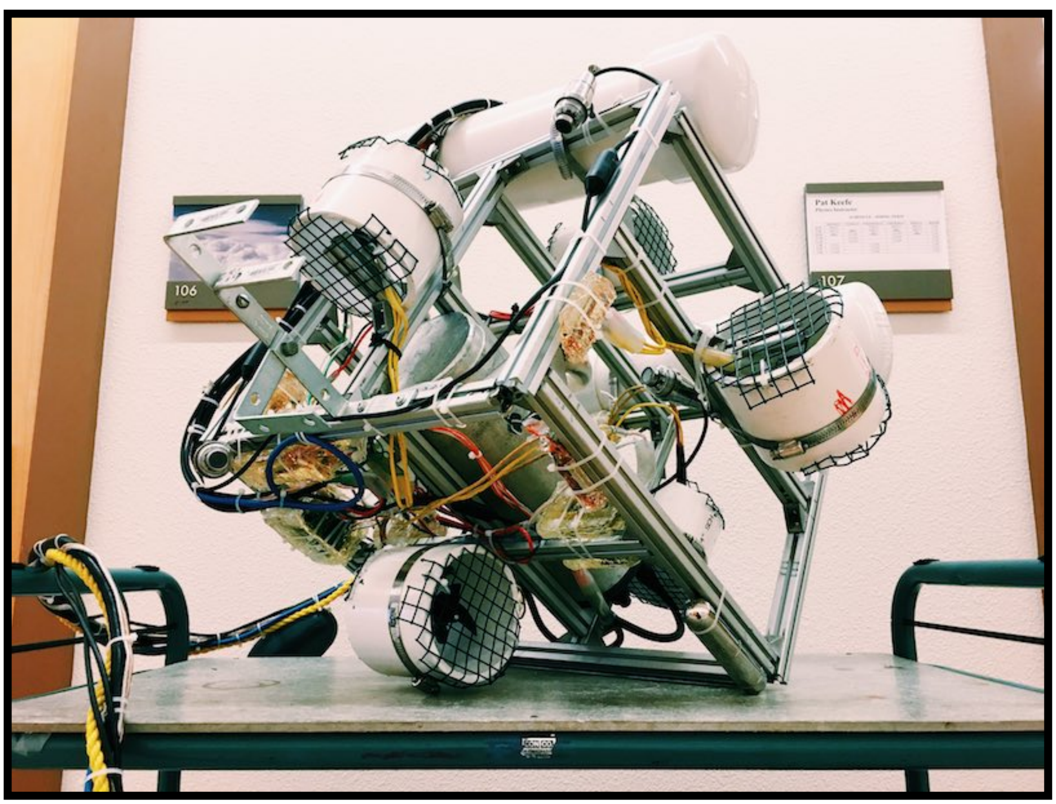
SQUAD

CLATSOP COMMUNITY COLLEGE ROV TEAM

TECHNICAL MEMORANDUM

NAME	POSITION	EDUCATION GOALS
Georges Oates Larsen	*CEO, CTO: Electrical, Software, and Design*	*Theoretical Mathematics*
Darby J. Cullen	*Co-Pilot, Vice President of Research & Design, Secretary*	*Mechanical Engineer*
Sam Daire	*Vice President of Manufacturing*	*Undeclared Engineer*
L Goyena	*Vice President of Publicity, Vice President of Damage Prevention*	*Pharmacist*
Kyle Leahey	*Manufacturing Technician*	*Undeclared Engineer*
Dylan Simmons	*Manufacturing Technician*	*Architectural Engineer*
Nick Porter	*Electrical Technician*	*Electrical Engineer*
Chris Patenaude	*Research and Development Intern*	*Software Engineer*
Chris Anguiano	*Research and Development Intern*	*Mechanical Engineer*
Tanner Robinson	*Research and Development Intern*	*Mechanical Engineer*
Elijah Hirsch	*Research and Development Intern*	*Mechanical Engineer*
Pat Keefe	*Team Mentor*	



Magnificus “Maggie” Praesegmen

ASTORIA, OREGON, USA.

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ABSTRACT

The following is a technical memorandum produced by SQUAD (Specialized tasQ-force for Underwater Advanced Development) detailing the design, budgeting, manufacturing, and specifications of Magnificus Praesegmen (Latin: Magnificent Scrap, "Maggie" for short), SQUAD's latest remote operations product. Of particular importance are the unique and effective design decisions made by SQUAD, including Maggie's six-thruster cubical arrangement, and her remarkably frugal construction.

The following sections overview Maggie's general design rationale, covering the important details, safety features/procedures, and possible improvements to/of each aspect of Maggie's design. Then, a variety of key schematics explaining Maggie's general operation are provided. The sections thereafter cover SQUAD's budget, expenses, project management, and approaches to problem solving. Next, some of the challenges that SQUAD has had to overcome are detailed, and reflections from each of the current employees are provided. To conclude, a list of references related to the project is given.

DESIGN RATIONALE

At its core, our system is designed with two ideals in mind: flexibility, frugality, and efficacy. Every aspect of our design has been carefully considered to maximize flexibility while minimizing costs without sacrificing quality. We are not afraid to think outside the box (or in this particular case *inside* the box) to achieve effective results. The entirety of our design is based around a unique six-thruster arrangement that offers all six possible kinetic degrees of freedom, (full control over net torque and force in all axes), a level of maneuverability well beyond those achieved by more standard thruster arrangements. That is, Maggie can tilt, rotate, and move however she wants in the water, giving her more maneuverability than a standard helicopter, or quad-copter.

MECHANICAL

The entirety of Maggie's design is based around this idea six-thruster idea. To achieve this, we essentially have three pairs of thrusters arranged in a cubically symmetrical fashion—each pair of motors can apply torque and force along a particular axes. Altogether, this gives us three axes of torque, as well as three axes of force.

SAFETY:
All thrusters are encased in plastic coated wire mesh to prevent foreign objects from interacting with the propellers. This serves both to protect the ROV, and anyone near it. (See figure 2).

THRUSTERS/PROPELLERS

We chose to use brushless motors (see figure 1) for our thrusters for their clear superiority to all other motors for this purpose. When compared to bilge-pump motors, the only other kind of motor even remotely applicable as thrusters; brushless motors operate at higher RPMs making these far more efficient, and when given the correct propellers they produce far larger amounts of thrust in the water. We carefully selected a variety of brushless motors roughly within our power specifications based on their no-load RPM and max-current at 12V, selecting those best equipped for thrust production. We purchased a variety of propellers, and chose the one that offered the highest thrust possible without compromising our power system. We had, for instance, the option to select a propeller that could supply up to 19N per thruster, but this would have added around $250 in costs to our power distribution system, and would have complicated our power system unnecessarily, so we opted to go with a set of propellers that resulted in 15N per thruster instead.

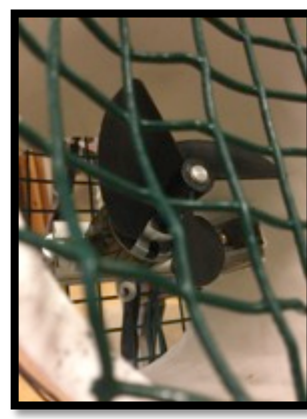


Figure 1

Figure 2

ELECTRICAL

POWER DISTRIBUTION

48V from the surface is routed directly down our tether into four 36A maximum high-efficiency 48VDC->12VDC switching regulators. Each converter is dedicated to a particular subsystem of the ROV – Three of them provide power in pairs for our thrusters. Power from the fourth is split amongst the cameras, main electronics control tube, main Ethernet switch, manipulators, and external sensors.

At the surface is a specialized solid-state on-off switch, which utilizes a high power, low R_DSon N-Channel MOSFET for main power switching, with the gate connected through a manual toggle switch and high impedance resistor to V_in, and with gate and source interrupting ground. This circuit functions not only as a highly efficient on-off switch, with almost no internal voltage drop, but also as a reverse-voltage protection circuit—the switch, due to how it operates, will not turn on if power is plugged in backwards – a feature that was deemed important after we suffered a system-wide regulator failure due to a miscommunication about the polarity of our battery connections.

SAFETY:
All power is routed through a 40A fuse, as well as a FET-based non-mechanical switch / reverse voltage protection circuit.

SAFETY:
All power received by the ROV is converted to 12V by high efficiency DC48V-DC12V switching regulators. These regulators can take an input voltage range from 36V to 78V, have output-short-circuit detection, overheat shutdowns, built-in under-voltage protection, and a variety of other power safety features. These features work together to automatically shut down the ROV and protect its subsystems in the event of dangerous power situations.

CENTRAL CONTROL

Our main electronics tube is equipped with a 0.9GHz Raspberry Pi 2, Arduino Mega 2560, Inertial Measurement Unit (IMU), a PWM signal generator, as well as a variety of data/power support electronics (see figure 3).

The Raspberry Pi functions as Maggie's central processor, handling all incoming control data, and directing the rest of her electronics—both inside the control tube, and out.

Figure 3

The Arduino Mega 2560 is reserved for timing-sensitive signal generation, such as control signals for stepper motors, and is an i^2c slave to the Raspberry Pi.

SAFETY:
The control tube IMU features a barometric pressure sensor, allowing early detection of leakage into the control tube.

The PWM signal generator is also an i^2c slave to the Raspberry Pi, and controlled directly by the Pi to generate the PWM signals required by the electronic speed controllers driving our thrusters.

The Inertial Measurement Unit contains a variety of sensors, including temperature and pressure sensors for internal status monitoring, as well as a 3-axis magnetometer, 3-axis accelerometer, and 3-axis gyroscope, for use by Maggie for automatic piloting.

STATUS INDICATOR

The ROV is equipped with 12LED RGB status indicator that allows the control tube to, via I^2C, output a visual signal indicating the status of its subsystems in the event of a communications failure. This indicator has its own microprocessor that allows it to perform limited status updates autonomously, without even having a connection to the control tube. This feature is used, for instance, to display a timer showing how close the central electronics hub should be to establishing Ethernet communications, and to booting up. If this timer reaches zero, and contact still cannot be made with the tube, this indicates a communication error. Similarly, if this timer reaches zero, and the central processor does not attempt to take control over the status indicator, the status indicator knows there has been a failure with the central processor boot up, and will change its indication accordingly.

SAFETY:
The status indicator has special reprogramming pins that are kept sealed when not in use, to prevent electrical shorting.
The status indicator itself can be considered a safety feature, as it helps pilots to ensure the ROV is working properly and speeds up troubleshooting in the event that it is not.

CAMERAS

Our cameras are all digital IP cameras capable of streaming video data via only a single Ethernet cable to any surface laptop on the ROV's network, after being routed through an underwater Ethernet switch. Each digital camera (see figure 4) runs a Linux kernel and is configured to assign itself a unique IP address on our network. We use MJPEG wherever possible in order to minimize camera latency.

Figure 4

THRUSTERS/PROPELLERS

Each thruster is powered and controlled by its own 30A maximum electronic speed controller (ESC), reprogrammed with a custom build of the ESC firmware known as KKMulticopter for bi-directionality. These ESCs are then powered, in pairs, by three of the previously discussed switching regulators.

SENSORS

External sensors include temperature sensor, a network of six high-sensitivity pressure sensors that allow for extremely accurate depth sensing, and pressure differential sensing, which can be used by the Raspberry Pi for automatic piloting.

PROGRAMMING

The ROV is programmed, using python, in a highly compartmentalized structure, which allows for maximum flexibility. All motors, sensors, etcetera are represented as objects within the data system. The ROV, when powered on, automatically boots a control server, which can be connected to over the Ethernet network. This control server, once activated, awaits control requests from the surface laptop, and establishes communications with all sensors, thrusters, and manipulators. Sensor, and previous thruster output data, is fed into a pseudo-kalman filter to generate a highly accurate internal model of the ROV's current state. This state is used in various kinematic state approach algorithms to generate target output forces and torques that should ring the ROV's state to the state desired by the client sending command data. These target forces and torques are fed through a pre-programmed thrust computation matrix to generate final thruster outputs. Finally, these thrust outputs are throttled to ensure the ROV thrusters stay within proper operating specifications, and do not trigger an emergency shutdown by the DC-DC switching regulators.

SAFETY:
The ROV's central processor, being a Raspberry Pi, runs a variant of Debian Linux, and is thus always fully accessible and reprogrammable via SSH. This means that software problems can be diagnosed and solved on the fly, without having to open up the electronics tube, or take the ROV out of operation. ROV software always ensures PWM outputs are set to zero before exiting, to prevent motors thrusters from going rogue.

TETHER

Tether consists of two conductors for power, plus an Ethernet cable for data and polypropylene rope for security. Floats are distributed along the tether to give it neutral buoyancy.

For future improvement, it would be advantageous to replace our evenly distributed floats with some form of positively buoyant

SAFETY:
Our tether is equipped with a polypropylene rope for safe retrieval of the ROV in the event of a total system failure.

line. This would have the advantage of truly evenly distributing buoyancy along the tether, rather than at a set of key locations, and in turn reducing the impact of our tether on the ROV.

HEADLIGHTS

For future improvement, we would like to incorporate headlights to increase visibility.

STRUCTURAL

FRAME

The arrangement of our frame is based entirely around our six-pair thruster arrangement. We chose to build a 37cm by 35cm by 37cm, cubically symmetrical 80/20 T-slot aluminum extrusion frame designed to support these thrusters, and provide space for all of their associated electronics (see figure 5) because of its redesign flexibility, and from there ended up with our cubical frame design. The entire system fits within a sphere of a diameter of 64cm. All attachments are temporary and easily adjustable, but still robust. All electronics are attached using zip ties and hose-clamps.

SAFETY:
All bolts are hot-glued to prevent vibrations from unscrewing the frame.

For future improvement, we would like to invest in new 80/20 to be machine cut as opposed to being cut with a hacksaw. Doing so will improve the structural alignment of our frame.

Figure 5

Figure 6

BUOYANCY

Though our system is theoretically capable of operating at and maintaining any orientation, we deemed the ability to fully tilt Maggie this way to be useless for piloting, and in all probability, cumbersome. As such, we chose to make the center of buoyancy of the ROV off-center, creating passive, built-in self-righting. Our pseudo-kalman filter, IMU, and differential pressure sensors are still used to ensure correct self-stabilization under temporary and minor tilting still allowed by the off-center buoyancy.

Buoyancy is provided by two 37cm pieces of 4in PVC pipe with 4in PVC end caps (see figure 6).

ELECTRONIC CONTROL HUB

All electronics that need to be easily modifiable are kept inside the electronics housing. All other electronics are epoxied in modular form, distributed around the frame, and soldered into the system.

The internal electronics of the hub are mounted to a hexagonal set of threaded rods protruding from a specially machined end-cap, and secured at the other end with a PVC insert. The threaded-rods are electrically insulated using heat shrink. A breadboard is used, internally, as a dynamic mount and wiring system for small electronics subsystems.

These electronics are then inserted, along with the aforementioned end-cap into a cylindrical aluminum pressure housing (see figure 7) with special machined-smooth inner walls near its top, and holes drilled for locking screws. This end cap has two notch indentations for O-Rings to create a doubled O-Ring seal. Bulkhead-connector pass-throughs are used to allow electronics power and data in and out of the hub. This has the added advantage of meaning the electronics hub can be completely detached from the ROV.

> **SAFETY:**
> All circuits inside the aluminum pressure housing are separated from the housing with HDPE sheets.

Figure 7

ROV CONTROLLER

We use a PS2-like USB controller plugged into a laptop to pilot the ROV.

WATERPROOFING

THRUSTERS

Brushless motors are protected from corrosion with a nail-polish coating on coils, and by replacing all bearing with stainless steel equivalents.

Figure 8

SERVO-MOTORS

The motors are waterproofed (see figure 8) by using a specialized multi-step technique—all motors are first disassembled, then their control electronics are epoxied, and their output shaft/gears filled with marine grease. Next, the motors are reassembled inside of a vat of mineral oil to fill in all remaining air. Once assembled, the motors are carefully removed and dried, and their joints are sealed with superglue. From here, they are dipped, all but the output shaft in liquid rubber. The liquid-rubber is removed around the mounting brackets for the servos, and then a specially sized O-Ring is inserted over the servo, and a servo horn is placed on top of it to hold on the O-Ring in place.

WIRING

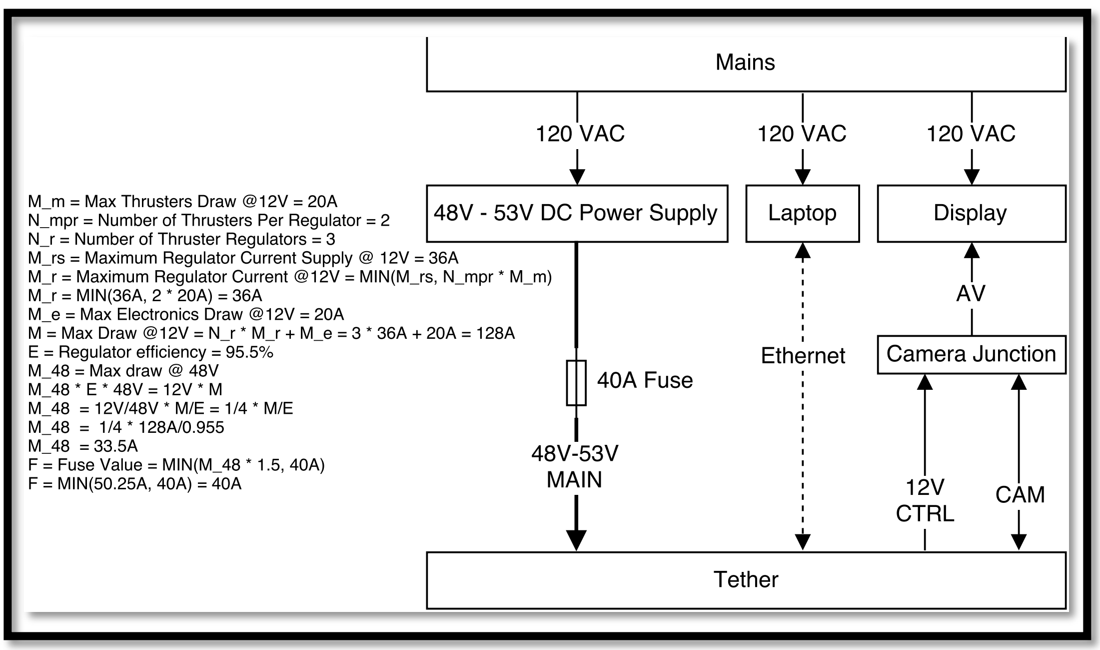
All joints are sealed using hot-glue and a specialized clear 3:1 ratio heat-shrink with built-in adhesive to create seals capable of withstanding ocean depths.

SAFETY:
The materials used for our wiring waterproofing can all be made transparent, removed, or adjusted, using the heat from a heat gun. This allows us to non-destructively inspect our solder joint quality, and make modifications if necessary.

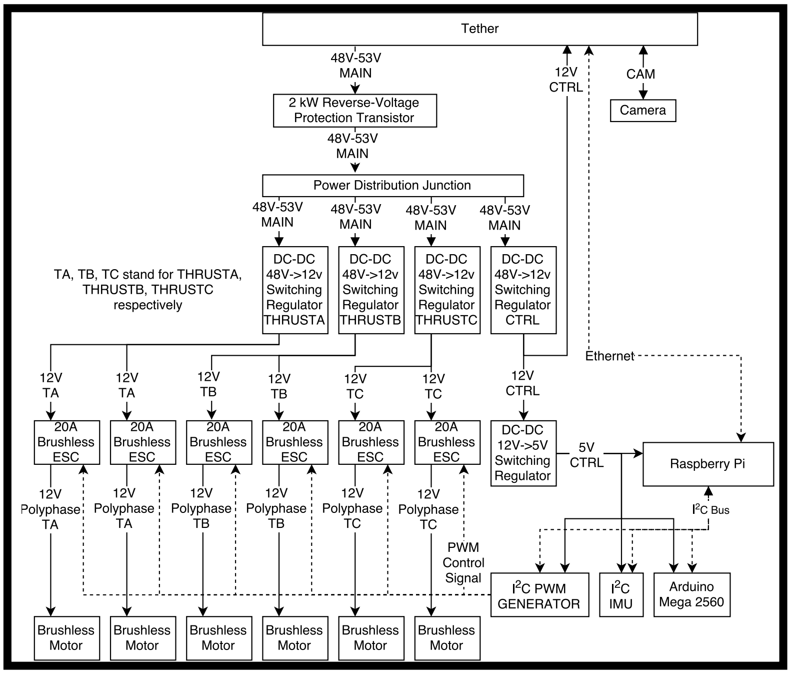
SCHEMATICS

SYSTEM INTERGRATION DIAGRAMS (SID's)

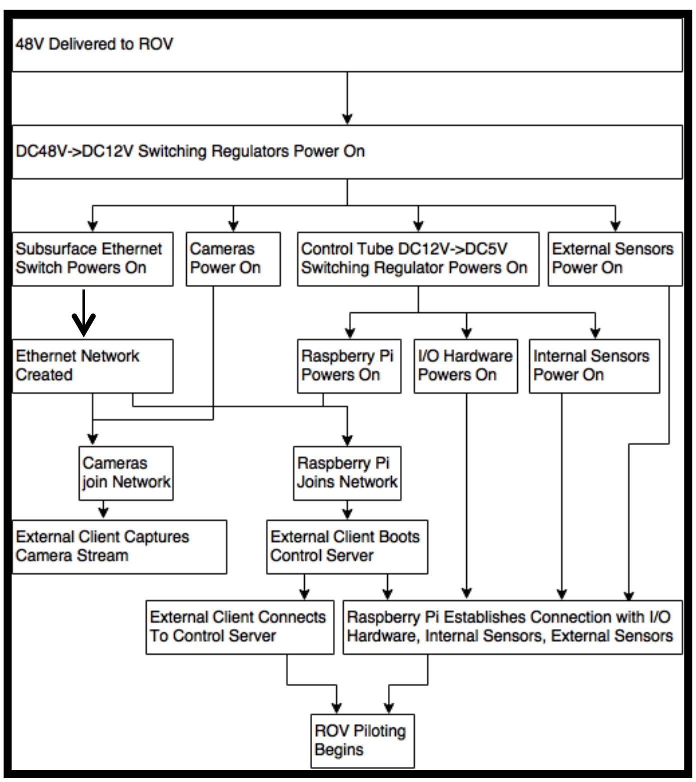
SURFACE SID

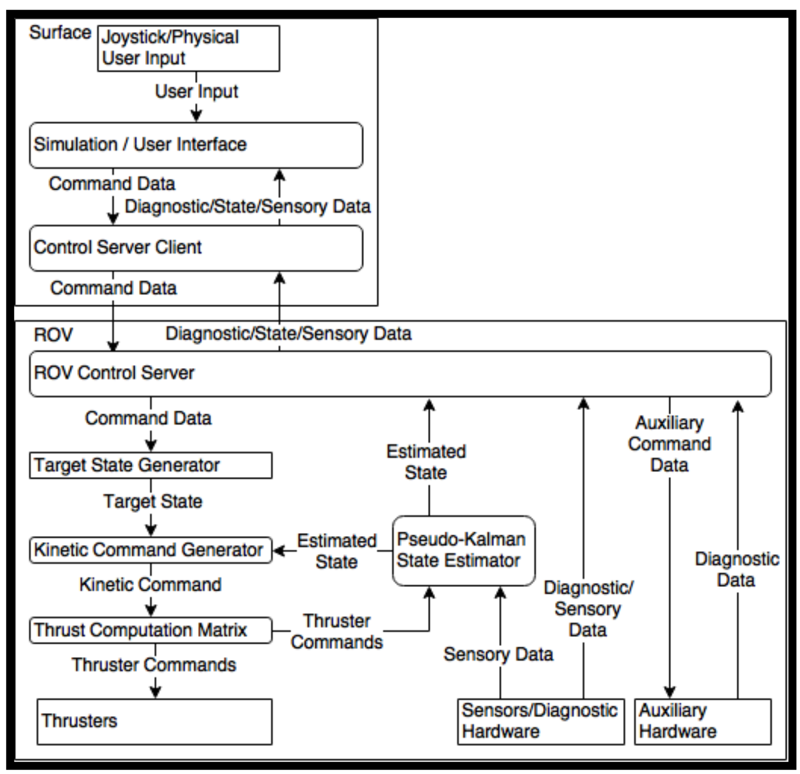


UNDERWATER SID



BOOT UP SEQUENCE DIAGRAM (LEFT) | DATA FLOW DIAGRAM (RIGHT)





BUDGET

BUDGET

FUNDS	VALUE (USD)	GIVEN
Donation from Marine Technology Society	$500.00	2016
Donation from United States Coast Guard	$500.00	2015
Donation from Larsen Family	$200.00	2016
Donation from Salsberry-Charlton Family	$682.00	2016
Donation from Goyena Family	$682.00	2016
Donation from Clatsop Community College Foundation	$500.00	2015
REMAINING FUNDS FROM ROV CLUB	$800.00	2015
Rochester Fund	$847.99	2016
TOTAL	$4,711.99	

EXPENSE SHEET

ITEMS	VALUE (USD)	QUANTITY	Theoretical Cost (USD)	Actual Cost to Company	ORIGIN
80/20 Frame	$53.83	N/A	$53.83	$53.83	Purchased
80/20 Parts	$238.52	N/A	$238.52	$238.52	Purchased
Ethernet Cable	$10.00	N/A	$10.00	$10.00	Purchased
ose-3bld-316 Propellors	$2.49	6	$14.94	$14.94	Purchased
Stainless Steel Bearings	$23.59	N/A	$23.59	$23.59	Purchased
Propellor Adapters	$1.89	6	$11.34	$11.34	Purchased
NTM PropDrive Outrunners	$13.93	6	$83.58	$83.58	Purchased
Hobby King 30A ESC 3A UBEC	$10.00	6	$60.00	$60.00	Purchased
PWM Generator	$14.95	1	$14.95	$14.95	Purchased
IMU	$57.44	1	$57.44	$57.44	Purchased
Raspberry Pi	$35.00	1	$35.00	$35.00	Purchased
Arduino Mega 2560	$45.95	1	$45.95	$0.00	Pre-Owned
Jumper Cables	$28.79	N/A	$28.79	$28.79	Purchased
PVC	$20.00	N/A	$20.00	$0.00	Donated
Wires	$30.00	N/A	$30.00	$0.00	Pre-Owned
Aluminum Pressure Housing & Insert	$100.00	1	$100.00	$0.00	Donated
Nail Polish	$10.00	1	$10.00	$10.00	Purchased
Digital IP Camera	$40.00	4	$160.00	$160.00	Purchased
Cable Connector O-Rings	$0.29	40	$11.76	$11.76	Purchased
Servo Motor O-Rings	$0.25	10	$2.50	$2.50	Purchased
RJ45 Plug	$0.25	5	$1.25	$1.25	Purchased
Zip Ties	$30.00	N/A	$30.00	$30.00	Purchased
Hose Clamps	$52.20	N/A	$52.20	$15.00	Purchased & Pre-Owned
Mini Wires	$20.00	N/A	$20.00	$20.00	Purchased
Cable Connectors	$10.00	7	$70.00	$0.00	Donated
Servo Motors	$18.00	4	$72.00	$76.99	Purchased
RGB LED Ring	$10.00	1	$10.00	$10	Purchased
Adafruit Trinket	$10.00	1	$10.00	$10	Purchased
Clear 3:1 Ratio Heat Shink	$126.16	N/A	$126	$126	Purchased
Power MOSFET	$22.00	1	$22.00	$22	Purchased
Power Heatsink	$4.52	1	$5	$5	Purchased
Zener Diodes	$0.08	25	$2.05	$2.05	Purchased
Pressure Sensors	$7.83	6	$46.98	$46.98	Purchased
I^2C ADC	$3.11	6	$18.66	$18.66	Purchased
Pressure Sensitive Epoxy	$50.00	N/A	$50	$50	Purchased
Acrylic	$50.00	N/A	$50	$50	Purchased
2016 MATE ROV COMP. Registration Fee	$250.00	N/A	$250.00	$250.00	Purchased
TOTAL	*$1,401.08*		*$1,598.01*	*$1,549.69*	

TRAVEL EXPENSES	COST (USD)	Quantity	TOTAL
UNITED Plane Tickets	$442.00	5	$2,210.00
Marrott Hotel	$190.46	5	$952.30
TOTAL	$632.46		$4,711.99
MINUS DONATIONS			*$4,711.99*
GRAND TOTAL (USD)			**$0.00**

PROJECT MANAGEMENT

Our company hails from a small community college with little funding and few able or willing to participate in its robotics team. As a result, our company's leadership style has been focused on enabling a small number of very talented individuals to get as much accomplished as possible, rather than limit the potential of its employees through an overly structured command chain, that would frankly have been impossible considering the size of our group. At any given point, our company has consisted of between three and five individuals doing their best to make Maggie a reality. Our CEO, Georges Oates Larsen, has led the company for three years, serving as a taskmaster, and lead of overall design. He is responsible for the key overall design elements that make Maggie, along with her annual prototypal precursors, what they are.

Georges' mission, as CEO, has been to guide and maximize the efficacy the remainder of our company's employees. He has assigned tasks, roles, and positions dynamically, based on the skills, predispositions, and interests of our employees. Each assignment made initiates a step towards Maggie’s completion, and these assignments are made to make the most out of the resources and skills of our company's employees. As each employee completes the tasks given to him or her this informs the decision on what tasks to assign next. Individuals who do well with specific instructions and highly technical procedures are given tasks of such nature. Individuals who demonstrate a knack for leadership, and who do well with less specific instruction, are given broader projects that require more planning. From there, such individuals are given the authority to make requests of the remainder of the group.

Such a command style may seem haphazard at best, but works very well for small groups such as ours. Were we to insist that our employees have specific roles, and that they stay within these boundaries, we would not get anything done. We capitalize on the skills of our employees, rather than force our employees into a box. This is why our CEO handles all electrical design. This is why our damage prevention officer is our VP of publicity. Our management rationale is very similar to out design rationale: we take full advantage of the skills our employees have to offer, and focus more on efficacy, than on traditional structures and hierarchies.

TROUBLESHOOTING TECHNIQUES

As problems came up we as a team carried out a process that got us through every thing. For our process we simply followed these troubleshooting techniques:

1. Recognize the problem
2. Background Research
3. Brainstormed solutions
4. Agreed on the best solution for our situation
5. Built a prototype—if necessary

6. Test and redesign—if necessary

CHALLENGES

WATERPROOFING THE CENTRAL ELECTRONIC SYSTEM

Waterproofing the central electronics system was quite a challenge. We've had the option to simply pot all of our electronics with epoxy, but the problem is that this leaves our electronics inaccessible, and impossible to reconfigure (see figure 9). At the same time, there was no way we were going to fit the entirety of our electronics in a single resealable box. Eventually, we realized that the vast majority of our electronics—motor control, power distribution, and signal distribution—are fundamentally modular, and do not need to be reconfigured except as whole units. Taking advantage of this, we were able to pot and move all of these subsystems directly into the water, leaving only the relatively much more compact central control and internal sensory subsystems. We were able to fit these subsystems inside a resealable double-gasket pressure housing with special, detachable bulkhead connectors, meaning that not only are our central electronics removable and reconfigurable, but the entire pressure housing itself can be removed.

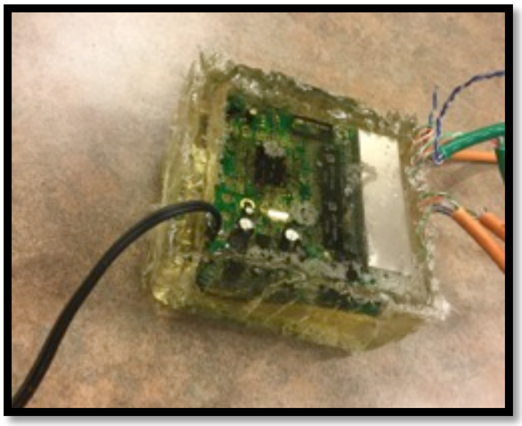


Figure 9

SYSTEM WIDE SUDDEN SHUT DOWN

Upon the completion of our basic platform (frame, motors, basic control system), we experienced some very concerning issues with our main power system. In essence, we found that while the ROV would operate completely normally on land, once submerged, it would, at random, completely shut down. Determining the source of this issue was quite a challenge—at first, it appeared simply that the current draw from our motors was creating a fatal voltage drop in the power supplied to our main switching regulators, resulting in these regulators shutting down. However, after taking several extreme measures to reduce the voltage drop in our batteries, and across our tether, we determined that this could not possibly be the issue. Eventually, we discovered a correlation with sudden-direction-switch in our thrusters, and were able to write a program for the thrusters capable of triggering the shutdown even on land. This has allowed us to determine that switching the motor directions too rapidly creates a transient current spike in motor current draw. Our switching regulators can sense this draw, and trigger an (unneeded) safety shutdown to protect their subsystems. Throttling the motor direction shifts easily solved this issue.

THRUSTER SYSTEM OVERHAUL

Our current design was born out of a major challenge overcome the previous year. Until early this year, we were still using a much less powerful variant of motor known as bilge-pump motors. These motors, being, essentially, pressure-housed brushed motors, required completely different control electronics. We spent several months designing optocoupled H-bridge control circuits for them, only to find out, in later testing, that the motors had completely different operational specifications than their labeling had lead us to believe. As a result, all of the electronics, which we had just perfected, were rendered useless. We were forced to return, essentially, to the very start of our design process, and pick a new type of motor capable of serving our needs. Eventually, we discovered brushless motors, which turned out to not only have less expensive, pre-designed control electronics than the boards we were producing ourselves for our bilge pump motors, but were also capable of much higher thrusts at much higher power efficiencies. Of course, these motors, relying on tri-phase AC, as opposed to DC, had much more complicated control electronics demands. Over the next few months, we were forced to completely redesign our electronics systems to accommodate them, including the addition of a PWM signal generator to our central control tube, and the acquisition of an AVR serial programming tool for re-flashing the required ESCs with a custom, multidirectional variant of the ESC firmware known as KKMulticopter. Every step of this process was filled with unexpected delays, and we were forced to develop the system without any kind of comprehensive guidance, but our system is now far superior for it.

CONTROL TUBE UNDER VOLTAGE FAILURES

Midway through the switch to brushless motors, we began experiencing power problems with our central electronics hub. Its subsystems began shutting down at random, and/or refusing to turn on at all. We were quickly able to determine that the problem had to do with the 12VDC->5VDC switching regulator powering the tube—but the problem was quite mysterious. Where the regulator would operate perfectly fine under some load conditions, for instance, only powering an Arduino, other load conditions, such as powering a Raspberry Pi, would cause it to begin exhibiting strange oscillations, and to output sub-par net voltages. We suspected that we had simply somehow damaged the regulator, and so we replaced it, and the problem went away. However, within a few weeks, the problem would return as though no repair had been made. To make matters worse, the problem would mysteriously fix itself at random, and was not consistently reproducible, leading to several false solutions seeming successful. Eventually, we noticed a correlation between the failures, and a special brownout state caused by our motors switching directions while connected our test power supplies. Essentially, the motors would switch directions, creating a transient current spike that caused the 10A-max power supply we were using for testing to drastically lower its voltage. This would send the entire electronics tube into a browned-out state, causing random shutdowns. After a great deal of research, we discovered that brown-outs like these, or any kind of insufficient voltage to insufficiently advanced switching regulators is enough to damage them, and so these brown-outs became our immediate suspicion. Eventually, we were able to create a simple under-voltage protection circuit, using a special resistor-diode-op-amp network to activate a FET only when the voltage being supplied to the tube had surpassed the minimum operating voltage for the switching regulator. Since implementing this circuit, we have had no more failures. As for the power cutouts, these were resolved when ceased using our low-amperage test-supplies and switched to batteries and switching regulators.

UNDERWATER ETHERNET SWITCH

One major challenge we had to overcome, with the shift from AV cameras to digital IP-cameras, was the implementation of an underwater Ethernet switch, so that all of our cameras could be routed through a single Ethernet cable to the surface. The primary challenge in this was waterproofing the Ethernet switch—potting it with epoxy was out of the question, or so we thought, because this could create massive air pockets in the circuit that might collapse under pressure, and the epoxy stood a high chance of getting between the contacts in the RJ45 jacks, essentially breaking our connections the minute the epoxy finished. To add to all of the trouble, these switches, being very large, would have a tendency to crack their epoxy during solidification. At the same time, we did not have enough room inside our electronics housing to place an Ethernet switch, and to place one inside an identical housing would be incredibly bulky, and add complications to our production schedule. Eventually, we had two key realizations: one, we could remove the outer-casing on our switch, and just epoxy the board directly. Two, we did not need to use the RJ45 jacks, but could instead solder twisted pair onto the board pads directly. One third realization also came in handy: Being that the switch was only capable of 100Mbps communications, half of the twisted pairs available in the RJ45 jacks were going completely unused, meaning we could cut our solder joints in half. Finally, the cracking of epoxy could be combatted by doing the epoxy job in two stages—with all of these modifications, we were able to successfully epoxy an entire Ethernet switch without compromising its operability.

LESSONS LEARNED

The past several months have forced our team to grow in ways we could not have predicted, both on a technical, and an interpersonal level. Every aspect of our design is a testament to experiences we have gained, and the challenges we have overcome. We had no instruction manual when we put Maggie together. It wasn't as simple for us as, for instance, searching on the Internet for an underwater thruster. We had to do our research, looking at competing designs to see some of the solutions that have worked, and attempting to make as educated a conclusion as possible on what would work best for us. And when it came time to actually select a solution, we didn't have the luxury of simply buying a pre-made solution. We had to order the motors, propellers, electronic speed controllers, shaft adapters, nail polish, stainless steel bearings, and signal generators required to make an underwater thruster. Finding out that we needed these parts was a challenge in and of itself -- We had to learn to ask ourselves questions like: "Even though brushless motors theoretically work in water, what actually happens when we put them in a corrosive environment?" -- leading to discoveries such as the stainless steel bearing replacements and coil nail polish. This example, though quite specific, serves to illustrate the general dynamic of the entirety of Maggie's design, through which this process of unguided research and self-direction has been constant.

This is where we, as a team, have truly been forced to grow. A self-directed project such as this simply cannot succeed unless its contributors truly dedicate themselves to that success; there are too many unknowns, too many possibilities, and no instructions whatsoever on where and how to proceed. Maggie required us to consider and create our own path to success, and to commit to this path ourselves. We had no instructor or boss telling us what to do. If we wanted instruction, we had to issue it on our own, sometimes to ourselves, and sometimes to each other. We had to learn to create these plans, to make these commitments, to tolerate and understand one-another's needs, skills, and weaknesses, and we had to do all of this together, not as individuals, but as a team. When we first started this project, it was merely our president calling all of the shots, but now, we work as an integral whole towards the success of our project. It is our ability to operate as a team, if anything, rather than Maggie's ability to operate as an ROV, of which we are truly proud. Without this, Maggie would not even exist.

REFLECTIONS

"Working on this ROV for the past three years has been a huge learning opportunity for me, not only head of design, but as the leader of the company. Almost everything I know in electronics, I learned because of this project, and to make sure this project succeeds; I have had to grow immensely as a leader. When I first joined, I insisted on doing all of the work myself, was terrible with time management, and honestly had no idea what I was doing. Now, I am much different. I have mastered electronics in ways I had not thought possible, and learned to truly successfully plan and manage a project like Maggie. Most importantly, however, I have learned to truly lead—to work with my teammates, find their skills, and give them the tools necessary to do work themselves, so that in all the areas in which I still have yet to grow, they can flourish and make the team strong as a whole. I am pleased, this year, to be a part of the single most effective team of four I have ever encountered in my time as CEO. I know I can trust these individuals with the future of Maggie, especially in the areas where my skills are at their weakest. I would like to thank them for their dedication, as well as our mentor, Pat Keefe, who has, with remarkable patience, been the one driving forward and facilitating my growth as a student, leader, and individual over the past three years."

—Georges Oates Larsen, CEO

"I was intimidated by the thought of joining a robotics club because I was not knowledgeable in that field. However, Georges, CEO, approached me with the invitation to be in the club earlier this year.

Shortly after, I was invited to attend the 2016 MATE International Competition. That being said, I found that by being a part of the CCC ROV Team led me down a path that I never thought about going down simply because I never knew I would be interested in robotics. I feel that I have obtained a whole new set of skills that I can use for the rest of my life, such as leadership, secretary skills, and a broader set of mechanically inclined skills. I cannot be more thankful for my team and mentor for their dedication and passion for Maggie. I have learned so much from each and every person I have crossed paths with throughout this journey, and I cannot be more grateful."

—Darby Cullen, VP of Research and Design

"I've learned a lot with the ROV Team, electrical assembly, manufacture, even teamwork and social skills. I'm incredibly grateful for the chance to work with such a wonderful group of like minds, and for the unique opportunity of the MATE competition. These skills and experiences will serve me well along the paths I intend to take."

—Sam Daire, VP of Manufacturing

"The time I have spent with the ROV team has been short compared to the countless hours my teammates have dedicated towards this collaborative effort. It is wonderful to be a part of a team that consists of not only hardworking fellow students, but who also happen to be my very close friends. I admire watching each and every one of the members get in the zone and "geek out" during our weekly meetings. Immersing myself in this driven atmosphere of big-dreamers has changed my entire college experience for the better, and I am thankful for the life-long friendships that I have developed."

—L Goyena, VP of Publicity

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