2024 Technical Document

Desert Star Robotics

Estrella Mountain Community College
Avondale, AZ, United States

Mentored by Jeff Miller

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Brennan Mai(CTO)
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Electrical Team
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Andrue Anaya
Steven Dotts(CEO)

Marketing/Outreach Team
Shayla Lee(Marketing/Outreach Manager)
Andrue Anaya

Software Team
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Abstract

Once known as the “Ambitious Axolotls,” Estrella Mountain Community College’s MATE ROV team this competition season strives to build a new underwater vehicle. Placing 4th in the MATE ROV World Championship last year, the team learned from our experience last year and aims to overcome the challenges from last year while rebranding ourselves “Desert Star Robotics.”

The new vehicle designed this year, named “Nomad,” is equipped to handle marine cable management, aiding in ecosystem restoration, and transporting key oceanic observation tools. Boasting an improved frame composed of high-density polyethylene, pneumatic claw, and an updated control system, Nomad is set to accomplish the tasks presented by MATE.

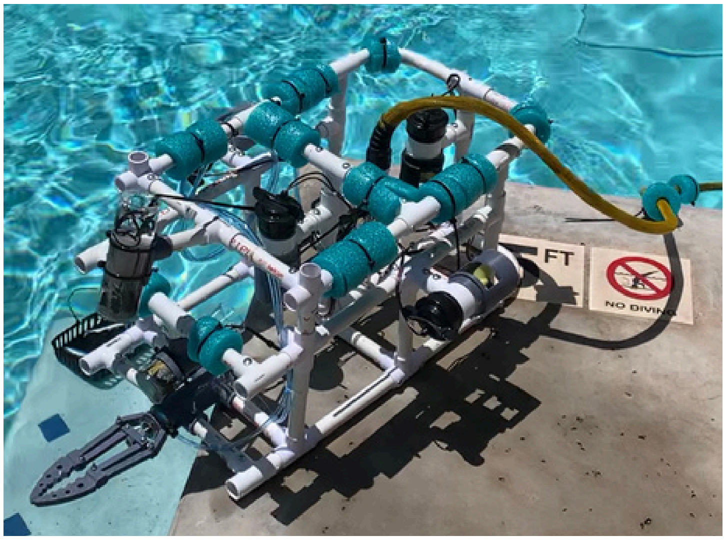

Fig 1. EMCC’s vehicle last year

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Project Management

Chief Executive Officer: Steven Dotts

The CEO of Desert Star Robotics provides leadership and strategic direction for the entire team. He coordinates specialized teams, manages resources, and ensures clear communications and collaboration among team members. The CEO coordinates with external relations, mentors, and organizers while upholding compliance with current safety and regulatory standards. He oversees documentation, risk mitigation, and failure analysis to ensure the team's continual improvement. Through Steven's leadership, the team stays on task and meets deadlines and goals.

Chief Financial Officer: Robert "Tony" Mannarelli

Desert Star Robotics' CFO manages the team's budget and resources. He delegated funds to each sub-team and communicated any changes in budget status to the team. Tony ensures funds are allocated appropriately, and each team makes wise financial decisions on their portion of the project. Through the CFO's support, the team was able to work efficiently through its budget constraints.

Chief Technical Officer: Brennan Mai

The CTO is the lead for researching and developing innovation techniques. Brennan oversees the design, construction, and integration of the ROV's systems to ensure all electrical, software, and mechanical components function cohesively. He organizes sub-teams, is the spearhead for problem-solving and troubleshooting, and ensures competition requirements are met. Through leadership and technical knowledge, Desert Star Robotics' CTO assures Nomad performs optimally and can functionally achieve its goals.

Outreach and Marketing Manager: Shayla Lee

Our marketing and outreach manager oversees the design of any company merchandise or media. Shayla coordinates with the CEO and mentor for any offsite outreach events. These events range from demonstrations to school visits. The manager must coordinate team personnel to attend and brief them on the objective of the outreach event. She also is tasked with being up-to-date on current environmental concerns and being able to communicate these concerns effectively to a wide range of audiences. Through marketing and outreach efforts, the marketing and outreach manager boosts the team's visibility and support within the community.

The whole team is separated into four specific sub-teams. As deadlines and priorities changed, members would fluidly move between teams except for team leaders. All leaders report to the CEO on progress and collaboration with the CTO during their engineering processes.

Electrical Team

The electrical team is in charge of all wiring and electrical components on the ROV. The electrical engineers' main tasks were soldering the control boards within the canister of Nomad and the non-ROV device. They also built and tested the 48-volt power supply box.

Fig 2. Electrical team member building 48-volt power supply.

Software Team

The software team are the experts in all code associated with the ROV and nonROV device. They made and adjusted the code necessary to map the thrusters to the controller. Python and Arduino are the main languages the software engineers used to program Nomad. The software engineers and electrical engineers were often collaborating and working closely together to guarantee a harmonious system.

Mechanical Team

The mechanical team is in charge of all mechanical components of the vehicle. Their main focus is the pneumatic manipulator arm. They worked closely with the electrical engineers to ensure no power conversions happened outside the vehicle's canister. Buoyancy was also a major component the electrical engineers were tasked with finding a solution to.

Marketing Team

The marketing team organizes all information and brand material pertinent to the team. They were tasked with designing a logo and finding outreach events to engage the community.

Safety

Safety Philosophy

Desert Star Robotics considered safety a top priority for all ages while developing the ROV. This year the team coordinated more outreach in the community. Thus, had to make sure Nomad would be safe to be around for a wide range of age groups, because we engaged a large range of age groups from fellow college academics to curious middle schoolers. In addition, the returning members mentored the new team members by giving safety training for operation of potentially dangerous tools, equipment, and/or chemicals. By implementing these safety precautions, senior members were able to mentor the new recruits effectively and to attend outreach events without the risk of injury.

Fig 3. A Scout MATE competitor piloting Nomad at a regional competition at University of Arizona

Safety Standards

During the design, prototyping, testing, and building process of Nomad and its components Desert Star Robotics, adhered to a code of safety standards that was emphasized and established by both the team and the EMCC MakerSpace. Most team meetings and build days happen at the EMCC MakerSpace where safety standards were already in place and enforced. These standards included: wearing ear and eye protection while using any drills, cutting, and laser devices, using fume fans when soldering and assembling electrical components, first aid kit, and eye wash station that are easy to access around the MakerSpace. Appropriate training on equipment operation and post-use clean up processes were given to each member when constructing Nomad to understand how to safely use and put away any tools used. Lastly, when building and testing the ROV outside of the campus, the team exercised the same safety procedures adhered to while on campus while maintaining open communication to ensure all members of the team understood proper tool handling and questions about equipment operation were fully addressed.

Safety Features

To ensure safety to members, customers, and the ROV itself while working with and around people, Nomad was equipped with several safety features. First the team smoothed, sanded, and sheathed down any sharp and ridged edges of the components of the ROV by using a deburring tool. Since most of the material that is exposed and being held was given to use directly from the manufacturer or was cut or drilled by the mechanical team. The tether is protected with a casing to keep all the cables, ethernet, and other accessories grouped together. In addition, strain relief is attached to both the top and bottom sides of our tether to prevent any damaging tugs that could rip the electronic connection to the control station (Fig 4). In case of the possibility of shorts, surges, and/or damaged electrical components, fuses were added to both the top side and bottom side of the ROV. One 30-amp fuse for the power cable on top side, two 20-amp fuses for both of our power supply boards, and one 7.5-amp fuse on the control board.

Also, 3D printers accessed at EMCC were used to printed shrouds specifically designed for the Blue Robotics T200 thruster motors. These shrouds are securely mounted using the already built attachments for the T200 motors (Fig 5).

Fig 4. View of bottom strain relief

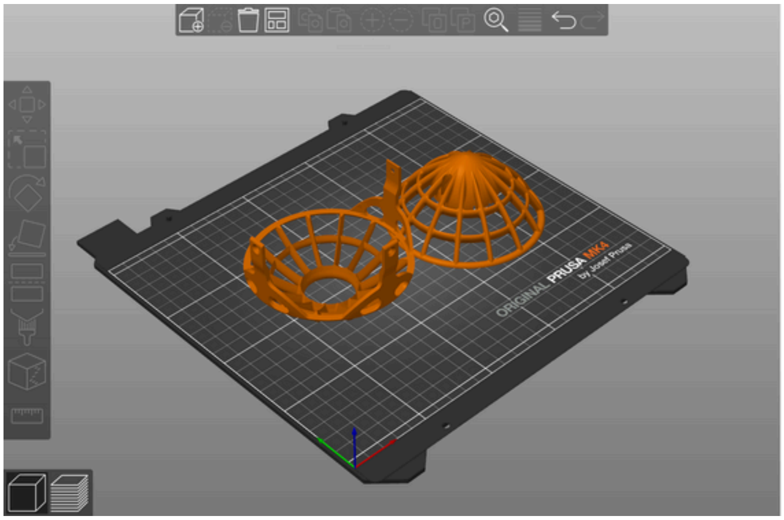


Fig 5. Initial prototyping of shrouds

Design Rationale

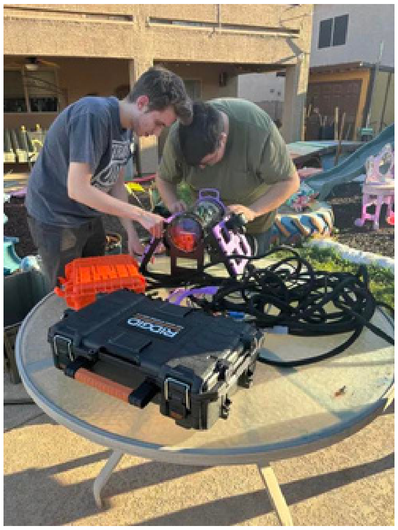


Fig 6. Mechanical team trouble shooting with ROV

Desert Star Robotics aimed for simplicity and versatility this year. As a team with a large variation in member availability, it was essential that Nomad excel in performance and be easily transportable from workstation to workstation. Our primary objective was to craft a vehicle that could fulfill all missions assigned by MATE while being user-friendly. The general simple base design was meant to empower both new and returning members to let their creativity flow while creating mission specific tools and assigning thruster positioning. It also served as an inviting introduction to the world of ROVs for beginners and newcomers.

Frame

The goal this year was to keep the design process simple to allow the team's newest members the opportunity to dive headfirst into designing and building parts of the vehicle. It was imperative any new features were tested for safety and troubleshooted before being displayed or demonstrated at outreach events.

The mechanical team elected to use the frame design provided by MATE. They cut it out of a high-density polyethylene (HDPE) sheet on a computer numerical control (CNC) machine. we used the HDPE that was provided because of its high density, strength, and melting point. The team had the necessary equipment to cut out the frame (Fig 7). Lastly, frame design was deemed ideal for the mission tasks, since the vector positioning for the thrusters allows us to have a wide range of motion while still having enough thrust to accomplish our tasks in a quick and efficient manner. As well as provides an excellent platform for the acrylic enclosure that houses the electronics (Fig 8).

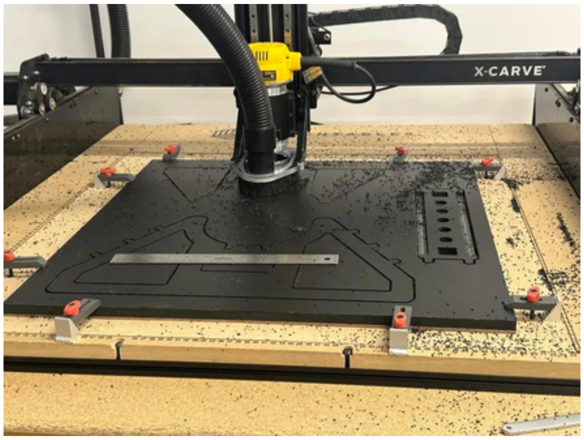


Fig 7. CNC machine cutting frame

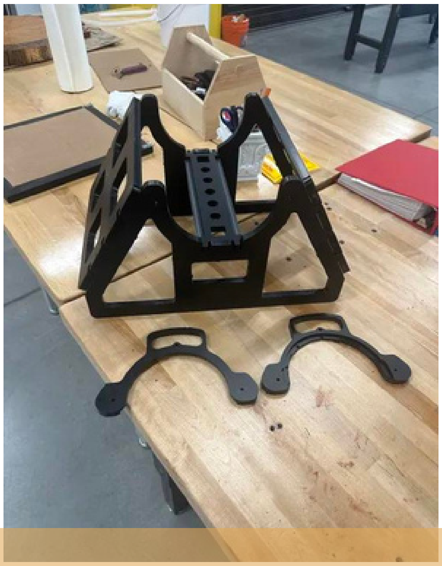


Fig 8. Finished frame design

Electrical/Controls

A requirement for the 48-volt system is voltage changes needed to happen on the bottom side. The electrical team worked to ensure majority of all electronics were housed in the canister of Nomad. The cylindrical acrylic enclosure ensured all electronics were safe guarded against leaks and accessible for any alternations. The enclosure, also referred to as canister, is sealed off using two enclosure caps, one with a clear acrylic face for the camera to see out of, and one with holes for wires and cables to run to from the enclosure (Fig 9).

For the hardware and electronic design, the members of the Desert Star Robotics team used the components and design provided by MATE's Eagle Ray kit. Some of the most important components are the Eagle Ray control board, with an Arduino mega, two supply boards with four ESCs (Electronic Speed Controllers) and DC to DC converts on each board for power distribution of the four T200 motors, and other passive electrical converters for the camera and ethernet code. As for controlling the pneumatic, there are two electrical pieces for its functionality, a 5/2 solenoid electrically driven to control the pneumatic actuator's compressed air, and a relay board which acts like an electronic signal switch that can be coded for control. All components, except for the solenoid, are inside the enclosure with power, ethernet, and other cables running through the enclosure. For the topside, a laptop, Xbox controller, and power supply are used to pilot and relay Nomad's code and ensure a stream of power to the ROV.

To connect the top and bottom sides for our product, we used a 23-meter-long tether that contains our ethernet cord, power cable, and high-pressure resistant tubing. This is then collected together in an expandable mesh cover with a high dense buoyancy foam tubing inside it to keep the tether buoyant (Fig 10). The tether is then managed by one or two people on deck to be certain that the tether is not kinking and to pull back or give away any slack that the pilot needs for the needs or does not need.

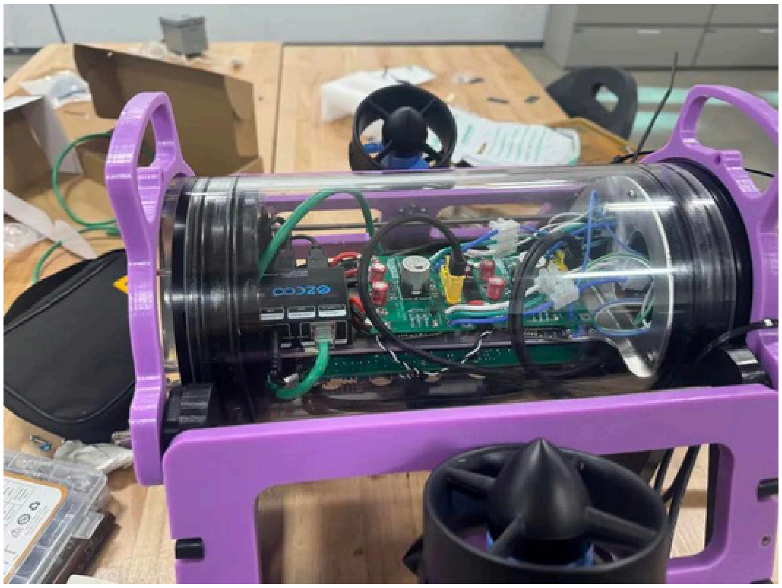


Fig 9. Enclosure of electrics after completion of ROV with no features

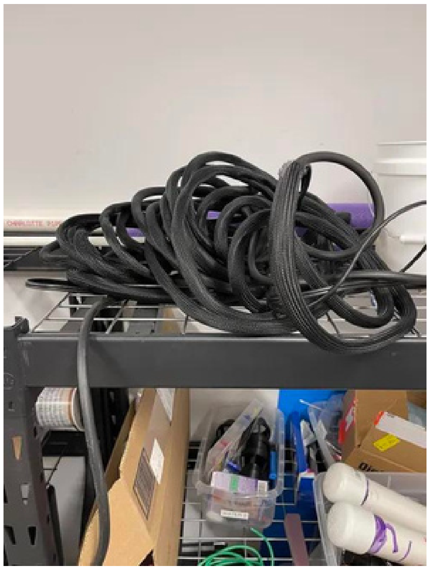


Fig 10. Constructed tether for Nomad

Software

The ROV the team built last season, Buggy, had minimal software involved since it was primarily hardware used for that ROV. The team was able to complete the mission tasks for last year, but Buggy had the restriction of a rigid control system. Conversely this season, the new vehicle's control system allows for adjustments and implementation of equipment. As a result, more programming was necessary for Nomad's controls. This year, MATE provided two different codes that both can be used for controlling the four thrusters, one base in LabView and one base in Arduino/Python. The software team decided to use the Arduino/Python code since a majority of members had prior experience with these languages. With the provided code, the software engineers were able to adjust and add additional programming to control the pneumatic arm, control the linear actuator gripper add-ons, and adjust the maximum thruster output (gain) for each degree of freedom. Testing in the water proved functionality and connection with the ROV is operating correctly.

Propulsion

A pitfall from last year's ROV design was the lack of power in the thrusters. This year Desert Star Robotics wanted to implement a more powerful and efficient propulsion system into this year's ROV. Four T200 motors were purchased from Blue Robotics, which from are initial testing have more thrust than last year's motors. The decision to use 4 thrust motors was motivated by the frame and software system proved by MATE. It had promising qualities without needing adjustments to Nomad's frame design. This allowed the design process to remain simple, reduced financial strain for more motors, and reduced power consumption in the overall power supply. Thruster positioning was designed to go with the recommended vector profile for the thrusters that MATE recommended. The positioning allows for a great amount of motion flexibility (forward, back, up, down, roll, yaw, and sway), and power balance to accomplish this year's task all while being cost effective in the team's budget (Fig of the allowable degree of motion). With these more powerful motors, the pilot has more options for thrust range when accomplishing missions.

Buoyancy

For Nomad's buoyancy, the goal was to come close to or achieve neutral buoyancy. To do so, the team took the assembled ROV to a pool and, after doing safety checks, docked it into the pool. The air within the enclosure made the vehicle positively buoyant. To combat the positive buoyancy, the mechanical team added tire weights around the Nomad, and repeatedly tested buoyancy of Nomad until approximate neutral buoyancy was achieved (Fig 11).

Fig 11. Nomad's positive buoyancy in first pool test

Payloads and Tools

Camera

Fig 12. mounting piece designed by MATE for Nomad's Camera

ROV's required additional tools and payloads for effective for usage. Cameras are attached to serve as "eyes" underwater so the operator can see from the ROV's perspective bottom side on the top side. The team decided to use the one camera to conserve funds and the single camera already gives a wide, clear view of Nomad's surroundings. The recommended heat plated from MATE was used as a mounting slot for the camera's mounting piece (Fig 12).

Claw (pneumatic):

To grab and move objects used in this year's competition, the mechanical team designed a claw operated by a pneumatic system to provide motion to our gripper. The team decided to use last year's pneumatic manipulator as a backup gripper in case the new electrical gripper failed (Fig 13). Since the previous claw design has been proven and tested from last year's competition and the ease of waterproofing for a pneumatic system would be easy to accomplish compared to an electric actuator. The gripper was attached by designing and 3D printing a U-bracket to mount the gripper to the ROV frame. The claw was designed by using pre-existing files and making alternations CAD software Fusion360 for the specific mission.

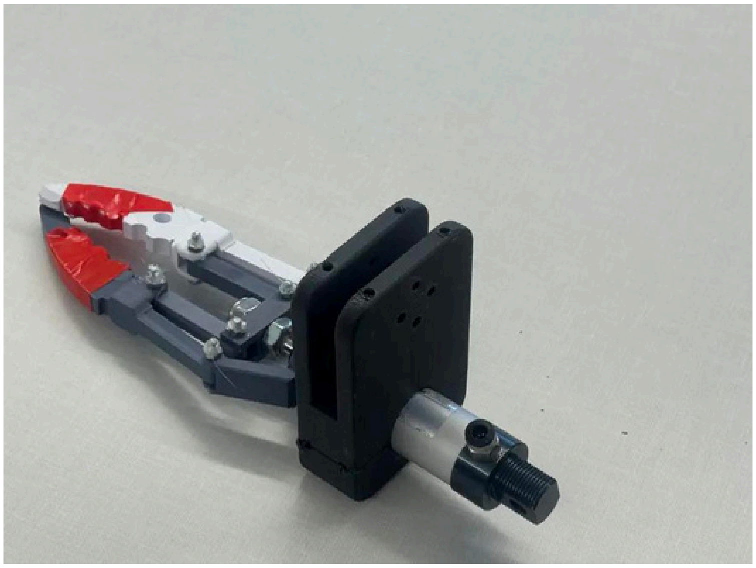


Fig 13. Last year's pneumatic claw with U-bracket

Claw (electrical):

While the pneumatic claw is still useful to the vehicle's design, the team wanted to expand members' skills and experiences in gripper design, so it was decided to build and design an electrical actuator claw this year. This design would be easier to implement into Nomad's electrical system. An electric actuator driven claw has the benefits of specifically selecting the force that the actuator can produce from the manufacturer's specs, while a pneumatic actuator grip will be dependent on the amount of pressure supplied to it. Another benefit is code can be written to program any desired positioning for the actuator's shaft, while the pneumatic actuator from last year's shaft that could only expand full out or in. However, waterproofing the electric actuator was a greater burden compared to a pneumatic. To accomplish this, a resin printed case was designed to hold the actuator (Fig 14). A hole with two greased O-rings secured in place for the actuator to function while keeping water out for the electrics (Fig 15). Note, at this point the mechanical team has not finished assembling the electric claw yet, due to time constraints, and shipping delays. There are plans to finish the claw and seal with RTV rubber (room temperature vulcanizing) to waterproof (Fig 16). Thus, last year's claw was implemented as a backup.

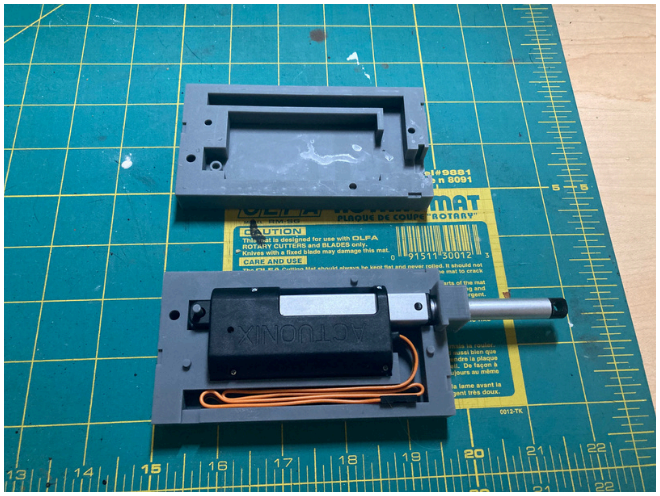


Fig 14. resin printed case for actuator (opened)

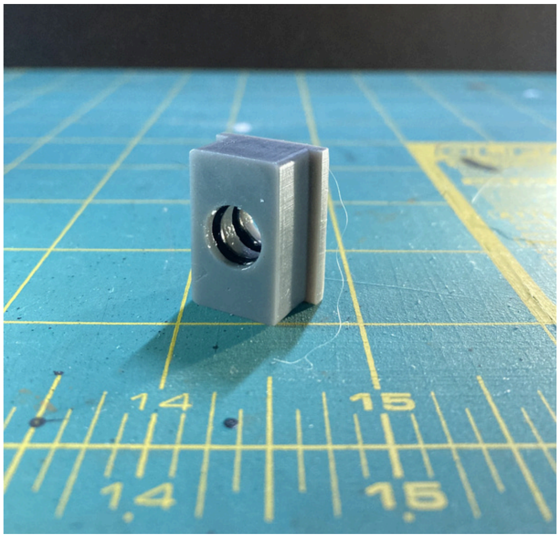


Fig 15. Cap with greased O-rings for waterproofing

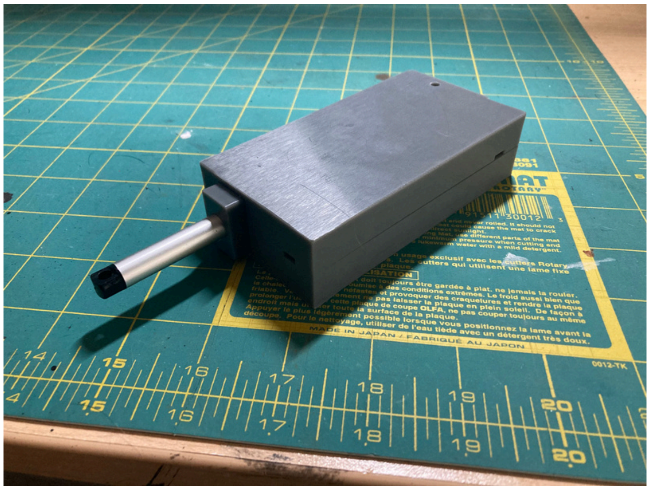


Fig 16. Resing printed case with no RTV sealant (closed)

Build v. Buy, New v. Used

Because of the decision to move from a 12-volt system to a 48-volt system, the majority of the vehicle's components were bought and new. Most major parts came from the MATE's Eagle Ray kit. The team used the files and material provided by the kit to build the basis of the vehicle then moved onto designing mission specific aspects. Handles were added to the frame for easy mobility and as a safety precaution. Anyone topside is able to distinguish when Nomad has returned to surface and can notify the pilot to cease all controls. Prior art research was conducted for the shrouds that were built to MATE's safety codes.

A provisionally used feature is the pneumatic claw. The grip strength allotted to the vehicle built last year was a large reason why we chose to temporarily implement the claw into this year's system for the demonstration video. It has a relatively small power consumption so trade-offs were not a factor to be worried about. It is easy to train new team members in the safety protocols for assembling and operating the pneumatic system. However, a new electrical claw allows more flexibility of motion, closes at a slower speed to all more fine tuned controls, closes more completely, and simplifies the control systems (Fig 17).

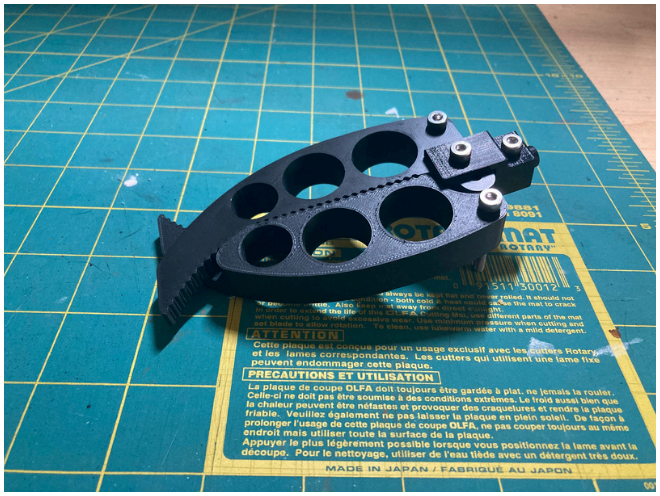


Fig 17. Renewed claw that can closed completely

Troubleshooting and Testing

This is the team's second year working on the ROV development and competition. The knowledge and experience from last year were implemented into our design, scheduling, and testing of the vehicle for this season. The team prototyped and tested the material before moving on to the final product, ensuring the design of the frame and the claw was sound. Electrical components were tested using a multimeter to see conductivity in the electrical works before use. We used the standard industry solder requirements and multimeter to check the quality and conductivity of the solder joints. The camera and gripper were both tested before integrating onto the ROV. The T200 from blue robotics thrusters needed to be tested in the water since they are water lubricated. For testing the integrity of Nomad's enclosure, the CTO used a hand pump and measured the amount of air that is lost after 5 minutes. In addition, Nomad was capable of functioning while the power was off. It was fully submerged underwater to check for any air leaks. This ensures we reduce the risk of damaging the electronics underwater. Afterward, we tested the ROV's maneuverability, camera view, and actuator arm by performing various tasks underwater.

Challenges

The first challenge was scheduling with the team. Because we are from a community college, most students have other obligations such as work to find a time to meet up. The team has been using Discord to communicate with each other to get the most interaction possible. Another challenge was ordering parts for the ROV. This was a complex bureaucratic process that required approval from more than three people. Delays happened because we could not get the parts when we expected. Similarly, retention and recruitment was difficult. As a small community college, recruiting more members was a challenge because the students are usually too busy with other commitments; also most students are transferring out of community college to a higher university in a two year time so the team that we have will not be as experienced as a four year institution. An obvious challenge was when testing at the pool and our electronics were overheating. There is not much shade at the pool but we used towels to shade our equipment.

Our manipulator is a huge challenge. The design recycled from last year turns out to do poorly with the tasks for this year's competition. We have decided to go with a different design based on the testing we did. Through our experience and testing with the Nomad, we solved initial challenges with the ROV. We were able to adjust the code for controlling the ROV's movements. The dead zone was the most challenging. We went from a cross dead zone to a square deadzone. Right now scaling the dead zone is the most arduous task. It takes the mapping of the joystick input and turns that into movement for the ROV. The camera angle was also adjusted because we could not see the manipulator when it was underwater. We did see the manipulator when it was out of the water but during testing we fixed the position.

Fig 18. All sub-team leads troubleshooting during pool testing

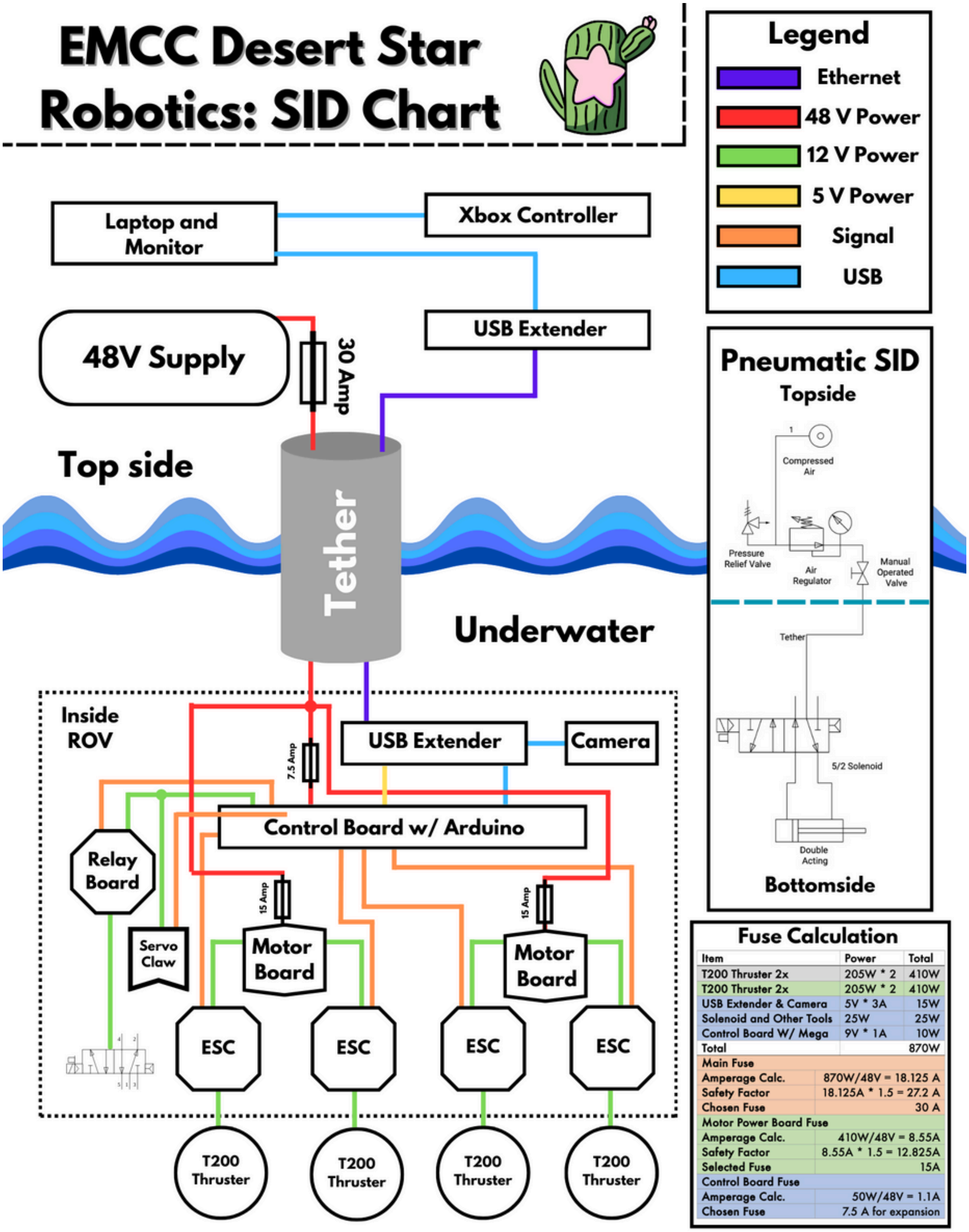
Budget

This competition season, the team saw an increase in budget due to the shift from 12-volts to 48-volts. Given the design path being largely driven by the instructions provided by MATE, a large portion of this year's budget went towards designing and building mission specific items such as the manipulator arm and non-ROV device.

	A	B	C	D	E
1					Balance:
2	Total Spendable Budget				$ 10,000.00
3	Total Expenses				$ 9,884.07
4	Ending Balance				$ 115.93
5					
6	Expenses:	Account descri	Amount	Date	
7	MATE Eagle Ray Kit	MATE Supplied	$1,595.82	10/10/24	
8	McMaster - Procard RS	Supplies	$ 219.81	12/04/23	
9	BlueRobotics - Procard RS	Supplies	$ 128.40	12/05/23	
10	Sparkfun - Procard RS	Supplies	$ 110.35	12/05/23	
11	DigiKey - Procard RS	Supplies	$ 9.82	03/20/24	
12	Amazon - Procard RS	Supplies	$ 141.43	04/07/24	
13	Amazon - Procard RS	Supplies	$ 25.87	04/07/24	
14	Amazon - Procard RS	Supplies	$ 60.63	04/24/24	
15	Amazon - Procard RS	Supplies	$ 50.26	04/23/24	
16	Amazon - Procard RS	Supplies	$ 32.03	04/23/24	
17	Amazon - Procard RS	Supplies	$ 32.63	04/30/24	
18	Amazon - Procard RS	Supplies	$ 29.05	04/26/24	
19	Amazon - Procard RS	Supplies	$ 48.80	05/04/24	
20	Actuonix - Procard RS	Supplies	$ 120.93	05/10/24	
21	Actuonix - Procard RS	International Fee	$ 1.81	05/10/24	
22	McMaster - Procard RS	Supplies	$ 31.01	05/09/24	
23	BlueRobotics - Procard RS	Supplies	$ 269.64	05/11/24	
24	Travel Expenses	Travel	$ 8,571.60	6/17/24	

Fig 19. Spreadsheet used to track all team expenses

System Integrated Diagram



Fuse Calculation

Item	Power	Total
T200 Thruster 2x	205W * 2	410W
T200 Thruster 2x	205W * 2	410W
USB Extender & Camera	5V * 3A	15W
Solenoid and Other Tools	25W	25W
Control Board W/ Mega	9V * 1A	10W
Total		870W
Main Fuse		
Amperage Calc.	870W/48V = 18.125 A	
Safety Factor	18.125A * 1.5 = 27.2 A	
Chosen Fuse	30 A	
Motor Power Board Fuse		
Amperage Calc.	410W/48V = 8.55A	
Safety Factor	8.55A * 1.5 = 12.825A	
Selected Fuse	15A	
Control Board Fuse		
Amperage Calc.	50W/48V = 1.1A	
Chosen Fuse	7.5 A for expansion	

Acknowledgements

Desert Star Robotics would like to thank Estrella Mountain Community College's Physical and Natural Science departments for their continued financial support. The team is also grateful to the employees and management team of EMCC's MakerSpace for providing us with tools and workspace. We also thank Jeff Miller, our mentor for his continued mentorship and guidance as the team develops. Lastly, the team would like to acknowledge and thank MATE and MTS for continuing to educate and challenge students in the world of marine technology.

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