SARCTRAC
Satellite **A**ntenna **R**otator **C**ontroller & **TRAC**ker
SCHOOL AMATEUR RADIO CLUB NETWORK
www.sarcnet.org

SARCTRAC Manual

Document Version 1.14 for Hardware Version 2 and Software Version 1.03

Contents

Introduction

SARCTRAC was developed so that students at our School Amateur Radio Clubs can have fun and learn about Low Earth Orbiting satellites during our lunchtime sessions. To make friends with a satellite you first have to know when and where it will be; point a small, directional antenna at it and use an Amateur Radio transceiver to listen or talk to it. It is a bit like fishing in the sky and just as challenging. It is really exciting when the kids hear their first satellite and then realise where it is. They always ask. "Can we talk to it?" We say. "Of course, you can." But the reality is that satellites move so fast that their position and radio frequency is constantly changing. Tracking a satellite by hand, while trying to tune an Amateur Radio transceiver for a typical 10-minute overhead pass, is a real chore for kids. Setting up an automatic tracking system, with a commercial antenna rotator and all the computers, cables and programs needed, is both tricky and expensive. So, we made SARCTRAC quick and easy for the kids to set up and now it does all the work for them. SARCTRAC helps kids spend more time listening to signals from space, receiving data or pictures and even communicating with others via satellites. School kids in space? No problems!

What is SARCTRAC?

- It is a little box which does all the satellite tracking, antenna steering and Amateur Radio transceiver (rig) control automatically, so that students can just enjoy working satellites!
- It is best suited to portable operation, mounted on a sturdy tripod and attached to a small, hand-held, dual-band, satellite antenna. It can be quickly set up in a school playground and runs off batteries (it has reverse-polarity protection) or the same power supply (12-15VDC) as the rig. Best of all, it is self-contained in a small 125x85x55mm (5.0x3.3x2.2inch) weather-resistant enclosure.
- It does not require any on-site calibration or levelling: A one-time, 3D sensor calibration is all that is required. It automatically repositions the antenna even if the tripod is moved! It has been successfully used in playgrounds, in the bush, on mountain tops and even on the deck of a pitching and rolling ship!
- It has a built-in WiFi web server so students can control it via a web browser on their Mobile Devices or on a Personal Computer (PC) in the classroom. It allows students to select which satellites they want to track from a list of available satellites. It displays the system status and the next pass time, azimuth and maximum elevation of the selected satellite.
- It automatically schedules the tracking of each selected satellite in turn. It uses the latest orbital-prediction models to accurately track the selected satellites. It sounds an alarm at Acquisition Of Signal (AOS) and Loss Of Signal (LOS) before moving or re-positioning the antenna. It even automatically unwinds the antenna cables if they get wrapped around the tripod.
- It automatically controls the frequency and mode of an Amateur Radio transceiver. It compensates for the Doppler effect on the frequency of fast-moving satellites. It has a built-in satellite transponder/beacon database to set the correct frequency and mode of the rig. It connects to the popular Yaesu FT-817/818/857/897, all-band, all-mode, transceiver via a Yaesu CT-62 USB cable. It even has a TUNING page for manual frequency and mode changes.
- It automatically connects to the Internet via an access point such as a home WiFi router or personal hotspot on a Mobile Device. It automatically gets the network time and downloads the latest satellite orbital elements from the Internet.
- It uses a 3D Magnetometer/Accelerometer Sensor to detect the position of the antenna and two, geared DC motors, one for Azimuth (AZ) and one for Elevation (EL), to point the antenna

at the selected satellite. The sensor and motors work in a stabilized, closed-loop control system.

- It has a built-in GPS receiver to get accurate time (if the Internet is unavailable) and location information. It starts up quickly using the last known position until a better GPS fix is available. It displays the local time when started and the street address of the current location. It uses a built-in World Magnetic Model to get the Earth's local magnetic inclination and declination so it can convert between magnetic and true compass directions.
- It can be configured, updated and backed-up using a plug-in USB Disk. Update files can be downloaded from the Internet and copied to the USB Disk using any personal computer. They load automatically when the USB Disk is plugged into SARCTRAC and the power is switched on

Requirements

To build this DIY project you will first have to purchase the complete SARCTRAC kit from the Products page on our website at https://www.sarcnet.org/products.html. Note: The kit contains a micro SDHC card with bootable, Raspberry Pi operating system and our compiled SARCTRAC application pre-installed fully tested and ready to go. Please note that our SARCTRAC software is not available separately or as freeware, nor is it transferrable. It is licenced to the original purchaser, who is then permitted to download and install free lifetime updates from our website. Our software will only run from the actual micro SDHC card and on the Raspberry Pi provided with the kit. If for any unforeseen reason you need to replace either of these components, just contact us.

Then, all you have to do is:

1. Provide your own assembly tools and sundries.
2. Accurately mark, drill and file holes in the enclosure using our detailed engineering drawings.
3. Wire up the components using our step-by-step instructions.
4. Assemble the components into the enclosure.
5. Use a PC to add your WiFi router credentials to the network.txt file on the USB Disk.
6. Insert the USB Disk into SARCTRAC.
7. Connect SARCTRAC to a DC power supply.
8. Wait until SARCTRAC beeps, twice.
9. Connect to SARCTRAC with via a WiFi enabled Mobile Device web browser.
10. Perform a simple, one-time, 3D Sensor calibration by turning the sensor all around.
11. Mount SARCTRAC on a sturdy tripod.
12. Attach a counterbalanced lift-arm for a hand-held satellite antenna.
13. Attach the 3D Sensor to the antenna boom using Velcro.
14. Connect an Amateur Radio transceiver to SARCTRAC via a USB cable.
15. Select satellites to track from a list.

SARCTRAC will then automatically track the selected satellites and control the rig.

SARCTRAC Features

Setup

- Tripod-mounted for portable operation and quick set-up - Easily splits into two separate pieces: Tripod/rotator and antenna/lift-arm.
- DC powered for battery or solar operation - Typically uses the same power source as the radio.
- Integrated rotator and controller in one unit - Smaller with less cables. No third-party tracking software to wrestle with.
- Weather proofing possible - IP68 sensor and IP65 case with neoprene O-ring motor shaft seals. DIY seal around connectors with silicone sealant.

Networking

- WiFi enabled - Works with home WiFi network or WiFi-enabled mobile device with personal hotspot and broadband Internet connection.
- Internet enabled - Automatically downloads date, time and satellite orbital elements from the Internet.
- WiFi enabled mobile device used for control and display - No cables to separate PC or laptop.
- Built-in web server accessible by any web browser on the WiFi network - No tracking applications to install and configure.

Start-up

- Displays satellite SELECTION, satellite TRACKING and radio TUNING web pages - Logically organised pages.
- Start-up alert tones - Warn of disconnected USB CAT Cable, GPS or 3D Sensor.
- Access to START/STOP, RESTART and SHUTDOWN buttons on each web page - Important for rotator safety and tracker control.
- Starts with motors stopped - Operator action is required to start motors after power up for safety.
- Displays Local Time with Time Zone selection - Easier for scheduling.
- Date and time information provided by built-in GPS receiver or Internet time source - No clock setting required.
- Latitude and Longitude information provided by built-in GPS receiver - No station location entry required.
- Uses last saved location until GPS is available - Quicker startup.
- Stops polling GPS when location error is minimised -   Reduces processor load.
- Displays reverse geocode address lookup - Confirms that the correct latitude and longitude is used.
- Antenna pointing information provided by boom-mounted 3D Sensor (magnetometer/accelerometer) - No compass calibration or levelling required.
- Magnetic inclination and declination information provided by built-in World Magnetic Model - No online searching for local magnetic offsets.
- Satellite orbital element information updated from Internet each day - No manual download required.
- Satellite position determined from the latest SGP4 orbital predication models - More accurate tracking.
- Uses last saved satellite selection - Quicker startup.

Satellite Selection

- Access to thousands of satellite orbital elements over the Internet - Distributed by Dr. T.S. Kelso at www.celestrak.com since 1985.
- Permits user-entry of selected orbital element library URLs - Select which satellite libraries are of interest.
- Each orbital element library contains hundreds of satellites in different categories, like weather, cube-sats, amateur and NOAA - Select only the categories you want.
- Permits loading of user-defined orbital element library files - Load pre-launch or unlisted orbital elements.
- Permits user entry of satellite names to be rejected - Omit whole series of unwanted satellites from the satellite selection list.
- Displays satellite statistics: Number of each type loaded, duplicates removed, number rejected and the total available - Helps manage your satellite database.

Satellite Tracking

- Tracks only selected satellites - Schedules tracking of each satellite in turn.
- Selected satellites displayed in order of their Acquisition Of Signal (AOS) time - Provides a next pass schedule.
- Visible satellites displayed in order of Loss Of Signal (LOS) time - Provides a best pass schedule.
- Displays next-pass, AOS time, azimuth and max elevation for each selected satellite - Easy to decide which satellite passes to track.
- Displays currently tracked satellite azimuth, current elevation and LOS time - Easy to compare current satellite LOS time with next satellite AOS time.
- Automatically points the antenna at a visible satellite - No manual antenna steering required.
- Built-in 3-second alert tone indicates immanent antenna movement - Safer operation. Alerts at the start and end of the current pass.
- Intelligent search algorithm selects the best visible satellite to track - Only tracks the longest passes.
- Permits selection of any one of multiple visible satellites - Compare and select the best of the currently visible passes.
- Automatically re-positions antenna ready for the next pass - No waiting at the start of each pass.
- Intelligent anti-windup algorithm - Unwinds the cables in between passes.
- Tracks multiple selected satellites in turn - No resetting selections between passes.

Radio Control

- Radio CAT control enabled - Automatically controls the radio frequencies and modes.
- Automatically controls the radio frequencies correcting for satellite Doppler shift - Accurate frequency control.
- Satellite beacon/transponder frequency and mode information provided by built-in satellite database - No online searching for satellite data.
- Permits selection of known satellite beacons or transponders - Useful to check the beacon frequency if the transponder is not heard.
- Permits manual adjustment of transmit and receive frequencies and modes - Useful to avoid interference and use the transponder bandwidth more efficiently.

Sensor Calibration

- One-Time 3D Sensor calibration required - Recalibration not usually required.

- Provides manual Start, Abort and Save calibration controls with tone feedback - Easier and more accurate calibration.

Miscellaneous

- Low Radio Frequency Interference (as compared with Arduino and Raspberry Pi 3) - Easier to hear selected satellites.
- DC reverse polarity protection - Setup at night with no more smoke and tears.
- Low power consumption - Runs 8 hours on 2Ah battery.
- Stall resistant motors and gearboxes with all metal gears - Safer operation with longer lasting gearboxes and no stripped gears.

SARCTRAC Specifications

- Enclosure Size: 125x85x55mm (5.0x3.3x2.2inch)
- Operating voltage (typical): 12-15VDC
- Operating current (typical): 300mA
- Startup time (max seconds): 60
- Antenna rotation speed (max): 0.6 RPM azimuth and elevation
- Supported WiFi Network: 2.4GHz (IEEE 802.11bg)
- Supported Amateur Radios: Yaesu FT-817/818/857/897
- Supported USB CAT Cables: Yaesu CT-62 (Genuine FTDI Chip)
- Sensor cable length: 1m
- Power cable length: 1m

SARCTRAC Cautions

Please read the following very carefully. We accept no responsibility or liability for the following:

- This is a DIY project for the experience builder. We are not responsible for your time, costs, tools, availability or substitution of parts.
- Beware of moving parts - Unit may move at any time without warning. Do not stand or permit anyone to stand in the vicinity of the operating unit.
- Beware of eye hazard - Moving satellite antennas are prickly. Eye protection is recommended.
- Beware of pinch hazard - Keep fingers away from moving parts.
- Beware of electromagnetic radiation hazard - Do not use with high power transmitters. Recommend 10 Watts maximum.
- Beware of electrocution hazard - Do not use near power lines.
- Beware of lightning hazard - Do not use in thunderstorms, rainy or windy conditions.
- Beware of fire hazard - The unit has no built-in over-voltage or over-current protection.
- Not suitable for unattended operation.
- Not suitable for fixed or permanent outdoor operation.
- Automatically connects to the Internet: Adult permission and charges may apply.
- Constant adult supervision of the operation is required to prevent injury, especially around children.
- Constant adult supervision of the operation is required to prevent damage to the unit, anything attached to the unit or anything in the vicinity of the unit.
- Constant adult supervision of the operation of radio transmitters is required at all times. You must check your licence conditions and operating frequency.

- Antenna, tripod, lift arm, mountings, cables or anything in the vicinity of the unit may be damaged under normal operation or due to software malfunction.
- The motors a light-duty: Do not force them. Avoid striping the metal gears.
- Installation of a safety DC cut-off switch is recommended.

SARCTRAC Limitations

- Suitable for rotating only a single, small directional antenna (e.g. A handheld, dual-band, Yagi antenna such as an Arrow antenna) using a counterbalanced lift arm.
- Currently only suitable for controlling the Yaesu FT-817, All-band, All-mode, radio transceiver at this time. Others types to be advised.
- Performance may become sluggish if more than ten (10) satellites are actively selected for tracking.
- Unit will oscillate unless solidly mounted only on a rigid stand, such as a heavy-duty (speaker) tripod.
- Any formatting or data errors in the configuration files will stop the operation of the unit. Always keep a backup of the working configuration files.
- Oscillates between start azimuth points if predicted passes have the same AOS time in minutes
- Displays predicted passes even with zero degrees maximum elevation
- Web pages are static: Track button must be re-pressed to refresh correct tracking status

SARCTRAC Assembly

Getting Started

1. Follow these instructions in order. Strike through the number, like this ~~1.~~, when complete.
2. Check off all the parts in the SARCTRAC kit as shown in Table 1.
3. Place all the parts into a sealed container for safe-keeping during the assembly process.
4. Get ready all the tools and sundries required for assembly as shown in Table 2.
5. Check that the DC Motors work smoothly in both directions: Connect them to a 12V supply. See Troubleshooting if they don't work.

Marking the Enclosure and Heatsink

6. Study the Enclosure drawings carefully, particularly the orientation of each face, as shown in Figure 4.
7. Study the Enclosure pictures carefully, particularly the orientation of each face, as shown in Figure 8, Figure 9, Figure 10, Figure 11 and Figure 12.
8. Mark the enclosure to be machined very accurately. Sub-millimetre precision is required. We couldn't do it using a ruler or even self-adhesive 1:1 scale templates. The following works well:
9. Attach self-adhesive paper labels to the outside surfaces of the Enclosure covering the areas which will be machined as shown in Figure 4. Four on the base of the enclosure and one on the lid.
10. Use the sharp points on a digital calliper to scribe construction lines on the labels as shown in Figure 4. Note that the Enclosure is chamfered and some measurements are from the top edge, while others are from the bottom edge. Use a set square on a level surface to extend these construction lines vertically as shown in Figure 6. Circle the final hole positions on the labels with a pen.
11. Use a pointed scribe to indelibly mark the centre positions of the round holes through to the outside surface of the Enclosure.
12. Use a box-cutter blade to indelibly mark the outlines of the rectangular holes through to the outside surface of the Enclosure.
13. Similarly, attach self-adhesive paper labels to the outside surfaces of the Heatsink covering the areas which will be machined.
14. Use a digital calliper to scribe construction lines on the heatsink labels as shown in Figure 5.
15. Use a pointed scribe to indelibly mark the centre positions of the round holes through to the outside surface of the Heatsink.
16. Remove the paper labels.

Table 1 – Parts List

ITEM	DESCRIPTION	QTY	Checked
SDHC Card	Micro SDHC card with SARCTRAC software	1	
Rpi0	Raspberry Pi Zero WH	1	
Motors	DC 12V 0.6RPM DC Motor Right Angle Gear	2	
Motor Driver	L298N H-bridge Dual DC Motor Driver Board (Modified with 4x10kΩ 1206 SMD Resistors)	1	
3D Sensor	LSM303DLHC 3-Axis Accelerometer/Magnetometer	1	
USB Disk	8GB USB Disk	1	
USB Hub Hat	4 Port USB HUB for RPi0 & Micro USB Joiner.	1	
USB GPS Receiver	VK-172 USB GPS Receiver (U-blox7)	1	
Regulator	LM2940CT-5 5V, 1A, Low Dropout Regulator (Modified with 22uF Tantalum SMD Capacitor)	1	
Diode	1N5819 Schottky Diode	1	
Enclosure	125Lx85Wx55Hmm IP65 Sealed ABS Enclosure	1	
Heatsink	25x25x1.6mm Aluminium Angle	60mm	
Buzzer	3-16V Mini Sealed PCB Mount Buzzer	1	
Shaft Hubs	6mm Rigid Flange Motor Shaft Coupler	2	
O-Rings	O-Rings Nitrile Rubber 5mm x 8mm x 1.5mm	2	
USB Adapter	USB Right Angle Adapter	2	
Grommet	Sleeved Grommet 6.1mm	1	
Ceramic Capacitors	0.1uF Ceramic Monolithic	4	
16mm Pan Screws	M3 x 16mm Pan Pozi Nickel Bolt	1	
10mm CSK Screws	M3 x 10mm Countersunk Pozi Nickel Bolt	3	
6mm CSK Screws	M3 x 6mm Countersunk Pozi Nickel Bolt	14	
6mm Cap Screws	M3 x 6mm Hex Cap Screw Stainless Steel	4	
Allen Key	2.5mm Allen Key	1	
Metal Nuts	M3 Hex Nut	4	
Poly Nuts	M3 Nut Polycarbonate (used as spacers)	2	
Metal Washers	M3 Flat Washer	2	
Fibre Washers	M3 Red Fibre Washer	2	
10mm Spacer	M3 x 10mm Tapped Nylon Spacer	1	
6mm Spacers	M3 x 6mm Tapped Nylon Spacer	3	
13mm Heat-Shrink	Black 13mm Adhesive Heat-Shrink Tubing	30mm	
1.5mm Heat-Shrink	Black 1.5mm Heat-Shrink Tubing	10cm	
3.0mm Heat-Shrink	Black 3.0mm Heat-Shrink Tubing	5cm	
Veroboard	0.1" Pitch Vero Board PCB - 4x2 holes	10x7mm	
Hookup wire	7/0.16 Tinned Light Duty Hook Up Cable: 7xBlack, 4xBrown, 3xRed, 1xYellow, 1xGreen, 1xOrange, 1xBlue, 1xPurple and 1xGrey	20x 150mm	
DC Power Cable	24/0.2 Red / Black DC Power Cable	1m	
3D Sensor Cable	4 Core Flat Modular Telephone Cable	1m	
Cable-Tie	100mm x 2.5mm Nylon Cable Ties Black	3	

Item	Qty	Checked	Item	Qty	Checked
Pen or pencil	1		Hot air gun	1	
Parts container	1		PZ2 Screwdriver	1	
Large self-adhesive labels	5		Flat face pliers	1	
Digital callipers	1		Quick-Grip bar clamp	1	
Set square	1		Non-stick frying pan	1	
Pointed scribe	1		Velcro double-sided, 19mm	1x15cm	
Box-cutter	1		Velcro double-sided, 25mm	2x25cm	
Electric hand drill	1		PVC tape	40cm	
Drill bit 2.5mm – 3/32"	1		Silicone Sealant	A/R	
Drill bit 3mm – 1/8"	1		12-15VDC Power Supply	1	
Drill bit 6.5mm – 1/4"	1		Yaesu FT-817/818/857/897 Transceiver	1	
Drill bit 8mm – 10/32"	1		Yaesu CT-62 USB CAT cable (Genuine FTDI Chip)	1	
Drill bit countersink	1		Arrow antenna or similar	1	
Dremel tool with cutting bit	1		Tripod: Jaycar CW2860 or Altronics C0524	1	
Small hacksaw	1		Counterbalanced Lift-Arm	1	
Small rat-tail file	1		Windows, Linux or Mac PC	1	
Small, sharp, side-cutters	1		Home WiFi Router and Admin Password	1	
25W Soldering iron	1		WiFi Enabled Mobile Device	1	
Solder wick, 3mm	10cm		Rosin-cored solder, 1.5mm (Lead Free)	20cm	
Heat Sink Compound	A/R				

Machining the Enclosure and Heatsink

1. Drill all the round holes (1x2.5mm, 14x3mm, 2x6.5mm and 1x8mm) in the Enclosure.
2. Deeply countersink all the 3mm holes on the <u>outside</u> of the Enclosure.
3. Countersink (only 1mm deep) all 6.5mm holes in the <u>inside</u> of the Enclosure for the O-rings.
4. Drill and then file square the four (4) rectangular holes in the Enclosure as shown in Figure 9.
5. Check that the USB joiner connectors for the USB Hub Hat, as shown in Figure 15, fit entirely through the small rectangular holes.
6. Check that the USB Type A connectors fit through the larger rectangular holes.
7. There are ten mounting posts on the inside of the enclosure. Grind all of these flush as shown in Figure 7, ideally using a Dremel tool and a cutting bit, or carefully with a <u>very</u> slow 8mm drill bit.
8. Drill 2x3mm holes in the heatsink as shown in Figure 5. Countersink the mounting hole for the regulator on the rear of the heatsink. Chamfer two edges of the heatsink as shown.
9. Enlarge the four mounting holes on the RPi0 using a 3mm drill bit.
10. Drill out the threads of the two Poly Nuts using a 3mm drill, so they can be used as spacers.

Wiring and Assembly

Wires and Cables

11. Cut the 1.5mm Heat-Shrink into ten 1cm pieces.
12. Cut the 3mm Heat-Shrink into two 2.5cm pieces.
13. Mount the Sleeved Grommet to the Enclosure base: Squeeze the inner gland and insert a corner of it into the 8mm hole. Use the shank of the 2.5mm drill bit to press the rest of it through the hole.
14. Push and pull the 3D Sensor and Power Cables together (they will be tight) through the Sleeved Grommet to their final positions as shown in Figure 26.
15. Remove 15mm of the sheath of the 3D Sensor cable, at both ends, carefully using a box-cutter.
16. Strip both ends of all Wires, 3D Sensor Cable and Power Cable to 2mm with side cutters and tin the ends with the soldering iron.
17. Clip the Diode leads to 5mm.
18. Solder the anode of the Diode to the positive lead of the Power Cable as shown in Figure 13.
19. Solder a Brown Wire to the cathode (ring-end) of the Diode as shown in Figure 13.
20. Solder a Black Wire to the negative lead of the Power Cable as shown in Figure 13.
21. Shrink 3.0mm Heat-Shrink over the Power Cable as shown in Figure 13.
22. Loop a cable tie around the inside of the Sleeved Grommet to secure it.

Regulator

23. Cut the 3 Regulator pins down to 5mm.
24. Solder the Tantalum Capacitor to the Regulator close to the package. The orientation of the capacitor is CRITICAL. Positive goes to the output pin. The capacitor is NOT optional. Extra heat will be required for the central GND pin which connects to the tab. Note: This step is already completed for the Regulator provided in the SARCTRAC kit.
25. Solder a Brown, Black and Red wire to the Regulator as shown in Figure 13.
26. Shrink 1.5mm Heat-Shrink over the Regulator pins as shown in Figure 13.
27. Apply a smear of Heat Sink Compound to the rear of the Regulator.
28. Mount the Regulator on the Heatsink using a 6mm CSK Screw, a Metal Washer and a Metal Nut as shown in Figure 14.
29. Mount the Regulator to the Enclosure Lid using one 6mm CSK Screws, a Metal Washer and a Metal Nut as shown in Figure 26.

Controller

30. Cut off all forty header pins on the USB Hub Hat (NOT THE RPi0!) 2mm from the PCB surface.
31. Attach two 6mm Spacers to the USB Hub Hat with 6mm CSK Screws as shown in Figure 16.
32. Attach one 10mm Spacer to the RPi0 with an 16mm Pan Screw as shown in Figure 17.
33. Connect the RPi0 to the 40-Pin socket of the USB Hub Hat as shown in Figure 17.
34. Attach one 6mm Spacer to the USB Hub Hat over the 16mm Pan Screw as shown in Figure 17.
35. Solder the Red Wire from the Regulator to pin 2 on the USB Hub Hat as shown in Figure 15.
36. Solder the remaining 10 Wires to the indicated pins of the USB Hub Hat as shown in Figure 15.
37. Check that the right coloured Wires are soldered to the right pins as shown in Figure 15.
38. Secure a small cable-tie around the Wires at the USB Hub Hat end as shown in Figure 16.
39. Remove the plastic case from the USB GPS Receiver by prising it apart with fingernails.
40. Connect the GPS to the USB Hub Hat as shown in Figure 18.
41. Tape over the RPi0 header pins using PVC tape to stop them touching the EL Motor as shown in Figure 19.

42. Tape over the battery side of the GPS board using PVC tape to stop it touching the heatsink as shown in Figure 19.
43. Mount the Controller assembly to the Enclosure using three 6mm CSK Screws as shown in Figure 8.

Motors

44. Solder the Ceramic Capacitors from the motor chassis to the motor terminals as shown in Figure 22.
45. Solder Brown Wires to the Red dot terminal on the Motors.
46. Solder Black Wires to the other terminal on the Motors.
47. Shrink the 1.5mm Heat-Shrink over the Motor terminals using a hot air gun.
48. Attach lightly lubricated O-Rings to the Motor shafts.
49. Mount the AZ Motor to the Enclosure Base using four 6mm CSK Screws as shown in Figure 10.
50. Mount the EL Motor to the Enclosure Lid using four 6mm CSK Screws as shown in Figure 11.

Motor Driver

51. Remove all three jumpers from the Motor Driver as shown in Figure 20.
52. Solder 4x10kΩ 1206 SMD resistors to pins IN1-IN4 on the rear of the Motor Driver as shown in Figure 21. Solder a 15mm piece of bare, tinned, copper wire to the other side of the SMD resistors, connecting them to the ground pins on either side. Note: This step is already complete for the Motor Driver provided in the SARCTRAC kit.
53. Slip 1.5mm Heat-Shrink over the Orange, Blue, Purple and Grey Wires.
54. Solder the Orange Wire to the IN1 pin on the Motor Driver.
55. Solder the Blue Wire to the IN2 pin on the Motor Driver.
56. Solder the Purple Wire to the IN3 pin on the Motor Driver.
57. Solder the Grey Wire to the IN4 pin on the Motor Driver.
58. Shrink the Heat-Shrink in place.
59. Re-install all three jumpers on the Motor Driver.
60. Solder the Brown Wires from the Regulator and Power Cable together in parallel to avoid them pulling out of the Motor Driver screw terminals.
61. Connect the Brown Wires to the +12V terminal on the Motor Driver.
62. Solder the Black Wires from the Regulator, Power Cable and RPi0 together in parallel to avoid them pulling out of the Motor Driver screw terminals.
63. Connect the Black Wires to the GND terminal on the Motor Driver.
64. Secure a small cable-tie around the Wires at the Motor Driver end as shown in Figure 26.
65. Connect the Black Wire from the AZ Motor to the OUT1 terminal on the Motor Driver.
66. Connect the Brown Wire from the AZ Motor to the OUT2 terminal on the Motor Driver.
67. Connect the Black Wire from the EL Motor to the OUT3 terminal on the Motor Driver.
68. Connect the Brown Wire from the EL Motor to the OUT4 terminal on the Motor Driver.
69. Mount the Motor Driver to the Enclosure using two 10mm CSK Screws, two Poly Nuts as spacers, two Fibre Washers as spacers and two Metal Nuts. The order of assembly is Screw, Enclosure, Poly Nut, Fibre Washer, Motor Driver and Metal Nut.

Buzzer

70. Slip 1.5mm Heat-Shrink over the Buzzer wires from the USB Hub Hat and solder them to the Buzzer. The polarity is CRITICAL. Red = + (the long lead).
71. Shrink the 1.5mm Heat-Shrink over the Buzzer terminals using a hot air gun.
72. Mount the Buzzer to the Enclosure using silicon sealant as shown in Figure 26. Use a 2.5mm drill shank to protect and align the sound hole in the Buzzer with the hole in the Enclosure while the sealant cures.

Sensor

73. Solder the wires to the Sensor as shown in Figure 23. Cut any excess wire and solder flush to the Sensor board. The bottom side of the sensor must be perfectly flat.
74. Shrink the 13mm Heat-Shrink over the 3D Sensor using a hot air gun. Avoid too much heat. Crimp the free end, while hot, with flat face pliers to seal it as shown in Figure 24.
75. Solder the 3D Sensor Cable to the Veroboard as shown in Figure 25.
76. Solder the Wires from the USB Hub Hat to the Veroboard as shown in Figure 25.

USB Adapters

77. The USB Adapters do not quite fit together into the USB Hub Hat. They can be used singly, but both will be required if using separate Amateur Radio transceivers for transmit and receive or if weather-proofing the cable entry points is needed.
78. The USB Adapters can be optionally heat-treated and fused together as shown in Figure 28.
79. Determine the two faces that must be fused together. Press the faces to be fused face down onto a flat, non-stick frypan, heated to 200 degrees Celsius, until the plastic becomes soft and pliable and the ridges are flattened.
80. Align the two heated faces together and, while still hot, squeeze together using the parallel jaws of a quick-grip bar clamp, until they cool. Do not squeeze too hard. The outside metal part of the USB plugs should be 29.3mm apart.

Final Assembly

81. Check the wiring and assembly as shown in Figure 3 and Figure 26.
82. Connect the USB Joiner and Dual USB Adapter to the USB Hub Hat via the outside of the Enclosure.
83. Insert the gasket, supplied with the enclosure, to the Enclosure Lid and clip off any excess.
84. Check the EL Motor clearance between the RPi0 pins and the AZ Motor. There is only 1mm clearance.
85. Secure the Enclosure Lid and EL Motor assembly to the Enclosure Base as shown in Figure 27.
86. If required, use silicone sealant to seal around the USB joiner holes first and then the USB Adapter holes.
87. Replace the grub screws in the Shaft Hubs with the Cap Screws.
88. Mount the Shaft Hubs on the Motor shafts using the 2.5mm Hex key as shown in Figure 27.

SARCTRAC Checkout, Configuration and Calibration

Power-up Checks

1. Make sure SARCTRAC is powered down.
2. In preparation for testing and calibrating SARCTRAC, lay it on one of its flat sides on the desk, so that the shaft hubs are clearly visible and are not touching anything.
3. Make sure the 3D Sensor, GPS Receiver and USB CAT cable (optional) are connected to SARCTRAC.

> **IMPORTANT:** Always power-down SARCTRAC before plugging in or removing any USB devices. Not doing so will likely reset the RPi0.

4. Connect the SARCTRAC power cable to a 12VDC power supply and power it up.
5. Wait for SARCTRAC to beep according to Table 3. If the beeps occur, they occur in the order shown. If SARCTRAC does not beep at all after a few minutes: See Troubleshooting. If it indicates that the 3D Sensor, GPS Receiver or USB CAT cable is not connected when they are connected: See Troubleshooting.

Table 3 – SARCTRAC Audible Alerts

Order	Alert tone	Meaning	Type
1	One short 100ms beep	USB CAT cable not connected	ERROR
2	Two short 100ms beeps	GPS not connected	ERROR
3	Three short 100ms beeps	3D Sensor not connected	ERROR
4	One long 3-second beep	ABOUT TO MOVE	WARNING
5	Five short 100ms beeps	Started tracking new satellite	INFORMATION

WiFi Network Configuration

> **IMPORTANT:** SARCTRAC automatically connects to the Internet to download new orbital element files every day. Internet charges may apply. Always seek adult permission to use the Internet.

1. Make sure your WiFi Router or Mobile Device Personal Hotspot (aka Mobile Hotspot) is powered up and enabled.
   a. For a WiFi Router: Log in to the administrator page using a PC browser and the administrator password. Record the WiFi Router Service Set IDentifier (SSID aka Network Name) and Password required to access the 2.4GHz WiFi port. Note: At the time of writing the RPi0 does not support 5GHz WiFi networks. Each band will have a different SSID. If necessary, configure the WiFi Router security settings to accept new devices. For information on how to configure your WiFi Router please see the instruction booklet.
   b. For a Mobile Device: Select Settings and turn on the Personal Hotspot.
      i. iPhone: Settings | Personal Hotspot.
      ii. Android: Settings | Connections | Mobile Hotspot and Tethering. Long-press for details.
   c. Record the Personal Hotspot SSID and Password required for WiFi access. For information on how to configure your Mobile Device please see the instruction booklet. Note that apostrophes and spaces used in some iPhone SSIDs may be a

problem and may have to be removed. For example, change "joe's iPhone" to "joe". Please see iPhone Settings|General|About|Name to change it.

2. To configure SARCTRAC to connect to a WiFi Router or Mobile Device Personal Hotspot, a new network configuration file must first be installed.

3. On a PC, Windows/Mac/Linux etc, download the www.sarcnet.org/sarctrac/network.txt file. See Table 4 for the actual contents of this default network.txt file.

4. Edit the network.txt file, using a simple text editor (not MS WORD), supplying the items shown in bold: **Country**, **SSID** and **Password** and **any other parameters** needed by your home WiFi Router or Mobile Device Personal Hotspot. You can configure more than one network – for example at home and at school. For more technical details on how to configure the network .txt file for your WiFi please see: https://linux.die.net/man/5/wpa_supplicant.conf.

5. Plug a USB Disk (aka thumb-drive or memory-stick etc) into the PC.

6. If necessary, format the USB Disk as FAT32 and/or erase the entire contents of the USB Disk – Note: All data will be deleted.

7. Edit the volume label of the USB Disk: It must be 'SARCTRAC'.

8. Copy the edited network.txt file to the root folder of the USB Disk (it should be the only file there).

9. Eject the USB Disk from the PC and insert it into a SARCTRAC USB port.

IMPORTANT: Always power-down SARCTRAC before plugging in or removing the USB Disk. Not doing so will likely reset the RPi0 and/or corrupt the USB Disk. Backup and repair a UDB Disk, if necessary, on a PC.

10. Power-up SARCTRAC, it will beep according to Table 3.

11. Wait one minute or so until SARCTRAC beeps one long beep indicating that it has powered up.

12. SARCTRAC will automatically load the network.txt file, restart and try to connect to your WiFi network.

13. Wait another two minutes or so until SARCTRAC beeps one long beep again indicating it has powered up after the restart.

14. Check your WiFi Router or Mobile Device Personal Hotspot to see if there is a new SARCTRAC device connected to it via the WiFi network:

    d. On a WiFi Router: List the connected WiFi devices. Look for the device called SARCTRAC. Alternatively, each device on the WiFi network has a MAC address. The MAC address of an RPi0 starts with 'b8:27:eb'. Check that the RPi0 MAC address is listed in the connected or allowed devices. If it is not listed there, check to see if it is shown in a list of blocked devices. If your WiFi Router has blocked the RPi0 MAC address, fix it by adding the full MAC address to the router's allowed list or by configuring it to accept new devices. The WiFi Router may need to be restarted to enable this.

    e. On a Mobile Device: Successful connections to the Personal Hotspot are usually shown in a banner.

15. If SARCTRAC cannot connect to the WiFi network: See Troubleshooting.

16. Discover which IP address or URL to use to connect to SARCTRAC via a web browser on the WiFi network:

    f. For iPhone or Mac PC or any device supporting zeroconf (bonjour) automatic network configuration, just open the browser app and enter 'sarctrac.local' as the URL.

    g. For Android, download and use a free Network Scanner app such as Network Analyser (https://techet.net/netanalyser) to determine the IP Address of SARCTRAC.

h. For a Windows, Mac or Linux PC, without zeroconf, download and use Angry IP Scanner (https://angryip.org/) to determine the IP Address of SARCTRAC.

i. If all else fails, you can set your WiFi Router DHCP server to reserve a Static IP address for the SARCTRAC RPi0 MAC address. Then always use that IP address. See the WiFi Router manual for details.

17. Connect to SARCTRAC with the URL or IP Address using a web browser on the same WiFi Network.

18. Once connected you should see the SARCTRAC SELECTION page on your browser. See SARCTRAC Operation for details. Note: The page is designed to be displayed on mobile phones in portrait orientation. Please resize or reorient the browser display to suit.

19. Press the SHUTDOWN button. Wait 10 seconds. Power-down SARCTRAC and remove the USB Disk.

Table 4 – SARCTRAC network.txt file

```
#network.txt version 1.0
#WiFi network settings for the Satellite Antenna Rotator Controller and Tracker (SARCTRAC)

###########################################################################
#Copyright(c) 2018. All rights reserved by Julie VK3FOWL and Joe VK3YSP for #
#The School Amateur Radio Club Network (SARCNET), www.sarcnet.org.          #
#This is NOT free software: Only the original purchaser may use it.         #
#Do not remove this notice or re-distribute any part of this software.      #
###########################################################################

#Please do not modify the following lines
ctrl_interface=DIR=/var/run/wpa_supplicant GROUP=netdev
update_config=1

#Please change your two-letter country code here. For current codes please see:
https://en.wikipedia.org/wiki/ISO_3166-1_alpha-2#Current_codes
country=AU

#Please provide the settings for one or more home WiFi network routers or mobile device
personal hotspots
#Copy the network={} template for each device and insert your specific information. Then
delete the examples.

#Example iPhone Personal Hotspot settings (Note: Apostrophes and spaces in the ssid may
cause problems. See iPhone Settings|General|About|Name to change it)
network={
        ssid="MYSSID1"
        psk="MYPASSWORD1"
        proto=RSN
        key_mgmt=WPA-PSK
        pairwise=CCMP
        auth_alg=OPEN
}

#Example Home WiFi Router settings
network={
        ssid="MYSSID2"
        psk="MYPASSWORD2"
}
```

System Status Checks

1. Power-up SARCTRAC and wait for it to beep.
2. Connect to SARCTRAC using a web browser.
3. The SARCTRAC SELECTION page should be displayed.
4. Press the START button, the Motors should start moving. If not: See Troubleshooting.
5. When the motors start moving: See if you can control them with the 3D Sensor. If not: See Troubleshooting.
   a. Hold the 3D Sensor in your hand with the flat side down and the front side (opposite the cable) pointing North.
   b. Point the 3D Sensor upward: The EL Motor hub should turn counter-clockwise.
   c. Point the 3D Sensor downward: The EL Motor hub should turn clockwise.
   d. Point the 3D Sensor to the East: The AZ Motor hub should turn counter-clockwise*.
   e. Point the 3D Sensor to the West: The AZ Motor hub should turn clockwise*.
   f. *Note the AZ Motor may turn in the opposite directions if the Anti-Windup function has engaged. In this case. Keep the 3D Sensor facing North. Cycle power to SARCTRAC, wait for it to beep, then try East and West again. If the motors move in the wrong direction, see Troubleshooting.
6. Check the SYSTEM STATUS and START-UP LOG for any errors as shown in the Troubleshooting section.
7. Note: The system status may change over time. Press the browser refresh button to update the display.

> **IMPORTANT:** Refreshing an old web page on a browser after a system RESTART or a SHUTDOWN will just resend the last command again – which will, of course, be RESTART or SHUTDOWN. In this case you should always close the web page first then reopen it.

3D Sensor Calibration

1. There is a video of the 3D Sensor Calibration procedure on YouTube at: https://www.youtube.com/watch?v=oJnpO5Nj7Gc&t=30s
2. Tape the 3D Sensor across the centre of a plastic or wooden ruler.
3. Hold the ruler firmly with both hands. Don't bump it or jerk it while calibrating. Don't change hands.
4. On the SARCTRAC SELECTION page scroll down to SENSOR CALIBRATION and get someone to press BEGIN.
5. You can ABORT or SAVE the calibration at any time by pressing those buttons.
6. Calibrate the 3D Sensor by GENTLY moving it all around until SARCTRAC stops beeping.
7. However, there is a trick to calibrating SARCTRAC properly: Think of the 3D Sensor as a cube with six faces. You need to point each face in the direction of the Earth's magnetic field and also in the direction of the Earth's gravitational field. The order does not matter. Now, the gravitational field points straight down while, here in the Southern hemisphere, the magnetic field points up and to the North at an angle of about 70 degrees to the horizontal. So, there are 12 directions in all to point the 3D Sensor at and you have to move it a little bit around each point so SARCTRAC can collects its calibration points. If while moving it beeps again: Search a little around that general area for additional calibration points. SARCTRAC just loves calibration points! Eventually it will stop beeping no matter where you point it.
8. Don't forget to get someone to press the SAVE button when you have finished calibrating, or ABORT - if you sneeze.

SARCTRAC Installation

Mounting

CAUTION: If mis-configured or malfunctioning, SARCTRAC may move the antenna without warning or in an unexpected direction. Satellite antennas are PRICKLY BEASTS. The antenna may be damaged or bystanders may be injured. NEVER operate SARCTRAC without constant adult supervision. NEVER stand next to the antenna when SARCTRAC is operating. Be prepared to IMMEDIATELY disconnect the power if the antenna moves in an unexpected direction, before it hurts someone or damages something.

1. Once 3D Sensor calibration is complete and the WiFi connection is working, SARCTRAC should be functioning correctly. However, before performing SARCTRAC functional testing, it has to be mounted rigidly on a stand or tripod with a lift-arm to attach the antenna and the 3D Sensor. SARCTRAC is a closed-loop AZ-EL feedback control system. If not rigidly mounted to the ground and to the 3D Sensor it will oscillate wildly.

2. You can mount SARCTRAC on a tripod with a real lift-arm and antenna or you can make a simple bench-test setup as shown in Figure 32.

3. For the simple bench-test set up, in addition to the parts listed, you will need a base-plate of at least 150x150mm, a 200x6mm aluminium rod, a 6mm shaft-coupler and a 150x25x25x1.8mm PVC angle. Mount the 3D Sensor and EL Motor Hub at either ends of the PVC angle. Mount the AZ Motor Hub on the base-plate. Attach SARCTRAC to the base-plate using the shaft-coupler and the rod. You can now perform full functional testing on a bench (so long as it has GPS coverage and is free from magnetic interference). Otherwise continue to mount SARCTRAC properly and then conduct functional testing.

4. Prepare an Extra Heavy-Duty Speaker Tripod. Try a Jaycar CW2860 or Altronics C0524. Remove the speaker bracket, if fitted.

5. Attach a 6mm shaft-hub to the top of the tripod using a 25mm irrigation-pipe threaded plug, 3mm cheese-head bolts, flat washers, spring washers and nuts. See Figure 30.

6. Fix with self-tapping screws to the tripod. Replace the grub screws on the shaft hub with cap screws to obtain additional torque and avoid screwdriver slippage.

7. Attach SARCTRAC via the AZ Motor shaft to the tripod and tighten the hub screws.

8. Round the sharp edges of a lift-arm made from 500x30x30x3mm aluminium angle.

9. Make a counterweight from a 101x51x25mm diecast aluminium box: Altronics H045, or similar. Filled with lead to 860g (for the Arrow Antenna).

10. Attach the counterweight to one end of the lift-arm with self-tapping metal screws.

11. Attach the Arrow antenna to the lift-arm using Velcro. This is for quick release of the antenna and hand-held operation, if required.

12. Attach a 6mm shaft-hub to the lift-arm close to the balance point. Ours was 140mm from the antenna end. A slight front-heavy balance offset will reduce backlash.

13. Attach the lift-arm to the SARCTRAC EL Motor shaft using the 6mm shaft-hub and tighten the hub screws with the 2.5mm Hex key.

14. Raise the centre shaft of the tripod to ensure that the lift-arm cannot, in any position, touch the tripod legs.

SARCTRAC Testing

Functional Testing

1. Having performed Power-up Testing, System Status Checks and 3D Sensor calibration and with SARCTRAC mounted rigidly to the tripod or bench and with the 3D Sensor attached to the lift-arm, it is now time to put SARCTRAC through its paces.
2. Power-up SARCTRAC. Check that it beeps. Browse to the SELECTION page.
3. Press the START button. The lift-arm will be rotated to the North and Horizontal position. This is called the "starting position".
4. Press the STOP button to stop the motors or disconnect power if anything goes wrong. Try it.

> **IMPORTANT:** The SARCTRAC starting position will be Magnetic North until the first 3D GPS fix is obtained. Then it will point True North. Ensure that SARCTRAC always has a clear view of the sky.

5. Check the starting position with the compass on your mobile device and a spirit level. SARCTRAC should be accurate within a few degrees, maybe five. Note: The beamwidth of a small Yagi satellite antenna is substantially more than this. The better the 3D Sensor calibration, the better the accuracy. Note that any local magnetic anomalies will cause a static offset in the AZ-EL position.

> **IMPORTANT:** SARCTRAC only re-positions the lift-arm to the starting position if no satellites have been selected for tracking. Otherwise it will track the first selected satellite, if visible or reposition to where the first satellite will next rise.

6. Turn the base-plate/tripod left and right: SARCTRAC should correct for that error.
7. Tilt the base-plate/tripod up and down: SARCTRAC should correct for that error.
8. The rotator motion should be smooth, speeding up after starting and slowing down before stopping.
9. Press RESTART to restart the RPi0. Wait till it beeps. Close and reopen the SELECTION page.
10. Press SHUTDOWN to gracefully shutdown the RPi0. Wait ten (10) seconds, then power-down SARCTRAC. Power-up SARCTRAC. Wait till it beeps. Close and reopen the SELECTION page.
11. Check that there are numerous satellites in various categories to be selected in the SATELLITE SELECTION group box.
12. Select the first six of these satellites for monitoring then press the SELECT button: SARCTRAC will automatically display the TRACKING page showing the previously selected satellites.
13. Select the first three of these selected satellites for tracking and press the TRACK button.
14. SARCTRAC will beep and rotate the lift-arm to point directly at the first satellite if it is visible or to point at the azimuth position where the first satellite will rise.

> **IMPORTANT:** When a satellite first rises above the local horizon it is called "Acquisition Of Signal" (AOS). The satellite is regarded as "visible" as it commences its overhead "pass". When a satellite finally sets below the horizon it is called "Loss Of Signal" (LOS). The satellite is regarded as "not visible". SARCTRAC always tracks a selected satellite if it is visible. If multiple selected satellites are visible, SARCTRAC will track the satellite with the longest time to set. If there are no currently visible satellites, SARCTRAC points to the AOS position of the satellite with the shortest time to rise.

15. If one or more of the selected satellites are visible (i.e. above the horizon) it will be displayed with a Check (✔) or a Cross (✗) symbol. Note: The symbols and colours may vary on

different platforms. The Check symbol indicates that the selected satellite is being tracked. The Cross symbol indicates that the selected satellite is not being tracked (in the case of multiple visible satellites, SARCTRAC can only track one satellite at a time). After selecting a visible satellite for tracking the initial symbol may be a Cross. Press TRACK again to see the Check symbol when SARCTRAC starts tracking the satellite.

> **IMPORTANT:** Since the satellite tracker and web server are running simultaneously in different threads and since the displayed web page is always static, it is often necessary to press the TRACK button again to update the information on the web page.

16. Visible satellites are displayed <u>above</u> the TRACK button with their Local LOS time, Current AZ and Current EL. They are sorted by their Local LOS time first (i.e. with the next satellite to set first).
17. Non-visible satellites are displayed <u>below</u> the TRACK button with their Local AOS time, AOS AL and MAX EL for the next pass. They are sorted by their Local AOS time. (i.e. with the next satellite to rise first).
18. Shutdown and Power-down SARCTRAC.
19. Plug in a Yaesu CT-62 USB cable to the SARCTRAC USB socket.
20. Plug the Mini-DIN connector of the Yaesu CT-62 USB cable into the ACC Jack of the Yaesu FT-817.

> **IMPORTANT:** Always shutdown and power-down SARCTRAC before plugging in or removing any USB devices. Not doing so will likely reset the RPi0.

21. Power-up SARCTRAC. Check the SELECTION page and TRACKING page. Observe that the previously selected satellites are still selected.
22. Power-up the Yaesu FT-817. Press the F button for 2 seconds. Rotate the SEL knob to display menu item "14 CAT RATE". Use the MAIN DIAL knob to select 38400. Press the F button again for 2 seconds to lock in the setting. This sets the baud rate of the USB communications.
23. Press the F button for ½ a second. Rotate the SEL knob to display "A/B A=B SPL". Press the C button as necessary to display the S symbol at the lower right-hand side of the display. This sets split VFO mode. Note: Don't forget to reset this mode after tracking satellites.
24. Select up to six of the transponder satellites from the following list on the SELECTION page:

AIST-2(RS-43), BIRD-BT, BIRD-MY, BIRD-PH, CAS-2T&KS-1Q, DUCHIFAT-1, DX-1, E1P-U2, FALCONSAT-3, FIRST-MOVE, FMN-1 (FENGMANIU-1), FOX-1A (AO-85), FOX-1B(AO-91), FOX-1D(AO-92), FUNCUBE-1(AO-73), FUNCUBE-2, ISS(ZARYA), ITAMSAT(IO-26), JAS-2(FO-29), LAPAN-A2(IO-86), LILACSAT-1, LILACSAT2, METEOR-M2, NANOSATC-BR1, NAYIF-1(EO-88), OSCAR7(AO-7), PCSAT(NO-44), PSAT-A/B (NO-84), SAUDISAT1C(SO-50), SKCUBE, SPACECUBE, SRMSAT, TECHSAT1B(GO-32), TY-2 (TIANYI-2), X-CUBESAT, ZACUBE-1(TSHEPISOSAT), ZHOU ENLAI (HA-1)

> **IMPORTANT:** The number of satellites selected for monitoring is not strictly limited. However, the more satellites selected, the more time SARCTRAC will take to find the next available satellite passes and to render the TRACKING page. Remember the RPi0 only has one core and is running simultaneous tracking, rotator and server threads.

25. These satellites all have transponder frequencies (for TX and RX) listed in the SARCTRAC Frequency / Mode database, so SARCTRAC will automatically control the Amateur Radio transceiver transmit and receive frequencies to account for Doppler shift.

26. Select the satellite with next available pass for tracking on the TRACK Page and wait for the satellite pass to being.

27. When the satellite pass begins SARCTRAC will beep. Press the TRACK button again to verify which satellite is being tracked as indicated by the Check symbol.

28. Verify that the Yaesu FT-817 frequencies are being updated: The RX frequency every second and the TX frequency every 10 seconds.

29. Note: Although these update rates are adequate for SSB voice communications they do seem pretty slow. Unfortunately, this is realistically the fastest that the Yaesu FT-817 frequencies can be updated over the Yaesu CAT interface. The problem is not with SARCTRAC, nor the CAT communication rate. It is the speed of the transceiver's internal microcontroller and EEPROM. In addition, every time the receiver frequency is changed, there is an unavoidable 3ms audible click as the receiver is muted. Strangely, the TX frequency cannot be updated at all during transmission. There is also a chance that the TX and RX VFOs will be left in the wrong state if the PTT is pressed at the instant of the TX VFO update. Despite all these major problems the Yaesu FT-817 provides a pretty usable demonstration of Amateur Satellite communications. We have researched this phenomenon extensively and there is absolutely nothing that can be done about it. Other tracking programs experience the same issues. The good news is that these problems do not occur with any of the other rigs we plan to support in the future - Only our first and of course the most popular one!

WARNING: Pressing the PTT button on the Yaesu FT-817 while the TX frequency is being updated by SARCTRAC can result in inadvertent transmission on the RX frequency. Dropping the PTT until the next TX VFO update will correct the error. Operators are ultimately responsible for ensuring that they are transmitting on the correct frequency at all times. Careful timing of PTT activation to avoid this problem is recommended.

SARCTRAC Maintenance

Update, Backup and Restore Procedure

SARCTRAC can be updated if new features become available or if orbital element libraries or databases need to be updated. SARCTRAC does not use the Internet for updates as it can be unreliable. It uses a USB Disk (aka thumb drive or memory stick) to update, backup and restore all application and configuration files. In fact, the USB Disk is the only option available to initially configure SARCTRAC to access your WiFi network. Here's how the SARCTRAC update, backup and restore procedure works:

1. Power-down SARCTRAC:
   a. SARCTRAC must be powered-down before inserting or removing any USB devices.
2. Prepare the SARCTRAC files to be updated on a PC (with Internet connection and a USB port):
   a. Download new application and configuration files from our website: www.sarcnet.org/sarctrac; or
   b. Copy the files from a previous backup on the USB Disk.
   c. Edit the files with a simple text editor (not MS WORD) as required.
   d. Save a copy of the files on the PC.
3. Prepare the USB Disk on a PC:
   a. It must be formatted as FAT32. Note: This will erase ALL data.
   b. It must have the volume label "SARCTRAC".
   c. Copy the files to be updated to the root folder of the USB Disk.
   d. Make sure you have a backup of the files on the PC as well.
   e. Eject the USB Disk from the PC.
4. Update and Backup SARCTRAC application and configuration files:
   a. Insert the USB Disk into SARTRAC and power-up SARCTRAC. At least one application or configuration file must be in the root folder of the USB disk or it will be ignored. Note: Only the following application or configuration files are permitted:
      i. sarctrac file – A complete archive of all application and configuration files.
      ii. network.txt file – The WiFi network configuration file.
      iii. freqmode.txt file – The Satellite Frequency / Mode database.
      iv. tle folder – A folder containing Orbital Element Library files (*.txt files).
   b. SARCTRAC starts up and beeps once.
   c. SARCTRAC creates a sequential backup folder on the USB Disk starting at Backup00.
   d. SARCTRAC copies previous application and configuration files to the backup folder on the USB Disk.
   e. SARCTRAC installs any update files from the root folder of the USB Disk.
   f. SARCTRAC erases any update files from the root folder of the USB Disk.
   g. SARCTRAC restarts with the new configuration and beeps again.
5. Restore SARCTRAC application and configuration files:
   a. Copy all the files and folders from a previous backup folder to the root folder of the USB Disk.
   b. As a minimum, or to force a backup, just copy a working "network.txt" file.
   c. Eject the USB Disk from the PC.
   d. Go to step 4 above.

Orbital Element Libraries

Orbital element libraries are simple text files containing the orbital prediction data for various categories of satellites. SARCTRAC needs this data to track satellites. Many different libraries exist for amateur, weather, CubeSats and other types of satellites. The full range of orbital element libraries can be viewed at https://celestrak.com/NORAD/elements/. Each library has a URL like: "https://celestrak.com/NORAD/elements/amateur.txt". An example library is shown in Table 5. The library contains the name of each satellite followed by its Two-Line Element (TLE) data used to predict its location. Unfortunately, you don't get to choose which satellites are in which libraries. There are thousands of satellites in dozens of libraries. So, even if you want to track just a few satellites you often have to download multiple libraries containing hundreds of satellites. The SARCTRAC SELECTION page makes this task a little easier: First select the libraries you need in the ORBITAL ELEMENTS LIBRARY LIST, then filter out the satellites you don't want listed on the SELECTION pages by entering all or part of their names in the REJECT SATELLITE LIST.

Table 5 – Orbital Element Library file: amateur.txt (abridged)

```
OSCAR 7 (AO-7)
1 07530U 74089B   19074.89258090 -.00000020  00000-0  15747-3 0  9995
2 07530 101.7324  43.5703 0012141 168.5314 215.9583 12.53637172 28644
UOSAT 2 (UO-11)
1 14781U 84021B   19075.04151860  .00000058  00000-0  13217-4 0  9994
2 14781  97.6212 104.1863 0006967 270.6765  89.3651 14.83069344884738
LUSAT (LO-19)
1 20442U 90005G   19075.40230244 -.00000011  00000-0  12247-4 0  9990
2 20442  98.6398  17.6074 0012869  69.3662 290.8900 14.32919404522879
ITAMSAT (IO-26)
1 22826U 93061D   19075.48805833  .00000008  00000-0  21146-4 0  9996
2 22826  98.8908  62.0113 0007855 261.7961  98.2330 14.30386372328683
RADIO ROSTO (RS-15)
1 23439U 94085A   19074.90823556 -.00000019  00000-0  65735-3 0  9996
2 23439  64.8139 269.4042 0148428 131.3893 330.9583 11.27568272997205
JAS-2 (FO-29)
1 24278U 96046B   19075.05016564  .00000012  00000-0  45104-4 0  9998
2 24278  98.5226 241.3663 0351231 125.4143 238.0335 13.53089605115008
TECHSAT 1B (GO-32)
1 25397U 98043D   19075.37262523 -.00000020  00000-0  10293-4 0  9994
2 25397  98.6803  16.7045 0000903  10.4258 349.6939 14.23661749 74453
ISS (ZARYA)
1 25544U 98067A   19076.04640698  .00000999  00000-0  23313-4 0  9993
2 25544  51.6421  99.3024 0003974 112.3476 286.4746 15.52811995160948
```

Downloading Orbital Element Libraries

SARCTRAC downloads local copies of Orbital Element Libraries from the URLs listed in the ORBITAL ELEMENT LIBRARY LIST on the SARCTRAC SELECTION page. However, the online libraries will only be download at power-up and if local copies don't already exist or are older than 24 hours. You can edit the list and press UPDATE to save it. Press RESTART to download any new online libraries.

Loading user-defined Orbital Element Libraries

Sometimes the online orbital element libraries don't include newly-launched satellites. The satellite TLE data may only be available from another source. In this case, you can make your own orbital element library and load it into SARCTRAC using the USB Disk. Simply follow the Update, Backup and Restore Procedure with these additional steps:

1. Create a folder called "tle" in the root folder of the USB Disk.

2. Create a new text file called "user.txt" (or a name of your choice) inside the "tle" folder.
3. Copy the satellite name(s) and the TLE data to the "user.txt" file in the same format as shown in Table 5.
4. The USB Disk and its contents should look like Figure 1.
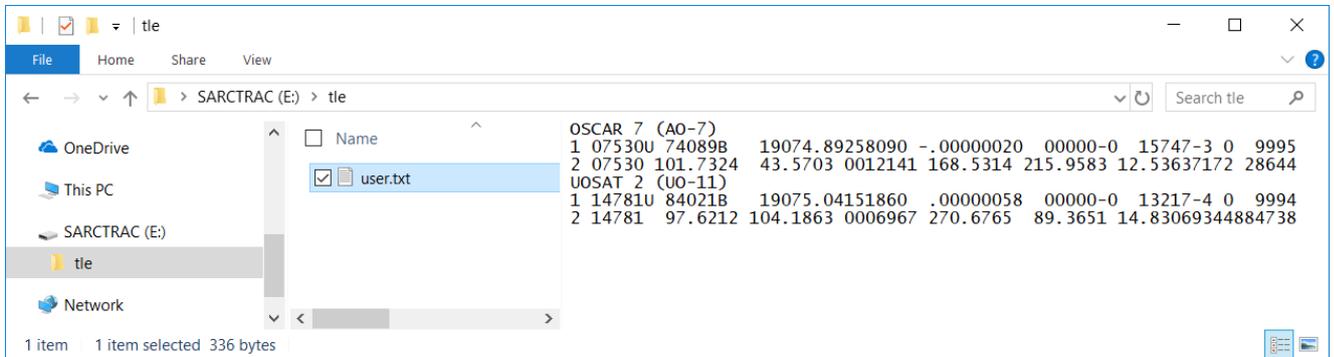5. Update SARCTRAC as normal.

Figure 1 - User-Defined Orbital Element Library on SARCTRAC USB Disk

Purging local Orbital Element Libraries

SARCTRAC saves local copies of all downloaded orbital element libraries, just in case the Internet is not available the next time SARCTRAC is started. So, even if your remove the URL from the SARCTRAC ONLINE ORBITAL ELEMENT LIBRARY LIST, they will continue to be loaded at power-up. To remove ALL local orbital element libraries, including ALL user libraries, press PURGE. Note: The action is immediate.

Updating the Frequency / Mode Database

The Frequency / Mode Database is a text file called "freqmode.txt", which can be edited on a PC and installed into SARCTRAC using the USB Disk and the SARCTRAC Update Procedure. An abridged version of the freqmode.txt file is shown in Table 6.

The entries in the freqmode.txt file are matched with the exact satellite name in the TLE library file. When a satellite of the same name is being tracked on the TRACKING page, SARCTRAC automatically uses the Frequency / Mode data to control the rig. The total number of matched satellite frequencies is shown in the satellite statistics on the SELECTION page.

The freqmode.txt file must be edited very, very carefully. Always make a backup first. Always check the exact name in the orbital element library file before adding a name to the database. Keep each entry in alphabetical order. Copy and paste the entry of an existing satellite with similar transponders and beacons then edit the name, frequencies and modes. Note: The transponder and beacon names and information are just for user information only. They do not affect the operation of SARCTAC or the rig.

IMPORTANT: The format of each line of the freqmode.txt file must be precise. A single comma, quote or bracket out of place will stop the tracker working. Always make a backup of the freqmode.txt file before trying to edit it and update SARCTRAC. If the tracker stops working after an update, restore the backup. As a last resort, restore the current software from our website.

Table 6 – Satellite Frequency / Mode Database

```
#freqmode.txt version 1.0
#Frequency and Mode database for the Satellite Antenna Rotator Controller and Tracker (SARCTRAC)
################################################################################
#Copyright(c) 2018. All rights reserved by Julie VK3FOWL and Joe VK3YSP for #
#The School Amateur Radio Club Network (SARCNET), www.sarcnet.org.           #
#This is NOT free software: Only the original purchaser may use it.          #
#Do not remove this notice or re-distribute any part of this software.       #
################################################################################
#MODEn is one or more satellite modes, e.g.: Different transponders or beacons
#INFOn is information about satellite MODEn
#TXFREQn and TXMODEn is the uplink frequency and mode for satellite MODEn
#RXFREQn and RXMODEn is the downlink frequency and mode for satellite MODEn
#All frequencies are in MegaHertz
#Modulation Modes are LSB, USB, CW, CWR, AM, FM, DIG and PKT
#Strings must use single quotes (')
#Warning ANY formatting errors will crash the program: KEEP A BACKUP OF THE LAST WORKING DATABASE!
#Database format: [LINE1,LINE2,..]
#Line format:
['NAME',['MODE1','MODE2',..],['INFO1','INFO2',..],[[TXFREQ1,TXMODE1,RXFREQ1,RXMODE1],[TXFREQ2,TXMODE2,RXFREQ2,RXMODE2],..]
[['1KUNS-PF',['NORMAL'],['1k2/2k4/4k8/9k6 GMSK',[[0,'LSB',437.3,'USB']]],
['AALTO-1',['NORMAL'],['9600bps FSK CW'],[[0,'LSB',437.22,'USB']]],

LINES DELETED FOR BREVITY

['FOX-1A (AO-85)',['NORMAL','BEACON'],['FM CTCSS 67.0Hz/200bps
DUV','BEACON'],[[435.172,'FM',145.98,'FM'],[0,'FM',145.98,'CW']]],
['FOX-1B(AO-91)',['NORMAL','BEACON'],['FM CTCSS 67.0Hz/200bps
DUV','BEACON'],[[435.25,'FM',145.96,'FM'],[0,'FM',145.96,'CW']]],
['FOX-1D(AO-92)',['NORMAL'],['FM CTCSS 67.0Hz/200bps DUV'],[[435.35,'FM',145.88,'FM']]],
['FUNCUBE-1(AO-73)',['NORMAL'],['1200bps BPSK'],[[435.14,'LSB',145.96,'USB']]],

LINES DELETED FOR BREVITY

['OSCAR7(AO-7)',['TRANSPONDER A','TRANSPONDER B','BEACON A','BEACON B','BEACON U'],['Non-Inverting Transponder','Inverting
Transponder','2m Beacon','10m Beacon','70cm
Beacon'],[[145.9,'LSB',29.45,'USB'],[432.15,'LSB',145.95,'USB'],[0,'LSB',145.975,'CW'],[0,'LSB',29.502,'CW'],[0,'LSB',435.
1,'CW']]],

LINES DELETED FOR BREVITY

['XW-2A',['NORMAL','BEACON'],['9k6/19k2 GMSK','CW BEACON'],[[435.04,'LSB',145.675,'USB'],[0,'LSB',145.660,'CW']]],
['XW-2B',['NORMAL','BEACON'],['9k6/19k2 GMSK/CW','CW BEACON'],[[435.1,'LSB',145.74,'USB'],[0,'LSB',145.725,'CW']]],
['XW-2C',['NORMAL','BEACON'],['9k6/19k2 GMSK/CW','CW BEACON'],[[435.16,'LSB',145.805,'USB'],[0,'LSB',145.790,'CW']]],
['XW-2D',['NORMAL','BEACON'],['9k6/19k2 GMSK/CW','CW BEACON'],[[435.22,'LSB',145.87,'USB'],[0,'LSB',145.855,'CW']]],
['XW-2F',['NORMAL','BEACON'],['9k6 GMSK/CW','CW BEACON'],[[435.34,'LSB',145.99,'USB'],[0,'LSB',145.975,'CW']]],
```
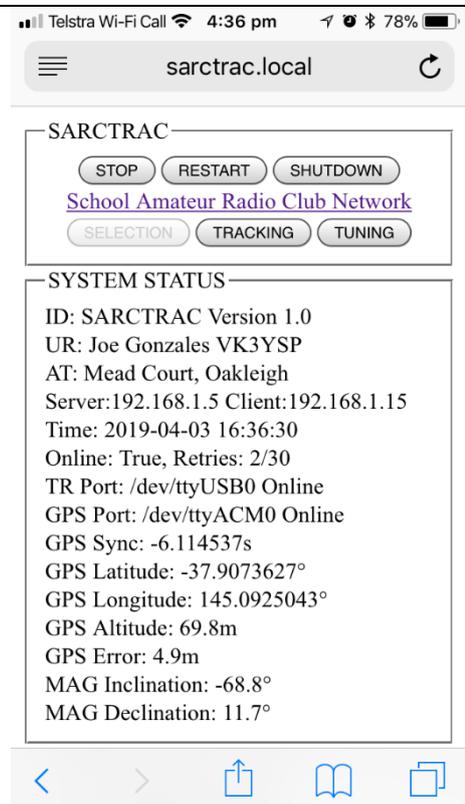
SARCTRAC Operation

1. Gather all the equipment required, including tripod, antenna, lift-arm, Velcro, hex key, rig, CAT cable, coax cables, WiFi Router or Mobile Device and AC or battery power. A trestle table is handy.
2. Mount SARCTRAC's azimuth shaft on the tripod.
3. Mount the hand-held satellite antenna on the lift-arm with 25mm Velcro.
4. Mount the lift arm on SARCTRAC's elevation shaft.
5. Connect SARCTRAC to the rig and to the power supply.
6. Connect the rig to the antenna and to the power supply.
7. Strap the flat side of the 3D Sensor to the top side of antenna boom with 19mm Velcro.
8. Power-up SARCTRAC and the rig.
   a. STAND CLEAR of the antenna.
   b. Prepare to SHUTDOWN POWER IMMEDIATELY before any injury or damage could occur.
9. Connect to SARCTRAC using a web browser on a PC or Mobile Device.
   a. Enter sarctrac.local for iPhone, Android and zeroconf devices.
   b. Enter the IP Address for all other devices.
   c. SARCTRAC automatically opens the SELECTION page.

10. SELECTION page comprises:
    a. SARCTRAC control panel.
    b. SYSTEM STATUS panel.
    c. SATELLITE SELECTION panel.
    d. ORBITAL ELEMENT LIBRARY LIST panel.
    e. REJECT SATELLITE LIST panel.
    f. LOCAL TIME ZONE panel.
    g. 3D SENSOR CALIBRATION panel.
    h. SYSTEM START-UP LOG panel.
11. SARCTRAC control panel:
    a. System control buttons:
       1. Press STOP to stop the motors.
       2. Press START to start the motors.
       3. Press RESTART to shutdown and restart SARCTRAC.
       4. Press SHUTDOWN to shutdown SARCTRAC.
    b. Help link:
       1. Press School Amateur Radio Club Network to visit our web site.
    c. Page selection buttons:
       1. Press SELECTION for the SELECTION page.
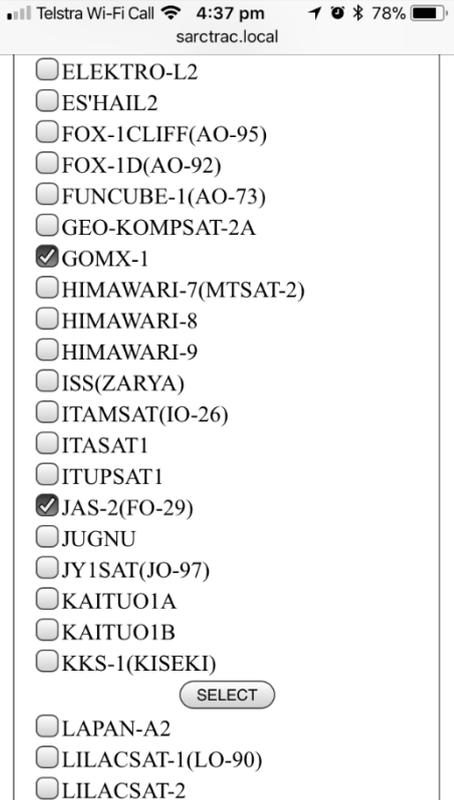   2. Press TRACKING for the TRACKING page.
       3. Press TUNING page.

SARCTRAC
STOP RESTART SHUTDOWN
School Amateur Radio Club Network
SELECTION TRACKING TUNING

SYSTEM STATUS
ID: SARCTRAC Version 1.0
UR: Joe Gonzales VK3YSP
AT: Mead Court, Oakleigh
Server:192.168.1.5 Client:192.168.1.15
Time: 2019-04-03 16:36:30
Online: True, Retries: 2/30
TR Port: /dev/ttyUSB0 Online
GPS Port: /dev/ttyACM0 Online
GPS Sync: -6.114537s
GPS Latitude: -37.9073627°
GPS Longitude: 145.0925043°
GPS Altitude: 69.8m
GPS Error: 4.9m
MAG Inclination: -68.8°
MAG Declination: 11.7°

12. SYSTEM STATUS panel:
    a. SARCTRAC Software version
    b. User ID (Name and Callsign)
    c. Current Street address (Road, Suburb only)
    d. Server and client IP addresses. (IPV4 only)
    e. Current date and time. (Local)
    f. Internet online status and retry attempts.
    g. Transceiver port and online status.
    h. GPS port and online status.
    i. GPS time correction applied to local clock.
    j. GPS 3D Fix data and error (Decimal degrees).
    k. GPS 3D Fix error based on HDOP (Metres).
    l. Local magnetic field inclination (+ Down)
    m. Local magnetic field declination (+ East of True)
13. Scroll down to see the SATELLITE SELECTION panel.
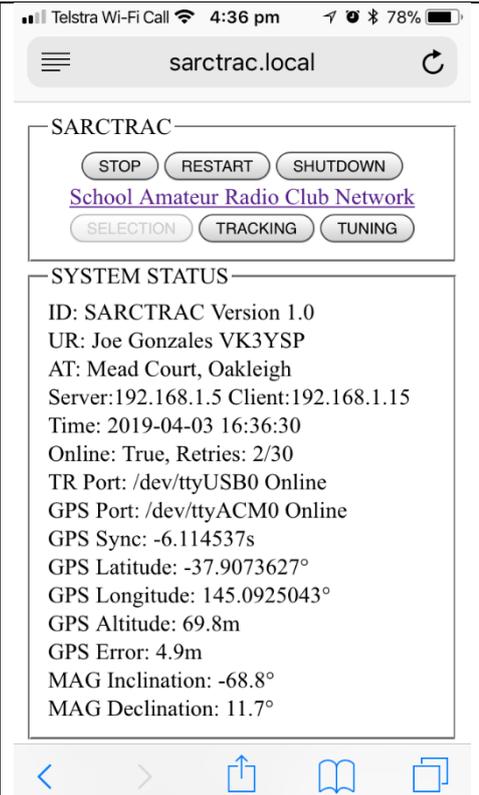
14. SATELLITE SELECTION panel:
    a. Satellite statistics:
        1. Quantity of satellites loaded from each online orbital element library.
        2. Number of satellites loaded with matching frequencies in the Frequency / Mode database.
        3. Number of duplicate satellites removed from libraries. The same satellite can be listed in more than one library.
        4. Number of satellite names rejected (not displayed) due to a partial match with entries in the REJECT SATELLITE LIST.
        5. Total number of satellites available for tracking on the SATELLITE SELECTION panel.

b. Satellite selection list:
    1. Satellite names are sorted alphabetically.
    2. Scroll up and down through hundreds of satellites.
    3. Rejected satellites are not shown.
    4. Use this list to select satellites for monitoring only. Pass prediction information will be shown on the TRACKING page, where satellites can be down-selected for tracking.
c. Unselected satellites are shown as: ☐
d. Selected satellites are shown as: ☑
e. Select one or more satellites up to, say 8.
f. Selecting more than 8 will slow SARCTRAC down.
g. SELECT buttons are distributed regularly for quick access. They all operate in the same manner.
h. Press SELECT.
i. SARCTRAC automatically opens the TRACKING page.
	▪ıll Telstra Wi-Fi Call 📶 4:37 pm ⬈ ⏰ ✳ 78% ▰
	sarctrac.local
	☐ ELEKTRO-L2
	☐ ES'HAIL2
	☐ FOX-1CLIFF(AO-95)
	☐ FOX-1D(AO-92)
	☐ FUNCUBE-1(AO-73)
	☐ GEO-KOMPSAT-2A
	☑ GOMX-1
	☐ HIMAWARI-7(MTSAT-2)
	☐ HIMAWARI-8
	☐ HIMAWARI-9
	☐ ISS(ZARYA)
	☐ ITAMSAT(IO-26)
	☐ ITASAT1
	☐ ITUPSAT1
	☑ JAS-2(FO-29)
	☐ JUGNU
	☐ JY1SAT(JO-97)
	☐ KAITUO1A
	☐ KAITUO1B
	☐ KKS-1(KISEKI)
	   (SELECT)
	☐ LAPAN-A2
	☐ LILACSAT-1(LO-90)
	☐ LILACSAT-2

15. ORBITAL ELEMENT LIBRARY LIST panel:
  a. The list shows the URLs of online orbital element libraries, which are downloaded on start-up, but no more than once per day.
  b. Scroll up or down the list. Add or delete entries.
  c. Press UPDATE to save the entries and re-download the online orbital element libraries.
  d. Press PURGE to clear ALL local orbital element library files, <u>including ALL user-defined library files</u> and re-download the online orbital element libraries. Note: The action is immediate.
16. REJECT SATELLITE LIST panel:
  a. The list shows all the satellite names to reject from the orbital element libraries.
  b. Rejected satellites will not be displayed.
  c. Satellites will be rejected on even a partial name match.
  d. Scroll up or down the list.Add or delete entries.
  e. Press REJECT to save changes. Then press RESTART to update the SATELLITE SELECTION page.
17. LOCAL TIME ZONE panel:
  a. Set your local offset from UTC in hours.
  b. Note: SARCTRAC does not automatically compensate for daylight saving time. Manually change the UTC offset for daylight saving time.
	▪ıll Telstra Wi-Fi Call 📶 4:38 pm ⬈ ⏰ ✳ 78% ▰
	sarctrac.local
	┌ ORBITAL ELEMENT LIBRARY LIST ┐
	Download the following TLE libraries:
	https://celestrak.com/NORAD/elements/amateur.txt
	https://celestrak.com/NORAD/elements/weather.txt
	https://celestrak.com/NORAD/elements/noaa.txt
	  (UPDATE) (PURGE)
	┌ REJECT SATELLITE LIST ┐
	Reject the following names:
	FLOCK
	CHUB
	LEMUR
	2015
	2017
	2018
	FENGYUN
	GOES
	  (REJECT)
	┌ LOCAL TIME ZONE ┐
	Set local UTC offset in hours
	(UTC+11.0 ▾) (SET)
	┌ 3D SENSOR CALIBRATION ┐

18. 3D SENSOR CALIBRATION panel:
    a. Press BEGIN to start 3D sensor calibration.
    b. SARCTRAC will beep for each new calibration point found.
    c. Press ABORT at any time to exit the calibration process. The existing calibration data will not be changed.
    d. Press SAVE only at the end of a successful calibration process to replace the existing calibration data with the new calibration data.
19. SYSTEM START-UP LOG panel:
    a. Shows the SARCTRAC system messages since the last power-up.
    b. Scroll up or down the list.
    c. Can be used for debugging purposes. See: Troubleshooting.
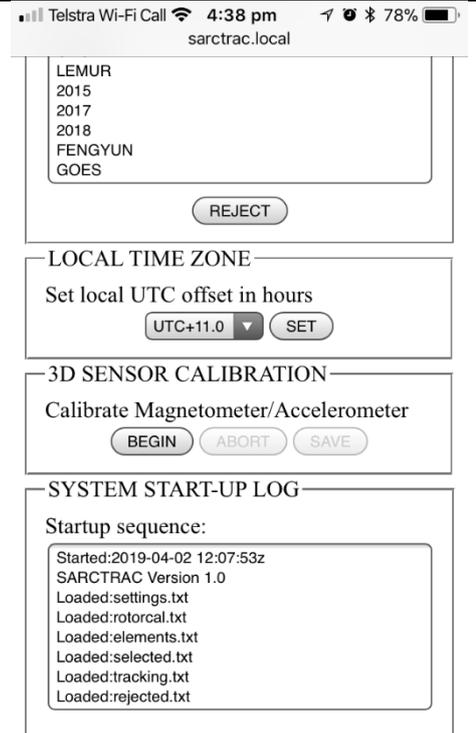
20. TRACKING page cpmprises:
    a. SARCTRAC control panel.
    b. SATELLITE TRACKING panel.
21. SATELLITE TRACKING panel:
    a. Shows visible satellites above the TRACK button.
    b. Show future satellite passes below the TRACK button.
    c. Visible satellites are displayed with a Check (✔) symbol indicating they are currently being tracked.
    d. Visible satellites are displayed with a Cross (✘) symbol if they are not being tracked.
    e. Visible satellites are displayed with their LOS time and current AZ and EL angles.
    f. Visible satellites are sorted by their LOS time.
    g. Non-Visible satellites are displayed with their AOS time, AOS AZ and max EL angle for the next pass.
    h. Non-Visible satellites are sorted by their AOS time.
    i. Non-Visible unselected satellites are shown as: ☐
    j. Non-Visible selected satellites are shown as: ☑
    k. Select one or more satellites and press TRACK.
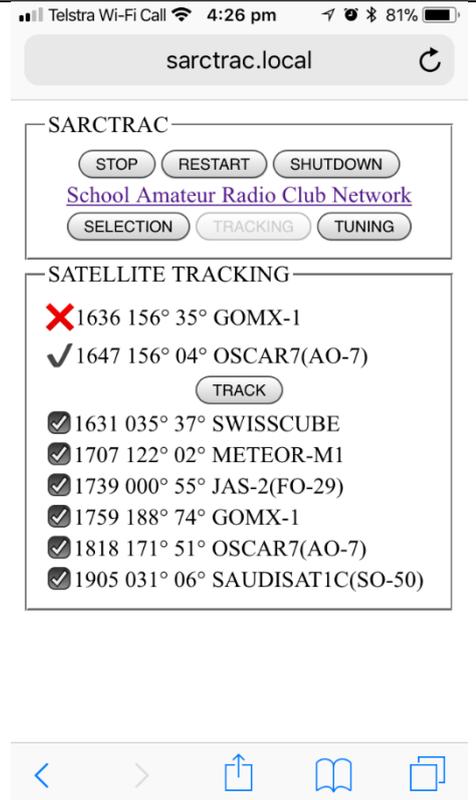
22. SATELLITE TRACKING panel (cont):
    a. If more than one satellite is visible and your preferred satellite is not being tracked, simply deselect all other satellites and press TRACK.
    b. The tracking status of newly selected or deselected satellites may not be as expected. In this case simply press the TRACK button again. The web server and satellite tracker software work independently and the latter may take some time to catch up with your changes.
    c. The TRACKING page only shows the next pass of each satellite when the TRACK button was last pressed. Be sure to press the TRACK button again after each pass starts to see updated prediction information as the order of the next satellite passes may have changed.
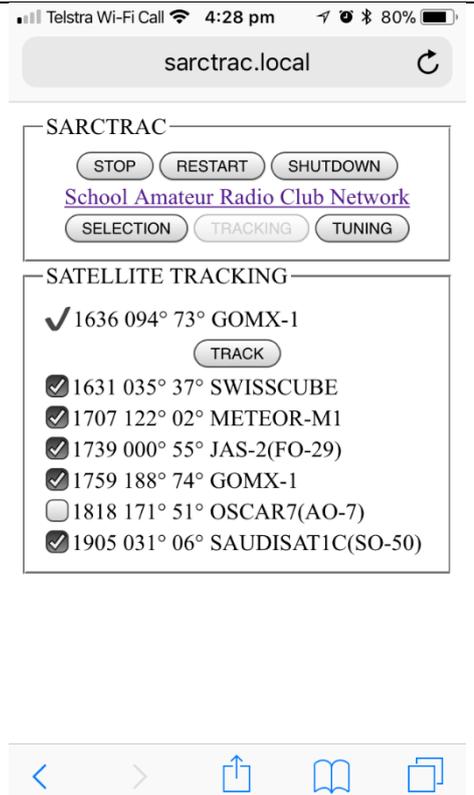
23. TUNING page comprises:
    a. SARCTRAC control panel.
    b. RADIO TUNING panel.
24. RADIO TUNING panel:
    a. The RADIO TUNING panel is only active when SARCTRAC is automatically controlling the radio's frequency and mode, and that is only when a satellite is being tracked with a matching entry in the Frequency / Mode database.
    b. When the RADIO TUNING panel is active it shows the available selections from the Frequency / Mode database together with the Doppler-corrected transmit and receive frequencies as follows:
       1. Satellite name (or NONE if not active)
       2. Satellite mode.
       3. Satellite mode information.
       4. Radio transmit frequency.
       5. Radio transmit tuning offset.
       6. Radio transmit mode.
       7. Radio receive frequency.
       8. Radio receive tuning offset.
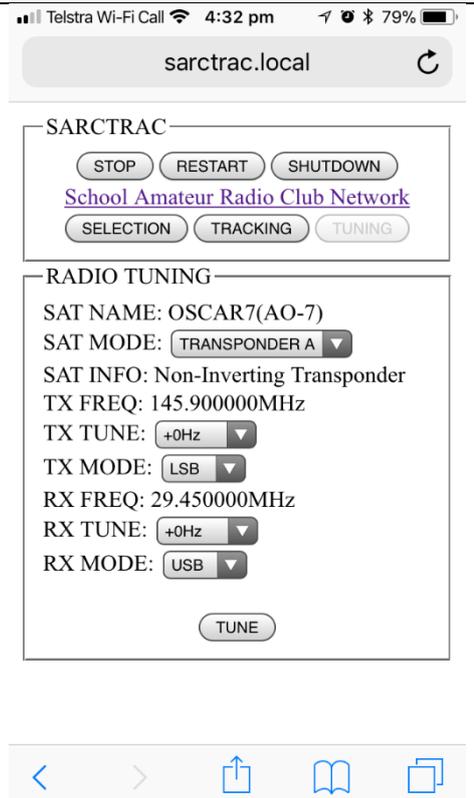
c. You can select different satellite modes (if available) by using the SAT MODE drop-down box. With some satellites there are a variety of transponder and beacon frequencies to choose from.
d. Select the new mode then press TUNE.
e. SARCTRAC will automatically change the radio frequencies and modes for the selected satellite mode.
f. Note: The licenced Amateur Radio operator is responsible for the radio transmitter frequency and mode at all times. Use of certain radio frequencies or modes and the automatic control of transmitting apparatus may not be permitted. Please ensure you fully comply with your Amateur Radio licence conditions when using SARCTRAC.
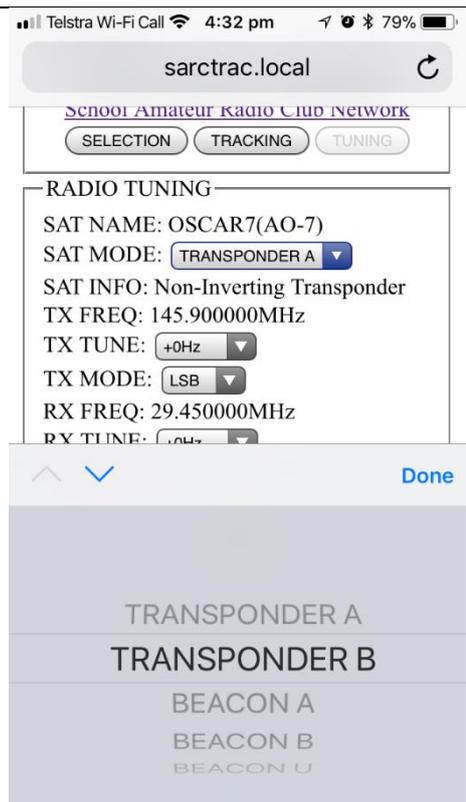
g. You can offset the radio transmitter or receiver frequency independently by using the TX FREQ and RX FREQ drop-down boxes. This can be useful when a station is slightly off frequency or reports that you are off frequency.
h. The available offsets are +/- 0Hz, 10Hz, 20Hz, 50Hz, 100Hz, 200Hz, 500Hz, 1kHz.
i. Select the new offset then press TUNE.
j. SARCTRAC will automatically offset the computed Doppler-corrected radio frequencies.
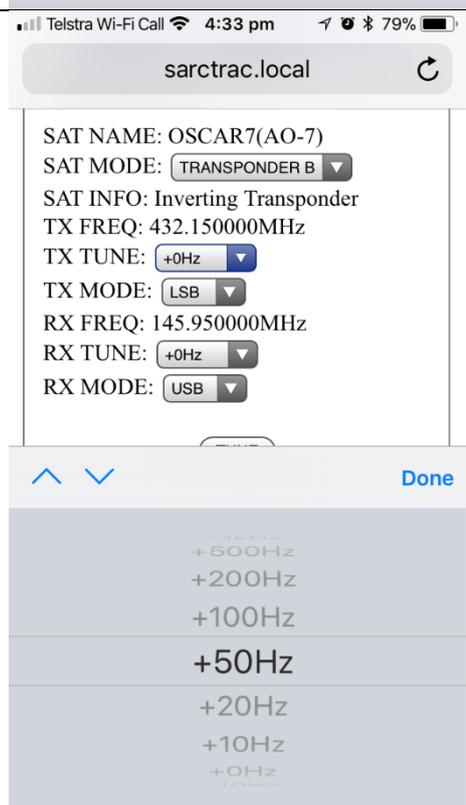
k. You can change the radio transmitter or receiver modes independently by using the TX MODE and RX MODE drop-down boxes. This can be useful when a station is operating on a different mode.

l. The available modes are: LSB, USB, CW, CWR, AM, FM, DIG or PKT.

m. Select the new mode then press TUNE.

n. SARCTRAC will automatically change the radio mode.
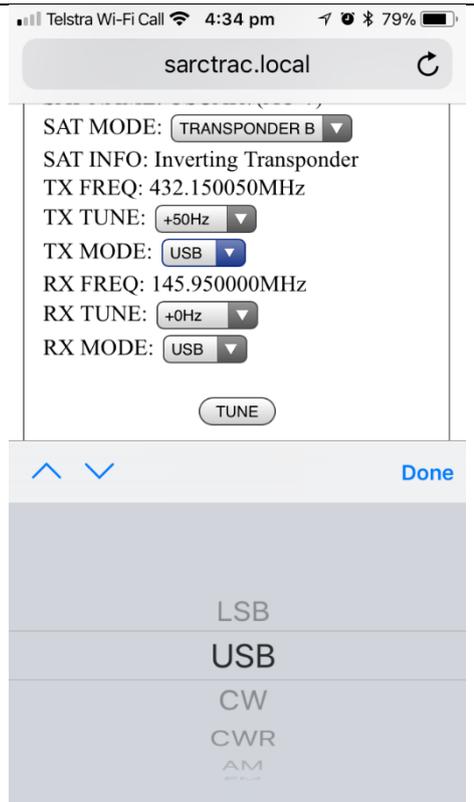
o. The RADIO TUNING panel is only updated after the TUNE button is presses. To get updated information simply press the TUNE button again.
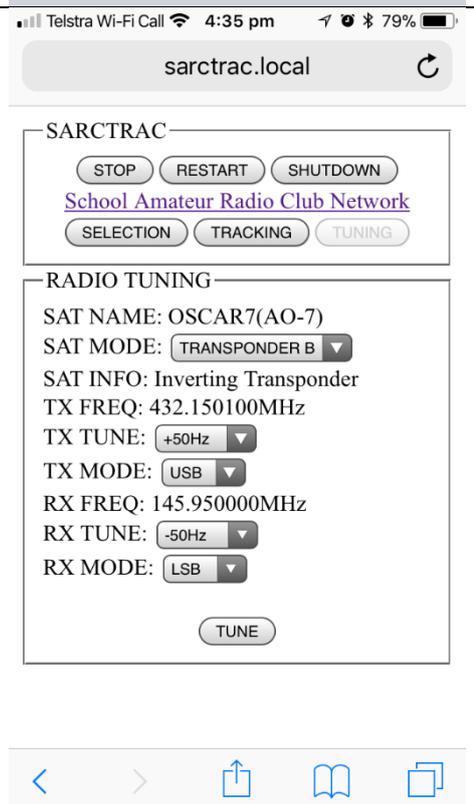
Hints and Tips

1. Operating conditions
    a. SARCTRAC runs on 13.8VDC at around 300-350mA. It can run on 12V, but with much less torque.
    b. SARCTRAC gets warm because it uses low-noise, linear voltage regulators. Power dissipation is reduced if you remove the USB Disk.
    c. SARCTRAC uses a microprocessor which generates an unavoidable amount of Radio Frequency Interference at VHF and UHF frequencies. The use of clip-on, ferrite cores on the power and sensor cable may be effective in reducing RFI. Shielding the 3D Sensor is not recommended due to excessive capacitance on the I2C bus.
    d. SARCTRAC is a closed-loop AZ-EL feedback system. The final positioning of the antenna is subject to all of the usual aberrations of such systems, including tracking error, overshoot and dither. These factors have been reduced by careful tuning of the 3D Sensor Filter and PID Motor Controller constants. However, they all interact and are affected by: The inertia of the antenna; the balance offset of the boom; and even the O-ring seals on the Motors. Future updates may permit fine tuning of the controller parameters.
    e. SARCTRAC is only accurate to +/- a few degrees, dependent on good calibration and freedom from local magnetic interference. Most small Yagi antennas have a 3dB beam width of ten-times this angle, so it doesn't really matter from a performance point of view. The extra gain of even a small linearly-polarised Yagi antenna really helps. Nevertheless, very high overhead passes often suffer from deep polarisation fading: So our next project will be a small dual-band, circularly-polarised, Yagi antenna.
    f. Static magnetic interference can be reduced by re-orienting the 3D Sensor slightly.
    g. SARCTRAC can be made weatherproof by using silicone sealant around the USB Joiner and USB Right-Angle Adapters.
2. Operating modes:
    a. SARCTRAC can work off-line (not connected to the Internet), so long as the GPS is available and while the local TLE libraries are still fresh. Or, it can work without the GPS, so long as it is on-line (connected to with the Internet) and hasn't moved very far since the last time it was used. Without Internet or GPS availability SARCTRAC will not be able to get the time. Without the last saved location or GPS SARCTRAC will not be able to get the location. We designed SARCTRAC not to require any on-site data entry or calibration and that is how it works.
3. Motors
    a. SARCTRAC Motors growl all the time. It is normal, while they are doing their job positioning the antenna. To reduce noise and current consumption you can press STOP until it is time for the next pass and then press START.
    b. SARCTRAC Motors are stall-resistant and will not burn out under any circumstances.
    c. SARCTRAC uses 0.6 RPM DC Motors for high torque and smooth operation. It can be a challenge for it to keep up with overhead passes greater than 75 degrees. For a 90-degree pass, the AZ motor has to spin around 180 degrees, which takes 50 seconds. Faster motors are available, but they will have less torque and stability. So, it is a trade-off.
4. Operating tips
    a. SARCTRAC is a rotator and tracker: It will not plan your whole weekend of satellite hunting nor explain how to work satellites. Use it in conjunction with good satellite

information and prediction websites. Check out www.amsat.org, www.amsat-uk.org and www.n2yo.com.

b. SARCTRAC accepts connections from more than one web browser at a time. So, multiple students can see the action (and control it too!).

c. SARTRAC is perfect for scheduling all passes of all compatible weather satellites for Automated Picture Transmission decoders.

d. SARCTRAC provides automatic Doppler frequency correction for all satellites listed in the Frequency / Mode Database. When listening for a CW (Morse code) beacon using SSB or CW mode on the rig, remember that terrestrial signals will vary in frequency while satellite signals will remain constant. SARCTRAC doppler correction mode operates to ensure a constant transmit and receive frequency at the satellite.

e. SARCTRAC audible beeps give you a good idea of what it is doing. It provides a long beep when it starts, and at LOS before repositioning, and five short beeps at AOS before tracking. Short beeps at power-up indicate something is not connected properly.

f. Press the TRACK button after SARCTRAC beeps to see the latest tracking status.

g. SARCTRAC doesn't complete each overhead pass until right up until LOS. With multiple visible satellites, it will save time to deselect the current satellite before it's LOS and jump onto the next best satellite.

h. SARCTRAC can track new satellites, even before their orbital elements are published on www.celestrak.com. Just copy their estimated TLEs into a new text file, say "user.txt", and include it in the "tle folder" prior to an update using the USB Disk. You can also add the new satellite frequencies and modes to the freqmode.txt file.

5. SELECTION page:
   a. Always check the time and location on the SELECTION page prior to operations. Refresh it after the first GPS 3D Fix. It either setting is wrong, SARCTRAC won't be pointing in the right direction at the right time.
   b. Use the REJECT SATELLITE LIST to get rid of any unwanted satellites published in the on-line TLE libraries.
   c. Selecting too many satellites to monitor on the SELECTION page will slow down the rendering of the TRACKING page. Selecting up to six satellites is a practical compromise.

6. TRACKING page:
   a. Some selected satellites are not shown on the TRACKING page because they never appear to rise.
   b. Only the next pass of each satellite is shown.
   c. If you see only Cross (✘) symbols, press TRACK again to see a Check (✔) symbol.

7. TUNING page:
   a. Only shows tuning information for tracked satellites with associated entries in the Frequency / Mode database.
   b. Check out http://www.ne.jp/asahi/hamradio/je9pel/satslist.htm for other satellite frequencies and modes.

Troubleshooting

This section lists possible problems, including their possible causes and solutions. Please read this information and collect as much diagnostic information as you can before requesting support.

1. Motors don't work when connected to 12VDC: If you bought our kit, the motors are 100% tested prior to shipping. However, during transport, shock and vibration sometimes makes the brushes disconnect from the commutator: See Figure 2 to see how it works. This can be fixed easily by poking a squashed toothpick into the crescent-shaped holes and GENTLY tickling the gold brush wires. Connect the motor to 12VDC, lift and re-seat the brushes until it starts working. In some cases, a spray of Isopropyl Alcohol through the holes can help shift grease on the commutator. Contact us for gearbox issues, BEFORE you open the gearbox.
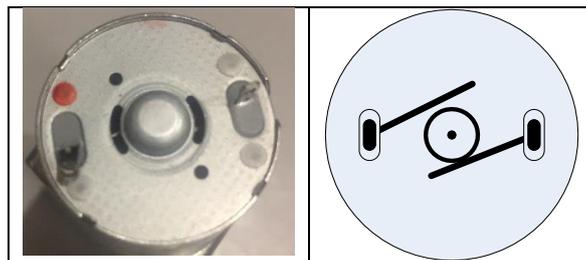
Figure 2 – Motor Brushes

2. SARCTRAC does not beep at all when started: This indicates a major system fault.
    a. No power: Check the power with a multimeter. Restore the power.
    b. Wiring error: Check the wiring against Figure 3. Fix the wiring.
    c. No SARCTRAC micro SDHC card installed: Install the SARCTRAC micro SDHC card.
    d. Faulty Schottky Diode: Check the orientation and the +13V output with a multimeter to the RPi0 Ground. Replace a faulty component.
    e. Faulty regulator: Check the +12V and +5V regulator voltages with a multimeter to the RPi0 Ground. Replace a faulty component.
    f. Faulty Buzzer: Connect the Buzzer Red and Black Wires to +5VDC. Check it beeps. Replace a faulty component.
    g. Faulty 3D Sensor: Check the 3D Sensor type (LSM303DLHC only). See Figure 23. Substitute a working 3D Sensor.
    h. Faulty USB Hub Hat: Check the Red Power LED is on. Check the green USB LEDS: D1, D2 and D3 should be on. Check 5V USB output. Check the USB Joiner is firmly connected.
    i. Faulty RPi0: Check the Green Activity LED flashes on start up. Note: 2 out of 10 RPi0s purchased here did not work and had to be returned to the vendor for a free replacement. Either the WiFi or HDMI output was faulty. Connect an HDMI monitor to the RPi0 using a micro HDMI adapter. Observe the Linux start-up display on the monitor.
3. SARCTRAC beeps one 100ms beep when started: This indicates the USB cable is not working:
    a. No Power: Check the USB Hub Hat power and USB Joiner.
    b. Wiring error: Check the wiring against Figure 3. Fix the wiring.
    c. USB port not working: Try another USB Hub Hat port.
    d. Check for a genuine FTDI-chip CT-62 Cable. Note: These are more expensive than counterfeit cables.
    e. Note: SARCTRAC does not monitor the state of the radio connection or function.
    f. Faulty USB CAT cable: Try a replacement Yaesu CT-62 CAT cable.

4. SARCTRAC beeps two 100ms beeps when started: This indicates the USB GPS Receiver is not working.
    a. No Power: Check the USB Hub Hat power and USB Joiner.
    b. No Power: Check if the blue USB GPS fix LED flashes at 1Hz when it has a clear view of the sky.
    c. Wiring error: Check the wiring against Figure 3. Fix the wiring.
    d. USB port not working: Try another USB Hub Hat port.
    e. Faulty USB GPS: Test the USB GPS connected to a PC: Download the UBLOX u-centre app.
    f. Faulty USB GPS: Try a replacement USB GPS Receiver.
5. SARCTRAC beeps three 100ms beeps when started: This indicates the 3D Sensor is not working.
    a. Check it is a LSM303DLHC, not a LSM303D 3D Magnetometer/Accellerometer.
    b. Wiring error: Check the wiring against Figure 3. Fix the wiring.
    c. Faulty 3D Sensor: Try a replacement 3D Sensor.
6. SARCTRAC beeps one long 3s beep when started, but the Motors don't start moving:
    a. Wiring Error: Check the wiring against Figure 3. Fix the wiring.
    b. Faulty motor: Connect the Motor wires to +/-12VDC and check movement in both directions.
    c. Faulty Motor Driver PCB: Check Red Power LED is on. Disconnect the Orange, Blue, Purple and Grey Wires from the Motor Driver PCB at the RPi0 header. Connect each Wire in turn to GND. Check that the appropriate Motor drives in the appropriate direction.
7. SARCTRAC Motors moving, but can't be controlled by the 3D Sensor:
    a. Faulty 3D Sensor: Check the 3D Sensor type (LSM303DLHC only). Substitute a working 3D Sensor.
    b. 3D Sensor calibration is way out. Re-do the 3D Sensor Calibration.
8. SARCTRAC Motors moving, but turn in the wrong direction:
    a. Wiring Error: Check the wiring against Figure 3. Fix the wiring.
    b. 3D Sensor upside down: Check the flat side of the 3D Sensor is down.
    c. 3D Sensor way out of calibration. Re-do 3D Sensor Calibration.
9. SARCTRAC cannot connect to the WiFi network, via a WiFi Router or Mobile Device Personal Hotspot:
    a. Failed to download, copy, edit or insert a new network.txt file on a USB Disk on start-up.
    b. Misconfigured SSID, Password or WiFi Parameters in the network.txt file.
    c. WiFi router is not configured to accept new devices.
    d. WiFi router is blocking RPi0 MAC address.
    e. Mobile Device Personal Hotspot is disabled.
10. SARCTRAC cannot connect to the Internet:
    a. WiFi Router is not connected to the Internet.
    b. WiFi Router is not configured to route the Internet to the WiFi network using NAT.
    c. Mobile Device Personal Hotspot is not connected to a 4G Mobile Broadband Network.
    d. Check the WiFi connection to the internet via another WiFi device.
11. SARCTRAC SELECTION page cannot be displayed:
    a. SARCTRAC did not beep. See: SARCTRAC does not beep at all when started.
    b. The IP Address or URL is incorrect: See: WiFi Network Configuration.
    c. SARCTRAC is not connected to the WiFi: See: SARCTRAC cannot connect to the WiFi.

12. SARCTRAC beeps one 3s beep, but does not beep a second time when started with the USB Disk attached:
    a. The first beep should be after one minute, the second after three minutes.
    b. The USB Disk label is not "SARCTRAC": Open the USB Disk Properties window on a PC and change it.
    c. There were no configuration or update files or folders copied to the foot folder of the USB Disk prior to it being inserted into SARCTRAC: Place the configuration and update files in the root folder first.
    d. Note: Only the following files and folders are considered configuration and update files:
        i. sarctrac file
        ii. network.txt file
        iii. freqmode.txt file
        iv. tle folder containing *.tle files
    e. The USB Disk is unreadable, unwritable or corrupted: Replace with a working USB Disk.
13. SARCTRAC beeps two 3s beeps when started with the USB Disk attached, but does not update.
    a. The files and folders copied to the root folder of the USB Disk were not new or edited and contained the same information as the last backup.
    b. To check if SARCTRAC has been updated: Power SARCTRAC down, plug the USB Disk back into the PC. Note: When SARCTRAC installs a file or folder from the root folder of the USB Disk, it automatically creates a backup folder on the USB Disk, starting with Backup00, containing a full backup of the SARCTRAC applications and configuration files. It then deletes any installed files from the root folder of USB Disk. So, after an update, you should now see a new, sequential folder called "BackupXX" and no other files or folders in the root folder. If not try again.
14. SARCTRAC was working but stopped working after an update with the USB Disk.
    a. A configuration file may have been corrupted.
    b. Restore the last known working backup from the USB Disk: Insert the USB Disk into a PC. Copy the contents of the BackupXX folder to the root folder. Eject the USB Disk. Power-down SARCTRAC. Insert the USB Disk into SARCTRAC. Power-up SARTRAC.
15. SARCTRAC points North and Horizonal when started, but does not track any selected satellites:
    a. Check satellites are selected for monitoring on the SELECTION page.
    b. Check satellites are selected for tracking on the TRACKING page.
    c. Check satellites are displayed with a Check symbol.
    d. Contact info@sarcnet.org for further instructions.
16. SARCTRAC SELECTION page SYSTEM STATUS errors:
    a. **ID: SARCTRAC Version X.Y**, where X.Y is the wrong version, indicating an update has failed:
        i. Check the version of the update files on the website.
        ii. Repeat the update procedure.
    b. UR: First name Last name Callsign, where it is not you:
        i. Contact info@sarcnet.org for further instructions.
    c. **AT: Street Address**, where it is the wrong location, indicating GPS/Internet/Geocoding failure:
        i. SARCTRAC only displays the current address if the GPS is working and the Internet is connected.

ii. SARCTRAC initially displays 'UNKNOWN ADDRESS' or the last known location until the first GPS 3D Fix.

iii. SARCTRAC displays "UNKNOWN ADDRESS' or the last known location after the first GPS 3D Fix if SARCTRAC has moved more than 250m from its last location but the Internet is not connected.

iv. SARCTRAC only changes the last known location when the GPS is working, it has moved more than 250m from the last known location and the Internet is connected.

v. SARCTRAC may display a nearby location due to inaccuracy of the GPS 3D Fix or if the correct address is not found on-line.

vi. SARCTRAC uses the current GPS position to do an on-line, reverse-geocode lookup of the street address: Try searching for your address at: https://nominatim.openstreetmap.org/search. The website may not be online or your address may not be listed.

vii. It may take some time to establish the first GPS 3D FIX. Ensure a clear view of the sky. Refresh the SELECTION page while waiting.

viii. Check for **Online: False, Retries 30/30** indicating no Internet connection or **GPS Port: /dev/ttyACM0 Offline** indicating no USB GPS Receiver connection.

d. Server: aaa.bbb.ccc.ddd Client: aaa.bbb.ccc.ddd, where it is the wrong IP address.

i. These are the actual IP addresses in use so they should be correct.

ii. Check if the WiFi Router DHCP server has renewed the existing lease.

iii. You can set WiFi Router DHCP to reserve a static IP address for the RPi0 MAC address. See the WiFi Router manual for details.

e. **Time: YYYY-MM-DD hh-mm-ss**, where the date or time shown is incorrect:

i. Check LOCAL TIME ZONE. Set the correct time zone.

ii. No Internet NTP service and no GPS satellites = No time.

iii. Provide an Internet connection and a clear view of the sky.

iv. Refresh the SELECTION page while waiting.

f. **Online: False, Retries 30/30**, indicating SARCTRAC has tried for 30 seconds after boot up and has failed to connect to the Internet in that time:

i. See Troubleshooting: SARCTRAC cannot connect to the Internet.

g. **TR Port: /dev/ttyUSB0 Offline**, indicating SARCTRAC cannot detect the rig control cable:

i. You can ignore this if you don't need to control the rig.

ii. Shutdown and Power-down SARCTRAC.

iii. Connect a Yaesu CT-62 USB Cable to a SARCTRAC USB Port

iv. Power-up SARCTRAC and Check **TR Port: /dev/ttyUSB0 Online**, if not:

1. Try again with a different USB Port or substitute USB Cable.

2. Note: The USB cable does not need to be connected to the rig.

h. **GPS Port: /dev/ttyACM0 Offline**, indicating SARCTRAC cannot detect the USB GPS:

i. Disconnect any USB Cables and USB Disks from SARCTRAC.

ii. Check the Red Power LED (PWR) is illuminated on the USB Hub Hat, if not:

1. Check power and wiring.

2. Try a substitute USB Hub Hat.

iii. Check the Green USB Port LED (D1) is illuminated on the USB Hub Hat, if not:

1. Check the USB Joiner is firmly plugged into the USB Hub Hat and RPi0.

2. Check the USB GPS is firmly plugged into the USB Hub Hat.

3. Try a substitute USB Hub Hat.

iv. Check that the USB GPS Blue LED is pulsing at 1 Hz indicating the GPS is working, if not:
1. Check that the USB GPS has a clear view of the sky.
2. Try again outside or at another time.
3. Try a substitute USB GPS Receiver.
i. **GPS Sync 0s**, indicating SARCTRAC did not update the time from the USB GPS:
i. It may take some time to establish a GPS 3D FIX. Ensure a clear view of the sky.
ii. Refresh the SELECTION page while waiting for a GPS 3D FIX.
iii. Check **GPS Port: /dev/ttyACM0 Online**, indicating the USB GPS is online
iv. Check the SYSTEM START-UP LOG for "**Started:gps**", indicating the GPS Thread has started.
j. GPS Latitude, Longitude, Altitude, Error and MAG Inclination or Declination is incorrect:
i. Initially shown as 0.0, 0.0, 0m, 100000m, 0.0°, 0.0° respectively until the first GPS 3D Fix.
ii. It may take some time to establish the first GPS 3D FIX. Ensure a clear view of the sky.
iii. Refresh the SELECTION page while waiting for a GPS 3D FIX.
iv. Check **GPS Port: /dev/ttyACM0 Online**, indicating the USB GPS is online.
v. Check the SYSTEM START-UP LOG for "**Started:gps**", indicating the GPS thread has started.
vi. Check the SYSTEM START-UP LOG for "**Stopped:gps**", indicating the GPS error is below 5m.
17. SARCTRAC SELECTION page SATELLITE STATISTICS errors:
a. See Table 7 for errors in the satellite statistics.

Table 7 - Satellite Statistics

Item	Description	Problems	Solutions
53 Weather satellites loaded. 22 Noaa satellites loaded. 68 Amateur satellites loaded. 44 Frequencies matched. 0 Duplicates removed. 43 Satellites rejected. 100 Satellites available.	Loaded satellite statistics, indicating: 1. Number of satellites found in each TLE library file. 2. Number of satellites matched to Frequencies in the freqmode.txt file. 3. Number of duplicate satellites found in the TLE library files. 4. Number of satellites rejected due to partial name matches with names in the REJECT SATELLITE LIST. 5. Total number of satellites available for monitoring and tracking.	Corrupted TLE Library file. No match in freqmode.txt file. Partial satellite name matches an item in the REJECT SATELLITE LIST.	Fix the TLE library file format. Only occurs for user-defined TLE Library files. Add an entry in the freqmode.txt file. Remove the offending item from the REJECT SATELLITE LIST

18. SARCTRAC SELECTION page SYSTEM START-UP LOG errors:
    a. See Table 8 for errors in the system start-up process.

Table 8 – Typical System Start-Up Log

Item	Description	Problems	Solutions
Started:2019-03-30 09:50:14z	Start time in UTC possibly before the Internet or GPS time is available.	Not known.	Try RESTART.
SARCTRAC Version 1.0	Current software version number	Current software version number is not correct: Update problem.	Redo update.
Loaded:settings.txt Loaded:rotorcal.txt Loaded:elements.txt Loaded:selected.txt Loaded:tracking.txt Loaded:rejected.txt Loaded:freqmode.txt Loaded:location.txt Loaded:licences.txt	Loaded: Indicates successful loading of local configuration file. Failed: Indicates unsuccessful loading of local configuration file.	Corrupt file: The following files could have been corrupted by the user during the update process: freqmode.txt. Generally, this will stop the tracker.	Restore a known working backup set. Precise formatting is required for all configuration files.
Online:True, Retries:0/30	Number of 1-second retries to connect to the Internet out of a total of 30 before giving up.	No Internet connection.	See Troubleshooting.
Loaded:https://celestrak.com/NORAD/elements/weather.txt Loaded:https://celestrak.com/NORAD/elements//noaa.txt Loaded:https://celestrak.com/NORAD/elements//amateur.txt	Loaded: Indicates successful loading of remote TLE library files. Failed: Indicates unsuccessful loading of remote TLE library files.	Only occurs once every 24 hours. But not unfortunately on first installation because the timestamp is now!	Wait 24 hours or press PURGE and then RESTART.
Loaded:tle/weather.txt Loaded:tle/noaa.txt Loaded:tle/amateur.txt	Loaded: Indicates successful loading of local TLE library files. Failed: Indicates unsuccessful loading of local TLE library files.	Missing URLs in the SATELLITE ORBITAL ELEMENT LIBRARY LIST and PURGE has removed the local file(s).	Add URLs or Reinstall last working backup.

Item	Description	Problems	Solutions
53 Weather satellites loaded. 22 Noaa satellites loaded. 68 Amateur satellites loaded. 44 Frequencies matched. 0 Duplicates removed. 43 Satellites rejected. 100 Satellites available.	Loaded satellite statistics, indicating: 1. Number of satellites found in each TLE library file. 2. Number of satellites matched to Frequencies in the freqmode.txt file. 3. Number of duplicate satellites found in the TLE library files. 4. Number of satellites rejected due to partial name matches with names in the REJECT SATELLITE LIST. 5. Total number of satellites available for monitoring and tracking.	Some orbital element libraries are not loaded. Some frequencies are not matched. Some satellites are incorrectly rejected.	The URL in the ORBITAL ELEMENT LIBRARY LIST is incorrect or the file is not available. Fix the associated entry in the freqmode.txt file. Remove the offending item from the REJECT SATELLITE LIST
Opened:gps:/dev/ttyACM0	Opened indicates the GPS USB port was opened. Failed indicates the GPS USB port was not opened.	GPS not connected or not working.	See GPS Port Offline.
Opened:transceiver:/dev/ttyUSB0	Opened indicates the radio USB port was opened. Failed indicates the radio USB port was not opened.	USB Cable not connected	See TR Port Offline.
Created:observer Latitude:0.0° Longitude:0.0° Altitude:0.0m Error:1000000.0m Declination:0.0° Inclination:0.0° Address:UNKNOWN ADDRESS	The initial location on the very first power-up, but before the first GPS 3D Fix. You may not see this if the first GPS fix is fast.	GPS not connected or not working. No GPS 3D Fix.	See GPS Port Offline. Ensure a clear view of the sky or try again later.

Item	Description	Problems	Solutions
TimeZone:11.0	The initial time zone. Please change it to suit.	Incorrectly set.	Set correctly.
Started:gps Started:rotator Started:tracker Started:server	Started indicates that threads were started successfully: • gps provides position updates • rotator provides motor control • tracker provides satellite prediction • server provides web pages,	Not known.	Not known.
Stopped:gps Stopped:rotator Stopped:tracker Stopped:server	Stopped indicates a NORMAL thread shutdown. All threads are stopped when the application closes. The gps thread is stopped when the gps error is less than 5m.	Not known.	Not known.
GPSdate:2019-03-30 09:50:15z GPSsync:-1.695586s	Values from the first 2D GPS fix indicating the current GPS date in UTC and the time difference between the GPS and system clock (which would have been previously synchronised to NTP, when the Internet was connected).	GPS not connected or not working or not acquiring GPS satellites.	See GPS Sync 0s Fix GPS. Ensure a clear view of the sky.
Loaded:https://nominatim.openstreetmap.org/reverse Loaded:reverse.txt	Loaded indicates that the Internet reverse geocode lookup of the address at the GPS position was successful. Failed indicates an error. Your address could be incorrect.	No internet connection. OSM website is down. Your address is not listed.	Fix Internet connection. Check OSM website.

Item	Description	Problems	Solutions
GPSfix:3D Latitude:-37.90745166666667° Longitude:145.09235566666666° Altitude:61.1m Error:7.2m Moved:True Distance:14490817.1m Address:Mead Court, Oakleigh	Here the location has changed from the previous values. These values are from the first ever 3D GPS fix. It is only displayed if the error is less than the best error for this location or if the location has changed. In this case yes: We are 14,491km from the default 0° latitude, 0° longitude location. With a 7.2m error (but not less than 5m yet)	GPS not connected or not working or not acquiring GPS satellites.	Fix GPS. Ensure a clear view of the sky.
Declination:11.7° Inclination:-68.8°	Indicates Local values at the GPS position from the World Magnetic Model.	GPS not connected or not working or not acquiring GPS satellites.	Fix GPS. Ensure a clear view of the sky.
Moved:False Fix:3 Distance:2.4m Error:4.9m Latitude:-37.907433999999995° Longitude:145.09234300000003° Altitude:66.9m Address:Mead Court, Oakleigh Declination:11.7° Inclination:-68.8° Stopped:gps	Here: The location hasn't changed, but a better 3D Fix was obtained. The GPS thread was stopped since the error is less than 5m	GPS not connected or not working or not acquiring GPS satellites.	Fix GPS. Ensure a clear view of the sky.

SARCTRAC - Satellite Antenna Rotator Controller and TRACker
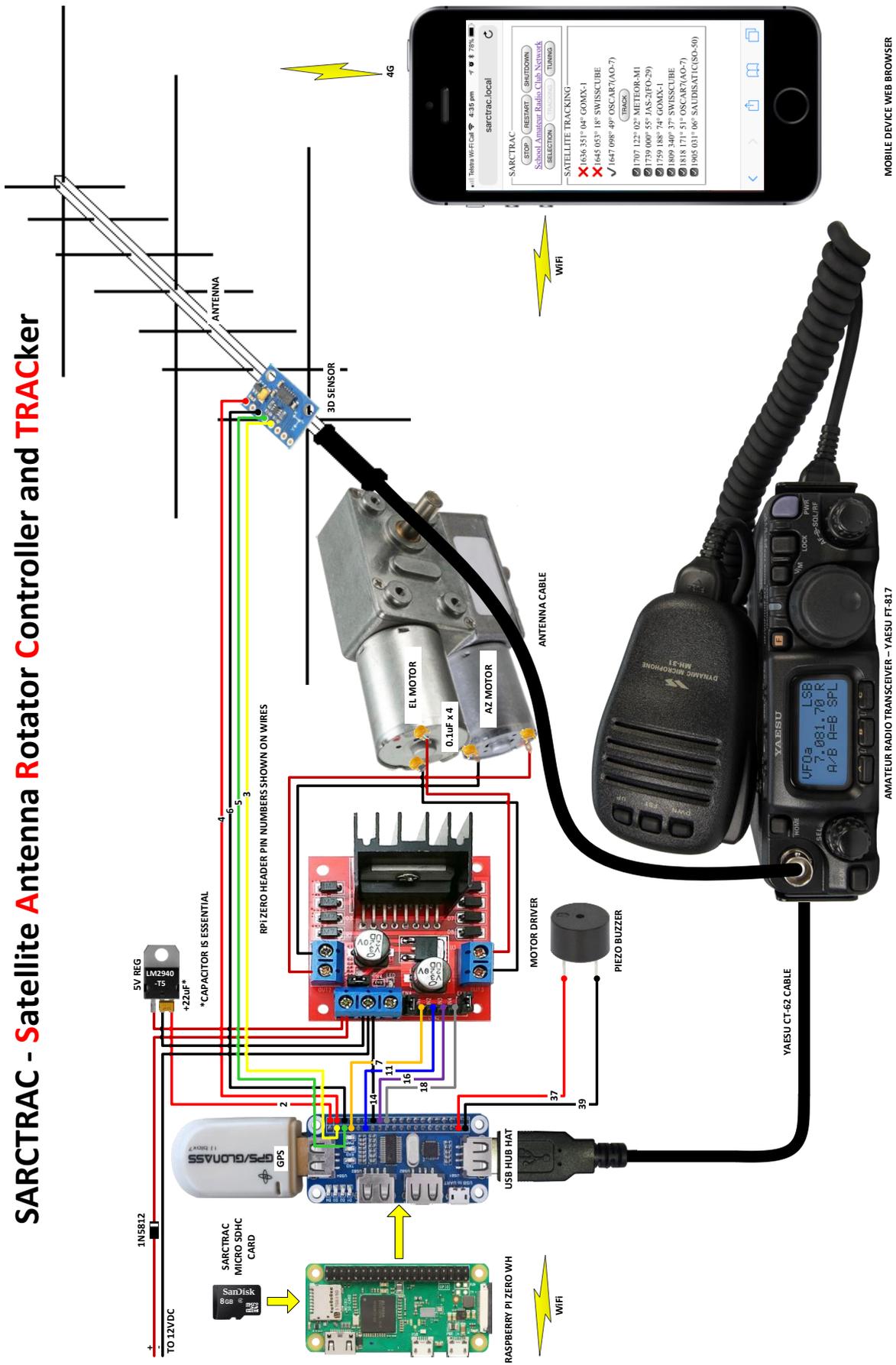
Figure 3 – Pictorial Schematic
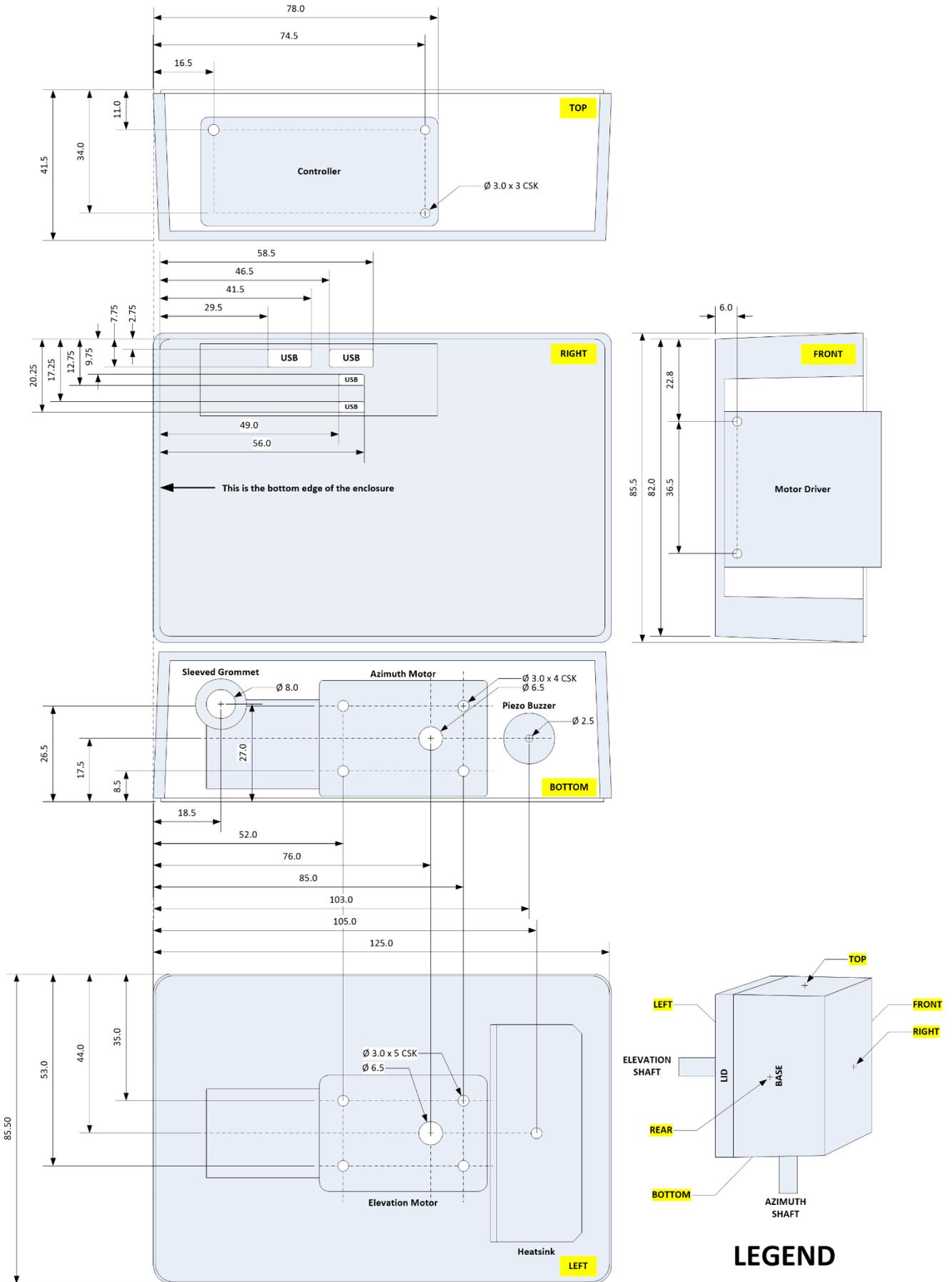
Figure 4 – Enclosure drawings
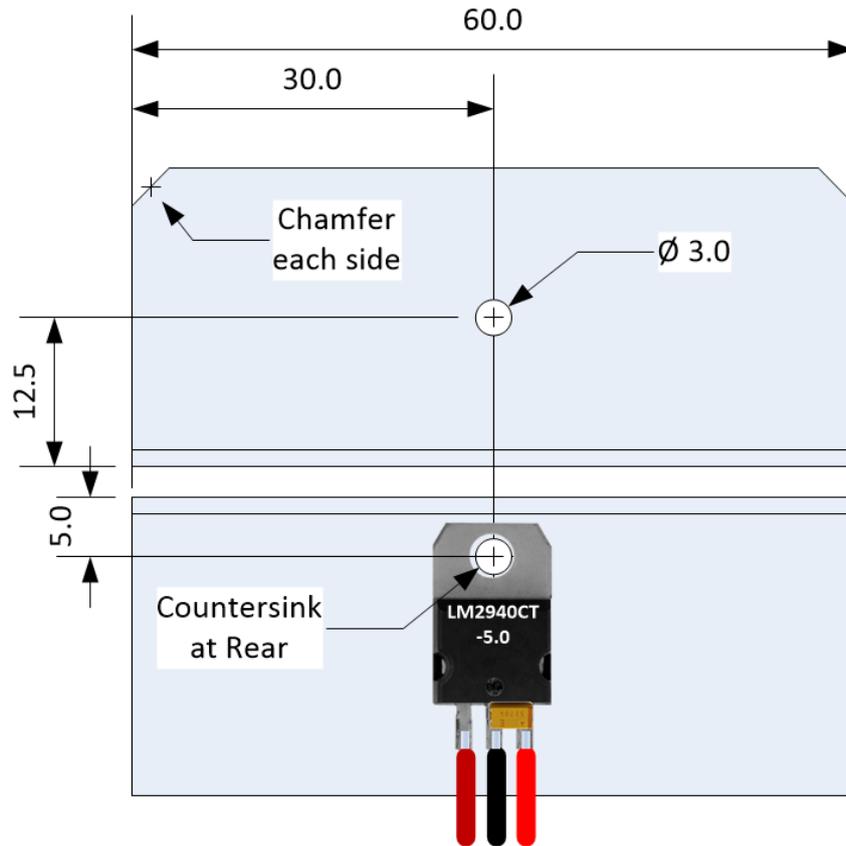
Figure 5 – Heatsink drawing

Figure 6 – Scribing construction lines on self-adhesive paper labels

Figure 7 – Enclosure Inside

Figure 8 - Enclosure Top Side

Figure 9 - Enclosure Right Side

Figure 10 - Enclosure Bottom Side

Figure 11 - Enclosure Left Side

Figure 12 - Enclosure Front Side
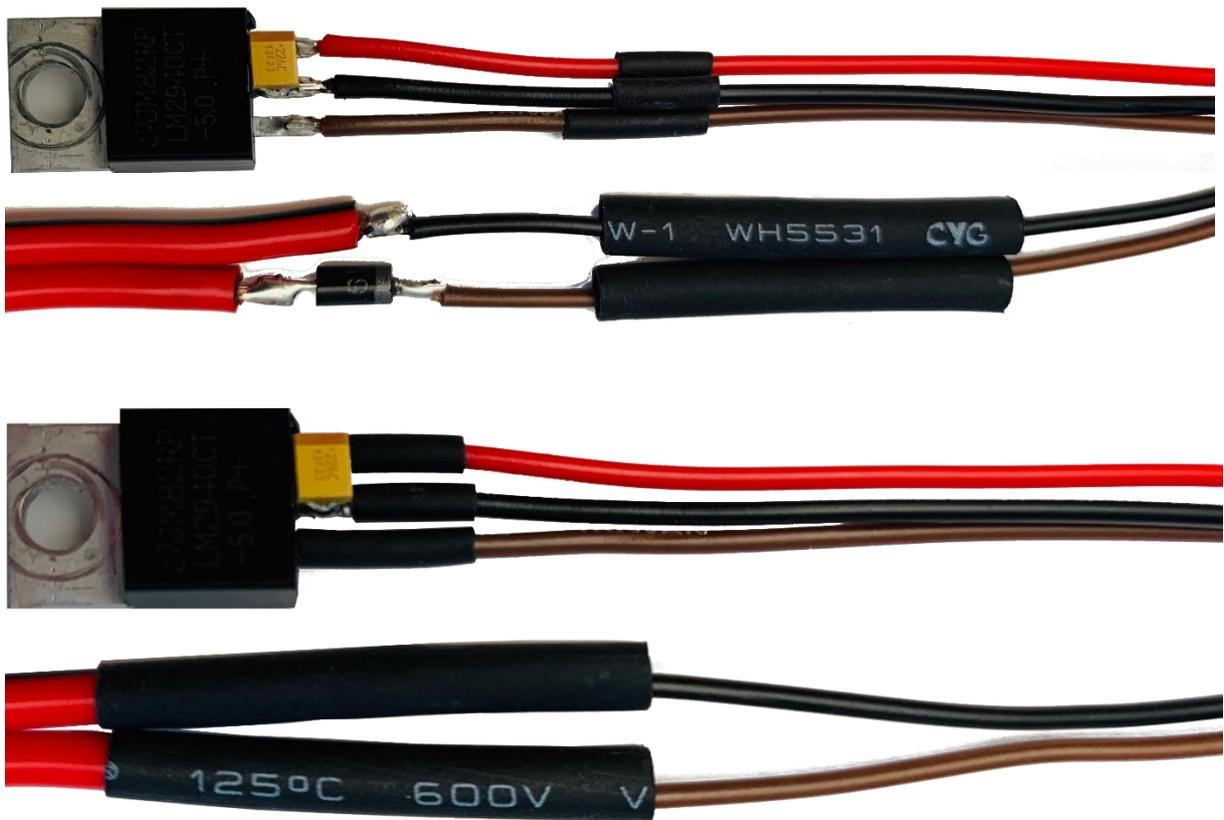
Figure 13 – Regulator and Power Wire Preparation.
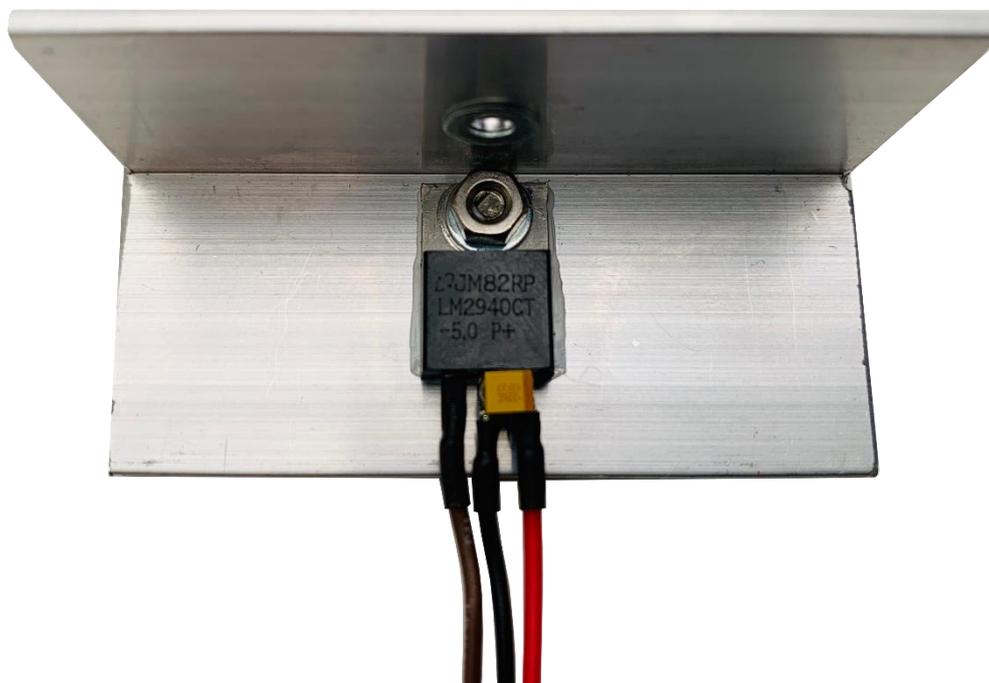
Figure 14 - Mounting the Regulator on the Heatsink
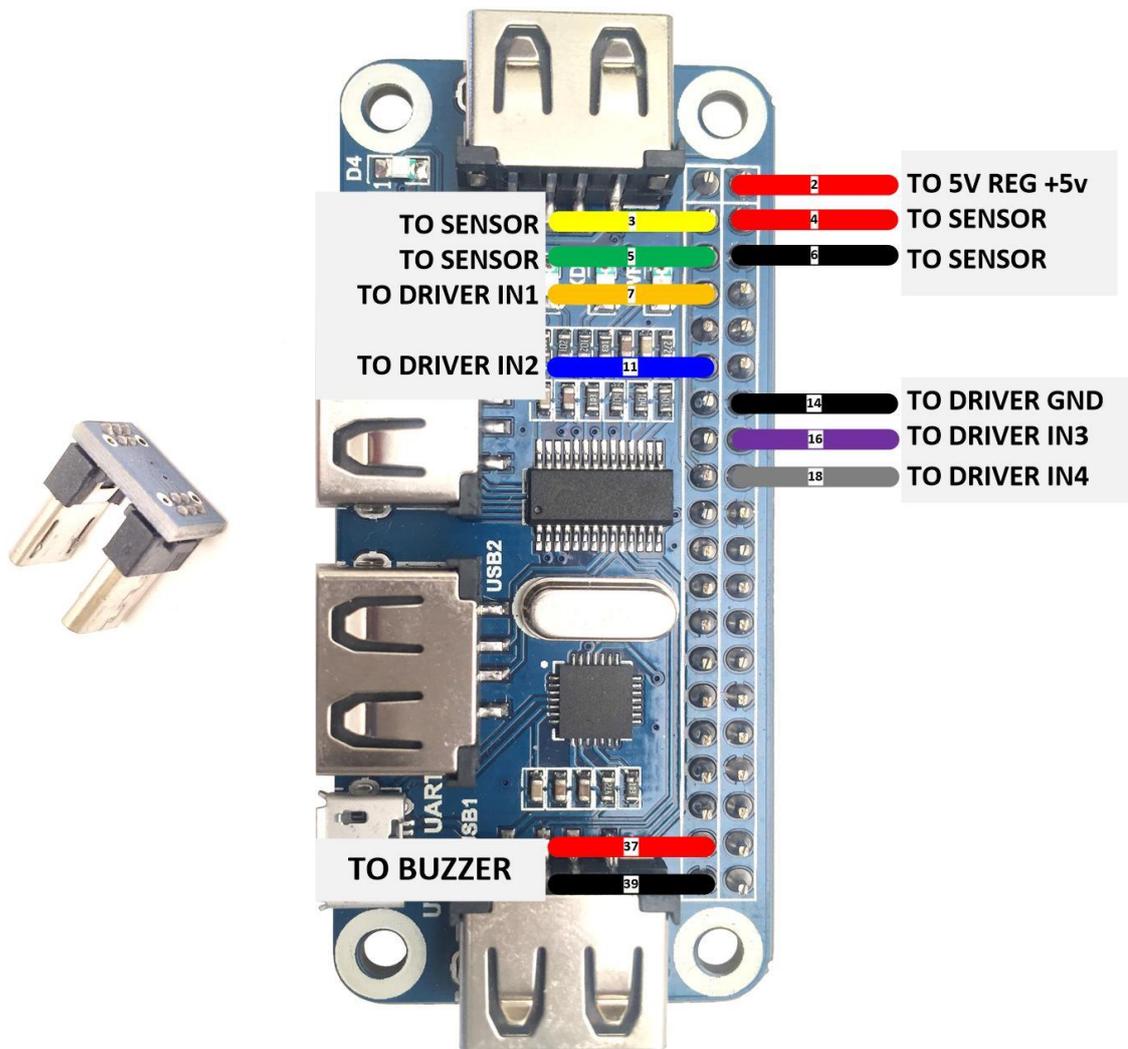
Figure 15 - USB Joiner and USB Hub Hat

Figure 16 – RPi0 Assembly showing two 6mm spacers
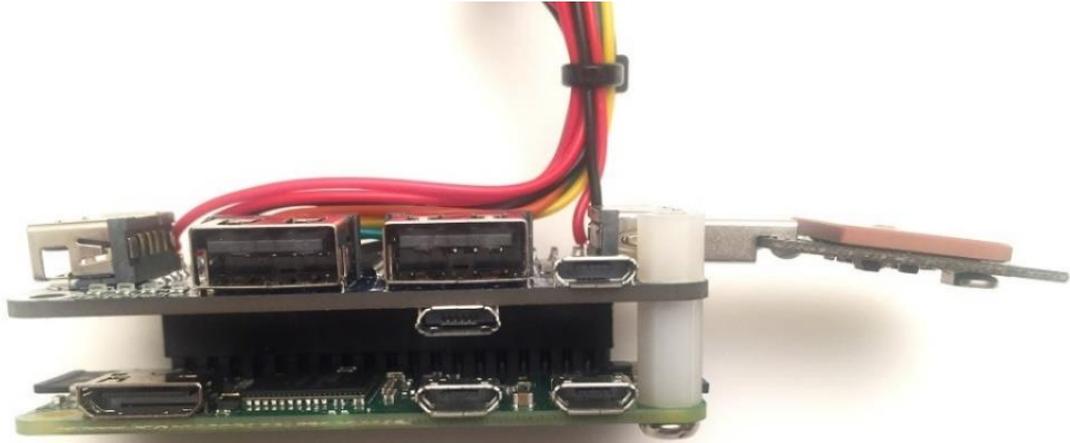
Figure 17 - RPi0 Assembly showing one 10mm and one 6mm spacer
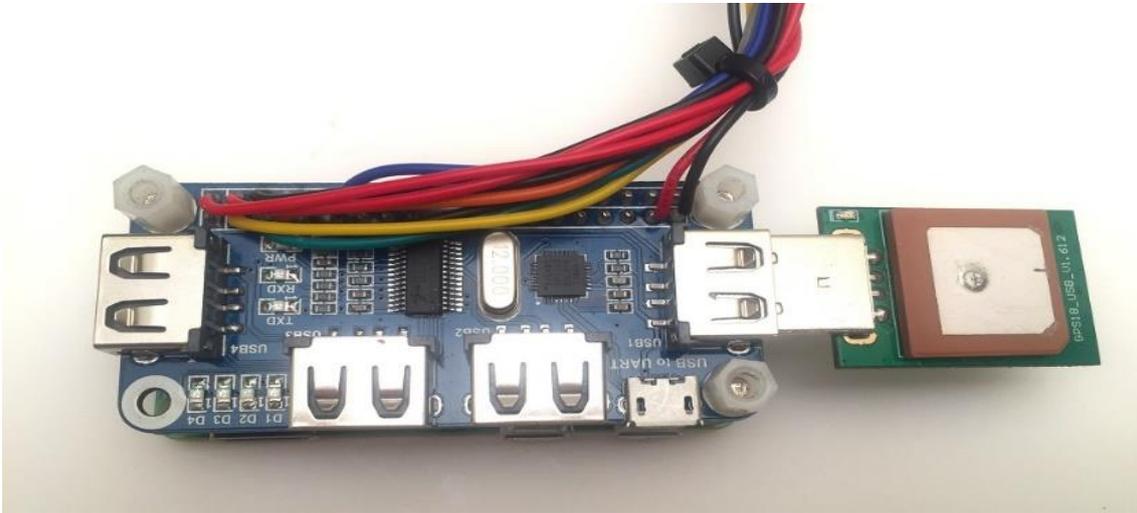
Figure 18 - RPi0 Assembly showing USB GPS Receiver
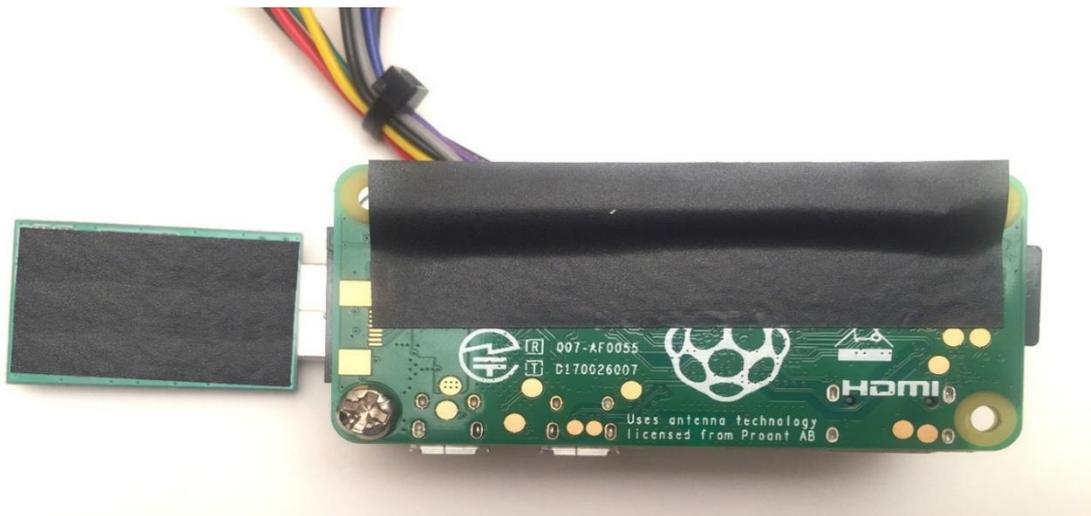
Figure 19 - RPi0 Assembly showing PVC tape
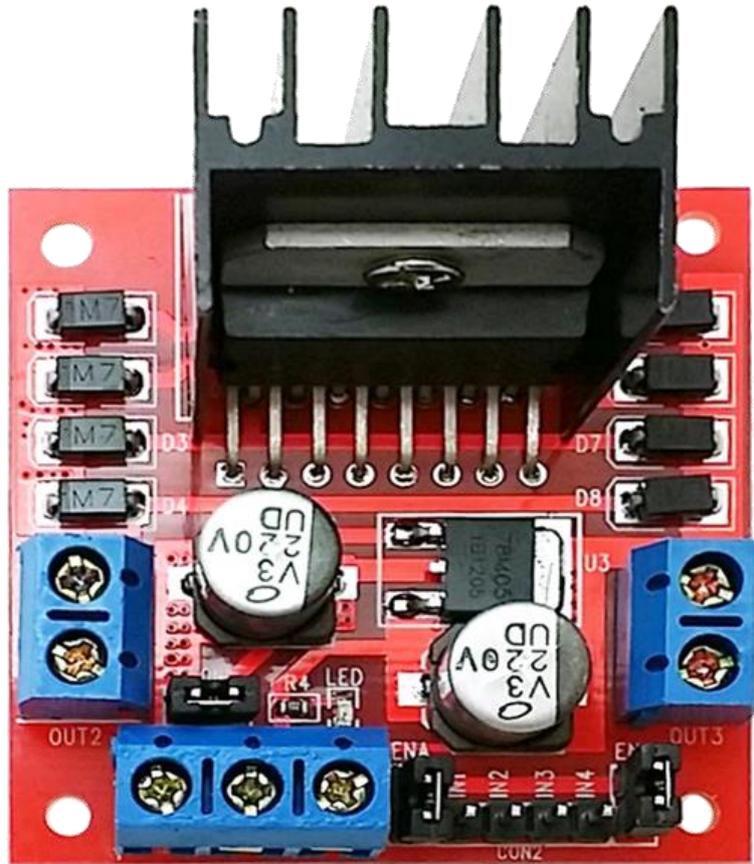
Figure 20 – Motor Driver Front
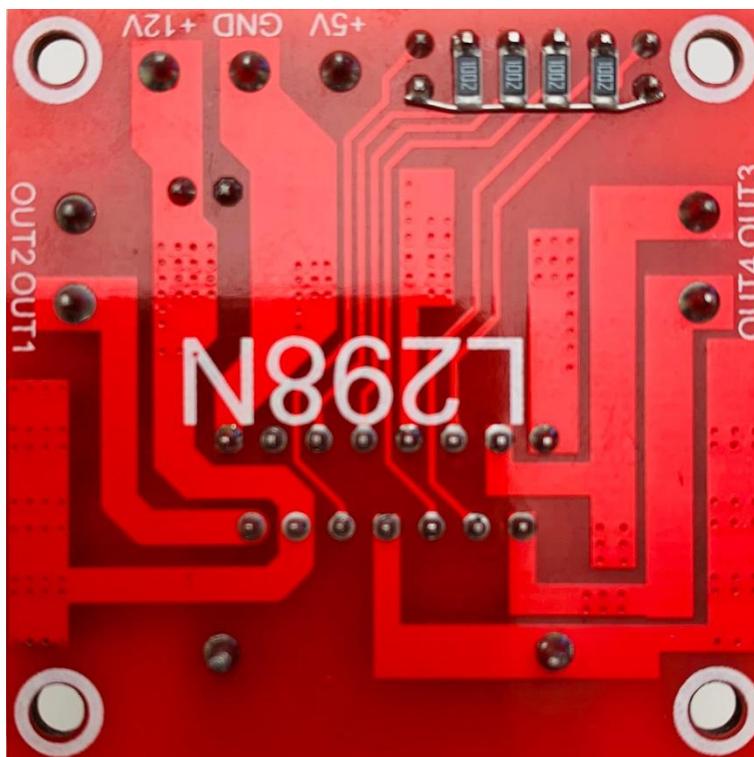
Figure 21 – Motor Driver Rear
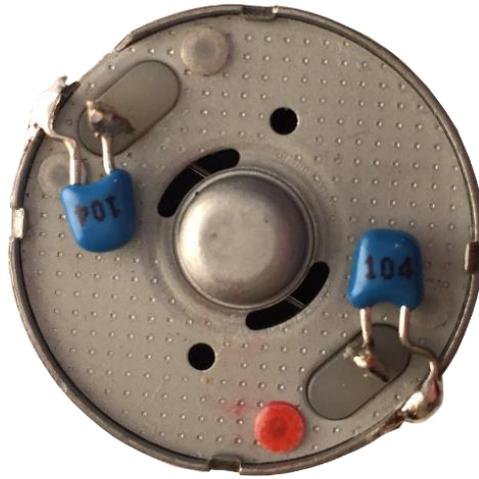
Figure 22 – Motor RFI Suppression Capacitors
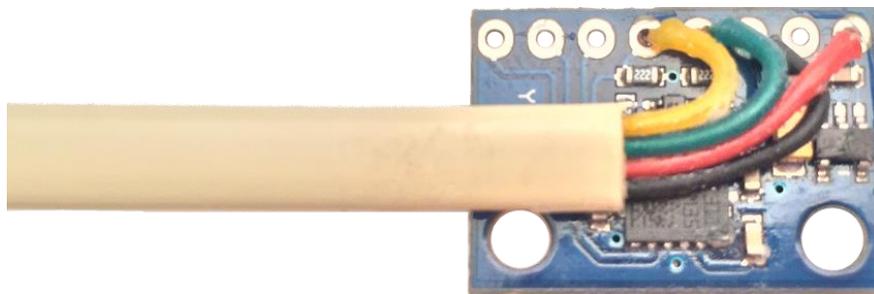
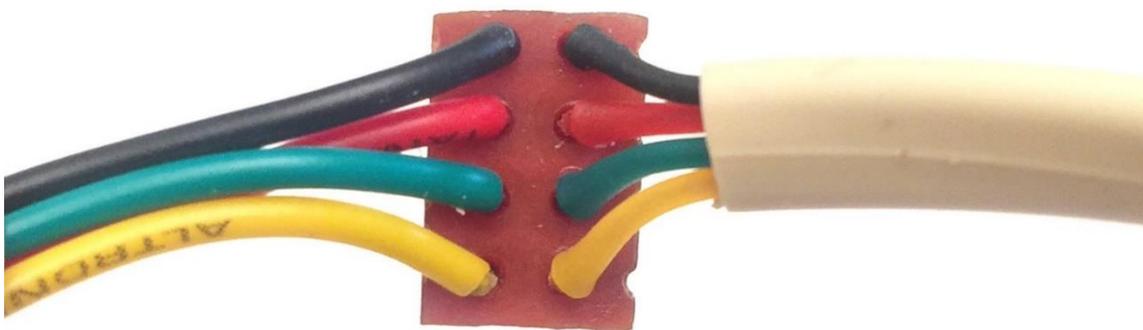*Figure 23 – 3D Sensor Wiring*

Figure 24 – 3D Sensor with Heat-Shrink

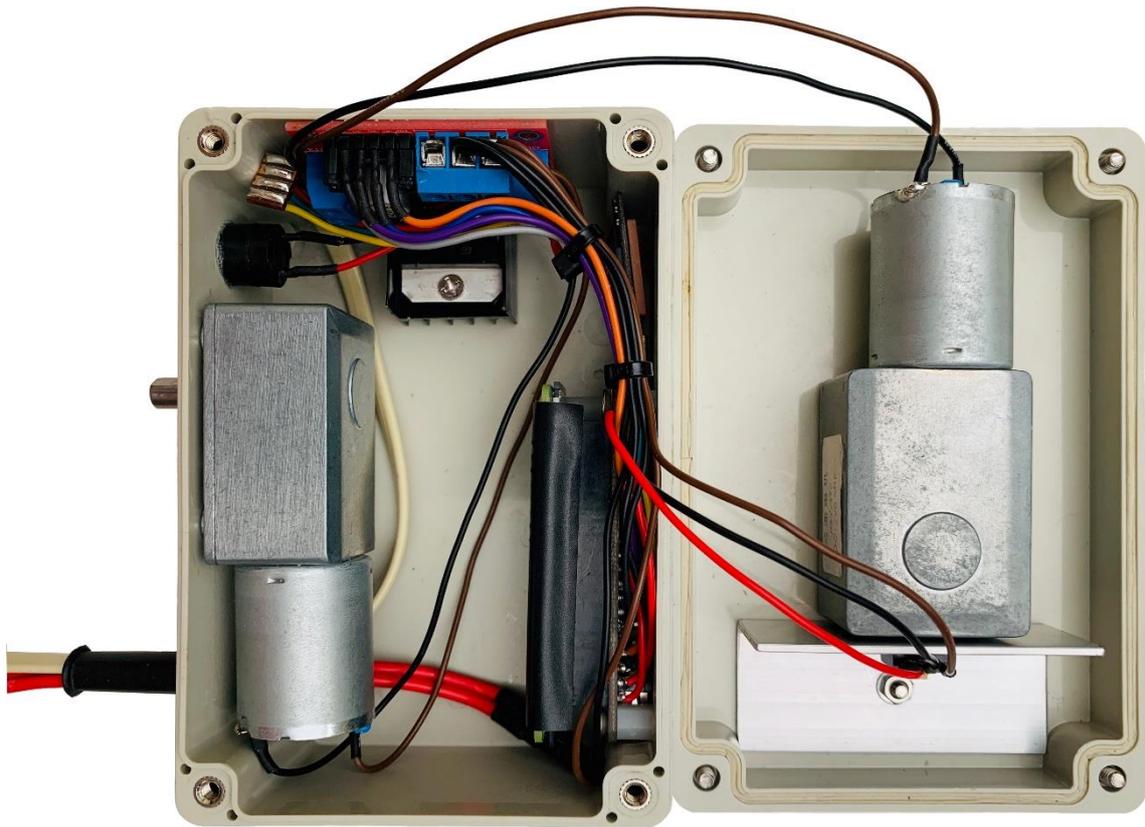*Figure 25 – 3D Sensor Cable Breakout Board*

Figure 26 - Wiring and assembly complete

Figure 27 – Finished unit. AZ Motor at top. EL Motor at front.

Figure 28 – Fusing together the USB Right-Angle Adapters (optional)

Figure 29 - Completed Unit

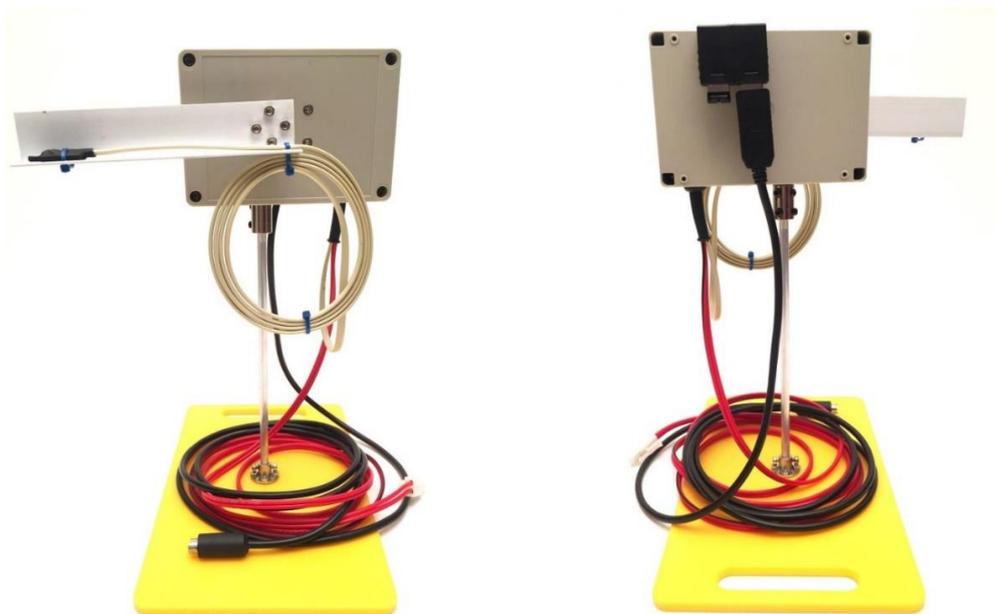*Figure 30 – Tripod mounting*

Figure 31 – Counterbalanced Lift-arm

Figure 32 – Simple Bench-Test Setup (Optional)