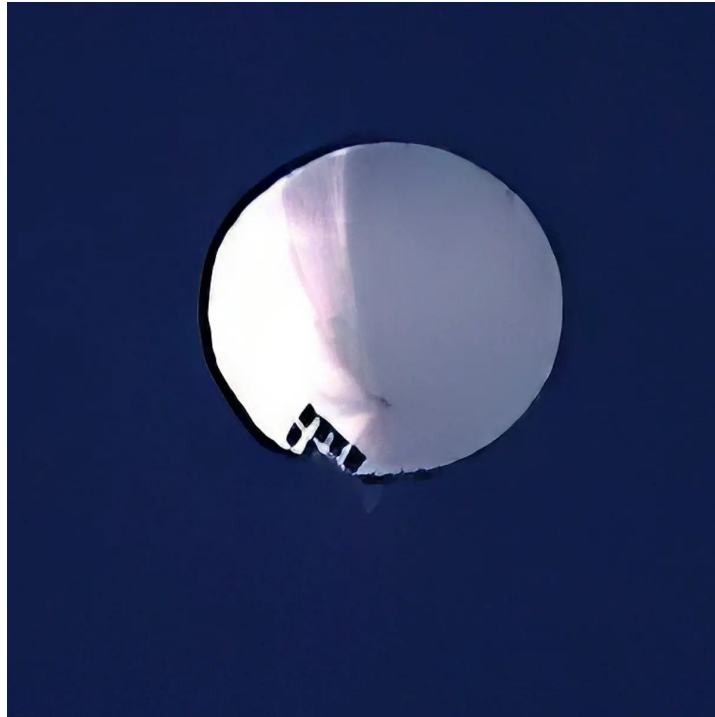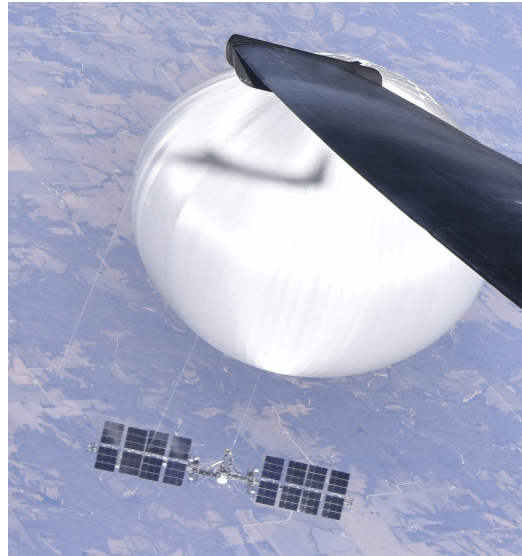# Amateur Radio Ballooning for Fun and Science

Martin Rothfield W6MRR https://sf-hab.org
ARRL/MDARC Pacificon Oct 21, 2023

RIP: Chinese Spy Balloon & K9YO-15
(Northern Illinois Bottlecap Balloon Brigade)

Types of Balloons	**HAB (Strechy)**	**Superpressure (Inelastic)**
Flight duration	~4 hours	Days to Months
Goal	High altitude	Around the world Long endurance
Altitude	Up to ~120k feet, then down	Constant at ~43k feet
Payload mass	Up to 12 lbs	10 to 20 Grams
Gas Needed	Huge Tank	0.5 l
Comms	APRS	WSPR
Payload recovered?	Yes (usually)	No
Balloon material	Latex	Multilayer plastics
Power	Batteries	Photovoltaic
Science opportunities	Short duration tests	Developing for long duration

From HABs to Picos

Where Does a Balloon Float?
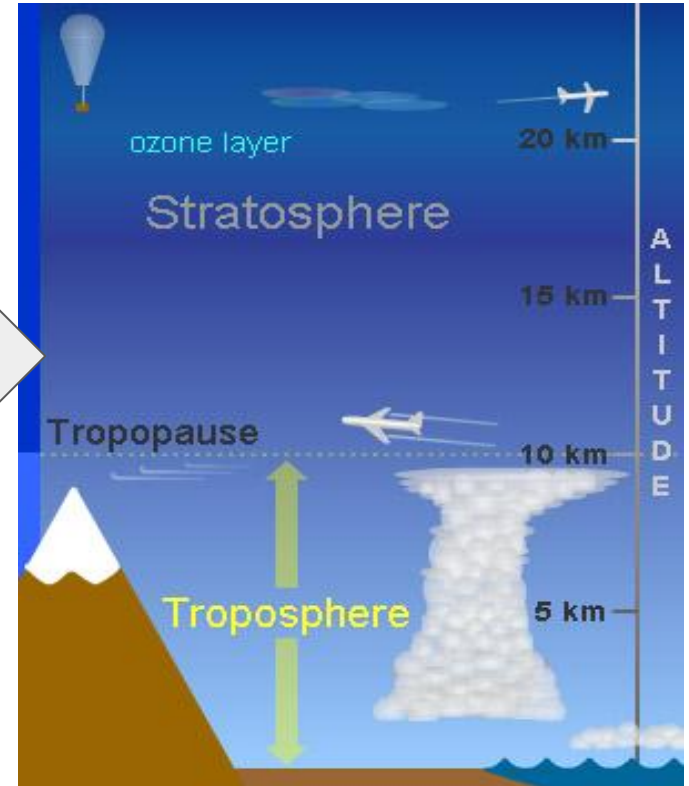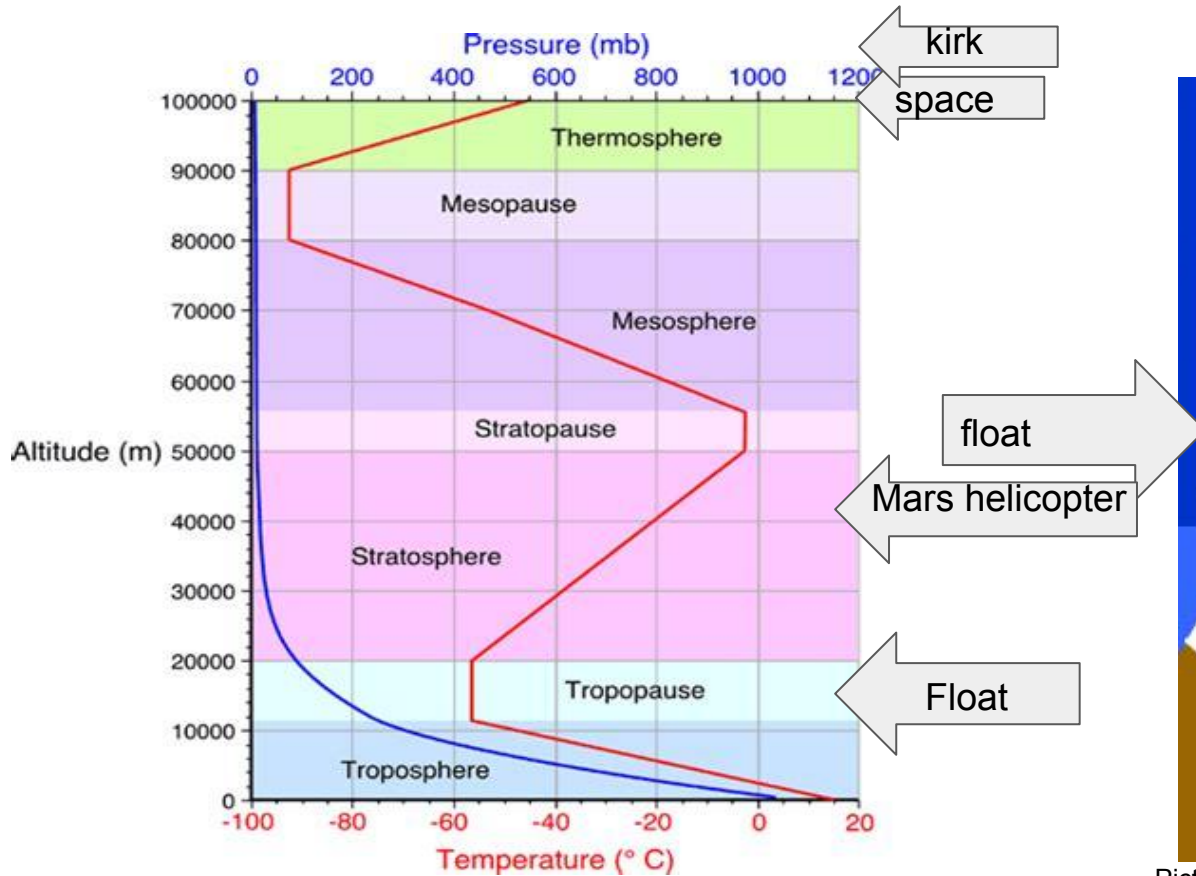
Picture taken from https://scied.ucar.edu/atmosphere-layers

How Balloons Float (and Burst)

- The density (volume/mass) of an object is less than the fluid it is immersed in
- The pressure inside a balloon exceeds envelope strength - pop!
- Pre-stretching the balloon increases volume but not weight - flies higher

The Spreadsheet float1g predicts the float altitude

float1g.ods - OpenOffice Calc

File Edit View Insert Format Tools Data Window Help

SuperPressure Balloon float calculator (by Steve Randall)   Version 1g – 17/11/2020

	Chosen Gas Density	Free Lift (g)	SP balloon vol (cu m)	SP balloon weight (g)	Payload Weight (g)	Gas Mass (g)	Total Mass (Kg)		Neck Lift (g)	Launch Gas Fill (cu m)	
Gas											
Hydrogen	0.0852	6.50	0.600	105.00	15.70	9.51275268	0.1302	>>>	22.2000	0.1116	<<<

Gas Density Table in Kg/cu m
at 101.325kPa at M 0 deg C   15 deg C

	0 deg C	15 deg C
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
0.2170   0.0392832

Float

Internal Pressure (kPa) External Pressure (kPa) Temp (deg C) Altitude (m)
14.1751879   13.468449   -56.46 >>>   14330 <<<
                                                               (47002.4 ft)

Atmospheric Pressure (kPa)
101.325

free lift ratio (see [1])   K/V
0.04991831   0.0654719

Differential Pressure at float
(kPa)   (psi)
>>> 0.7067   0.1025 <<<

Superpressure Onset (m)
>>> 14010 <<<
(45952.8 ft)

Altitude at which the balloon envelope becomes full, superpressure starts and the ascent rate slows down into float

Supper Pressure by [1]
(kPa)   (psi)
>>> 0.6723   0.0975 <<<

320	meters above inflation
0.3	Superpressure red line
0.0975	Superpressure, psi
33%	% of superpressure at red line
664	Altitude to red line, meters

Use:
Inputs in green cells   >>>
Results in arrowed pink cells

Inputs:
Gas – drop-down of the the type of gas you will use to fill the balloon (Hydrogen/Helium)
Free Lift – desired free lift – sets the amount of gas needed, float differential pressure and altitude
SP balloon vol. – the volume of the balloon (or total volume if multiple balloons) that you will be using
SP balloon weight – the weight of the balloon envelope (or total weight if multiple balloons)
Payload weight – weight should include everything that is not included in the balloon weight (so line, tape etc).

References:
[1] Superpressure Balloons for Horizontal Soundings of the Atmosphere V.E. Lally

Version History:
1 – 0-65.5Km in 1m steps (02-02-2011)
1a – 0 – 100Km in 10m steps (03-02-2011)
1b – corrected table range lookup (04-02-2011)

1d – changed so user now enters desired free lift and gas fill becomes an output (20-10-2020)
1e – added superpressure calculation as verification. (see [1]) (20-10-2020)
1f – Added Superpressure Onset Calculation, results in ft, NASA model (tropo temp) error corrected (13-11-2020)

Sheet 1 / 1   PageStyle_Calc   STD   Sum=0   100 %

How to Launch

Find a wide open space free from trees or power lines

Low winds a needed (< 4 mph). Walk or trot with wind to your back.

No low clouds

Winter favors circumnavigation. Summer favors interesting wandering trips.
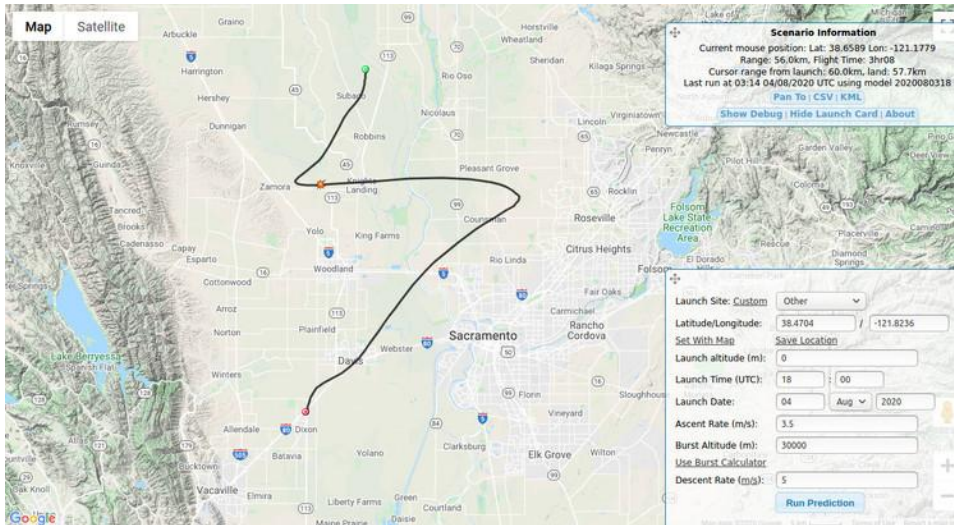
Use prediction software
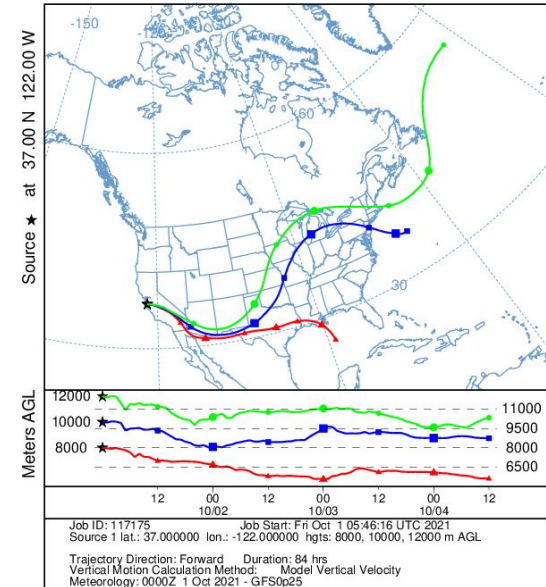
Where do these predictions come from?

Flight Path Predictions

- How do you predict where a Latex HAB will land?
- What direction will a superpressure Picoballoon float?
- Where does [HYSPLIT](#) get data from?

https://predict.habhub.org/

Radiosondes Directly Measure Upper Atmosphere Winds

- Small disposable transmitters on latex balloons
- Launched twice per day from ~1300 sites worldwide
- Our local radiosonde station is at the Oakland Airport
- Not amateur radio, but ham-adjacent at ~403 MHz or ~1680 MHz
- Vaisala RS41: 60mW, 403 MHz, 4800 baud GFSK, 84g (~3oz)

Vaisala RS41-SGP

This data comes from Radiosondes

- Radiosondes directly measure the upper atmosphere wind, temperature, humidity, and pressure from ground up to ~30k meters (~100k feet)
- This data gets fed back into the Global Forecast System (GFS) model
- GFS is used for weather predictions, volcanic ash, manned "hot air" balloons, wildfire smoke movement
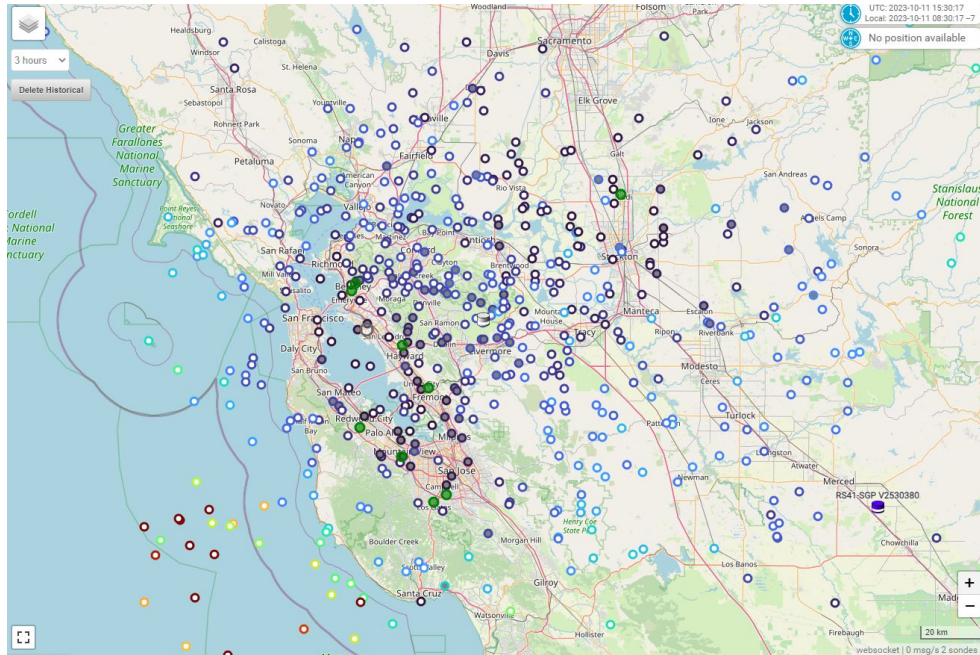

Skew-T plot from Oakland radiosonde
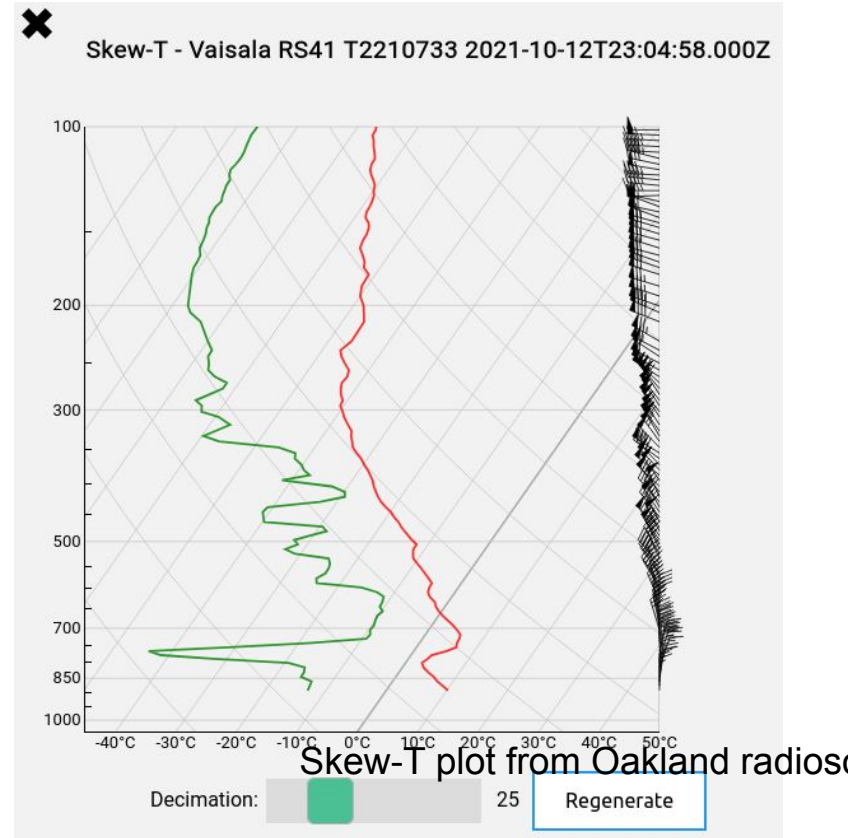
Typical Radiosonde Flight

- Radiosondes are launched at 1100 and 2300 UTC every day
  - 4am and 4pm Pacific time (until DST ends soon)
- Balloon ascends at ~5 m/s for 90 minutes, up to ~30k meters (~100k feet)
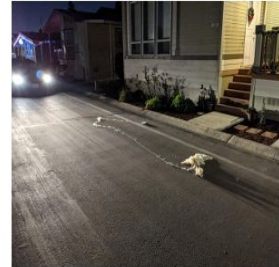- Balloon bursts, and free falls for 30 minutes until it hits the ground

Where do the radiosondes land?

2023 KOAK Landings

Radiosonde Recovery

Telemetry for Everyone

20 m WSPR - General

10 m WSPR & 70 cm APRS - Technician

Satellite (1811.25 MHz) SPOT - Unlicensed

LoRa 33 cm USA 863-870 MHz EU - Unlicensed

4FSK 70 cm - Technician

403 MHz - National Weather Service radiosondes

Never fly a cell phone to send data! - FAA Regulations prohibit

Different Types of Amateur Radio Position Reporting

	Automatic Position Reporting System (APRS)	Weak Signal Reporting System (WSPR)
Network	ARPS.fi (APRS-IS)	(AMSAT Argentina) LU7AA.org/wsprx.asp WSPRnet.org
Frequency	VHF - Typically 2m, 144.390 MHz (**Line Of Sight**)	HF - typically 20 m, 14 MHz (**Skywave**)
Antenna	17" guitar string	34 feet 34 AWG magnet wire dipole (human hair is 44 AWG)
Modulation	Binary AFSK over FM ~**1200 bps** (Bell 202 modem 1976 standard)	4-ary CPFSK, 50 bits/2 minutes = **0.42 bps**
Data Payload	Up to ~1,000 bits	50 bits
Power	typically 0.5 W	Typically 10 mW
Range	Range circle in miles ~ 1.2*sqrt(height in feet), 40 k' = **240 mi**	Beyond line of sight
Positition	Within ~60 to 100+ feet	4 digit grid square
Telemetry	Altitude, pressure, temperature	extra 2 digit grid square + using type 2 or 3 messages
Sound	AFSK	WSPR CPFSK
Weight	6 g 0.5 W transmitter	10 mW TXCO &Si5351 synthesizer
Efficiency	0.001 Joule/bit	0.02 Joule/bit

APRS Data

Callsign, ship name or locator: K7HAK-11   Search   Clear   **Completed generating statistics (took 0.016 s).**

It is possible to search using wildcards (*?) after a prefix. Example: OH*

←

APRS station **K7HAK-11** 🎈 - show graphs

|	
Comment:	*10 3.86 -7 11466 5*
Location:	60°23.43' N 146°06.81' W - locator BP60WJ63JR - **show map** - **static map**
	16.0 miles Southwest bearing 229° from Cordova, Valdez-Cordova Census Area, Alaska, United States [?]
	51.7 miles South bearing 171° from Valdez, Valdez-Cordova Census Area, Alaska, United States
Last position:	2021-03-30 18:26:06 PDT (187d 15h8m ago)
	2021-03-30 17:26:06 AKDT local time at Cordova, United States [?]
Altitude:	37619 ft
Course:	54°
Speed:	53 MPH
Last telemetry:	2021-03-30 18:55:19 PDT (187d 14h39m ago) – show telemetry
	Solar: 3.920 V, Temp: -6 C, Sats: 9, Lock: 1
Device:	WB8ELK: Balloon tracker (tracker)
Last path:	K7HAK-11>APELK0 via WIDE2-1,qAR,KL7JFT-5 *Seriously bad path.*
	This station appears to be flying at high altitude and using digipeaters, which causes serious congestion in the APRS network. The tracker should be configured to only use digipeaters when at low altitude.
Positions stored: 1408	
Other SSIDs:	**K7HAK** 🟢 K7HAK-7 🚶 K7HAK-9 🚗

Stations near current position of **K7HAK-11** - show more

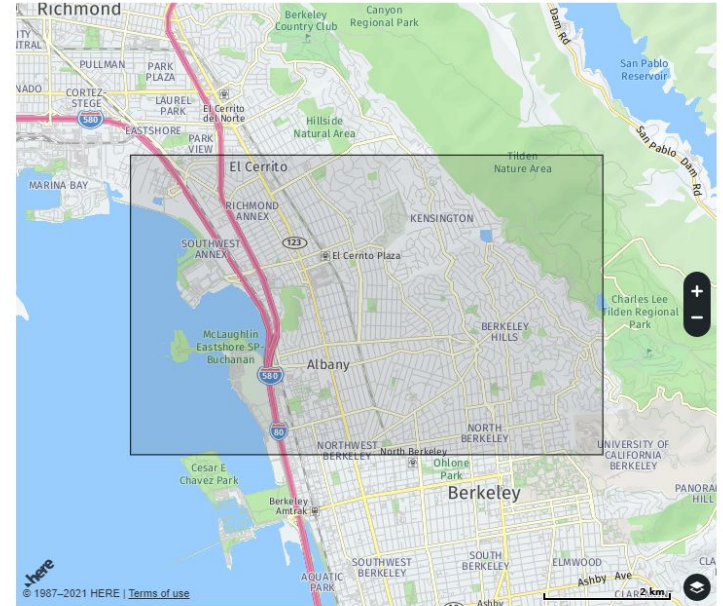| callsign	distance	last heard - PDT	callsign	distance	last heard - PDT

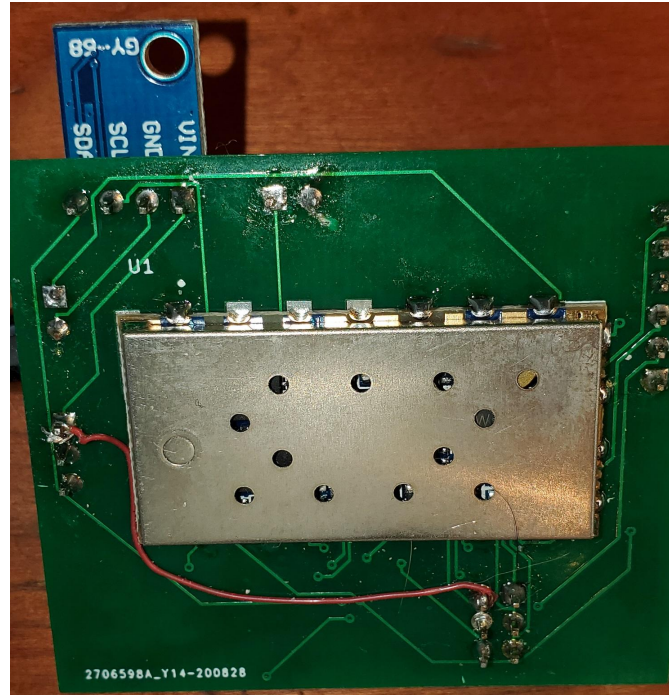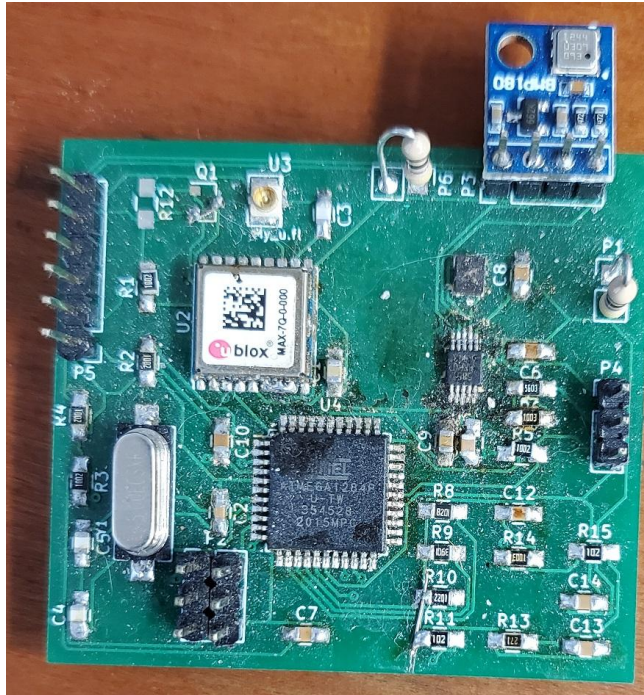# Maidenhead Locator System - Position Reporting

Grid Square: CM87
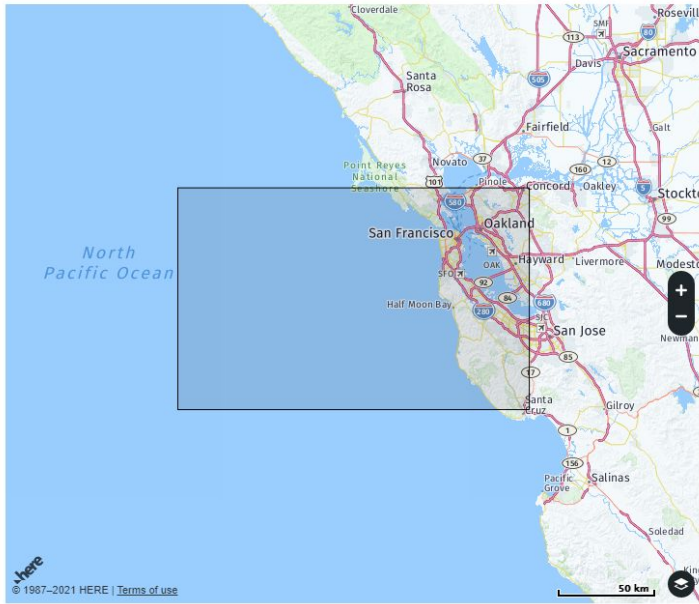
Grid Square: CM87uv

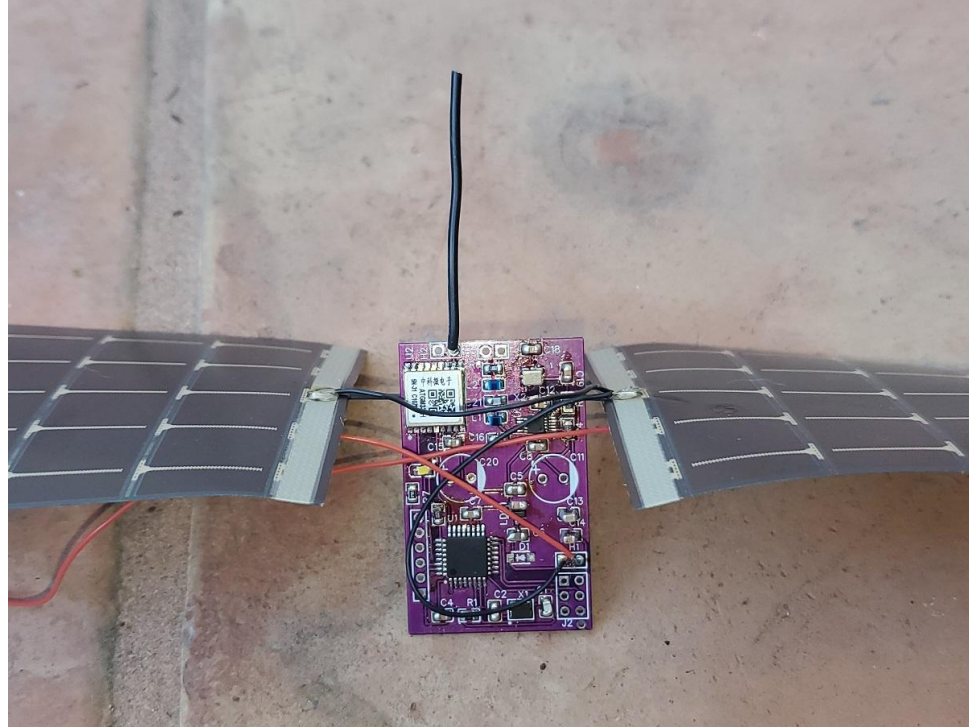Other Ham Radio / Amateur Radio pages by K2DSL on Levinecentral

Other Ham Radio / Amateur Radio pages by K2DSL on Levinecentral
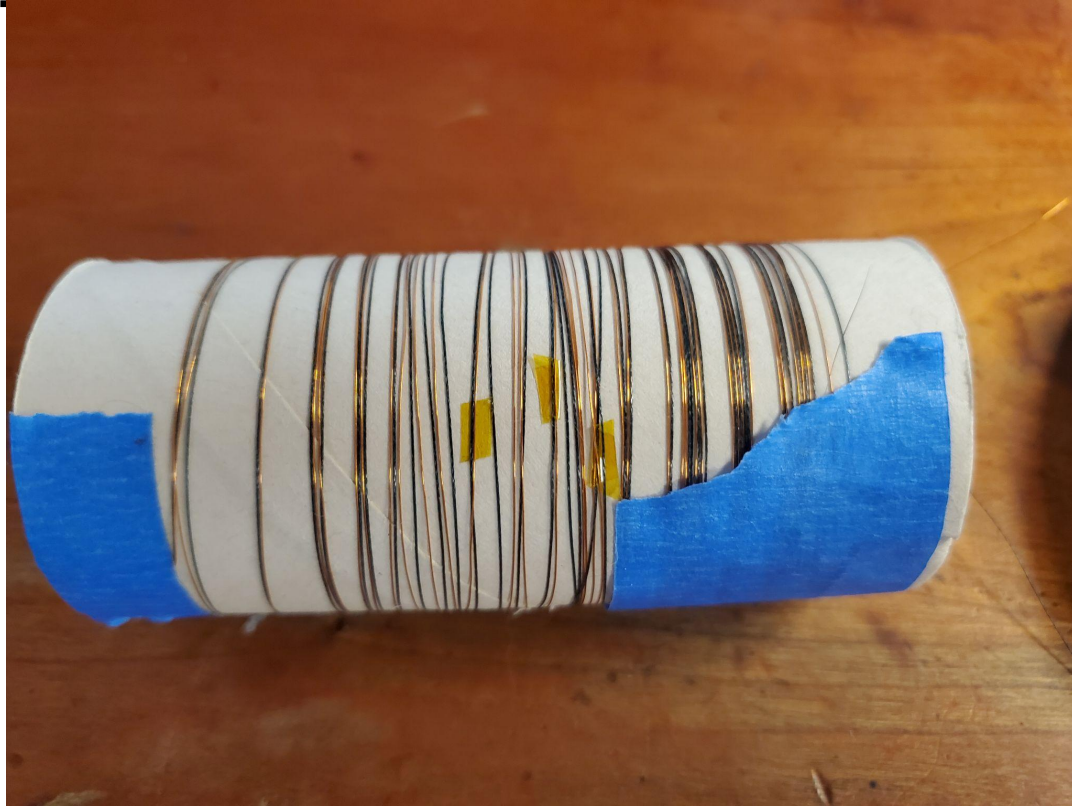
Tracker Generation 0

Tracker Generation 1

Tracker Generation 2

Half Dipole: 17' 1.5 g 36 AWG glued to fishing line

Current & Future Developments

AG6NS Tracker

Solar Arrays

HAB Payloads

     Particle Counter

     Crossband Repeater

     Controllable altitude

     Controllable azimuth

Questions

???