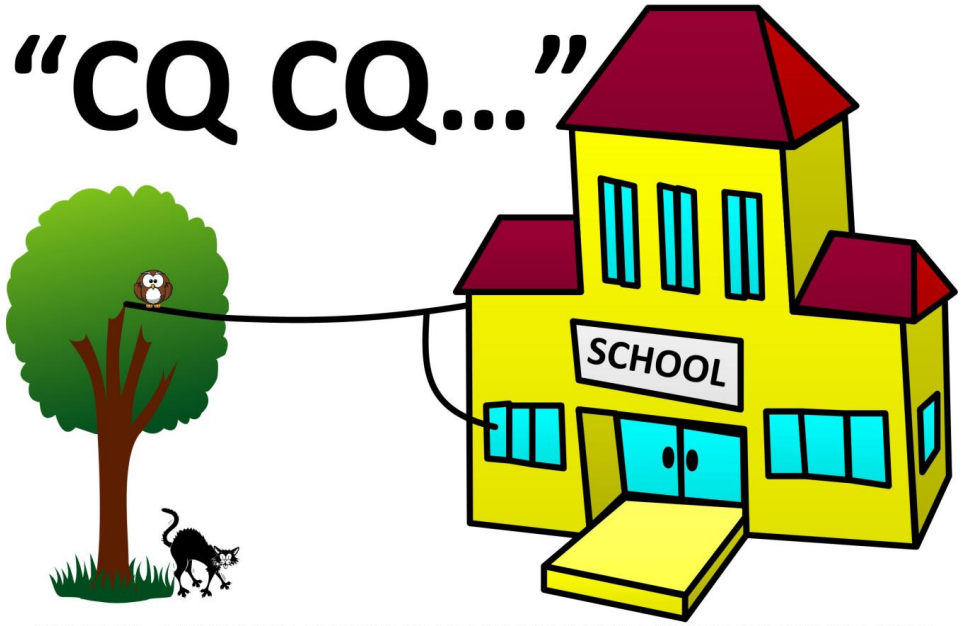
GippsTech

2018 Mini Satellite Ground Station

By Julie VK3FOWL and Joe VK3YSP



Why We Do It…

System Requirements

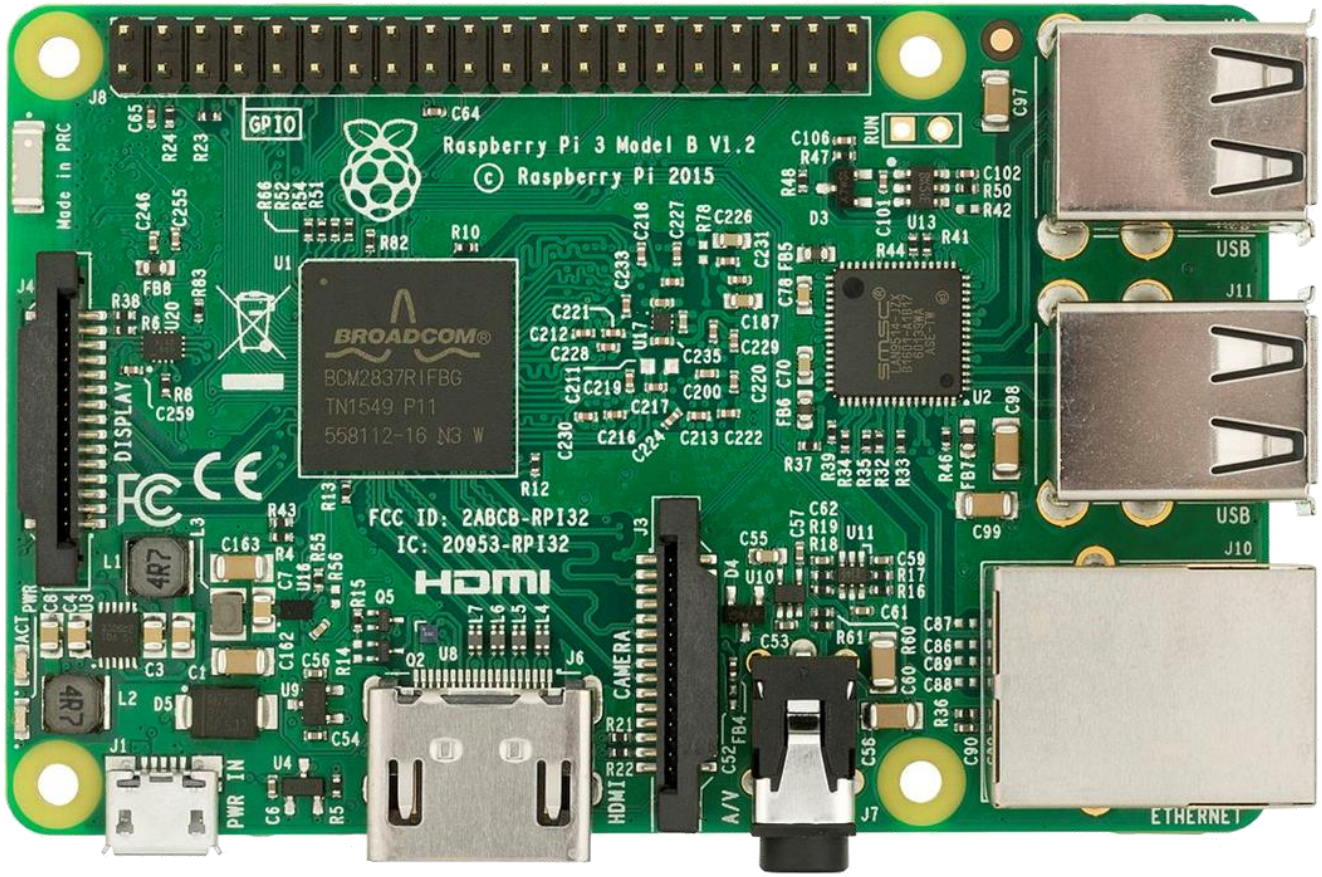
- Automatically points the antenna at the satellite
- Students use their mobile devices to select satellites to track
- Displays when the selected satellites will be visible
- Tracks multiple satellites in turn, then automatically sets up for the next pass
- No data entry required for location, time and orbital elements
- Self contained, no separate computer (difficult to see in sunlight)
- Portable tripod mounting with a dual-band, RHCP, satellite antenna(s)
- Can be set up anywhere within a few minutes
- Built-in receiver with decoder for weather satellites
- Doppler frequency correction for external Amateur Radio transceivers
- Two versions:
- Mini Satellite-Antenna Rotator Mk3: Light Duty, battery-powered, no external cables
- Mini Satellite-Antenna Rotator Mk4: Heavy Duty, AC-powered

Hardware – Enclosure

- Polycarbonate enclosure
- Ingress Protection to IP66
- Easy to work
- Transparent to GPS/BT/WiFi Signals

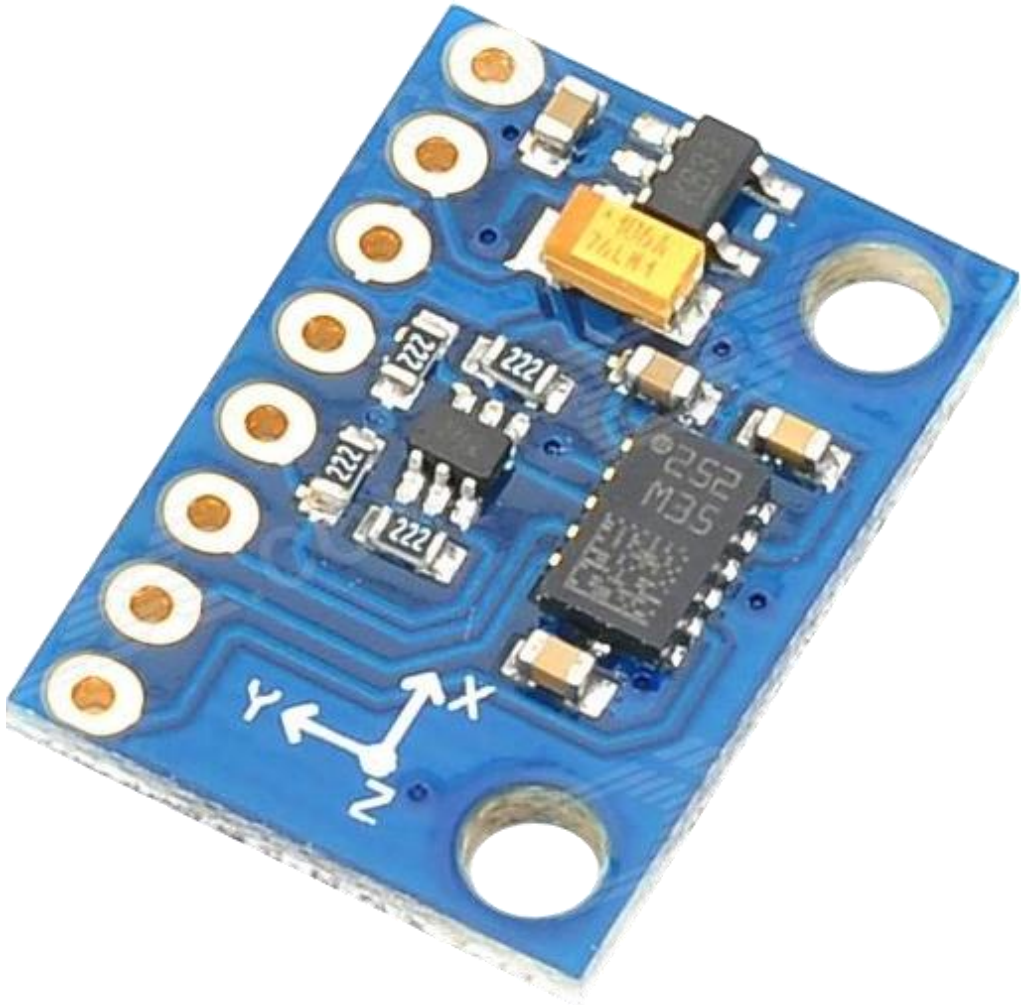
Hardware – Raspberry Pi

- Controls the rotator
- Pi 3 Model B
- Credit Card Size Computer
- Linux Operating System
- Built in WiFi/BT/Ethernet
- 1.2GHz 64Bit Quad Core
- 1GB RAM
- 4 USB Ports, 1 I2C Bus
- 1 HDMI with Audio Out



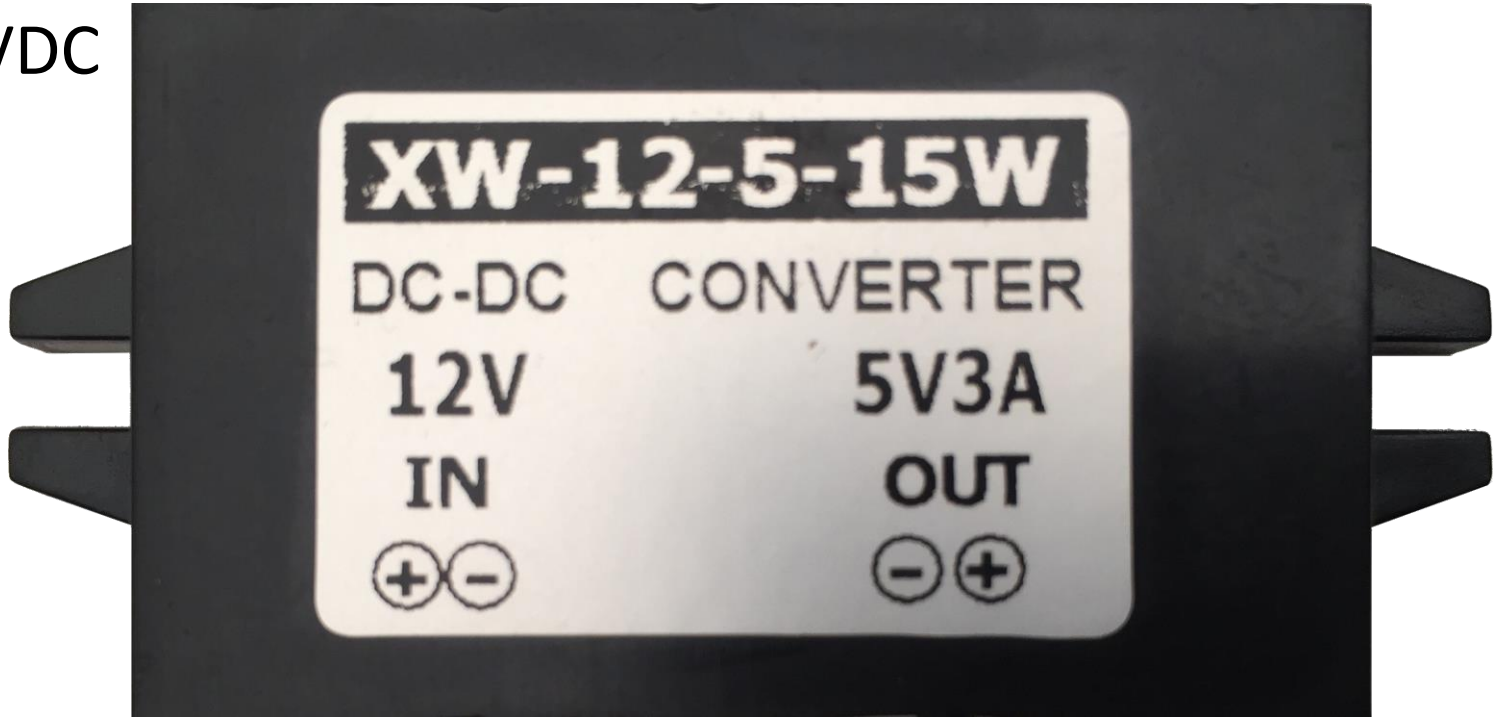
Hardware – 3D Sensor

- Senses the antenna position
- LSM303DLHC ($3)
- I2C Interface
- 3D Accelerometer
- 3D Magnetometer
- Cheaper than LSM303D ($10)



Hardware – DC/DC Converter

- Provides regulated 5VDC
- Efficient switch mode
- Sealed unit
- Easy to mount

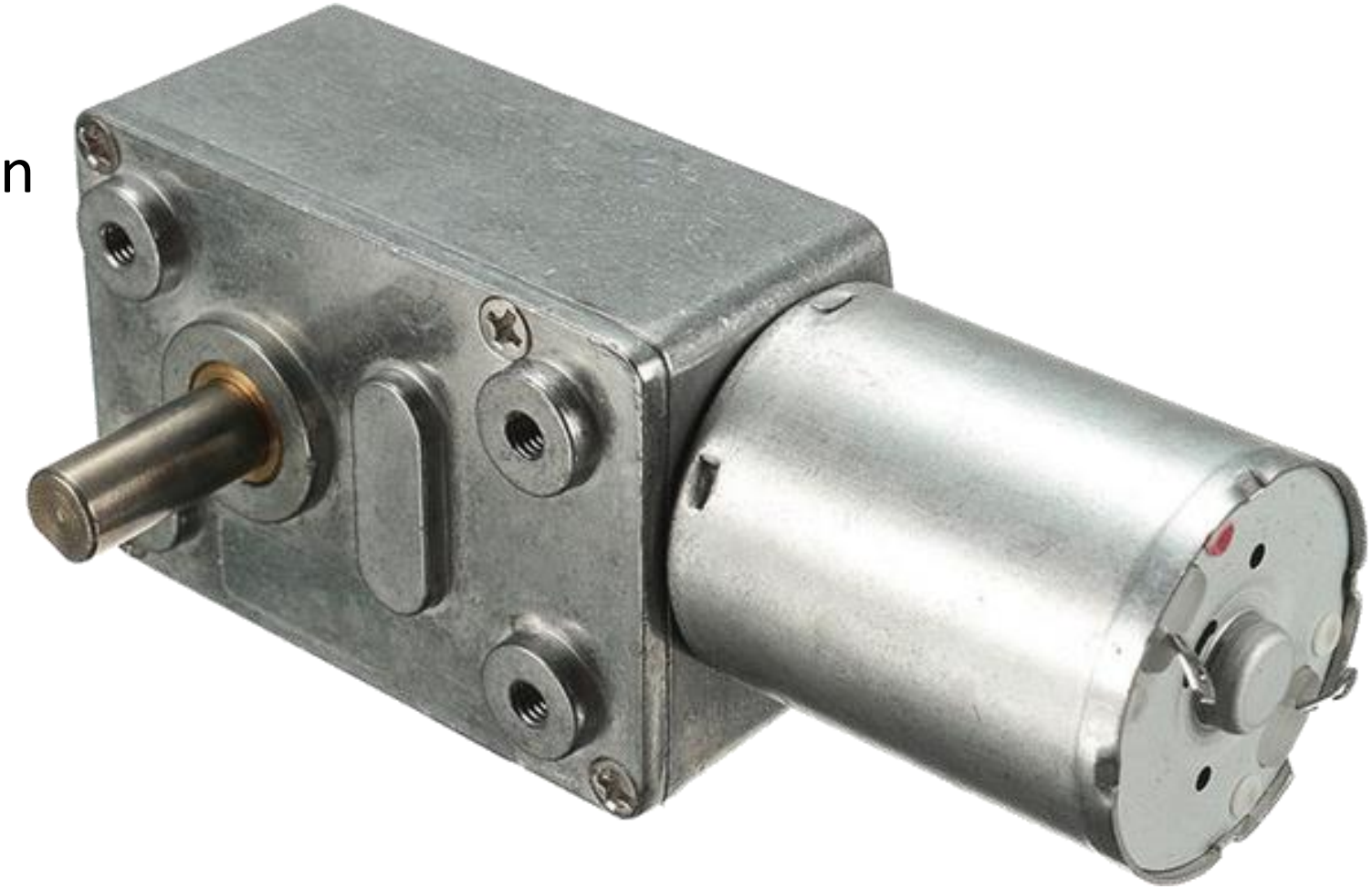


Hardware – GPS

- Sets up rotator location and time
- USB Interface
- 1s hot start
- 30s cold start
- -162dBm sensitivity
- 2.5m CEP accuracy
- 245mW power

Hardware – DC Motors

- Steers the antenna
- Azimuth and Elevation
- Right Angle Gearbox
- High Torque 53kg.cm
- 12 VDC 0.6 RPM
- Stall current 39mA
- Light duty

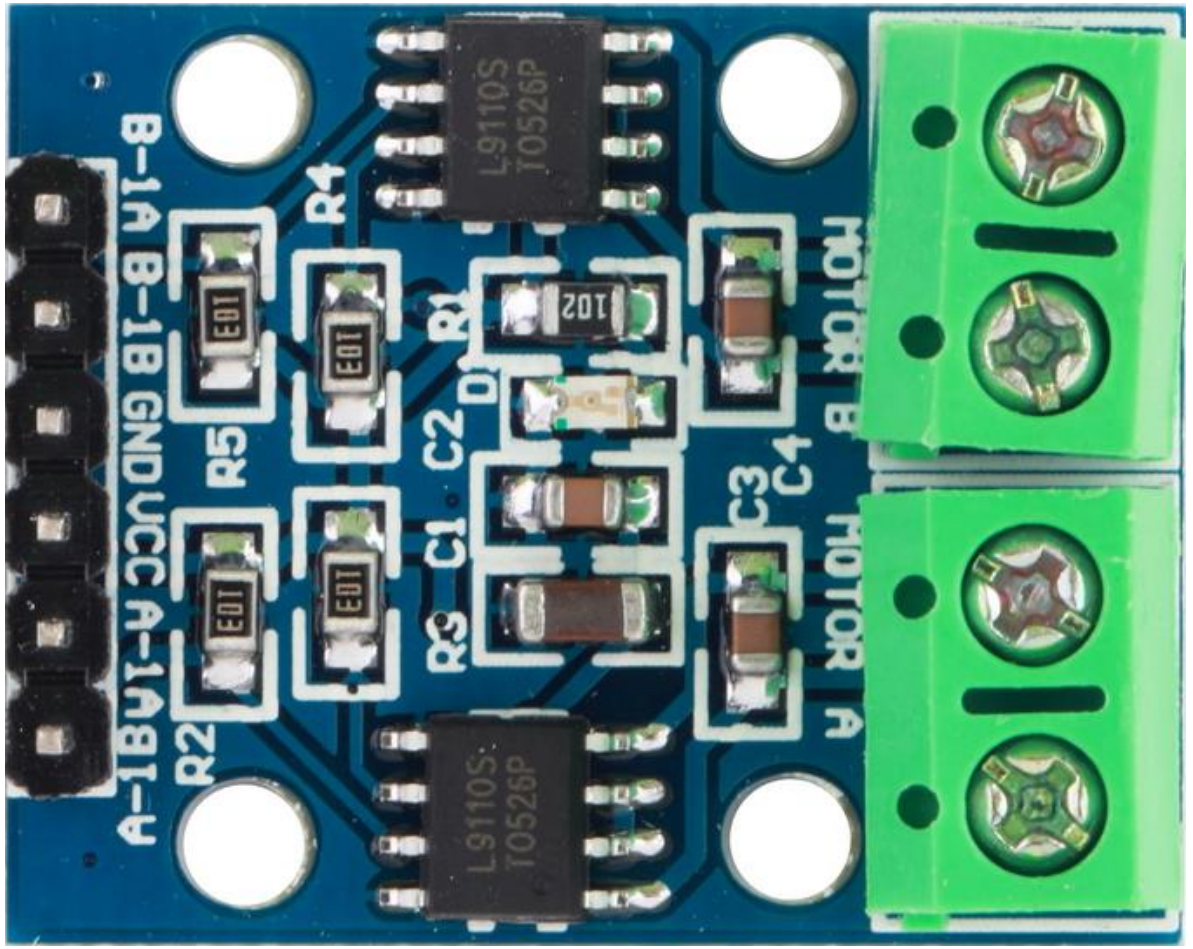


Hardware – AC Motors

- Steers the antenna
- Azimuth and Elevation
- 2 x ChannelMaster™ TV Antenna Rotators
- High Torque 1400kg.cm
- 18 VAC 1.0 RPM
- 50mm Mast Mounting
- Stainless Steel Brackets
- Heavy Duty

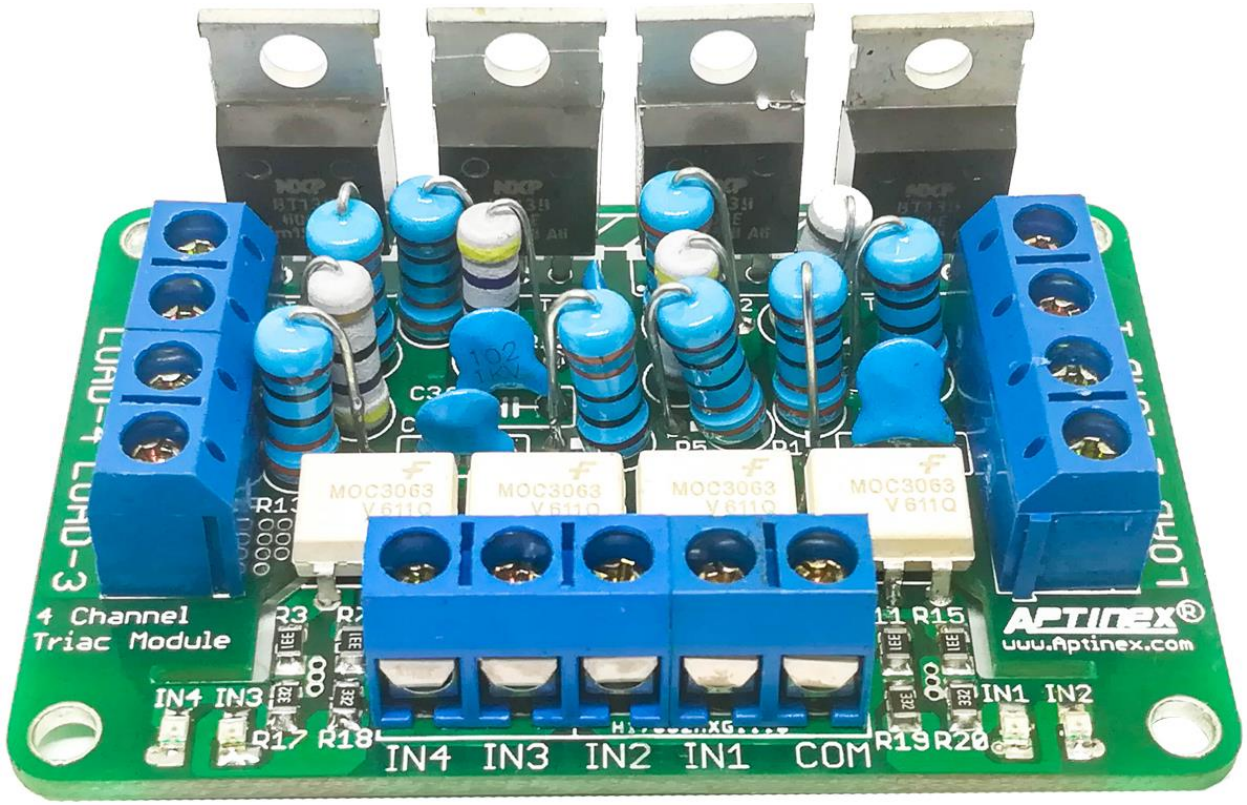
Hardware – DC Motor Driver

- Drives the DC motors
- Dual Channel: AZ and EL
- 800mA per channel
- 2.5-12VDC Supply
- 12V Regulated Supply Needed
- Four (4) PWM Inputs
- Inexpensive ($1)



Hardware – AC Motor Driver

- Drives the AC motors
- Dual Channel: AZ and EL
- 16A per channel
- 600VAC Supply
- Opto-Isolated
- Zero Voltage Switching
- Four (4) PWM Inputs



Hardware – SDR Dongle

- USB Interface
- Frequency: 24MHz – 1.766GHz
- All Mode: AM, FM, LSB, USB…
- Max Bandwidth: 2.4MHz
- Stable: 1PPM TCXO

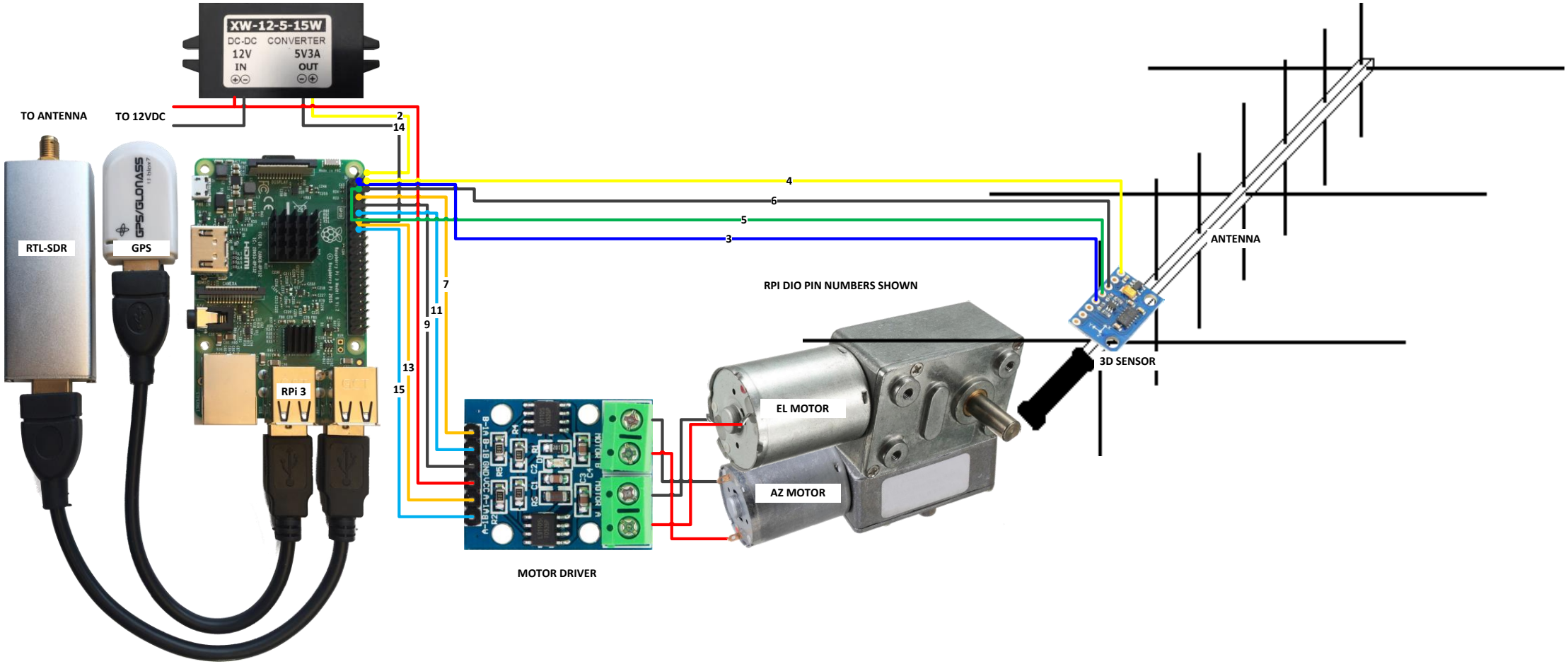
Hardware – Battery Pack

- 12V Rechargeable Battery Pack
- 10 x 2550mAh NIMH Batteries
- Up to 10 hours operation
- Batteries not included

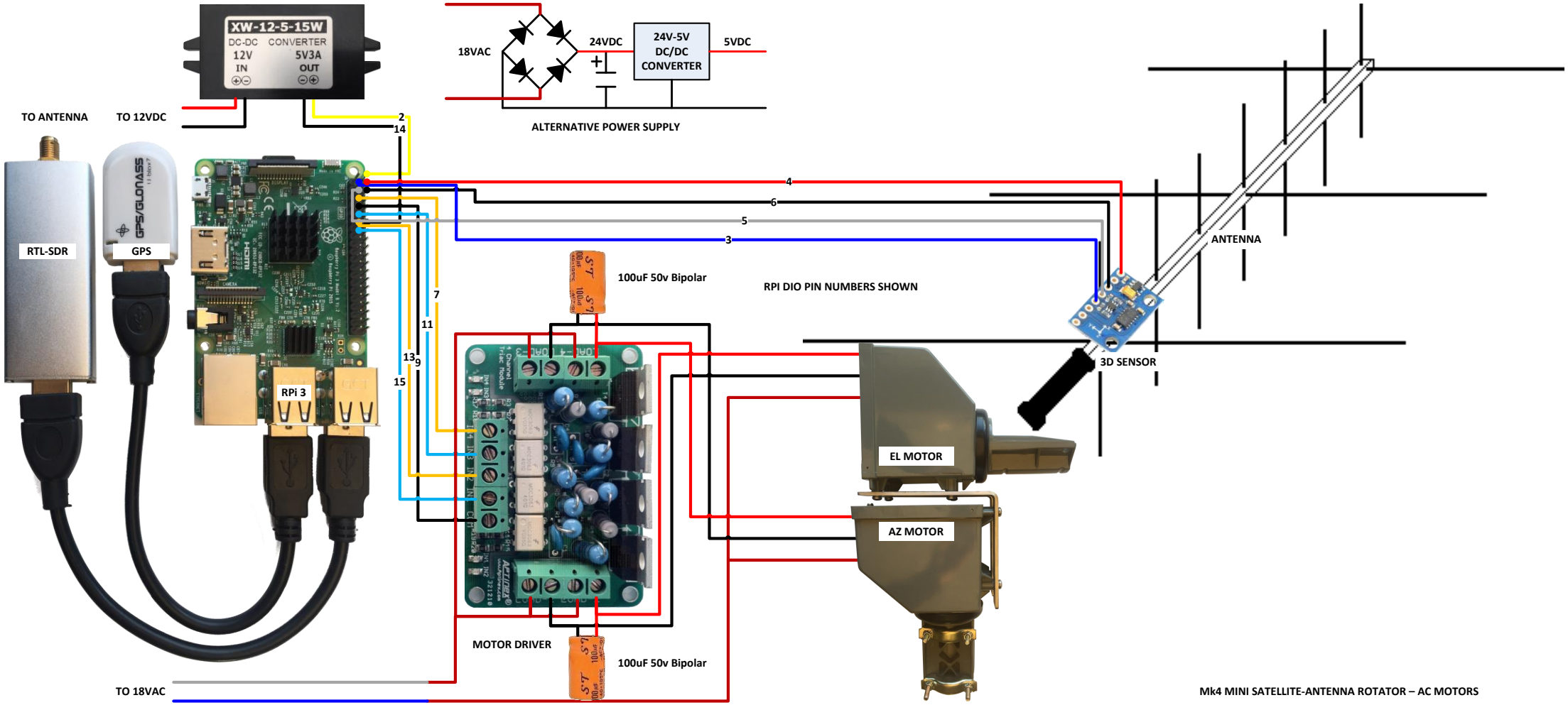
Hardware – Miscellaneous

- USB cables for SDR and GPS
- Right Angle Jack for Audio
- SDHC Memory Card for RPi

Pictorial Schematic Diagram - Mk3



Pictorial Schematic Diagram - Mk4



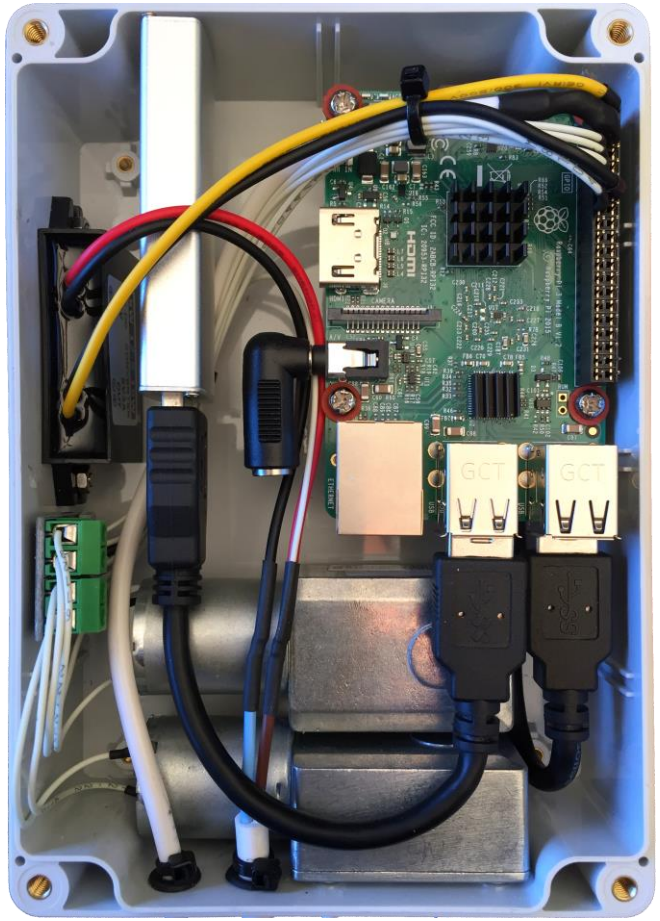
Cost – Mk3 Rotator

• Raspberry Pi 3	$ 65.15 – Pi Australia incl P&P
• RTL-SDR Dongle (US$20.95)	$ 28.17 – https://www.rtl-sdr.com
• Enclosure Sealed Polycarbonate HB6218	$ 19.95 – Jaycar
• GPS U-blox7 VK-172	$ 10.20 – eBay
• Motors 12V 0.6RPM Right Angle	$ 9.99 – eBay
• Micro SDHC card (>=8GB) + adapter	$ 9.95 – Officeworks (16GB)
• Battery Holder	$ 3.75 – Jaycar
• 3D Sensor LSM303DLHC	$ 3.19 – eBay
• DC/DC Converter 12V-5V 3A CPT-UL-1	$ 2.86 – eBay
• USB Extension Cables (2)	$ 1.14 – eBay
• Motor Driver L9110S	$ 1.00 – eBay
• Total Cost (Approx)	$150.00

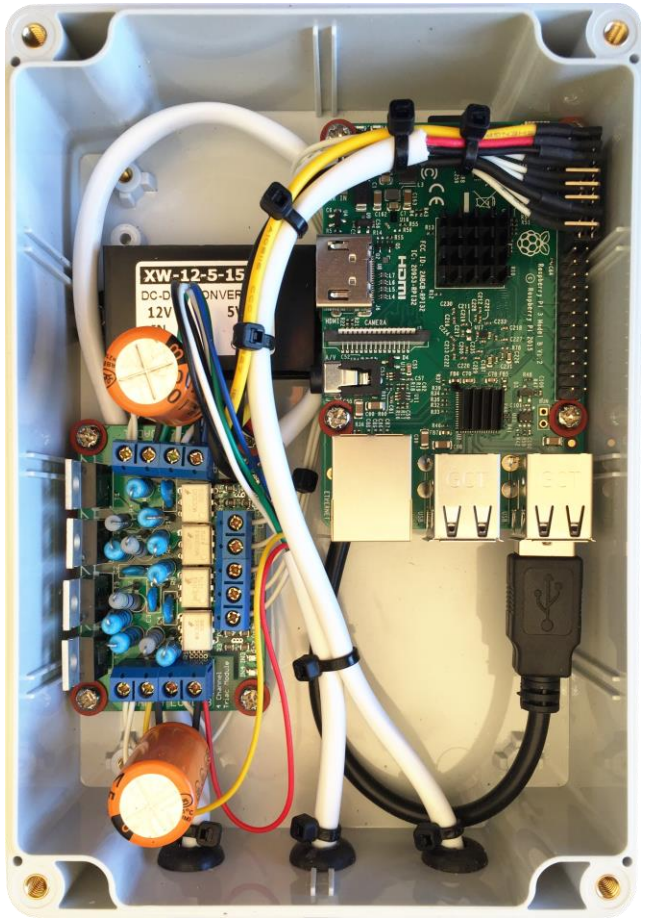
Cost – Mk4 Rotator

• ChannelMaster TV Antenna Rotators (2)	$390.00 – Radio Parts (2)
• Raspberry Pi 3	$ 65.15 – Pi Australia incl P&P
• Right Angle Bracket 150x175x30x5mm (2)	$ 38.00 – Bunnings
• Enclosure Sealed Polycarbonate HB6218	$ 19.95 – Jaycar
• GPS U-blox7 VK-172	$ 10.20 – eBay
• Micro SDHC card (>=8GB) + adapter	$ 9.95 – Officeworks (16GB)
• 100uF 50VAC Bipolar Capacitors (2)	$ 5.50 – Altronics
• 3D Sensor LSM303DLHC	$ 3.19 – eBay
• DC/DC Converter 12V-5V 3A CPT-UL-1	$ 2.86 – eBay
• USB Extension Cables (2)	$ 1.14 – eBay
• Motor Driver Aptinex 4ch Triac (2)	$ 1.00 – eBay
• Total Cost (Approx)	$550.00

Assembly



Mk3 Mini Satellite-Antenna Rotator



Mk4 Mini Satellite-Antenna Rotator

Software – Object Oriented Python

- Tracker.py is original software written for Python 2.7.9 and includes:
- GnuRadio Library by Ben Hilburn et al
  - Only works with Python 2, but not Python 3 yet
- PyEhem Library by Brandon Rhodes from XEphem by Edward Downey
  - Basic astronomical calculations including earth satellites
  - Includes SGP4/SDP4 Orbital Element Propagation Model
    - Spacetrack Report #3 (1980) Dr. T.S. Kelso (see www.celestrak.com)
    - Revisiting Spacetrack Report #3 (2006) Vallado, Crawford et al
- All SARCNET software is free. Distributed under the GNU GPL3

Software – Files

- tacker.py – Python script
- settings.txt – Configuration settings in Python dictionary format
- elements.txt – Satellite orbital element file names
- freqmode.txt – Satellite uplink/downlink frequency and mode data
- location.txt – Last known GPS location including error
- rejected.txt – List of satellite names to be rejected
- rotorcal.txt – 3D sensor calibration data
- selected.txt – Last selected satellites
- Files are in readable Python list format [‘ ‘ , ‘ ‘ , ‘ ‘]

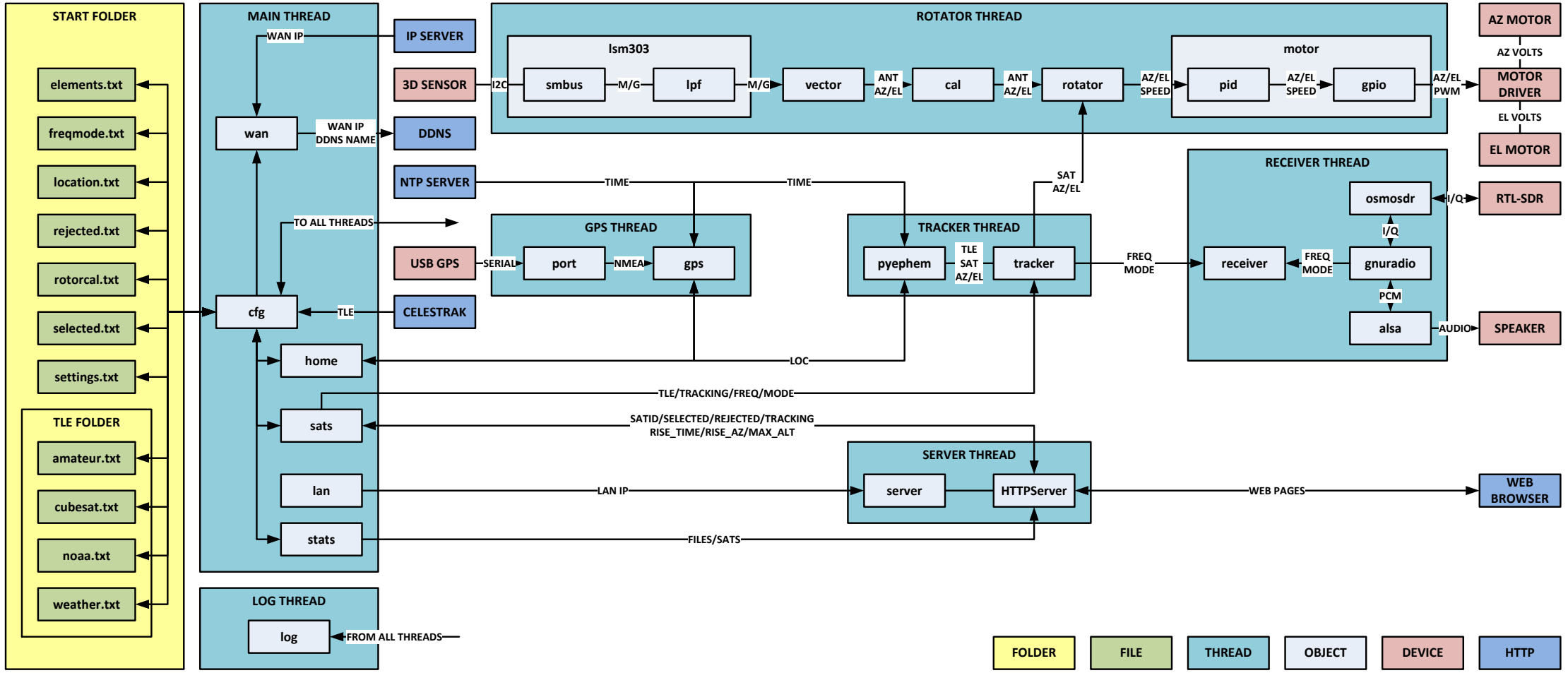
Software – Threads

- Main: Configures rotator and starts all other threads
- Log: Thread-safe logging of all events
- GPS: Updates time and location
- Rotator: Positions the antenna
- Receiver: Built-in SDR receiver
- Tracker: Built-in satellite tracker
- httpServer: Web server

Software – Objects

- cfg: Loads/Updates system configuration from files
- lan: Gets Local Area Network IP Address
- wan: Gets Wide Area Network IP Address (Static/Dynamic)
- vector: Cartesian vector arithmetic
- lsm303: Magnetometer/Accelerometer Interface (2-types supported)
- cal: 3D sensor calibration
- lpf: Low Pass Filter for sensors
- pid: Proportional, Integral, Differential controller for motors
- motor: Motor driver (3-types supported)
- port: Serial port driver
- home: PyEphem Observer

Software – Block Diagram



Setup

Operation – Start Up 1

Started:2018-06-16 17:14:58.110113 — Logging thread starting time

Load configuration files:
Loaded:settings.txt
Loaded:rotorcal.txt
Loaded:elements.txt
Loaded:selected.txt
Loaded:rejected.txt
Loaded:freqmode.txt
Loaded:location.txt

Download orbital element files:
Loaded:https://celestrak.com/NORAD/elements/amateur.txt
Loaded:https://celestrak.com/NORAD/elements/weather.txt
Loaded:https://celestrak.com/NORAD/elements/cubesat.txt
Loaded:https://celestrak.com/NORAD/elements/noaa.txt

Load saved orbital element files:
Loaded:./TLE/weather.txt
Loaded:./TLE/noaa.txt
Loaded:./TLE/cubesat.txt
Loaded:./TLE/amateur.txt

Operation – Start Up 2

45 Weather satellites loaded.
22 Noaa satellites loaded.
138 Cubesat satellites loaded.
66 Amateur satellites loaded.
49 Frequencies matched.
26 Duplicates removed.
50 Satellites rejected.
195 Satellites available.

Process orbital element files and display statistics

Operation – Start Up 3

LAN:192.168.1.17 } LAN IP Address
WAN:115.70.0.199 } WAN IP Address
DDNS:nochg } Update DDNS with Domain name and IP Address – No change since last update
Created:observer
Address:9 Mead Ct, Oakleigh VIC 3166, Australia } Google™ reverse geocode lookup result
Latitude:-37.9074318333°
Longitude:145.092346333°
Altitude:68.7m
Error:4.0m } Last saved GPS position information
Opened:gps:/dev/ttyACM0
Started:gps
GPSdate:2018-06-16 07:15:13
GPStime:0.056334s } GPS Time update

Operation – Start Up 4

Started:rotator
Stopped:gps
len(audio_taps) = 231
Started:receiver
Started:tracker
Started:server

Start remaining independent processing threads
GPS thread is stopped since error < 5m

Operation – Start Up 5

Next:JAS-2(FO-29) in 7m 49°az 29°max
Next:JAS-2(FO-29) in 6m 49°az 29°max
...
Next:JAS-2(FO-29) in 1m 49°az 29°max
Next:JAS-2(FO-29) in 0m 49°az 29°max

Next satellite prediction is updated each minute

AOS:JAS-2(FO-29)

Acquisition Of Signal for FO-29

Tracking:JAS-2(FO-29) 49°az 0°el
Tracking:JAS-2(FO-29) 50°az 0°el
Tracking:JAS-2(FO-29) 50°az 1°el
...
Tracking:JAS-2(FO-29) 114°az 29°el
Tracking:JAS-2(FO-29) 115°az 29°el
Tracking:JAS-2(FO-29) 116°az 29°el

...
Tracking:JAS-2(FO-29) 182°az 1°el
Tracking:JAS-2(FO-29) 182°az 0°el

Tracking FO-29 update when AZ or EL changes

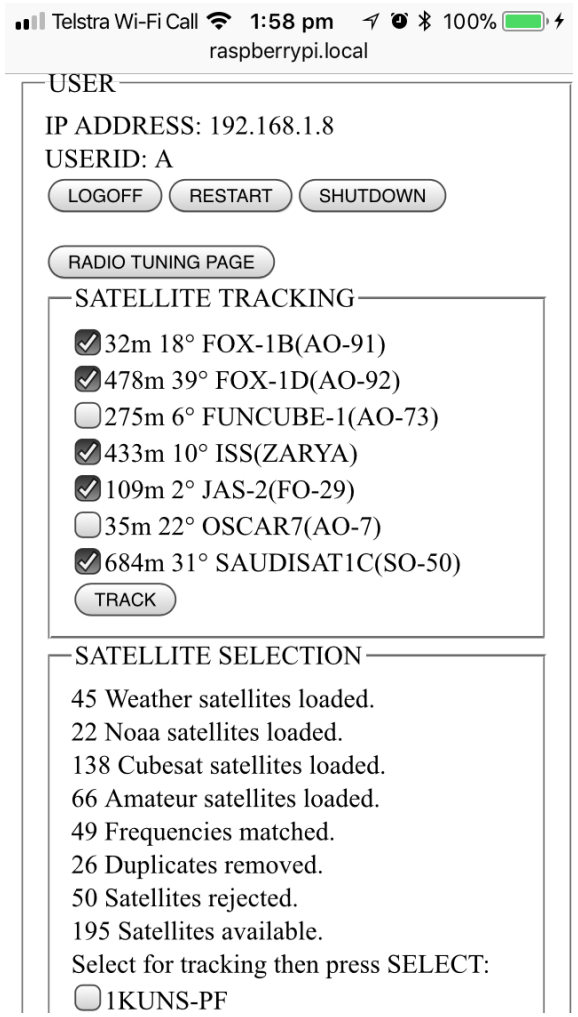
LOS:JAS-2(FO-29)

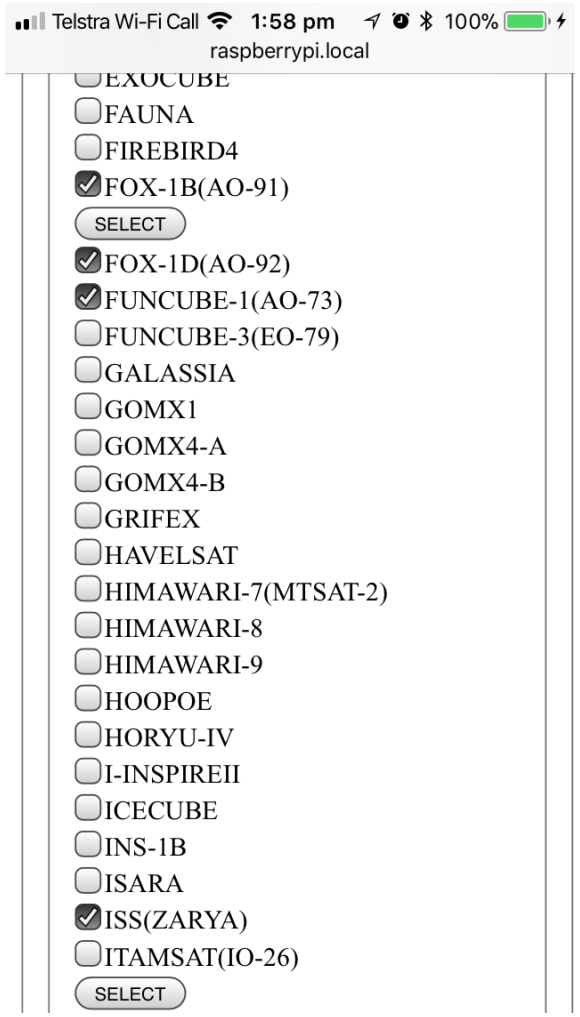
Loss Of Signal for FO-29

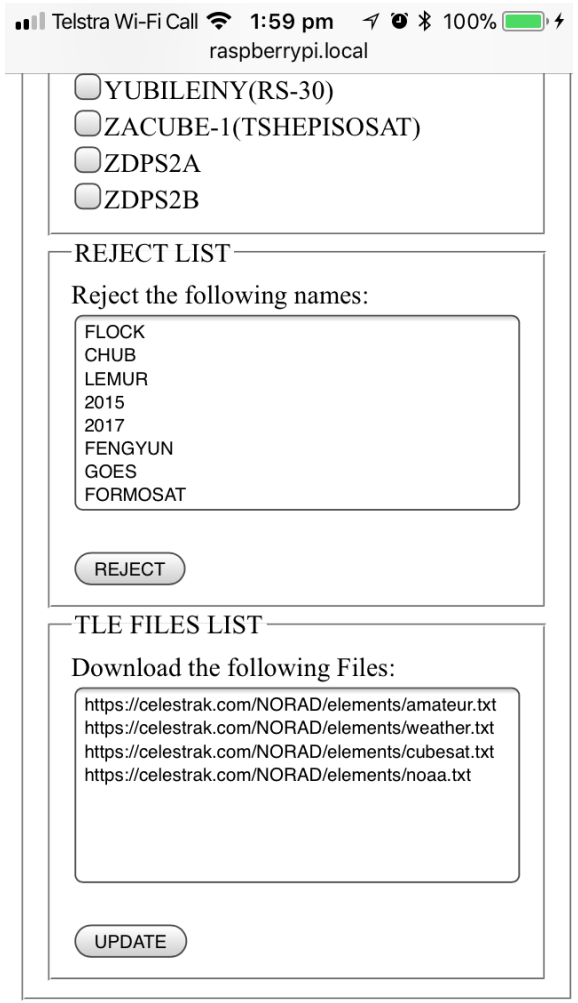
Next:JAS-2(FO-29) in 86m 357°az 49°max
Next:JAS-2(FO-29) in 85m 357°az 49°max

Next satellite prediction is updated each minute

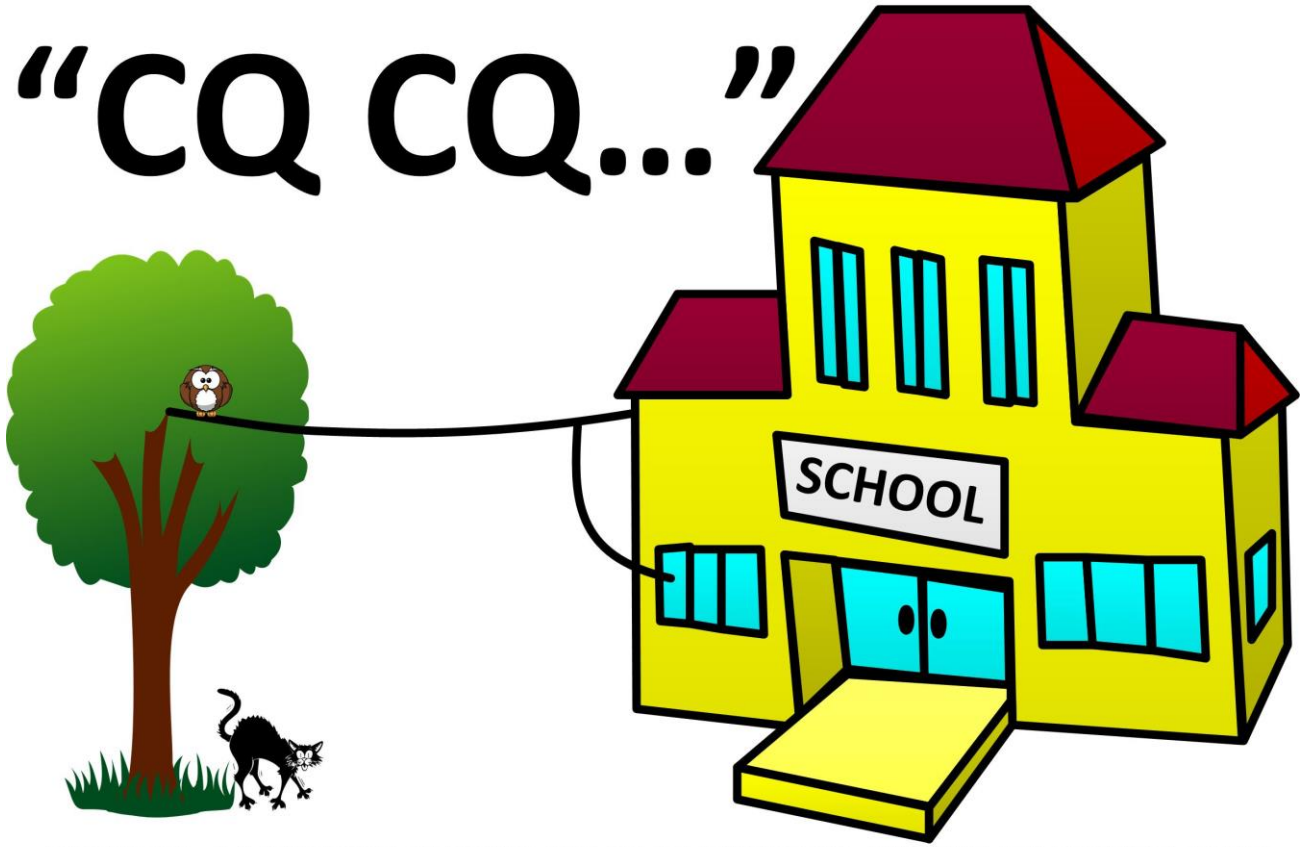
Operation – Web Page







Tracking – AO-91

Tracking – FO-29

The End – Thank You