$14.21	4	56.84	8SQ61
Silicone O-Rings, Pack of 5 + Shipping	Mc-Master Carr	$10.28	1	28.53	
Nuts and Bolts	Machine Shop	$0.00		0	
Manipulator Arm					
Bar Stock (6061-T6)					
0.5x2x12	Metal Craft Warehouse	*available upon quote*	12		A61FL5020
0.375x2x12			12		A61FL3715
2x3x12			6		A61FL92060
0.1875x1x6			6		A61FL1210
0.25x2x24			24		A61FL2520
Round Stock (6061-T6)					
2 dia x 12	Metal Craft Warehouse	*available upon quote*	12		A61RD200
3 dia x 24			24		A61RD300
0.5 dia x 6			6		A61RD050
0.25 dia x 12			12		A61RD025
Sheet Metal					
16 gage x 6 (.05in, 5052-H32 Al)	Metal Craft Warehouse	*available*	6		A52SA05

		upon quote			
Threaded Rod					
1/4 20 x 6	McMaster-Carr	$12.90	1	12.9	93225A882
Fasteners					
6-32UNC x 3-4 Phillips Pan Head Machine Screw (pack of 50)	McMaster-Carr	$7.87	1	7.87	91500A151
6-32UNC Nylock Nut (pack of 100)		$5.41	1	5.41	91831A007
6-32UNC x 3-8 SHCS (pack of 10)		$3.71	1	3.71	92200A146
8-32UNC x 5-8 SHCS (pack of 25)		$6.78	1	6.78	92185A149
1/4-20UNC x 1 Flat Head Machine Screw (pack of 10)		$5.22	1	5.22	93085A542
Rubber Covered Single Lip Shaft Seal With Spring					
6mm shaft dia x 16mm house bore dia x 7mm width	Applied.com	$4.78	1	4.78	563979
10mm shaft dia x 19mm house bore dia x 7mm width		$3.75	1	3.75	1430534
Motors					
Gear Head Motor- 12vdc; 50:1, 120rpm, 6mm shaft	Lynxmotion.com	$21.95	1	21.95	GHM-02
Planetary Gear Motor- 12vdc; 1:231, 64rpm, 4mm shaft		$31.95	1	31.95	PGHM-04
Planetary Gear Motor- 12vdc; 1:241, 241rpm, 4mm shaft		$29.95	1	29.95	PGHM-05
Planetary Gear Motor- 12vdc; 91:1, 65rpm, 6mm shaft		$37.95	1	37.95	PGHM-02
Commercial Miter Gear, 24 teeth, 24DP	sdp-si.com	$14.07	2	28.14	A 1B 4-Y24024
Brass 20 Deg Pressure Angle Spur Gear 24 Pitch, 12 Teeth, 0.5” Pitch Dia, 3/16” Bore	McMaster-Carr	$14.46	1	14.46	7880K37
Brass 20 Deg Pressure Angle Spur Gear 24 Pitch, 36 Teeth, 1.5” Pitch Dia, 1/4” Bore		$24.47	1	24.47	7880K44
Steel Ball Thrust Bearing Stainless Steel, for 3/8" shaft dia, 13/16"OD		$3.06	1	3.06	6655K35
Perma-Lube Steel Ball Bearing- ABEC-1 Double Sealed, No. R6 for 3/8" Shaft Da, 7/8" OD		$10.63	1	10.63	2342K85
Perma-Lube Steel Ball Bearing- ABEC-1 Double Sealed, No. R4 for 1/4" Shaft Da, 5/8" OD		$14.40	1	14.40	2342K83
Sample Depository Basket	Home Depot	TBD		TBD	
Mock OBS					
PVC Pipe, 0.5" Dia	Home Depot	$3.62	1	3.62	
ABS Pipe, 3"		$3.68	2	7.36	
ABS Caps		$3.82	6	22.92	
PVC Tee Connectors		$0.27	4	1.08	
PVC Side Outlet Connectors		$1.19	8	9.52	
PVC Male Adaptor Connectors		$0.38	8	2.04	
Tax				3.67	
Teflon Tape	Ace Hardware	$0.99	1	0.99	
PVC Cement		$4.99	1	4.99	
PVC Primer		$4.99	1	4.99	
Tax				0.85	
Competition Traveling Costs					
UCSD Housing		$175.00	4	700	
University Vehicle Rental		$500.00	1	500	
TOTAL COST				**2239.01**	

DESIGN SUMMARY

The basic features of our ROV design include:

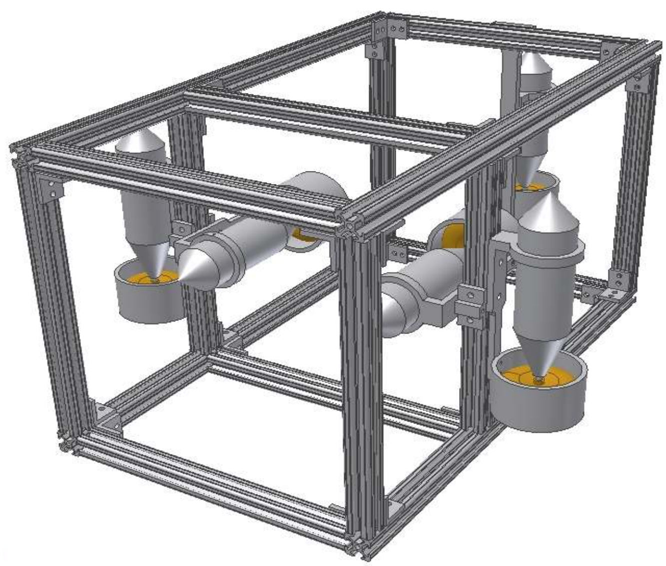
Vehicle Frame
Thrusters
Cameras
Manipulator Arm
Electronics Dry Box
Flow Concentrator
Control System
Buoyancy Device
Tether and Wiring



Vehicle Frame

The vehicle frame is 2x1x1.166 ft. made from anodized T-slot extruded aluminum connected using aluminum L-shaped brackets and socket cap screws which hold the frame together in a rigid fashion. The T-slot extruded aluminum was specifically chosen by our team for its low weight to strength ratio. The slots in the extruded aluminum allow for easy attachment of vehicle components to the frame. Also, the extruded aluminum does not have an interior air-filled region like PVC which would require waterproofing.

The Vehicle frame has two vertical T-slot extruded aluminum crossbars affixed to the outer right and left hand sides and one vertical crossbar centered at the vehicles rear. These crossbars mount the thrusters for both vertical and horizontal translation.



The use of the T-slot extruded aluminum gives great flexibility for attachment of components and easy re-configuration of the vehicles overall center of gravity during testing. No problems occurred during the construction of the vehicle frame and the T-slot extruded aluminum proved to be an excellent design choice.

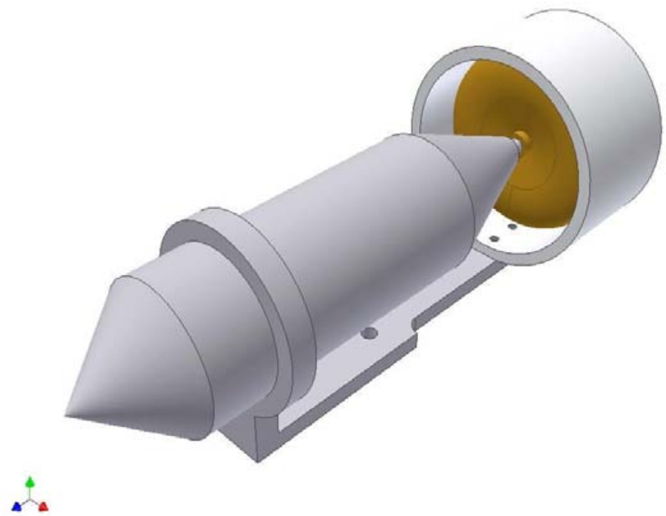
Thrusters

The ROV has 5 thrusters mounted to the vehicle frame using custom machined aluminum mounts attached to the T-slot. The thruster bodies themselves are cylindrically shaped 2 inch diameter machined aluminum.

The thrusters consist of 7 parts that include:

Solid nose cap
Hollow cylindrical body
Hollow end cap
Solid brass propeller
Planetary Gear
Driveshaft
DC Motors

The nose and end caps are fitted to the cylindrical portion of the thruster body by way of two smooth, flat-butted surfaces each having precisely machined circular seat grooves for oiled O-ring placement. The nose and end caps are then tightly secured to the thruster body with 4 screws which are evenly placed throughout the thruster body's circumference. These screws, when properly torqued, compress the O-rings and create a watertight fit. The brass propeller is affixed to a rotating driveshaft - which protrudes through the end cap of the thruster body – and is secured with a set screw.



The interior of each of the thrusters consists of a 12-volt DC motor seated snugly inside the hollow thruster body. The anodes and cathodes are soldered to 10-AWG copper wires which protrude through two evenly spaced holes drilled into the thruster body. Both holes are sealed with JB Weld brand steel/epoxy resin for a watertight fit. The DC Motors output shaft is connected to a planetary gear-set which transfers rotational motion and torque to the output shaft and brass propeller. The planetary gear-set is designed to give the required gear reduction to step-down the motors output RPM. The output shaft is tightly fitted through the end cap using a rubber lip seal which prevents water from entering the thruster housing.

The thruster mounts consist of a circular 2 inch inner diameter ring - into which the thruster body is seated and held with set screws - and a flat plate attaching the ring section to the vehicle frame. The flat plate portion bolts directly into the T-slot aluminum and can be slid along the channels to reposition the thrusters axially. This attachment design is a great advantage as it allows for easy re-configuration.

The ease and modularity of this axial repositioning design allows for easy reconfiguration of torque-moments about the vehicles center of gravity (COG) as well as adjustments to the COG location itself.

The advantage of using DC motor thrusters is the ease and cost of finding reliable and powerful motors that work well under the power restrictions given. If time and cost permitted the option of developing hydraulically powered thruster motors would be advantageous due to problems that have arisen while attempting to keep the water out. However, were hydraulic motors to be used a separate pump solution would have to be developed for the hydraulic fluid - which adds complexity. However, a hydraulic thruster system would have a lot less risk of failure than the electrical one chosen.

Cameras

3 B&W cameras are housed in clear cylindrical watertight acrylic containers. All cameras provide closed-circuit viewing forward and aft of the vehicle for underwater operations. Camera specs are:

Camera apparatus:	1/3,1/4 Picture sensor	
Validity Pixel:	CCIR: 500 X 580	EAI: 510 X 492
Sensitive area:	4.9mm X 3.7mm	
Beaconage:	CCIR/EIA	
Horizontal Definition:	420 TV LINES	
Lens:	3.7mm/F2.0	
Min Illumination:	F1.2 inch , 0.05Lux	
S/N Ratio:	>48db	
Shutter speed:	1/50 or 1/60 - /100,000	
Video output:	1.0Vp-p,75	
Power supply:	DC-12V	
Power Consumption:	90mA	
Size:	30mm X 30mm X 13mm	

The camera configuration allows multiple views for the vehicle pilot during underwater operations. The more camera views the pilot has at his or her disposal the better and future teams may want to increase the number of cameras on the vehicle if budgets allow.

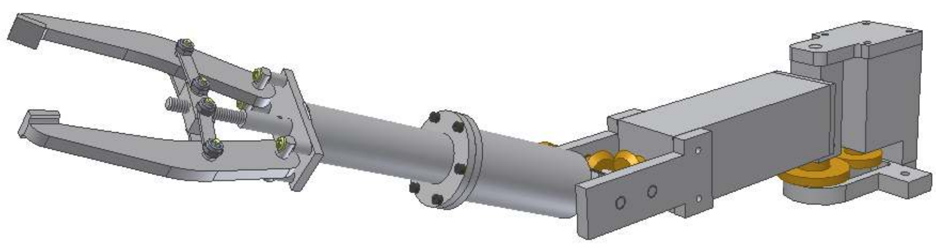
Manipulator Arm

The manipulator arm is attached to the front-right-bottom of the vehicle and deploys forward during operation. The manipulator consists of 3 main parts starting with an arm section powered by a DC motor-driven actuator that swivels horizontally from the vehicle frame. At the end of the arm a joint providing vertical rotation to a forearm section (also powered by a DC motor) is attached. The horizontal and vertical motion of the arm and forearm joints along with the maneuverability of the vehicle itself provide a manipulator that can be placed anywhere in 3-D space by its operator. In addition, at the end of the forearm section a claw has been designed which will open and close using a jack-screw mechanism powered by another DC motor. The combinations of maneuverability and added claw provide a manipulator with high dexterity for careful underwater operations.

All DC motors are enclosed in watertight machined aluminum housings which are smartly integrated into the manipulator arm itself. The Manipulator is fastened to the vehicles T-slot frame with ¼ inch screws and sliding bolts for lateral-axis adjustment. The watertight motor housings are designed to withstand a depth of approximately 50 feet or a pressure = 48.6 psi. The motor drive shafts will extend from the watertight housing through a press-fit rubber shaft lip seal designed to withstand these pressures.

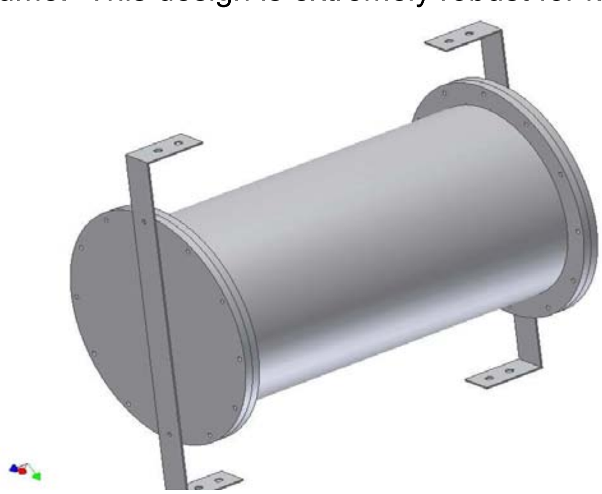
The forearm section has a length = 1ft and has a weight ≈ 2 lbs. The motor for the forearm section provides enough power to move itself under its own weight plus the weight of a 2 lb dive weight at its end. Calculations of power requirements to maneuver these estimations were done by our team and a Mabuchi 12-volt motor was selected with the following parameters:

113:1 gear ratio
$\omega \approx 142$ RPM (stepped-down from 16130 at max efficiency)
Torque ≈ 4 ft*lbs

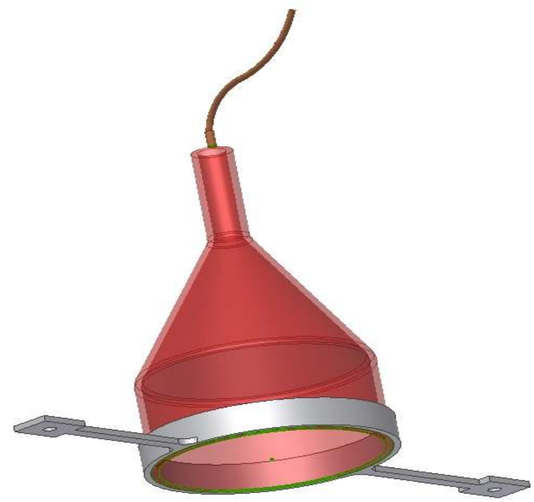


<u>Electronics Drybox</u>

The drybox is designed to house the control system onboard the vehicle. The drybox is actually a ¼ in thick 12 inch long dry cylinder made of schedule 40 6 inch aluminum pipe. Both ends of the drybox have 8 inch diameter welded flanges with highly polished surfaces. Both drybox flanges are fitted with 8 in diameter round flat plates fitted with 1/8 inch diameter silicone O-rings[1]. The highly polished surfaces and O-rings provide a watertight seal when the flat end plates are attached using 12 bolts at each end. This configuration creates a dry interior space for electronics and electrical connections consisting of 1 atm and 0.1964 ft^3 volume. This design is extremely robust for keeping water out. The drybox is machined to high tolerances and should be reliable to a much deeper depth than will be required for this competition.



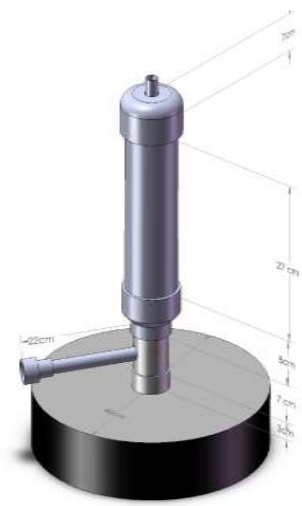
The tether cable from the surface enters one side of the drybox. Once inside, the tether wires enter the control system. At the other end of the drybox wires to each thruster, camera, thermocouple and manipulator arm protrude. The weakness of this drybox design lays in the wire penetration holes. JB Weld and silicone were used liberally to seal the protruding wires but these holes are likely a place for future water leakage. If time permits special watertight electrical connectors may be designed and manufactured to overcome this potential area of failure.



The drybox is designed to give the vehicle a safe and reliable place to house our mission-critical control system at a low cost. Materials for this design are much less expensive than buying an off the shelf container.

Flow Concentrator

The mock hydrothermal vent, from whose ½ in vertical spout hot water will flow, will fit into the flow concentrator mounted on the vehicle frame directly behind and to the center of the interior thrusters. The flow concentrator will funnel the hot water vertically toward the thermocouple for accurate temperature reading.



The flow concentrator is mounted on a specially designed bracket which bolts directly into the vehicles T-slot frame for simple axial positioning. After flowing past the thermocouple the hot water will be directed vertically through the top of the vehicle frame and away from the vehicle so as to mitigate external forces induced from the upward stream.

The flow concentrator is made of a plastic funnel and the mount is machined aluminum. Dimensions for the flow concentrator are:

Height = 10 in.
Base Inner Diameter = 4 in.
Top Inner Diameter = 1/2 in.
Thickness = 1/8 in.

Control System

The ROV is controlled via joysticks with a camera system as feedback. There are 5 degrees-of-freedom for the motion of the vehicle, and 4 degrees for the manipulator arm. The joysticks provides analog signals to a microcontroller, which sends these signals down the tether to the vehicle, where they are transformed via a matrix and sent out as PWM signals to a series of bi-directional motor controllers. These are composed of op-amps and H-bridges and in turn send PWM signals out to the motors of the thrusters and the arm. A system of CCD cameras placed at strategic points around the vehicle provides visual feedback to the operator.

The brain of the control system is the ATmega168 microcontroller, which is programmed using the Arduino Integrated Development Environment (IDE) for code development and the USBtiny In-System Programmer (ISP) to upload code to the chip. There is one chip at each end of the tether (onboard and offboard), and each performs a different function while remaining in communication with the other. The data is sent between microcontrollers serially via a RS485 physical layer, which allows communication over long distances (up to 1200m) using only one twisted pair and a shield.

How it works:

The joystick provides analog signals and the switches provide digital signals to the microcontroller (MCU) for the purpose of controlling the thrusters and arm. These signals go into the first MCU and are processed before being sent to the ROV. First, the analog signals are transformed using a matrix, which provides the proper input signals for the motor drivers based on the desired movement of the vehicle. Then these transformed numbers and the state of the switches is sent serially to the DS1487N chip (RS485), which converts the data into a voltage differential and sends it down the tether. Onboard the ROV, this data is then decoded by another DS1487N chip and fed into the second MCU, which parses it out to the proper motor drivers. Feedback about position and heading is obtained visually through cameras.

How the code works:

The Onshore MCU listens to the transmission line for a byte from the onboard MCU, signaling that it is ready for a packet of data. When it receives this byte, it polls the joystick and switch inputs for values and sends them down the tether and, once again, returns to a listening state.

The Onboard MCU sends a byte indicating that it is ready to receive a packet of data, and listens to the receiving line for it. If it doesn't get anything after a short wait, it sends another indicator byte. If it receives a packet, it parses the bytes out to the proper variables (motor and arm). It then performs a transformation on the motor values so that the proper speeds are obtained from the proper thrusters. It then writes these values to the motors of the thrusters and arm.

Benefits and drawbacks:

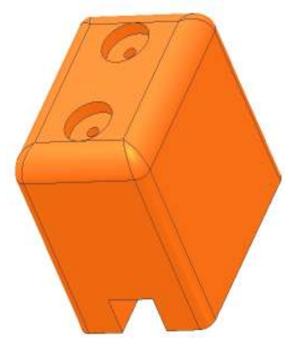
The Arduino environment was chosen for a couple of reasons. First, it presents a quite simplified method of microcontroller programming, as the language used is based on Processing, which is a subset of C. All of the fuses, pins and ports of the chip are already set within the environment, leaving room to focus purely on writing the software. It is also open source, which lets the user configure the system to his or her needs, and make it as complex or as simple as desired. The code is uploaded to the chip using the USBtinyISP, which can be used with many other development environments (AVRStudio, avrdude, WinAVR, etc.) as well as Arduino. It is a low cost kit which, when assembled, allows for the chip to be programmed while it is in the system, i.e. it does not need to be removed from its circuit. This greatly speeds up debug cycles and gives the flexibility to use other programming environments, should a more qualified Control Systems Engineer be assigned to this task.[2]

We chose to use RS485 as the physical transmission layer because it is virtually immune to noise, as it works by means of a voltage differential, which allows the use of a long tether in a relatively noisy environment. In addition, only one shielded twisted pair is needed for the data, which reduces the weight and bulk of our tether.

The motor driver circuits are based on a DIY bidirectional motor controller kit which uses a quad op-amp to generate PWM signals to an H-bridge based on the analog voltage present at a potentiometer, thus driving the motor forward, backward, or stopping it. We replaced the potentiometer with the PWM signals from the MCU, which is a bit of a hack but seems to work well. The benefit to doing this is that we only use one output from the MCU to control both directions of one motor, and as each MCU has only 6 PWM outputs, it saves us from having to use extra MCUs.

Buoyancy Device

The design of the buoyancy device is at this time still purely conceptual. Until the manipulator arm is completed the exact weight and center of gravity of the vehicle are still unknown. Our preliminary design is an epoxy poured foam device. The foam will be formed as to be easily attached to the T-slot frame and allow for easy repositioning.



CHALLENGES

One of the most challenging aspects of this project was the fact that we had to build a control system from scratch without the benefit of having an electrical or computer science engineer on the team (all four of us are mechanical engineers). Although we tried several times over the course of the year to obtain someone knowledgeable in these areas, and had several near-prospects and “friends-who-might-be-interested,” nothing ever panned out and we were left having to design a control system while knowing next to nothing about how one worked. However, one of the members of the team had a fairly decent rudimentary understanding of electronics so we basically overcame this challenge by relentless studying of microcontroller datasheets and websites devoted to DIY robotics and physical computing projects and their corresponding forums. We pieced-together advice from classmates, professors, and industry professionals. We slowly built the control system a bit at a time, modeling it on other successful systems. For example, our motor driver circuits are based on a DIY bi-directional motor controller kit. One piece at a time, we developed and tested our ideas for code and circuits, learning the basics, and then more complex ideas, often using a voltmeter and oscilloscope for troubleshooting and confirmation that our system was behaving as expected, when expected. Eventually, we arrived at a fully functional control system that made our vehicle do what we wished it to do. This is quite a feat, considering that not one of us has ever taken a class in control systems design, remote communications, circuit design or electromechanical systems.

LESSONS LEARNED

Throughout this design and manufacture of our ROV, our team has learned many valuable lessons about engineering design, time management and team communication. System integration was one of the most novel yet most important engineering design concepts we had to learn and put into practice from the very beginning. The multiple system types and components that make up the ROV had to be concurrently designed to ensure that every part worked together effectively and did not interfere with each other. Additionally, because our team was comprised of solely mechanical engineering majors, the electronics and control system were a major challenge. Actually designing and building our own control system turned out to be much more of an involved and difficult task than initially expected, due to our lack of comprehensive knowledge of and experience in electrical engineering. Because of the extensive amount of time and research it has taken us to make and program our own controls, we now realize we should have recruited an electrical engineer to be part of our team from the beginning. Realistic time management proved to be a challenge due to this unprecedented challenge with the electronics, as well as lack of experience working on major team projects like this, with so much work and so many different tasks. However, we can definitely say that we have seen significant improvement in our team communication throughout the project duration. Getting to know one's teammates and what one can and cannot expect of each other is crucial to delegating tasks and making progress with the project. Because we have been able to do this, making this ROV has been an enjoyable and profitable experience for all of us.

PROJECT MANAGEMENT INFORMATION

Over the course of these past two quarters, our team "Aggie Deep ROV" has managed to take on a project of incredible magnitude. This endeavor has encompassed aspects of electrical engineering, computer science, mechanical engineering and several other dimensions. In most cases, a team of only four individuals would be unlikely to integrate all aspects, design and manufacture in the short time period, however our planning and ability to communicate has enabled us to tackle such a large assignment.

While we now fully understand precisely how much was involved in this project, we also recognize how much we had initially underestimated the workload. As a result, we had a very dynamic task list and project management plan. Over the past several project reports, our Gantt charts have drastically changed. Initially, we had assumed each component of the vehicle to be simply designed and manufactured with an easily estimated time associated with it. Our first draft Gantt chart contained just that, component design and manufacture.

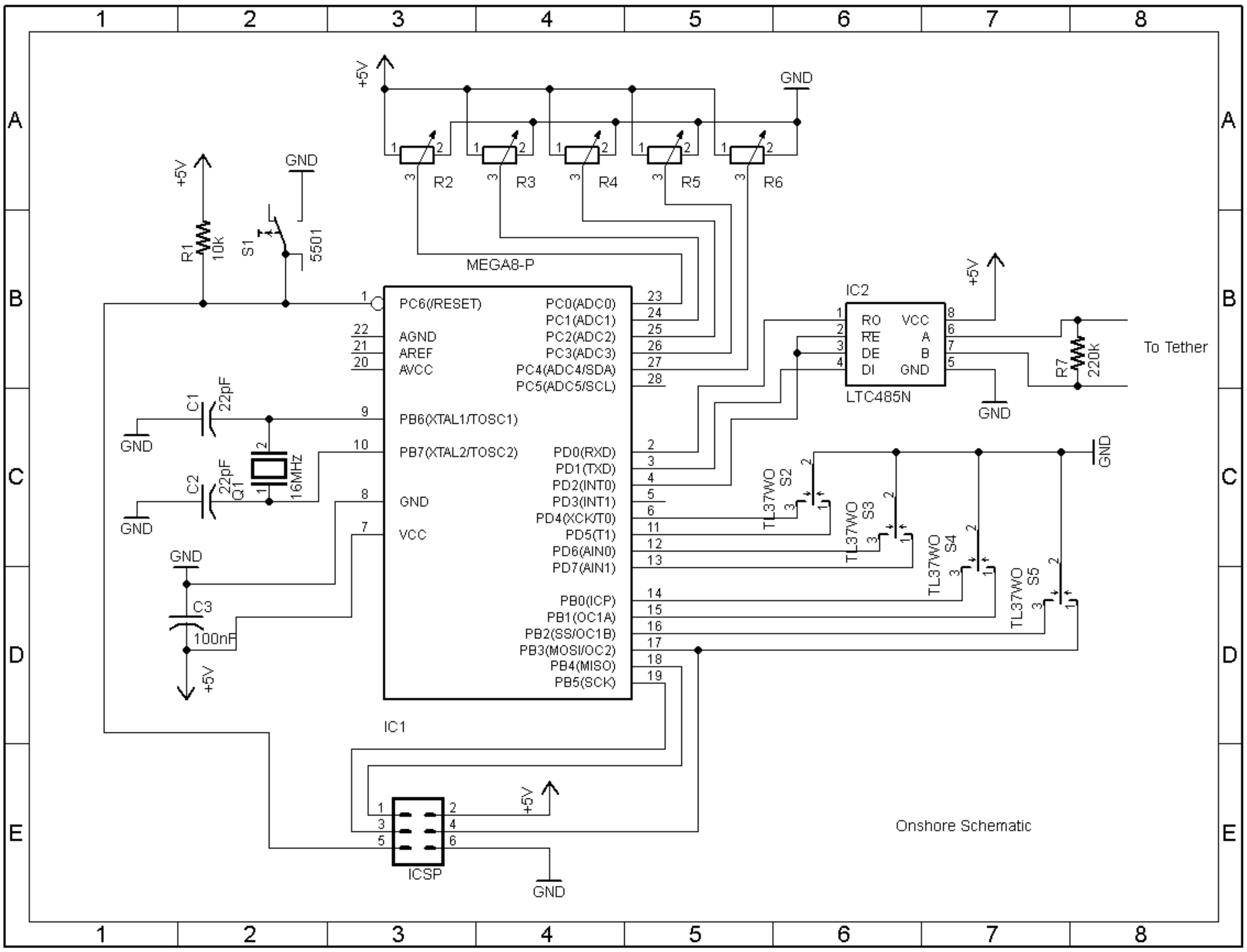
As we continued to meet three days a week, we realized that more and more unexpected tasks were popping up. Not only was this creating more work for us, but it was pushing us behind schedule. Even at this point, we had mistakenly made the assumption that we would not run into any significant problems and everything would work according to plan, even if a few new tasks did pop up. Additionally, we had not compensated for shipping time of bought materials and had underestimated machine shop time. We did not factor in the scheduled time with our advisors, as well as our own group meeting to discuss our progress.

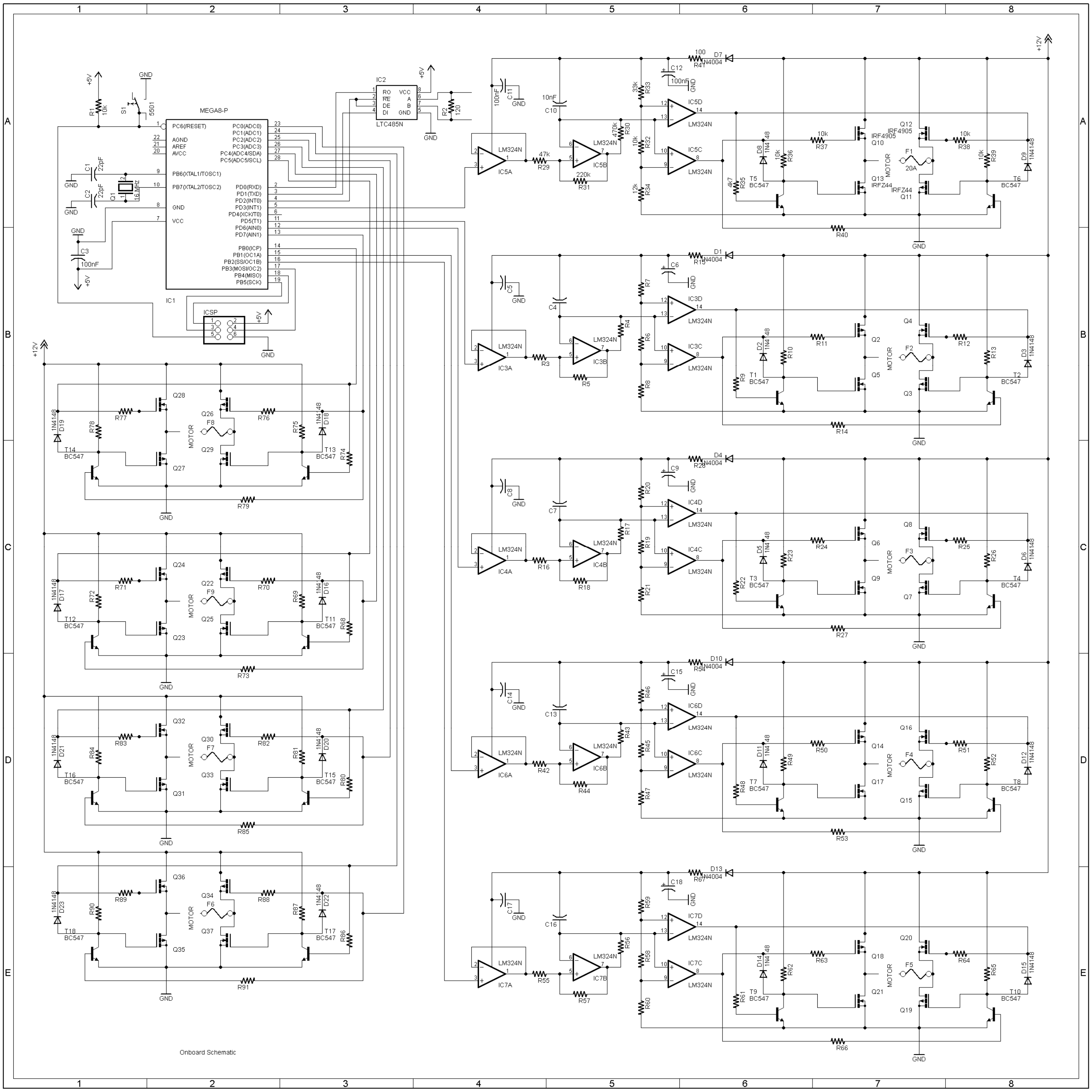
As we continued to shift further and further behind schedule, we found ourselves naturally moving along a critical mean path, focusing on the aspects of the design that were critical in moving forward. Instead of working on the cameras and thermocouple system, for example, we focused our attention on the vehicle chassis and thrusters. We knew that we would be able to work on these aspects later, while we had a deadline of May 10^{th} to have a maneuverable vehicle. On this same note, we had neglected to realize the complexities and lack of help associated with designing our control system. While we had been continually pushing this off schedule, we should have focused solely on this, as it is the heart of the vehicle. As a result, we crammed many last minute hours trying to get our control system functional before our May 10^{th} deadline. Unfortunately we ran into an unexpected problem and were unable to meet that deadline given our time constraint. Given team leader motivation and lots of work, a simplified secondary control system was constructed in the last couple hours which allowed us to make the deadline. This represents one of the most significant changes in our final Gantt chart.

Aspects of our design system propagated to other components of the system. We discovered last minute that we would be able to control the vehicle via a serial connection, requiring only two wires, rather than two wires for each motor. As a result, this changed both out tether design and dry box design. This prevented us from being able to finish manufacture of the dry box until near the deadline of the qualifying event. This prevented us from using the waterproof electrical connecters as planned, which have subsequently been removed from the Gantt chart all together.

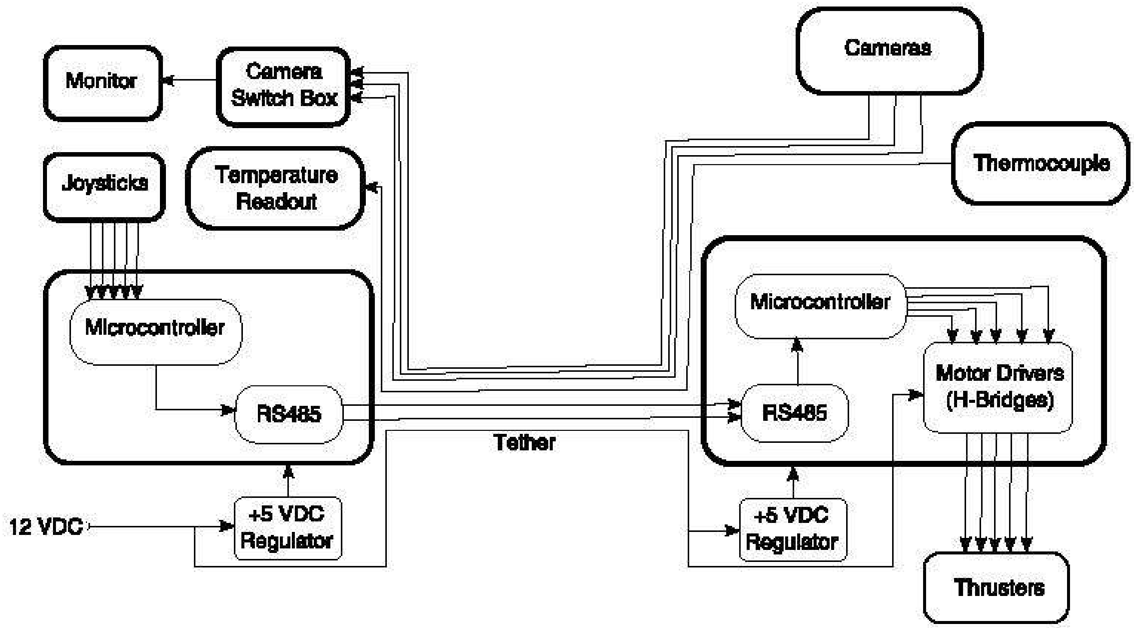
APPENDIX

ELECTRICAL SCHEMATIC




MEGA8-P
IC1
IC2
LTC485N
ICSP
LM324N
MOTOR
IRF4905
IRFZ44
BC547
1N4148
1N4004
16 MHz
+5V
+12V
GND
Onboard Schematic

ROV FLOW-CHART



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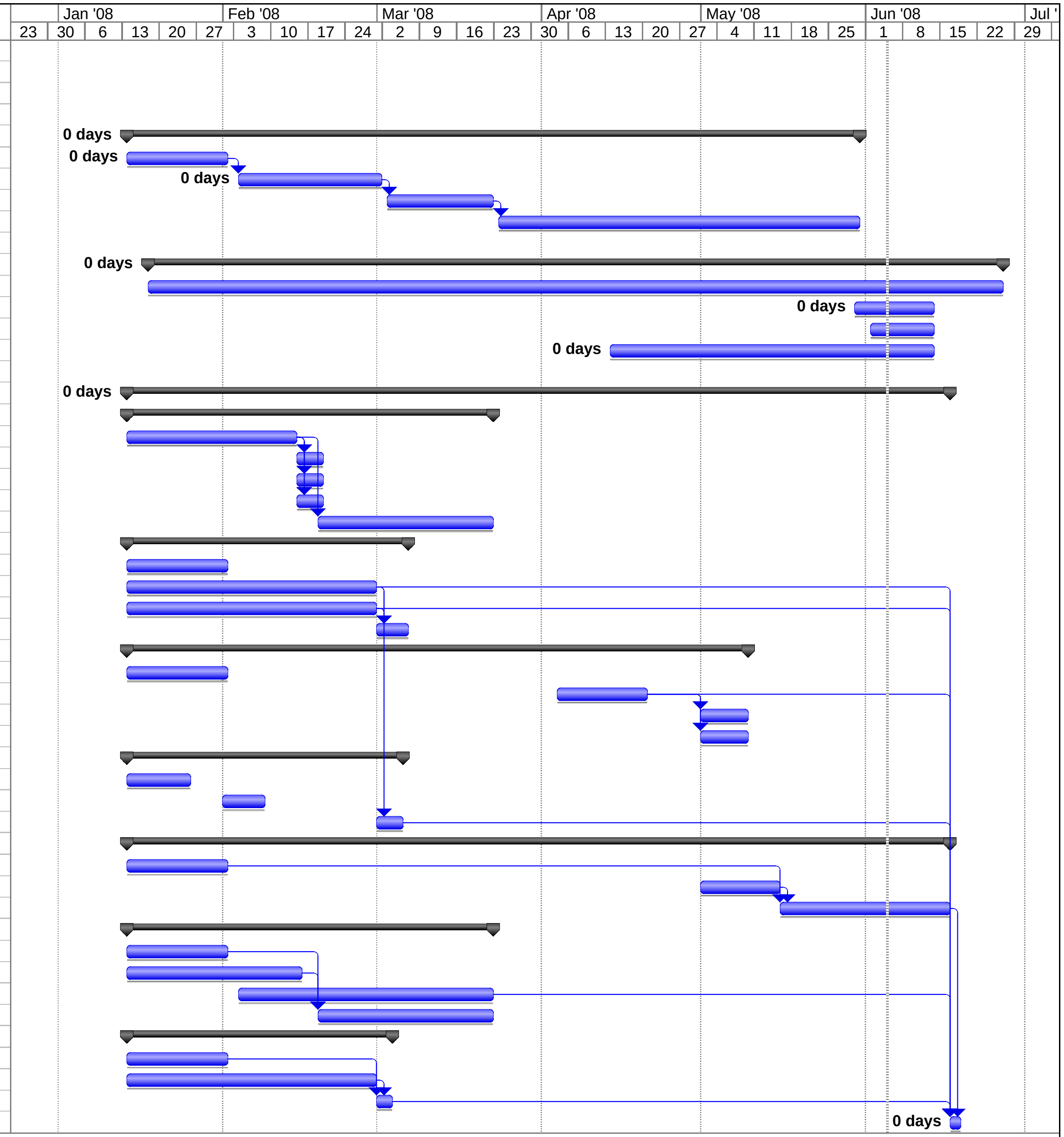
[1] Parker O-Rings Handbook. ORD 5700 Parker_O-Ring_Handbook.pdf. www.parker.com. 2008.

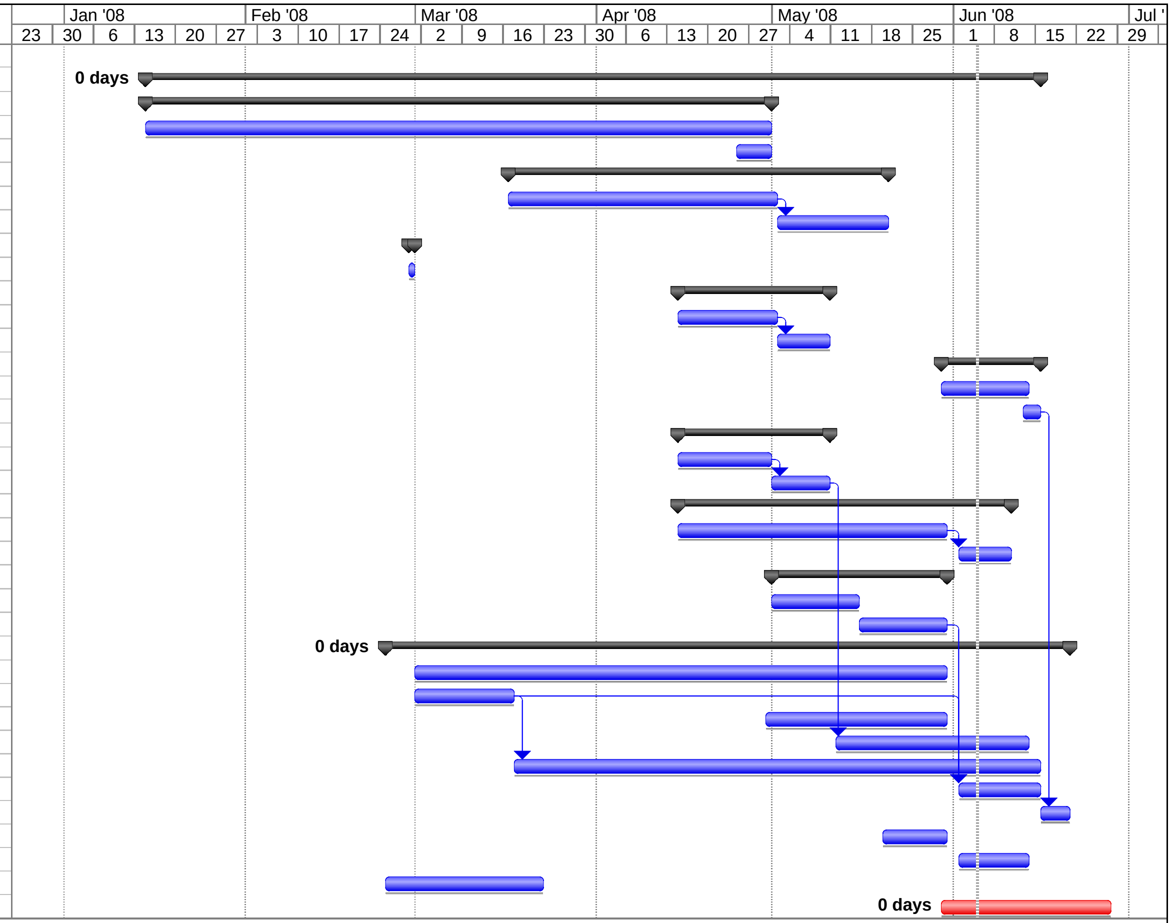
ID		Task Name
1		
2		
3		
4		
5		**Report**
6		Design Project Proposal, Spec. and Objective Report
7		Preliminary Design Report
8		Preliminary Machine Architecture Report
9		Final Report
10		
11		**Marketing**
12		Fundraising
13		Uniforms
14		Posterboard
15		Website Upgrades
16		
17		**Preliminary Analysis/Sourcing**
18		**Thrusters**
19		Disassemble, Machine off Paint and Epoxy
20		Replace O-rings
21		Lubricate Seals and Gearbox
22		Run New Wires, seal with epoxy
23		Reassemble
24		**Tether**
25		Source Vendors, and MATE sponsors
26		Decide on Wire Count, and Gage
27		Decide tether length
28		Calculate Tether Buoyancy effects
29		**Dry Box**
30		Examine Availability of Sealed Connectors
31		Source Dry Box
32		Examine Sealing Characteristics
33		Examine Wire in/out junctions
34		**Chassis**
35		Consider Chassis Materials
36		Choose Extruded Aluminum Type and Size
37		Source/Price T-Slot Vendors
38		**Thermocouple**
39		Talk to Prof Ericksson About Possiblities
40		Decide on Measurement system type
41		Order system from Omega
42		**Controls**
43		Discuss Control System Options
44		Consult Electrical Engineering Dept
45		Source System Components
46		Design Rough System
47		**Manipulator Arm**
48		Decide on Manipulator Arm Material
49		Rebuild and Test Previous Actuators
50		Source Materials
51		Estimate Rought Component Cost



Project: gantt
Date: Thu 6/5/08

Task	Summary	Rolled Up Progress	Group By SummTask
Critical Task	Rolled Up Task	Split	Critical Task
Progress	Rolled Up Critical Task	External Tasks	
Milestone	Rolled Up Milestone	Project Summary	

ID	Task Name
52	
53	**Design**
54	**Control Systems**
55	Design and Finalize System
56	Order Necessary Components
57	**Tether System**
58	Determine Official Wire Count/Gage
59	Order
60	**Chassis**
61	Design Finalize and Model
62	**Dry Box**
63	Model Design
64	Manufacture Dry Box
65	**Collection Tray**
66	Model
67	Order Tray Materials
68	**Camera/housing**
69	Design/Model
70	Order system/components
71	**Robotic Arm**
72	Design and Finalize System
73	Order Necessary Components
74	**Thermocouple System**
75	Design and Finalize System
76	Order Necessary Components
77	**Manufacture**
78	Control Systems
79	Chassis
80	Wiring
81	Camera/housing
82	Robotic Arm
83	Thermocouple System
84	Collection Tray
85	OSB Mock Up
86	Hydrothermal Vent Mock Up
87	New thruster Motor Shafts
88	Testing



Project: gantt
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Task	Summary	Rolled Up Progress	Group By SummTask
Critical Task	Rolled Up Task	Split	Critical Task
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