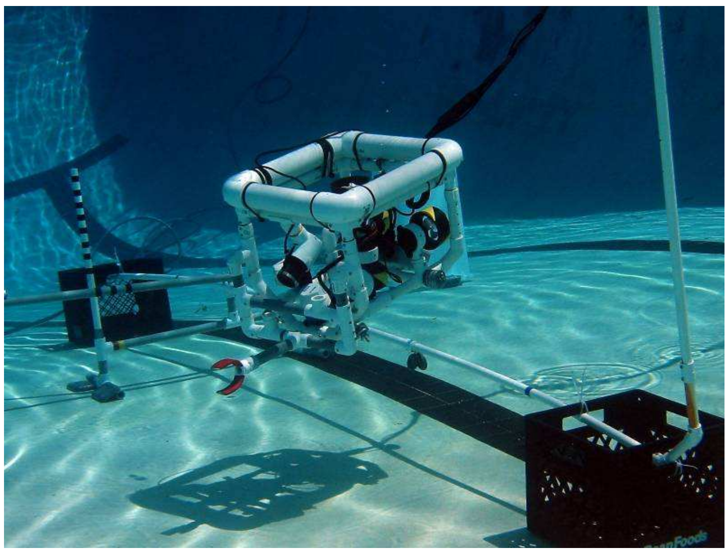
Technical Report

CABRILLO HIGH SCHOOL AQUARIUM
Remotely Operated Vehicle

For:
The Marine Advanced Technology Education Center
2005



☆ **Dagmar** : Remotely Operated Vehicle ☆

Team Members:

Tariq Falfal
Amanda Wilson
Ryan Garner
Juan Elenes

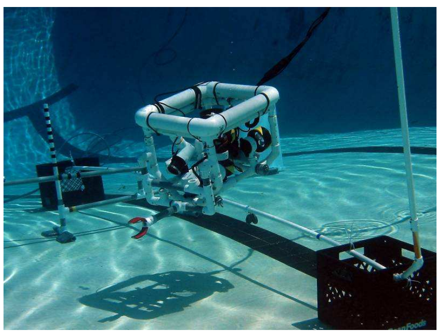
Mentors:

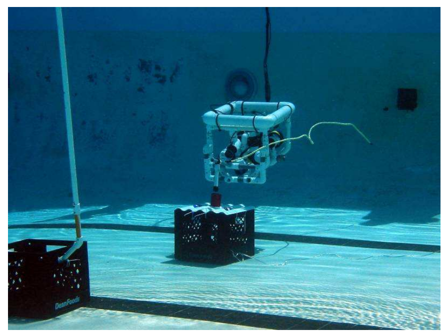
Robert Ranard
Shirley Pillus
Lisa Wilson
Steve Wilson

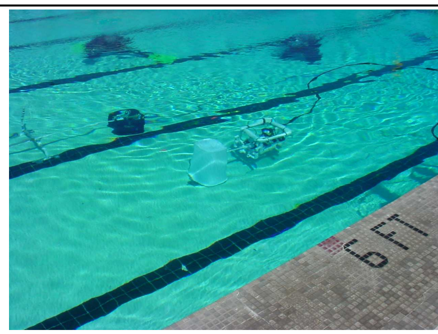
Abstract

Dagmar, designed and constructed in Lompoc, California by students from Cabrillo High School, was created to compete in the 2005 MATE (Marine Advanced Technology Education) Center's National ROV Competition held in Houston, Texas June 16-19, 2005.

Dagmar was built to perform Underwater Olympic events that correspond to three real world events. The first event simulates capping an oil well in the Gulf of Mexico. The second event requires the repair of a damaged fiber optic cable connection, which is necessary to establish a communications link between several platforms and their base operations on shore. The third, and final, event requires installation of a new instrument module to a specific location on the Hubble space telescope.







Dagmar was built mission specific to complete the aforementioned tasks in the most cost efficient manner possible, while still maintaining a robust, yet practical, nature of delivery. Unique features of Dagmar include the following:

- The modular design allows for quick repair of any breakable parts.
- The ROV boasts a powerful design, while efficiently utilizing its battery's power.
- The thrusters have the ability to vector to increase turning capacity.

The accompanying report also includes a description of design rationale, procedures/troubleshooting techniques employed during construction, and refinements made since the regional competition in Monterey, California.

Acknowledgements

The Cabrillo High School ROV Team would like to thank the following contributors and supporters who helped to make this project possible:

Special Thanks for the Underwater Pictures by Lionel
MATE (Marine Advanced Technology Education)
Sue Schuyler, Schuyler Custom Embroidery
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National Oceanic and Atmospheric Administration (NOAA)
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Channel Islands National Marine Sanctuary, Ventura, CA
Don Barthelmess, Santa Barbara City College (SBCC)
R Lompoc ACE Hardware, Lompoc, CA
Bob Floyd, California Electric Supply, Santa Maria, CA
George Weber, Weber Electric, Lompoc, CA

Additionally, we would like to thank Shirley Pillus for weathering the storm with us through Regionals. Special thanks to Lisa and Steve Wilson for stepping in after Regionals to fill the void and help us prepare for Nationals. Finally, we send great appreciation to our mentor, leader, and friend, Mr. Robert Ranard, for all of his time, patience, energy, and support leading to the culmination of this endeavor.

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Team Introduction

The 2004/2005 Cabrillo High School ROV team is comprised of four students. Two of the students are returning from the 2003/2004 team; the remaining two students are new to the team this year. One is a senior, while the rest are in their junior year. (Appendix C contains further details on team members.)

Our ROV was named after Mr. Ranard's mother, Dagmar. Dagmar was just eleven years old in Berlin, Germany when World War II broke out. She has gone from a time with no television and no advanced technology, to a time where robots are exploring the far reaches of the galaxy and the mysterious blackness of the deep ocean. Dagmar is a wonderful woman, with strong will power and great personality. Our Team is proud to have an ROV that flies under her name.

Juan testing Propellers

Ryan & Amanda pose with their Soldered Relays

Tariq flying Dagmar

Project Management

The Cabrillo High School ROV team began meeting one night a week in mid-November 2004. In January 2005, the team began meeting twice a week, every Monday and Thursday evening. Initial sessions consisted of lectures and theory in ROV basics. Subsequent meetings consisted of hands-on construction and testing/application of theory. Mondays remained "theory" study; Thursdays were reserved for design, construction, and operation.

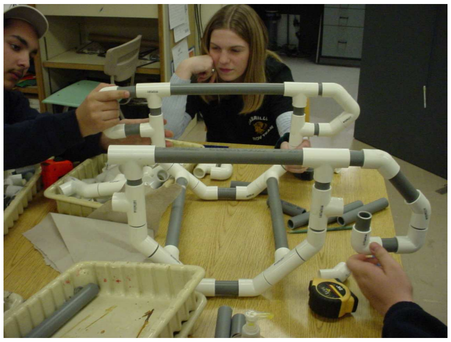
While experience taught the team that time efficiency mandated individual specialization, all of us were afforded the opportunity to experience every phase of the ROV development. At one time or another, each of us worked on frame development, electronics, piloting, and historian duties. However, an area of special interest for each of us soon became apparent. This led to an efficient, productive team.

Through the use of scheduled areas of focus on particular work days and the emergence of individual strengths and fields of excellence, a sound base of knowledge evolved upon which the team's ROV, Dagmar, emerged.

Design Specifications/Rationale

Main Structure Design

1. **Frame –** A great deal of discovery learning led to the construction design of Dagmar. Although the original intent was to build the ROV with a round body and wings, changes had to be made when it was discovered that a square body lent itself to more stability. Also, the wings were too bulky and seemed to serve no useful purpose. Size was increased from last year's design to allow more room for motors, and thus advanced moving capabilities. The frame was made of readily available and cost efficient ¾" PVC pipe. The ROV was made mission specific and did not need to be constrained on size since the specs did not indicate confined spaces.



Tariq explains the "wing" to Ryan

2. **Control System –** Dagmar's control scheme consists of an Atari 2600 joystick with two switches added to control up and down thrusters. The joystick controller was chosen to afford more fluid movement and sensitivity to the pilot's multidirectional commands, allowing movement of the ROV in three directions: x, y, and z. Seven relays switch power, one for each motor; while the five CAT5 cables supply power, four for the motors and the fifth for accessories. Parallel wires were used to increase the wires' size and handle the amperage of the motors.

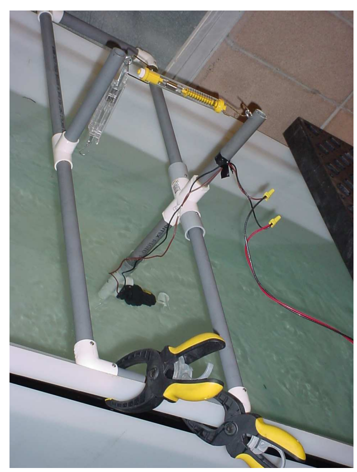
Amanda piloting Dagmar

3. **Camera** – Dagmar's camera, made by Aquaview, was recycled from the 2003/2004 ROV as a cost saving measure. The camera, which is black and white with ten infrared diodes, contains sensors for temperature, a relative position indicator, a compass, and has a depth rating of 65 feet. It is factory sealed for waterproofing. Also, adding a depth gauge allowed us to know the position of the ROV in the pool.

4. **Tether** – The original length of the tether was 45 feet, to which an additional 15 feet was added to allow for greater mobility of the ROV. The tether consists of five CAT5 cables, each containing eight individual wires, for a total of 40 available conductors (eight are currently spare). The tether is bundled with tape connections at intervals of 12-18 inches. Neoprene rubber floatation was added and spaced 32 inches apart to within four feet of the control box.

5. **Propulsion** – Seven thrusters were incorporated into Dagmar's design to allow for multi-directional movement. The left, right, and reverse thrusters provide finer movement using bilge pumps (water jets). The two forward, the up, and the down thrusters use propelling power. Thrust of the ROV was measured with a fabricated thruster test rig. Each thruster, at full power, produces 4.26 amps, for a total push of 10 newtons. A propeller matching exercise (see appendix B) indicated that larger props drew more amps and produced less thrust. Smaller props drew fewer amps and provided more thrust. Forward positioned thrusters can be vectored 180° to allow for finer directional adjustments, both right and left.

Propellers Tested



Propeller Testing Rig

Task Specific Manipulation Tools

Individual tools that can be manually attached and removed from the moveable hard points on the ROV were selected for mission completion. Friction fit allows for quick connection and disconnection of the tools.

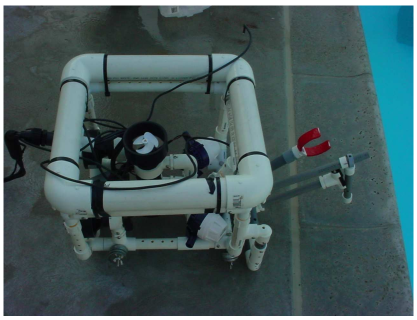
1. **Task 1 – Oil Well Capping** – A U-shaped clamp tool is manually installed onto the anterior frame of the ROV. This clamp is needed to cap the oil well by turning a valve (lever) one-quarter turn to stop the flow of oil from the pipeline. The tool chosen for this task loosely fits the lever, is lightweight, and serves to keep the bot from slipping off the lever. The tool necessary for completion of this task did not need to have a gripping capability. Therefore, the open-faced, U-shape of the tool proved to be adequate in pushing the lever to a closed position. Additionally, this eliminated any complications that may have occurred from gripping mechanism failure.

2. **Task 2 – Damaged Fiber Optic Cable Connection Repair** – The tools used for this task consist of a probe holder and a probe supporter that can be manually installed onto the anterior frame of the ROV. These tools are needed to allow for repair of a damaged fiber optics communication cable, which provides a link between platforms and their base operations on shore. The probe holder transports the probe and its attached cable to the open port on an undersea junction box. The probe supporter tool accompanies the holder and ensures that the probe position doesn't conflict with the view of the ROV camera. The supporter restricts the movement of the probe and provides stabilization for this instrument during transport to and insertion into the junction box.

3. **Task 3 – Installation of a New Hubble Instrument Module** – The selected tool for completion of this task consists of a Velcro lined patch inserter constructed of Class 200 PVC. This tool, as with the tools used for Tasks 1 and 2, is manually installed onto the anterior frame of the ROV. It is needed to transport a new instrument module to the Hubble space telescope. Equipping the Hubble with the new module will allow for furthering of the telescope's current capabilities. The patch inserter tool was designed to restrict movement of the female pipe and to create enough resistance so that the patch will not fall out of the pipe. The ROV approaches the telescope horizontally, while applying enough force to release the patch onto the telescope.

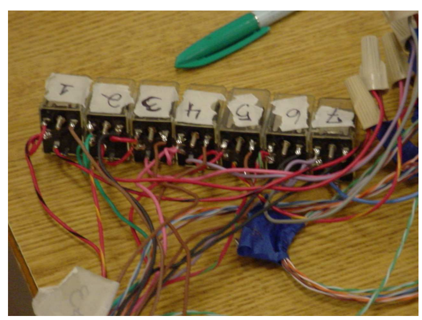
Refinements

The initial version of Dagmar included a mechanical arm designed to complete the mission tasks. After experiencing technical difficulties with this mechanism, the team decided to resort to the individual, manually attached tools currently in use. The benefits of these tools are many. The primary benefit is the elimination of the mechanical failures that the initial arm experienced. Reliability in regard to task completion was increased significantly with the new tools. Additionally, the manually attached tools are friction fit to allow for quick connect/disconnect for each task. They are attached at the moveable hard points on the frame of the ROV, and the simple design of each tool makes mission efficiency invaluable.



Dagmar showing off her tools!

The relay pack was originally attached to the ROV, which proved to be detrimental when water leakage into the box short-circuited the enclosed relays. At this point, the relay pack was moved to the control panel. This redesign prevented any future damage to the relays from leaking water.



The 1st relay pack, before water damage!

After regional competition, refinements made to Dagmar included lengthening the tether to allow for freer movement of the ROV. An additional fifteen feet of tether was added, for a total of 60 feet. Another refinement made after the regional competition was to change two of the thrusters to increase the power of the ROV. Two of the 500 bilge pumps were replaced with 750 pumps. Also, fuses were increased in number, from one to seven, allowing each motor to operate independently from the others. Finally, a depth gauge was installed to allow the pilot to know the relative position from the task completion site to the side of the pool.

Troubleshooting Techniques

Every project has its problems, and with every problem there's a solution. In this case, wiring, testing, and labeling were a must in organizing the remotely operated vehicle. The tether had to be labeled and tested to make sure all the components were operating in an exceptional fashion. The positive and negative wires had to be paired up in separate sections making identification easier. Throughout our observational learning process, we gained knowledge of blue and brown wires as being the "B," or bad wires (negative). The orange and green wires did not start with the letter B; therefore, we concluded they were positive.

The Atari 2600 joystick needed the same process of elimination. Identification and labeling of the appropriate switches had to occur to guarantee maneuverability of the ROV. The relays were tested and labeled to identify which relay connected with the corresponding motor. Before we were able to work on the relays (by matching the motors), the motors had to be tested and identified. Once we tested the motors and all of the connections were working, we were able to advance to the next phase. We tested amperage with a volt meter, and we tested the thrust of the propeller by using our propeller testing station. This consisted of a scientific scale, which measured the force pulled by the thruster in grams. This amount was then converted to newtons. The batteries were tested for voltage using the volt meter. To check the fuses, we were able to measure the wire resistance with a volt meter. Finally, after we tested and labeled our components, the ROV was assembled in an organized manner that met with the team's approval.

ROV Dimensions/Specifications

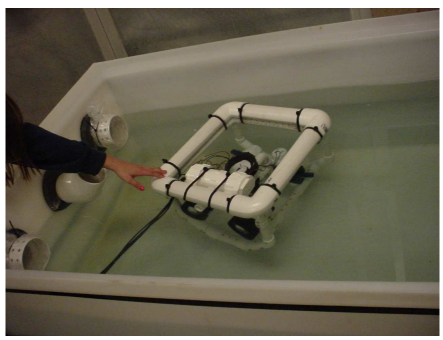
Description	Centimeters	Kilos
Height	41	
Length w/ manipulators	71	
Length without manipulators	48	
Width	38	
Weight		11.4
Weight without Ballast		10.9

Thrust at full power = 10 newtons

Challenges

The strict schedule and motivation of the team members kept challenges to a minimum. However, as in all real world endeavors, challenges cannot be entirely eliminated. The first challenge encountered was the malfunctioning mechanical arm used to complete the mission tasks. Although frustrating in that it did not prove to be a success, it did serve to remind the team to follow a long- standing team motto: “keep it simple silly.” Engineering and design had to be revisited to provide for an alternate way of completing the task requirements. This ultimately led the team to devise the currently used individual, manually attached tools. These worked beautifully, hence solving the unreliability problem inherent in any mechanically driven tool.

Buoyancy issues initially presented themselves to be obstacles that needed to be addressed. There was no effective way to place weights on the ROV in a manner that allowed for easy change and adjustments. The team finally designed the current system consisting of four bolts, two on the front and two on the back, onto which individual weights could be added or taken off quickly and easily and secured with wing nuts.



Testing the Buoyancy

Another challenge that the team encountered was the loss of two team members (we originally had 6) during the middle of construction. The remaining team members had to immediately take over vacant positions in order to keep Dagmar’s progress on schedule. Although the losses were unfortunate events, we quickly learned that we were capable of broadening our skills to cover the newly opened positions. We had to quickly restructure ourselves and bond together to fill the void.

Lessons Learned/Skills Gained

During the design and construction of Dagmar, the team has reaped the rewards of a vast array of lessons learned and newly acquired skills. First and foremost was the knowledge gained that the journey is more important than the destination. Each of us has grown in many ways that not only assisted in this project but will carry on into our individual endeavors.

Ryan taking Notes

Juan Soldering

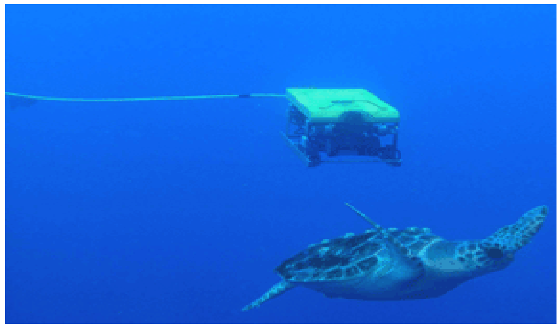
Amanda, Ryan & Tariq Brainstorming

We've learned about construction, mechanics, machining, and electronics involved in building an ROV. It was necessary to learn machining skills, such as using the drill press with a cross vise to cut prop guards out of ABS plastic fittings and soldering relay wires. We learned how to read schematics and color code wires to identify positive and negative wires. We also acquired knowledge of buoyancy and water flight theory.

In addition to technical skills, we learned how each individual's contributions were vital to the success of the team. We gained knowledge of our own strengths and weaknesses and applied what we learned about ourselves to the success of the team. Each strength revealed a weakness, and each weakness provided us with what we needed to improve ourselves. The technical skills we learned are secondary to the interpersonal skills we have gained. These will last throughout our lives. What we have gained will help us communicate with future co-workers and friends. As we have been taught, patience is a virtue.

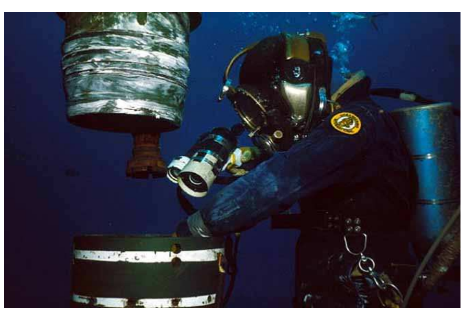
After all we have learned, the most important lesson was the value of family. Since becoming part of this team, we have become closer than anyone could have imagined. We've learned more about each other and have gained greater mutual respect. We have been through the worst and the best, and the four of us have lasted through it all.

Real World Mission Association -Deep Oceaneering Offshore Essay



Technology is the world's best friend in helping with everyday jobs. Humans have found a way to discover all of life's mysteries throughout the centuries. Today we can be sure that there are two places that man still cannot fully comprehend - two places that can be very hard to reach, and both in opposite directions. Space and ocean explorations include two of the hardest of locations for humans to contact. Technology has helped many people to reach goals of explorations, through spacecraft such as spaceships, satellites, and even astronauts, to obtain knowledge of these faraway places. Underwater destinations can be just as tough to reach, but through the use of ROVs (remotely operated vehicles), AUVs (Autonomous Underwater Vehicles), and divers, we can obtain our goals of underwater advancement.

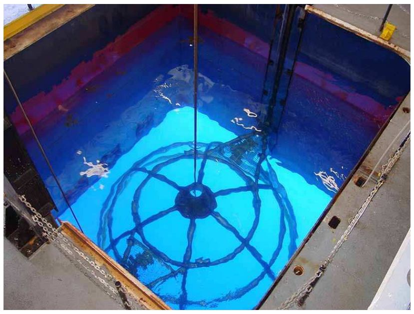
Remotely Operated Vehicles are "robots" that perform a multitude of tasks given by the pilot on the deck. The pilot can relay information to the "robot" by means of tether or "umbilical" cord. Some "robots" are built with arms, cameras, lights, and temperature sensors to perform the tasks at hand, thus making jobs easier to do in the deep ocean depths.



Oceaneering International, Inc. formed the Oilfield Projects Group (OPG) as a marine contracted organization group to perform tasks such as management, engineering, planning, and execution of small to mid-size deepwater projects in the Gulf of Mexico. Oceaneering's Oilfield Projects Group consists of experienced project managers and engineers operating out of Oceaneering's Projects Headquarters in Houston, Texas. Oceaneering and FugroChance have an alliance to work together offering integrated ROV and survey services to the offshore oil and gas industry in the Gulf of Mexico. OPG provides certified Remotely Operated Vehicles and pilots to perform manned diving, pipeline repair, topside inspections, jumper installations, and testing services.

In 2001, OPG set world records for distance (28.5 miles) and water depth (2,720 feet) for a coiled tube installation. The team laid their first umbilical containing fiber-optic cables while establishing a new Oceaneering umbilical lay at a water depth record of 5,320 feet. Then OPG performed their first two-sub sea well plug and abandonment, one of which was in water depths of 800 feet.

Oceaneering operates the largest technically advanced ROVs in the world. These vehicles are used for a variety of underwater oilfield tasks, including drill support, installation, and construction support, pipeline inspections and surveys, and sub sea production and facility operation and maintenance. Oceaneering, through its Advanced Technologies Group, also provides ROV services to include search and recovery and sub sea telecommunication cable installation, maintenance and repair. Additionally, Oceaneering provides a Remotely Operated Vehicle Training Program with ROV simulators for the person in training. These simulators mimic the appearance, function, and operation of Oceaneering's Hydraa Magnum, Millennium, and Quantum ROVs for virtual enjoyment. With the abilities to provide levels of difficulty and environmental conditions, pilots are able to learn basic skills and practice real work requirements prior to going offshore to actually perform the work.



Remotely Operated Vehicles have become one of the world's largest respected assistants in the discovery of the mysteries of the world's oceans. ROVs have come to help historians with the sinking of the great ship Titanic, and helped in collecting various specimens (both living and non-living) from different parts of the world. No matter if the water is as high as 400°C (750°F), ROVs have been known to survey specimens from "black smokers," or hydrothermal vents. The underwater habitat does not seem to phase these "robots." We can expect that they will continue to amaze humans everyday with the completion of more challenging tasks ahead.

Oceaneering - http://www.under-water.co.uk/2001/052000about7.htm

Rovexchange - http://www.rovexchange.com/mc_operators.php?p=operators_s

Budget and Financial Statement

Appendix A: Schematics

Appendix B: Propeller Matching Exercise

Appendix C: Team Members

Tariq Falfal – Tariq is a Senior at Cabrillo High School. This is his second year working on the ROV team. His first year, he worked as a videographer. This year, he is Captain and Primary Pilot.

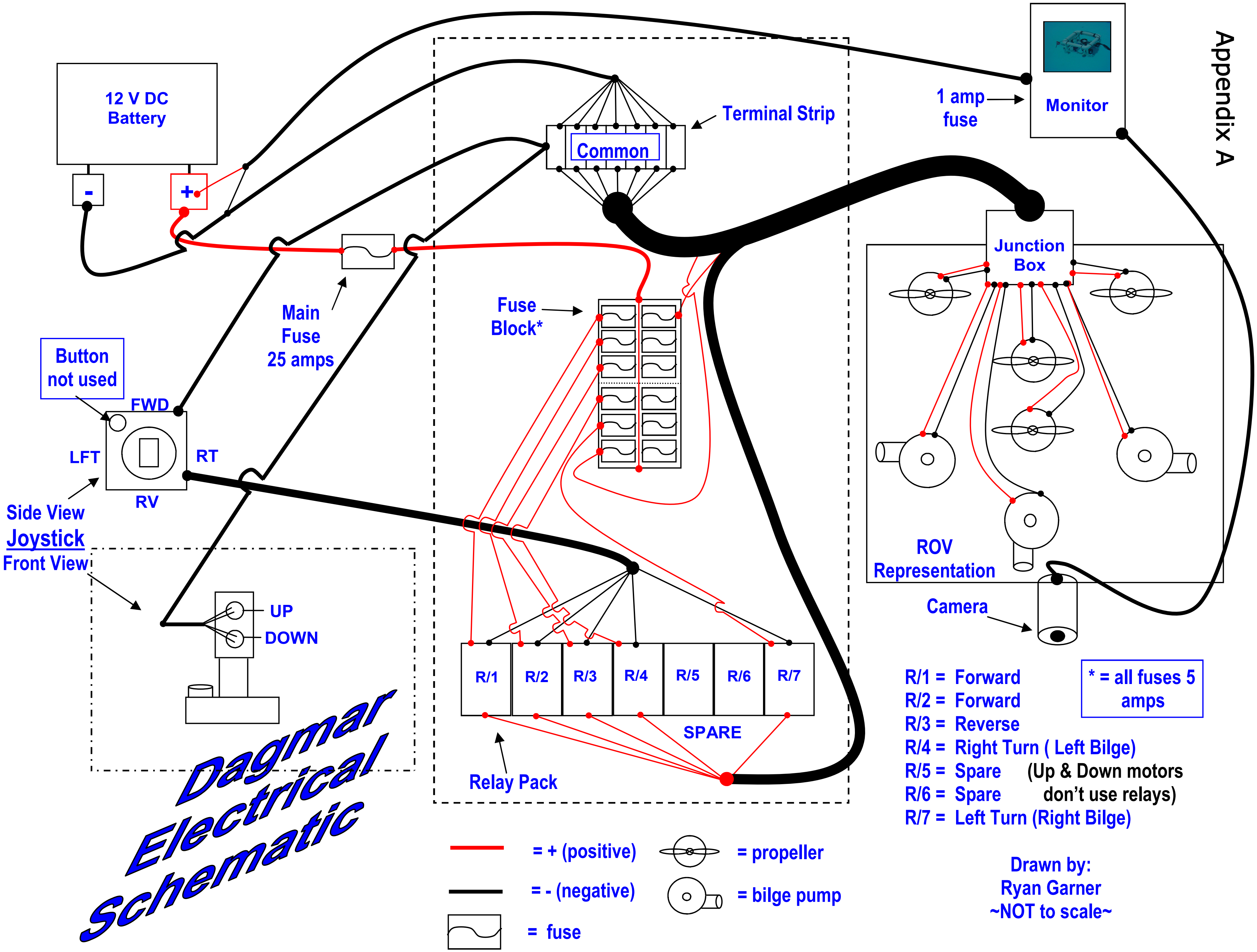
Amanda Wilson – Amanda is a Junior at Cabrillo High School. This is her first year on the ROV team. She is Co-Captain and Deck Supervisor. Amanda aspires to work in the Marine Biology/Technology field upon graduation from college.

Juan Elenes – Juan is a Junior at Cabrillo High School. This is his second year on the ROV team. His first year on the team, he worked as Tether Manager. This year, he serves as Task Instrument Manager.

Ryan Garner – Ryan is a Junior at Cabrillo High School. This is her first year on the ROV team. She is the team's Tether Manager, and has plans to continue work in the Marine Biology/Technology field in the future.

Ryan Garner, Amanda Wilson, Tariq Falfal & Juan Elenes win second place at the Monterey Regional Competition

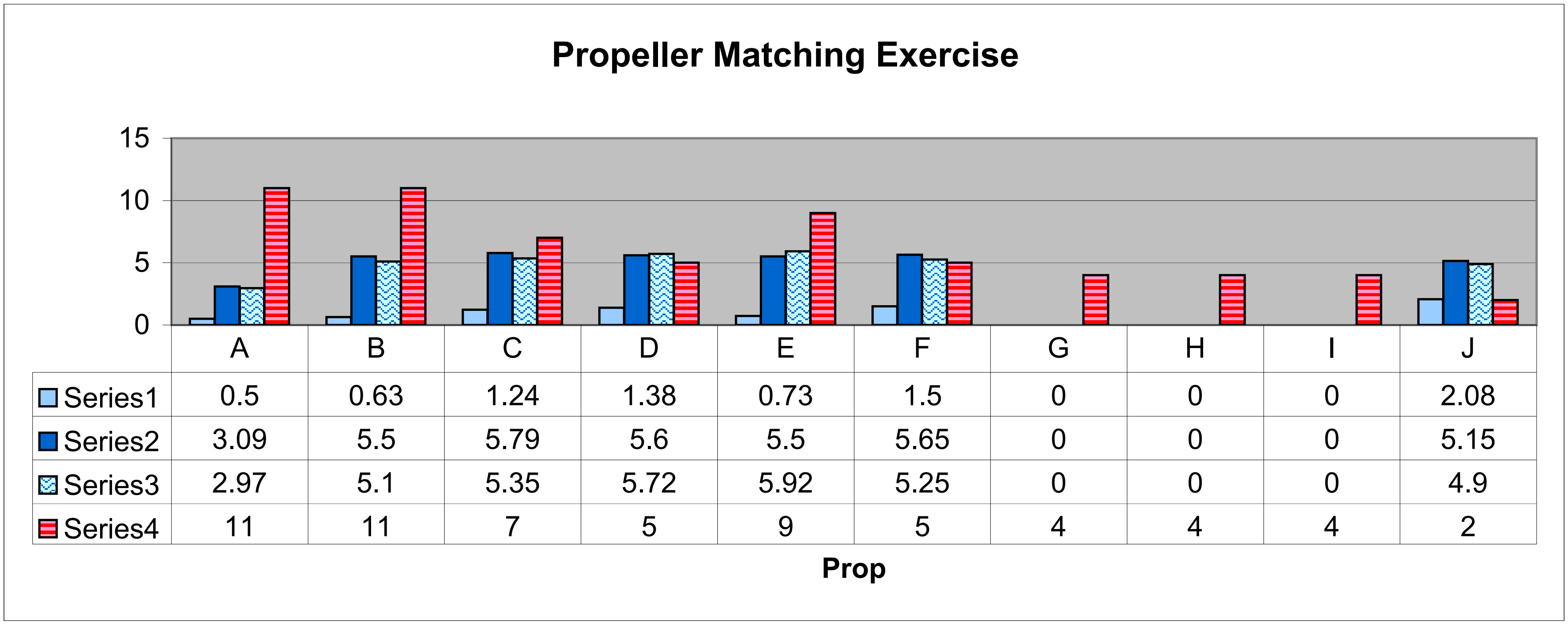
Appendix A



12 V DC Battery
-
+
Monitor
1 amp fuse
Terminal Strip
Common
Junction Box
Main Fuse 25 amps
Fuse Block*
Button not used
FWD
LFT
RT
RV
Side View
Joystick
Front View
UP
DOWN
R/1
R/2
R/3
R/4
R/5
R/6
R/7
SPARE
Relay Pack
ROV Representation
Camera
R/1 = Forward
R/2 = Forward
R/3 = Reverse
R/4 = Right Turn (Left Bilge)
R/5 = Spare
R/6 = Spare
(Up & Down motors don't use relays)
R/7 = Left Turn (Right Bilge)
* = all fuses 5 amps
= + (positive)
= - (negative)
= fuse
= propeller
= bilge pump
Drawn by:
Ryan Garner
~NOT to scale~
Dagmar Electrical Schematic

Appendix B

Amps Drawn	A	B	C	D	E	F	G	H	I	J	
Stopped in Air	0.5	0.63	1.24	1.38	0.73	1.5	No Test	No Test	No Test	2.08	Series 1
Stopped in Water	3.09	5.5	5.79	5.6	5.5	5.65	No Test	No Test	No Test	5.15	Series 2
Moving in Water	2.97	5.1	5.35	5.72	5.92	5.25	No Test	No Test	No Test	4.9	Series 3
Newtons of Pull	11	11	7	5	9	5	4	4	4	2	Series 4



Cabrillo High School Aquarium ROV Team
Budget and Expense Statement

Item	Qty	Amount	Expense	Donation	Used For	Donation	See Key
Aquaview Underwater Camera (original cost $299)	1	$0.00	$0.00		Camera		ROV
6"x12"x6" fiberglass box	1	$80.00		$80.00	Electrical	(1)	ROV
Atari 2600 joystick	1	$9.95		$9.95	Electrical	(2)	ROV
1/2" Strain Reliefs	6	$4.00		$24.00	Electrical	(1)	ROV
3/4" Strain Relief	1	$6.00		$6.00	Electrical	(1)	ROV
4"x4" junction box	3	$5.00		$15.00	Electrical	(1)	ROV
4"x4" junction box cover	3	$3.00		$9.00	Electrical	(1)	ROV
spst relays	12	$6.00		$72.00	Electrical	(1)	ROV
terminal block	3	$4.00		$12.00	Electrical	(1)	ROV
Cat5 cable (5 60 ft runs)	300	$0.14		$40.50	Electrical	(1)	ROV
fuse block/6 space	2	$10.00		$20.00	Electrical	(2)	ROV
fuses (7 5 amp, 1 3 amp, 1 25 amp)	1	$4.50	$4.50		Electrical		ROV
3/4x3/4x3/4 condollette	1	$5.50	$5.50		Electrical		ROV
momentary switches	2	$4.00	$8.00		Electrical		ROV
1/2" LB PVC	1	$3.00	$3.00		Electrical		ROV
3/4" Class 200 Pipe (10 ft)	1	$4.00		$4.00	Frame	(3)	ROV
6 lbs galvanized steel washers for ballast	6	$1.00		$6.00	Frame	(3)	ROV
3/4" PVC T's	18	$0.79	$14.22		Frame		ROV
3/4" PVC 45's	10	$0.59	$5.90		Frame		ROV
3/4" 90's	6	$0.35	$2.10		Frame		ROV
3/4" to 1/2" reducers	4	$0.49	$1.96		Frame		ROV
2x2x1/2" T	4	$1.79	$7.16		Frame		ROV
2x2x1 T	1	$1.90	$1.90		Frame		ROV
3" ABS pipe (4 ft)	1	$4.00	$4.00		Frame		ROV
2"x2" 90 degree fittings	4	$0.80	$3.20		Frame		ROV
2" class 200 pipe (8 ft)	8	$0.50	$4.00		Frame		ROV
stainless steel screws #8x1/2" (100/box)	1	$6.00	$6.00		Frame		ROV
1/2 inch stainless steel set screws	12	$0.25	$3.00		Frame		ROV
5/16 stainless steel bolts w/wingnut	4	$0.75	$3.00		Frame		ROV
Velcro Pads (misc set)	1	$6.00		$6.00	Misc ROV Parts	(2)	ROV
Caution Tape for Thrusters (1 roll)	1	$11.00		$11.00	Misc ROV Parts	(2)	ROV
Velcro Ties	3	$2.89		$8.67	Misc ROV Parts	(2)	ROV
wire ties (asst)	1	$10.00	$10.00		Misc ROV Parts		ROV
toilet bowl wax rings	2	$1.50	$3.00		Misc ROV Parts		ROV
silicone gel	4	$5.00	$20.00		Misc ROV Parts		ROV
pvc glue	1	$2.00	$2.00		Misc ROV Parts		ROV
1 1/2"x3" ABS reducer (thruster guards)	4	$5.49	$21.96		Propulsion		ROV
Atwood 750 bilge pumps	3	$18.00		$54.00	Propulsion	(2)	ROV
3 bladed props (from personal fans)	4	$0.99		$3.96	Propulsion	(2)	ROV
1/2" closed cell foam (10 ft)	10	$0.50		$5.00	Tether/Floatation	(2)	ROV

Key:
ROV = Parts used to build ROV
S = Spares for Repairs
MU = Mock Ups for Practice
ENG = Engineering/Comm. Supplies
TR = Travel Expenses
MSC = Miscellaneous Expenses

Donations:	
(1) CA Electric	$492
(2) Robert & Shirley	$515
(3) R Lompoc ACE	$10
(4) Sue Schuyler	$190
(5) MATE	$2,044
(6) WESTCO	$500
(7) Weber Electric	$200
(8) Jim Ludwig	$100
(9) UCSB	To Be Determined

Cabrillo High School Aquarium ROV Team
Budget and Expense Statement

Item	Qty	Amount	Expense	Donation	Used For	Donation	See Key
1/2" Strain Reliefs	4	$4.00		$16.00	Electrical	(1)	S
550 Mayfair bilge pump cartridges	4	$15.00		$60.00	Electrical	(2)	S
Atari 2600 joystick	2	$9.95		$19.90	Electrical	(2)	S
extra set of relays (spst)	12	$6.00		$72.00	Electrical	(1)	S
motors - complete atwoods 550 set	3	$10.00		$30.00	Electrical	(2)	S
1/2 inch stainless steel set screws	12	$0.25	$3.00		Frame		S
toilet bowl wax rings	1	$1.50		$1.50	Misc ROV Parts	(2)	S
thruster guards- machined	4	$5.49	$21.96		Misc ROV Parts		S
props - 4 each	4	$0.99		$3.96	spares	(2)	S
1000 ft of CAT 5	1000	$0.14		$135.00	spares	(1)	S
Milk Crates	3	$0.00		$0.00	Mock-Ups	(2)	MU
18"x18"x1/4" plexiglass (2 ft.)	2	$6.00		$12.00	Mock-Ups	(2)	MU
1 1/2" PVC coupling	1	$5.00		$5.00	Mock-Ups	(2)	MU
small trash can (recycled from last year)	1	$0.00		$0.00	Mock-Ups	(2)	MU
20 ft. of 3/4" schedule 40 PVC gray	1	$10.00		$10.00	Mock-Ups	(1)	MU
1/2" ball valve	1	$5.50	$5.50		Mock-Ups		MU
18 guage speaker wire (50 ft)	2	$2.99	$5.98		Mock-Ups		MU
3/4" T's	8	$0.79	$6.32		Mock-Ups		MU
90's	6	$0.35	$2.10		Mock-Ups		MU
Digital Timer	1	$6.42		$6.42	Time Trials	(2)	MU
colored paper	1	$2.50		$2.50	Presentation Board	(2)	ENG
picture flip chart (recycled from last year)	1	$0.00		$0.00	Presentation Board	(2)	ENG
Report Cover	1	$2.38		$2.38	Technical Paper	(2)	ENG
presentation board (regionals & ntnl)	2	$12.99		$25.98	Presentation Board	(2)	ENG
Regional Travel (2 Adults, 3 Students)							TR
School District Van (Lompoc to Monterey & Back)	1		$246.00				TR
Housing (2 Hotel Rooms)	1			$181.00			TR
National Travel (3 Adults, 4 Students)							TR
Air Fare (Santa Barbara to Houston and Back)	1	$2,795.10	$795.10	$2,000.00	Aquarium	(5) (6)	TR
Rental Van - Houston (7 passenger)	1	$262.48	$262.48		$1,435.98		TR
Hotel Room (MATE paying for 1 room)	1	$363.40	$363.40	$363.40	Donations	(5)	TR
Food (Dinners for 3 nights)	21	$15.00	$15.00	$300.00	$2,663.40	(7) (8)	TR
CHS Aquarium Shirts	3	$1.50		$4.50		(2)	MSC
CHS Aquarium Jackets				$202.00		(2)	MSC
CHS Hats	19	$10.00		$190.00		(4)	MSC
Graph Paper	1	$0.50		$0.50		(2)	MSC
Project Binders	8	$2.50		$20.00		(2)	MSC
Total			**$1,861.24**	**$4,051.12**			
Total Cost of 2005 ROV Experience:			**$5,912.36**				

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