

Amateur Radio Balloons

By KB7HTA

- High Altitude Balloons



- Bill launched his first balloon into the Stratosphere carrying an Amateur TV transmitter and 2m beacon 33 years ago and has been instrumental in using ARHAB flights to encourage STEM education. He has flown over 600 flights since 1987.
- These balloons are made of latex 8-28'
- Can achieve altitudes above 80,000'
- Recoverable payloads with repeaters, APRS, ATV and cameras



Pico/Floater Balloons

- Light weight – Less than 90 grams (3 oz.)
- Achieve altitudes of 35,000 – 55,000'
- Move with the winds 0 – 200+ MPH
- Balloon – Usually 32" in dia.
- Filled with Helium or Hydrogen gas
- GPS – Lightweight processor
- CPU – Low power with flash and RAM
- Transmitter(s)
- Solar Panels
- Structure
- Software

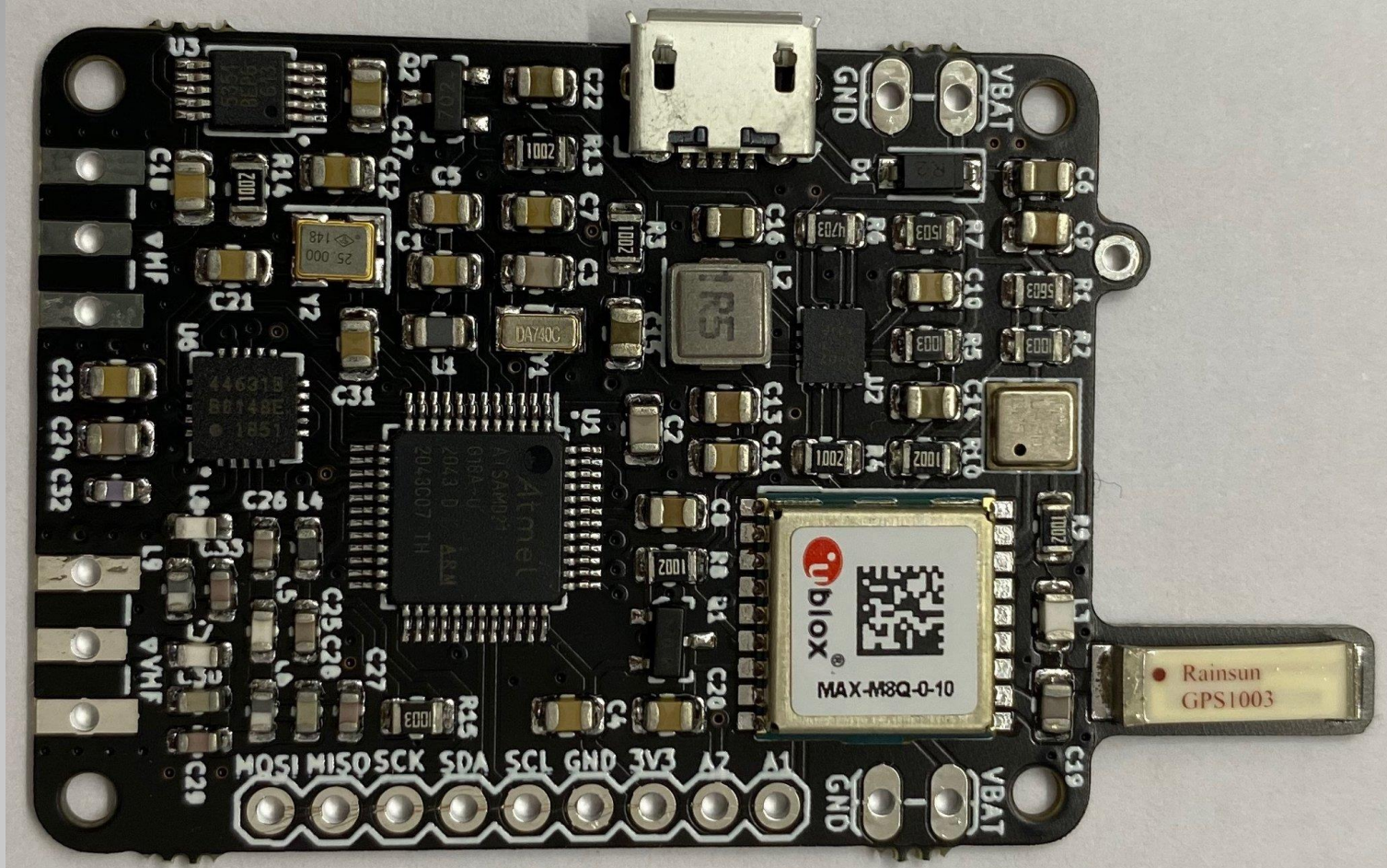
- An unmanned free balloon ARHAB may carry a single payload package that weighs up to six pounds
- An unmanned free balloon ARHAB may carry two or more payload packages that weigh up to 12 pounds.
- An unmanned free balloon ARHAB may carry a payload package that weighs up to four pounds and has a weight/size ratio of no more than three ounces per square inch on any surface of the package, determined by dividing the total weight in ounces of the payload package by the area in square inches of its smallest surface.

FAA Balloon Flight Regulations

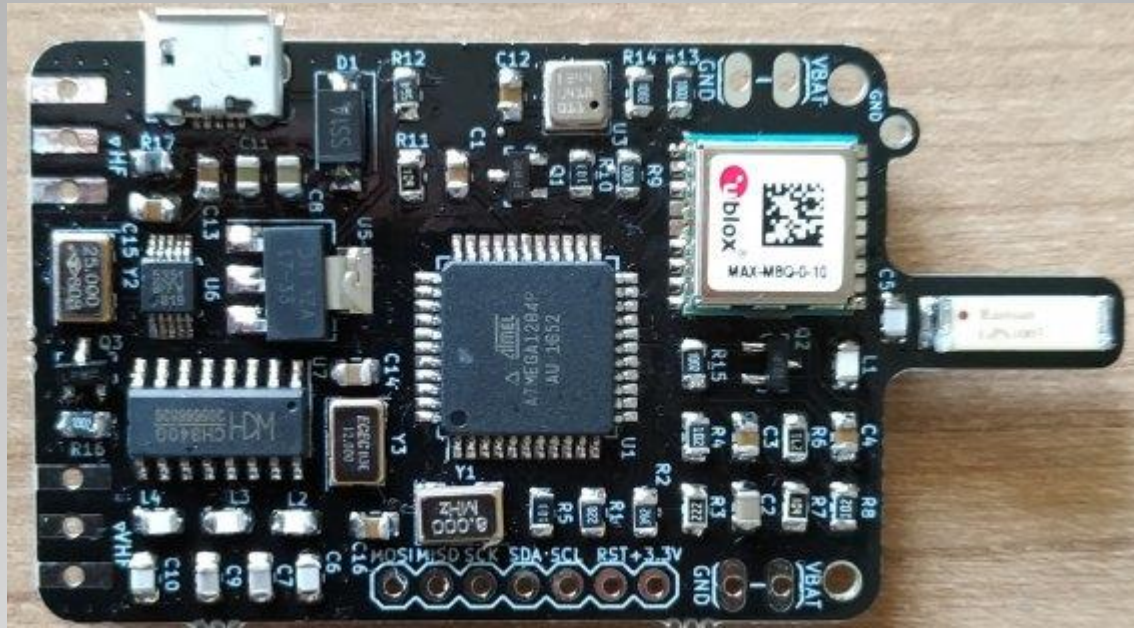
- You cannot launch a balloon ARHAB from an airport without permission.
- You need to be able to see 5 miles (visibility), have no more than 50% cloud cover at launch and across your entire flight path.
- You cannot fly over a town or open-air group of people for the first 1,000 feet of (vertical) flight.
- Your balloon and its payload cannot be a hazard to people if it should hit them.

- Bottom line -- Pico balloons are not ARHABs, because of their light weight, are exempt from [14 CFR 101](#) that regulates balloons.
- Some countries don't allow transmissions from balloons, so Pico Balloons following the rules have to geo-fence their transmissions.
- Bottom line – Opinion: As a US operator no one here in the UK is going to trouble you because you're transmitting a WSPR signal in UK airspace. As far as North Korea...nIn

FAA and Other Regulations



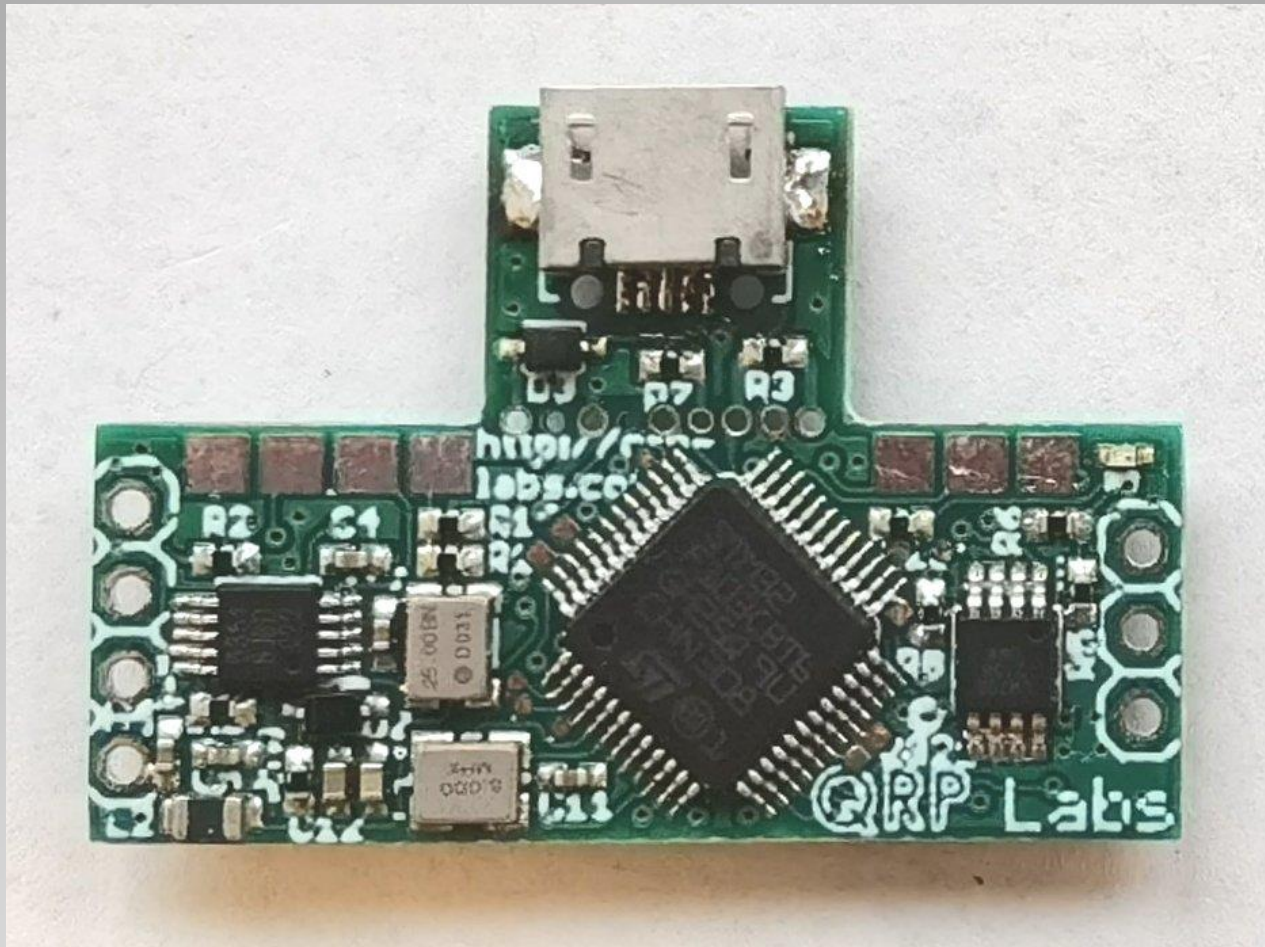
Comercially Available Trackers



QRP LightAPRS-WSPR Tracker

- **Software:** Open Source
- **Weight:** 9 grams
- **Dimensions:** 3.5 cm x 6 cm
- **IDE:** Arduino
- **Platform:** MightyCore
- **CPU:** Atmega1284P-AU
- **Flash:** 128 KB
- **Ram:** 16 KB
- **EEPROM:** 4 KB
- **Operating Frequency:** 8 MHz
- **Operating Voltage:** 3.3V
- **Input Voltage:** 4.5V (min) - 10V (max) via USB or VBat pin
- **BOD:** 2.7V
- **Sensor:** BMP180 (pressure and temperature)
- **VHF Radio Module:** [Dorji DRA818V](#)

- **VHF Radio Operating Frequency:** 134-174 MHz (configurable by software)
- **VHF Low Pass Filter:** Available (7 elements)
- **VHF Radio Power:** 0.5W or 1W (configurable by software)
- **VHF Power Consumption (TX):** ~460 mA (0.5W) / ~760mA (1W) (Automatically selected based on input voltage by code)
- **HF Radio Module:** Si5351A-B-GT (included)
- **HF Radio Operating Frequency:** 2.5kHz - 200Mhz (configurable by code)
- **HF Low Pass Filter:** No
- **HF Radio Power:** ~10mW
- **Power Consumption (Sleep):** ~5 mA
- **GPS:** [Ublox MAX-M8Q](#) (GPS-GLONASS)
- **Gps Antenna Gain:** 4.3dBi
- **Extended Pins:** I2C, SPI
- **USB Serial:** CH340G
- Cost -- \$130 plus shipping from Turkey

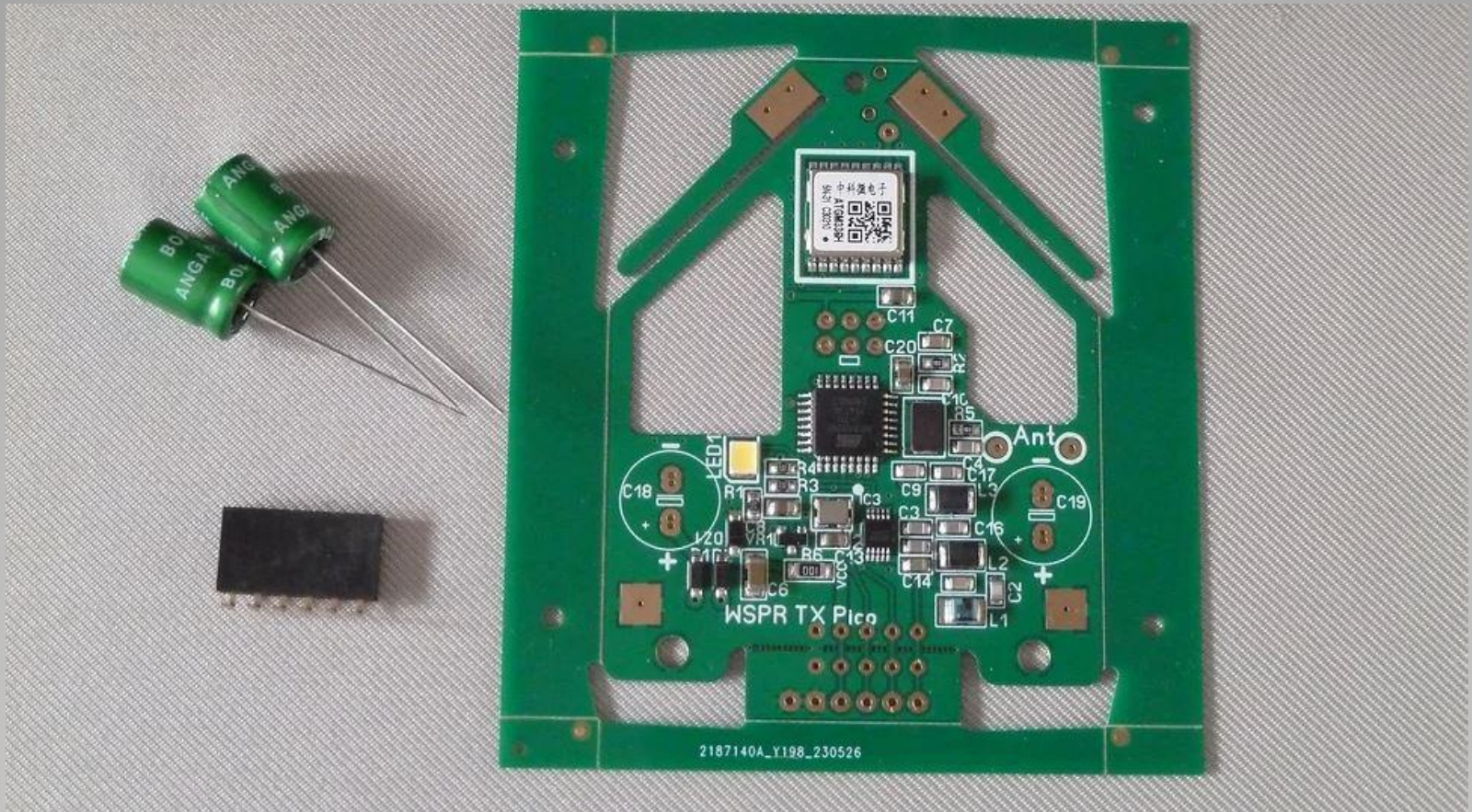


QRP Labs – U4B Tracker

- 33.0 x 12.7mm PCB (plus removable protrusion with USB connector)
- Weight: 1.8g (with USB protrusion removed)
- Onboard high performance GPS receiver
- 32-bit ARM microcontroller running QDOS (QRP Labs Disk Operating System)
- 128K disk (implemented on EEPROM chip)
- 10-27mW (approximately) transmitter using Si5351A synthesizer
- TCXO referenced frequency stability
- Band coverage 2200m to 2m
- LM75 temperature sensor
- Status LED
- USB interface for configuration, programming and easy firmware update (just copy the new firmware file into the apparent USB Flash drive)

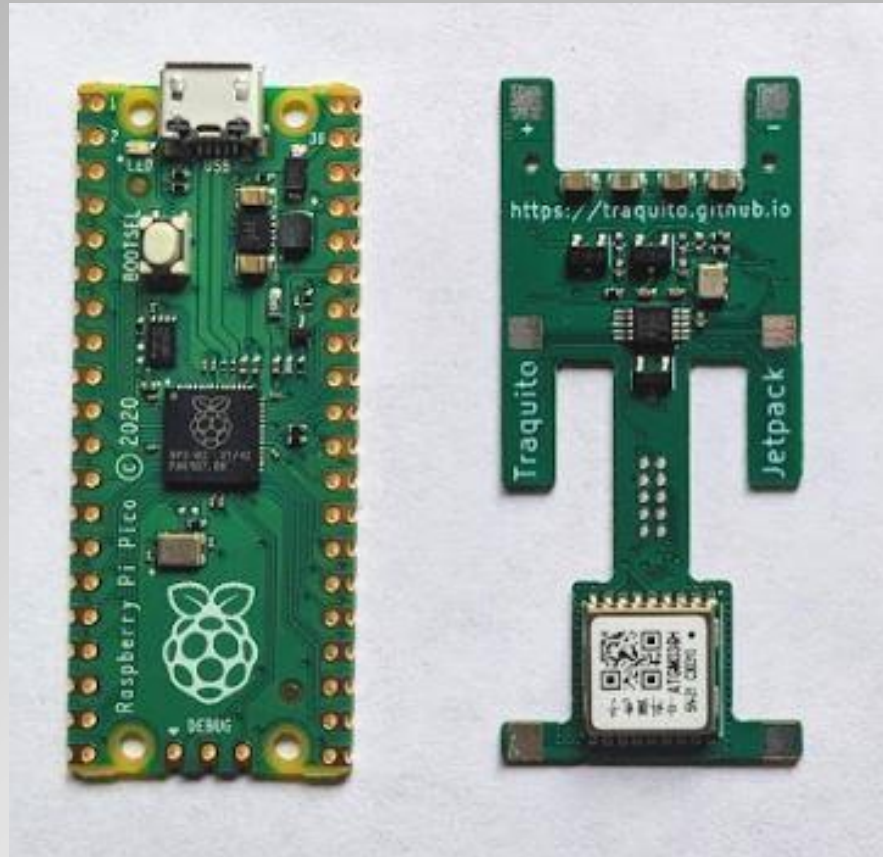
- 19 GPIO pins – of which 9 can be configured as analog inputs and 8 are easily accessible via PCB edge pads; all 19 can be used as digital input or output control pins
- I2C bus for connecting additional sensors e.g. pressure, humidity
- BASIC programming language with full-screen text editor, compiler and debugger
- 128K Disk storage for your programs and data; BASIC can read/write data files
- Command line utility
- Telemetry over WSPR for relaying your additional sensor data

- Free firmware updates for life, when enhancements are developed as the use cases expand
- QRP Labs tracking and telemetry over WSPR
- WSPR (including extended mode and slow 15-minute WSPR)
- JT9 (1, 2, 5, 10, 30 minutes)
- JT65 (modes A, B, C)
- Hellshreiber (standard, DX, and slow multi-tone FSK)
- CW (standard speed, QRSS, FSKCW and DFCW)
- Customized “Glyph” patterns can produce a unique identifier on QRSS
- Cost -- \$56.09 plus shipping from Turkey



ZachTek WSPR-TX Pico Tracker

- Low power 20mW autonomous shortwave WSPR transmitter for the 20m and 30m Amateur bands that continuously transmits its position and altitude during daylight.
- Onboard GPS module and antenna calculates position and altitude.
- Arduino compatible Micro-controller with open-source software and Phase-Locked-Loop oscillator with Lab-calibrated Temperature Compensated Crystal reference Oscillator (TCXO) generates transmissions.
- Weight 5.4gram (Without solar cells, HF antenna and balloon harness)



Traquito Tracker

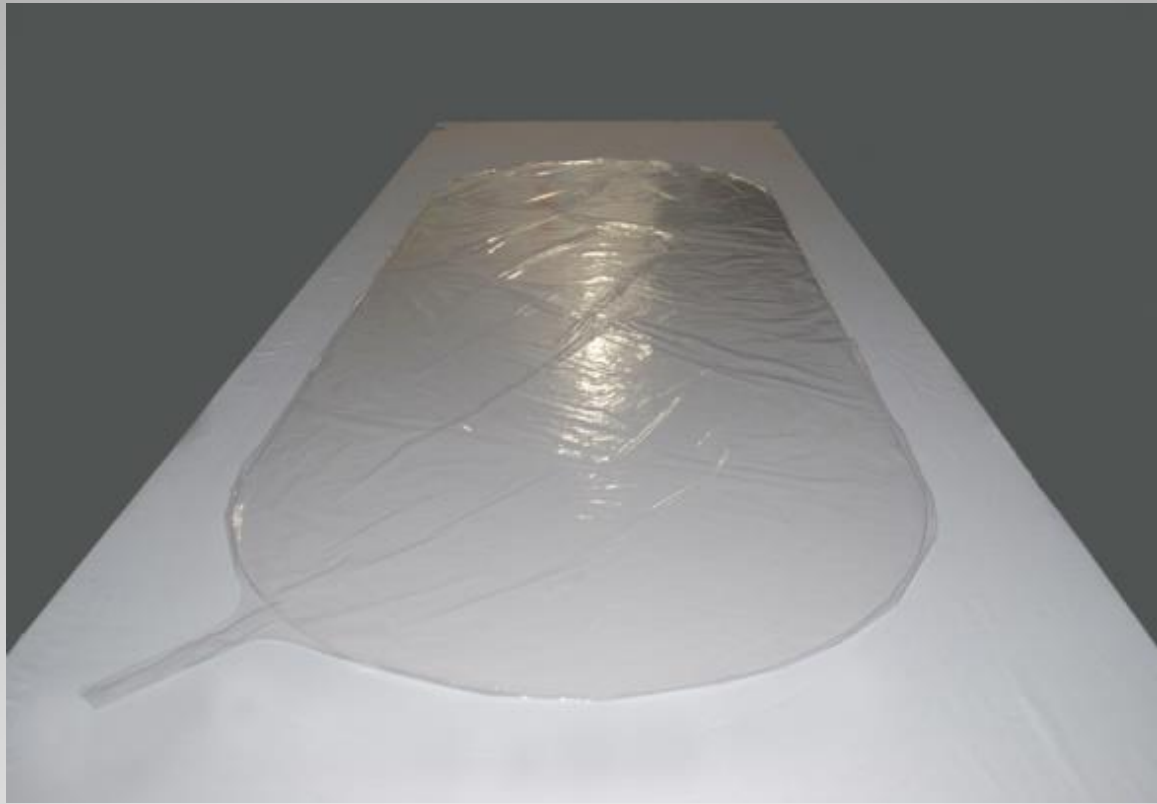
- RP2040 CPU
- Flash Memory
- Temperature sensor
- USB and support for Drag/Drop software upload
- GPS (ATGM336H)
- Radio Transmitter (SI5351A) + 0.5ppm TCXO
- Voltage Monitor
- Jetpack requires a maximum of 70mA at 3.3v to operate.
- Fixed programming
- Cost -- \$5.00 Pi + \$10.00 JetPack



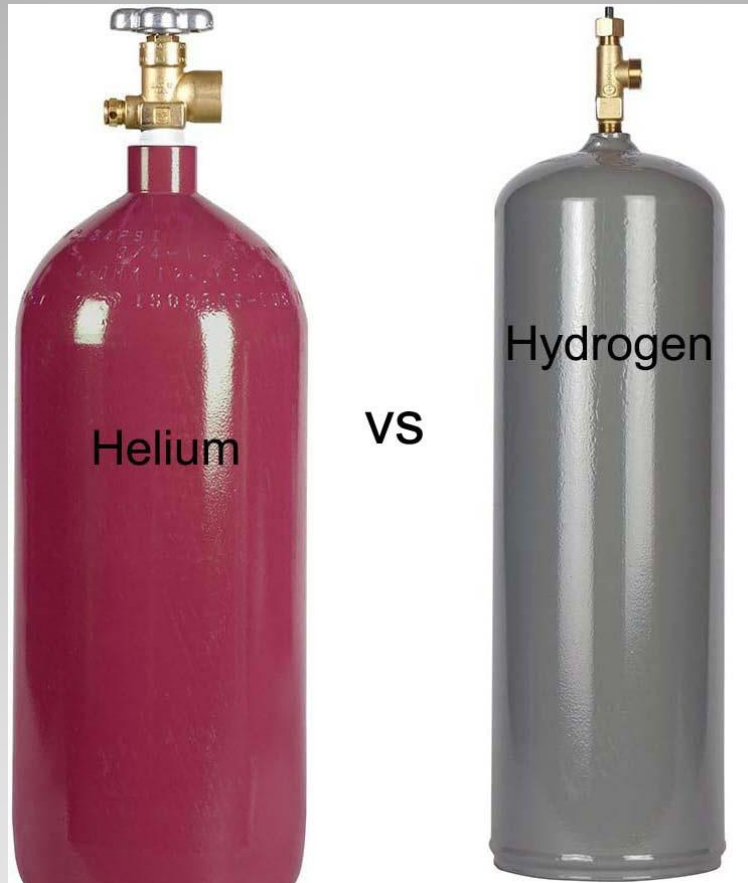
Yokohama 32" Balloon \$29



SAG 32" Balloon \$15



SBS Balloon - (3' W X 7.5' L) \$150



Best Balloon Gas to Use

- Non-Flammable
- Atom is 11% smaller, leaks
- 8% less lift
- Difficult acquire 100% pure
- Expensive

Helium

- Flammable
- Molecule 11% bigger, doesn't leak
- 8% more lift
- Easy to acquire
- Inexpensive

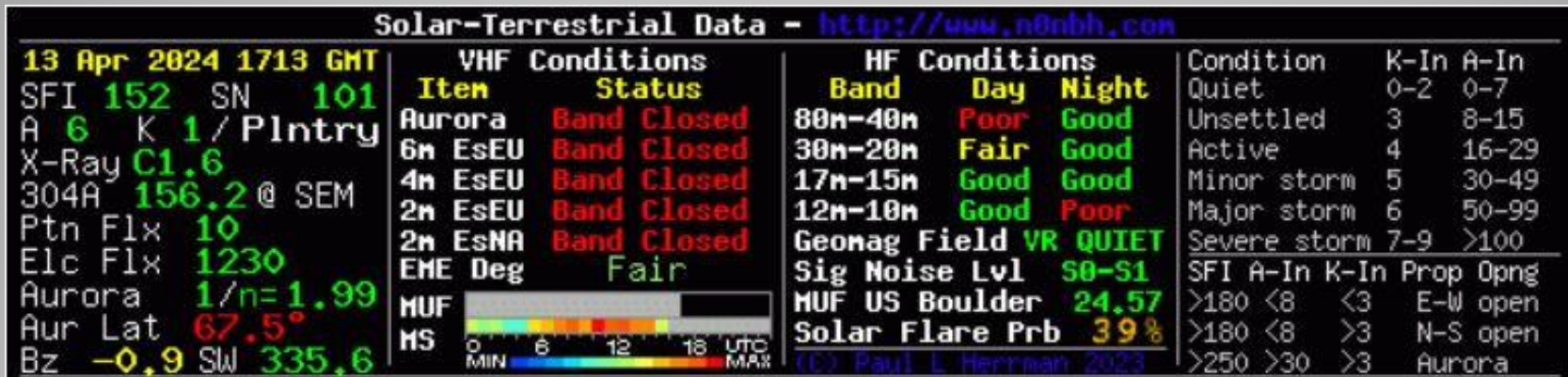
Hydrogen

- Transmitter design
- Power Output
- Band selection – 40, 20, 17, 15, 12, 10m
- Mode of transmission
- Antenna design

Getting the Signal Out

- The Silicon Labs Si5351, chip of choice
- I2C Programmable
- Each of 8 outputs 0 ppm error
- Replaces crystals
- Generate any frequency up to 160 MHz
- Output impedance 85 Ohms
- Operates on 3.3 Volts at 25 mA
- Power output, 13 - 30 mW
- Small footprint 3 x 5 mm
- Lightweight 0.2 gram

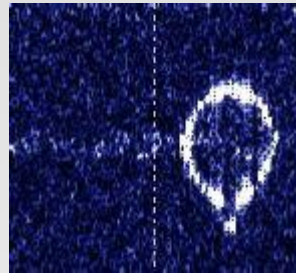
Transmitter Design



- Traditionally the balloons use the 20 m band
- More balloonists are now using 10, 12, 15 17 m
- TALARC ALPP40-A transmits on the 10 m band
- Balloons are only powered in daylight, so 10 m is OK
- TALARC ALP40-B had a battery, so it used 20 m

Band Selection – Propagation

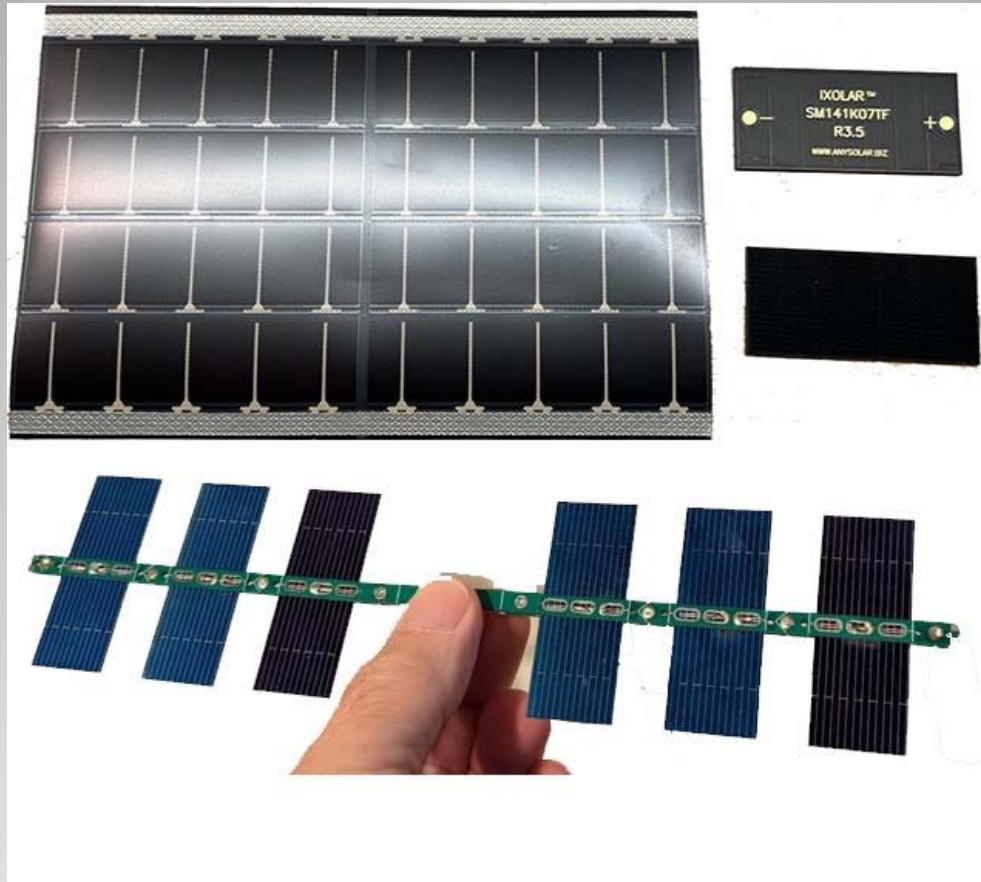
- WSPR is used as the primary mode
- CW is used as a secondary
- QRSS used for sending glyphs
- The modes above send little data
- FM APRS for line of sight secondary
- Other modes are under consideration



Mode of Transmission

- A dipole is the best choice for HF
- One copper wire goes up to the balloon
- The other dangles beneath the payload
- A trapped dipole is being looked at...Rudi
- The GPS has 1" twisted (six turns) #28 gauge wire and dipole lengths of 45 mm receiving antenna

Antenna Design



Solar Panels

- 10-20% more efficient at altitude
- Small commercially made panels
- Panels supply 4 – 7 Volts @50 – 100 mA
- Various sizes and masses
- Thin film (10%) & monocrystalline (25%)
- -----
- Construct panels from individual cells
- Cells supply 0.5 Volts @ 50 – 200 mA
- Various sizes and masses
- Cells are used to make custom panels
- Connected in series to get desired voltage

- Helps stabilize voltage and current for operation sunrise to sunset or at night
- Super Capacitor
 - Large number of charge/discharge cycles
 - Larger temperature range
 - Lower energy density
- Lithium Battery
 - Small number of charge/discharge cycles
 - Smaller temperature range
 - Higher energy density

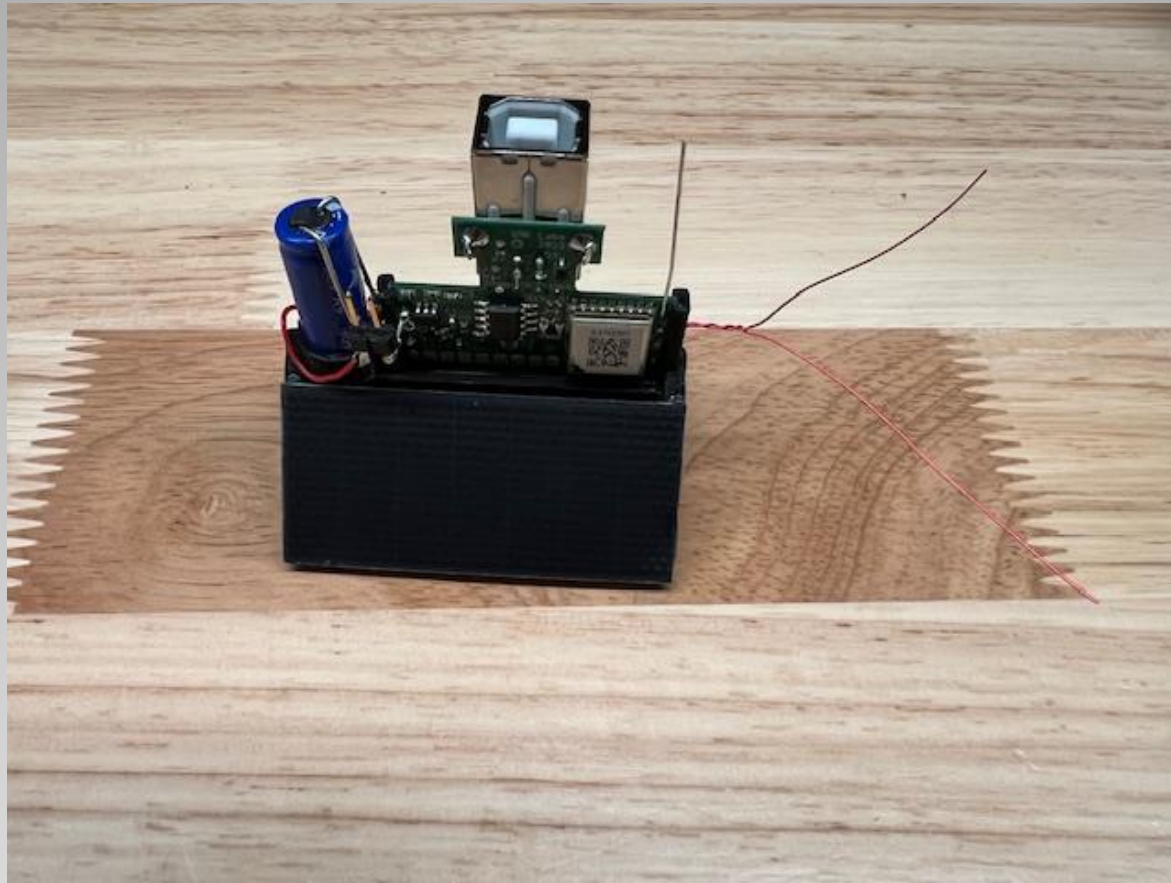
Payload Energy Storage

- Styrofoam
- Carbon fiber
- 3D Printed ABS plastic
- Composite

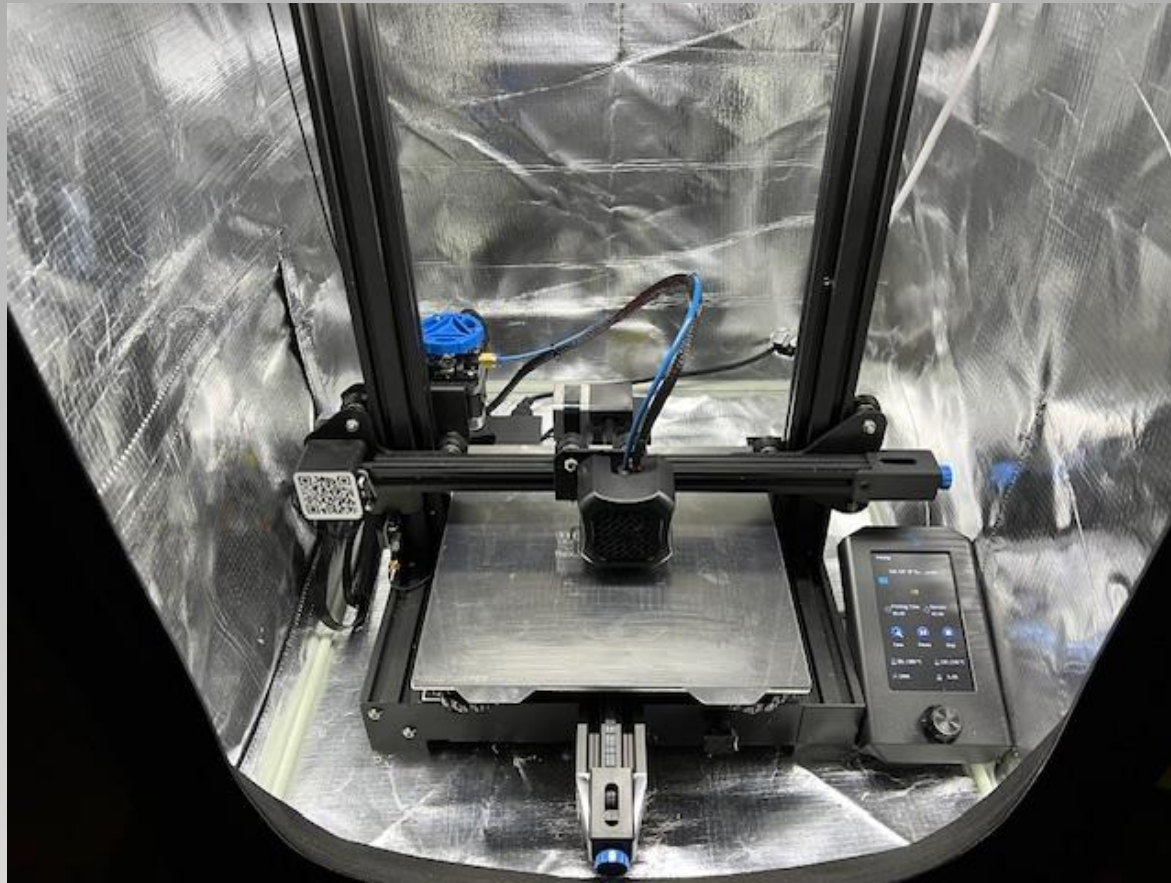
Payload Structure

- It's time to construct a balloon
- Pick items from what has been presented
- Take a deep breath and start construction

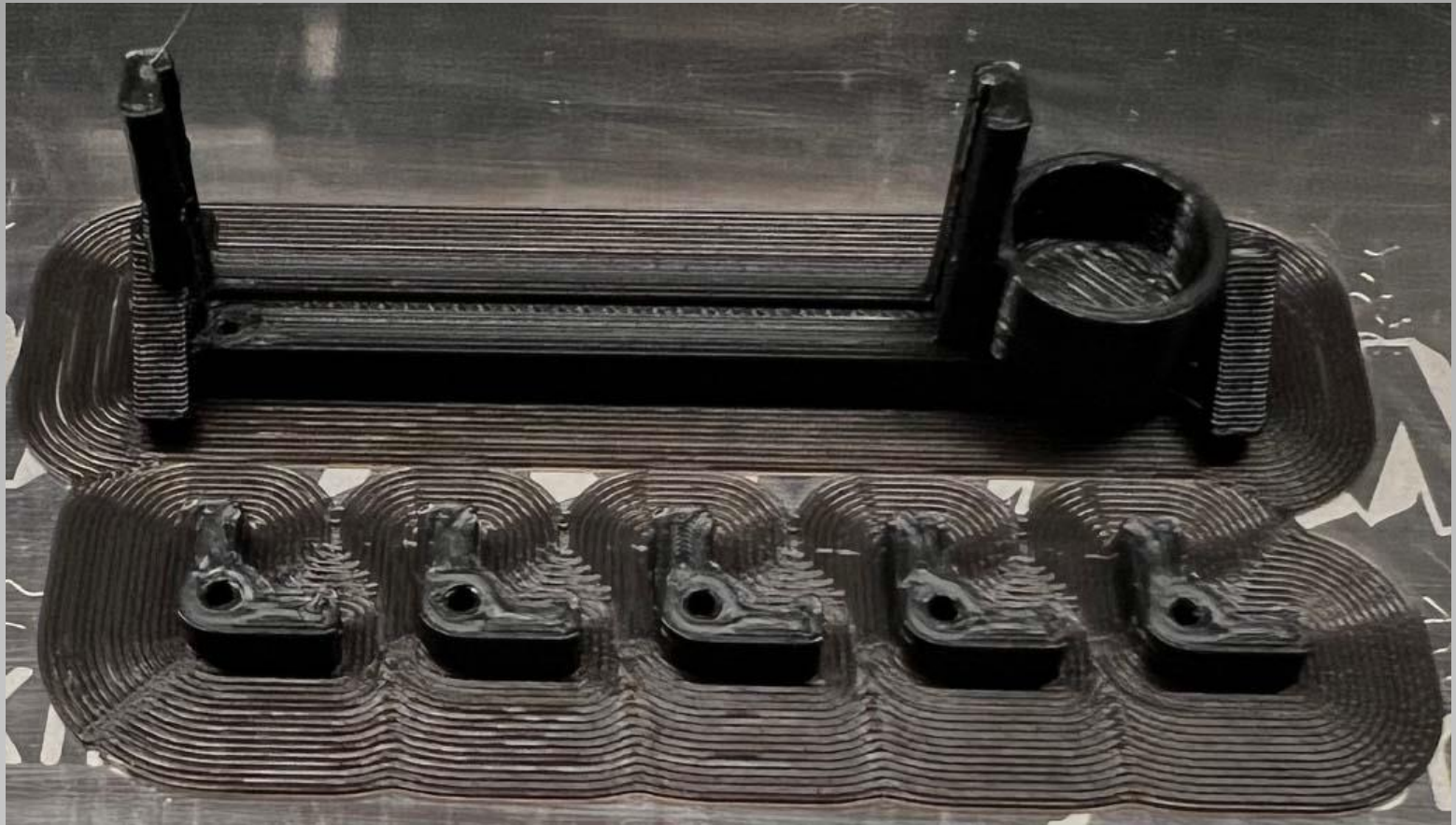
Putting It All Together



TALARC ALP40-A Balloon Construction



3D Print ABS Structure Parts



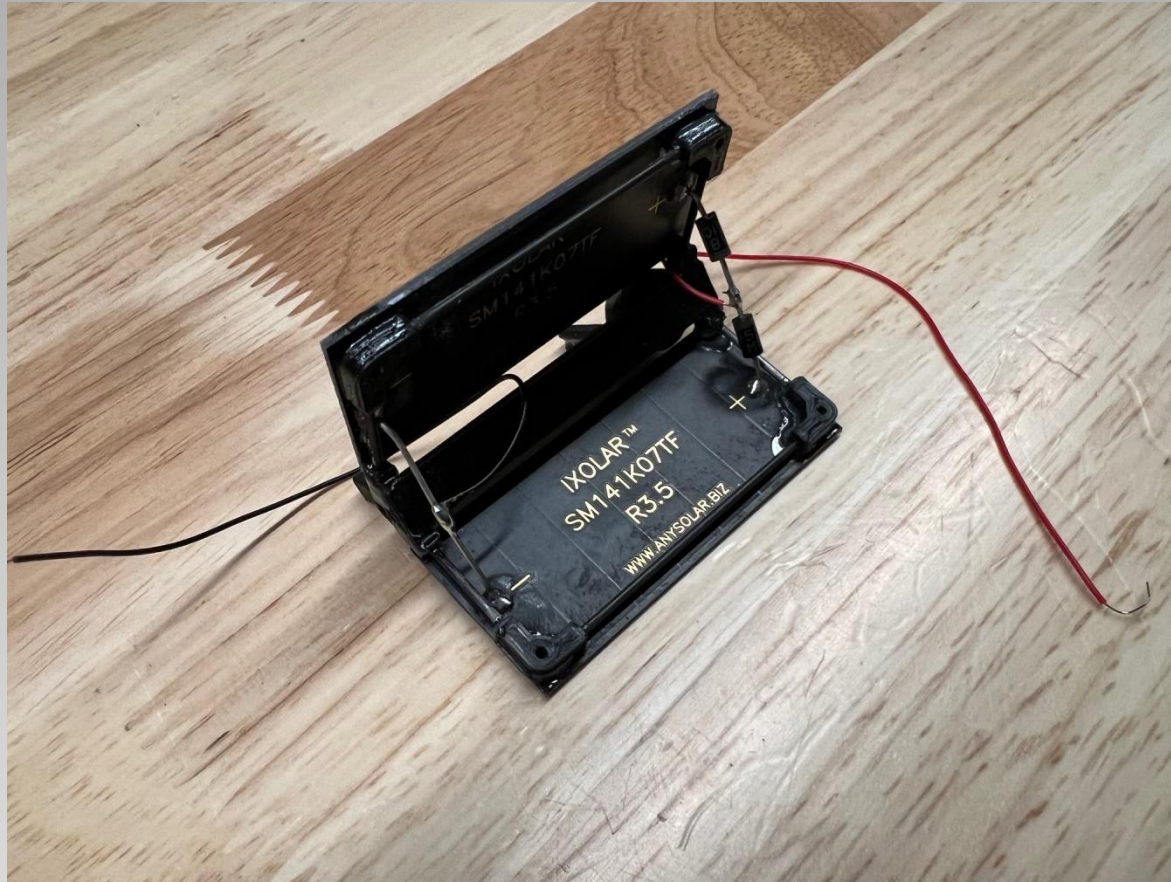
ALP40-A Type Structure



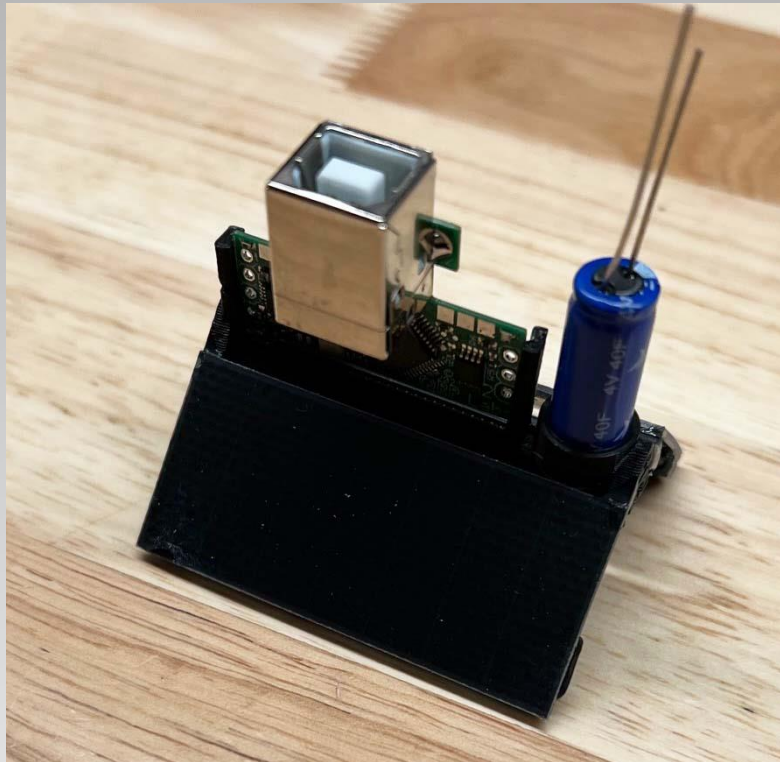
Completed Structure



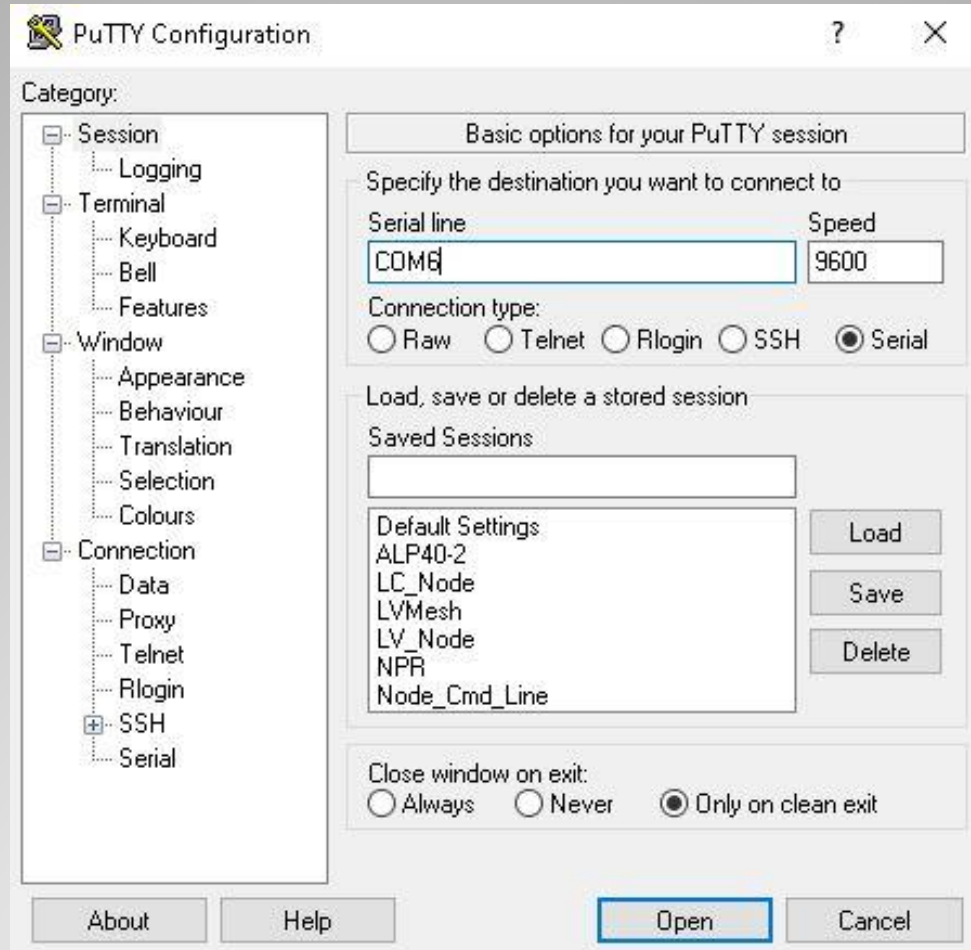
Gather the Components



Glue and Wire Solar Panels



- Insert U4B into plastic slot
- Solder supercapacitor and its Zener diode with jumper to PCB
- Construct and add GPS antenna to PCB
- Add 1" #28 gauge copper wires to PCB for connecting dipole
- Connect solar panel wires to PCB



Connect U4B to USB-PC-Putty

U4B 0_38_001
QRP Labs, 2022

Configuration

Run program
Text editor
File manager
Command line
Hardware test
Factory reset
Update F/W

```
+---Configuration+  
Callsign      GOUPL  
Band          20m  
Channel       536  
Autostart program TRACKER  
  
Frequency     14097180  
Telemetry format QX6XXX XXXX XX  
Start minute  00  
  
Use left & right arrow keys to  
change Band and Channel.  
+---Ctrl-Q = Quit---
```

Set Callsign, Band and Channel


```
/
Name      Type  Size  Blocks  Start  Compiled
..
TRACKER   TEXT  23    1        1      Yes

Ctrl-C = Copy      Ctrl-X = Cut      Ctrl-V = Paste    ENT = Enter/Up Dir
F = New file       D = New directory R = Rename       DEL = Delete
E = Edit file      V = View file     Ctrl-D = Disk Mgr Ctrl-Q = Quit
```

SSD (EEPROM) File Manager

U4B 1_00_002
QRP Labs, 2022

Configuration
Run program
Text editor
File manager
Command line
Hardware test
Factory reset
Update F/W

```
+---Hardware test-----+
| Date          27-APR-22      GPIO 0    0    1945
| Time          09:11:56      GPIO 1    1    2063
| Si5351A TX    OK            GPIO 2    0    1981
| LM75 temp    310 K          GPIO 3    1    2097
| Battery      4.54 V         GPIO 4    0    1980
| System freq. 8001318        GPIO 5    1    2105
| TCXO freq.   25000000       GPIO 6    0    1985
|              |             GPIO 7    1    2086
|              |             GPIO 8    0    1959
| GPS Longitude 02 49.9999 N   GPIO 9    1
| GPS Latitude  36 49.9999 N   GPIO 10   1
| GPS Altitude  0.            GPIO 11   1
| GPS Locator   KM 0000       GPIO 12   1
| GPS Validity  A            GPIO 13   1
| GPS Fix       3D            GPIO 14   1
| GPS Sats Fix  9            GPIO 15   1
| GPS Tracking  5            GPIO 16   1
| sat SNR       36            GPIO 17   1
|              |             GPIO 18   1
|
| Calibrating system freq...
+---Ctrl-R = Raw GPS-----Ctrl-Q = Quit-----+
```

U4B Hardware Test

- Test, test and test payload with software
- Prep balloon, stretch if desired $103'' = \text{Pi} * D$
- Construct antenna and connect to payload
- Morning of launch, fill balloon with gas
- Make sure balloon has enough lift
- Seal balloon valve and connect payload

Before Launch To Do List

SuperPressure Balloon float calculator (by Steve Randall)

Version 1g - 17/11/2020

Gas Density Table in Kg/cu m

Chosen Gas		Free Lift	SP balloon		Payload	Gas	Total	Neck		Launch	Gas Density Table in Kg/cu m			
Gas	Density	(g)	vol (cu m)	weight (g)	Weight (g)	Mass (g)	Mass (Kg)	Lift (g)	Gas Fill (cu m)		at 101.325kPa at MSL		0 deg C	15 deg C
Hydrogen	0.0852	5.00	0.305	48.00	14.00	5.010648	0.0670	>>> 19.0000	0.0588	<<<	Hydrogen	0.0899	0.0852	
											Helium	0.1786	0.1693	
											Helium 97%	0.2120	0.2010	
											Air	1.2920	1.2247	
System Density at float (Kg/cu m)			K		Float					Atmospheric				
0.2197			0.020692		Internal Pressure (kPa)	External Pressure (kPa)	Temp (deg C)	Altitude (m)		Pressure (kPa)				
					14.688178	13.63868	-56.46	>>>	14250	<<<	101.325			
								(46740 ft)						
free lift ratio (see [1])			K/V		Differential Pressure at float			Superpressure		Altitude at whi				
0.074615			0.067841		(kPa)	(psi)	Onset (m)		full, superpres					
					>>> 1.0495	0.1522	<<<	>>>	13780	<<<	down into floa			
					Supper Pressure by [1]			(45198.4 ft)						
					(kPa)	(psi)								
Use:					>>> 1.0177	0.1476	<<<							
Inputs in green cells														
Results in arrowed pink cells														

Calculate Final Altitude



New Flat Yokohama Balloon



Stretched Balloon



ALP40-A transmits on the 10 m band

Cut a #34 gauge copper wire and fishing line to 9' in length

Place them next to each other stretched and taped across room

Use a small amount of RTV and rub on the wire/fishing line, let dry

Cut the copper wire to length and solder to PCB

Fishing line ties to PCB and balloon



Mass of Tube to Fill Balloon (19g)



Attach the Balloon to Payload



Launch Day



Play Video of Launch Site



Where Did It Go - Tracking

- Callsign, 4-character locator and dBm
- Message length 50 bits with FEC
- Modulation 4-FSK tone separation 1.46Hz
- Transmission starts 2 s into even minute
- Duration of transmission 110.6 seconds
- Bandwidth of 6 Hz
- Minimum of -27 dB S/N (2500Hz ref BW)

WSPR Technical Information

WSJT-X - Wide Graph

Controls 200 400 600 800 1000 1200 1400 1600 1800 2000 2200 2400

19:54

Bin/Pixel 2 Start 0 Hz Palette Adjust... Flatten Ref Spec Spec 30 %

Split 2500 Hz N Avg 5 Default Cumulative Smooth 1

Call signs #1 All decodes

Callers : Alert Alerts Only

19:56:04 0 0 0 0 DT+0.1 VK8AW 10m WSPR default

HRD Logbook [HRD My Logbook - Access]

File Edit View Calendar Countries Logbook Tools Window Help

Open Layout A Layout B Satellite Tracking Rig Control Full Screen KB7HTA Home OM24C

Radio Pane

Connect Options

Radio

Main: Sub:

Filter QSL Award LOTW Upload LOTW Download

QSO date	Time on	Call	Mode	Subr
2/10/2024	01:21:00	VK8DAB	FT8	
2/10/2024	01:14:15	VK7DW	FT8	
2/10/2024	01:12:45	JA8TZP	FT8	
2/10/2024	01:10:30	VK3AXI	FT8	
2/10/2024	01:10:00	VK2ASG	FT8	
2/10/2024	01:03:45	WD4C	FT8	
2/10/2024	00:54:15	K1YKK	FT8	

My Logbook HRD My Logbook

Solar Cycle Progression

30 Day Solar Data Solar Cycle Progre... Audio Monitor DX Cluster: KB7HT...

Greyline

Clock

Alerts Settings View Sound OFF Help

WSJT-X v2.5.4 by K1JT, G4WJS, K9AN, and IV3NWW

File Configurations View Mode Decode Save Tools Help

UTC	dB	DI	Freq	Drift	Call	Grid	dBm	km
1950	-3	-0.1	28.126120	0	AL7US	EN61	40	2307
1950	-24	1.2	28.126149	0	KA9PGC	EN61	27	2507
1952	-26	1.0	28.126027	0	TI4JWC	EK70	30	4155
1952	-16	-0.0	28.126035	-3	W3HH	EL89	37	3085
1952	-16	0.2	28.126039	0	N8JJB	EN71	23	2674
1952	-23	0.1	28.126051	0	W8MI	EN75	20	2731
1952	-29	0.1	28.126061	0	VESMGM	DO62	3	1934
1952	-18	0.1	28.126089	0	KJSSZ	EM32	23	2074
1952	-18	0.1	28.126103	0	NO8PH	EN31	20	2010
1952	-8	0.4	28.126107	0	KC9UMR	EM12	37	1716
1952	-8	-0.1	28.126113	0	VE6REN	DO40	23	1636
1952	-23	-0.1	28.126145	0	KX4TD	EM84	23	2917
1952	-29	0.2	28.126173	0	KC1TYU	FN43	23	3824
1952	-21	0.7	28.126189	1	KB7HTA	CM01	10	2258
1954	-22	0.2	28.126008	0	KA8SAF	FN20	23	3516
1954	-21	0.1	28.126037	0	K7FL/M		23	
1954	-10	-1.7	28.126060	-4	KA9KEX	EN50	27	2331
1954	-26	-0.0	28.126101	0	AC9YY	EN51	23	2341
1954	-15	0.5	28.126113	-1	KCLLNQ	FN42	33	3831
1954	-16	0.7	28.126189	0	QF4NWU	MR87	33	6276
1954	-16	0.0	28.126192	0	N1PCE	FN44	30	3820

Stop Monitor Erase Decode Enable Tx Halt Tx Tune Receiving WSPR

10m 28.124 600

63 dB

2024 Feb 11 19:56:04

Tx 1497 Hz Upload spots Tx Pct 20 % Prefer Type 1 messages Band Hopping No own call decodes Schedule... Tx Next 43 dBm 20 W

Receiving WSPR 27 4/120

Receiving WSPR with WSJT-X

- [LU7AA](#) – Nice map display, telemetry, call sign of Hams receiving the balloon, track, winds aloft and footprint
- [Spot Search](#) – Shows multi-day track for balloon, telemetry, raw transmissions, days airborne, miles traveled and winds /weather aloft
- [Sonde Hub](#) – Shows track/path, telemetry, clicking the float button gives a predicted path for the future and basic information
- [WSPR NET](#) – Shows location and all hearing

Balloon Tracking Sites

- Google Sheets/Excel is telemetry's friend
- Once you download telemetry from [Spot](#)
- Look at map grid squares vs other data
- Make charts to compare different values

Analyzing the Telemetry

(download) or (copy to clipboard)

Map	DateTimeUtc	DateTimeLocal	RegCall	RegGrid	RegPower	EncCall	EncGrid	EncPower	Grid56	AltM	TempC	Voltage	Knots	GpsValid	Alt#Graph	AltFt	KPH	MPH	TempF	Grid	DistKm	DistMi	GpsKPH	GpsMPH
map	2024-04-11 14:12	2024-04-11 07:12	KB7HTA	DM80	10																			
map	2024-04-11 13:52	2024-04-11 06:52	KB7HTA	DM80	10	Q78STR	LK41	0	FH	1,500	8	3.85	0	1	1,500	4,921	0	0	46	DM80FH	5	3		
map	2024-04-11 13:32	2024-04-11 06:32	KB7HTA	DM80	10	Q78RER	KO26	17	FG	1,540	4	3.85	0	1	1,540	5,052	0	0	39	DM80FG	5	3		
map	2024-04-11 13:12	2024-04-11 06:12	KB7HTA	DM80	10	Q78STS	JL04	10	FH	1,520	-2	3.85	0	1	1,520	4,987	0	0	28	DM80FH	5	3		
map	2024-04-11 12:52	2024-04-11 05:52	KB7HTA	DM80	10	Q78REQ	JA43	7	FG	1,520	-5	3.85	0	1	1,520	4,987	0	0	23	DM80FG	0	0		
map	2024-04-11 12:32	2024-04-11 05:32	KB7HTA	DM80	10	Q78REQ	JH50	30	FG	1,520	-3	3.85	0	1	1,520	4,987	0	0	27	DM80FG	5	3		
map	2024-04-11 12:12	2024-04-11 05:12	KB7HTA	DM80	10	Q78STQ	JA43	7	FH	1,480	-5	3.85	0	1	1,480	4,856	0	0	23	DM80FH	0	0		

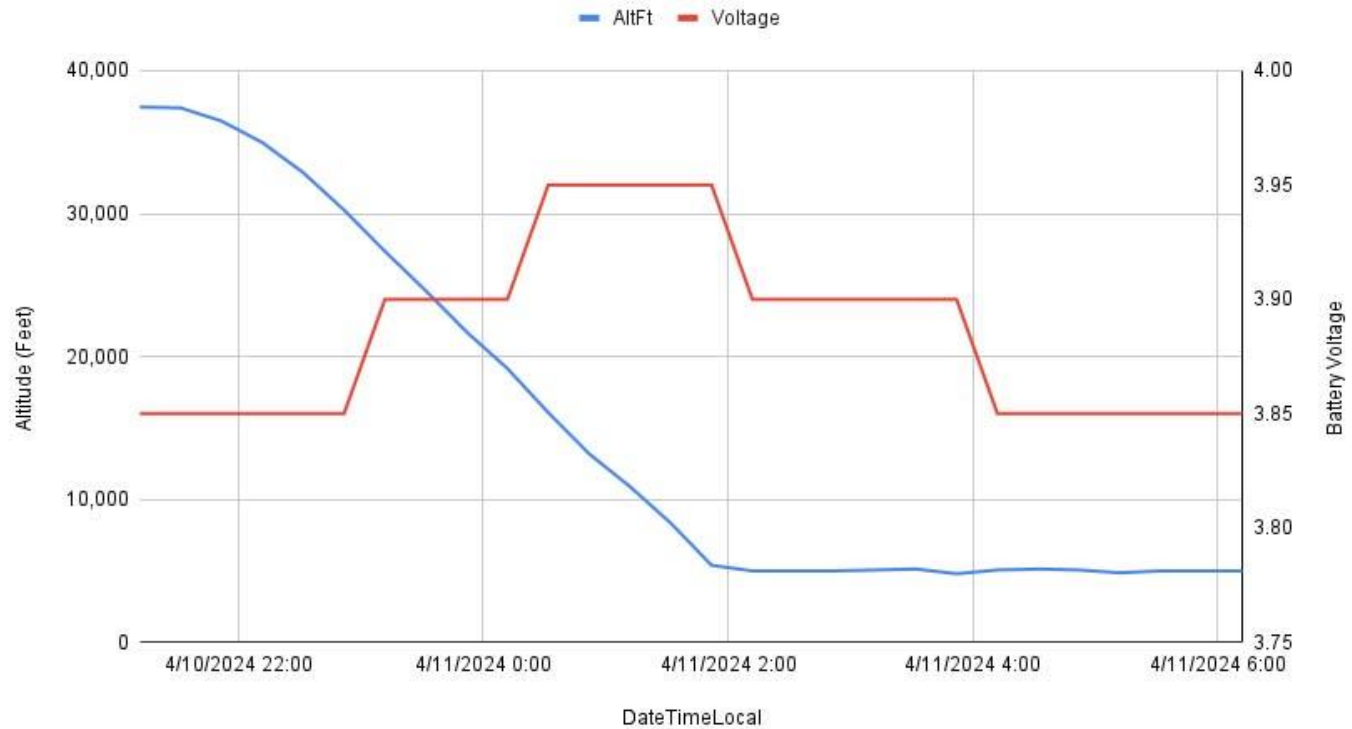


Finding ALP40-B



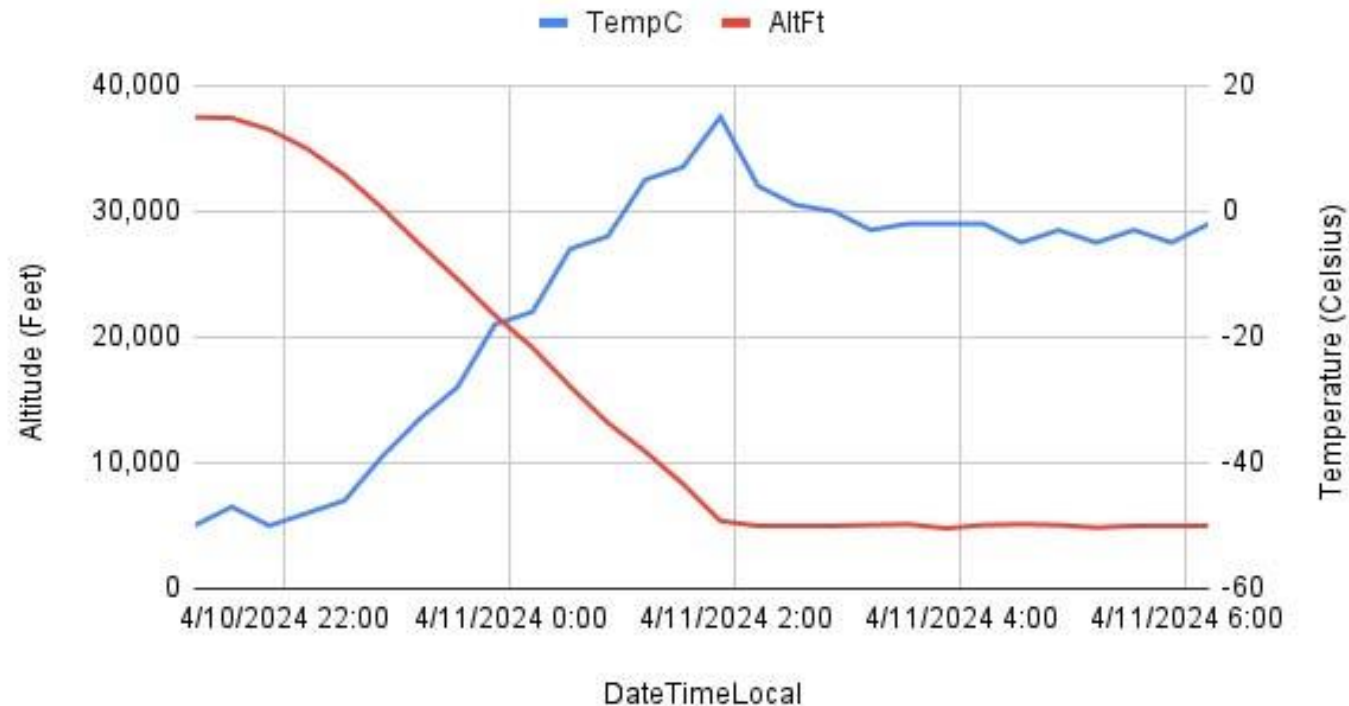
Charlie, N5CET of Alpine, Texas searched down one side of the line 50 yards out, shown in the previous slide and back down the other. After a 9 mile walk and just before getting back to the car parked on a dirt road, he was successful in finding the balloon. Thank you!

AltFt and Voltage



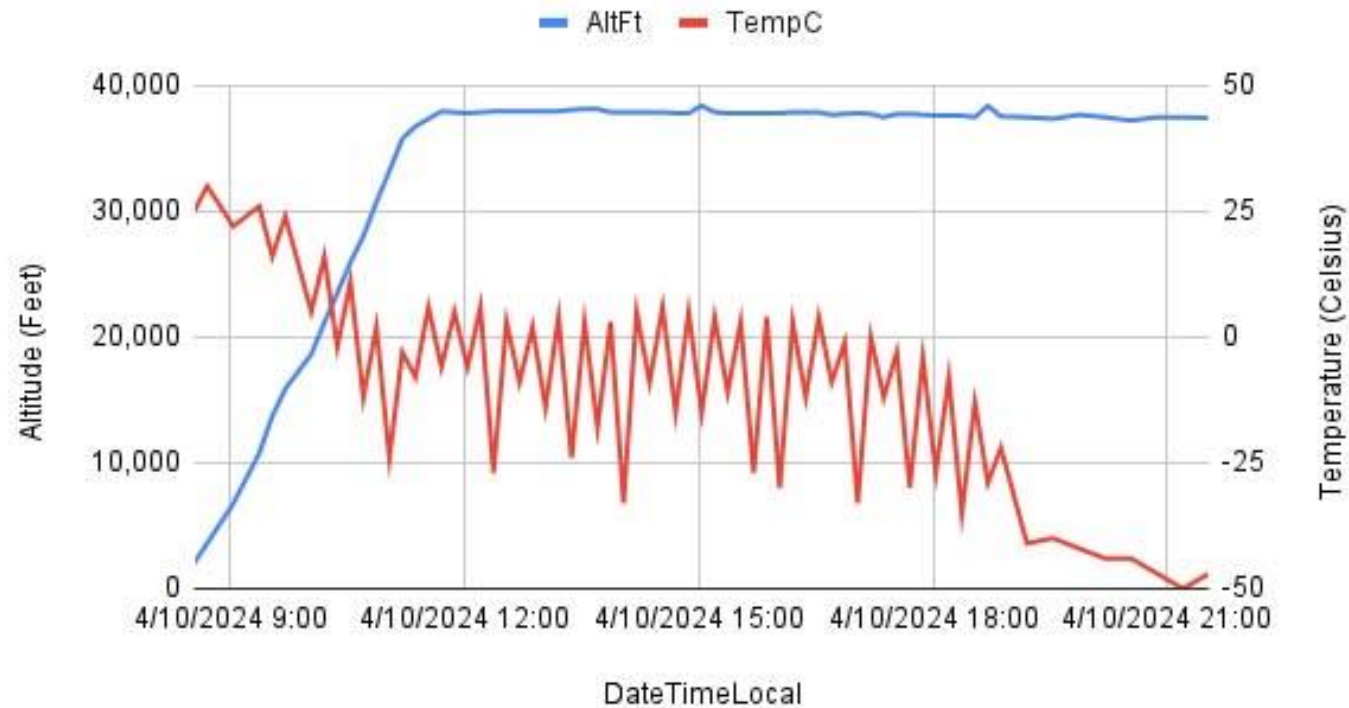
ALP40-B Descent to Alpine, Tx

TempC and AltFt on Descent

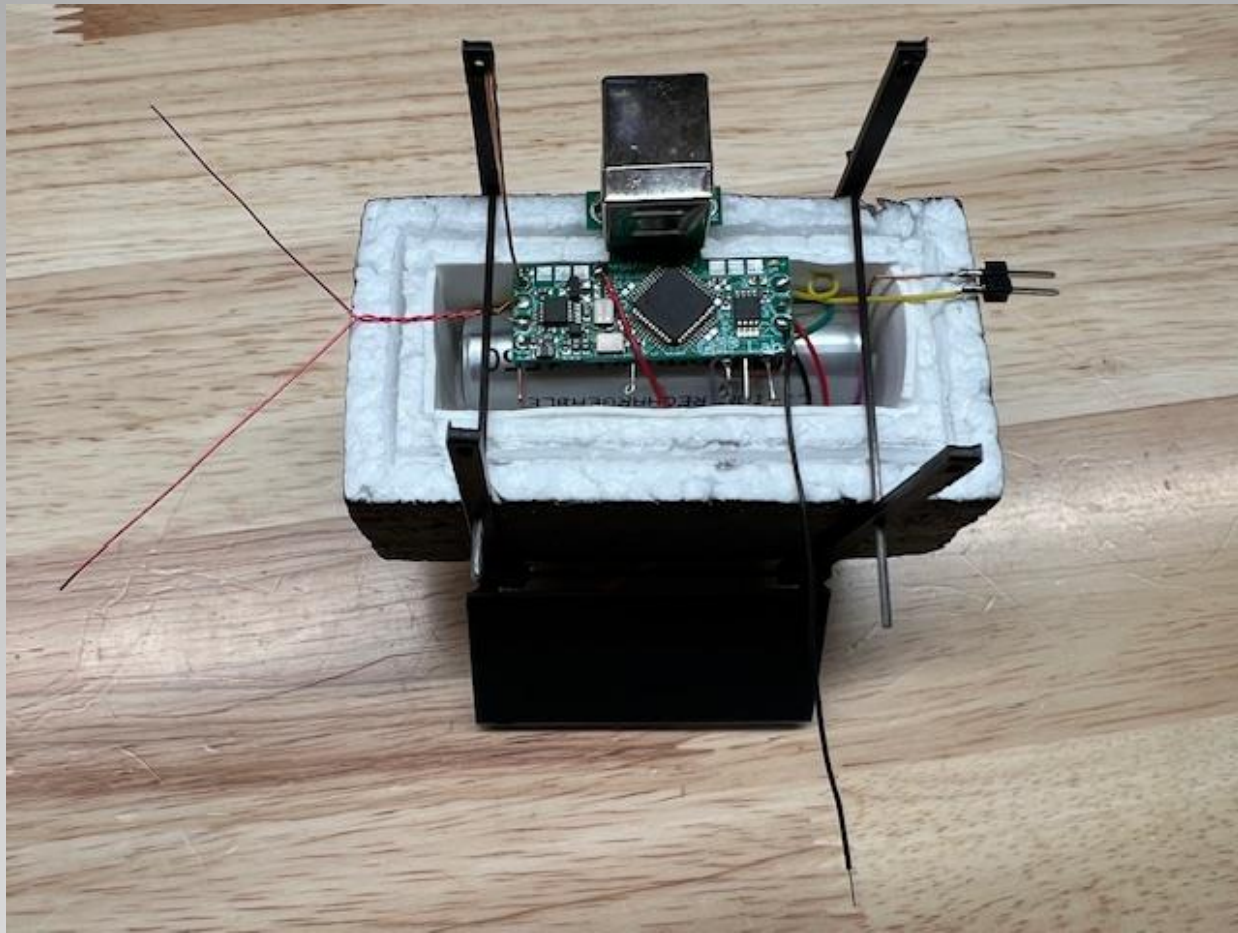


ALP40-B Descent to Alpine, Tx

AltFt and TempC



ALP40-B Insulation Effectiveness



ALP40-B Payload Photo

- Constructing a Pico Balloon is a lot of work. It is also very rewarding. It is kind of an ego trip watching your call sign show up all around the world, and you meet a lot of like minded Hams.
- It is not terribly expensive, \$120 or less.
- The American Legion LVARBG is growing, free membership. Come join in on all the fun and build a balloon of your own. We meet every 2nd Wednesday from 6 – 8 pm, American Legion Post 40 Annex (Trailer), 425 E. Van Wagenen Street, Henderson, NV.

Summary



Shane, KG7QWH at Work – Linda, KJ7OWF Provides an Extra Hand



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