The Glomar Explorer

University of California, San Diego
Tau Beta Pi, California Psi

Team Members:

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Faculty Mentor:
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Abstract

UCSD's ROV Team sought to create a simple and economical robot that made use of many repurposed and easily obtainable parts in an effort to replicate the time and money constraints faced by engineers in the professional world. The team sought to complete all of the tasks in the simplest and most efficient way by using a PVC frame that supported three motors for movement, one motor for the arm mechanism, a camera, an LED cluster for light, and an RTD for temperature sensing. The arm mechanism sweeps weights into the hopper so it can transport them to the surface. The ROV requires no software or programming, and is completely under the control of the driver through four switches on the control box. Outputs come in the form of one monitor for the camera and one panel meter for the temperature sensor. The UCSD ROV is a study in simplicity and economy that shows that seemingly low-tech solutions can still be effective.

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I. Photographs of Completed ROV

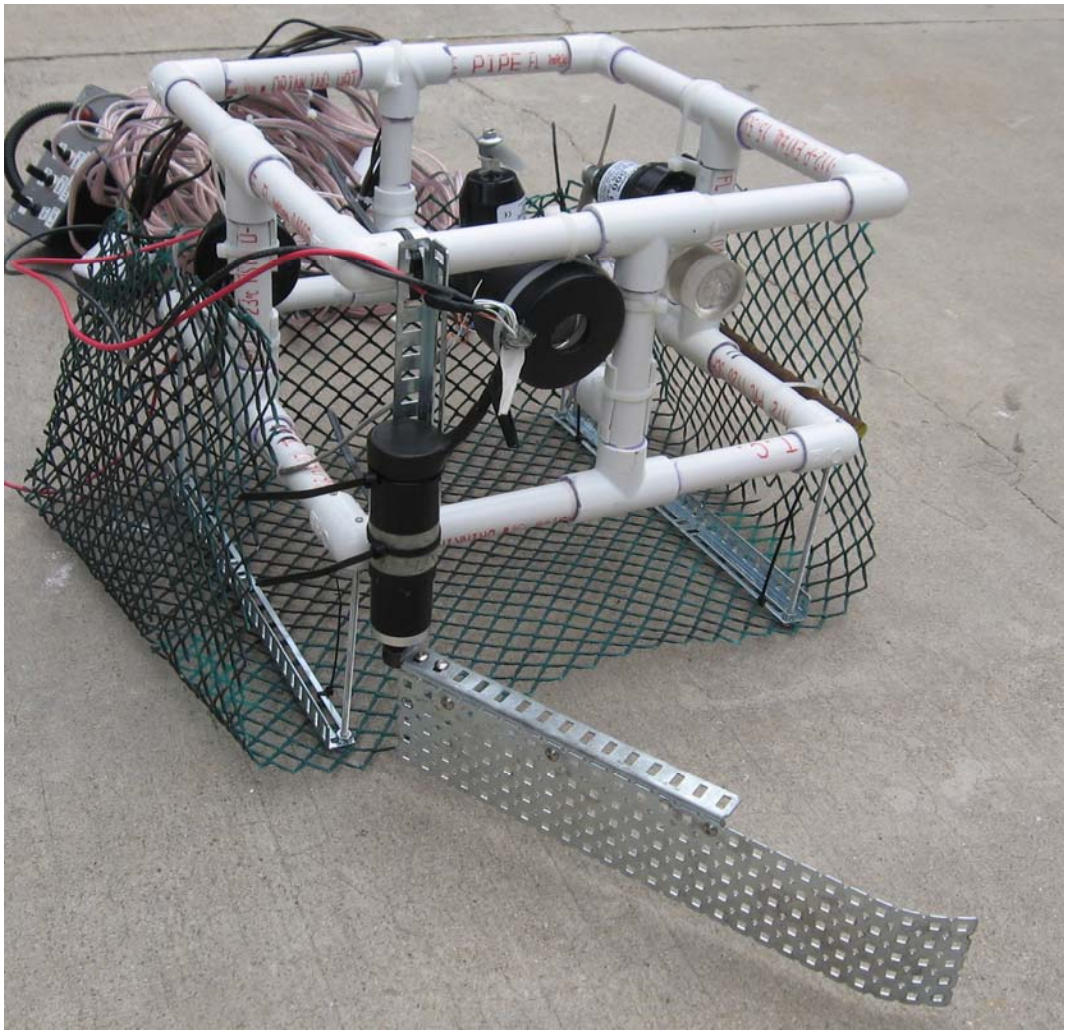

Fig. 1: The completed Glomar Explorer. Note the claw, just waiting to collect dive weights.

II. Budget/Expense Sheet

Budget/Expense Sheet

Period:

School Name: University of California, San Diego — From: 1/25/2008

Instructor/Sponsor: Instructor: Dr. Nathan Delson Sponsor:Tau Beta Pi, CA Psi — To: 1/6/2008

Funds

Date	Deposit or Expense	Description	Notes	Amount	Balance
1/25/2008	Deposit	Donation from TBP for project budget		$300	$300.00
1/25/2008	Expense	!nventivity ROV-in-a-box Project Kit, $250 donation from !nventivity			$ 300.00
2/9/2008	Expense	Maxon motors, Deutsch connectors, donated by Cosworth Racing			$ 300.00
2/16/2008	Expense	PVC, PVC cement, ABS from Lowe's		$ 20.00	$ 280.00
3/15/2008	Expense	Rocker Switch, fuses, wire from Radio Shack		$ 15.00	$ 265.00
5/3/2008	Expense	Switches, speaker wire, project box from Radio Shack		$ 30.00	$ 235.00
5/3/2008	Expense	Dive weight from Sport Chalet		$ 10.00	$ 225.00
5/10/2008	Expense	RTD Temp Probe from Automation Direct		$ 65.00	$ 160.00
5/10/2008	Expense	Panel Meter from Omega		$ 90.00	$ 70.00
		TOTAL			$ 70.00

III. Electrical Schematic

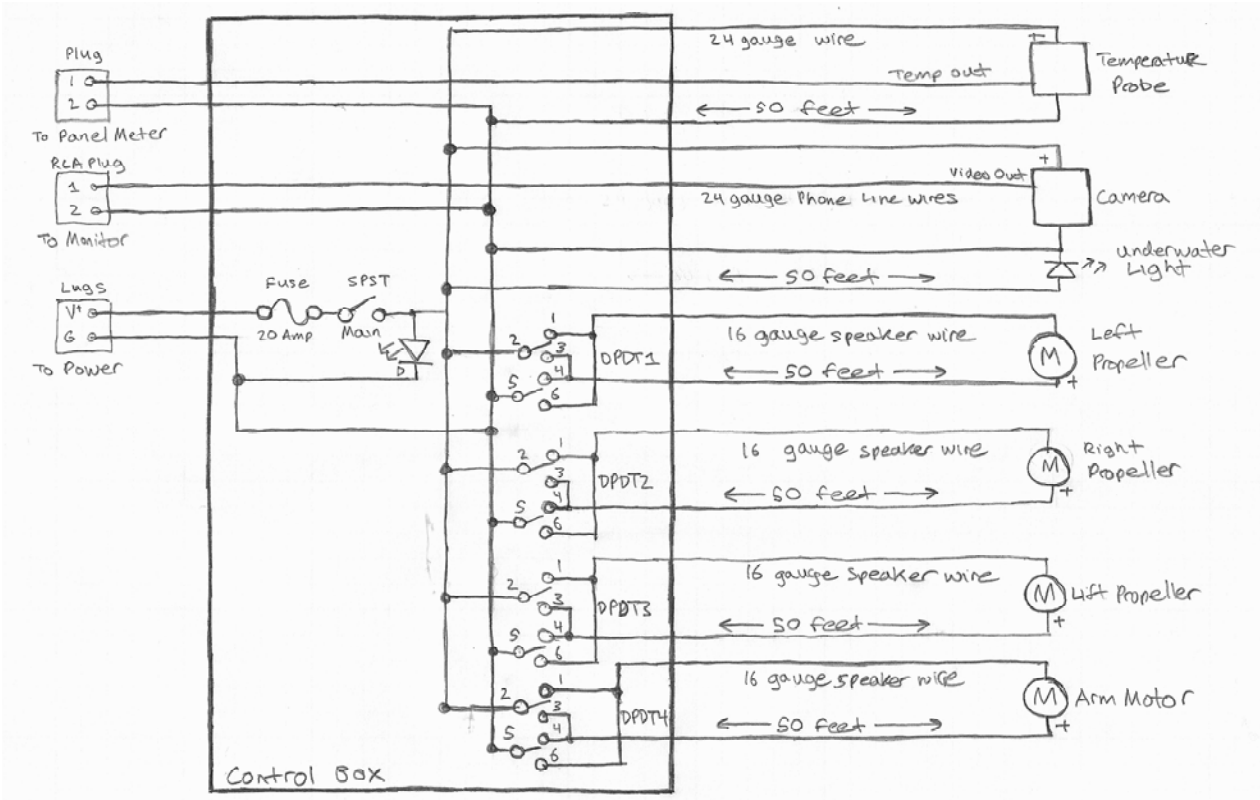

Fig. 2: Electrical Schematic for the Glomar Explorer

IV. Design Rationale

I. Materials selection
- A. PVC
  - i) PVC was deemed an appropriate frame material for its lightness, ease of fabrication, and affordability.
- B. Aluminum
  - i) Aluminum was chosen for the metallic frame and mechanism elements because of its lightness, water resistance, strength, affordability, ease of fabrication, and the fact that it was easily scavenged.
- C. Styrofoam
  - i) Styrofoam was used for buoyancy adjustment because of its low density and affordability.
- D. Tie-wraps
  - i) Tie-wraps were used for attachments to the frame because they are adjustable, lightweight, and affordable. They are also easily replaceable if modifications are made to the design.

II. Frame
- A. The PVC frame was made to be as compact as possible so as to be lightweight while still allowing room for all of the mechanisms. The size of the frame saved money on materials while also making balancing the ROV easier.

III. Camera
- A. The PC302XS Black/White CCD board camera was chosen for its affordability. It was waterproofed with a resin casing.

IV. Motors
- A. The Mayfair Marine 20112 500 GPH motors were chosen for their low voltage and current requirements, small size, and waterproof design. They were also designed to take a propeller.

V. Tether
- A. 16 gauge 50 foot speaker wires were chosen because it was deemed to be an appropriate length and durable without being too heavy.

V. Temperature Sensor
- A. An RTD was chosen for the temperature sensor for its accuracy and the quickness of the reading. The temperature sensor is the most expensive part of the robot, but the sensors are normally the most expensive and sophisticated part of a robot, and the economy of the rest of the project offsets this expenditure.
- B. A panel meter was used to read the output from the RTD. It was another large expenditure, but it made the temperature reading much easier by converting the output of the RTD directly into a temperature.

VI. Gathering Mechanism
- A. A simple arm powered by a Maxon motor was used to sweep the dive weights into a mesh hopper. The one degree of freedom mechanism was a solution that used a very small number of parts and little additional power to gather the weights. The plastic mesh was used so as to create little extra weight and water resistance, and o make retrieval of the gatherer weights as easy as possible.

V. Challenges

The biggest challenge faced by the UCSD team was finding time for Tau Beta Pi members to work on the robot as a team. Tau Beta Pi is the engineering honor society, and all TBP members share a serious commitment to academics as well as other extracurricular activities that build character. Accommodating the other time commitments of TBP members proved to be one of the most difficult aspects of the build, but by varying meeting times and holding long build sessions, many team members were able to come in and work on the robot at some time.

Another big challenge faced by the UCSD team was making the transition between design and construction. Brainstorming sessions produced a plethora of exciting ideas, but these ideas needed to be written down in a detailed design before their merits could be discussed. Nailing down the details of various designs so that the team could come to a consensus proved to be difficult, but encouraging team members to sketch out their ideas and look at available materials helped to flesh out concepts and arrive at a final design that the team agreed upon. Ensuring that everyone feels ownership in a project is difficult, but after designs were synthesized on paper it became much easier to settle on a design that everyone was happy with.

VI. Troubleshooting Techniques

The UCSD ROV team made an effort to preclude technical problems through a careful process of detailed design and prototyping. Ideas were mocked up using extra motors and materials, were made to scale, and tested in working conditions. If mechanisms or other parts of the robot were not functioning properly, we would attempt to trace the failure as logically as possible.

As an example, after the initial wiring of the robot, the main power rocker switch would work intermittently. We used a multimeter to check the connections, and by starting with the connections to the rocker switch and moving through the circuit, we were able to trace the problem back to the fuse. The fuse holder was maintaining the connection between the fuse and the rest of the circuit, but after the addition of some springs the circuit was completed.

Mechanisms like the weight gathering arm were perfected through trial and error. This procedure was mainly applied to the vertical placement of the motor and arm assembly after the dimensions of the hopper were determined based on the size of the dive weights. Different placements were tested with a dive weight that the team acquired, and several modifications were made to the frame of the hopper to increase rigidity and the ease with which weights could be pushed inside.

VII. Lessons Learned

For many of the team members, this ROV project was am exciting arena in which to learn both basic shop skills and the subtle complexities of completing a working robot on a strict time schedule.

Many of the team members, despite learning the rigorous process of circuit design and analysis in the classroom had never had the opportunity to physically put together a circuit. The simple wiring of the ROV was a great way for students to learn how to solder on a platform that was easy to correct if a mistake was made, and any mistakes were simply an opportunity to learn other techniques like how to desolder.

The ROV project was also an excellent way to train the team in how to apply the lessons learned in the classroom to an actual engineering project. Buoyancy and drag were important design parameters that were drawn from fluid mechanics, current draw and fuse selection were brought in from circuit design, and frame design and attachments used lessons from basic statics.

The ROV project also reinforced soft engineering principles like drafting ideas, prototyping, working in a team, maintaining a budget, and keeping a schedule.

VIII. Future Improvements

The UCSD ROV could be improved aesthetically and functionally. Functionally, the agility of the ROV could be improved by replacing the current motors with more powerful ones. Maxon motors might be an appropriate replacement if additional measures are taken to ensure that they are waterproofed properly. Also, some attachments to the frame could be improved by making them more permanent. Tie-wraps could be replaced with hose clamps, or permanent mounting brackets could be fashioned from PVC or aluminum.

The ROV could also benefit from some aesthetic improvements. Firstly, the ROV could be painted so that it looks more like a cohesive unit, and a bright color could serve a functional purpose by making the ROV easier to spot from the surface. The wiring could also be cleaned up, and the tether could be encapsulated in some sort of wire cover. Once again, this could serve a functional purpose as well by making the tether less likely to get caught on extraneous obstacles.

IX. Research Spotlight

The Woods Hole Oceanographic Institution (WHOI) is a non-profit research organization based in Woods Hole, Massachusetts. WHOI uses both Remotely Operated Vehicles (ROVs) and Autonomous Underwater Vehicles (AUVs) to conduct a variety of research expeditions[1]. The ROV used by the WHOI is actually an HROV, a Hybrid Remotely Operated Vehicle. The ROV is considered Hybrid because it can also run autonomously. The purpose of the HROV is to perform both general seafloor surveys and detailed sample analysis with a single vehicle. The HROV is actually still under development, but it should be ready for missions later this year. The HROV, named Nereus, is pictured in Fig. 3:

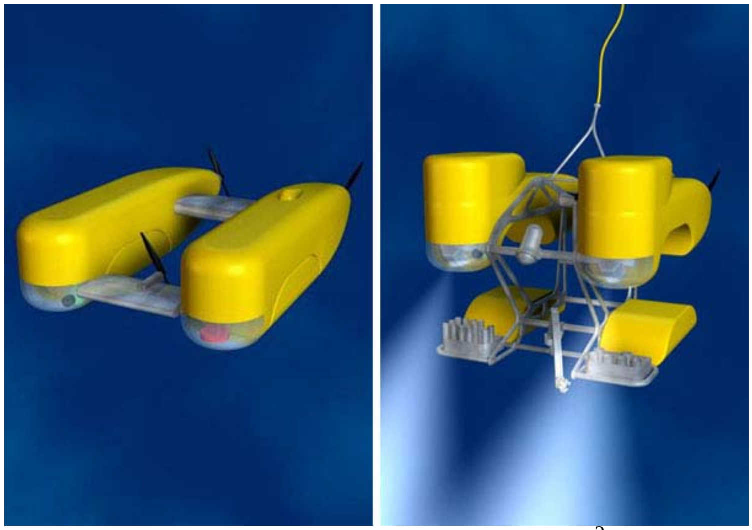

Fig. 3: WHOI's HROV the Nereus[2]

WHOI conducts a variety of expeditions, and one of their areas of interest is mid ocean ridges and in particular hydrothermal vents. One of the research tools used by WHOI to study hydrothermal vents is the Puma, an AUV. Puma is actually a portmanteau of "plume mapper," which is a simple description of its function. The Puma uses an array of chemical and temperature sensors to essentially sniff out the location of hydrothermal vents[3]. The Puma is pictured in Fig. 4:

Fig. 4: The Puma is deployed into the Artic Ocean during a June 2007 expedition[4]

The Puma works in conjunction with WHOI's Jaguar, another AUV. While the Puma roves along the seafloor, the Jaguar hovers over hydrothermal vents to take pictures and create solar maps[5]. The Jaguar was actually designed to tackle the icy depths of the Arctic Ocean. The Jaguar is pictured in Fig. 5:

Fig. 5: The Jaguar during a dock test at WHOI[6]

It is exciting to see the parallels between the work of WHOI and the UCSD team in the MATE competition. Our Glomar Explorer is outfitted with similar sensors as the Puma, and it roving around is similar to the intended purpose of the Nereus. As a non-profit organization, WHOI is also faced with the same budgetary constraints that the UCSD faced during the course of the build. WHOI also depends on volunteers and associates from a variety of disciplines, which is similar to the range of disciplines that make up Tau Beta Pi.

X. Reflections

The 2008 MATE ROV Competition was an exciting project that helped the UCSD team to hone their technical skills while learning about a fascinating real world application of robotics. We learned that a robot project, and any engineering project in general, demands the solution of technical problems and other problems like how to work on a budget or how to work in a team. The MATE Competition also faced the team with unique challenges, like designing a waterproof robot for the hostile environment of a pool. The MATE Competition also opened our eyes to an exciting area of research that demands the skills of engineers from every discipline, and is even sponsored by the Scripps Institute of Oceanography that is affiliated with our very own University. The MATE competition has increased the interest in engineering of every student involved on the team, and we all look forward to continuing our professional and educational development.

XI. References

1) *WHOI at a Glance.* Woods Hole Oceanographic Institute. 5/7/08. http://www.whoi.edu/page.do?pid=8117

2) *Hybrid Remotely Operated Vehicle Nereus*. Woods Hole Oceanographic Institute, 2/24/2005. < http://www.whoi.edu/page.do?pid=10076>

3) *Autonomous Underwater Vehicles: Puma.* Woods Hole Oceanographic Institute. 5/27/2008. <http://www.whoi.edu/page.do?pid=11399>

4) Ibid.

5) *Autonomous Underwater Vehicles: Jaguar*.. Woods Hole Oceanographic Institute. 5/27/2008. <http://www.whoi.edu/page.do?pid=11397>

6) Ibid.

XII. Acknowledgements

The UCSD ROV Team would like to extend our sincerest thanks to:

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