CRUSADER ROBOTICS

CHICAGO, IL

Photo credit: Brian Barkowski

Members:

Milo Bradshaw - Sr. - C.E.O. / Claw Operator - Computer Engineering

Alex Bilek - Sr. - Senior Advisor - Accounting

Patrick Nielsen - Jr. - Co-Chief Mechanical Engineer/ Driver - Mechanical Engineering

Peter Cwik - Jr. - T-shirt Designer/ Programer - Computer Engineering

Joseph Taylor - Jr. - Junior Advisor / Mechanical Engineer - Engineering/Biology

Jack McBrearty - Soph. - Co-Chief Mechanical Engineer - Biomedical Engineer

Matt McCormick - Soph. - Co-Designer / Mechanical Engineer - Computer/Biomedical Engineering

Vincent Zampillo - Soph. - Idea Generator - Computer Science

James McManus - Soph. - Mechanical Engineer- Education

Patrick Walsh- Fresh. -Team Historian / Mechanical Engineer / Tether Manager - Computer/Mechanical Engineering

Liam Coughlin - Fresh. - Mechanical Engineer/ Tether Manager - Aerospace Engineering

Connor English - Fresh. - Mechanical Engineer - Computer Science

Kyle English - Fresh. - Mechanical Engineer - Undecided / Engineering

CJ Dvorak - Fresh. - Mechanical Engineer/ Tether Manager - Computer/Mechanical Engineering

Jack Clisham - Fresh. - Mechanical Engineer - Computer Engineering

Tim Novick - Fresh. - Prop Engineer - Undecided / Engineering

Mentors: Daniel Mostyn & Eric Gamboa

TABLE OF CONTENTS

*There is no programming for the ROV.

Abstract

Crusader Robotics was first founded in 2015 by Dan Mostyn with the intention of teaching the engineering design process to Brother Rice students through competitive and cooperative ROV construction. Today, a year later, the Crusader Robotics team has exponentially improved since its inception in both its knowledge of ROV design and competitive placement. The team is still mainly run by the students. The new members are taught by the veteran members, while the coaches help with only the most difficult of tasks.

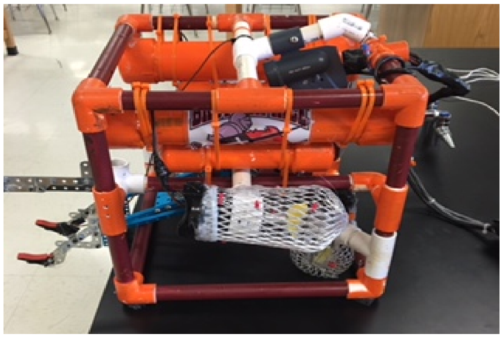
Construction and planning of the ROV Edmund Mk 2.5 began during November 2015 and ended June 2016. However, this was not a simple task. Mandatory adjustments, replanning, lack of essential experience and resources, and mechanical failures, that once seemed trivial, became great tribulations that required consistent and diligent effort to triumph over. Nevertheless, Crusader Robotics was not only able to overcome these issues, but was able to conquer them in an efficient and budget friendly manner.

Features

- Durable, lightweight Polyvinyl Chloride Frame optimized for underwater navigation and completing tasks.
- Unique four motor configuration designed to have smallest volume footprint and greatest potential speed, and mobility.
- Unique multifunctional mechanical arm tusks that grip and flip CubeSats.
- Miscellaneous custom made attachments - e.g. Side hook used for opening the ESP box.
- Small overall volume, weight, and area footprint to lower hypothetical costs to launch into space.
- Camera placement in the middle of the ROV to maximize viewing range, thus allowing vision of the coral, among other things.
- Temperature sensor designed to record accurate temperature.

Design Rationale

Frame



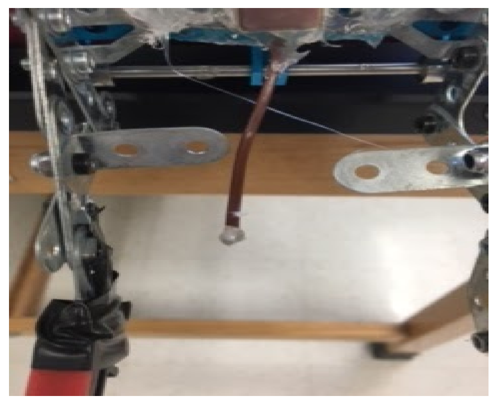
After a long period of testing and prototyping, the team decided a cubic shape for the ROV would be the fastest and the sturdiest model. For the material, the team chose PVC. This is because it is strong and easily adjustable, and is PVC is very cheap, which allowed the team to stay within the budget.

The cubic ROV frame

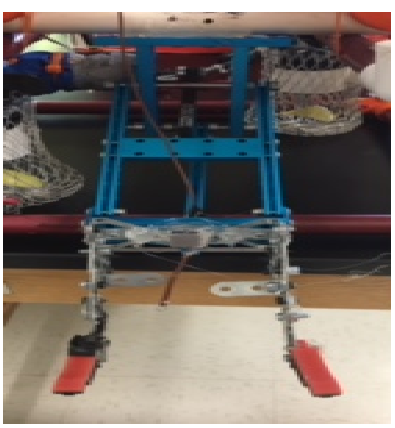
Temperature Sensor

The temperature sensor helps to complete one of the simplest tasks that also gives many points. The sensor is a thermocouple between the tusks of the claw, the position of which makes it easy to take the temperature of the water spout, as well as adjust if need be. The wire also has slack, which allows the sensor to move easily with the arm.

The small brown wire is the temperature sensor.



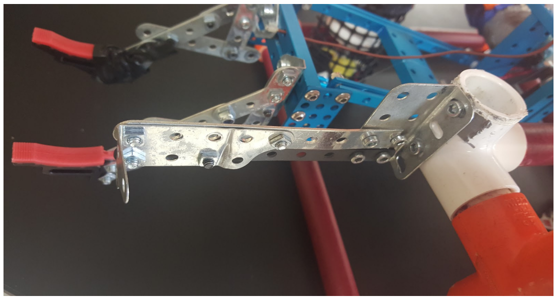
Claw



The claw has a unique design that the team decided would work the best for the missions that needed to be completed. The claw is shaped it like a tusk to make it easy to hook onto props, like the CubeSats and oil mats. The design of the tusk is custom, but the motor, arm, and grips of the claw came in a kit.

The grey part is the custom designed tusks. The blue is the robotic arm.

Hook



Next to the claw, the team decided that a side hook would make it easy to complete the task involving opening a door for the ESP cable. When the team tried to use the claw tusks, they were not able to open the door. After some brainstorming, the team placed a hook on the side would be sufficient to complete the task.

The hook allows the team to easily open the door to the port for the ESP.

Tether and Strain Relief

For the tether, the team went with with a design that they thought would be simple, but work as well. The tether is composed of the wires that need to go to the motors, claw, and thermocouple tip. Each wire is combined into one of the larger wires, which is zip tied together along most of the length of the tether. The team also designed their own stress relief to make sure no wire is pulled and disconnected when driving the ROV. The stress relief is made from two pieces of rope zip-tied together and connected to the frame and the tether right before it goes into the ROV's frame.

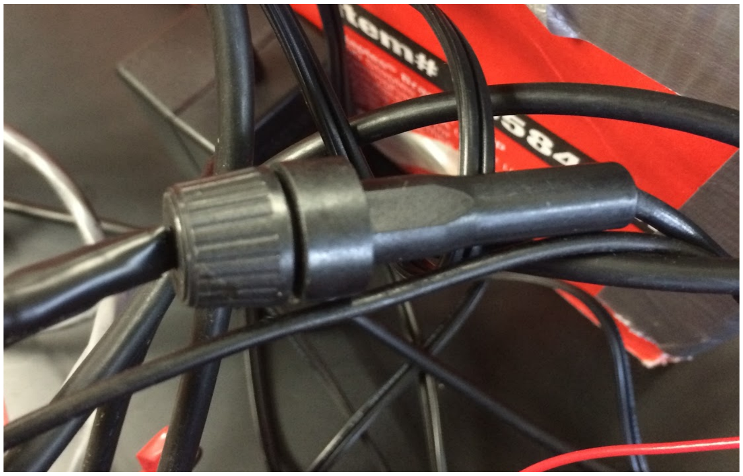
The rope prevents the black tether from being pulled, which could cause broken solder joints.

Camera

The camera is placed in the middle of the ROV and aimed slightly downwards. This is done so the team can have a wide viewing angle that can always see the claw and what is below the ROV. The camera is a simple black and white camera, usually used for fishing. Most of the fin was removed from the back in order to position it in a desirable location.

A simple black and white fishing camera.

20 amp Fuse

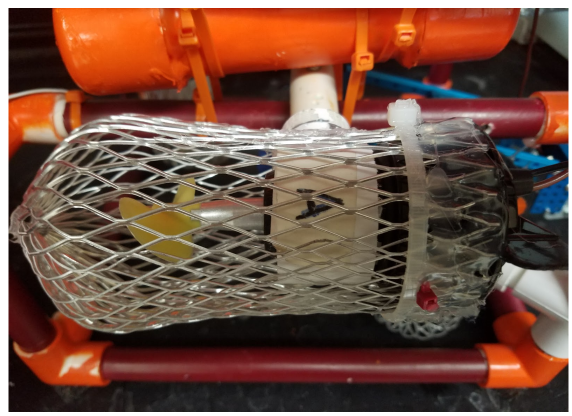


Off the ROV, there is a 20 amp fuse between the battery and control box through which everything is connected. There is also have a 3 amp fuse between the multimeter and claw control, and a .20 amp fuse in the multimeter. The fuses are in place so that the team will not be at risk of ruining a part of the ROV. The fuse will safely shut off the power incase of an emergency.

The fuse is contained within this case, and is located between the ROV and the main control box.

Motor and Shrouding

The motors were generously donated to the team by the Shedd Aquarium. The ROV has four motors, two for horizontal movement, and two for vertical movement. The team decided to use a shrouding design that allowed for water, and nothing else, to come in from everywhere, allowing the most thrust. The shrouding is an aluminum leaf strainer that is hot glued to the motor.



The leaf strainer is strong and prevents anything from interfering with the motors.

Buoyancy System

The two larger tubes are our buoyancy tubes.

The team wanted to make sure the ROV was neutrally buoyant. Foam was used originally, but because foam becomes less buoyant the deeper it goes,it was scrapped. The solution was using PVC pipes filled with air to keep the ROV neutrally buoyant. To do this, the team used an equation given to them by the Shedd Aquarium. The first thing was to find the wet weight of the ROV, which was 1,318.435g. For every 18.581g, 1 cm of 2in PVC was needed to make it neutrally buoyant. It looked like this:

1318.435g x $\frac{1cm}{18.581g}$ = 70.96cm of 2in PVC.

The problem was that the ROV had to fit inside of a 48 cm diameter circle. Two 32cm pipes were able to fit inside the circle, but the ROV required more buoyancy. The team took the PVC needed and subtracted the amount wanted, and then converted the remaining 6.96cm of PVC back into wet weight so that the team knew how much ¼ in PVC to use. It looked like this:

$$70.96\text{cm} - 64\text{cm} = 6.96\text{cm of 2 in pvc}$$

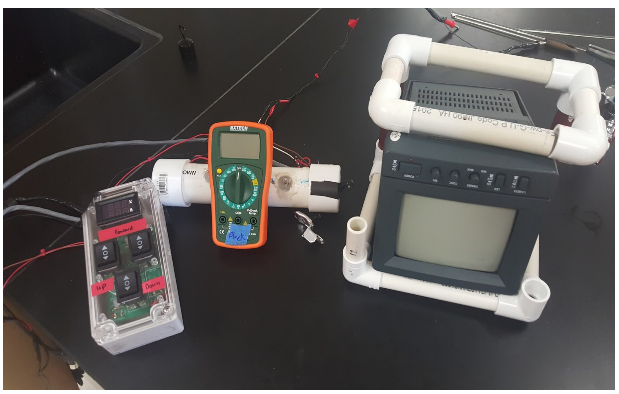
The remaining PVC was then converted back into kg. After that, the remaining weight was converted into ¼ PVC. It looked like this:

$$6.96\text{cm} \times \frac{18.581g}{1cm} = 129.32\text{g}$$

$$129.32\text{g} \times \frac{1cm}{7.603g} = 17 \text{ cm of } ¼ \text{ pvc}$$

The team finally decided on using two 32cm 2in PVC tubes and 2 8.5cm of ¼ PVC tubes.

Monitor and controller

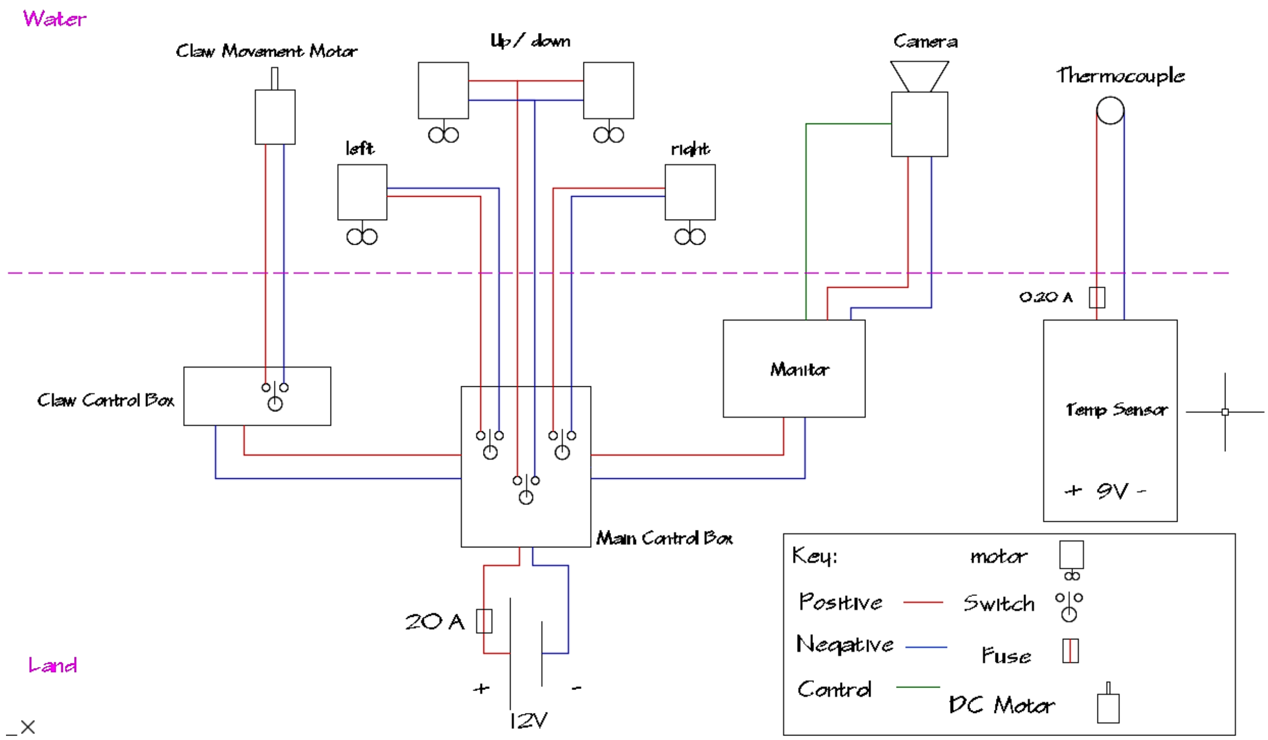


From left to right: main control box, claw control under multimeter, monitor in improvised holder.

For the control setup, the team decided to go with two controllers so that the driver could focus on the positioning of the ROV while another team member operated the claw. The ROV controller has two upper switches for horizontal movement. Pushing up sends the ROV forward, while pushing one up and one down will turn the ROV. The claw controller has one functioning switch, which controls the vertical movement of the arm. The other switch used to control a motor that would open or close the claw, but the motor it controlled has been scrapped. The team used a Cabela's fishing camera monitor and a multimeter to read the temperature that the thermocouple picks up.

All photo credit in this section: Peter Cwik

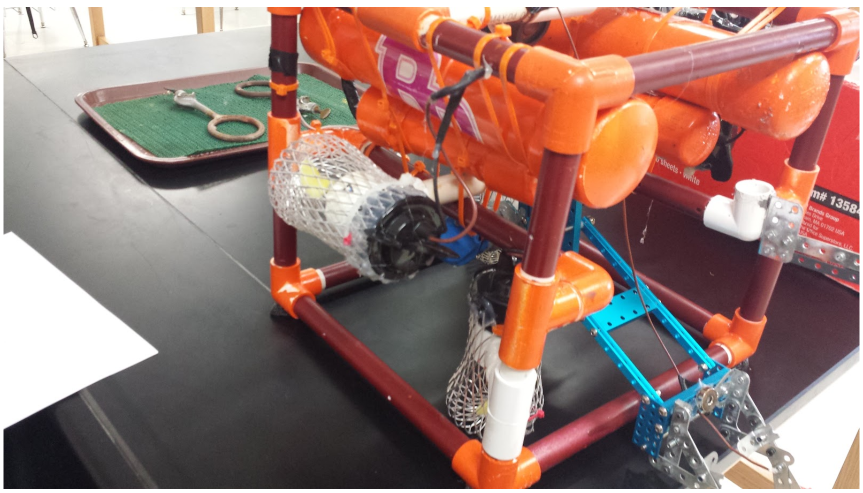
System Interconnection Diagram



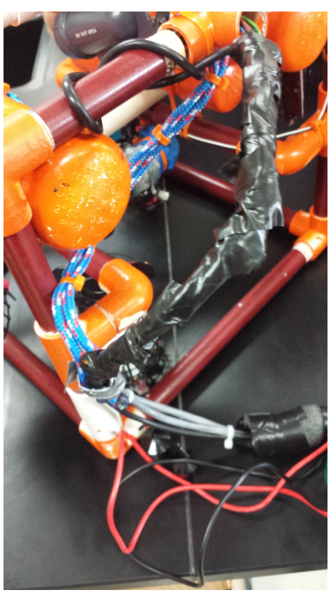
Amperage calculations	
Item Description	Charge
Motors x 4	2.5
Camera/monitor	1.3
Claw arm motor	1.1
Sum times 1.5	18.6
Total Amperage	18.6

Safety

Safety is of paramount importance to Crusader Robotics. Numerous features are present on the Edmund Mk. 2.5 ROV, such as propeller shrouding and fuses. The shrouding on the ROV is made up of aluminum leaf strainers that are present around each propeller on the robot. They protect anyone in the immediate vicinity of the blades from being injured by any of the Mk 2.5's 1000 gph bilge pump motors. The cages also protect the propellers from damage caused by the ROV striking the walls of the pool, or collisions with scenery. Unprotected propellers could do significant damage to the tether, which could paralyze the robot, leaving it dead in the water. The Mk. 2.5 also has two fuses attached to the controls: one 20 amp fuse in the tether, and one 3 amp fuse between the multimeter and claw controls. They are in place to prevent damage to either of the control boxes or the ROV itself, and also helps ensure the safety of the control team and the ROV.



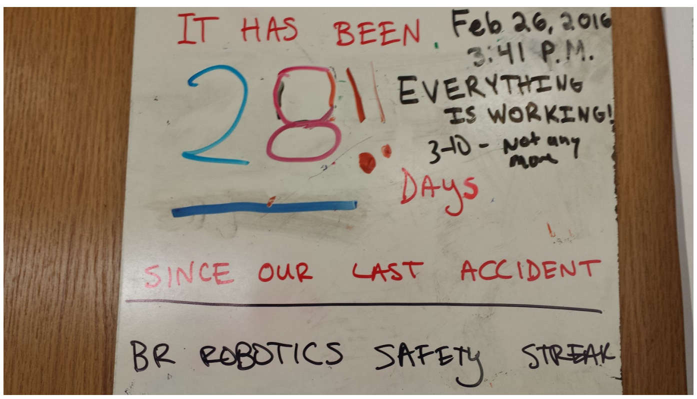
The prop shrouding can be seen surrounding the ROVs propellers. Photo credits: James McManus



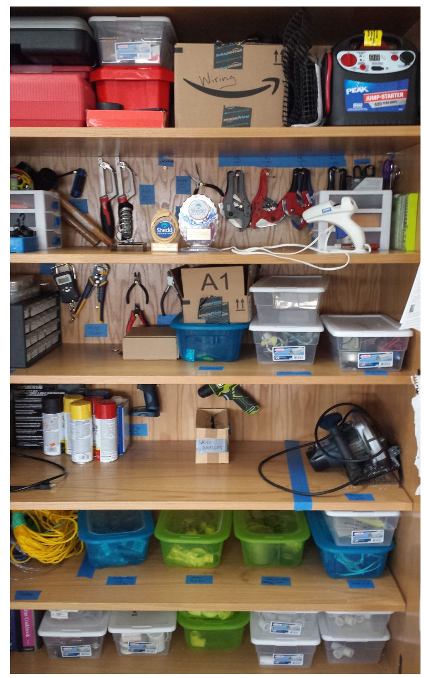
The strain relief system.

The Edmund Mk. 2.5's strain relief system safeguards against the risk of electric shock by employing a short length of elastic rope to take any strain. Simple but very effective, the rope takes the tension caused by the ROV moving out of range of the tether. This feature not only prevents the tether becoming detached from the ROV, but it prevents anyone who happens to be in the water at the time from being shocked. The ROV's power is supplied by a 12 volt direct current power supply that drives all four electric motors and onboard systems. A broken, exposed wire could seriously injure or even kill someone, considering the electrical conductivity of pool water. Electrical fuses are also present on the robot's design, further decreasing the risk of shock and making the Edmund Mk 2.5 even safer.

Crusader Robotics takes pride in its impressive safety record, considering the fact that it uses the variety of tools and practices to perform the tasks necessary to build the ROV. Mr. Mostyn and Mr. Gamboa are present in the team's adventures, keeping an eye on novice members and making sure that nobody is in danger. The workshop is also very well organized, with every tool arranged in specially labeled cabinet compartments. When the robot is transported to the swimming pool for tests and practice, a group of certified lifeguards are present in the water at all times to assure that everyone is safe from injury.



The team keeps a daily counter of how many days it has been since any kind of safety concern.



The team always keeps the tool cabinet nice and tidy, much like their workspace.

Photo credits: James McManus

Budget & Project Costing

Available Funds	
Starting Balance	
2015	1,000.00
Monetary Donations	
Jesus Perez and Associates	250
Total	1,250.00

Reused Parts	
Item Description	Estimated parts
Cabela's fishing camera/monitor	129.99
4x 1000 gph bilge pumps	95.96
Totals	225.95

Expenditures	
Item Description	Cost
PVC Pipes	30.79
PVC connectors	59.87
MakeBlock robotic arm	89.99
Erector set	44.99
Extech digital multimeter	19.99
4x Aluminum leaf strainer	10.52
Miscellaneous Home Depot supplies	78.58
Miscellaneous Menards supplies	65.45
Miscellaneous Loews supplies	13.69
Momentary switch	11.59
3x makeblock robotic gripper	90.00
Total	515.46

Total Final Vehicle Cost	
Total Vehicle Cost	Cost
Expenditures	515.46
Reused Parts	225.95
Material Donations	100.00
Total	841.41

Travel Costs	
Description	Estimated Cost
Team Travel	5640.00
Team Lodging	2295.00
Total	7935.00

Material Donations		
Donating Company	Donated Material	Estimated cost
Shedd Aquarium	pufferfish control box	70.00
Shedd Aquarium	back up camera	30.00
Total		100.00

Description of Challenges Faced

This year was a far cry from the mediocrity of the team last season. However, the team still faced multiple challenges, all of which were only with the ROV.

The team faced many technical issues this year, most of which was hardware related. One of the most difficult challenges was the battle with the claw. The claw used to have a small motor on it that would control the opening and closing of the claw, but all three motors wound up flooding. The team applied marine grease the first time, but it interfered with the functionality of the motor to the point that it was unusable. When it was opened, it was discovered that water got in anyways. The team then bought another one, and applied hot glue to the outside of it, and made sure that everything was covered. This one flooded too because there were areas with moving parts that couldn't be glued. The last motor got flooded because the team hot glued it again, this time applying marine grease as well. The marine grease wasn't good enough though, as the motor flooded again. After that, the team decided that they would go with a very simple two pronged hook with the elbow motor that had withstood the water every time.

The team had more technical challenges, besides the claw. The biggest of which was a car backup camera, provided to the team by the Shedd Aquarium. It flooded, and it was determined that the waterproofing that was on the back had weakened, allowing water to flood the camera. The team replaced it with a large, black-and-white fishing camera. There was also a problem with the temperature sensor, which was found out to be a broken solder joint. This fix came soon after the regional competition.

This year, the extent of any personal problems between team members came in the form of numerous conflicting ideas. Every conflict was always democratically decided, and no decision bred any ill feelings between team members. Otherwise, the team worked very well amongst each other, always listening to other's ideas and just generally enjoying what they were doing almost everyday of the week.

Lessons Learned and Skills Acquired

Not only did the Crusader Robotics come in first place at the Shedd Midwest Regionals, but the team also learned many lessons and skills along the way. Even as early as the first practice, new friendships were made daily. Many of the members know each other very well and communicate frequently, even outside of meetings.

The team also similarly acquired a great understanding of teamwork, as they needed to find a way to incorporate the multiple ideas that would benefit the ROV in the best way. The Crusaders also needed to split up the tasks to find the quickest and most efficient way to earn the most points in one run. The team learned patience as well, as they faced a wide variety of challenges that required critical thinking to fix. The team also acquired a deep understanding of the engineering process. The new members of the team learned the best ways to brainstorm, prototype, and find the most efficient way to complete a task or objective, while veteran members expanded their already strong understanding of the process.

One of the most important lessons learned was that failure is a part of life - especially for an engineer. The company encountered countless problems, but instead of giving up or scrapping an entire idea, they persevered and found a way to fix the problem. They continued to make progress with constant trial and error. All of these new skills, important lessons learned, and friendships made along the way culminated in the Crusader Robotics performing well in the competition in the Shedd-Midwest Regionals.

Future Improvements

Crusader Robotics looks to improve itself next year in a variety of ways, including better hardware, introducing software, and a larger budget.

The hardware is the most important point to the team. Areas of improvement would definitely include the claw, which had been a large source of issues. A better claw would allow the team to more easily accomplish tasks that a hook design wouldn't allow them to do easily, or at all. The control boxes are another big part of the focus on improvements. The current main controller is rather unwieldy, as the placement of the buttons requires the user to stretch their fingers if they wish to expertly pilot the ROV. Many controller ideas have been proposed, and will likely come to fruition early next year. A smaller, color camera designed for underwater use would be another welcome improvement, as for two years straight, the team's cameras have flooded shortly before the regional competition, forcing the team to scramble to secure and replace the old camera. A flexible buoyancy system would be another plus, as many aspects can affect the buoyancy of a pool. Currently, the team's buoyancy system is static, and is only changed by either adding weight or changing the lengths of the tubes, which means that the ROV may not perform as well in different places. Raspberry Pi hardware has also been suggested by members of the team, on the basis that it would automate many tasks, making them much easier.

Besides hardware improvements, the team will seek to gain a larger budget, which will likely come from more sponsors. This would allow the team access to more advanced materials and resources they would otherwise not be able to afford.

In the end, the goal of making a functioning, efficient robot will always be at the forefront of every effort made. Even as time goes on, and more people contribute their unique, creative ideas, the ROV will always have room for more improvements the following year.

Reflection of Experiences

In just the second year in the making, the Crusader Robotics team has managed to make numerous unforgettable memories. The first year taught many returning members a lot, and newcomers learned much from them. The amount of engineering knowledge each and every member has acquired in just one year is phenomenal, and there is much more to come. The team has been challenged with various physical obstacles, such as building props and designing the ROV itself. They also had to work on crafting a strong poster, and few had the task of creating a powerful oral presentation. As expected, the team persevered through these challenges, and came out with flying colors.

The team held a grade school tournament early in the year. Kids from grade schools in the area who were interested signed up, and got to build their own small ROVs in teams. This day taught the kids the fundamentals of engineering, and encouraged them to become Brother Rice Crusaders and to join the robotics team, since Rice is the only school in the area with such a team. Doing this yearly will help to build the size of the Crusader Robotics team and carry on its legacy.

The first run in the pool with the ROV is one that the team will never forget. Even though the ROV needed many tweaks after the first pool run, it was fantastic to see what the team had worked so hard on in action for the very first time. By the time the ROV Celebration at Northeastern Illinois University rolled around, the ROV was mostly ready to take on the tasks it had to do. Only small adjustments were made between then and the competition itself.

After many long days and a long fought battle, the team was just hoping to place better than last year. The whole team was shocked beyond belief when their name had been called for best in the pool and best in the oral presentation. But when they heard their name being called for the first place winners, the team was ecstatic. The team had not only placed better, but they had advanced to the international competition, a dream to many members. The fact that something they built together brought them to first place gave everyone a deep feeling of accomplishment, but the best part is the fact that the team came up from among the worst in last years competition. Crusader Robotics has only existed for a very short time, but has been very successful, and they are positive that they have a very bright future!

References

- 2016 Mate ROV Competition Manual. Marine Advanced Technology Education, n.d. Web

Acknowledgements

- The Shedd Aquarium website and staff, for providing the tools and knowledge to better take on the competition, especially the professional engineers present at the ROV Celebration Event, who helped with the team's tough problems
- Jesus Perez and Associates, for generous donations
- Motorola Solutions
- MATE Center, for making this event possible
- The Science Chicks, the team's sister team from Mt Prospect, IL in the Scout Class