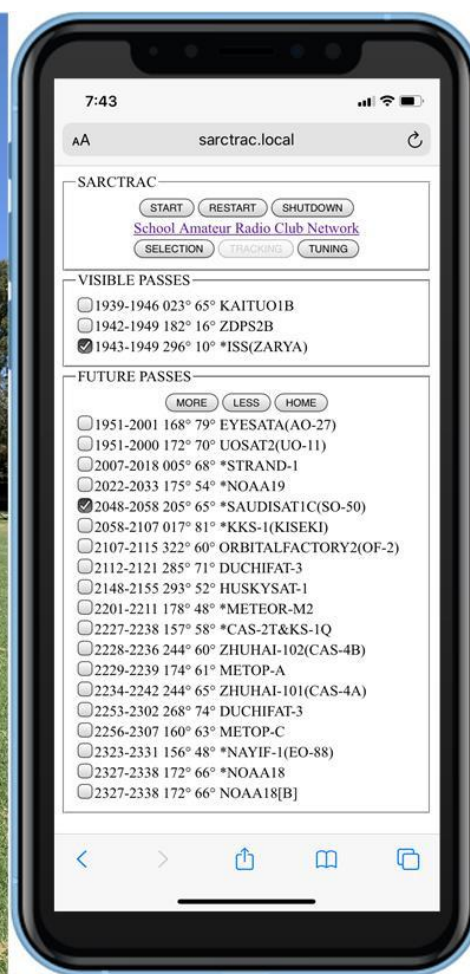
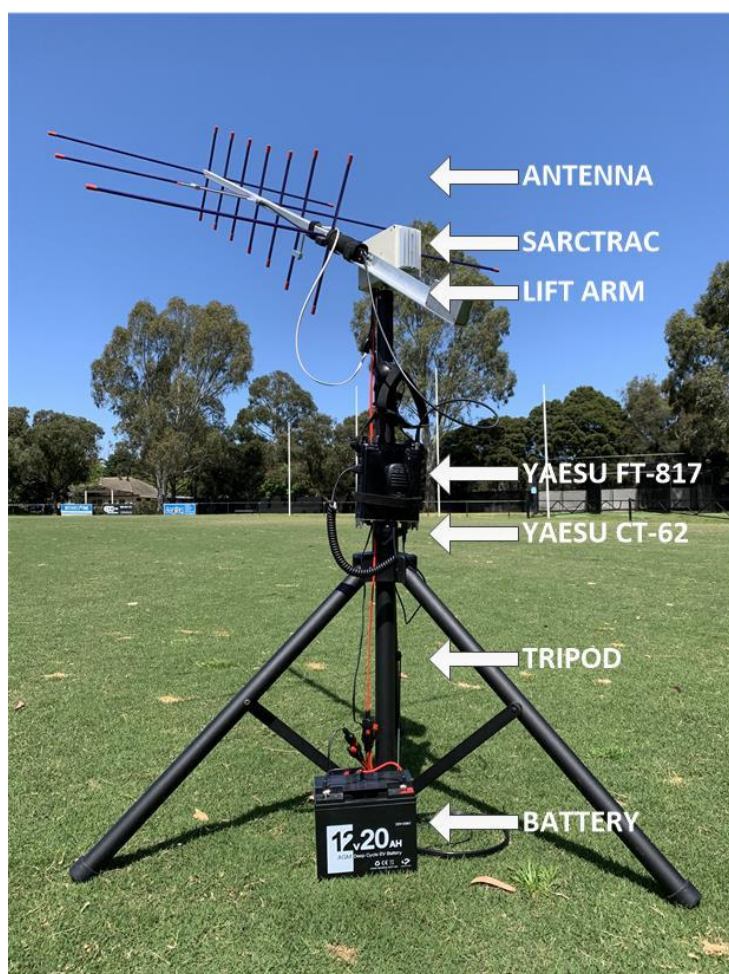


**SARCTAC**  
**Satellite Antenna Rotator Controller & TRACKer**  
**SCHOOL AMATEUR RADIO CLUB NETWORK**  
[www.sarcnet.org](http://www.sarcnet.org)

# SARCTAC Mk2 Manual



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## Introduction

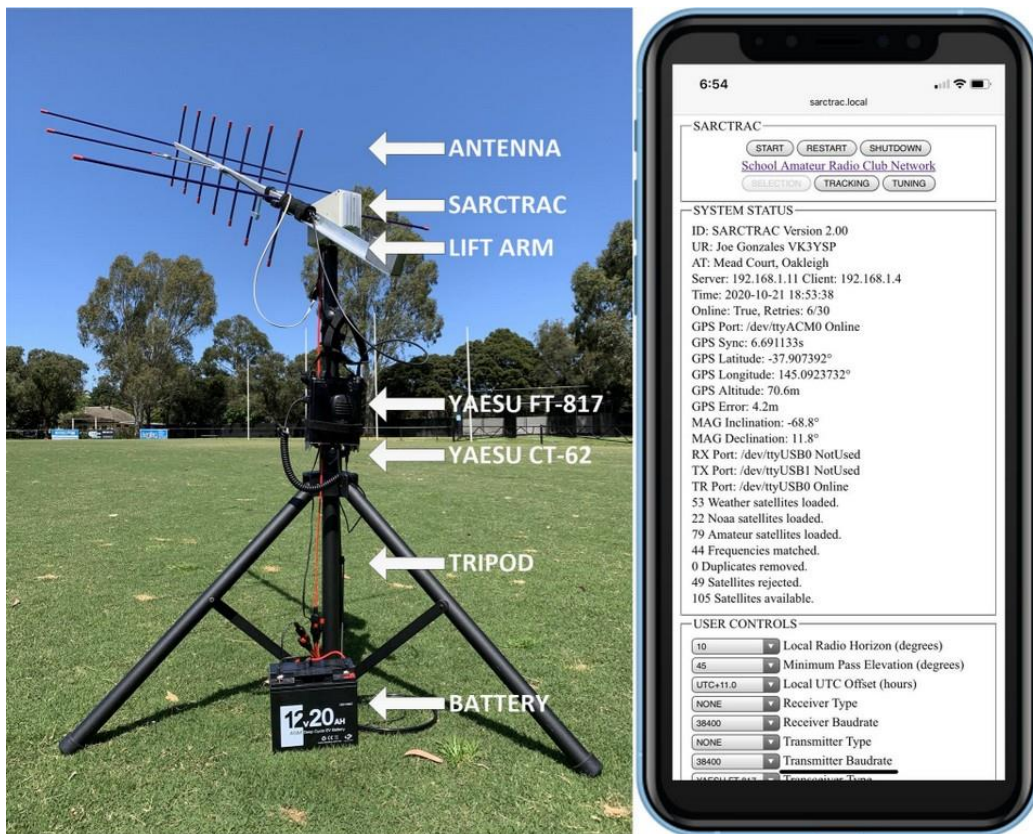
SARCTRAC is a portable, integrated, satellite tracking system, which is now available as a fully-assembled, tested and calibrated product: Simply mount it on your tripod; attach it to your hand-held satellite antenna using a counterbalanced lift-arm; connect it to your radio transceiver and battery; strap on the SARCTRAC 3D sensor to your antenna boom; then use your WiFi-enabled mobile device to control SARCTRAC and select the satellites you want to track. SARCTRAC will predict future satellite passes, track each satellite in turn and even tune you radio to the correct frequency and mode for each overhead pass. With a SARCTRAC system and your own equipment you can listen to orbiting space beacons, make two-way satellite contacts and use free, third-party software to download earth images and decode satellite telemetry. It's both fun and educational! Note: SARCTRAC comes with its own Demo Stand and a Demo Lift-Arm for demonstration purposes.

**New for 2020:** The Amateur Radio International Space Station (ARISS) team and NASA have installed a permanent radio repeater on board the ISS. So now you can use SARCTRAC and your own equipment to listen and talk to other Amateur Radio enthusiasts via the ISS!



***Figure 1 - SARCTRAC Mk2 Demo Setup***

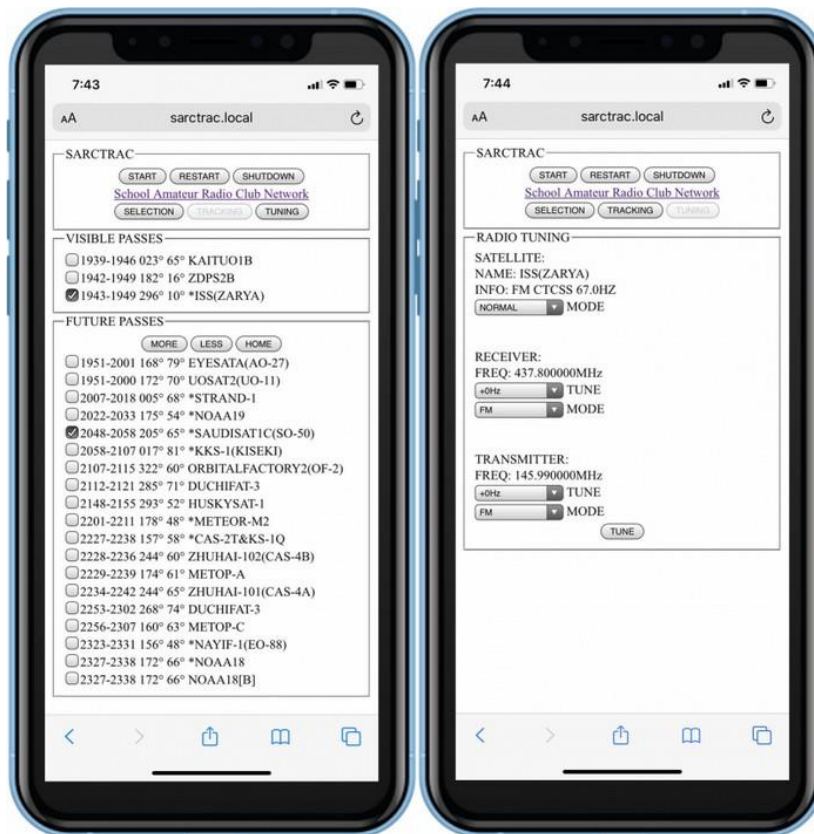




**Figure 2 - SARCTrac Mk2 Portable Setup**



**Figure 3 - SARCTrac Mk2 Selection Page**



**Figure 4 - SARCTRAC Mk2 Tracking and Tuning Page**

## Background

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. It takes minutes to set up, in the playground, on a mountain summit, down at our local footy oval or even in the backyard. It starts tracking visible satellites from the selected satellite list right away.

The inspiration for SARCTRAC was to help little kids have fun in space: Well, at least to play with things in low earth orbit! You might be surprised just how many tiny cube-sats and regular polar-orbiting satellites there are. The first challenge is to know when and where the satellites will be. Then to point a hand-held antenna up at them while they pass overhead. You also have to constantly adjust your radio transmitter and receiver frequencies to compensate for something called Doppler shift.

Tracking satellites is a bit like fishing in the sky and just as challenging. Our School Amateur Radio Club students think SARCTRAC is really fascinating to watch - and so do we. It is really exciting when the kids hear their first satellite. They try to imagine where the satellite is, by looking along the antenna boom and ask: "It's up there?" and then "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. It turned out that our young radio enthusiasts found all that quite challenging, which detracted from the fun of getting to know our new friends in space. It was hard for us, too, just getting everything to work at different schools. So, we set about to design a fully automated system.

We designed SARCTRAC to be 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? We say: "No problems"!



## History

We first introduced our free, Arduino-based, "Mini Satellite-Antenna Rotator" in 2015. It was a great success, with nearly 1000 radio enthusiasts from around the world building one. Unfortunately, sourcing the correct components, compiling and uploading the software and calibrating the sensor was too much for many who attempted building it. Let alone the pitfalls of setting up and using third-party, satellite-tracking software. And, as much as we love helping our readers out, we realised that we were spending more time supporting them than developing new projects and activities for the kids.

We partly solved that problem by designing an integrated satellite tracking system that just works: SARCTRAC Mk1 took us over 15 months to develop and was the second generation of our 3D-Sensor based antenna rotator. It was half the size of the original unit with many new features. SARCTRAC Mk1 was offered as a DIY kit with all the parts and software required. Unfortunately, it only supported one type of radio: The Yaesu FT-817 and was only suitable for the experienced builder. So, we were still confronted with a very large support effort.

In 2020, due to the COVID-19 pandemic, we experienced parts shortages, freight delays and months of home isolation. So, we spent another 5 months re-designing and developing SARCTRAC Mk2, with many more new features. In October 2020, we offered the first 40 units as a fully-assembled, tested and calibrated product. This approach provided us with a wealth of experience in the production process. In the end we decided manufacturing it ourselves was the only way to ensure high quality components, production processes, reduced support effort and, ultimately, reader satisfaction. We expect to continue our small-scale production effort of fully-assembled, tested and calibrated SARCTRAC Mk2 products in the future. However, we are not commercial manufactures and our primary goal is still introducing STEM to school kids using Amateur Radio. So, stocks may still be limited from time to time. We hope you understand.

# Acronyms and Abbreviations

This manual uses the acronyms and abbreviations shown in Table 1.

***Table 1 - Acronyms and Abbreviations***

<b>Term</b>	<b>Meaning</b>
3D	Three-Dimensional
A	Ampere
AC	Alternating Current
AM	Amplitude Modulation
AOS	Acquisition of Signal
ASAP	As Soon As Possible
AZ	Azimuth
CAT	Computer Aided Technology
CW	Continuous Wave
DC	Direct Current
DHCP	Dynamic Host Control Protocol
DIO	Digital Input/Output
EL	Elevation
EMC	Electro Magnetic Compatibility
EMR	Electro Magnetic Radiation
FM	Frequency Modulation
GHz	Gigahertz
GPS	Global Positioning System
HAMLIB	Ham Radio Control Library
I2C	Inter-Integrated Circuit
IP	Internet Protocol
LOS	Los of Signal
LSB	Lower Side Band
MAC	Media Access Control
NTP	Network Time Protocol
PC	Personal Computer
RF	Radio Frequency
RFI	Radio Frequency Interference
RIT	Receiver Independent Tuning
RPi	Raspberry Pi Computer
RPM	Revolutions Per Minute
RX	Receive
SARCTRAC	Satellite Antenna Rotator Controller and TRACker
SELV	Separated Extra Low Voltage
SSID	Service Set IDentifier
TX	Transmit
uF	Micro Farad
UHF	Ultra High Frequency
URL	Uniform Resource Locator
USB	Universal Serial Bus

USB	Upper Side Band
UTC	Universal Time (Corrected)
V	Volt
VFO	Variable Frequency Oscillator
VHF	Very High Frequency
WiFi	Wireless Network
XIT	Transmitter Independent Tuning
<b>CAUTION:</b>	This box provides advice to avoid injuries
<b>WARNING:</b>	This box provides advice to avoid damage
<b>IMPORTANT:</b>	This box provides advice for correct operation

## 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 safe 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.
- Networking
  - WiFi enabled - Works with home WiFi networks or WiFi-enabled mobile devices with a 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 or separate PC or laptop required.
  - 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 start-up.

- 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 a boom-mounted, strap-on 3D Sensor (magnetometer/accelerometer) - No compass calibration or leveling 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 the Internet each day - No manual download required.
- Satellite position determined from the latest SGP4 orbital predication models - More accurate tracking.
- Uses last-saved user controls and satellite selection - Quicker start-up.
- Satellite Selection
  - Access to thousands of satellite orbital elements over the Internet - Distributed by Dr. T.S. Kelso at [www.celestrak.com](http://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 the tracking of each satellite pass in turn.
  - Satellites displayed in order of their Acquisition Of Signal (AOS) time - Provides a convenient next-pass schedule.
  - Displays AOS time, LOS time, azimuth and max-elevation for each selected satellite - Easy to decide which satellite passes are best to track and any overlap between passes.
  - Displays the currently visible satellite azimuth and elevation - Easy to choose which visible satellite to track.
  - Automatically points the antenna at the first visible satellite in the list - No manual antenna steering required.
  - Built-in alert tone indicates immanent antenna movement - Safer operation. Alerts at the start and end of the current pass.

- Permits selection of any one of multiple visible satellites to track - Compare and select the best of the currently visible satellites.
- Automatically repositions antenna ready for the next pass - No waiting at the start of each pass.
- Motor stall warning with anti-stall shaker - Prevents motors stalling under certain conditions.
- 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
  - 3D Sensor is calibrated at the factory. Recalibration is possible if the sensor is changed.
  - Provides manual Start, Abort and Save calibration controls with tone feedback - Easier and more accurate calibration.
- Miscellaneous
  - Reduced Radio Frequency Interference by using analog regulators and RF chokes - Easier to hear selected satellites.
  - DC reverse polarity protection - Setup at night with no more smoke and tears.
  - Stall resistant motors and gearboxes with all metal gears - Safer operation with longer lasting gearboxes.
  - Field upgradable for new versions of Hamlib.

## New Features

SARCTRAC Mk2 provides the following new features over the original SARCTRAC Mk1:

- New Raspberry Pi 3B+ 1.4GHz Quad Core processor with 2.4/5GHz WiFi
- New Raspbian Buster Operating System
- New Enclosure with low noise analog regulator and external heatsink
- New Radio Types supported for Doppler frequency correction
- New Transmitter and Receiver pairs supported as well as Transceivers



- New Tuning Indicator for satellites in the SARCTRAC Frequency/Mode Database
- New Local Radio Horizon displays realistic AOS and LOS times in built-up areas
- New Minimum Pass Elevation displays future passes above a minimum elevation
- New Pass Predictor handles hundreds of satellites and multiple passes of each
- New Realtime display updates of visible and future passes every 5 seconds
- New Single-Touch satellite and pass selection controls
- New More/Less Passes and Home buttons
- New Anti-Windup algorithm - Unwinds cables to the home position
- New Anti-Stall algorithm - Detects, alerts and rectifies motor stall conditions
- New Fast Multi-Threaded compiled code with Quad-Core parallel processing
- New Production-Quality Web Server
- New Object-Oriented Design: Written in Python 3 - Cross compiled to C++
- Powered by Celestrak: Two-Line Elements since 1985 by Dr. T.S. Kelso
- Powered by Skyfield: Elegant Astronomy for Python by Brandon Rhodes
- Powered by World Magnetic Model: 24/3/2020 by NCEI and geomag by C.Weiss
- Powered by Nominatim: Reverse geocoding for Open Street Maps
- Powered by Hamlib: Ham Radio Control Library
- Powered by Flask: Web Development One Drop At A Time
- Powered by Waitress: Production Quality WSGI Server

## Links

### SARCTRAC Mk2

- [SARCTRAC Mk2 Product](#) - How to buy SARCTRAC
- [SARCTRAC Mk2 Manual](#) (New, 54 Pages, 2.0MB, PDF)
- [SARCTRAC Forum](#)
- [SARCTRAC Mk2 Video](#) (New)
- [SARCTRAC Mk2 Quick Start Guide](#) (New, 4 Pages, 520kB, PDF)

### SARCTRAC Mk1

- [SARCTRAC Mk1 Manual](#) (59 Pages, 4.5MB, PDF)
- [SARCTRAC Mk1 Modification Procedure](#) (For SARCTRAC Mk1, Version 1)
- [SARCTRAC Mk1 in the Bush Video](#)
- [Kicking goals with SARCTRAC Mk1 Video](#)
- [SARCTRAC Mk1 just keeps tracking all day Video](#)
- [Demonstrating Amateur Radio Satellite Tracking with SARCTRAC Mk1 Video](#)
- [SARCTRAC Mk1 FT-817 Video](#) (Showing how the FT-817 responds to fixed 1kHz steps with TX/RX VFO Switching)
- [SARCTRAC Mk1 3D Sensor Calibration Video](#) Note: The SARCTRAC Mk2 3D Sensor is now pre-calibrated.

See videos of SARCTRAC working on our [SARCNET YouTube Channel](#).

## Specifications

- Enclosure Size: 145x105x65mm (5.7x4.1x2.2inch)
- Sensor cable length: 1m
- Power cable length: 1m
- USB 2.0 Ports: 2
- WiFi: 2.4/5GHz
- Ingress protection: IP68 sensor. IP65 enclosure.
- Operating voltage: 12-15VDC (min - max)
- Operating current: 1A (typical)
- Overcurrent protection
- Overtemperature protection
- Reverse polarity protection
- Regulatory Compliance: See below
- Typical start-up time: 30 seconds
- Typical start-up time with update: 90 seconds
- Typical Internet upgrade time: 10 minutes
- Antenna rotation speed: 0.6 RPM (3.6 degrees per second) azimuth and elevation (max)
- Local Radio Horizon: 0-20 degrees in 1-degree increments.
- Minimum Pass Elevation 0-45 degrees in 5-degree increments
- Radio RX:TX Ratio: None, 1:1 to 9:1
- Radio Update Rates: 100, 200, 500, 1000, 2000, 5000 milliseconds
- Radio modes supported: AM, FM, CW, USB and LSB
- Radio baudrates supported: 1200, 2400, 4800, 9600, 19200, 38400, 57600, 115200
- Supported receivers and transmitters: Possibly only receivers and transmitters supported by HAMLIB's F and M commands. See Radio Control for caveats and limitations.
- Supported transceivers: Possibly only transceivers supported by HAMLIB's F, M I, X and S commands. See Radio Control for caveats and limitations.
- Supported USB CAT cables: Only USB to serial converters with compatible voltages and connectors that use devices supported by Linux including genuine chipsets such as FTDI and CH-340, but not PL2303. See Radio Control.
- The following radios have been verified to work, with the following anomalies identified in the Radio Control section:
  - Yaesu FT-817: RX clicks, TX lockout, VFO switching, RIT/XIT override.
- The following USB CAT cables have been verified:
  - Genuine Yaesu CT-62.
  - Yaesu CT-62 copies with genuine FTDI chips.
  - CH-340 USB-TTL converters.

## Radio Control

**Important:** We do not claim any particular radio or CAT cable is supported until we have either verified it ourselves or have received credible reports of its interoperability. Until then, the radio control capability is considered either an experimental or non-existent feature. Notwithstanding, our research shows that an indication of possible radio interoperability may be obtained from the HAMLIB version 3.3 rigctrl program, itself, which reports support for the specific radios shown in the Table 2.

### Where:

R = A Receiver, with a serial control port, which supports the HAMLIB F and M commands.

T = A Transmitter, with a serial control port, which supports the HAMLIB F and M commands.

X = A Transceiver, with a serial control port, which supports the HAMLIB F and M commands and in addition supports split mode VFO operation using the HAMLIB I, X and S commands.

### Notes:

1. A transceiver should be capable of operating as either a receiver or transceiver.
2. The first USB device plugged in is assigned to USB0.
3. The second USB device plugged in is assigned to USB1.
4. if two USB devices are plugged in at power-up they are consistently assigned as USB0 and USB1 respectively. In this case the USB0 port is indicated by a silver dot on the connector.

### Unavoidable anomalies with radio control:

1. RX Click: Some receivers produce an audible "click" or audio blanking whenever the receiver VFO is updated.
2. TX Lockout: Some transmitters and transceivers do not permit their frequency to be changed while transmitting.
3. VFO Switching: Some transceivers must switch to the transmitter VFO to update it, causing momentary reception of the uplink frequency.
4. RIT/XIT Override: Some receiver's RIT and transmitter's XIT controls are unusable because they are overridden by the RX/TX VFO CAT control. Hence the provision of TX and RX offset tuning on the SARCTRAC Tuning Page.

**Table 2 - Radio Control Capability**

<b>Radio Type, Capability</b>	<b>Radio Type, Capability</b>	<b>Radio Type, Capability</b>
ADAT WWW.ADAT.CH, T	ICOM IC-775, T	LOWE HF-235, R
ALINCO DX-77, X	ICOM IC-78, T	MICROTELECOM PERSEUS, R
AOR AR2700, R	ICOM IC-7800, X	OPTOELECTRONICS OPTOSCAN456, R
AOR AR3000A, R	ICOM IC-781, X	OPTOELECTRONICS OPTOSCAN535, R
AOR AR3030, R	ICOM IC-785X, X	RACAL RA3702, R
AOR AR5000, R	ICOM IC-820H, T	RACAL RA6790/GM, R
AOR AR5000A, R	ICOM IC-821H, T	ROHDE&SCHWARZ EB200, R
AOR AR7030, R	ICOM IC-910, X	ROHDE&SCHWARZ ESMC, R
AOR AR7030, R	ICOM IC-9100, X	ROHDE&SCHWARZ XK2100, T
AOR AR8000, R	ICOM IC-970, T	TAPR DSP-10, T
AOR AR8200, R	ICOM IC-PCR100, R	TEN-TEC DELTA, T
AOR AR8600, R	ICOM IC-PCR1000, R	TEN-TEC OMNI, T
AOR SR2200, R	ICOM IC-PCR1500, R	TEN-TEC RX-320, R
DRAKE R-8A, R	ICOM IC-PCR2500, R	TEN-TEC RX-331, R
DRAKE R-8B, R	ICOM IC-R7000, R	TEN-TEC RX-340, R
ELECRAFT K2, X	ICOM IC-R71, R	TEN-TEC RX-350, R
ELECRAFT K3/KX3, X	ICOM IC-R7100, R	TEN-TEC TT-516, X
ICOM IC, T	ICOM IC-R72, R	TEN-TEC TT-538, X
ICOM IC-1275, T	ICOM IC-R75, R	TEN-TEC TT-565, X
ICOM IC-271, T	ICOM IC-R9000, R	TEN-TEC TT-585, X
ICOM IC-2730, X	ICOM IC-R9500, R	TEN-TEC TT-588, X
ICOM IC-275, T	ICOM ICR-8500, R	TEN-TEC TT-599, X
ICOM IC-471, T	ICOM ID-5100, X	WATKINS-JOHNSON WJ-8888, R
ICOM IC-475, T	JRC NRD-525, R	XEIGU X108G, X
ICOM IC-7000, X	JRC NRD-535D, R	YAESU FRG-100, R
ICOM IC-703, X	JRC NRD-545, R	YAESU FRG-8800, R
ICOM IC-706, X	KENWOOD R-5000, R	YAESU FRG-9600, R
ICOM IC-706MKII, X	KENWOOD TH-D72A, T	YAESU FT-100, X
ICOM IC-706MKIIG, X	KENWOOD TH-D7A, T	YAESU FT-1000D, X
ICOM IC-707, X	KENWOOD TH-F6A, T	YAESU FT-1000MP, T
ICOM IC-7100, X	KENWOOD TH-F7E, T	YAESU FT-1200, X
ICOM IC-718, X	KENWOOD TM-D700, X	YAESU FT-2000, X
ICOM IC-7200, X	KENWOOD TM-D710(G), T	YAESU FT-450, X
ICOM IC-725, X	KENWOOD TS-140S, T	YAESU FT-736R, X
ICOM IC-726, X	KENWOOD TS-2000, X	YAESU FT-747GX, X
ICOM IC-728, X	KENWOOD TS-440, X	YAESU FT-757GXII, T
ICOM IC-7300, X	KENWOOD TS-450S, X	YAESU FT-767GX, X
ICOM IC-735, T	KENWOOD TS-480, X	YAESU FT-817, X
ICOM IC-736, X	KENWOOD TS-50S, X	YAESU FT-840, X
ICOM IC-737, X	KENWOOD TS-570D, X	YAESU FT-847, X
ICOM IC-738, X	KENWOOD TS-570S, X	YAESU FT-857, X
ICOM IC-7410, X	KENWOOD TS-590S, X	YAESU FT-890, X
ICOM IC-746, X	KENWOOD TS-590SG, X	YAESU FT-897, X
ICOM IC-746PRO, X	KENWOOD TS-680S, T	YAESU FT-900, X
ICOM IC-751, T	KENWOOD TS-690S, X	YAESU FT-920, X
ICOM IC-756, X	KENWOOD TS-711, T	YAESU FT-950, X
ICOM IC-756PRO, X	KENWOOD TS-790, X	YAESU FT-980, T
ICOM IC-756PROII, X	KENWOOD TS-811, T	YAESU FT-990, X
ICOM IC-756PROIII, X	KENWOOD TS-850, X	YAESU FT-DX5000, X
ICOM IC-7600, X	KENWOOD TS-870S, X	YAESU FTDX-9000, X
ICOM IC-761, T	KENWOOD TS-930, T	YAESU MARK-V, T
ICOM IC-7610, X	KENWOOD TS-940S, X	YAESU MARK-V, T
ICOM IC-765, X	KENWOOD TS-950SDX, T	YAESU VR-5000, R
ICOM IC-7700, X	KENWOOD TS-990S, X	

## Design Notes

The following design notes are included here for those interested in some of the more difficult design trade-offs.

### Radio Frequency Interference

Anyone having used a Raspberry Pi for Amateur Radio applications will be well aware of the RF noise produced by these little 1.4GHz, quad-core, powerhouses. Putting one right next to the receiving antenna would, therefore, not seem a sensible thing to do. However, in this application, it is unavoidable, since the 3D sensor must be mounted on the antenna boom and the I2C bus, which connects it to the RPi, does not work much over 1 metre of unshielded cable (less if shielded). To be able to receive weak signals from satellites, we needed to keep the RFI to a minimum. By using a short antenna probe on the end of a flying, coaxial, lead connected to a Yaesu FT-817, we found that the main sources of RFI in the SARCTRAC system were:

1. 5V Switch-Mode Power Adapter
2. Raspberry Pi 3B+
3. I2C bus
4. DIO lines
5. DC Motor commutators

The RFI from the 5V switch-mode power adapter, which powers the RPi, was absolutely incredible! It produced s9+ noise levels all over the VHF and UHF bands, within 1 metre of the operating unit. A dozen different AC plug-packs, AC inline power supplies and 12VDC - 5VDC switch-mode converter modules were tried with little success. Most of the RFI appeared to be coming from the wires connected to the input side of the DC/DC converter of the 5V switch-mode power adapter. Various types of RF chokes, bypass capacitors, pi-filters and shielding were tried, producing only minor improvements. The only effective solution we found was to use a linear, regulated power supply. In the end, the reduction of RFI was a clear priority over the additional power dissipation, extra heat, size and the huge production effort required for SARCTRAC to have its own linear power supply. See below for details.

The RFI from the RPi itself, running off a linear regulated 5V DC power supply, was considerably less. It also produced s9 noise levels all over the VHF and UHF bands, but only with the probe coming into close proximity with the power supply, I2C and DIO wires themselves. At 1-metre, the noise reduced to s0, but was still audible. Unfortunately, if you need its optimum performance and features, the RFI coming from the RPi is effectively unavoidable. Most of the RFI comes from the onboard 3.3V/1.8V DC/DC converter. The RPi draws about 1A at 5V when operating. There are a plethora of ways to reduce RPi power consumption to a minimum, by using software configuration options. That could, potentially, cause a reduction in RFI. In short, we tried them all. The reduction in power consumption and RFI was negligible. The source of the RPi RFI is on the input side of the onboard DC/DC converter. So, we routed the RPi power supply wires through an RF choke.



The I2C bus was also a source of RFI. We found that we could reduce it considerably by reducing the I2C clock rate to 10kbps without affecting the performance of the application. We routed the I2C wires through the same RF choke.

The DIO lines to the Motor Driver were also a source of RFI. So, we routed them through the same RF choke. That helped reduce the RFI next to those wires to about s6.

The DC motor commutators arc a little while operating, producing a clicking sound similar to motor-car ignition noise. In the past we had tried 0.1uF bypass capacitors on the motor terminals to the motor chassis. However, this solution didn't seem to have much effect with SARCTRAC and the interference was negligible, so we left it off.

The result of the above efforts was the reduction of RF wide-band noise from s9 levels across the VHF and UHF bands (i.e. unusable) to an acceptable s0 (on the Yaesu FT-817 meter) with only some slightly audible processor noise on VHF. Some birdies from the processor may still be present, but these were not disruptive as they pass quickly with Doppler frequency control engaged. The final measurement conditions were as follows: Yaesu FT-817 (146/437MHz, USB, RF Gain set to max) connected via the front antenna jack to an Arrow™ II 146/437-10 Antenna with inbuilt 2m/70cm duplexer.

### **Linear Regulated Power Supply**

Having to use a linear regulated power supply for the 5VDC RPi 3B+ with an input of 12-15VDC was unavoidable. It had its own complications: The RPi dissipates 5W. The linear power supply dissipates 7-10W. We got away with using a small internal heatsink for the RPi Zero in SARCTRAC Mk1. Clearly that was not going to work here. So, we designed and manufactured our own aluminium heatsink to fit the enclosure. It measures 80x40x25mm, has six fins and has a surface area of 22,400mm<sup>2</sup>. The temperature of the heatsink rises to 50 degrees Celsius at an ambient temperature of 20 degrees Celsius. Hence the "CAUTION HOT" sticker. It's hot, it isn't efficient, but its role in reducing the RFI to acceptable levels cannot be understated.

## Safety

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

- This is partly a DIY construction 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 burn hazard - The heatsink temperature may exceed 50 degrees. Do not touch it. Read the warning.
- 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 are light-duty: Do not force them or drop or bump the tripod to avoid stripping the metal gears.
- Installation of a safety DC cut-off switch is recommended.

## Safety Testing

We have conducted the following safety testing of the completed product:

- Motor stall: The motors do not overheat or draw excessive current under continuous, full-power, stalled conditions.
- Cable windup: A restrained power or coaxial cable is not damaged under continuous, full-power windup conditions.
- Antenna impact: The Arrow™ antenna elements were not damaged under full-power impact with stationary objects or under continuous, restraint conditions.
- Human impact: The human operator was not damaged under full-power impact with the antenna. Note: Eye damage could occur even when the antenna is motionless. Touching the operating heatsink for 10 seconds did not produce a burn.

## Regulatory Compliance

- SARCTRAC is essentially an embedded Raspberry Pi 3B+ (RPi) computer. The declarations of conformity, including local and regional approval certificates for the RPi can be found [here](#). This covers: USA, Argentina, Australia, Bolivia, Brazil, Canada, Chile, China, Colombia, Costa Rica, Dominican Republic, Ethiopia, Ecuador, Guatemala, Hong Kong, India, Israel, Japan, Kenya, Malaysia, Mexico, New Zealand, Nicaragua, Panama, Peru, Philippines, Russia, Rwanda, Serbia, Singapore, South Africa, South Korea, Taiwan, Tanzania, Thailand, Turkey, Uganda, Uruguay and Venezuela. The RPi regulatory compliance marks are shown in Figure 5.
- SARCTRAC has a technical folder, which indicates it comprises an RPi together with additional electronic components and assemblies such as small motors, drivers, sensors and USB devices.
- SARCTRAC operates on 12-15VDC @ 1A and complies with Separated Extra Low Voltage (SELV) device requirements.
- SARCTRAC has been assembled with lead-free components and solder and complies with Restriction of Hazardous Substances (RoHS) requirements.
- SARCTRAC uses an RPi, which has been tested to meet international RFI/EMC requirements. SARCTRAC uses additional sensors, drivers and motors, which due to their nature and operating conditions do not affect this base RFI/EMC qualification. In fact, the further reduction of RFI to nearby receivers and increased EMC with nearby transmitters, to levels exceeding international standards, was a key design requirement of this product.
- SARCTRAC introduces additional safety risks, which have been fully identified above. Some operational safety testing has been carried out to qualify these safety risks as minor. The additional safety risks have been reduced, by design, to as low as is reasonably practicable.



**Figure 5 - Raspberry Pi Regulatory Compliance**

## Limitations

- Only suitable for rotating a single, small, directional antenna (e.g. A handheld, dual-band, Yagi antenna such as an Arrow™ II antenna) using a counterbalanced lift-arm.
- May be suitable for controlling some radios, which are themselves controllable using HAMLIB commands: F, M, X, I and S via a USB CAT Cable. See Radio Control for caveats and the list of possibly suitable radios.
- Will not work indoors: GPS and satellite antennas require a clear view of the sky.
- Requires at least weekly connection to the Internet for updating the satellite orbital elements.
- Maximum tracking speed is 3.6 degrees per second. 180-degree azimuth rotation on high elevation passes may take up to 50 seconds.
- Unit will oscillate unless solidly mounted, via the azimuth shaft hub, on a rigid stand such as a heavy-duty (speaker) tripod.
- Unit will oscillate unless the 3D sensor is solidly mounted on the antenna boom, which itself is solidly mounted to the elevation shaft hub.
- 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.

## SARCTRAC Demo Setup

To get SARCTRAC ready for portable operation, we recommend setting it to work on a bench, without having to worry about the tripod, satellite antenna and the rig. It is then possible to check its configuration and familiarize yourself with its operation. SARCTRAC comes with a Demo Stand and with the 3D Sensor attached to a Demo Lift-Arm just for this purpose.

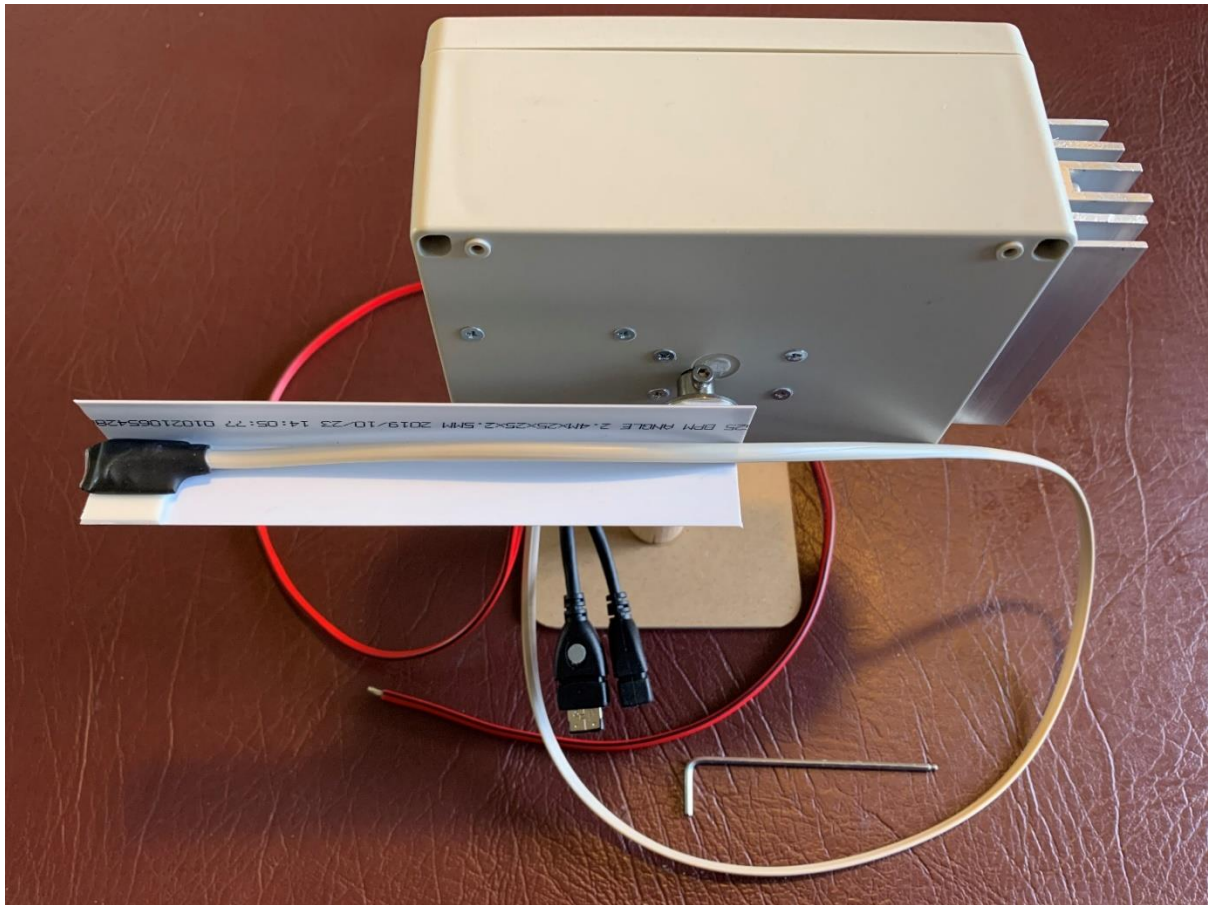
To prepare the SARCTRAC Demo Setup you will need:

- A WiFi enabled Windows or Linux PC with a USB Port and a simple text editor
- A Home WiFi Router with access to the Internet; or
- A Mobile Device with Broadband Internet access and a Personal WiFi Hotspot
- The SARCTRAC Rotator
- The SARCTRAC Demo Stand
- The SARCTRAC Demo Lift-Arm with the SARCTRAC 3D Sensor attached
- The 2.5mm Hex Wrench
- The SARCTRAC USB Disk
- A non-magnetic table, with a clear view of the sky, in range of the WiFi Router or Mobile Device Personal WiFi Hotspot

To begin the SARCTRAC Demo Setup follow this procedure step-by-step. If you have any problems, try repeating the steps, look for a solution in the SARCTRAC Maintenance section or contact us by email at [info@sarcnet.org](mailto:info@sarcnet.org) with a full description of the problem.

1. Place SARCTRAC on a non-magnetic table, outside, with a clear view of the sky.
2. Mount the SARCTRAC Unit on the SARCTRAC Demo Stand as shown in Figure 6 using the 2.5mm Hex wrench provided to lightly tighten the azimuth shaft hub screws. Always align one screw with the flat side of the shaft.
3. Mount the SARCTRAC Demo Lift-Arm with the SARCTRAC 3D Sensor on the SARCTRAC Unit as shown in Figure 6 using the 2.5mm Hex wrench provided to lightly tighten the elevation shaft hub screws. Always align one screw with the flat side of the shaft.
4. Bend the SARCTRAC USB Cables upwards so that they don't touch the base or the table. A rubber band may help keep them tidy.
5. Face the SARCTRAC Demo Lift-Arm with the SARCTRAC 3D sensor approximately North. This is known as the "start-up" position. Note that turning the SARCTRAC 3D Sensor around after start-up may activate the automatic Anti-Windup feature to unwind the cables back to within one turn of the start-up position.
6. Remove any magnetic items from the table such as the wrench and the Mobile Device.
7. Before starting SARCTRAC for the first time, perform the WiFi Configuration.





*Figure 6 - SARCTRAC Demo Set-Up*

### WiFi 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.

Before SARCTRAC can access your WiFi network, it must be configured. SARCTRAC is configured using the SARCTRAC USB Disk provided. First, files on the SARCTRAC USB Disk are edited on a PC. Then SARCTRAC is powered up, with the SARCTRAC USB Disk connected to one of its USB ports. These configuration files are installed and then deleted from the SARCTRAC USB Disk (so that they won't be inadvertently installed again). This initial configuration procedure is part of the more general SARCTRAC Configuration, Backup, Update and Restore Procedure described in the SARCTRAC Maintenance section.

1. Make sure your WiFi Router or Mobile Device Personal Hotspot (aka Mobile Hotspot) is powered up and enabled and has an Internet connection.
  - 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) and Password required to access the WiFi port. If necessary, configure the WiFi Router security settings to accept new

device connections. For information on how to configure your WiFi Router please see its 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.
  - iii. 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 your home WiFi Router or Mobile Device Personal Hotspot, the SARCTRAC network configuration file in the root folder of the SARCTRAC USB DISK must be edited on a PC and then plugged into a SARCTRAC USB Port prior to powering up SARCTRAC for the first time.
3. Connect the SARCTRAC USB Disk to the PC USB Port.
4. Open a file browser to view the contents of the SARCTRAC USB Disk, which should be in accordance with Table 3.

**Table 3 - SARCTRAC USB Disk**

Item (Folder or Filename)	Description
Backup00	Backup folder - Backup number 00
tle	Two-Line Element folder
amateur.txt	Amateur Radio Satellite TLE file
noaa.txt	NOAA Satellite TLE File
weather.txt	Weather Satellite TLE file
freqmode.txt	SARCTRAC Satellite Frequency and Mode Database File
licences.txt	SARCTRAC Licences file
network.txt	SARCTRAC Default Network Configuration file
radiocap.txt	SARCTRAC Radio Capabilities file
rotorcal.txt	SARCTRAC Rotator Calibration File
sarctrac	SARCTRAC Application Archive file
settings.txt	SARCTRAC Settings file
network.txt	SARCTRAC Network Configuration file – <b>Edit this file to configure SARCTRAC to access your WiFi Network</b>

**IMPORTANT:** If the SARCTRAC USB Disk files are displayed on your PC without the .txt file extension, please configure your file browser to show all file extensions. In any case do not add a .txt extension to an existing file, as it will not load.

5. Locate the original network.txt file in the root folder of the SARCTRAC USB Disk.  
Note: If not found, copy the network.txt file from the most recent BackupNN folder or, if there is no BackupNN folder, you can download the file from: <https://www.sarcnet.org/sarctrac/SARCTRAC%20Mk2/Version2.00/network.txt>.
6. Edit the network.txt file, using a simple text editor (not MS WORD). See Table 4 for the actual contents of the default network.txt file.

**Table 4 - SARCTRAC network.txt File**

```
#network.txt version 2.00
#WiFi network settings for the Satellite Antenna Rotator Controller and TRACKer (SARCTRAC)

#####
#Copyright(c) 2020. 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 two lines
ctrl_interface=DIR=/var/run/wpa_supplicant GROUP=netdev
update_config=1

#Edit this file as indicated below using a basic text editor, like notepad, not Word, on a
PC.
#Save this file to the root folder of the SARCTRAC USB Disk, but do not remove any backup
folders.
#Eject the SARCTRAC USB Disk from the PC.
#Shutdown and power Off SARCTRAC.
#Insert the SARCTRAC USB DISK into a SARCTRAC USB Port.
#Power up SARCTRAC.
#Wait up to 4 minutes for SARCTRAC to backup your settings, load the new settings, reboot and
beep
#Remove the SARCTRAC USB Disk.

#1. IMPORTANT: Please change your two-letter country code below to comply with local
regulations.
#   Note: For current codes please see: https://en.wikipedia.org/wiki/ISO_3166-1_alpha-
2#Current codes
country=AU

#2. Edit the settings below for one or more home WiFi network routers or mobile device
personal hotspots that you use.
#   Note: You can copy the network={} template for each device that you use and insert your
specific information for each.
#   A hash (#) at the start of the line indicates that the line is just a comment. Use it to
label your network settings.
#   Change the SSID and PASSWORD below as required to access your home WiFi network router
or mobile device personal hotspot.
#   Note: Please leave the double quotes (") in place. Insert your information between them.

#Home WiFi Network
network={
    ssid="SSID"
    psk="PASSWORD"
    proto=RSN
    key_mgmt=WPA-PSK
    pairwise=CCMP
    auth_alg=OPEN
}

#3. Please delete the following lines, as this network is no longer required.
#Production WiFi Network.
network={
    ssid="A"
    psk="One(1)$0llar"
    proto=RSN
    key_mgmt=WPA-PSK
    pairwise=CCMP
    auth_alg=OPEN
}
```

7. Carefully edit only the items shown in **bold** in Table 4. That is the Country Code, SSID and Password. You can delete the whole of section 3, which is no longer required. You can also configure more than one network – for example for use at home, at school or for different devices - by simply copying the network={ } template and editing the details therein. For more technical details on how to configure the network.txt file for your WiFi device please see [https://linux.die.net/man/5/wpa\\_supplicant.conf](https://linux.die.net/man/5/wpa_supplicant.conf).
8. Eject the SARCTRAC USB Disk from the PC and remove it.

**IMPORTANT:** Always eject the SARCTRAC USB Disk from a PC before removing it. You can backup and repair a SARCTRAC USB Disk, if necessary, on a PC. However, The volume label of the SARCTRAC USB Disk must be SARCTRAC.

### Starting SARCTRAC for the first time

1. Make sure SARCTRAC is powered down.
2. Insert the SARCTRAC USB Disk including the edited network.txt file in the root folder into the SARCTRAC USB Connector.
3. Connect SARCTRAC to a 12VDC Regulated Power Supply capable of supplying 2A peak and 1A continuous current. The wire with the black leader is the negative wire. Note: SARTCRAC has reverse polarity protection.
4. Power-up SARCTRAC.
5. SARCTRAC will automatically load the network.txt file, delete it from the root folder of the SARCTRAC USB Disk, create a new BackupNN folder, dismount the SARCTRAC USB Disk, restart and then try to connect to your WiFi network.
6. Wait for SARCTRAC to beep according to Table 5. If applicable, the beeps will occur in the order shown. SARCTRAC will normally beep after 30 seconds, if it has successfully connected to the WiFi network, or after 90 seconds, if it cannot connect to the WiFi network. If SARCTRAC does not beep at all or only after 90 seconds, it is likely there are issues with the edited network.txt file or your WiFi Access Point.

**Table 5 - SARCTRAC Audible Alerts**

Alert tone	Meaning	Type
1 short 100ms beep at start-up	USB CAT cable not connected	ERROR
2 short 100ms beeps at start-up	GPS not responding	ERROR
3 short 100ms beeps at start-up	3D Sensor not responding	ERROR
1 long 3-second beep at start-up	SARCTRAC is ready	INFORMATION
1 long 3-second beep	Motors started: About to move	WARNING
1 medium 500ms beep	Repositioning for next pass	WARNING
2 short 100ms beeps	Started tracking new satellite	INFORMATION

7. Remove the SARCTRAC USB Disk – It has been dismounted.
8. Connect the SARCTRAC USB Disk to the PC USB Port.
9. Open a file browser to view the contents of the SARCTRAC USB Disk to check that a new BackupNN folder has been created and that the network.txt file has

- been deleted. If not, it is unlikely that SARCTRAC has loaded your edited network.txt file. Edit and check the contents of the network.txt file in the root folder of the SARCTRAC USB Disk again, or replace it with the original network.txt from the Backup00 folder, and repeat the WiFi Configuration.
10. Once the previous step is successfully completed, 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:
    - a. 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 a Raspberry Pi starts with 'b8:27:eb'. Check that the RPi 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 RPi 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.
    - b. On a Mobile Device: Successful connections to the Personal Hotspot are usually shown in a banner or icon at the top of the page.
  11. If SARCTRAC still cannot connect to your WiFi network: Power down SARCTRAC and repeat and check the WiFi Configuration above.
  12. Next, discover the IP address or URL needed to connect to SARCTRAC via the WiFi network:
    - a. For iPhone or Mac PC or any device supporting zeroconf (bonjour) automatic network configuration protocol, just open the browser app and enter 'sarctrac.local' as the URL.
    - b. 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.
    - c. For a Windows, Mac or Linux PC, without zeroconf, download and use a free Network Scanner app such as Angry IP Scanner (<https://angryip.org/>) to determine the IP Address of SARCTRAC.
  13. Connect to SARCTRAC with the identified URL or IP Address using a web browser on the same WiFi Network.
  14. 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.
  15. Press the SHUTDOWN button. Wait 10 seconds. Power-down SARCTRAC.



## System Status Checks

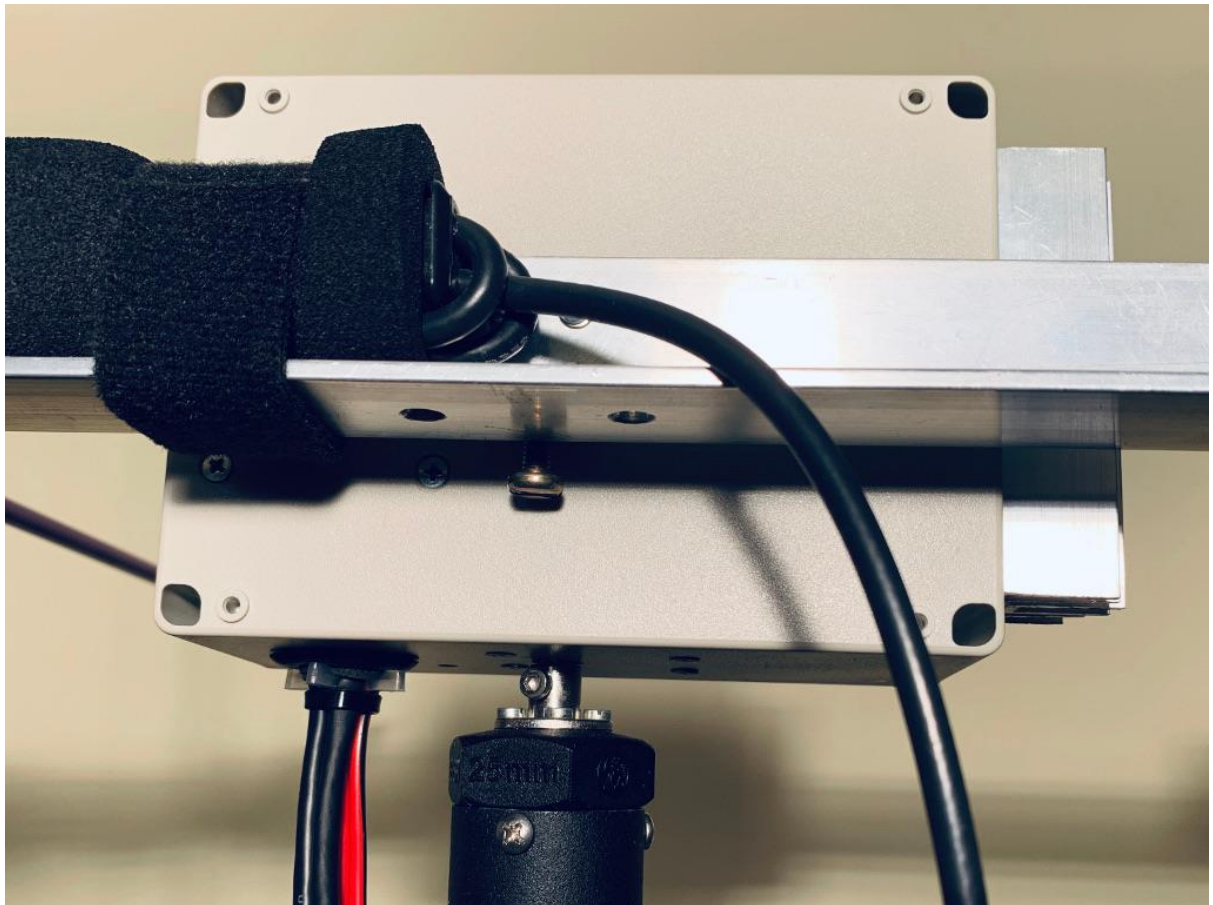
1. Power-up SARCTRAC and wait for it to beep for 3 seconds.
2. Connect to SARCTRAC using a WiFi enabled web browser.
3. Verify that the SARCTRAC Selection Page is displayed.
4. Note: The SARCTRAC Selection page is static and the system status may change over time. Press the browser refresh button to update the display as necessary.
5. Check ID: SARCTRAC Version 2.00
6. Check UR: Your correct name and call sign.
7. Check AT: Your Location. Note: You may need to refresh the page until there is a good GPS fix of your location.
8. Check Time: Your local date and time. If the local date and time is not correct, scroll down to User Controls: Select the Local UTC Offset (hours) at your location and press SET. Check that the local date and time is now correct.
9. Check Online: Your Internet status – Too many retries may indicate a problem.
10. Scroll down to Satellite Selection: Press NONE to deselect all satellites.
11. Check the System Start-Up Log at the bottom of the page for any errors as shown in the SARCTRAC Maintenance section.
12. Press START. The SARCTRAC Demo Lift-Arm should rotate to True North and Horizontal. Note: This is known as the “Home” position.
13. Tilt and turn the SARCTRAC Demo Stand. The SARCTRAC Demo Lift-Arm will rotate to the Home position.
14. Under Satellite Selection: Press ALL to select all satellites. SARCTRAC will beep and the SARCTRAC Demo Lift-Arm will move.
15. Press TRACKING.
16. Verify that the SARCTRAC Tracking Page is displayed. Note: The Tracking Page is automatically refreshed every 5 seconds.
17. Verify that the Lift-Arm rotates to the AZ EL position of the first selected visible pass or, if there are no selected visible passes, to the AOS AZ of the first selected future pass and horizontal.
18. If there are visible passes, but they are not selected, select one to track it.
19. If there are no future passes displayed, press MORE. Initially, SARCTRAC only shows future passes in the next two hours. Each time you press MORE, SARCTRAC searches a further hour into the future for any satellite passes.
20. The SARCTRAC Demo Setup is provided so you can familiarise yourself with its controls and displays as detailed in the section below on SARCTRAC Operation.

## SARCTRAC Portable Setup

Before SARCTRAC can be used in a portable setup to actually track satellites, the SARCTRAC rotator has to be mounted on a tripod, the antenna has to be mounted on a lift-arm and the antenna/lift-arm assembly has to be mounted on the SARCTRAC elevation motor shaft. Then the 3D sensor has to be strapped to the antenna boom and connections have to be made to the antenna, rig and battery. This section provides the step-by-step procedure for all the above.

### Tripod Mounting

1. SARCTRAC 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. Prepare an Extra Heavy-Duty Speaker Tripod. Try a Jaycar CW2860 or Altronics C0524. Remove the speaker bracket, if fitted.
3. Attach a 6mm shaft-hub to the top of 25mm plastic irrigation-pipe threaded plug using 3mm bolts, flat washers and nuts.
4. Press the plug into centre tube of the tripod. Secure it with self-tapping screws.
5. Mount the SARCTRAC AZ Motor shaft to the hub attached to the top of the tripod. See Figure 7.



*Figure 7 - Tripod Mounting*

### Lift-Arm Mounting

1. Round the sharp edges of a lift-arm made from 500x30x30x3mm aluminium angle.
2. Make a counterweight from a 101x51x25mm diecast aluminium box: Altronics H045, or similar. Filled with lead to 860g (for the Arrow Antenna).
3. Attach the counterweight to one end of the lift-arm with self-tapping metal screws.
4. Attach the antenna to the lift-arm using Velcro. This is for quick release of the antenna and hand-held operation, if required.
5. Attach a 6mm shaft-hub to the lift-arm close to the balance point using 3mm bolts, flat washers and nuts. Ours was positioned 140mm from the antenna end. Note: A slight front-heavy balance offset will help reduce backlash.
6. Attach the lift-arm/antenna assembly to the SARCTRAC EL Motor shaft using the 6mm shaft-hub and tighten the hub screws with the 2.5mm Hex key. See Figure 8.
7. Raise the centre-tube of the tripod to ensure that the lift-arm, in any position, cannot touch the tripod legs.

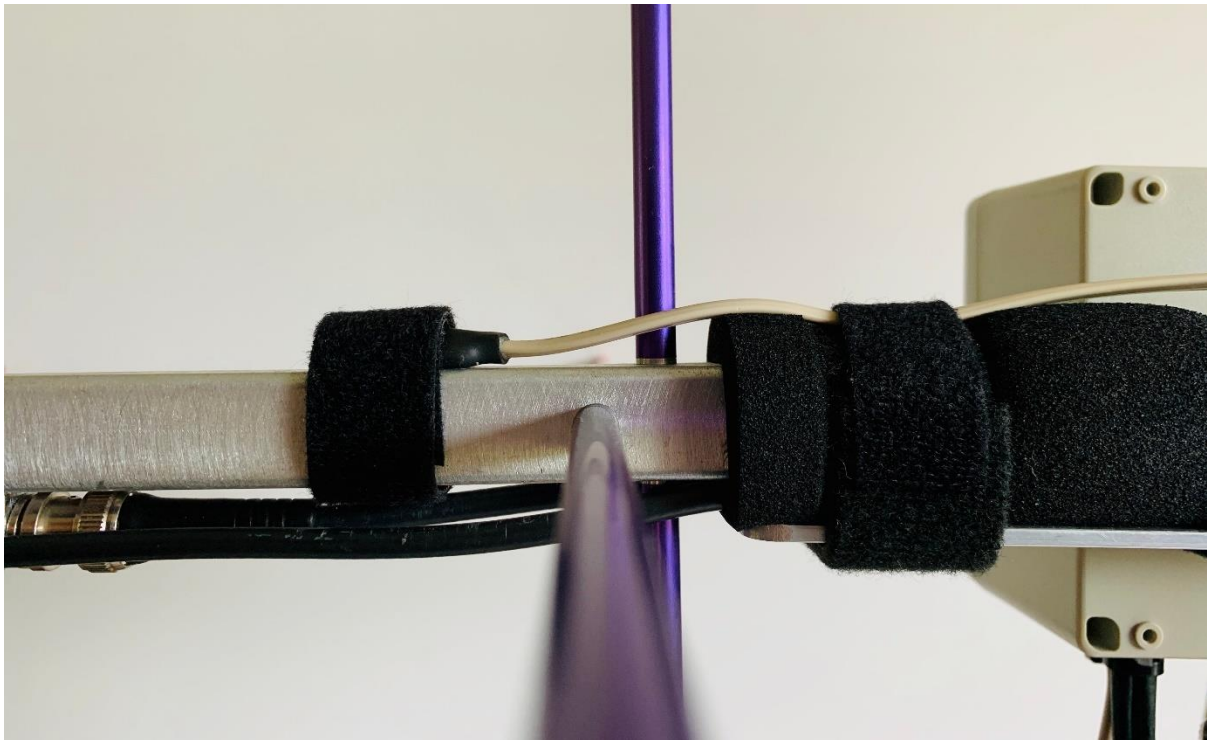
**WARNING:** Although the motor uses metal gears, they can easily be stripped by the leverage of the long antenna and lift-arm. Never mount an unbalanced antenna or lift-arm on the EL Motor Shaft. Never manually force the antenna up, down or sideways. Never drop or tip over the tripod. Never suddenly release the centre-tube of the tripod.



*Figure 8 - Lift-Arm Mounting*

### 3D Sensor Mounting

1. Place the flat side of the SARCTRAC 3D sensor against the top flat surface of the antenna boom. Alternatively, if the antenna boom is round, you can place it against the top flat surface of the lift-arm or counterweight. Typically, place it between 150mm and 300mm from the SARCTRAC elevation shaft.
2. Do not mount the SARCTRAC 3D sensor too close to the SARCTRAC rotator unit, which contains motors with permanent magnets, or to the antenna radiating elements, which emit RF energy.
3. Orient the SARCTRAC 3D sensor so that the cable exits towards the rear of the antenna.
4. Secure the SARCTRAC 3D sensor with Velcro or double-sided tape.



***Figure 9 - 3D Sensor Mounting***

### Antenna, Battery and Rig Connections

1. Orient SARCTRAC antenna/lift-arm assembly pointing approximately North.
2. Make sure that all the following cable connections are made with enough slack so that, if SARCTRAC turns 360 degrees in either direction from the start-up position, the cables will not tangle up or catch on the tripod.
3. Use Velcro to provide vertical strain-relief on the centre-tube at the tripod centre-tube for any heavy cables connected to SARCTRAC or the antenna.
4. Connect the antenna coaxial cable to the rig.
5. Connect the CAT cable to the rig USB Port.
6. Connect the CAT cable to the SARCTRAC USB Port.
7. Connect the rig to the battery.
8. Connect SARCTRAC to the battery, via a DC cut-off switch in the off position.
9. Make sure there are no cable trip hazards in the vicinity of the SARCTRAC setup.

## Starting SARCTRAC Portable Operation

The SARCTRAC Portable Setup is now ready to be powered up.

**CAUTION:** SARCTRAC may move the antenna with little 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. Power up the rig. Configure it for remote CAT control. See User Controls Panel.
2. Start the WiFi Personal Hotspot on the mobile device.
3. Power up SARCTRAC.
4. Wait 30 seconds for SARCTRAC to beep in accordance with Table 5.
5. Check the WiFi Personal Hotspot icon or banner on the mobile device.
6. Open the SARCTRAC Selection Page using the mobile device web browser.
7. Commence satellite tracking operations. See SARCTRAC Operation.

## SARCTRAC Operation

This section describes in detail the use of the controls and displays found on the SARCTRAC Selection Page, Tracking Page and Tuning Page.

### Selection Page

1. The Selection page comprises:
  - a. SARCTRAC Panel - Figure 10;
  - b. System Status Panel - Figure 11;
  - c. User Controls Panel - Figure 12;
  - d. Satellite Selection Panel - Figure 13;
  - e. Orbital Element Library List Panel - Figure 14;
  - f. Reject Satellite List Panel - Figure 15;
  - g. 3D Sensor Calibration Panel - Figure 16; and
  - h. System Start-Up Log Panel - Figure 17.

### SARCTRAC Panel



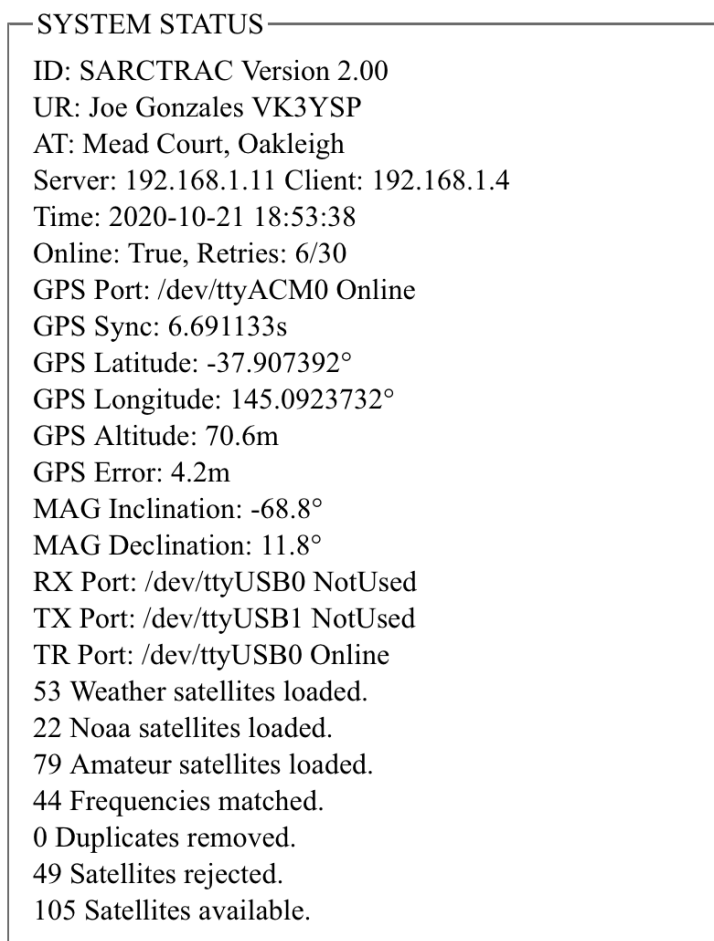
***Figure 10 - SARCTRAC Panel***

1. SARCTRAC control buttons:
  - a. Press START to start the motors: SARCTRAC will beep for 3 seconds.
  - b. Press STOP to stop the motors.



- c. Press RESTART to shutdown and restart: SARCTRAC will restart and beep again after about 30 seconds.
  - d. Press SHUTDOWN to shutdown SARCTRAC gracefully. Please wait 10 seconds, then Power Off. Power Up to start SARCTRAC again.
2. Help link:
  - a. Press [School Amateur Radio Club Network](#) to visit our web site.
3. SARCTRAC Page selection buttons:
  - a. Press SELECTION, TRACKING or TUNING to access these pages.

### System Status Panel



**Figure 11 - System Status Panel**

1. ID: SARCTRAC Software version number.
2. UR: Your Name and Callsign.
3. AT: Street address (Road, Suburb only) – Depends on GPS, OSM & Nominatim.
4. Server and Client IP addresses (IPV4).
5. Time: Current local date and time – Depends on User Controls Panel UTC Offset
6. Online: Internet status/retry attempts.
7. GPS Port: GPS USB port and status (Online, Offline).
8. GPS Sync: Time correction applied to local clock prior to NTP synchronization.
9. GPS Latitude: GPS fix in decimal degrees.
10. GPS Longitude: GPS fix in decimal degrees.



11. GPS Altitude: GPS fix in metres.
12. GPS Error: GPS error estimate in metres.
13. Mag Inclination: Local magnetic field inclination (+ Pointing Down)
14. Mag Declination: Local magnetic field declination (+ Pointing East of True)
15. RX Port: Receiver USB port and status. (Online, Offline, Not Connected, Not Used)
16. TX Port: Transmitter USB port and status. (Online, Offline, Not Connected, Not Used)
17. TR Port: Transceiver USB port and status. (Online, Offline, Not Connected, Not Used) Where:
  - a. Online: The radio is responding.
  - b. Offline: The radio is not responding.
  - c. Not Connected: USB CAT Cable not detected.
  - d. Not Used: Radio Type = NONE in User Controls Panel.
18. Number of satellites loaded from each online orbital element library.
19. Number of satellites loaded with matching entries in the SARCTrac Frequency/Mode Database. Satellite name will be prefixed with the Tuning Indicator (\*).
20. Number of duplicate satellites removed from libraries. Note: The same satellite can sometimes be listed in more than one library.
21. Number of satellites rejected due to a partial name match with entries in the Reject Satellite List Panel.
22. Total number of satellites available for tracking on the Satellite Selection Panel.

### User Controls Panel

**USER CONTROLS**

10	▼	Local Radio Horizon (degrees)
45	▼	Minimum Pass Elevation (degrees)
UTC+11.0	▼	Local UTC Offset (hours)
NONE	▼	Receiver Type
38400	▼	Receiver Baudrate
NONE	▼	Transmitter Type
38400	▼	Transmitter Baudrate
YAESU FT-817	▼	Transceiver Type
38400	▼	Transceiver Baudrate
4:1	▼	Radio RX:TX Ratio
500	▼	Radio Update Rate (ms)

SET

**Figure 12 - User Controls Panel**

1. Local Radio Horizon (degrees): Visible satellite passes are not tracked until they reach this elevation. AOS and LOS times are adjusted for this elevation. SARCTrac will remain horizontal, while waiting for AOS, then rise to track the

satellite. SARCTRAC will lower to the horizontal at LOS, if no other selected satellites are visible.

2. Minimum Pass Elevation (degrees): Future satellite passes are not listed in the Future Passes Panel unless they will reach this elevation during the pass.
3. Local UTC Offset (hours): The local time offset from UTC. Note: SARCTRAC does not automatically compensate for daylight saving time. Manually change the Local UTC Offset for daylight saving time. Note: It is a good idea to restart SARCTRAC after changing this offset and pressing SET, otherwise some visible passes may be displayed with a negative elevation.
4. Receiver Type: Receiver Make and Model.
5. Receiver Baudrate: Receiver CAT Rate.
6. Transmitter Type: Receiver Make and Model.
7. Transmitter Baudrate: Transmitter CAT Rate.
8. Transceiver Type: Transceiver Make and Model.
9. Transceiver Baudrate: Transceiver CAT Rate.
10. Radio RX:TX Ratio: Radio update sequence:
  - a. NONE: RX & TX every update.
  - b. 1:1 = RX, TX, RX, TX, RX, TX...
  - c. 2:1 = RX, RX, TX, RX, RX, TX... etc.
11. Radio Update Rate (ms):
  - a. 100, 200, 500, 1000, 2000, 5000 milliseconds
12. Press SET after making any changes to User Controls.

### Satellite Selection Panel

SATELLITE SELECTION

ALL NONE

☐ \*AAUSAT4

☐ BEESAT-1

☐ \*BEESAT-2

☒ \*BEESAT-3

☐ \*BEESAT-4

☐ BRICSAT2(NO-103)

☐ \*CAS-2T&KS-1Q

☒ COMS1

☐ \*CUBEBUG-2(LO-74)

☒ CUBESATXI-IV(CO-57)

☐ CUBESATXI-V

☐ CUTE-1(CO-55)

☐ CUTE-1.7+APDII(CO-65)

☒ \*DELFI-C3(DO-64)

☐ DIWATA-2B

☐ DMSP5D-3F15(USA147)

☐ DMSP5D-3F16(USA172)

☐ DMSP5D-3F17(USA191)

☐ DMSP5D-3F18(USA210)

☐ \*DUCHIFAT-1

ALL NONE

**Figure 13 - Satellite Selection Panel**

1. Satellite names are sorted alphabetically.
2. Satellite names are prefixed with the Tuning Indicator (\*) where there is a matching entry in the SARCTRAC Frequency/Mode Database.
3. Rejected satellites are not shown.
4. Scroll up and down through hundreds of satellites.
5. Use this list to select candidate satellites for tracking. Selected satellites are shown on the TRACKING page, where individual satellite passes can be down-selected for tracking.
6. Selected satellites are shown as: ☒
7. Unselected satellites are shown as: ☐
8. Select or deselect one or more satellites. The Selection Page is updated ASAP.
9. Press ALL to select all satellites.
10. Press NONE to select no satellites. Note: Rotator will reposition to Home.
11. The ALL and NONE buttons are distributed regularly for quick access. They all operate in the same manner.

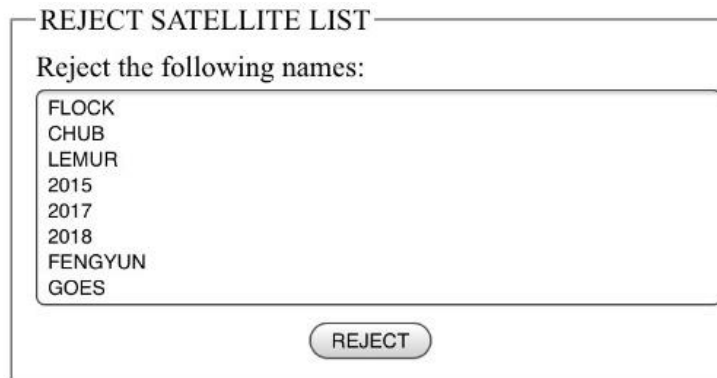
### Orbital Element Library List Panel



**Figure 14 - Orbital Element Library List Panel**

1. The list shows the URLs of online orbital element libraries, which are downloaded on start-up, but no more than once per day.
2. Scroll up or down the list. Add or delete entries.
3. Press UPDATE to save the entries and download the online orbital element libraries. Note: The action is immediate.
4. Press PURGE to first clear ALL local orbital element library files, including ALL user-defined library files, then re-download the online orbital element libraries. Note: The action is immediate.

### Reject Satellite List Panel



REJECT SATELLITE LIST

Reject the following names:

- FLOCK
- CHUB
- LEMUR
- 2015
- 2017
- 2018
- FENGYUN
- GOES

REJECT

The screenshot shows a software panel titled 'REJECT SATELLITE LIST'. Below the title is the instruction 'Reject the following names:'. A list box contains the following text: 'FLOCK', 'CHUB', 'LEMUR', '2015', '2017', '2018', 'FENGYUN', and 'GOES'. At the bottom right of the panel is a button labeled 'REJECT'.

**Figure 15 - Reject Satellite List Panel**

1. The list shows all the satellite names to reject from the orbital element libraries.
2. Rejected satellites will not be displayed.
3. Satellites will be rejected on even a partial name match.
4. Scroll up or down the list.
5. Add or delete entries.
6. Note: Be careful with special characters: [+] works, but [ or ] does not.
7. Press REJECT to save changes.

### 3D Sensor Calibration Panel



3D SENSOR CALIBRATION

Calibrate Accelerometer/Magnetometer

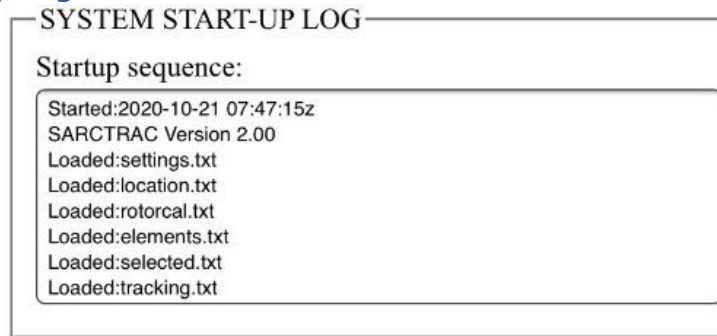
BEGIN ABORT SAVE

The screenshot shows a software panel titled '3D SENSOR CALIBRATION'. Below the title is the instruction 'Calibrate Accelerometer/Magnetometer'. At the bottom of the panel are three buttons labeled 'BEGIN', 'ABORT', and 'SAVE'.

**Figure 16 - 3D Sensor Calibration Panel**

1. See SARCTRAC 3D Sensor Calibration Procedure.
2. Press BEGIN to start 3D Sensor calibration.
3. SARCTRAC will beep for each new calibration point found.
4. Press ABORT at any time to exit the calibration process. The existing calibration data will not be changed.
5. Press SAVE only at the end of a successful calibration process to replace the existing calibration data with the new calibration data.

## System Start-Up Log Panel



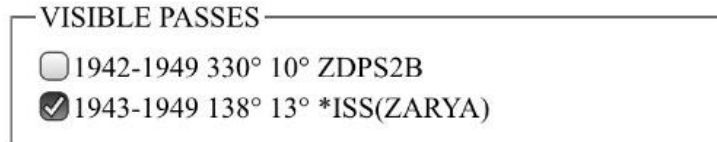
**Figure 17 - System Start-Up Log Panel**

1. Shows the SARCTRAC system messages since the last power-up.
2. Scroll up or down the list.
3. Can be used for debugging purposes. See SARCTRAC Maintenance.

## Tracking Page

1. The Tracking page comprises:
  - a. SARCTRAC Panel - Figure 10;
  - b. Visible Passes Panel - Figure 18; and
  - c. Future Passes Panel - Figure 19.
2. The Tracking page is automatically refreshed every 5 seconds.

## Visible Passes Panel



**Figure 18 - Visible Passes Panel**

1. Shows a chronological list of all visible satellites currently above the Local Radio Horizon, including:
  - a. Selection checkbox;
  - b. Local AOS Time and LOS Time;
  - c. Current AZ and EL;
  - d. Tuning Indicator (\*); and Satellite Name
2. The list is sorted by the AOS Time.
3. Note: The AOS time of all satellites visible when SARCTRAC was started will be the start time.
4. Completed satellite passes are removed from the top of the list.
5. Future satellite passes are added at the bottom of the list when they become visible. The selected state of future satellite passes is preserved when they are transferred from the Future Passes panel to the Visible Passes panel.
6. Toggle the selected state by pressing the selection checkbox.
7. SARCTRAC only tracks the first selected satellite in the list. Note: May need to press again if page update and checkbox change occur at the same time.



## Future Passes Panel

FUTURE PASSES

MORE

LESS

HOME

☐

1951-2001 168° 79° EYESATA(AO-27)

☐

1951-2000 172° 70° UOSAT2(UO-11)

☐

2007-2018 005° 68° \*STRAND-1

☐

2022-2033 175° 54° \*NOAA19

☒

2048-2058 205° 65° \*SAUDISAT1C(SO-50)

☐

2058-2107 017° 81° \*KKS-1(KISEKI)

☐

2107-2115 322° 60° ORBITALFACTORY2(OF-2)

☐

2112-2121 285° 71° DUCHIFAT-3

☐

2148-2155 293° 52° HUSKYSAT-1

☐

2201-2211 178° 48° \*METEOR-M2

☐

2227-2238 157° 58° \*CAS-2T&KS-1Q

☐

2228-2236 244° 60° ZHUHAI-102(CAS-4B)

☐

2229-2239 174° 61° METOP-A

☐

2234-2242 244° 65° ZHUHAI-101(CAS-4A)

☐

2253-2302 268° 74° DUCHIFAT-3

☐

2256-2307 160° 63° METOP-C

☐

2323-2331 156° 48° \*NAYIF-1(EO-88)

☐

2327-2338 172° 66° \*NOAA18

☐

2327-2338 172° 66° NOAA18[B]

☒

2340-2348 159° 57° FOX-1CLIFF(AO-95)

**Figure 19 - Future Passes Panel**

- Shows a chronological list of future satellite passes, where their maximum elevation will exceed the Minimum Pass Elevation, including:
  - Selection Checkbox;
  - Local AOS Time and LOS Time;
  - AOS AZ and MAX EL;
  - Tuning Indicator (\*); and Satellite Name
- The list is sorted by the AOS Time.
- The list shows all future satellite passes which are completed within the prediction period. By default, the prediction period is two hours.
- Future satellite passes are removed from the top of the list, when they become visible, and are transferred to the Visible Passes panel.
- Future satellite passes are added to the bottom of the list when they become completed within the prediction period.
- Toggle the selected state by pressing the selected button. Note: May need to press again if page update and checkbox change occur at the same time.
- Press MORE to increase the prediction period by one hour. Note: Additional passes may not be displayed for 15 seconds, or not at all if there are none in the new prediction period. The last LOS time in the list provides an

indication of the current prediction period. The maximum prediction period is twelve hours.

8. Press LESS to decrease the prediction period by one hour. Note: Fewer passes may not be displayed for 15 seconds. The minimum prediction period is two hours.
9. Press HOME to deselect all visible and future satellite passes. The effect of this is, initially, to return the rotator to the HOME position. However, new selected satellite passes may still be automatically added at the end of the list when they become completed within the prediction period. This will cause the rotator to move to the satellite AOS position instead. To keep the rotator at the home position: Deselect new future satellite passes as they occur; Press STOP, when the rotator arrives at the home position; or select NONE on the Satellite Selection Panel.
10. Some selected satellites (like geostationary satellites) may never appear on the Tracking Page because they never rise above the Local Radio Horizon.

## Tuning Page

1. Tuning page comprises:
  - a. SARCTRAC Panel - Figure 10; and
  - b. Radio Tuning Panel - Figure 20

## Radio Tuning Panel

RADIO TUNING

SATELLITE:

NAME: ISS(ZARYA)

INFO: FM CTCSS 67.0HZ

NORMAL

MODE

RECEIVER:

FREQ: 437.800000MHz

+0Hz

TUNE

FM

MODE

TRANSMITTER:

FREQ: 145.990000MHz

+0Hz

TUNE

FM

MODE

TUNE

**Figure 20 - Radio Tuning Panel**

1. Shows the available satellite usage information, the selected satellite operating mode and the receiver and transmitter default frequencies, tuning offsets and modulation modes.

2. The Radio Tuning Panel is only active when the satellite being tracked has a matching entry in the SARCTRAC Frequency/Mode Database. In which case, the satellite name is prefixed with the Tuning Indicator (\*) on the SARCTRAC Selection Page and Tracking Page.
3. Use the Radio Tuning Panel controls to override the default settings.
4. SATELLITE NAME: The name of the satellite, if active, or NONE.
5. SATELLITE INFO: Satellite information from the SARCTRAC Frequency/Mode Database.
6. SATELLITE MODE: The selected satellite mode, for example: BEACON A, BEACON B, TRANSPONDER A, TRANSPONDER B, if more than one mode is available, or NORMAL if not.
7. RECEIVER FREQ: The default satellite frequency including any tuning offsets applied.
8. RECEIVER TUNE: Receiver frequency offset to be incrementally applied whenever TUNE is pressed.
9. RECEIVER MODE: The receiver demodulation mode: LSB, USB, CW CWR, AM, FM, DIG, PKT.
10. TRANSMITTER FREQ: The default satellite frequency including any tuning offsets applied.
11. TRANSMITTER TUNE: Transmitter frequency offset to be incrementally applied whenever TUNE is pressed.
12. TRANSMITTER MODE: The transmitter modulation mode: LSB, USB, CW CWR, AM, FM, DIG, PKT.
13. The available offsets are +/- 0Hz, 10Hz, 20Hz, 50Hz, 100Hz, 200Hz, 500Hz, 1kHz.
14. Offsetting the transmitter and receiver frequencies from the default satellite frequencies can be useful when another station is slightly off frequency or reports that you are off frequency.
15. In addition, SARCTRAC automatically applies the Doppler correction to the default and offset frequencies shown. So that your transmitter signal is on frequency at the satellite and its signal is on frequency at your receiver.
16. Press the TUNE button to simultaneously update the selected satellite mode, radio frequencies and radio modes.
17. IMPORTANT: The radio frequencies will be changed, according to the offsets shown, whenever the TUNE button is pressed.
18. Press the TUNE button multiple times to incrementally apply the same offset, but always remember to return the radio frequency offsets to 0Hz when they are not required, so that they will not be inadvertently applied when the TUNE button is pressed again.
19. 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.

## Hints and Tips

### 1. Operating conditions

- a. SARCTRAC runs on 12-15VDC at around 1A. The heatsink will run cooler at 12VDC.
- b. RFI: SARCTRAC uses a microprocessor, which generates an unavoidable amount of RFI at VHF and UHF frequencies. This RFI has been minimised in development to a satisfactory level. However, the use of additional clip-on, ferrite cores on the power and sensor cable may be effective in reducing RFI even further. Shielding the 3D Sensor cable is not recommended due to excessive capacitance on the I2C bus.
- c. EMC: The SARCTRAC 3D Sensor and the I2C data bus is somewhat susceptible to stray RF energy. It can lock up occasionally if you transmit high power. We recommend using only 10W for EMR safety, especially around kids, and for satellite-usage etiquette. However, if higher powered transmitters are to be used, we suggest mounting the 3D Sensor on the Lift-Arm, further behind the antenna's radiating elements. Clip-on ferrite cores on the cable may also help in some cases.
- d. Polarization fading: The typical hand-held antennas used with SARCTRAC are linearly-polarised, since circularly-polarised antennas are much larger and heavier. Most satellites exhibit some form of polarization rotation during each overhead pass, either due to the spacecraft's rotating attitude or to various atmospheric effects. This can cause unavoidable uplink or downlink fading. Luckily the effects are usually transient, but it does explain why deep link fading can occur even at high elevations.
- e. To listen and talk to satellites we like to use our Yaesu FT-817 radio, but for some satellites you can just use a hand-held, VHF/UHF FM radio, or even a pair of them, so you can hear your own signal coming from the satellite. Always remember to program your radio with any CTCSS tone frequencies required to access the "birds".

### 2. Operating modes

- a. SARCTRAC can work off-line (not connected to the Internet), so long as the GPS is available and while the Orbital Element Libraries are still fresh – up to a few weeks old.
- b. SARCTRAC can work without the GPS, so long as it is on-line (connected to with the Internet) or if it hasn't moved very far since the last time it was used.
- c. Without Internet or GPS availability, SARCTRAC will not be able to get the time.
- d. Without GPS availability or the last saved location, SARCTRAC will not be able to get the location.
- e. The last saved location and displayed street address is updated only if SARCTRAC is moved by more than 250 metres from the previous location.

- f. SARCTRAC is either tracking a visible satellite, repositioning the antenna via the shortest path for the next satellite pass, or waiting either for the next satellite pass to start or at the home position if there is no selected satellite to track. When SARCTRAC is waiting it stays in the horizontal position. If a Local Radio Horizon is set, SARCTRAC will pop up to that elevation at the start of the pass and drop down to horizontal at the end of the pass.
- 3. Motors
  - a. SARCTRAC Motors growl all the time. It is quite normal while they are doing their job positioning the antenna in real-time. To reduce the noise and power supply current consumption (both minimal) 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.
- 4. 3D Sensor
  - a. The SARCTRAC 3D Sensor is a sensitive magnetometer and accelerometer. It is quite susceptible to nearby magnetic fields, so it shouldn't be mounted on a steel antenna boom or using steel screws. To prove it, hold a screwdriver near the sensor: The antenna will move toward or away from the screwdriver.
  - b. The SARCTRAC 3D Sensor is a Micro Electro-Mechanical System (MEMS) device mounted inside an integrated circuit package, which is mounted on a printed circuit board, which is mounted inside a heat-shrink tube, which is mounted on your antenna boom. The precise angular alignment of these four mounting points is not guaranteed. Hence there can be some final azimuth or elevation offset. The use of a simple wedge packer between the sensor and the boom can minimise this effect.
- 5. Operating tips
  - a. SARCTRAC is a rotator and tracker: It will not plan your whole weekend of satellite hunting, nor explain different satellite modes and how to work satellites. Use it in conjunction with good satellite information and prediction websites. Check out [www.amsat.org](http://www.amsat.org), [www.amsat-uk.org](http://www.amsat-uk.org) and [www.n2yo.com](http://www.n2yo.com). We provide our own on-line satellite prediction page at [www.sarcnet.org/satellites.html](http://www.sarcnet.org/satellites.html) which, uniquely, allows you to predict satellite co-visibility at two different locations, for up to 12 hours from a nominated date and time. It corrects the AOS and LOS times for the Local Radio Horizon and provides Minimum Pass Elevation filtering. It is our ultimate tool for planning satellite contacts!
  - 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. SARCTRAC is perfect for scheduling all passes of all compatible weather satellites for Automated Picture Transmission decoders. However, SARCTRAC should never be operated unattended.

- d. SARCTRAC provides automatic Doppler frequency correction for all satellites listed in the SARCTRAC 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 relatively constant in frequency. SARCTRAC Doppler correction mode operates to maintain constant transmit and receive frequencies at the satellite while automatically changing the ground station's transmit and receive frequencies.
  - e. SARCTRAC audible beeps give you a good idea of what the rotator is doing: It provides a long beep when it starts up and starts moving; at LOS before repositioning the antenna; and two short beeps at AOS before tracking a new satellite. Short beeps at power-up indicate something is not connected properly.
  - f. SARCTRAC can track new satellites, even before their orbital elements are published on [www.celestrak.com](http://www.celestrak.com). Just copy their estimated TLEs into a new text file, say "user.txt", and include it in a "tle" folder prior to an update using the SARCTRAC USB Disk. You can also add the new satellite frequencies and modes to the freqmode.txt file.
6. SELECTION page:
- a. Always check the local time, your location and UTC offset on the Selection page prior to operations. Refresh it after the first GPS 3D Fix. If any of these settings is wrong, SARCTRAC won't be pointing in the right direction, at the right time.
  - b. Use the Satellite Selection, Reject Satellite List, Local Radio Horizon and Minimum Pass Elevation to get rid of unwanted satellites and unusable satellite passes.
  - c. Use the Radio RX:TX Ratio and Radio Update Rate to minimise any disruption to listening to the satellite downlink. The TX frequency update is less critical, especially when using short transmission periods. This is very much radio-type dependent, considering their various, unavoidable, Radio Control anomalies.
7. TRACKING page:
- a. Some selected satellites (like geostationary satellites) may not appear on the Tracking page because they never rise above the local minimum horizon.
  - b. Repositioning the antenna between passes takes time: Up to 50 seconds for 180 degrees. Good, future satellite pass planning can ensure this is not disruptive. The following strategies can help.
  - c. Deselect any unwanted satellite passes in the Future Passes Panel.
  - d. Check the LOS time of one satellite against the AOS time of the next satellite to see if there is any overlap. In this case you can choose the better pass to track.



8. TUNING page:

- a. Check out <http://www.ne.jp/asahi/hamradio/je9pel/satslist.htm> or search the Internet to discover satellite frequencies and modes not listed in the SARCTRAC Frequency/Mode Database.
- b. Satellite Linear Transponders may be inverting or non-inverting and the satellite uplink and downlink may use the same or inverse sidebands. So, you need to figure out, in advance, if increasing your uplink frequency will increase or decrease your downlink frequency.
- c. Depending on the rig, its RIT/XIT controls may or may not be independently useable: They may be completely overridden by RX VFO CAT control.

# SARCTRAC Maintenance

## SARCTRAC Configuration, Backup, Update and Restore Procedures

SARCTRAC can be updated in the field if new features become available. SARCTRAC uses the SARCTRAC USB Disk for application and configuration updates; the Internet for third-party software and operating system upgrades and downloadable micro SDHC card images for major upgrades or card failures. Using the SARCTRAC USB Disk ensures that backups are automatically created before each update and these backups can be restored in the event of any future problems. This section explains how the SARCTRAC configuration, update and backup and restore procedures work.

### SARCTRAC Configuration Procedure

To configure SARCTRAC you need to copy the required files to the root folder of the SARCTRAC USB Disk and edit these files, if necessary, before proceeding to the SARCTRAC Update Procedure.

1. Insert the SARCTRAC USB Disk to a USB port on a PC.
2. Inspect the contents of the SARCTRAC USB Disk using a file browser on the PC. Turn on "Show all file extensions" to see which items are text files.
3. Save a copy of the entire contents of SARCTRAC USB Disk to a folder on the PC, just as a backup.
4. Download updated items from the [www.sarcnet.org/sarctrac](http://www.sarcnet.org/sarctrac) folder on our website to the root folder of the SARCTRAC USB Disk; or
5. Copy previous items from a backup folder on the SARCTRAC USB Disk to the root folder of the SARCTRAC USB Disk.
6. Note: Only the items shown in Table 3, when copied to the root folder of the SARCTRAC USB Disk will trigger a new backup and update to occur. You can copy individual files to the root folder, but if you want to copy items in a backup folder, for example, you must copy the folder as well as any files required inside it to the root folder. Any BackupNN folders and their contents will be ignored and preserved.
7. Edit update items in the root folder, if required, using a simple text editor. Only the following items should be edited, for the reasons shown:
  - a. The network.txt file – New WiFi network access credentials. See WiFi Configuration.
  - b. The freqmode.txt file – New satellite frequencies and modes. See SARCTRAC Frequency/Mode Database.
  - c. The user.txt file inside a tle folder – New satellite orbital elements. See Loading user-defined Orbital Element Libraries.
8. Eject the USB Disk from the PC.

### SARCTRAC Backup Procedure

SARCTRAC will automatically backup all its application and configuration items prior to applying any new updates. However, to create a backup without changing the configuration, you can trigger an update by copying the network.txt file from the last BackupNN folder to the root folder on the SARCTRAC USB Disk.

### **SARCTRAC Update Procedure**

After preparing the items to be updated in the root folder of the SARCTRAC USB Disk, perform the SARCTRAC Update Procedure as follows:

1. Shutdown and power down SARCTRAC.
2. Insert the SARCTRAC USB Disk in the SARCTRAC USB port with the silver dot.
3. Power-up SARCTRAC and wait for it to start. Do not disconnect the power.
4. SARCTRAC creates a new backup folder on the SARCTRAC USB Disk.
5. Note: The backup is stored in a sequential folder, starting at Backup00.
6. SARCTRAC installs update items in the root folder of the SARCTRAC USB Disk.
7. SARCTRAC erases update items in the root folder of the SARCTRAC USB Disk.
8. Note: This ensures that the update items will only be installed once.
9. SARCTRAC ejects the SARCTRAC USB disk.
10. SARCTRAC starts up with the upgraded items.
11. Note: This may take a minute for a single file update or up to 10 minutes to install a new SARCTRAC version.
12. SARCTRAC beeps, as normal, if the upgrade is successful.
13. Note: If SARCTRAC does not beep normally, see SARCTRAC Restore Procedure
14. Remove the SARCTRAC USB Disk.
15. You can shutdown, power down and power up SARCTRAC to verify the update.

### **SARCTRAC Restore Procedure**

SARCTRAC can be restored to a previous version or configuration using this restore procedure. The following are examples of using the SARCTRAC USB Disk to restore a SARCTRAC from previous backup:

1. To restore a full backup of all items, simply copy the sarctrac file to the root folder of the SARCTRAC USB Disk and follow the SARCTRAC Update Procedure.
2. To restore a partial backup of selected files, copy the selected files to the root folder of the SARCTRAC USB Disk and follow the SARCTRAC Update Procedure.  
Note: a description of the purpose of each file is shown in Table 3.
3. To restore an orbital element library, create a tle folder in the root folder of the SARCTRAC USB Disk, copy the orbital element library file(s) into the tle folder and follow the SARCTRAC Update Procedure.

### **SARCTRAC 3D Sensor Calibration Procedure**

The SARCTRAC 3D Sensor comes carefully pre-calibrated at the factory using a 3-axis magnetometer/accelerometer calibration gimbal. The factory calibration is saved in the rotorcal.txt files on the SARCTRAC USB Disk and can be restored at any time using the SARCTRAC Restore Procedure. The factory calibration should achieve +/- 5 degrees accuracy: More than enough for a hand-held yagi antenna, which may have a 3dB beamwidth of +/- 35 degrees. However, the Earth's magnetic field is weak and it is subject to local magnetic anomalies, such as iron and steel. Calibration, in itself, cannot mitigate the effect of local magnetic anomalies. On a ship, you may have seen that the compass is mounted on a binnacle, which has two magnetic balls designed to null-out local magnetic anomalies. This is impractical for SARCTRAC, where the

sensor is constantly moving. The best strategy is to remove the local magnetic anomalies or to relocate SARCTRAC to a magnetically quiet area. You can locate magnetic anomalies by moving a compass around the area and checking for any deviations. In the event that the SARCTRAC 3D Sensor needs to be recalibrated, for example if it had to be replaced, you can use the calibration procedure as follows:

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. Keep all magnetic materials, including your mobile device, away from the 3D Sensor.
5. On the SARCTRAC Selection page scroll down to 3D Sensor Calibration and get someone to press BEGIN.
6. You can ABORT or SAVE the calibration at any time by pressing those buttons.
7. Calibrate the 3D Sensor by GENTLY moving it all around until SARCTRAC stops beeping.
8. 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 separately 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 collect its calibration points. If while moving the 3D Sensor 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.
9. Don't forget to get someone to press the SAVE button when you have finished calibrating, or ABORT - if you sneeze.

## SARCTRAC System Start-Up Log

The System Start-Up Log on the SARCTRAC Selection Page can be useful for information and debugging purposes. An example of a normal start-up log is shown in Table 6.

**Table 6 – SARCTRAC System Start-Up Log**

Started:2020-10-30 04:52:20z SARCTRAC Version 2.00 Loaded:settings.txt Loaded:location.txt Loaded:rotorcal.txt Loaded:elements.txt Loaded:selected.txt Loaded:tracking.txt Loaded:rejected.txt Loaded:freqmode.txt Loaded:radiocfg.txt Loaded:radiocap.txt Loaded:licences.txt Licenced: Joe Gonzales VK3YSP Licence1: xxxxxxxxxxxxxxxxxx Licence2: yyyyyyyyyyyyyyyy Licence3: zzzzzzzzzzzzzzzz Online:True, Retries:5/30 Loaded:t1e/weather.txt Loaded:t1e/noaa.txt Loaded:t1e/amateur.txt 53 Weather satellites loaded. 22 Noaa satellites loaded. 79 Amateur satellites loaded. 44 Frequencies matched. 0 Duplicates removed. 49 Satellites rejected. 105 Satellites available. Opened:gps:/dev/ttyACM0 Opened:rx:/dev/ttyUSB0:NotUsed Opened:tx:/dev/ttyUSB1:NotUsed Opened:tr:/dev/ttyUSB0:Online	Created:observer Latitude:-37.90743403333326° Longitude:145.09235666666666° Altitude:67.1m Error:5.2m Declination:11.8° Inclination:-68.8° Address:UNKNOWN ADDRESS TimeZone:11.0 Started:gps Started:rotator Started:tracker Started:server Next:None GPSdate:2020-10-30 04:59:43z GPSSync:436.209203s Loaded:https://nominatim.openstreetmap.org/reverse Loaded:reverse.txt GPSfix:3D Latitude:-37.90743483333326° Longitude:145.09234666666666° Altitude:66.3m Error:4.7m Moved:False Distance:6.9m Address:Mead Court, Oakleigh Declination:11.8° Inclination:-68.8° Stopped:gps AOS:UNISAT-6 LOS:UNISAT-6 Next:None
---	--

## 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, cube-sats 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 abridged example library is shown in Table 7. The library contains the name of each satellite followed by the 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 page by entering all or part of their names in the Reject Satellite List.

**Table 7 - Orbital Element Library File**

OSCAR 7 (AO-7)									
1	07530U	74089B	19074.89258090	-.000000020	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	.000000058	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	-.000000011	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	.000000008	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	-.000000019	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	.000000012	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	-.000000020	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	.000000999	00000-0	23313-4	0	9993	
2	25544	51.6421	99.3024	0003974	112.3476	286.4746	15.52811995160948		

### Downloading Orbital Element Libraries

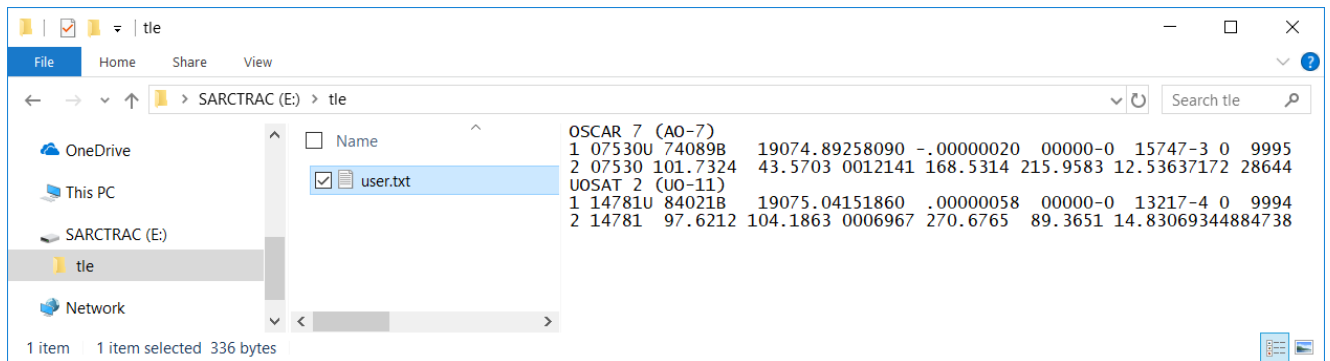
SARCTRAC downloads local copies of Orbital Element Libraries from the URLs listed in the Orbital Element Library List on the SARCTRAC Selection page. However, the online libraries will only be download at power-up and if local copies don't already exist or are older than 24 hours. You can edit the list 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 7.
4. The USB Disk and its contents should look like Figure 21.
5. Update SARCTRAC as normal.





**Figure 21 - User-Defined Orbital Element Library**

### 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 you 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.

### SARCTRAC Frequency/Mode Database

The SARCTRAC Frequency/Mode Database is a text file called "freqmode.txt", which can be edited on a PC and installed into SARCTRAC using the SARCTRAC USB Disk and the SARCTRAC Configuration, Backup, Update and Restore Procedure. An abridged version of the freqmode.txt file is shown in Table 8.

The entries in the freqmode.txt file are matched with the exact satellite name in the Orbital Element Library file. When a satellite of the same name is being tracked on the Tracking Page, SARCTRAC automatically uses the frequency and 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 sure you have a backup. 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 SARCTRAC 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 sure you have 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 8 - SARCTRAC Frequency/Mode Database**

```
#freqmode.txt version 2.00
#Frequency and Mode database for the Satellite Antenna Rotator Controller and Tracker (SARCTRAC)
#####
#Copyright(c) 2020. 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']]],
```