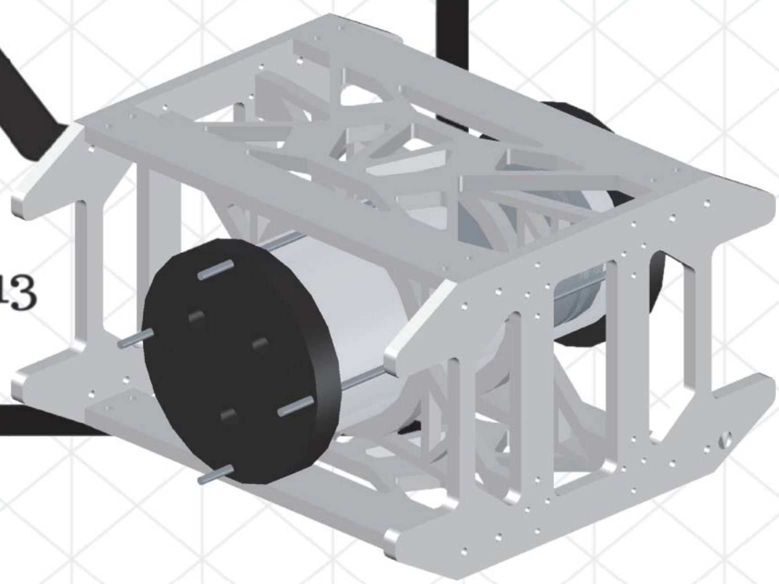
Est. 2013



Vector Robotics

Explorer Post 49 - Lemont, IL
Instructor - Mark Huegelmann

Eamon Bracht – Chief Product Officer
12th grade, Lyons Township

Kevin Leahy – Chief Executive Officer
12th grade, Lemont High School

Marty Snarskis – Chief Technology Officer
12th grade, Lemont High School

Akash Gandhi – Chief Financial Officer
9th grade, Lemont High School

Luke Pawlak – Research & Development
11th grade, Lemont High School

Nathan Pawlak – Safety Officer
9th grade, Lemont High School

Zachary Heatherington – Programmer
11th grade, Lemont High School

Alex Bacon – Programmer - Pilot
10th grade, Lemont High School

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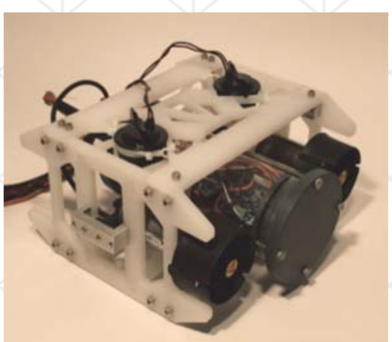

Figure 1: The ROV (credit L. Pawlak)

1 | Abstract

Vector Robotics brings together the craftsmanship and dedication of eight STEM-focused individuals to create a state-of-the-art Remotely Operated Vehicle (*ROV*) we call Flipper, which we specifically designed with the MATE mission challenges in mind.

Before our company began constructing the physical *ROV*, we created a comprehensive 3D *CAD* drawing. That enabled us to visualize how all of the individual components were going to come together while staying within the ideal size limitation. The result is a vehicle that has been engineered to provide a user-friendly experience while simultaneously enabling the operator to seamlessly measure water temperature and monitor continuous depth readout while moving around with our specially modified Xbox controller. Navigation is viewed through onboard High-Definition color cameras.

Our *ROV* brings together the perfect mix of proprietary systems as well as pre-fabricated components. The epitome of this vision is our control system. We took advantage of the Python and C++ coding environments to create our most advanced control system yet. The process starts with an XBOX controller connected to a Raspberry Pi2 Model B that transmits data over our carefully crafted, 15 meter tether to an Arduino Uno. In turn, the Uno sends out a signal to power our motors and onboard sensors.

By taking advantage of the electronic control system we were able to create an *ROV* that is significantly below the eleven kilogram weight specification. The innovative use of these otherwise common devices enables our team to provide a low-cost and performance-driven *ROV*.

2 | Systems Integration Diagram (SID)

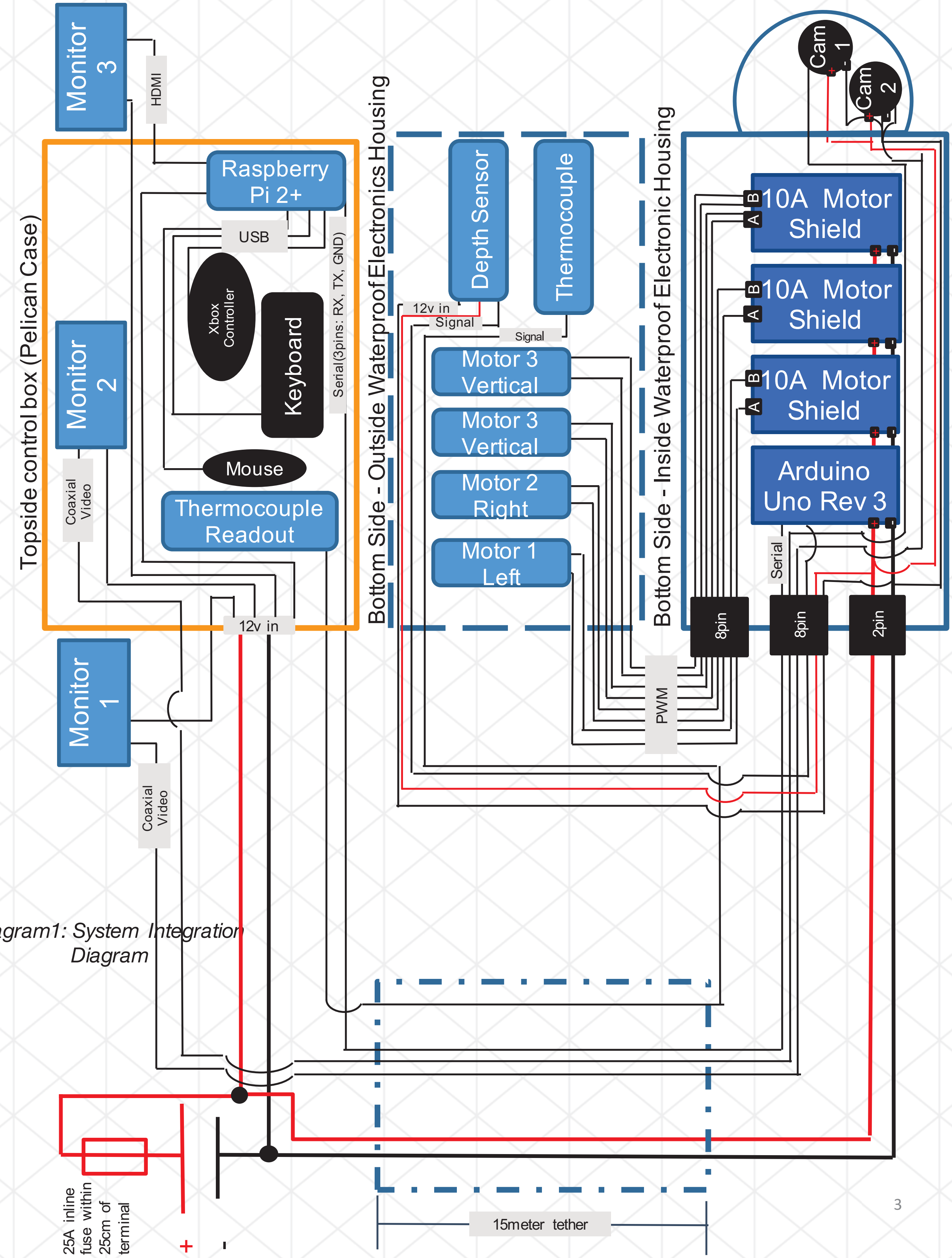

Diagram1: System Integration Diagram

3 | Company Information

Eamon Bracht
Company Role: Chief Product Officer
Eamon is a 12th grader at Lyons Township High School in La Grange, Illinois. This is his 3rd year participating in the MATE ROV Competition and he hopes to pursue a degree in Biomedical Engineering with minors in applied math and pre-medicine.

Kevin Leahy
Company Role: Chief Executive Officer
Kevin is a 12th grader at Lemont High School in Lemont, Illinois. This is his third year participating in the MATE ROV competition and he hopes to pursue a dual Business-Engineering degree.

Luke Pawlak
Company Role: Research & Development
Luke is an 11th grader at Lemont High School in Lemont Illinois. This is his third year participating in the MATE ROV competition and he hopes to pursue a degree in User Experience design.

Alex Bacon
Company Role: Programmer & Pilot
Alex is a 10th grader at Lemont High School in Lemont, Illinois. This is his first year participating in the MATE ROV competition. He hopes to pursue a degree in Computer Science.

Akash Gandhi
Company Role: Chief Financial Officer
Akash is a 9th grader at Lemont High School in Lemont, Illinois. This is his first year participating in the MATE ROV competition however, it is not his first year of robotics. He hopes to pursue a degree in Medicine.

Marty Snarskis
Company Role: Chief Technology Officer
Marty is a 12th grader at Lemont High School in Lemont, Illinois. This is his first year participating in the MATE ROV competition. He hopes to pursue a degree in Computer Engineering.

Nathan Pawlak
Company Role: Safety Officer
Nathan is a 9th grader at Lemont High School in Lemont, Illinois. This is his second year participating in the MATE ROV competition. He hopes to pursue a degree in Engineering.

Zachary Heatherington
Company Role: Programmer
Zach is a 11th grader at Lemont High School in Lemont, Illinois. This is his first year participating in the MATE ROV competition. He hopes to pursue a degree in Chemical or Nuclear Engineering.

Company Information Photo credits: E. Bracht

4 | Theme

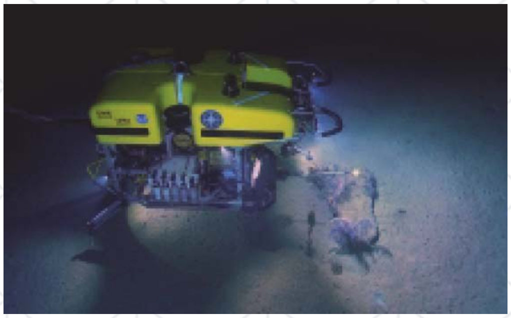

Figure 2: Hercules ROV[1]

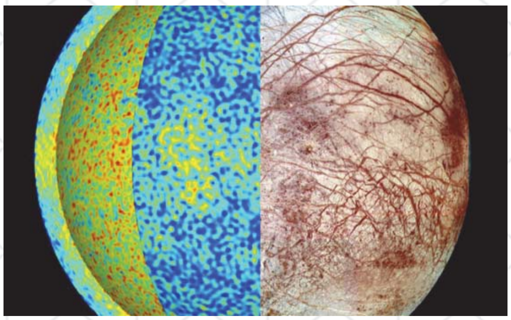

Figure 3: Temperature fields of Europa [2]

Team Vector designed a *ROV* that is both functional and aligns with the 2016 MATE mission tasks. We took inspiration from National Oceanic and Atmospheric Administration's (NOAA) *ROV Hercules* as exemplification of the real world purpose of the competition's theme.

Hercules features include abilities to measure oceanic factors such as water temperature as well as perform mechanical tasks underwater. These fundamental abilities are analogues to those required to complete the Mission to Europa tasks, which is why *Hercules* was so influential to us.

The *NOAA's* primary focus is on underwater studies, and that is essentially what constitutes the competition. From measuring liquids (ocean water with Hercules) to performing manual tasks, the *NOAA's* operations coincide with MATE.

5 | Safety

As a team, safety has been identified as our main priority. Whenever using or working on the *ROV*, all team members took proper safety precautions. After all work was completed, mechanics were shut off and housed in a room temperature storage space. To ensure our robot was safe during the competition, all our *ROV's* electronic components are stored in a waterproof housing(s). All motors are shrouded and wires secured to the frame. Warning signs have been added to all areas of danger to prevent injury.

While building the robot, no team member was left alone to prevent accidents. During all electrical work and testing, power was removed and all residual current grounded. All soldering was completed in well ventilated areas, and our engineers wore safety glasses.

The electronic components of our ROV also has multiple safety features. We used an inline 25 amp fuse within 30 cm of the battery to prevent a power surge. All components are in a waterproof housing, and we conducted extensive testing to eliminate electronics failure. For the tether strain relief cord, strain relief was added to prevent damage to the tether. While using power tools, all team members in the danger areas wore safety glasses, ear protection, and closed-toed shoes.

While constructing the *ROV* all team members wore Personal Protective Equipment, followed the Job Safety Protocol, and carried, at all times, our Job Safety Analysis to prevent any injuries.

PRE-WATER CHECK	YES / NO
25 amp fuse in place and functional	
All propellers shrouded	
SubConn connectors greased	
No exposed wires/motors	
Strain relief couplings in place	
Power connected to the correct sign potentials	
All ROV parts hard connected	
Closed-toed shoes (poolside crew)	
External power source is connected and functional	
No internal power source	
3-6 company members on deck	
Successful dry-land test	
MacArtney plugs connected	
Nuts and wingnuts fully tightened	
Greenlight (all previous requirements are met)	
POST WATER CHECK	
No moisture in the electronics or camera housings	
No exposed wire in the tether	
No structural damage	

Table 1: Safety Protocol (credit N. Pawlak)

6 | Design Rationale

While endeavoring to build a state-of-the-art *ROV*, there are almost an innumerate number of factors to consider. First and foremost we had to conform to MATE guidelines, but after meeting those requirements, we set additional goals as a team. We set design goals to meet MATE's best-case-scenario *ROV*: an *ROV* whose major axis was not larger than 48 cm and whose total weight was less than eleven kilograms. We also set technical goals: designing our own waterproof thrusters, a digital electronic system and frame out of innovative material. We also wanted to engineer and build our own waterproof housings for our camera and pressure sensor.

6.1 | Buoyancy and Frame

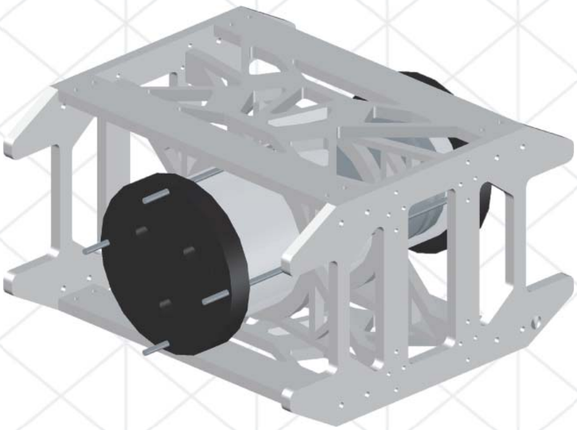

Figure 4: An AutoCAD rendering of Flipper's frame and WEC (credit E. Bracht)

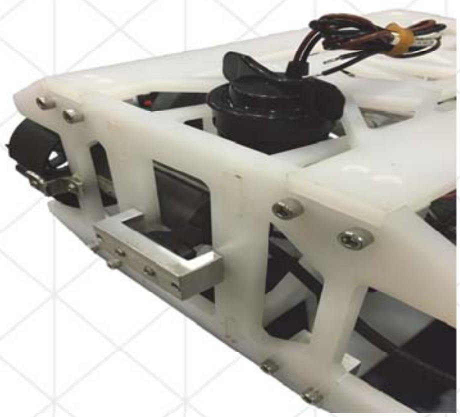

Figure 5: Early side view of Flipper's frame and thruster mounts (credit K. Leahy)

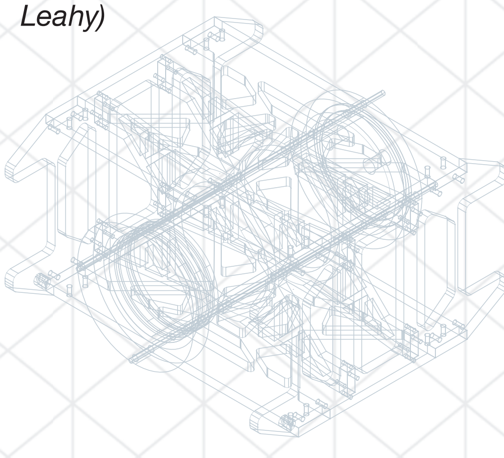

Figure 6: An AutoCAD rendering of Flipper's frame and WEC (credit E. Bracht)

Design Description

The frame is constructed from Computer Numeric Controlled(CNC)router-cut low density polyethylene (*LDPE*). The frame is constructed using trusses, or compound triangles. The frame was designed using a tongue and groove system, and reinforced with *CNC* machined aluminum corner brackets. Buoyancy was increased by adding polyisocyanurate foam, a closed-cell and incompressible foam.

Material	Density cm/g^3	Ratio to LDPE
PVC	1.43	1.6
Aluminum	2.7	3

Table 2: Alternative Frame Density (credit E. Bracht)

Design Rationale

We used LDPE because it has a slightly positive buoyancy and a forgiving, flexible nature. This feature allows for extreme amounts of stress to be put on the frame without risk of structural damage. Strength and reliability in a frame is an obvious concern when building a *ROV*. After deciding to use *LDPE*, we were faced with the engineering challenge of creating rigidity using geometry. As such, the minimal, yet robust, truss system was designed because they componentize them equally in two directions. Our goal was to achieve neutral buoyancy as that would allow for the most maneuverability. When designing the frame in *CAD*, we found that calculating the *ROV's* estimated buoyancy based on weight alone to be nearly impossible; there was a camera housing, an electronics housing, and thruster housings whose contents were variable. As such, neutral buoyancy was ultimately achieved through iterative testing and the use of polyisocyanurate foam. This type of foam was used because of its relatively low price. Although inexpensive, this foam is rated to deeper than 50 meters before any compression occurs.

6.2 | Waterproof Electronics Housing (WEH)

Figure 7-8-: WEH during its machining process.
Figure 7 – Front endcap on machine
Figure 8 – back endcap on lathe being turned down (credit E. Bracht)

Design Description
The body is constructed from ¼" cross sectional diameter acrylic tubing, and is 25.4 cm long, Two different PVC end caps, machined by Eamon, the teams CPO, seal the ends. Both caps utilize 3/8" O-ring seals. The removable cap uses an axial gland and the non-removable end utilizing two high-profile, shallow-gland radially sealing O-rings. The WEH's removable end-cap is a precise and reliable seal for our three waterproof connectors, two 8-pin and one 2-pin connector. As such there are three different way in which wires enter and exit. Built into the female connectors on the removable endcap is our strain relief system which places unexpected strain on the the coarse threaded hole and not the connection.

Figure 9: Front/side view of the WEH cap w/ electronics (credit K. Leahy)

Figure 10: Waterproof male and female connector (credit E. Bracht)

Design Rationale
The WEH is what makes Flipper innovative and unique. It is designed to safely and integrally house the ROV's electronics (Arduino, motor shields, etc) in a workflow-minded and efficient manner. We choose acrylic because it provides a strong, yet transparent housing that allows for continuous visual inspections and aids in troubleshooting.

O-rings were chosen to ensure waterproofness that was robust and reliable. The number of connectors and their pin number where specifically choose based on preemptive planning. One 8 pin allots 5 pins to transmits serial from the surface to the Arduino and the data stream from the pressure sensor. Three pins currently are unused, this is to allow for future expansion. The 2-pin delivers power from the surface while the other 8-pin distributes that power to the different systems on the ROV. Strain relief was used to ensure no unintentional detachment or damage occurs, however low-profile enough as to not become obstructive.

6.3 | Control System

Design Description
The decision to use an electronics control system and remote programming meant the use of a two brain structure: one located on the land module/controller and one in the *ROV* itself. The topside communication is facilitated by a Raspberry Pi running Raspian—a distro of Linux OS—which receives the raw serial from the XBOX controller via the XBOX driver and interprets, & translates it using a Python program into a more usable form. It transmits that signal through a GPIO and RX TX connection using serial communication to the ROV and the onboard Arduino Uno Atmega328P. Wired in parallel with the Arduino are three 10 A motor shields. The onboard Arduino acts as a MSC, interpreting the serial from the Pi and turning on and off the thrusters and the various sensors. The whole system is a full-duplex, meaning that the topside network send and receive data simultaneously to and from the ROV.

Design Rationale
The control system was designed with efficiency and the user interface in mind. As such, the *ROV* is controlled by an XBOX controller, whose ergonomics are endogenous. Additionally, the buttons, or the operating commands on the controller can be fully customized to meet the pilots preference. The variable switches in the XBOX controller, ie the “bumpers” and “joysticks” provide variable speed control to allow for precision adjustments, an ability often lost in momentary switches.

By using a two brain structure, the control system is split between the control box and the *ROV*, making troubleshooting easier as the main code is on the surface. The advantage of using motor shields is that you can use high amperage motors as an Arduino only outputs a maximum of 5A.

The logos and to some extent, the pathos, of the entire user interface design was to not think of the the *ROV* as the complement of hardware and software, but rather, the complement of man and machine. As such, we created a system optimized to that “part” of the ROV: an environment in which the pilots actions and controls feel natural not awkward, harnessing the full ability of the person and not just the technology and hardware.

Figure 11: The topside control box with Xbox controller (credit C. Leahy)

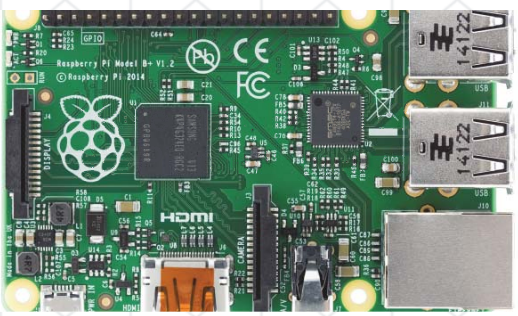

Figure 12: Top view of unconnected PCB (credit K. Leahy)

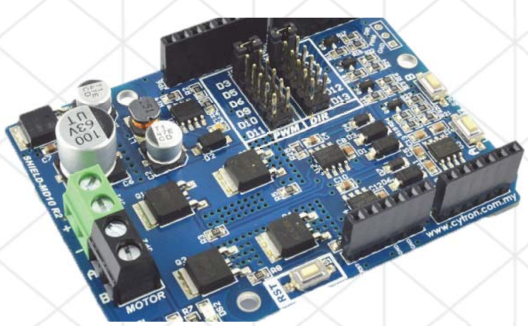

Figure 13: 12V motor shields that connect to Arduino (credit K. Leahy)

Figure 14: The tether, with varied gauge wires (credit E. Bracht)

6.4 | Tether

The tether is constructed from various gauge wires:

- 12 gauge braided wires for power
- 22 gauge solid core wire signal
- One k-type thermocouple wire
- Two coaxial cables for video
- 22gauge cable for ground

The advantage of using a hybrid tether over a multi-wire cable is you are able to reduce weight by not using an unnecessarily large amount of wires that are larger then the requisite gauge for a system

6.5 | Cameras

The cameras represent a creative repurposing of existing technology. Both of our two cameras are ultra-wide angle high definition aftermarket backup cameras you might find on an older car. The cameras can be found inside of the custom machined Delrin housing on the front end of the *ROV*. One camera is mounted at a slightly downward (85 degree) angle to see forward but have a view of the sea floor ahead. The second camera is pointed directly downward to view the sea floor or features directly below the manipulator. In event of specialized tasks such as laying an ESP cable through waypoints, this camera angle proves especially useful.

6.6 | Mission Specific Tooling

Figure 15: Version 1 of the claw, machined from Aluminum (credit E. Bracht)

6.5.1 | Manipulator

In order to accomplish all five tasks, the manipulator was built using a 3-finger clamp as a model. Its advantage is its ability to exert a massive amount of translational force by converting torque, or radial force. It is powered by a 110 rpm brushless motor attached to a differential to increase torque and increase sensitivity.

Figure 16: The thermocouple, with tapered probe (credit E. Bracht)

6.5.2 | Thermocouple

In order to accomplish part of mission one, a k-type thermocouple is attached to the *ROV*. A k-type thermocouple eliminates the need to transmit over the Digital Communication Line, saving valuable pin space on the Arduino. This is an example of utilizing existing technology when it is simply better than anything our team could make.

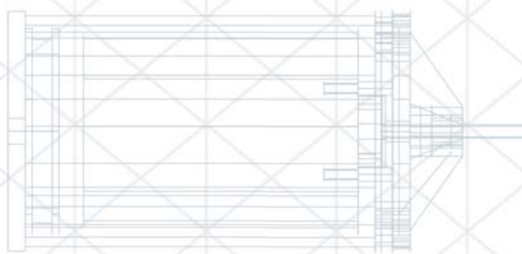

Figure 17: Schematics of proprietary thrusters. (credit E. Bracht)

Figure 18: Seabotix thrusters, utilized for forward/backward movement (credit K. Leahy)

6.5.3 | Pressure Sensor

Using the Arduino IDE, we used an Mx4250A pressure sensor and a proprietary algorithm to determine depth. The pressure sensor is used for measuring the depth of the iceberg and the depth of the pool.

6.5.4 | Thrusters

Due to the 48 cm diameter constraints our team wanted to meet, we had to use a combination of commercial and proprietary thrusters. As such our vertical thrusters are custom-built by the team out of machined Aluminum.
We utilized both oil seals and o-rings to create a dynamic yet reliable and waterproof seal. The advantage of fabricating our own thrusters is that it allows us to use brushless motors, which are cheaper and more economic alternatives to brushed motors.

7 | Future Improvements

Our ROV is an impressive machine but there are is always more to improve. To start, we could switch the forward/backward/up/down thrusters that we are currently using to corner mounted smaller thrusters angled at 45 degrees. By doing this, we would not only be able to lower the weight of the *ROV*, but also achieve full 5-axis navigation. This would enable the *ROV* to navigate even more smoothly in all directions, helping prevent potential collisions and allowing for more delicate work.

Another improvement that we hope to make in the future is to replace the Arduino Uno (and other Arduino components) with custom printed PCB boards. By personally designing the boards, we can increase the functionality of our PCB's and fully optimize the electronics for our specific use.

8 | Reflections

Zachary Heatherington: "This program has taught me that nothing is impossible, even if you have no clue how to accomplish your goal."

Alex Bacon: "By participating in the MATE 2016 competition, I learned of the importance of communication and attending meetings. Not showing up to things is not a good idea, and holds progress back."

Akash Gandhi: “MATE has taught me of the importance of hard work and the idea of persistence. We as a team have had many problems but have come together to solve the problem in an efficient manner.”

Luke Pawlak: “Getting to work with a varying group of kids who share the same unique interests as me has been nothing short of amazing. Nothing feels better than having a blast doing something worthwhile.”

Eamon Bracht: “The experience this year for me as a member was very formative. I found myself with the opportunity to hone my leadership abilities as one of the team leaders. The complexity of our robot this year also gave me the opportunity to learn more and educate a lot of our team on different engineering concepts and machining.”

Kevin Leahy: “This has been an unforgettable experience. Not only has it taught me the value of engineering and the practical application of all those years of math classes, it has been an opportunity to form lasting friendships. I am sad that this will be my last year participating in the competition with this group. I am hopeful that the future will bring new opportunities.”

Nathan Pawlak: “My overall experience was very educational and fun. I love doing anything STEM related and through *ROV* I got to learn many new skills. Due to the technical frame and electronics housing, I also learned how to use CAD.”

9 | Technical

9.1 | Technical Challenge

In order to achieve our goals, we needed to need to learn how to code. Prior to the MATE competition, no one on our team had practical programming experience. The summer provided an opportunity to gain the necessary experience in programming. We learned the two most practical languages for our purposes: Python and the Arduino language, based off of C. These programming skills provided the backbone for the entire ROV.

9.2 | Non-Technical Challenge

Our company this year was comprised of a diverse group of participants. Several of our members are highly experienced whereas other members are newcomers. Everyone had their respective skillsets and talents, all of which were invaluable, but often the abstraction and conjecture involved in describing how the challenges work and the robot would look proved to be a challenge. Ultimately harnessing the potential of the team into ideas that worked was a challenge that we were fortunately able to overcome.

10 | Project Management

Planning for this year's ROV began immediately after the 2015 competition. We realized that if we were going to be competitive on an international stage, our ROV was going to need some major improvements—most significantly: the control system. We knew that by digitalizing the control system, Flipper's overall weight would be drastically reduced as a result of having a fraction of the number of wires in the tether. The reduction in weight would be complimented by the addition of an ergonomic control system, increasing the maneuverability and overall functionality of the ROV.

The diagram below shows that the team members created every aspect of the vehicle, technical report, and marketing display. All non-commercial components were designed and built by the members of Vector Robotics. Our Mentors offered only the work space and necessary 2-deep adult presence required by the Boy Scouts for youth protection.

Task	Name	Mo	Winter	February				March				April				May				June		
		Wk	N/A	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3
R & D	Whole team		■																			
Establishing Roles	Whole team		■																			
Plan Frame Design	Eamon, Kevin		■																			
CAD Designs	Eamon, Kevin		■	■	■	■																
Buy Supplies	Akash			■	■	■																
Electronics	Marty, Alex, Zach				■	■	■															
Electronic Housing	Eamon, Marty					■	■	■	■													
Programming	Marty, Alex, Zach					■	■	■	■	■	■	■										
Static Claw	Eamon, Luke							■	■	■												
Tether	Kevin, Alex							■	■	■												
Camera Housing	Eamon								■	■												
Vertical Thrusters	Eamon. Luke										■	■	■	■								
Buoyancy	Luke											■	■									
Build Final Frame	Eamon												■									
Control Box	Kevin, Luke											■	■	■								
Build Props	Luke											■	■	■								
Technical Report	Whole team												■	■	■	■	■					
Pool Practice	Pool Deck Team												■	■	■	■	■	■	■	■	■	■
Marketing Display	Whole team											■	■	■	■	■	■	■	■			
Sales Presentation	Whole team											■	■	■	■	■	■	■	■	■	■	■
Finalize ROV	Whole team														■	■	■	■	■	■	■	■
Fundraising	Whole team																	■	■	■	■	
Safety inspection	Nathan					■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

Table 3: Work-product timeline (credit K. Leahy)

11| Lessons Learned

11.1 | Technical Lesson

With many first-time MATE participants, there were a lot of lessons learned, but more importantly, perspective and understanding were learned. The first year always provides exponential learning year for many and those members of our team gained more knowledge this year: members were exposed to machining, CAD, graphics software, CNC, coding, soldering, waterproofing and being able to conceptualize in 3D. However, a technical skill learned by everyone was CAD. This was the first year Vector Robotics used CAD, and it was a learning process for everyone, but by the end of the building period, everyone is proficient to some degree in CAD. We feel that using the resource greatly improved the quality of our work-product.

11.2 | Interpersonal Lesson

Time management was a major skill learned this year. At the beginning, many members did not know how to prioritize and balance school with extracurriculars, but as the season progressed, there was noticeable progress and development in the maturity and the responsibility of all of the members.

12 | Project Costing

Vector Robotics is loosely organized through the Boy Scouts of America. (BSA) While Vector did not receive any money from the BSA, We raised money for our travel through donations and fundraisers under the nonprofit umbrella of the BSA.

We also received generous donations from two benefactors totaling to $3,000. Additionally, we had a dues system, in which each team member contributed $100 toward the financing of the team. Another source of revenue for our team was from our GoFundMe where we raised $4,705 (as of 05/25/2016). Ultimately, we raised $8605, which was used for the robot and travel. Every member of our team has tremendous ideas, but part of making a robot is determining the financial feasibility of certain items, some high end products can be cost-prohibitive. And in those cases, we made sure to personally speak or write an e-mail to the companies explaining our team and request for discounts/donations.

Item	Amount Spent (USD)	Total Cost (USD)	Purchased/Donated/Discounted/Reused
Control System Items	**$194.61**	**$234.61**	
Raspberry Pi	$46.54	$46.54	Purchased
Arduino UNO - Kit	$65.10	$65.10	Purchased
Xbox Controller	$0.00	$40.00	Donated
Motor Shields - 12 V	$65.00	$65.00	Purchased
Ribbon Cables	$17.97	$17.97	Purchased
Thrusters	**$84.61**	**$924.61**	
SeaBotix Thrusters	$0.00	$700.00	Reused
Bilge Pumps	$0.00	$100.00	Reused
Couplings		$40.00	Material Donated
Motor Shields - 12 V	$65.00	$65.00	Purchased
Propeller	$19.61	$19.61	Purchased
Thermometer	**$28.62**	**$28.62**	
Thermocouple	$2.29	$2.29	Purchased
50ft Thermocouple Cable	$10.14	$10.14	Purchased
K-Type Digital Thermometer	$16.19	$16.19	Purchased
WEC	**$0.00**	**$400.50**	
PVC	$0.00	$350.00	Donated
Acrylic	$0.00	$10.50	Donated
Hardware/O-rings	$0.00	$40.00	Donated
Camera	**$34.24**	**$34.24**	
2 Cameras	$12.49	$24.99	Purchased
Delrin 1.5 Inch Dia 12 Inch	$9.25	$9.25	Donated
Tether	**$40.48**	**$40.48**	
200ft 22 gauge wire	$9.49	$9.49	Purchased
50ft RCA DC Cables	$30.99	$30.99	Purchased

Connectors	**$279.41**	**$558.82**	
SubConn Connectors	$279.41	$558.82	Purchased @ 50% Discount
Frame	**$200.00**	**$691.39**	
Total Cost for Frame	$200.00	$691.39	Purchased @ 71% Discount
Presentational Items	**$48.00**	**$48.00**	
Scientific Tri-Fold Poster	$48.00	$48.00	Purchased
Reports/Pamphlets	$0.00	$0.00	Donated (printed @ home)
Project Reports	$0.00	$0.00	Donated (printed @ home)
T-Shirts	$384	$384	Purchased
Miscellaneous/Travel	**$20.00**	**$100.00**	
Nuts/Adapters	$20.00	$100.00	Donated

Table 4: Project Costing (credit A. Gandhi)

Table 5: Project Costing Summary (credit A. Gandhi)

Total Cost of ROV (USD)	$3,061.27
Total Value Donations	$600.50
Total Value of Reuse	$800.00
Total Value of Discounts	$718.80
Total Amount Spent (USD)	$909.97

Table 6: Trip Costing Summary (credit E. Bracht)

Vector Robotics International Competition Estimated Trip Cost		
Category	Unit Cost/description	Category Total
Airfare	One way ~150 * 2	~300
Hotel	119/night (4 people/room) (4 nights) + tax	137
T-shirts	20 * 3 shirts (1 for each day of competition)	60
Incidentals	unexpected costs	150
Food	Recommended 30/day (breakfast included in hotel) * 4	120
Total	Cost of trip/person	767
Total Cost for Youth Team Member		6136

13| Lessons Learned

Item	Amount Spent (USD)
Electronics	**$565.00**
Control System	$320.00
Rapsberry Pi	$40.00
Aruino UNO - kit	$70.00
50ft ethernet	$20.00
Xbox Controller	$40.00
3 motor shields - 12 v	**$70.00**
Ethernet Sheild	$40.00
Logic Converter	$10.00
x3 Ribbon Cables	$30.00
Thermometer	$35.00
Thermacouple	$5.00
Thermacouple Cable	**$10.00**
K-Type Digital Thermometer	$20.00
Camera	$170.00
Esky Backup camera	$30.00
Monitor	**$140.00**
Tether	$40.00
50ft ethernet	$10.00
50ft RCA DC Cables	$30.00
Hardware	**$225.00**
Housing	$125.00
Binder Plugs	$125.00
Frame	**$100.00**
Presentation	$250.00
Poster	**$100.00**
Reports/Pamphlets	$75.00
Project Reports	$75.00
Total	$1,040.00

Table 7: Project Budget (credit E. Bracht)

14 | Acknowledgements

Thank you to the Lemont United Methodist Church for allowing us to use their facilities.

We would like to thank all of the parents and instructors who generously donated hours of their time.

We would like to thank H&B Machine for providing the supplies necessary to machine our teams various components.

We would like to thank the Lemont CORE for allowing us to use their pool for testing our ROV.

We would like McCartney Plugs for the generous discount they gave to our group.

We would like to thank the Lemont United Methodist Church for allowing us use of their meeting room for weekly sessions.

Every ounce of outside help has contributed to this amazingly rewarding and successful experience. We cannot thank you enough.

We would like to thank MATE for their hard work in organizing and promoting this program and STEM education around the world.

15 | References

1. Digital image. N.p., n.d. Web. <http://subseaworldnews.com/2014/08/04/video-quick-tour-of-ev-nautilus/>.
2. Digital image. *Space.com*. N.p., n.d. Web. 26 May 2016.

Appendix A | Software Flow Chart

Xbox Translator (PI)

1 Xbox Controller Inputs are pressed
2 *XboxDRV* driver reads them, passes long string of all button settings
3 If the button is a variable trigger/joystick
3.1 Pass through a scalar filter and dead zone applicant
4 Python script filters it through regular expressions and only outputs those button values which have changed

To

Serial Generator (PI)

1 Initializes values and establishes connection with Arduino
2 Reads values from the Xbox Translator
3 If value is the pressure data button
3.1 Send command to retrieve data
3.2 wait for response
3.3 apply math to response and print out on the console
4 send a command of motor corresponding with the pressed button, if applicable
5 back to step 2

To

Command Interpreter (Arduino)

1 Initialize values, including motor patching information, and establish communication with the raspbian
2 Read in commands (button, value)
3 If data receive command
3.1 Read data and send it back though GPIO
4 If assigned key, relay the proper value to the correct motor shield for power to the motor
5 repeat from step 2