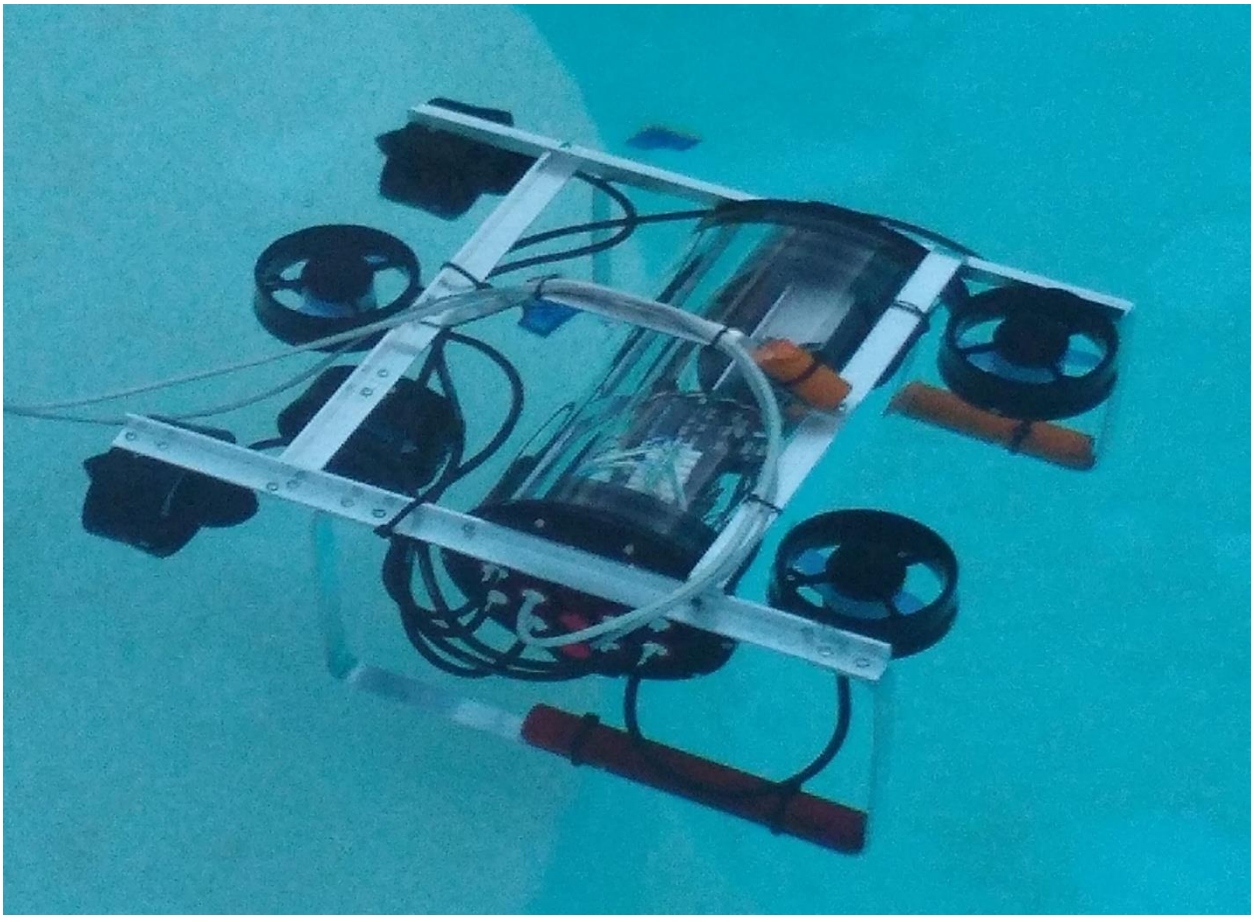
2019 National Underwater Robotics Challenge (NURC)

Journal Submission for

The Typewriter Repairmen

21 June, 2019



Team Members: Jim Forbes, David Forbes, Janet Forbes, Linus Forbes, Carol Forbes

Sierra Vista and Tucson, AZ

Abstract

The Typewriter Repairmen underwater robotics team has been revived after competing in NURC from 2009 through 2013. We are a family team, and compete for fun. In past years we made two ROVs, notBob, and Babs (reference 1). These robots used mostly specially fabricated parts. This year we decided to build a new ROV using mostly off the shelf technology. We purchased thrusters, control system parts, and a waterproof enclosure from Blue Robotics. We made our own frame and power distribution system.

Our analysis of the mission led us to decide to build a robot that is highly maneuverable, with good all-around vision and lighting, and a single degree of freedom manipulator.

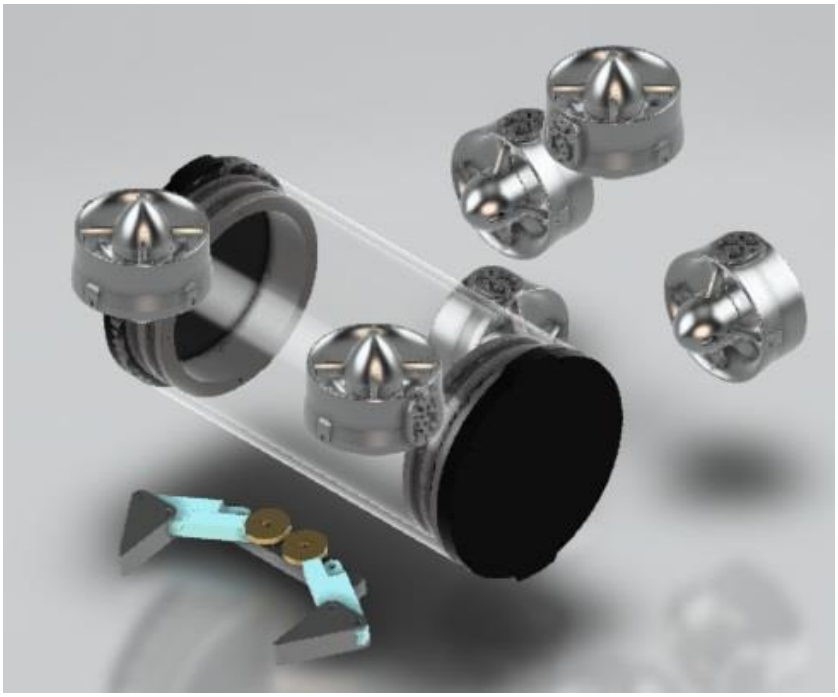
As typically happens with complex projects like this, we did not get as early a start as we should have, and we are having last minute problems with some parts of the robot. The driving and vision systems are working okay, but the manipulator does not yet work as it should. We may scale back our mission goals, perhaps we will see if we can develop some passive manipulators in the remaining time, or we may purchase an off the shelf gripper.

Table of Contents/Headings

1. Introduction: The Typewriter Repairmen is a family robotics team. Jim, the lead engineer, is a retired mechanical engineer. He has worked with the local FIRST high school robotics team NERDS for the past 13 seasons as an engineering mentor. Janet, his wife, is a retired engineer. Jim's brother David is an Electrical Engineer at the University of Arizona's Steward Observatory, and also runs a side business Cathode Corner, which sells neat electronic gadgets. Carol has been competing in NURC first as a student, since 2007. She is employed as a technician. Linus has competed in robotics through high school, and is now preparing for engineering school.

2. Design Rationale. As we have in past years, w analyzed the requirements of a robot to play the NURC game. Using this analysis, we figured out what the robot capabilities need to be. In all games the same general requirements of small size, high maneuverability, good vision, and good lighting, apply. The need for a manipulator changes, but not much—this year it seems that a single claw that is fixed to the robot, should be able to handle most of the game pieces. There is no need for temperature measurement, but there is for depth, and for measuring a horizontal distance.

We discussed and decided on using a six (6) thruster layout with two verticals in front, one vertical in rear, two forward on the sides, and a lateral thruster in the center. We conceived a frame consisting of a "box" of thin 1" aluminum angle. The design was made so that the thrusters could be easily relocated if necessary and so that the enclosure is easy to work on. Having some experience with redesigning a previous NURC robot (Babs) a few times, the importance was known of thruster location relative to the centers of mass, buoyancy, and drag, in all directions. We also considered the relative location of the center of mass and buoyancy, with the tentative requirement that the robot be stable, but not too stable. The stability helps keep it level, but too much will make it hard to tilt if needed to reach down with the claw, for example.



We discussed several ideas for manipulators. One idea is a "barb" to skewer the brain blood. However, the ability to tilt it presented some issues and the idea did not progress very far. We talked about using a commercially available manipulator, such as the BlueRobotics claw and at the vEx claw. We discussed using a 70:1 reduction. vEx claw with a BlueRobotics brushless motor, and using a combination of worm and spur gears to drive the claw. A tentative design of about one (1) second opening/closing time would be good, and motor speed of 4000 RPM, would require about a 70:1 reduction.

3. Systems Overview.

3.1. Control System: The control system is based on the Pixhawk autopilot includes a Raspberry Pi 3 as a companion computer, a Pixhawk controller, an Xbox gamepad, and a laptop. It also has six BlueRobotics motor speed controllers to power the six T100 thrusters, and a USB camera with onboard H264 encoding.

3.2. SCULL: Most of the control system is mounted in the Sealed Compartment for Underwater Light and 'Lectronics (SCULL). The lights, power supplies, camera, Pi, Pixhawk, speed controllers, and servo are inside the nominal six-inch diameter, one-foot long enclosure, which is from Blue Robotics (reference 2). The ends are aluminum, the tube is acrylic, and it is all sealed with O rings. The cable penetrations are also from Blue Robotics, and are threaded aluminum units with the cables potted in marine epoxy.

3.3. Power System: The ROV is powered by an on shore 48v battery pack. This consists of four 12v sealed lead acid batteries, with necessary switching to charge in parallel at 12v, or in series at 48v to provide power to the tether cable. The battery pack also includes a voltmeter, and a solar charging controller. In past years we have used solar power to recharge the battery pack, but there is no requirement this year, so we plan to use a small automotive type charger, plugged into a wall outlet.

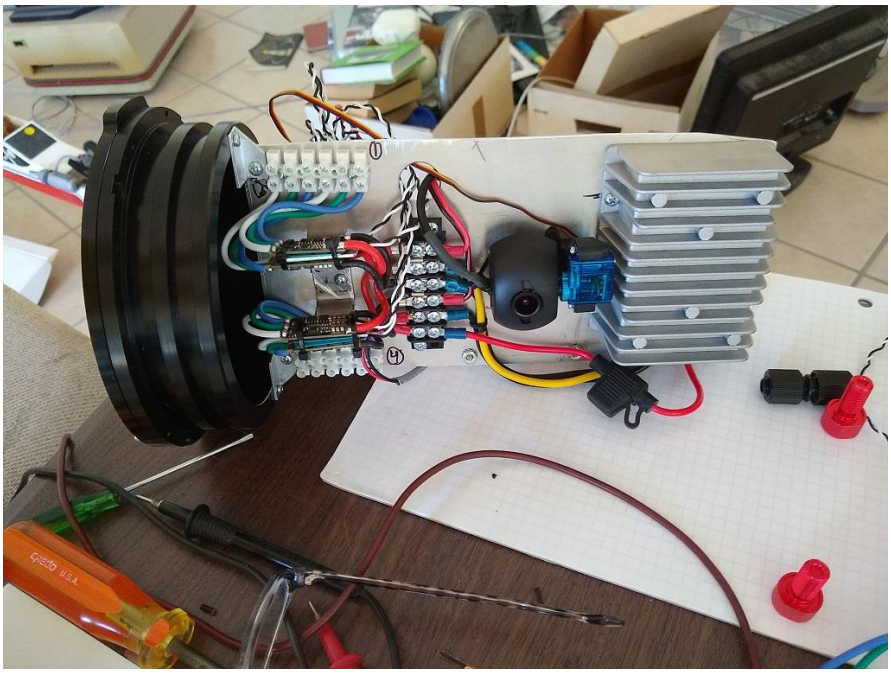
4. Features

4.1. Electronics Panel. The electronic components are mounted to an aluminum panel that is mounted vertically lengthwise in the SCULL. This panel holds the computer, terminal strips, camera, motor controllers etc. It also provides some heat sinking capability for the motor controllers.

4.2. Power Supply. The robot is powered by an onshore battery box with four 12V, 7AH SLA batteries. These are wired to switches to allow either series connection for operation, or parallel connection for charging. The tether power cable is a 16 AWG cable carrying 48V to the robot. The use of the high voltage and onshore battery pack allows the robot to be very small and lightweight, while not requiring expensive lithium batteries. Additionally, the battery system can be charged via a solar panel. The Raspberry Pi requires 5V to operate. A 3 Ampere USB car lighter power adapter was modified by adding wires to permit direct connection to 12V. An additional adapter was used to provide 5v power to the Pixhawk servo rail, to support the camera tilt servo.

4.3. Camera. The camera is a 1080P resolution, H.264 USB board camera. It is mounted on a micro servo to permit it to be tilted vertically, for viewing the path ahead, the claw and the surface as needed. The entire ROV can be turned in the yaw direction, so there is no need to have a pan mount and servo. This simplifies the camera mount.

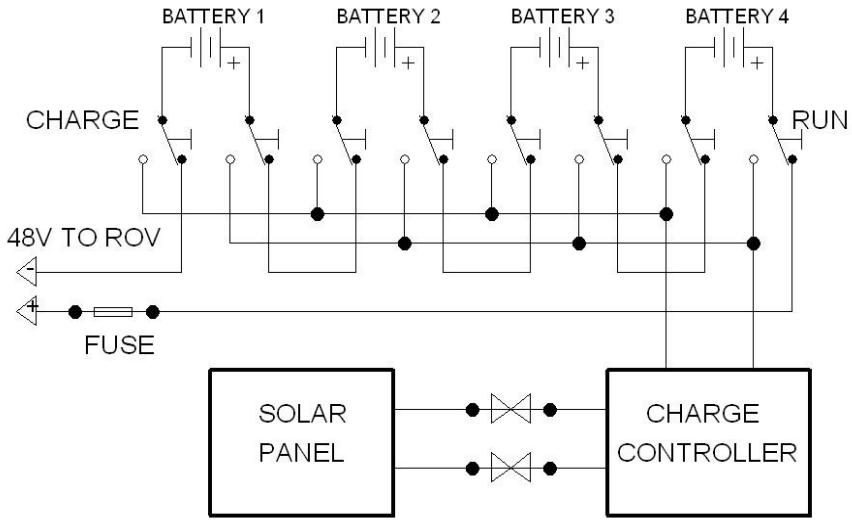
4.4. LED Lighting. The mission takes place at night, so illumination of the scene is provided by a pair of 10 Watt LEDs mounted near one end of the SCULL. The LEDs are powered from 12V through current controllers. The current controllers were modified to make the PWM dimming function available to the Pixhawk, by adding wires to the PT4115 chips. The LEDs are mounted to a panel that is bolted to one SCULL end plate, for cooling purposes. A light baffle blocks the LED light from reaching the camera directly.

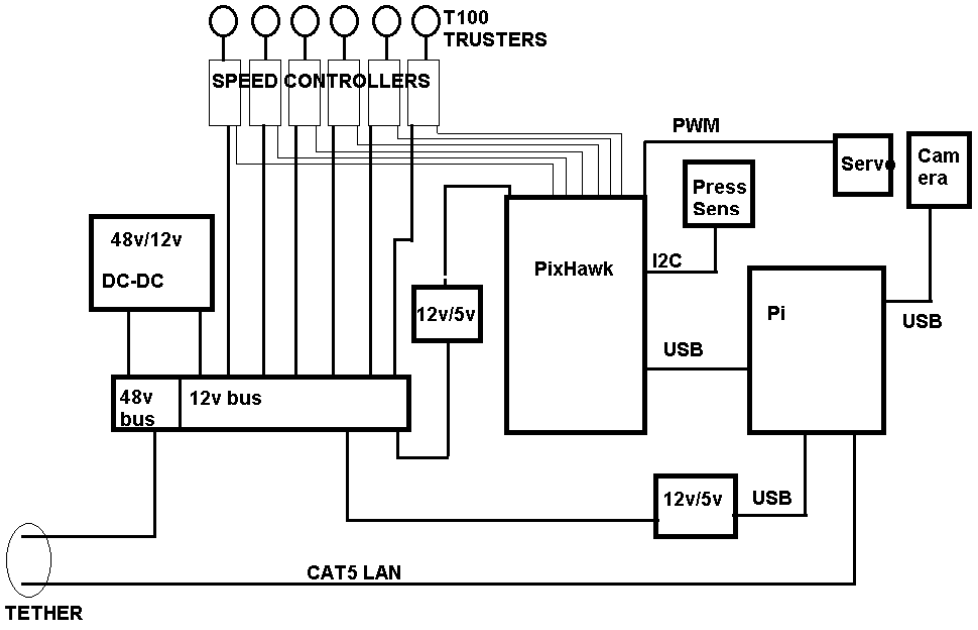


4.5. Frame: The robot frame is designed to connect the various parts together. The philosophy behind the design is “cheap, light, and fast”. The frame members are locally available aluminum extrusions, connected with screws and nuts. The thrusters are screwed to the frame, and there is also steel rod ballast attached to balance the robot.

4.6. Thrusters: The six thrusters are from Blue Robotics, the smaller T100 model. They provide plenty of thrust for this small ROV, even at the default half power setting.

5. Electrical Schematics. The following is the electrical schematic for the system.

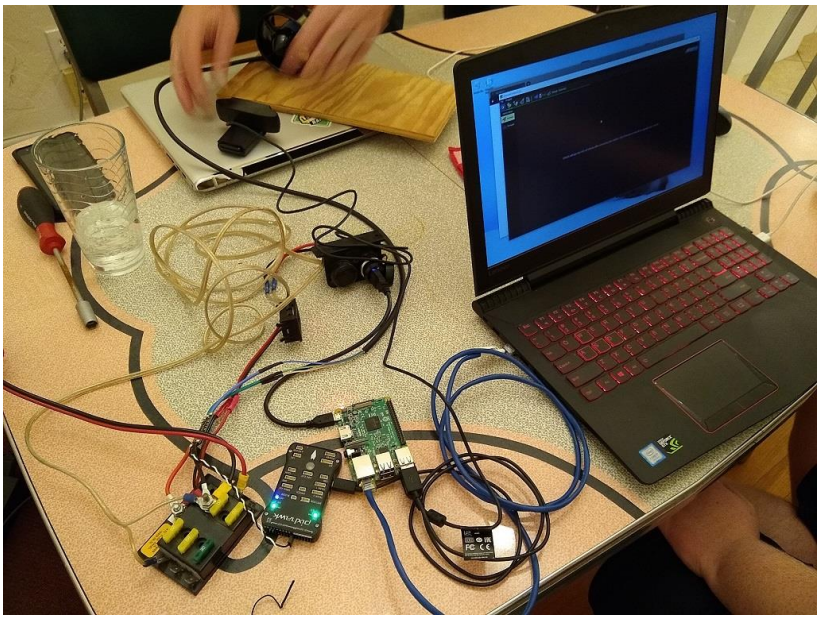




6. Expense Sheet. A detailed list of materials is provided at Appendix A. The summary cost is provided here for each subsystem of the ROV. Total cost for the ROV is $2,177.24:

External Parts	$1,313.39
SCULL	$ 646.68
Power	$ 217.17

7. Test and Evaluation: We tested various parts of the robot as we were building it. For example, we connected the control system components together while they were sitting on a table, and checked for operation of the camera, thruster, servo, etc.



We then tested the systems after installing the electronics on the panel, and again after installing it in the SCULL. We did encounter some problems with the power supply for the camera tilt servo, and our first version of the manipulator did not work as well as we hoped. Linus got to spend some time driving the robot in a pool before the competition, and we hope to get more practice in the final week.

8. References

1. The Typewriter Repairmen Technical Report 2010 National Underwater Robotics Challenge, June 2010
2. Blue Robotics, https://www.bluerobotics.com/

9. Acknowledgements. Thanks to the Martinez-Jones family and Jim Malmberg for the generous use of their swimming pools.

Appendix A – List of Materials

2019 NURC Expense Sheet					
Item Description	Source	Part #	Qty	Unit price	Total Price
External Parts					
T100 Thruster	Blue Robotics	T100-THRUSTER-R1-RP	6	$ 119.00	$ 714.00
Basic ESC	Blue Robotics	BRDC30-R3	6	$ 25.00	$ 150.00
Newton Subsea Gripper	Blue Robotics	NEWTON-GRIPPER-ASM-R1-RP	1	$ 329.00	$ 329.00
Angle 1/8x3/4x8 Alum	Ace Hardware	51420	1	$ 16.99	$ 16.99
Bar Flat 1/8x3/4x4 Alum	Ace Hardware	5117973	3	$ 5.99	$ 17.97
MD 3/8-IN x 20-FT Backer	Lowe's	41298	3	$ 3.46	$ 10.38
1/16-IN x 1/-1/2-IN x F-F	Lowe's	215753	1	$ 15.99	$ 15.99
1/16 x 1-8 Alum Angle 8-B2	Lowe's	55970	1	$ 14.48	$ 14.48
3/8-IN MIP x 1/8-IN FIP B	Lowe's	877200	1	$ 3.88	$ 3.88
Game pad controller	Walmart	61788501135	1	$ 14.96	$ 14.96
100FT Gray CAT5E UTP Patch Cable	NEWEGG	STA-45PATCH100GR	1	$ 17.15	$ 17.15
USB to LAN adapter	valuebuybattery	USB3.0-LAN	1	$ 8.59	$ 8.59
				Subtotal	$1,304.80
SCULL					
Bar 30 High resolution 300m Depth Sensor	Blue Robotics	BAR30-SENSOR-R1-RP	1	$ 86.00	$ 86.00
M10 Cable Penetrator for 6mm Cable	Blue Robotics	PENETRATOR-M-BOLT-6MM-10-25-R2-RP	7	$ 4.00	$ 28.00
Micro-USB to USB-A Cable	Blue Robotics	MISC-CAB-USB-MICRO-STRAIGHT-6IN-R1	2	$ 8.00	$ 16.00
Potting kit (x 10)	Blue Robotics	TOOL-POTTING-KIT-R1-RP	1	$ 10.00	$ 10.00
Camera Tilt System	Blue Robotics	CAMTILT-ASM-R2-RP	1	$ 29.00	$ 29.00
Loctite Marine Epoxy	Blue Robotics	LOCTITE-MARINE-EPOXY	2	$ 6.00	$ 12.00
Aluminum End Cap (6" Series)	Blue Robotics	WTE6-M-END-CAP-R1-RP	2	$ 34.00	$ 68.00
Cast Acryllic Tube - 11/75" x 6"	Blue Robotics	WTE6-P-TUBE-12-R1-RP	1	$ 90.00	$ 90.00
Pixhawk	Blue Robotics	PIXHAWK-R1-RP	1	$ 120.00	$ 120.00
Aluminum Sheet 0.060" x 12" x 12"	McMaster Carr	88895K101	1	$ 7.69	$ 7.69
Raspberry Pi	adafruit	3055	1	$ 35.00	$ 35.00
Camera	spinel	UC20MPG_L36	1	$ 6.99	$ 6.99
O-Ring Flange (6" Series)	Blue Robotics	WTE6-M-FLANGE-SEAL-R1-RP	2	$ 59.00	$ 118.00
Enclosure Vent and Plug	Blue Robotics	VENT-ASM-R3-RP	1	$ 8.00	$ 8.00
M10 Cable Penetrator Blank (No Hole)	Blue Robotics	PENETRAOR-M-BLANK-10-25-R3-RP	3	$ 4.00	$ 12.00
				Subtotal	$ 646.68
Power System					
Jumper Barrier BLK 2POS SPADE	DigiKey	WM9711-ND	4	$ 0.27	$ 1.08
Conn Barrier Strip 6CIRC 0.375"	DigiKey	WM5763-ND	2	$ 4.70	$ 9.40
48vDC-12vDC Converter	daygreen	B30-3648-12A	1	$ 32.00	$ 32.00
Conn Term Strip 12CIRC 0.315"	DigiKey	WM16251-ND	2	$ 4.52	$ 9.04
USB Car Charger	monoprice	14160	1	$ 6.99	$ 6.99
USB Car Charger	Griffin	GC-23089-2	1	$ 9.99	$ 9.99
Battery Charger	Shumacher	XC60CA	1	$ 28.95	$ 28.95
Cable 2COND 16AWG Gray 100'	DigiKey	BEL1266-100-ND	1	$ 39.73	$ 39.73
10W LED + 10W Driver Set of 5	Direct Voltage	252534941464	1	$ 21.99	$ 21.99
Battery, 12V 8Ah SLA (4 pack)	Expert Battery	Q04BLMFM12_8	1	$ 58.00	$ 58.00
				Subtotal	$ 217.17
Total					$2,168.65