Smithsonian

Tethered Exo-Mariner Remotely Operated Vehicle

Smithsonian Marine Station Student Interns, Fort Pierce, Florida

Team STEM ROV

Emma Bennett, 17
CEO & Chief Design Engineer; STEM ROV
MAST Academy: Maritime and Science Technology High School
11th Grade
Mecha Makos Engineering & Robotics Club Treasurer
Hometown: Miami, Florida
Field of Interest: Medicine, Biotechnology, Robotics, Botany
Special interests: Art, Scuba Diving, Languages, Conservation

Kendall Lee, 17
Fluid & Payload Specialist, Engineer; STEM ROV
John Carroll High School, Ft. Pierce
11th Grade
Hometown: Stuart, FL
Field of Interest: Engineering
Special interests: sailing and fishing

Barry Smith, 17
Safety Captain, Co-Pilot, Engineer; STEM ROV
Lincoln Park Academy, Ft. Pierce
11th Grade
Hometown; Port Saint Lucie
Field of Interest: Environmental Engineering,
Special interests: Game Design

Nicholas Stange, 17
Engineer, Stats Technician; STEM ROV
MOA school @ Westwood High School
10th Grade
Hometown: Fort Pierce, Florida
Field of Interest, Environmental Engineering
Special interests: Sailing

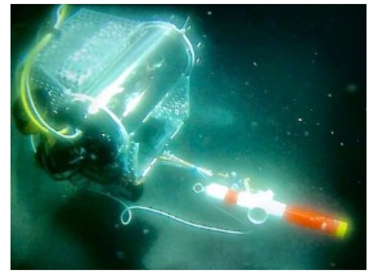
Mentor

Woody Lee
Mentor, Captain, STEM ROV
Research Specialist
Smithsonian Marine Station
Fort Pierce, FL
Hometown: Stuart, FL

Prepared For:

Marine Advanced Technology Education Remotely Operated Vehicle Competition

ABSTRACT



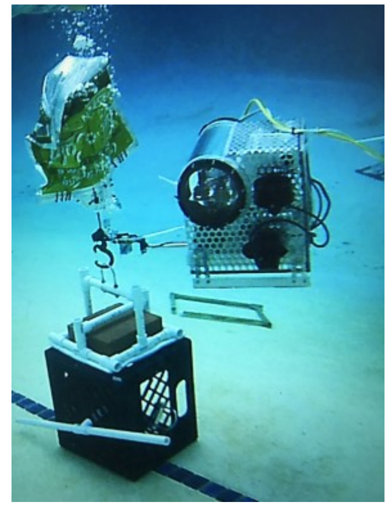
The Smithsonian Tethered Exo-Mariner ROV, STEM for short, is in its third year of business. With the experience gathered from two previous missions we are more prepared and specialized to provide real-world marine technology services. We have a well-seasoned, tightly knit group of highly trained engineers, technicians and scientists ready to win the contract from the MATE Center and the Applied Physics Laboratory at the University of Washington.

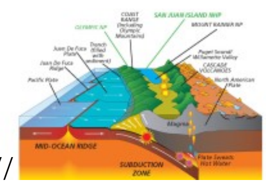
Our Remotely Operated Vehicle has been prepared and outfitted to perform the specific tasks, which include: locating the wreckage of an aircraft and returning its engine to the surface, the installation/ recovering of a seismometer, and installing a tidal turbine with instrumentation.

The modular chassis design is small, highly maneuverable, and adaptable; payloads objectives can quickly be changed depending on the mission. The on board multi-configurable actuator arm and gripper system is capable a wide range of work from sensitive sea grass transplantation to having enough torque to recover heavy loads.

We have made a few changes to our ROV specific for this missions' success. The budget for the mission allowed for new thrusters capable of lifting and retrieving the wreckage, new drone software and technology for implementing greater maneuverability. Additional sensors have been added for murky conditions and Bluetooth communication has been programed between the ROV and the OBS to release only when triggered by the STEM ROV ensuring no loss of equipment.

Six hundred man hours have been devoted to accomplish the proposed missions.





http:// cdn3.theeventchronicle.com/wp-content/uploads/2016/05/ cascadia.jpg

https://marineenergy.biz/

Team STEM ROV Interns

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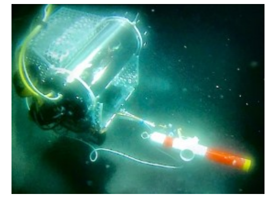
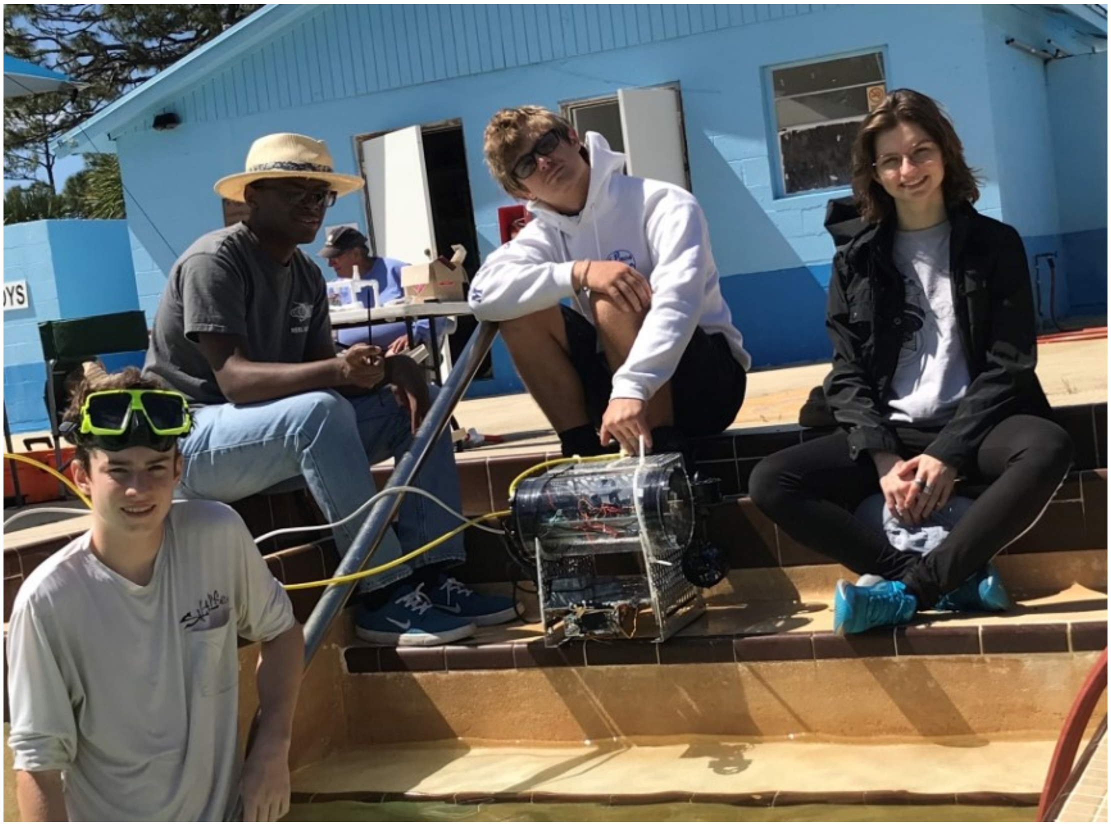
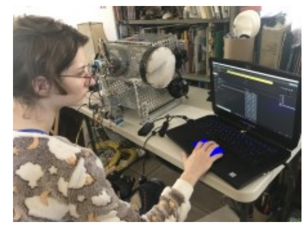
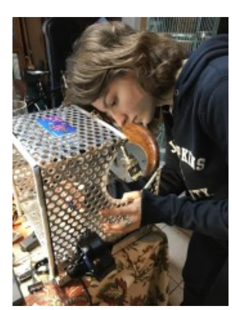


The STEM TEAM







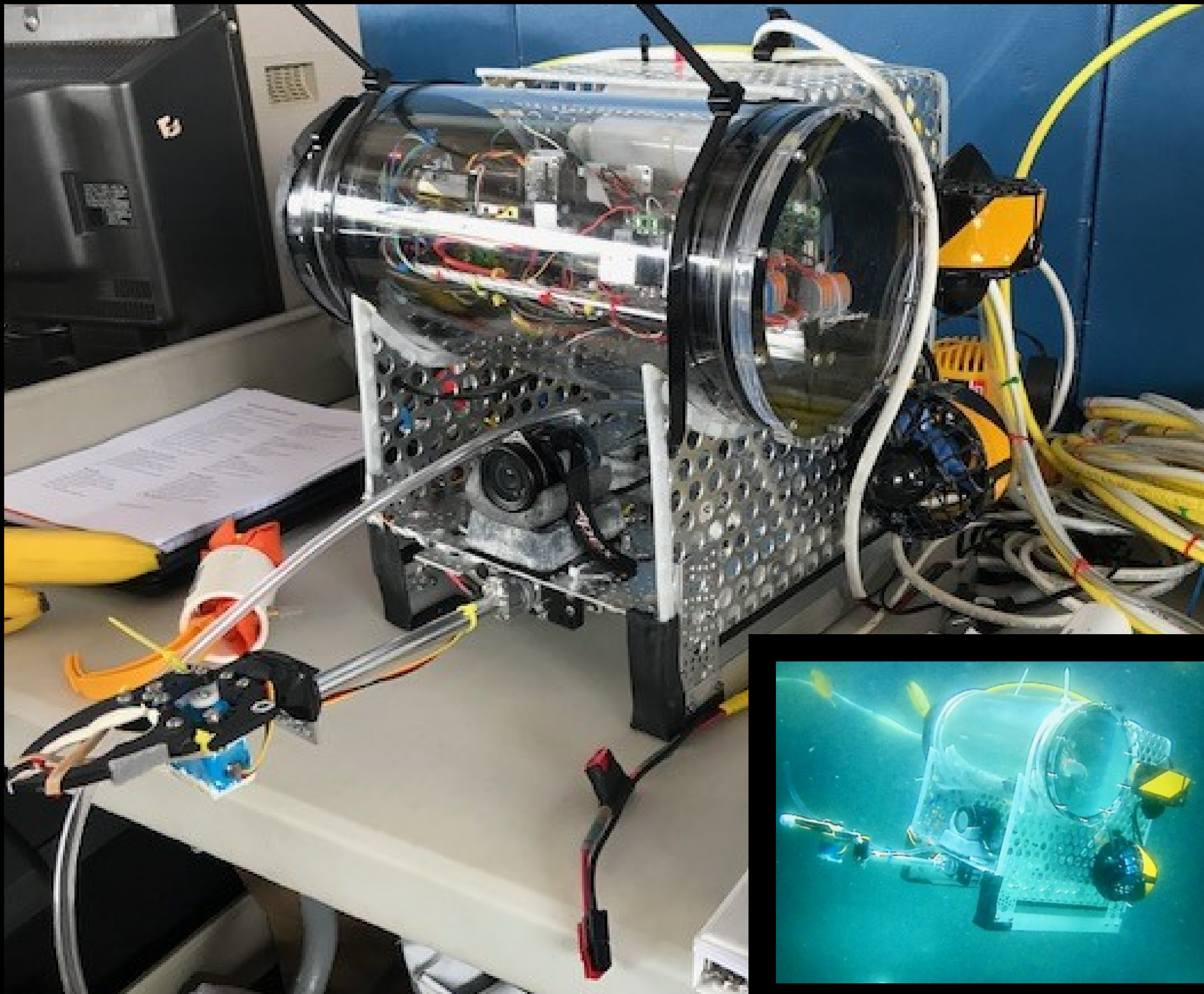
The STEM ROV team has been working together since we met over 4 years ago at the Smithsonian Marine Summer program; where besides working on collecting specimens and participating in local marine industries we would work on small ROVs at the Smithsonian Marine Station with our now Mentor, Woody Lee, a Research Specialist at the Lab. Three years ago I proposed the idea to Mr.Lee that I would like to form a team to build ROV's for competitions. We established our team and since then our team has become ambassadors for STEM ROV Robotics and Smithsonian Interns; volunteering and putting on demonstration at events like the World Ocean Day at the Smithsonian Aquarium in Ft. Pierce. Traveling from as far as Miami, we are committed to meet on the weekends and work on the ROV. We have participated in the last three MATE competitions in Florida and are proud to be going to the Internationals in June.

Emma Bennett, CEO,
Chief Design ENG.
11th Grade 17
MAST Academy
3rd year MATE 215hrs

Kendal Lee, Mission Specialist, Engineer
11th Grade 17.
John Carrol Catholic HS ,
3rd year MATE 140hrs

Barry Smith, Safety Captain, Co-Pilot
11th Grade 17
Lincoln Park Academy
3rd year MATE 115 hrs

Nicholas Stange, Engineer, Research Technician
10th Grade 16
MOA-Westwood HS
2nd year MATE 130hrs



STEM ROV

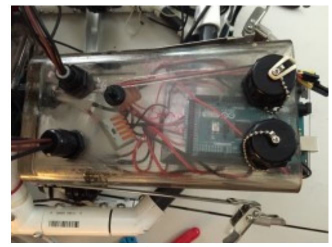
Smithsonian Tethered Exo-Mariner ROV

Design Process

The process and design rational starts with analyzing the parameters of the mission; constraints and tasks to be accomplished *underwater*.

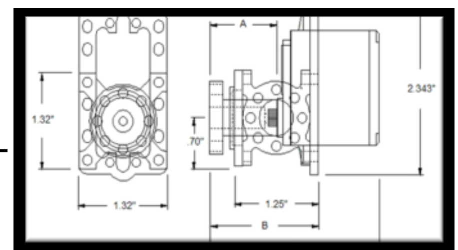
Year 1

The Design development of the Smithsonian Tethered Exo-Mariner ROV has lasted 3 years and it's far from being finished, there are always to improve upon its design. The team has spent countless hours prototyping and testing, failing and learning from those failures. It is a labor of ingenuity and hard work. This years mission started the day after the Florida Regional last year. We gather as a team and discuss what went wrong and what went right. How we could improve as a team and started planning for the following year. It is a critical analysis but, we as a team are incredibly proud of the work we have done to date.



repurposed camera case

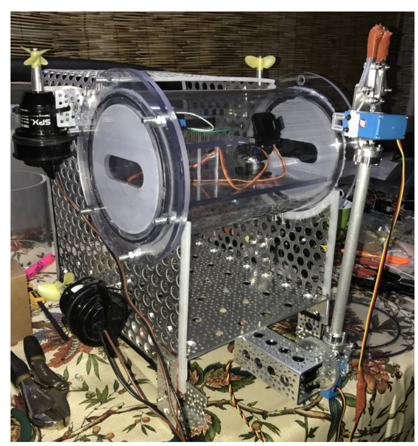
The first Mission our client sent us out of this world to Europa one of Jupiter's moons, we kept in mind the volcanic vents deep under our own Ocean in order to design and build a small robust ROV.



Servo gear box manipulator

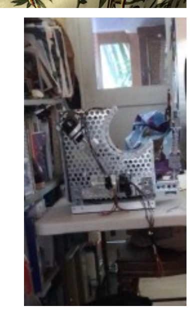
A series of designs options were discussed and sketches were drawn. Budget and materials were reviewed, and schedule of meeting and individual jobs were assigned. Its pvc frame held a manipulator with 3 degrees of freedom, two cameras and several sensor, we learned to pot the camera and sensor to protect them from the harsh environment where our mission would take us. We learned how to become electrical, software and environmental engineers. Electricity and water were formidable opponents.

Year 2



The second year our client was the Port of San Diego where we mapped lost cargo containers, cleaning up toxic material and fixing the light show equipment.

We had learned the effects that water pressure had on our waterproof containers and how neutral buoyancy was ever changing. We abandoned the PVC and the small repurposed camera case and built a new modular aluminum chassis. A Local plastic shop, Faulkner Inc. of Miami, sponsored the labor to create our polycarbonate 6"dia. Water proof container . We laser cut the opening at the cap for our new penetrators from Bluerobotics, an improvement from the plastics compression fitting from the previous year. We added to our payload tools a brushless motor water pump with an agar collector and an HD low light Raspberry Pi Camera.



Design Process

The Third Year :

Present mission is in JET CITY and our ROV needs to maneuver around wreckage to remove debris and recover a vintage airplane engine using our custom made lift bags, install a co Ocean Bottom Seismometer (OBS) and activate a its release from the ROV. Finally, our ROV must install a tidal turbine and monitoring equipment but first we must find the Wreckage, we leave the computations to Nick, while I pilot the ROV to transplant sea grass. On deck Kendall is ready with lift bags and props while Barry makes sure all safety protocol if being followed tether in hand.

New custom propeller safety guards

MOTORS

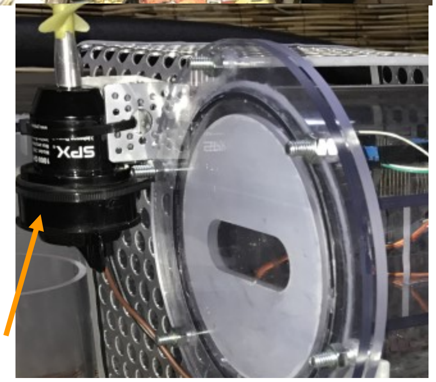
Time to retire our old bilge motors.

To accomplish the Jet City missions we needed more power and efficiency in our motors.

Motors; brushed vs brushless,

The brushless motors were more efficient, compact, had greater thrust, and were water cooled. We researched and found that the Bluerobotics thrusters were the most economical and would work seamlessly with our Pixhawk and QGround control from the previous year.

We switched over to Electronic Speed controls ESC for the brushless motors. The software we were using in our Raspberry Pi (Ardusub) was already giving us on board telemetry including a compass and a gyroscope. The ESC's are programed into the software for easy motor configuration and control.

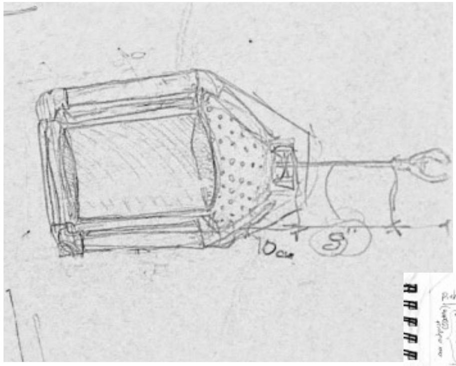


The difference in power and performance was amazing! We use two T100's as vertical thrusters and two T200's for horizontal movement. This was a budgetary decision.

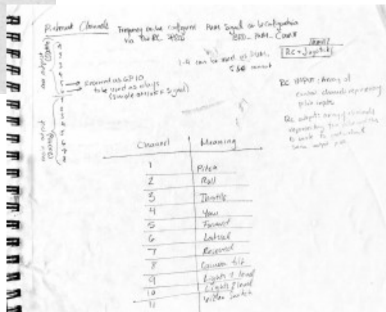
At 50 % power 12volts we have more than enough thrust to get the job done. The motors were also the perfect size to replace the existing bilge motors on our frame with no modifications, we mounted them with low profile aluminum hub spacers.

Design Process

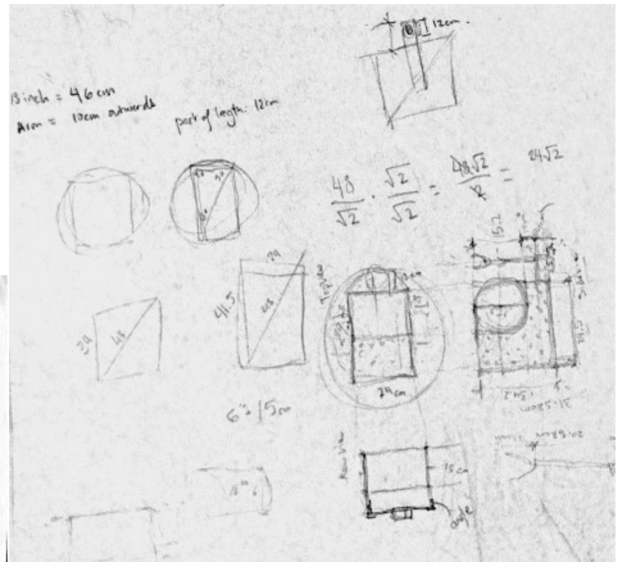
Sketches/Brainstorming



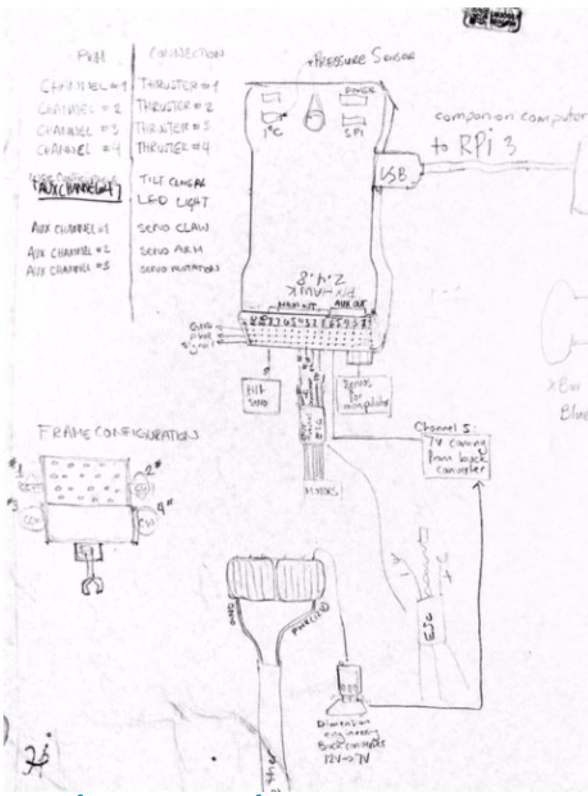
Alternate WPC layout



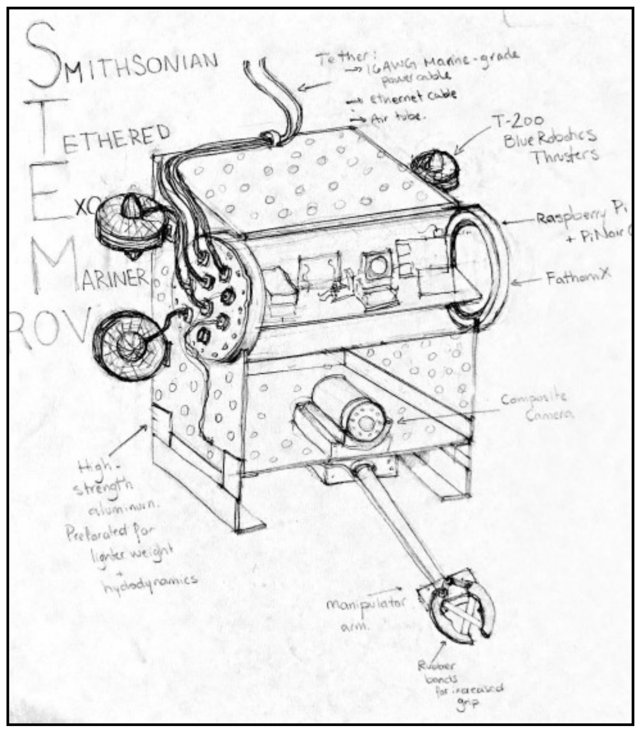
Software Ardusub components

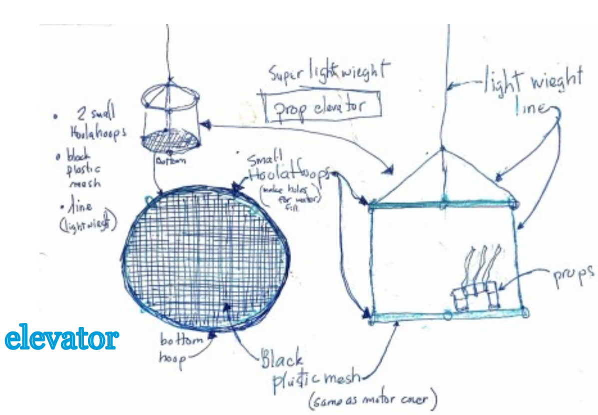


Size calculations



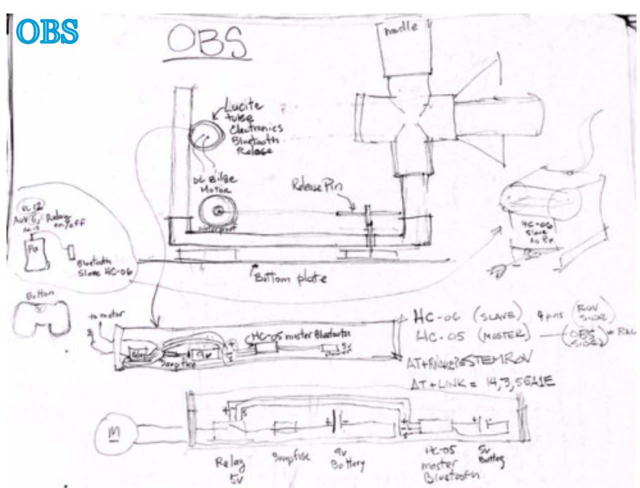
interconnections





elevator

OBS



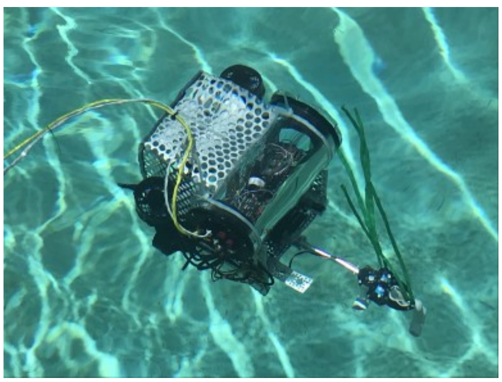
Design Process con't

QGround Control is a free app that works as a mission planner providing full flight control with MAVLink (drone technology). It provides configuration with Ardusub an open source software that runs on our Raspberry Pi, allowing us to calibrate our motors from the laptop mission planner! This also allows use an Xbox controller via Bluetooth to control the ROV.

2017 Aluminum frame

The Frame designed from last year was still the perfect size for Jet City mission and the light weight pattern aluminum allows for easy changes and add-ons.

The footprint 23cm x 30 cm (9"x12" Actobotic pattern plate) is the bottom platform of the ROV and additional plates can be added for multi platforms/payload missions.

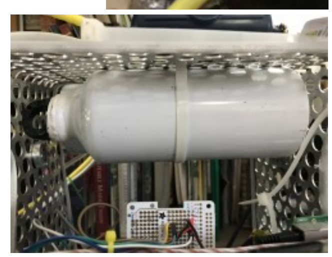


Put polycarbonate **WPContainer** housing our on-board electronics needed replacing; it became our prototype. This was the most important budget item of the year. We wanted to use the same frame and we needed to reuse our penetrators; fortunately Bluerobotics added to their products last summer a 6" diameter acrylic WPC-the perfect solution, allowing us to keep out existing frame and reuse the penetrators.

Prototype—New purchase Waterproof containers

We designed an aluminum slide tray for the new WPC that acts as a sink acts to dissipate the heat from the electronics. We also installed a valve to vacuum test the integrity of the waterproof container and for easy end cap removal.

Keeping our electronics dry has been the key to our success .



Buoyancy is supplied by the WPC and balance in the rear with a pair of Aluminum water bottles.

Tether

This year we replaced our commercial cat 5 ethernet cable with a buoyancy neutral high impact, Kevlar strength tether . It features:

High-visibility yellow polyethylene foam jacket and water block fibers throughout cable to stop any leaks from rips/holes , we were able to purchase a remnant for $20.00! This was an excellent find , last year our cable got pinched in the car and a whole day of practice was wasted because the kink ended up damaging the twisted pairs and it took another day of trouble shooting the electrical system to find the problem. We at-

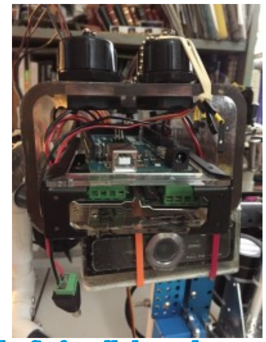
Development of Control and Electronics

Development and prototyping of the controls and electronics on board of the STEM ROV:

Our process has developed over the last three years and our team has taken lessons learned and applied them to the final MATE 2018 STEM ROV and this is no exception when it come to the controls and electronics.

First year 2016 :

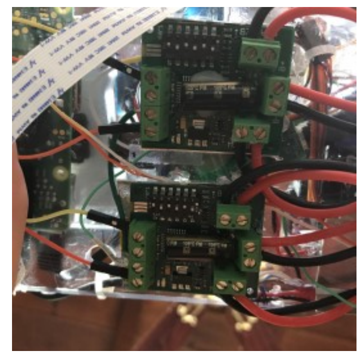
We worked very closely with the MATE website emulating the Triggerfish ROV; the information was invaluable to our team. We put together a system that encompassed an Arduino Mega programed to control the 3 servos with a Joystick and two Sabertooth Motor controllers for our 4 brushed bilge motors with a PlayStation 2 using Bill Porters outstanding opensource software for PS2 to control motors.



Tight fit for all the arduinos and cable conectors

Second Year 2017:

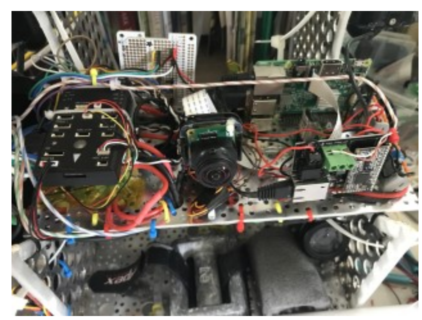
We reused our 4 brushed Motors and our 2 Arduinos that communicated by RX/TX serial to the deck laptop and our PlayStation 3 and we added a Pololo mini servo controller for our Manipulator Arm. Our main addition that year was a Raspberry Pi camera which replaced. With the RPi on board we needed to view the video feed on the laptop and found that Qground Control worked very well. Using QGroundControl app (downloadable for free) to view our video stream was not the only benefit, BlueRobotics had adapted a open source drone software from ardupilot and adapted it for ROV's; we had our first shot at ARDUSUB. Now with telemetry on board we had the sensors added to the QGroundContol on our laptop via a Pixhawk that read the yaw and pitch and compass heading on mission planner QGC. Dreams of on day creating our own flying ROV was a possibility.



Sabertooth 2x5 motor controls/ RPi camera

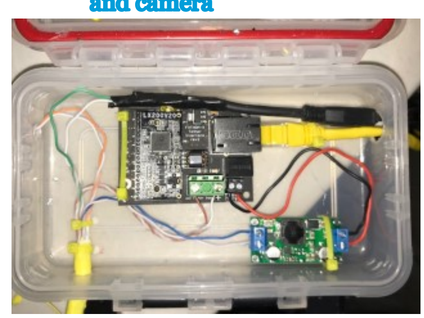
Present Day 2018:

We had a design decision to make that was critical to our controls and electronics–our motors needed updating and as a team we decided to upgrade to brushless motors (for all the benefits see, motor section). The new thrusters would enable us to build upon last years design by fully implementing the capabilities of the Pixhawk–Raspberry Pi w/Ardusub—QGoundControl mission planner. Using the Pixhawk with the Rpi expands the peripherals that can be added to the board safely. Its ease of use makes it possible to set up many types of motors anf switches



Pixhawk ESC' RPI board and camera

The Raspberry Pi 3 B+ was an improvement over the Arduinos; it is a true computer able to do many tasks at once. We were now able to eliminate the arduinos, sabertooth and pololu servo controller. The Pixhawk is able to handle up to 8 motors and several servos, relays and additional sensors, leaving room to add more motors for future missions. The Arusub software allows the design of the ROV to be configured with different motor setups ups for outstanding manuverability. Electronic Speed Controls ESC's are connected to the Pixhawk to control the thrusters , the RPi communicates between the ROV and the on deck laptop via two wire Ethernet tether. Ardusub and QGround Control is setup to use a variety of gaming controllers , we chose the Xbox Bluetooth to control the system because of its many possible button and joystick variations. The software uses RC drone controls and converts them as the joystick buttons on the Xbox. The XBox controls the thrusters, relays and actuator servos for ease of use by the pilot. We also reduced the number of cables and wires in our tether to one twister pair by consolidating the controls; leaving us 3 pairs with which to take power back up to the deck and additional wires for cameras or sensors. Making it highly adaptable to any mission.



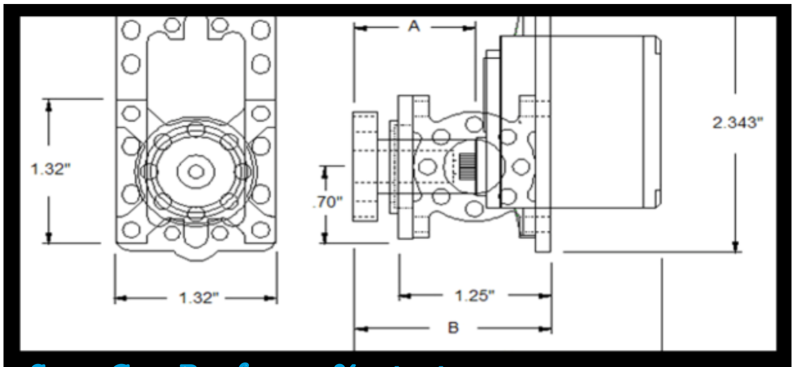
Deck control box fathom X ethernet board

Step-up 12v reg. and signal for composite camera

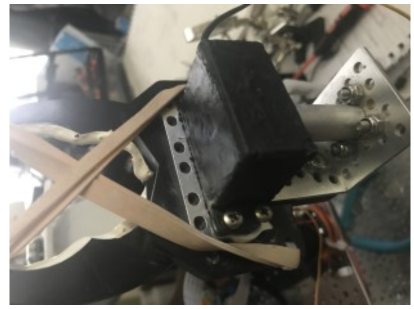
Design Process con't

Waterproofing SERVOS for the Actuator

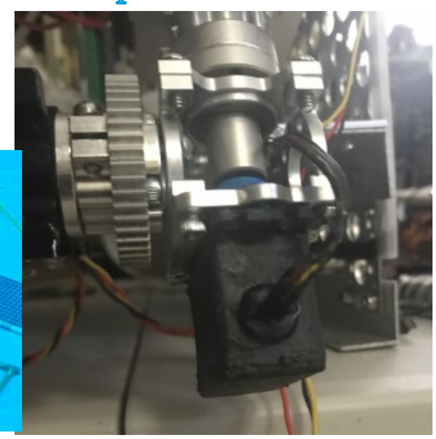
Two years and 10 servos later we have learned that the best way to keep water out of a servo is by filling them with a non conductive oil. So far this solution along with a few other exterior sealants has work for the STEM Actuator. For this mission we did not need many degrees of freedom so we as a team opted to remove a servo at the shoulder of the arm and shortened the reach, leaving two servos to manipulate to actuator –reduces the % risk of a malfunction.

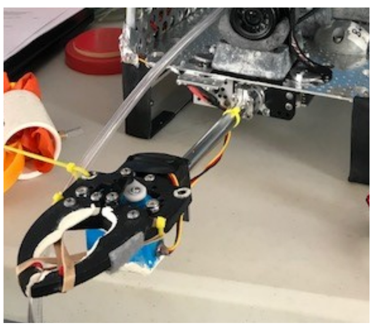


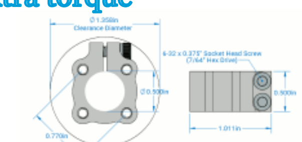
Servo Gear Box for 200% extra torque



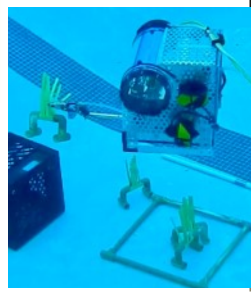
Waterproofed WP Hitec







Actobotic gripper, pattern plate and gear boxes

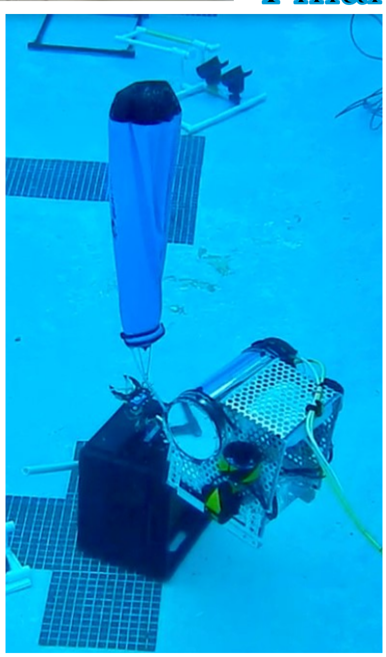


OBS

Prototype

Frezzer bag

Final Product



Lift bags for Vintage Plane Weckage Mission

System Components and Future Improvements

Electrical:

Use of Dimension Engineering switching regulator to smooth out the electrical fluctuations have improved the brown outs between the piPhawk and RPi . Everything works smoother with a steady flow of current. The regulators/buck down are very efficient 88 % . We have several : a 12v to 7v for the servos, a 12v to 5v for the raspberry pi3 and small pan and tilt servos, the composite camera and the Fathom . We have a boost up on deck in our control box to supply power to the Fathom X tether boards. SEE SID for future info.

Cameras:

Two cameras on board and we might add another under the platform to better see the lift bag connections. to the claw . Raspberry pi noir and a Ken-a-Vision Aqua Flex composite Camera

The composite camera now powered on the ROV and a twisted pair in the tether carries the signal back up to a tube Commodore Monitor, (CRT monitor screen is visually superior in the sunlight). The PI camera is feed to the QGround Control mission planner on the laptop.

Safety features for the STEM ROV:

- Motor shrouds,
- 10 cm abs prop mesh guards ,
- Thermoplastic molded skid covers and penetrator shield,
- Plastic trim on all exposed edges,
- Wiring channeled and secured brightly marked motor shroud,
- Bright yellow Kevlar strength neutrally buoyant tether,
- QGround Control has mission parameters

  that can be set to disarm the ROV instantly if a problem is detected,
- Ardusub can configure the thrusters to hold a depth and heading.

Future Improvements:

- Design and build a actuator without brushed motor servos.
- Buy an auto CAD or Mastercam sketch our designs so,

  Barry and Nick can become masters at CAD designs
- Work on making a second Chassis with some improvements in strengthening the exterior aluminum with a higher grade and work with some polycarbonate.
- Improve our electronic tray
- Add more cameras and manipulators
- Add more thrusters

Acknowledgments

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Thank you to the people that make this possible for our team:

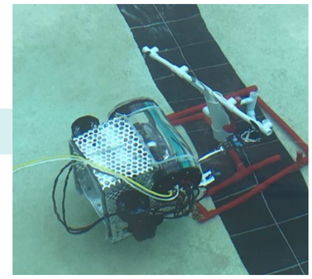
Our Mentor Woody Lee, who is always looking for pools and never lets us slack off, in a good way.

Gratitude to All OUR PARENTS, for their constant support.

The Tanah Keeta Scout Reservation facility for pool use.

The Smithsonian Marine Station, Ft. Pierce Florida for allowing us the incredible opportunity To be part of there Institution,

Smithsonian Tethered Exo-Mariner ROV MATE Competition 2018



Budget Summary

Estimated Budget **$1,500.00**

Item	Category	Qty	purchase	Reused	Cost	donated	Total Cost
Aluminum (for frame)	hardware	1		✓	$ 35.00		$ 35.00
actobotic gears, beams and plates	hardware	1		✓	$ 120.00		$ 120.00
actobotic gripper	hardware	1		✓	$ 30.00		$ 30.00
aluminum nuts and bolts	hardware	1		✓	$ 45.00		$ 45.00
prop materials	Supplies	1		✓	$ 100.00		$ 100.00
marine 16 awg power cable	tether	1		✓	$ 40.00		$ 40.00
3/16" ID vinyl air hose	tether	1	✓		$ 35.00		$ 35.00
20 meters tether (remanent)	tether	1	✓		$ 20.00		$ 20.00
raspberry pi 3 b	electronics	1		✓	$ 40.00		$ 40.00
pixhawk	electronics	1		✓	$ 60.00		$ 60.00
dimension engineering voltage regulator	electronics	3	✓		$ 30.00		$ 90.00
raspberry pi camera	electronics	1		✓	$ 30.00		$ 30.00
WPC 6" Dia	Hardware	1	✓		$ 225.00		$ 225.00
penetrators	hardware	13		✓	$ 5.00		$ 65.00
pressure gauge	sensors	1	✓		$ 40.00		$ 40.00
valve penetrator	hardware	1	✓		$ 12.00		$ 12.00
waterproofing materials/ epoxy	supplies	1		✓	$ 45.00		$ 45.00
tether conectors	electronics	2	✓		$ 80.00		$ 160.00
Hi-tec WP servos	motors	2	✓		$ 35.00		$ 70.00
thrusters	motors	4	✓		$ 175.00		$ 700.00
ESC	electronics	4	✓		$ 30.00		$ 120.00
composite camera	electronics	1	✓		$ 60.00		$ 60.00
air compressor/on loan	tools					✓	$ -
donation					$ 500.00	✓	$ -
regional hotel rooms	travel	3	✓		$ 100.00		$ 300.00
							$ -
						Total expences	$ 1,762.00
						Total Expenses Re-use/ Donations	$ 1,000.00
						Total Fundraising	$ 1,262.00

Smithsonian Tethered Exo-Mariner ROV **MATE Competition 2018**

Project Costing

Estimated Budget **$1,715.00**

Item	Category	Qty	purchase	Reused	Cost	donated	Total Cost
ROV FRAME/ manipulator	hardware	1		✓	$ 500.00		$ (500.00)
Servos	motors	2	✓		$ 40.00		$ 80.00
Thrusters	motors	4	✓		$ 200.00		$ 800.00
Tether	hardware	1	✓		$ 45.00		$ 45.00
Electronics/software	electronics	1		✓	$ 100.00		$ 100.00
Electrical/Power components	electrical	1	✓		$ 100.00		$ 100.00
Water-proof container	hardware	1	✓		$ 250.00		$ 250.00
waterproofing materials/ epoxy	supplies	1	✓		$ 40.00		$ 40.00
air compressor/battery/laptop (on loan)	tools					✓	$ -
travel	travel	3	✓		$ 100.00		$ 300.00
cash donated	general					✓	$ 500.00
						Total Raised	$ 500.00
						Total spent	$ 2,215.00
						Final balance	$ 1,715.00

Job Safety Analysis (JSA)

HOUSEKEEPING

TASK HAZARD PROTOCOL Follow safety checklist, use personal protection equipment(PPE), Keep all non-authorized people out of work areas, and/or at a safe distance.

Smithsonian Machine Room:

- Mentor Supervision of Machine Room on Site at all times as per Smithsonian protocol.

Keep a Well Organized CLEAN Environment at all times. Follow Safety Check List for each situation.

- Machine Rooms
- Electrical Work Area
- Pool Side Protocol

PERSONAL PROTECTIVE EQUIPMENT

HAZARD PROTOCOL

- MUST WEAR PPE (personal protection equipment) at all times.
- Use Personal Protection Equipment when working with machinery and electrical equipment
- Safety Glasses, Gloves, Thermal Gloves, Close toe shoes, appropriate clothing; no lose clothing that can entangle in machinery or catch fire. Hair appropriately restrained.
- Deck Crew near edge of pool wear life vests in case of unexpected immersion in water. Deck crew handling ROV wear helmets in case of slip and fall while carrying/handling ROV.

Electrical Work Area Protocol:

- Follow safety checklist, use personal protection equipment(PPE)
- Electrical wiring avoid equipment failure -use correct voltage-power down before any work or connection of electrical wires.
- Proper grounding, double, triple check wires are in proper location before powering on. All PCB, Microcontroller current turned off while connecting, splicing or soldering.

POOL SIDE PROTOCOL: Mission Runs, Perform Operational and Safety Checklist(see add.list)

- all electrical wiring and motor are appropriately waterproofed and sealed prior to submersion. No exposed wires or motors.
- WPC is vacuumed checked prior mission to ensure NO LEAKS!
- Leaking and breaching of electrical systems preform immediate shut down and removal from water.
- Keep all electrical tools and extension cords at a sake distance from the pool side, ask for driver assistance if unforeseen problem occur with ROV or Tether entanglement.
- No Running

General Shop work:

- Keep tools organized and area swept at appropriate intervals,
- Wear PPE:
- Prevents stepping on sharp items and tools, Putting all items back where they belong,
- Wear close toed shoes, no lose clothing or hair to prevent entanglement or a fire hazard.
- Electrical Power Tool (soldering iron), use appropriate holding stand and wear PPE, keep at specified safe temperatures.
- Avoid Unsafe contact with skin or clothing, flying or hot debris.
- Hold and use tools as per manufacturer's instruction for intended use.
- Accident Prevention: Puncturing of skin, burns, flying debris;WEAR Eye protection, gloves, close toed shoes.
- Stay alert of your surroundings.

HAND SAFETY

HAZARD PROTOCOL

- Laser Cutter: Contact with fingers, keep lid closed, watch for sharp edges.
- Drilling: Contact with fingers, wear work gloves, keep hand clear of drill bit.
- Soldering: The use and contact of hot objects, keep clear of hot surfaces, notify others of hot surfaces, stow hot iron in designated areas.
- Drill Press: To prevent hitting fingers,use designated clamps, Keep hands clear.

LIFTING & BACK SAFETY

HAZARD PROTOCOL

- Moving the ROV- Heavy lifting injury prevention; appropriately lift heavy objects- Lift with the knees.
- Launch/Recovery of ROV poolside from awkward position. Kneel on deck, use caution,- don't overreach and don't fall in the water.

- ROV supply boxes- Lift with the knees, use handholds, keep the load close, Moving ROV Monitors, Batteries, Case- Use wheels when possible, ONLY lift in pairs; transport of ROV Heavy weight/ Use rolling cart.

TOOL SAFETY

HAZARD PROTOCOL

- Drill Press; Damage to skin / Crushing of fingers
  Safety Glasses, Gloves, Close Toed Shoes
- Dremel; Breaking of skin, flying debris eye injury; Safety Glasses, Gloves, Close Toed Shoes
- Soldering Iron; Serious burning of skin or eye injury, solder splattering- Safety Glasses, Close Toed Shoes,
- Hot tip always returns to holder/cleaner
- PVC cutter; Cutting of fingers, flying debris eye injury- Safety Glasses, Close Toed Shoes
- Compressed Air /Pneumatics – MATE Fluid Pressure Quiz- must Pass.

ELECTRICAL SAFETY

HAZARD PROTOCOL

- ROV Operation / Electrical Shock Prevention
- Follow all checklists, keep extension cord dry.
- Troubleshooting ROV Control System/ shock - Power Off.
- ROV Electrical Design & Fabrication
- Electrical systems failure: Use fuse, diodes, comply with MATE regulations.
- No AC Current on ROV
- Non-ROV powered equipment limited to DC power with 3 amp fuse.
- OBS WP container built in such a way that it cannot hold pressure more than a few PSA above ambient in case of venting of gases. Two rubber stoppers at each end of a Lucite tube held only by friction applied by hand
- Marine approved waterproof power cables- power supply in water.
- Anderson Pole Connectors/ No Lithium Batteries on board

Operational and Safety Checklist

Vacuum Test Procedure

• Connect vacuum hand pump to ROV electronics housing

• Pump electronics housing to -35 kpa vacuum

• Verify electronics chamber holds -35 kpa vacuum for 5 minutes

• Remove vacuum pump and securely cap vacuum port

Pre-Power

• Area clear/safe (no tripping hazards, items in the way)

• Tether laid-out on deck

• Tether connected to Control Box and Secured

• Control Box/Composite Camera connected to Monitor

• Power source connected to Monitor

• Tether connected and secured to ROV

• Tether strain relief connected to ROV

• Electronics housing sealed

• Visual inspection of electronics for damaged wires, loose connection

• Penetrators tight on electronics housing

• Thrusters free from obstructions

• Check vacuum port is securely capped

• Deck crew check each other to make sure all wearing appropriate Personal Protection Equipment.

Power-Up

• Air Compressor connected/receiving 12 Volts nominal

• Control computers up and running

• Ensure deck crew members are attentive

• Call out, "powering on!"

• Power on: Top control box, Xbox, Monitors

• Call out, "performing thruster test"

• Verify video feeds, QGround Control

• ROV lights indicate "Safe Mode" (blue)

• Calibrate Sensors

Launch

• Call out, "prepare to launch"

• Deck crew members handling ROV call out "ready"

• Call "launch"

• Launch ROV, maintain hand hold

• Perform thruster test/verify thrusters are working properly (xBox movements correspond with thruster activity) Test Thrusters: Forward, Reverse, Left, Right, Up, Down

• Wait for release order

In Water

• Visually inspect for water leaks

• If there are large bubbles, pull to surface immediately

• Engage thrusters and begin operations

ROV Retrieval

- Pilot calls “ROV surfacing”
- Deck crew calls “ROV on surface”
- “ROV captured”, kill thrusters
- ROV lights indicate “Safe Mode” (green)
- Power Down
- Call out “safe to remove ROV”
- After securing the ROV on deck, deck crew calls out “ROV secured on deck”

Leak Detection Protocol

- Surface immediately
- Power down ROV
- Inspect (may require removal of electronics)

Loss of Communication

- Cycle power on TCU to reboot ROV
- If no communication, power down ROV, retrieve via tether
- If communication restored, confirm there are no leaks, resume operations

Pit Maintenance

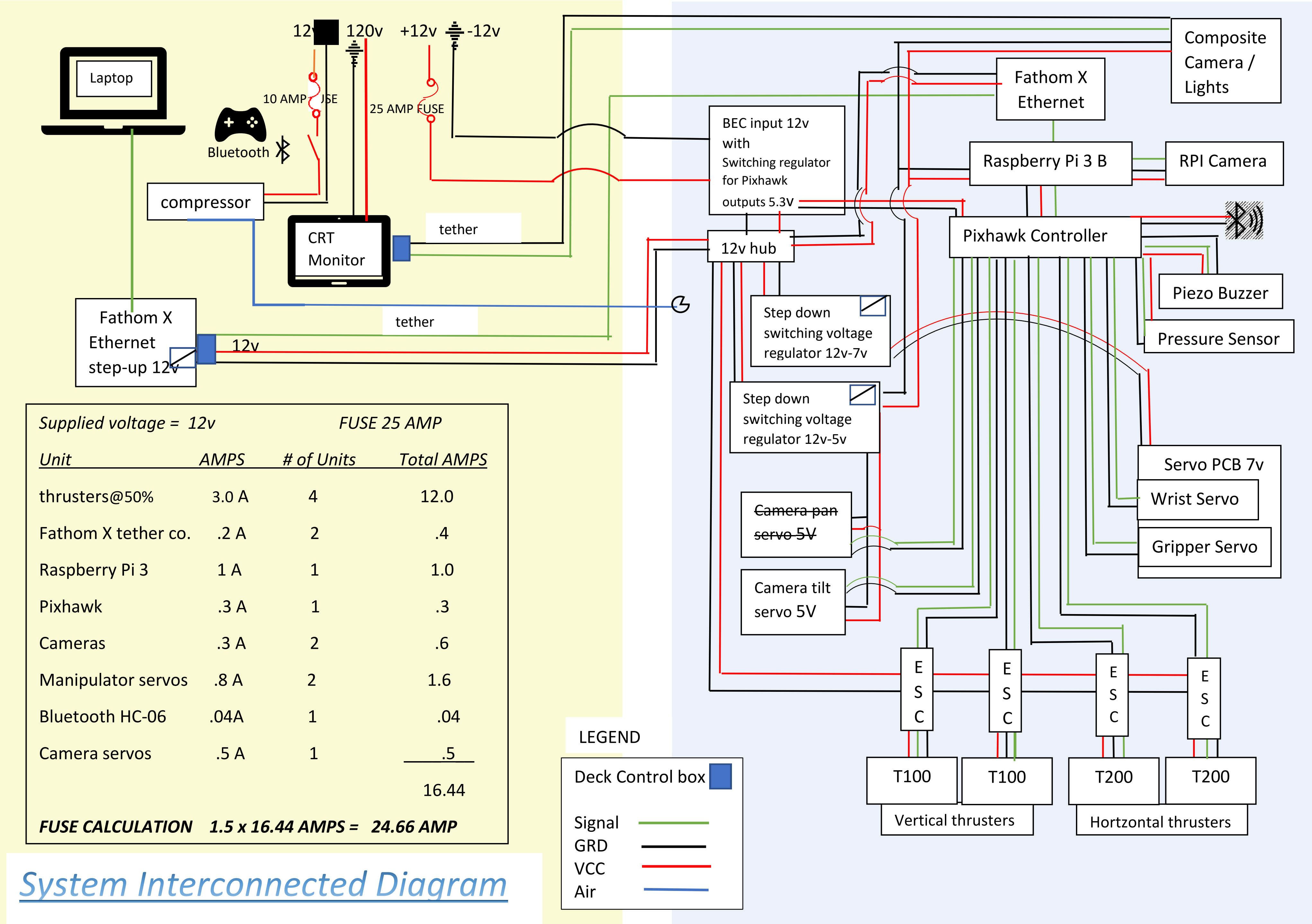
- Verify thrusters are free of foreign objects and spin freely
- Visual inspection for any damage
- All cables are neatly secured
- Verify tether is free of kinks
- Visual inspection for leaks
- Washdown ROV

Smithsonian Tethered Exo-Mariner ROV

Electrical STEM ROV SID

Smithsonian Marine Station Interns, Ft. Pierce Florida

TOPSIDE — ROV SIDE



Supplied voltage = 12v *FUSE 25 AMP*

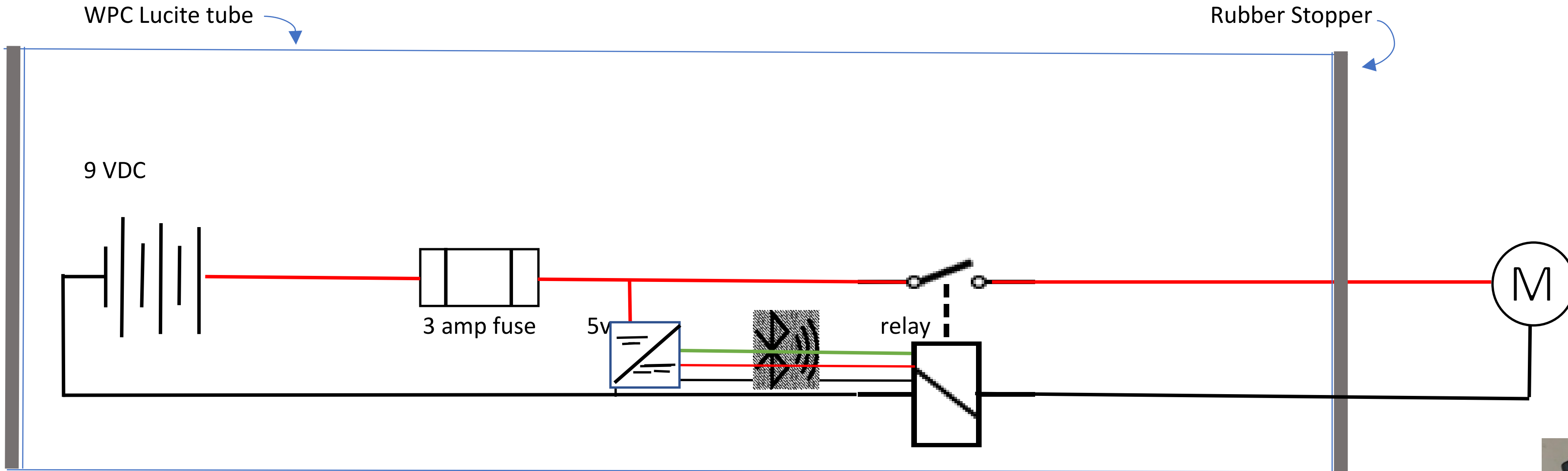
Unit	*AMPS*	*# of Units*	*Total AMPS*
thrusters@50%	3.0 A	4	12.0
Fathom X tether co.	.2 A	2	.4
Raspberry Pi 3	1 A	1	1.0
Pixhawk	.3 A	1	.3
Cameras	.3 A	2	.6
Manipulator servos	.8 A	2	1.6
Bluetooth HC-06	.04A	1	.04
Camera servos	.5 A	1	.5
			16.44

FUSE CALCULATION 1.5 x 16.44 AMPS = 24.66 AMP

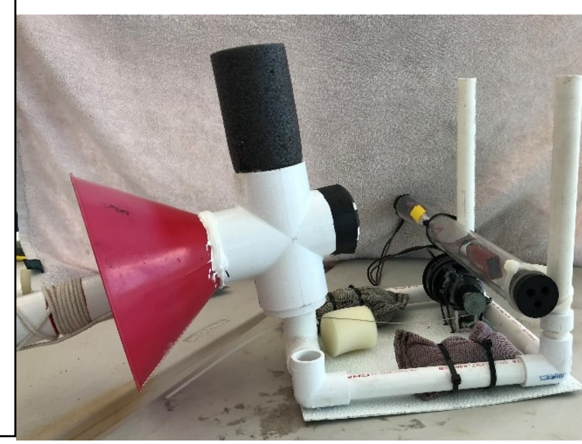
System Interconnected Diagram

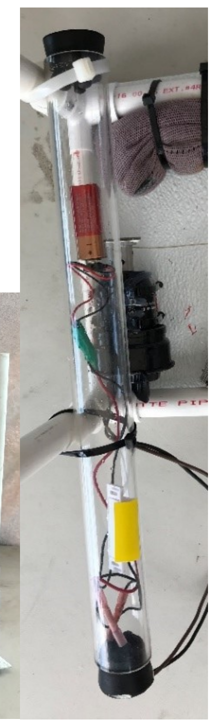
Smithsonian Tethered Exo-Mariner ROV ***OBS SID*** ***Smithsonian Marine Station, Ft. Pierce, FL.***

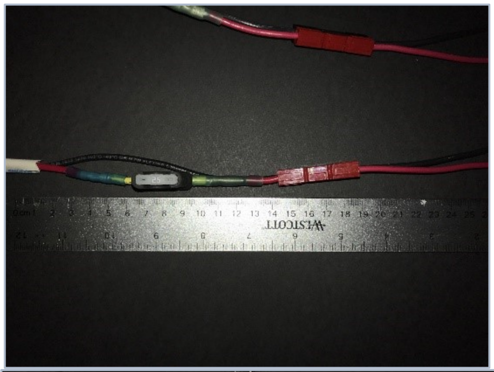
Ocean Bottom Seismometer *SID NON- ROV*

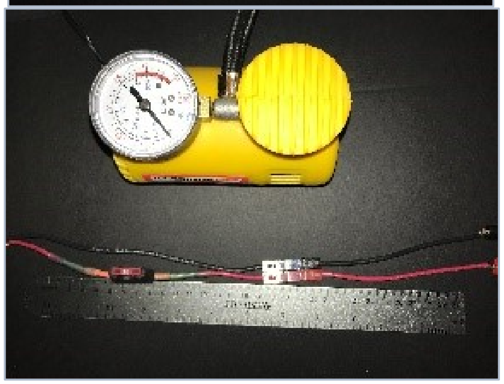


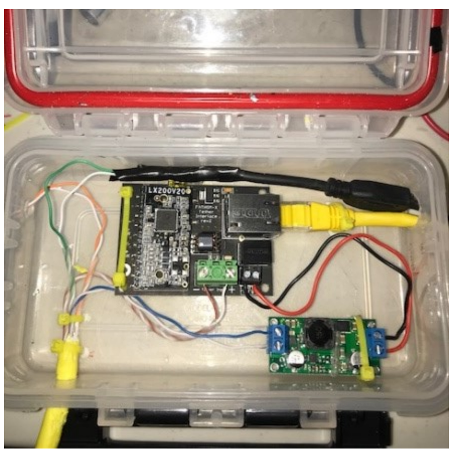
- **Bluetooth (**MasterHc-05**) Proximity / Relay Switch activation 5v**
- **Bilge Motor winch**
- **Lucite WPC**
- **Rubber stopper ends (over pressure release/pop off)**
- **9VDC Alkaline Battery**
- **3 amp inline fuse**
- **NO AC CURRENT**
- **Battery secured in Lucite tube**
- **NO thrusters or cameras**
- **.5A+ .2A+ 1A= 1.7Ax 1.5= 2.55 A FUSE**
  Relay+Bluetooth+motor









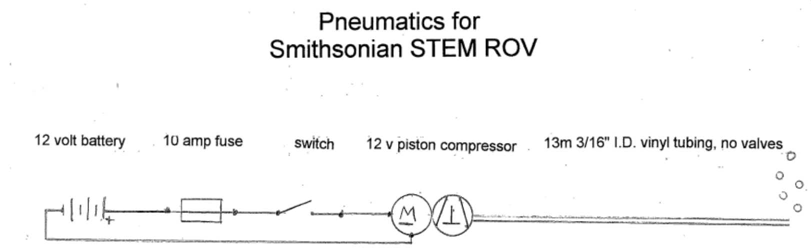


Anderson Powerpole connectors are the main point of connection to the MATE supply

A properly sized fuse is within 30 cm of the main point of connection of both the ROV and Air Compressor.

SEE SID Fuse Calculation for ROV

Air pump 6.5A x 1.5= 9.75 Amp ~10 amp FUSE



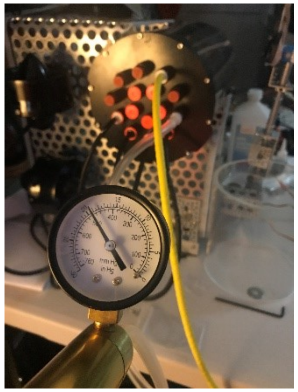
Pneumatics used consist of small battery powered bicycle pump / no pressurized containers are used and the company has ***passed the Fluid Power Quiz***. Ambient Air pressure used- no valves or obstruction; the pressure at the end of the tube on the ROV is ambient to the water pressure at depth.

The inside of the control box is does not have exposed wiring, the control box

is neatly laid out.

NO AC Current Used in Control Box

COMPANY SAFETY REVIEW STEM ROV



All wires entering and leaving the ROV and control box have proper strain relief;

zip tied, and the Tether is clamped to top of Chassis

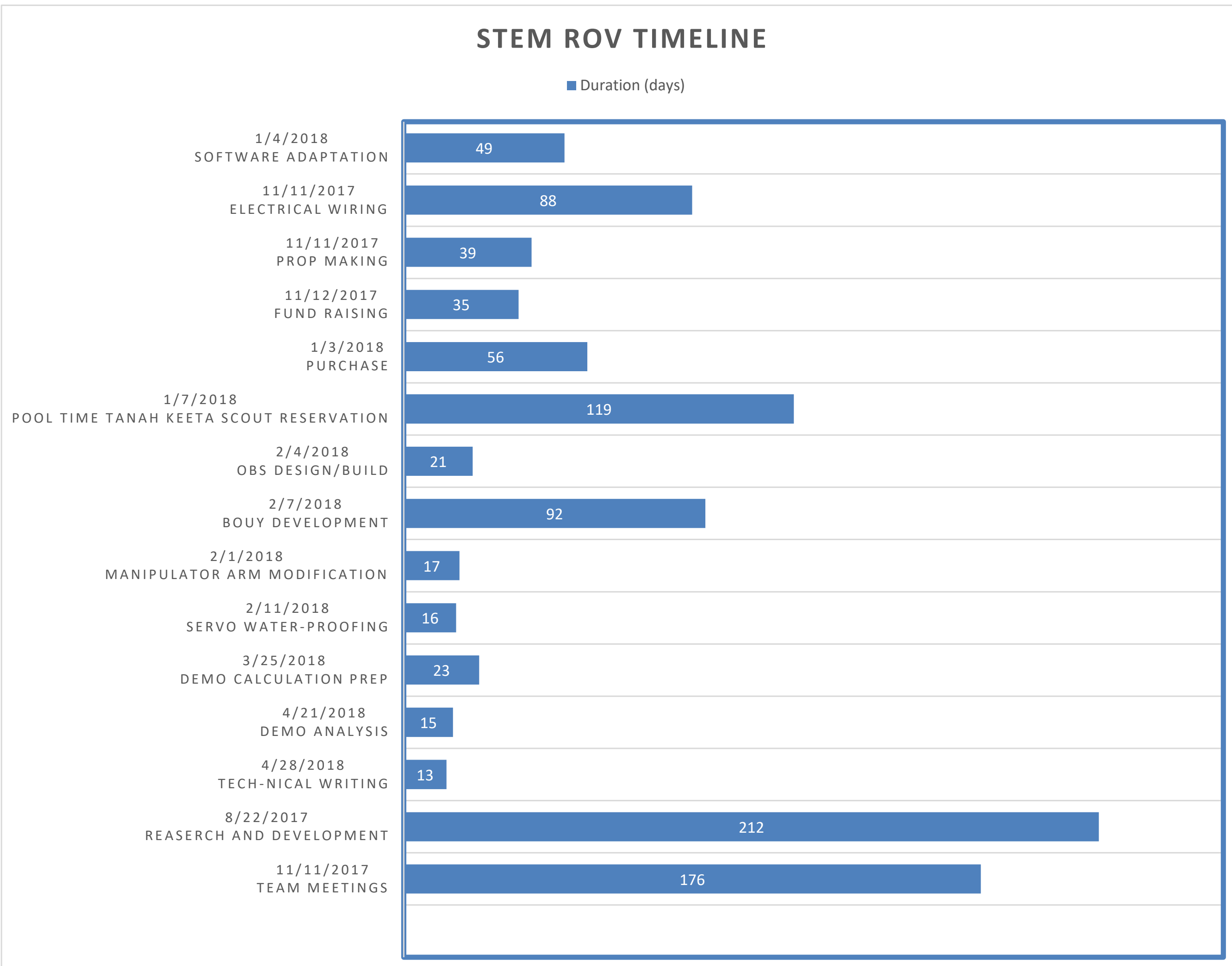
Watertight housing on the STEM ROV can withstand pressure at 150 meters.

The 6”diameter acrylic cylinder by BlueRobotics was a new acquisition for us this year-when the new product came out this summer; it was a perfect replacement for our 6” polycarbonate WPC from last year.

All propellers are shrouded and guarded to IP-20 standards (MECH-006). The guard / shroud completely encloses the thruster so no object of > 10 mm can reach the propeller.

The ROV has no sharp edges or elements of the ROV that could cause damage: all aluminum edge that have been cut are filed smooth and trimmed in plastic corner guard.

ThermoPlastic Molded to Skids, Guard on cables and penetrator to protect from snagging.



STEM ROV TIMELINE
Duration (days)
1/4/2018 SOFTWARE ADAPTATION
49
11/11/2017 ELECTRICAL WIRING
88
11/11/2017 PROP MAKING
39
11/12/2017 FUND RAISING
35
1/3/2018 PURCHASE
56
1/7/2018 POOL TIME TANAH KEETA SCOUT RESERVATION
119
2/4/2018 OBS DESIGN/BUILD
21
2/7/2018 BOUY DEVELOPMENT
92
2/1/2018 MANIPULATOR ARM MODIFICATION
17
2/11/2018 SERVO WATER-PROOFING
16
3/25/2018 DEMO CALCULATION PREP
23
4/21/2018 DEMO ANALYSIS
15
4/28/2018 TECH-NICAL WRITING
13
8/22/2017 REASERCH AND DEVELOPMENT
212
11/11/2017 TEAM MEETINGS
176