

# The Typewriter Repairmen

## 2024 National Underwater Robotics Challenge

### Technical Report

June 9, 2024

Tucson and Sierra Vista, AZ  
Adult Team

[selectric.org/nurc24](http://selectric.org/nurc24)

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## Abstract

The Typewriter Repairmen is a family adult team. Several team members have vast experience in high school robotics, both with For Inspiration and Recognition of Science and Technology (FIRST) Robotics Competition (FRC) and NURC. This is the team's eighth year of competition in NURC.

In past years we made three Remote Operated Vehicles (ROVs): notBob, Babs, and Casper. Last year, the folks who put on the competition asked us if we could develop a kit ROV, which any team could purchase, build, and operate. We took on the challenge, and the result is the RovoTron Cadet. We will use the Beta Cadet ROV, named "Sebastian", in the competition this year.

## Team Goal

The Typewriter Repairmen is a family team. Our goal is to have fun and enjoy each other's company while doing a very good job of completing the requirements of the NURC competition and sharing our experiences with the other teams.

## Mission Analysis

We built a spreadsheet of the mission tasks, estimated execution time, and point rewards to create a ranked list of the reward/effort ratio for each task. Based on this spreadsheet, we have decided to attempt to perform all tasks in the mission. We are planning on building some special robot hardware for some tasks.

Task	Value	Required ROV equipment	Very Difficult	Special Equipment Required
1. Turn on lights	10			
2. Measure Temperature	50	Temperature probe		x
3. Place Hose	60	Gripper		
4. Place Device	30			
5. Release Device, go 15 Feet				
6. Remove Debris	45			
7. Measure	75	tape measure or	x	x

distance from lead case to new opening		laser		
8. Flip Lever on Substation	10			
9. punch combination lock	45			
10. Enter chamber, remove 3 fuel rods	60			
11. place rods in case, close case	75		x	
12. Flip lever to activate lift				
13. Catch 1-3 fish	75	Net or claw		x

The basic Cadet design provides good maneuvering and vision. To be able to complete the mission, the ROV will need a device to manipulate several objects, some which just need to be moved in place, others need to be moved to other locations. Most of these have a ring that can be “hooked”, but the air hose will need to be grasped.

We will need to be able to measure distance, and temperature.

### ROV System

The ROV frame is made of high density polyethylene (HDPE) plastic sheets. The “Noggin” flotation tank/electronics housing is a 6 inch diameter horizontal tube made of transparent cast acrylic (Plexiglas). The starboard side plate has the O-ring seal for the Noggin, and cable seals for all the electrical cables to the thrusters and tether. The port side plate has a hole for the Noggin tube to be easily removed and installed without tools.

The two side plates are fastened to each other with an HDPE tie bar located above the Noggin, and another two steel tie bars are located below the Noggin. The steel bars act as most of the ballast, and provide a mounting place for the manipulator.

The control board, camera and LED are mounted inside the Noggin. A laser-cut plastic frame holds the control circuit board, the LED heatsink and the camera’s tilt servo.

All of the tether and thruster cables pass through the starboard side plate. The thruster cables are wired to terminal blocks soldered to the motor speed controller terminals.

The tether and thruster cables need to gain entrance to the Noggin without leaking. The ROVotron approach is to use a cylindrical rubber sealing gland around the cable itself, seated into a countersunk hole in the end plate. The gland is held in place with a three-hole, aluminum clamping plate on the inside of the Noggin. Two self-tapping screws that compress the gland by pressing the clamping plate against it are set in blind holes.

The Cadet uses off the shelf brushless motor thrusters. The fore-aft thrusters are located near the rear of the ROV, in line with the Noggin centerline, to provide the best control by placing the center of force in line with the center of drag. This has been found to produce the most predictable behavior, with no pitching on acceleration. The up-down thrusters are located at each end of the Noggin. The strafing thruster is behind the center of the Noggin.

The ROV needs a few hundred Watts of power to run the thrusters and other electronics. We use a 24V tether and 24V Electronic Speed Controllers (ESCs). Doubling the supply voltage allows the motors to operate well with a few volts of drop over the length of the tether, so the tether does not need to be as heavy. A battery voltage monitor is built into the control board to allow the operator to observe the voltage drop of the tether in real time. It is also used to monitor the battery charge level and to allow the operator to know when to return to shore mpower is low.

The two batteries are 12v 18Ah sealed lead acid batteries, as used in FIRST FRC robots. We had tried 12V 8AH batteries at first, but found that the voltage drop was too high.

The sensors in the Cadet include the camera, the depth (pressure) sensor, and the temperature sensors. The LED temperature sensor is a thermistor mounted to hte LED heat sink. It was included to allow monitoring of hte LED temperature to be sure that it wasn't overheating.

The water temperature probe is a Dallas/Maxim DS18B20 OneWire digital sensor. It was chosen because it was available with a waterproof housing and round cable. Unfortunately, it has a rather slow response time. The team plans to measure the vent temperature rise over time to be able to extrapolate the actual temperature in only ten seconds. This will be tricky, because the ROV may be damaged by the heat. A second problem with the OneWire sensor is that the Arduino code library interferes with the Servo code library's interrupts, which causes the motors to glitch when reading the temperature! The code was carefully written to read the temperature only twice a second, when the Y button is pressed on the gamepad, to minimize these disruptions to the drive system.

## **Testing**

We built the Alpha version of the Cadet, and tested it in late 2023. It worked OK, but needed some improvements. The hull size and shape was modified to allow the Noggin end cap to be removed easily, and to allow the ROV to be turned upside-down for servicing. The internal wiring was cleaned up, by mounting the motor speed controllers on the control board.

The Beta version was built in early 2024. It has reasonable performance. There are some issues still with full-power driving. We have had a few blown fuses. This problem has been narrowed down to the root cause by reducing the drive power level range in the software. Reducing the thruster drive to

0.6 of full power has reduced the total current draw to below 20A when diving and driving at full speed, which should prevent future problems.

### **New skills**

New skills for this ROV include making Computer Numerical Control (CNC) routed parts from HDPE, and laser cut parts from acrylic. We used several new-to-us software tools such as KiCad, OnShape and OpenSCAD.

Another important skill is finding usable parts from Amazon to reduce the cost of the ROV kit.

### **Acknowledgements**

We would like to thank Si Se Puede Foundation, and the judges and other volunteers, for their hard work in putting on this competition.

## Schematic diagrams

Figure 1. Battery system schematic diagram

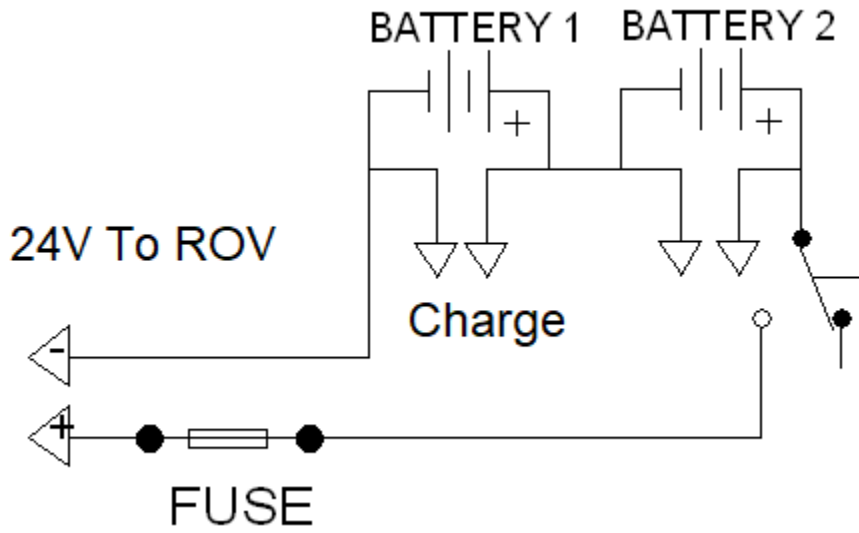


Figure 2. ROV block diagram

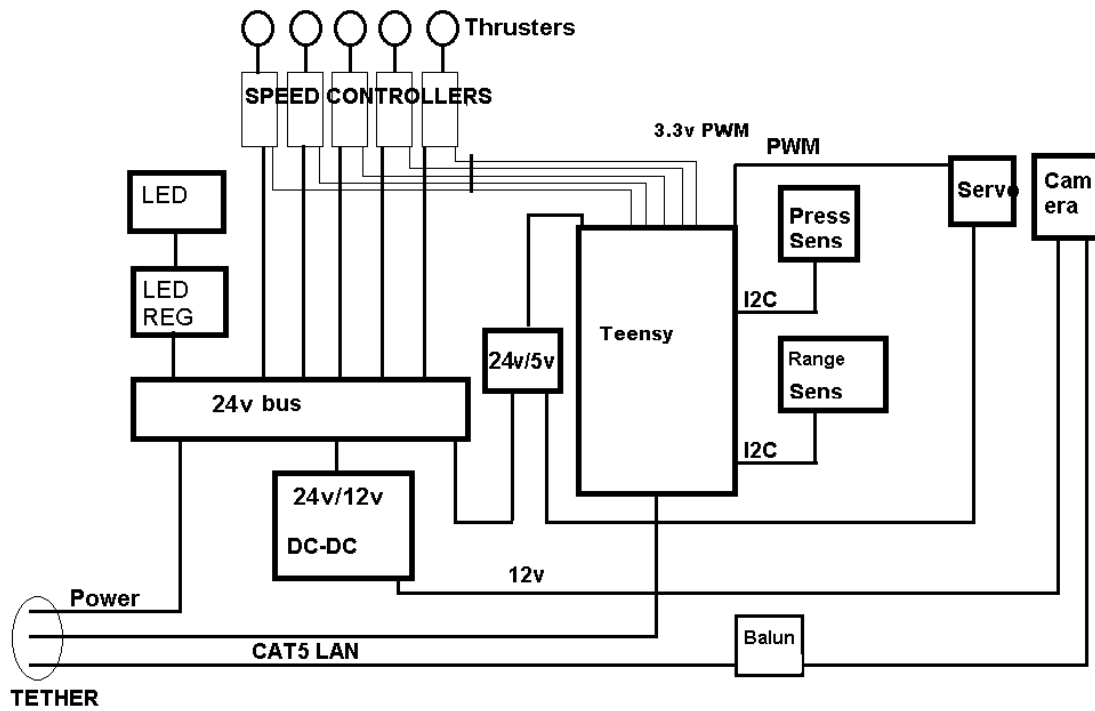


Figure 3. RVTOP-C control board schematic diagram

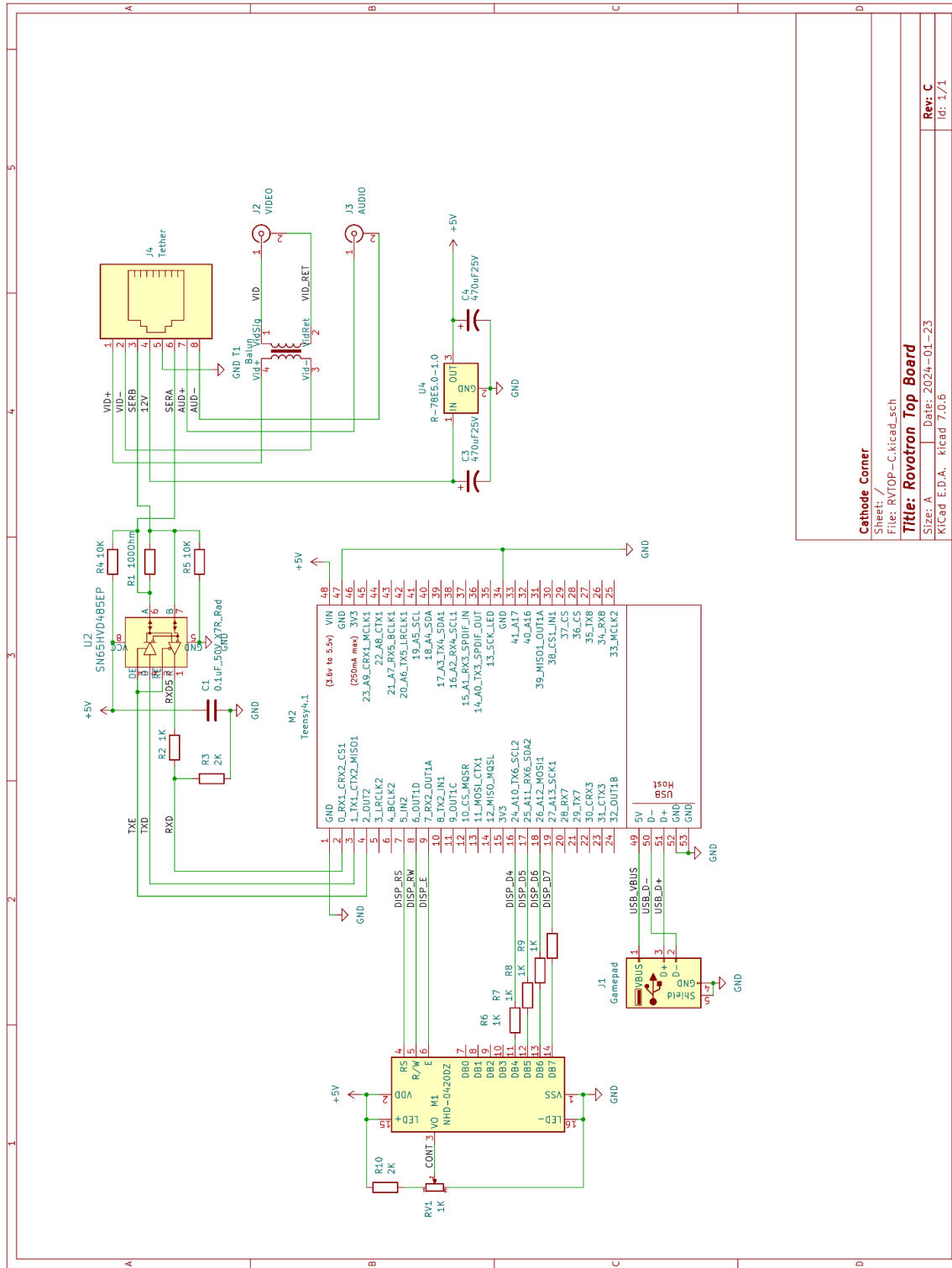
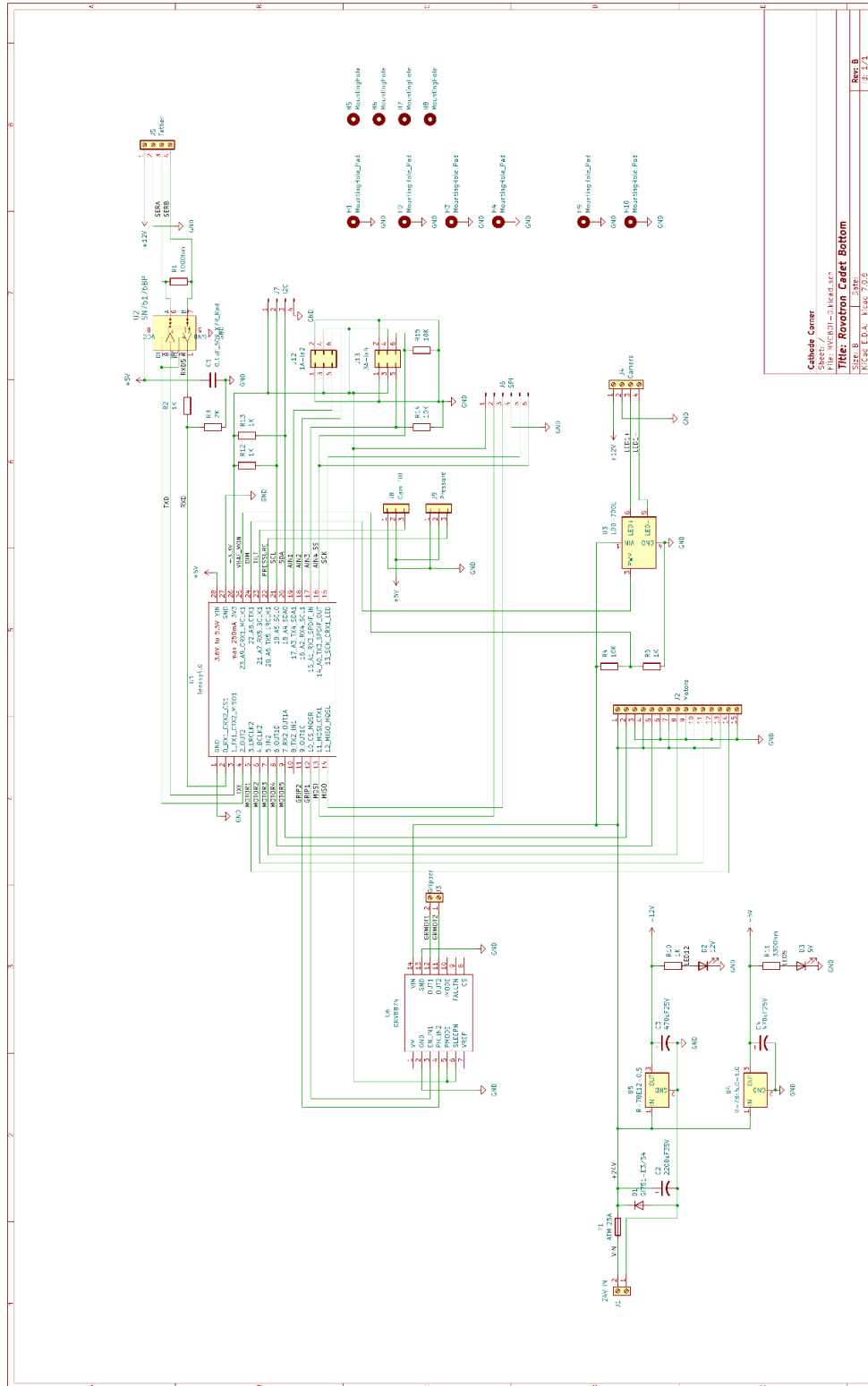




Figure 4. RVCBOT-D ROV control board schematic diagram



## Bill of Materials

Qty	Item	Dimensions/Value	Vendor	VendorPN	Each	Total
2	Starboard side plate	18x12 x 3/4 HDPE	Sisepuede		30.00	60.00
2	Handle	8x6 x 3/4 HDPE	Sisepuede		12.00	24.00
2	Ballast bars	Steel 1-1/8 x 7.25	IMS		5.00	10.00
2	Port side plate	18x12 x 3/4 HDPE	Sisepuede		30.00	60.00
6	Thruster cable clamp	Aluminum	Sisepuede		1.00	6.00
3	Data cable clamp	Aluminum	Sisepuede		1.00	3.00
2	Power cable clamp	Aluminum	Sisepuede		1.00	2.00
2	End cap tabs	Aluminum	Sisepuede		1.00	2.00
2	End cap	6 dia x 3/4 HDPE	Sisepuede		25.00	50.00
1	Acrylic tube	6 Dia x 8 L x 1/8			20.00	20.00
4	Screws handle	#10 x 1.25" panhd	McMaster-Carr		0.23	0.90
4	Screws ballast	10-32 x 1" panhd	McMaster-Carr	91772A833	0.23	0.90
5	Thrusters	75mm	UnderwaterThrusters	U2	25.00	125.00
22	Screws thruster	M3x10 SS pan head	McMaster-Carr	92000A120	0.06	1.37
8	Thruster cable seals	9/32" ID 1/2" OD	O'Reilly	GL022023	0.10	0.80
12	Tether cable ring	Acrylic	David		0.10	1.20
24	Screws cable clamp	#8x1/2 ST 1/4 hex	McMaster-Carr	92400A230	0.19	4.56
0.25	Tether power cord	12-2 speaker cord	Monoprice		140.00	35.00
0.5	Tether signal cable	Cat6x75'	HomeDepot	928517-001713	50.00	25.00
0.15	Foam backer	3/8x50Ft	HomeDepot	77578-06026	30.00	4.50
1	Self-fusing tape	1" x 10 ft	HomeDepot		8.88	8.88
1	Data tether insert	Brass tube 3/16x3/4	Ace		1.00	1.00
2	Data cable seals	1/4" ID 7/16" OD	O'Reilly	GL032123	0.10	0.20
4	Data cable ring	Acrylic	David		0.10	0.40
2	Power cable seals	5/32" ID 5/16" OD	O'Reilly		0.10	0.20
4	Power cable ring	Acrylic	David		0.10	0.40

4	Seal plugs	1/4x1 Delrin rod	McMaster-Carr	8579K12	0.10	0.40
1	Pressure sensor	G1/4-19 thread	Digikey	1597-1515-ND	12.90	12.90
1	Sensor seal	G1/4-19	McMaster-Carr	50915K814	1.03	1.03
2	End cap tab screws	6-32 x 1.5" SS pan Phillips	McMaster-Carr	90087A106	0.09	0.18
2	End cap washers	#6 SS flat washer			0.03	0.06
2	End cap locknuts	6-32 Nylock	McMaster-Carr	90631A007	0.04	0.08
1	Outer Base	Acrylic	David		1.00	1.00
1	Inner Base	Acrylic	David		1.00	1.00
2	Braces	Acrylic	David		2.00	4.00
1	Plate	Acrylic	David		2.00	2.00
1	Outer servo	Acrylic	David		0.50	0.50
1	Inner servo	Acrylic	David		0.50	0.50
2	Camera pivots	Acrylic	David		0.50	1.00
1	Camera plate	Acrylic	David		0.50	0.50
1	Servo support	Acrylic	David		0.50	0.50
1	Servo support	Acrylic	David		0.50	0.50
1	Pivot support	Acrylic	David		0.50	0.50
1	Port base	Acrylic	EStreetPlastic	12x24x1/8 blk	7.50	7.50
24	Nuts noggin	4-40 square	McMaster-Carr	94855A281	0.03	0.81
24	Screws noggin	4-40x1/2 pan Phillips	McMaster-Carr	90272A110	0.02	0.50
1	LED 10W 18V white	Square in bag	Digikey	90-CMB1510-R108-0 OPFOU0A30G-ND	6.00	6.00
1	heat sink	50 x 50 x 25mm	Digikey	ATS1590-ND	4.68	4.68
2	Screws LED	#4x1/4 F pan Phillips	McMaster-Carr	90087A106	0.09	0.18
4	Screws heatsink	6-32x1.5 pan Phillips	McMaster-Carr	90272A157	0.15	0.58
4	Spacers heatsink	#6x1" Nylon round	McMaster-Carr	94639A306	0.19	0.75
4	Nuts heatsink	6-32 Nylock	McMaster-Carr	90631A007	0.04	0.16
1	video camera	NTSC 2.1mm lens	Amazon	B00LRE801Y	15.88	15.88
2	Screws camera back	M2x8 pan Phillips	McMaster-Carr	92005A029	0.05	0.10
1	Camera servo	MG90S	TowerPro	MG90S	0.00	0.00

1	Screw servo horn	M2.5x6 pan Phillips	McMaster-Carr	92005A066	0.06	0.06
1	Circuit board, blank	RVCBOT-D	Oshpark	RVCBOT-D	30.00	30.00
1	Res 100 1/4W	Brn-Blk-Brn-Gold	Digikey	100QBK-ND	0.02	0.02
5	Res 1K 1/4W	Brn-Blk-Red-Gold	Digikey	1.0KQBK-ND	0.02	0.10
1	Res 2K 1/4W	Red-Blk-Red-Gold	Digikey	2.0KQBK-ND	0.02	0.02
3	Res 10K 1/4W	Brn-Blk-Org-Gold	Digikey	10KQBK-ND	0.02	0.06
1	Res 330 1/4W	Org-Org-Brn-Gold	Digikey	330QBK-ND	0.02	0.02
1	Capacitor, 0.1uF	104M	Digikey	399-4264-ND	0.05	0.05
1	IC, RS-485 transceiver	SN75176BP	Digikey	296-6875-5-ND	1.60	1.60
1	Header 4 pin RA	Green	Digikey	732-2771-ND	0.79	0.79
1	Fuseholder	Yellow	Digikey	36-3568-20-ND	1.19	1.19
2	LED	Green	Digikey	67-1098-ND	0.10	0.20
2	Socket strip	Black 14 pin	Digikey	S7047-ND	0.81	1.62
2	Socket strip	Black 7 pin	Digikey	S7040-ND	0.53	1.06
1	Diode 6A 100V	GI751	Digikey	GI751-E3/54GICT-ND	0.74	0.74
1	Regulator, LED	LDD-500L	Mouser	709-LDD-500L	3.42	3.42
1	Header, 24 pin	black 24 pin	Digikey	900-0022284245-ND	1.20	1.20
1	Regulator, 5V	R-78K5.0-1.0	Mouser	919-R-78K5.0-1.0	3.37	3.37
1	Regulator, 12V	R-78K12-0.5	Digikey	945-R-78K12-1.0-ND	3.31	3.31
1	Header, Molex 6 pin	White 6 pin	Digikey	WM2704-ND	0.92	0.92
1	Header, Molex 4 pin	White 4 pin	Digikey	WM2702-ND	0.60	0.60
1	Header, Molex 3 pin	White 3 pin	Digikey	WM2701-ND	0.58	0.58
3	Terminal block	Green 2 pin	Digikey	277-1667-ND	0.53	1.59
10	Terminal block	Green 3 pin	Digikey	277-1578-ND	0.70	7.04
2	Capacitor, electr	470uF16V	Digikey	P5532-ND	0.32	0.63
1	Terminal block	Green 2 pin tall	Digikey	277-1269-ND	1.98	1.98
1	Capacitor, electr.	2200uF35V	Digikey	P5556-ND	1.34	1.34
1	Fuse ATM 20A	Yellow 20	Digikey	283-2330-ND	1.97	1.97
1	Microcontroller	Teensy4.0	PJRC	TEENSY40_PINS	26.80	26.80
5	Speed controller	ESC 6S 35A	Amazon	B09F3G4KNB	10.00	50.00
12	Ferrule med	red 17 AWG	Digikey	A129216-ND	0.10	1.20

6	Ferrule small	blue 23AWG	Digikey	A114627-ND	0.12	0.72
1	Tape, foam	Red roll	David		0.10	0.10
1	Heat sink	3/8x1/2 C channel	HomeDepot	269-210	0.30	0.30
2	Screws heatsink	4-40x1/2 pan Phillips	McMaster-Carr	90272A110	0.05	0.10
2	Nuts heatsink	4-40 square	McMaster-Carr	94855A281	0.07	0.14
1	Blank board	RVTOP-C	Oshpark	RVTOP-C	15.00	15.00
1	Res 100 1/4W	Brn-Blk-Brn-Gold	Digikey	100QBK-ND	0.02	0.02
5	Res 1K 1/4W	Brn-Blk-Red-Gold	Digikey	1.0KQBK-ND	0.02	0.10
2	Res 2K 1/4W	Red-Blk-Red-Gold	Digikey	2.0KQBK-ND	0.02	0.04
2	Res 10K 1/4W	Brn-Blk-Org-Gold	Digikey	10KQBK-ND	0.02	0.04
1	Cap 0.1uF 50V cer	104K	David		0.05	0.05
1	SN65HVD485EP	65HVD485	Digikey	296-17498-5-ND	1.65	1.65
1	USB jack type A	Metal, white	Digikey	A113391-ND	1.35	1.35
2	Socket strip 24 pin	Black 24 pin	Digikey	S7057-ND	1.26	2.52
1	Socket strip 5 pin	Black 5 pin	Digikey	S7038-ND	0.43	0.43
1	Socket strip 16 pin	Black 16 pin	Digikey	S7049-ND	1.03	1.03
1	Trim pot 2K 3/8"	X202	Digikey	3386X-202LF-N	1.61	1.61
1	5V regulator IC	R-78K5.0-1.0	Digikey	945-R-78K5.0-1.0-ND	3.33	3.33
1	Video balun	NTSC/TV-HDI	Amazon	B07YCD5XXQ	1.90	1.90
2	Capacitor Electr.	220uF25V	Digikey	P13477-ND	0.41	0.82
1	RCA jack Yellow	Yellow insert	Digikey	CP-1403-ND	0.81	0.81
1	RCA jack White	White insert	Digikey	CP-1402-ND	0.81	0.81
1	RJ45 jack	Black cube	Digikey	609-1046-ND	0.68	0.68
1	Pin strip 5 pin	Gold 5 pin	Digikey	S1011EC-05-ND	0.18	0.18
1	Microcontroller	Teensy4.1	PJRC		32.50	32.50
4	Standoff 20mm	M2.5x20-FF	Digikey	AE10863-ND	0.26	1.04
4	Standoff 5mm	M2.5x5-MF	Digikey	732-12896-ND	0.20	0.80
1	Pin strip 16 pin	Gold 16 pin	Digikey	SAM12363-ND	2.73	2.73
1	LCD display	NHD-0420DZ	Digikey	NHD-0420DZ-FSW-F BW-ND	26.64	26.64
4	Standoff 10mm	M2.5x10-MF	Digikey	732-12917-ND	0.22	0.88
8	Screw, box	M2.5x6 pan Phillips	McMaster		0.05	0.40

2	Box bottom/top	Rounded rectangle	David		0.50	1.00
1	Box front	Long with holes	David		0.50	0.50
1	Box left side	Short with hole	David		0.50	0.50
1	Box right side	Short, no hole	David		0.50	0.50
1	Box rear	Long, no holes	David		0.50	0.50
25	Ferrules motor	Red 17 AWG	Digikey	A129216-ND	0.10	2.50
10	Ferrules power	Grey 11 AWG	Digikey	A112905-ND	0.15	1.50
10	Ferrules data	Blue 23AWG	Digikey	A114627-ND	0.08	0.80
1	Video balun	black	Amazon		5.00	5.00
1	Camera power cable	5.5/2.1mm 8"	Amazon		0.80	0.80
10	Zip Ties	6" black	Home Depot		0.10	1.00
2	O-rings for tube	OS5568-356 EPDM	McMaster-Carr	9557K333	1.90	3.79
12	Screws noggin to side	#8x1/2 ST 1/4 hex	McMaster-Carr	92400A230	0.19	2.28
1	Sensor connector	White 3 pin	Digikey	WM2001-ND	0.20	0.20
1	Tether plug	Plug,screw,4pin	Digikey	732-2753-ND	1.97	1.97
2	actuator shaft	1/4" D x 3" 10-32 SS	McMaster-Carr	91125A037	6.03	12.06
2	diode 100V 1A	1N4002	Digikey	1N4002DICT-ND	0.08	0.16
2	end seal o rings	2-1/4" OD x 1/8"	McMaster-Carr	9557K494	0.40	0.80
1	Lead nut	Tr8x8 brass 2 hole	Amazon	B08LZ1V56T	5.00	5.00
1	Lead screw	Tr8x8 x 75mm	Amazon	B08JPM29FD	2.00	2.00
1	Lexan tube	2-1/4 OD x 8" L	McMaster-Carr	9176T9	5.68	5.68
2	limit switch	subminiature	Digikey	2449-DM3CQF1003L01-ND	0.90	1.80
1	Motor	37D 24V 50:1	Pololu	4683	32.95	32.95
1	Motor controller	DRV8874	Pololu	4035	9.95	9.95
1	Shaft coupler	6mm x 8mm	Amazon	B09LC7WTT2	3.20	3.20
2	shaft seals	1/4" ID x 1/2" OD x 3/16"	McMaster-Carr	9505K13	3.95	7.90
6	Spacer	#6x1" Nylon round	McMaster-Carr	94639A306	0.19	1.14

1	Spring	.375" x 4" expansion	McMaster-Carr	9433K64	1.78	1.78
1	switch board	RVLIM-B	OshPark		4.00	4.00
1	Terminal jack strip	4 pin 3.5mm	Digikey	732-2771-ND	2.02	2.02
2	Terminal plug	2 pin 3.5mm	Digikey	732-2751-ND	1.47	2.94
1	thrust ball	8mm	McMaster-Carr	9292K45	0.20	0.20
				<b>Total cost</b>		<b>869.72</b>