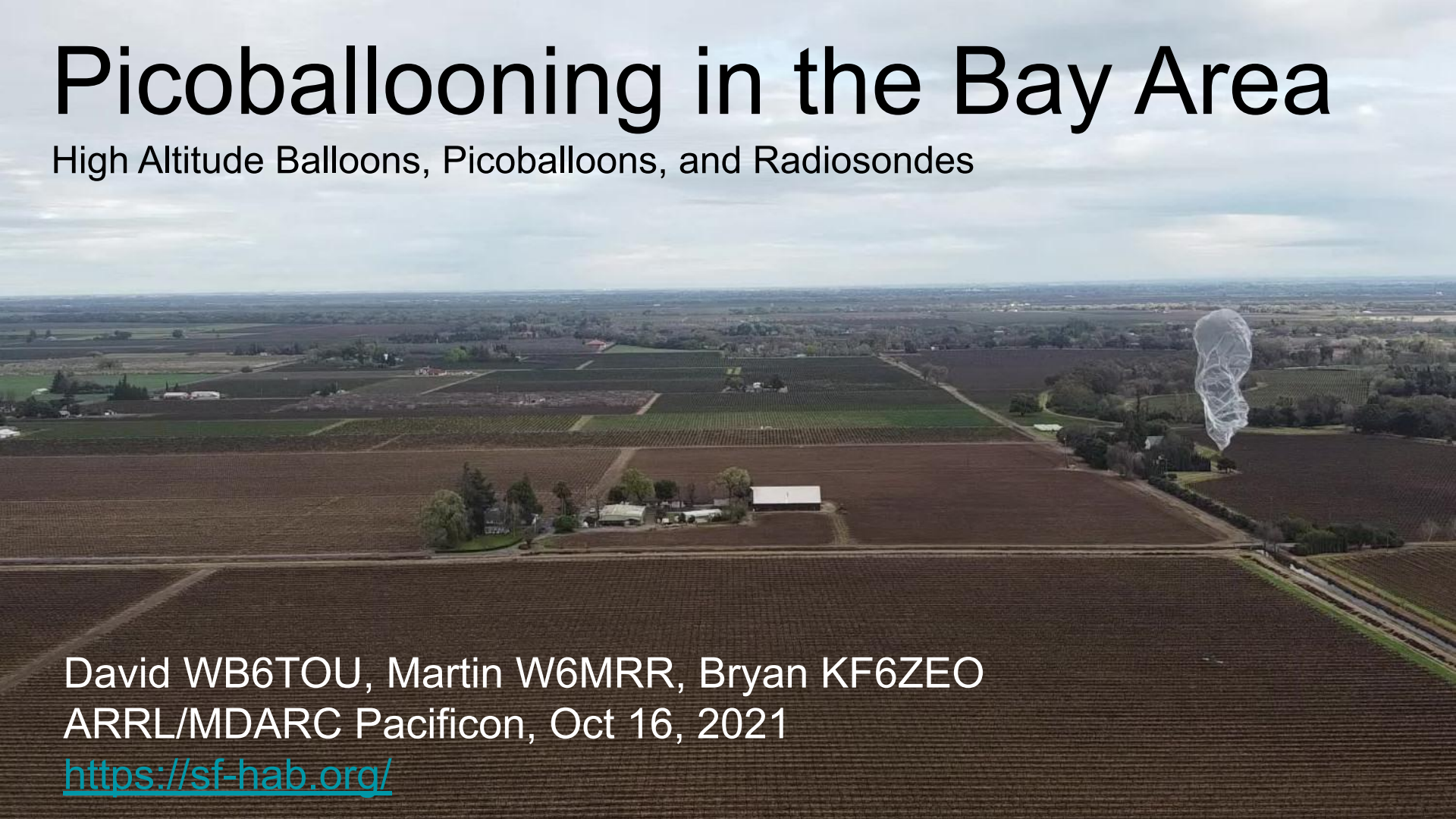
Picoballooning in the Bay Area

High Altitude Balloons, Picoballoons, and Radiosondes



David WB6TOU, Martin W6MRR, Bryan KF6ZEO

ARRL/MDARC Pacificon, Oct 16, 2021

https://sf-hab.org/

The two types of Balloons Amateurs Launch

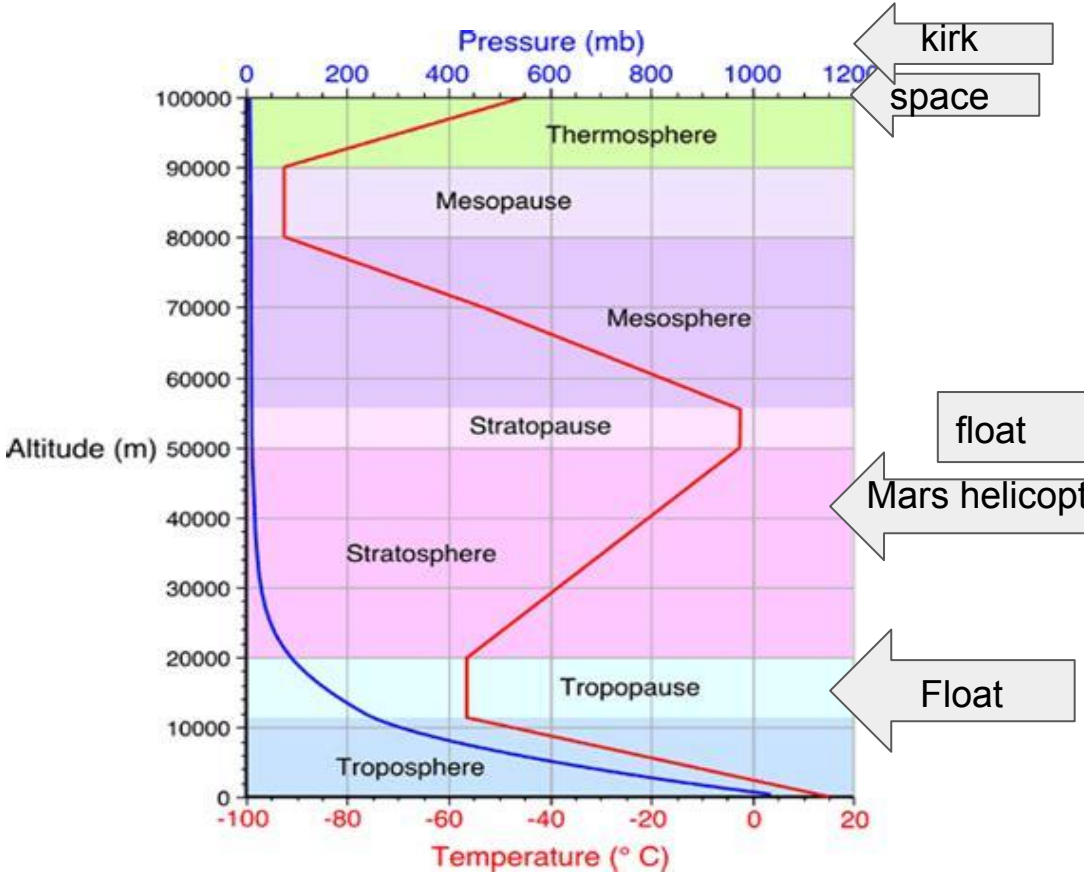
Bursting Latex Balloons

Floating Superpressure Balloons

HAB/Superpressure Balloon Comparison

	HAB	**Superpressure**
Flight duration	~4 hours	Days to Months
Goal	High altitude	Around the world Long endurance
Altitude	Up to ~120k feet, then down	Constant at ~38k feet
Payload mass	Up to 12 lbs	10 to 20 Grams
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

Where Does a Picoballoon Float?



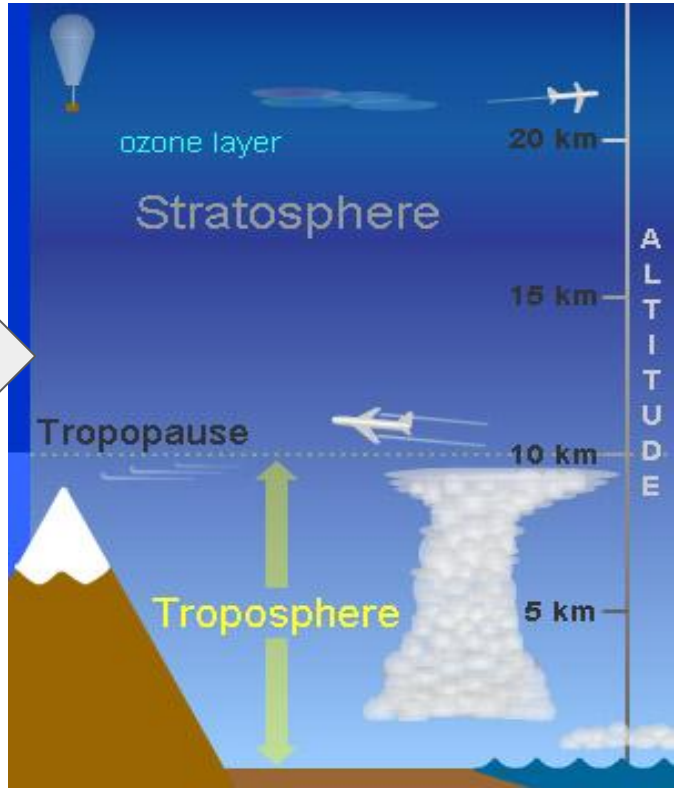
kirk

space

float

Mars helicopter

Float



Picture taken from https://scied.ucar.edu/atmosphere-layers

How Balloons Float (and Burst)

Ideal Gas- particles don't attract or repel.

One mole is 22.4L regardless of weight.

Air weighs 29 grams. Hydrogen weighs 2 grams. One mole gives 27 grams of lift.

Each expands the same with altitude so the lift is constant.

SBS-13 balloon weight = 105 grams

Payload = 15 grams.

5 moles hydrogen = 10 grams.

5 moles hydrogen lift =135 grams

Total weight = 130 grams

Free lift = 5 grams

Spreadsheet float1g has detailed calculations and accurately predicts what will happen.

When gas volume = balloon volume, the density is fixed. It will rise to equilibrium.

At equilibrium, the gas is higher pressure than atmosphere. That is superpressure.

The SBS-13 from Scientific Balloon Solutions

The balloon is high quality

The permeability is about ⅛ that of the clear chinese balloons

The balloon is expensive, about $165 each.

The volume is about 0.5 cubic meters.

It has a slightly better ratio of volume to weight than clear chinese balloon so it floats a bit higher. Up to as much as 43,000 feet.

Chinese Balloons from AliExpress

AliExpress sells them for about $1.50 each

Quality is variable so testing and prestretching is required.

The stretched volume is about 0.16 or 0.17 cubic meters.

Two are usually needed for a launch.

It will float a bit lower but these have stayed aloft for months. The record is probably 305 days.

Pre-stretching Balloons

Prestretching increases volume

Pinholes are present is some balloons

The balloons burst somewhere around 0.6 to 0.65 psi. Stretching to around 0.55 psi is reasonable to get 0.16 to 0.17 cubic meters

An aquarium air pump is perfect, a water column provides pressure control.

Holding at pressure for a few days does a good job of sorting out the bad ones.

How to prepare for launching.

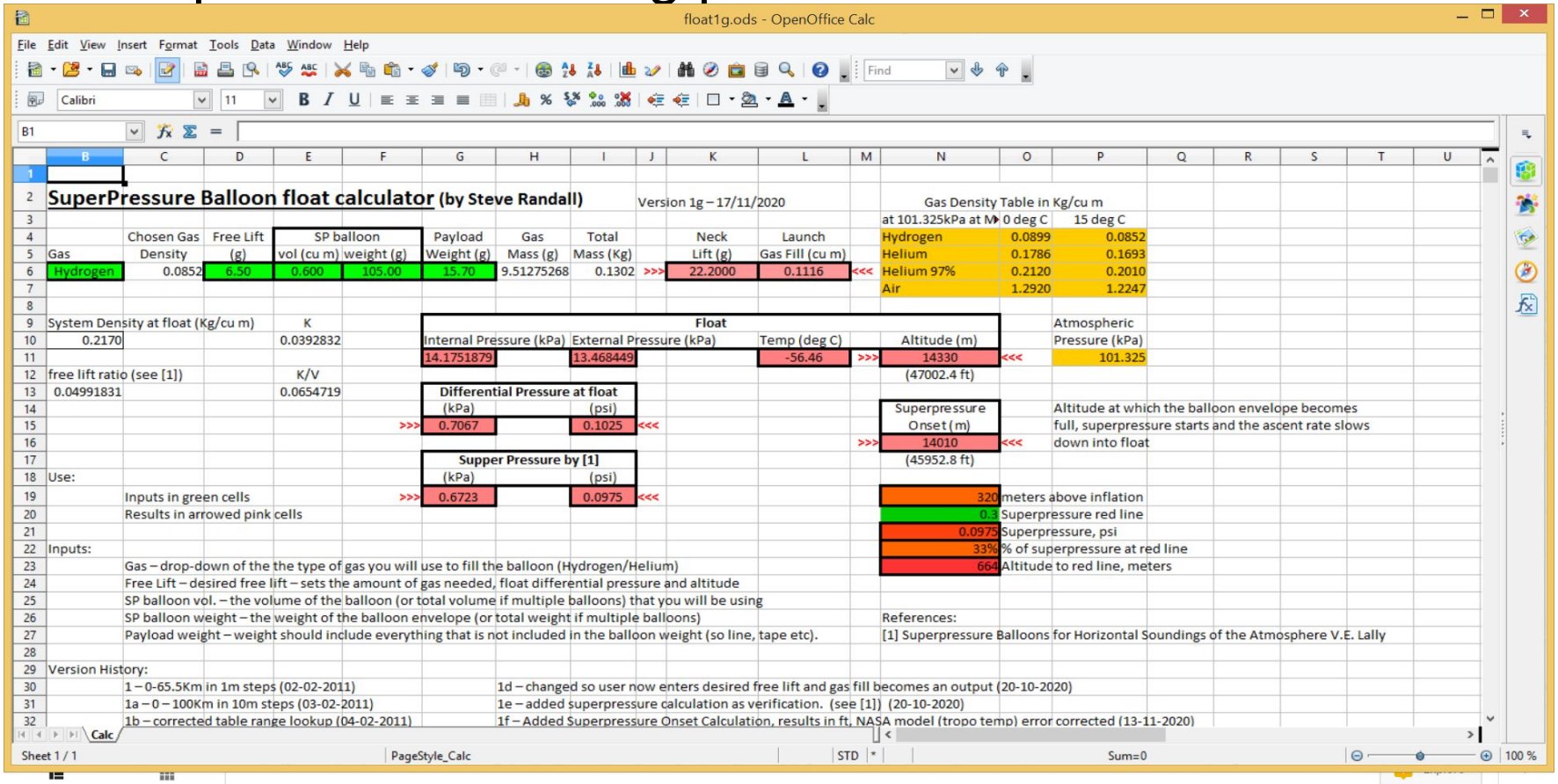
Gas is put into the balloon.

Must know balloon volume, balloon and payload weight, type of gas, and desired free lift. For the SBS-13 it is around 6.5 grams free lift, and for the clear chinese balloons it is from 4 to 8 grams per balloon.

The spreadsheet float1g accepts this data and predicts where the balloon will float and superpressure. https://ukhas.org.uk/projects:splat

The gas is put in, the lift of the balloon measured, and when correct, the neck is heat sealed. The balloon is put in a plastic bag for transport and the beacon carefully carried along. Assembly is usually done at the launch site.

The Spreadsheet float1g predicts the float altitude



float1g.ods - OpenOffice Calc

File Edit View Insert Format Tools Data Window Help

Calibri 11

B1

SuperPressure Balloon float calculator (by Steve Randall)

Version 1g – 17/11/2020

Gas	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)	
Hydrogen	0.0852	6.50	0.600	105.00	15.70	9.51275268	0.1302	>>>	22.2000	0.1116	<<<

System Density at float (Kg/cu m)	K
0.2170	0.0392832

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

Float

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

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

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

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

Atmospheric Pressure (kPa): 101.325

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

Gas Density Table in Kg/cu m

	at 101.325kPa at M	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

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)

Calc

Sheet 1 / 1 PageStyle_Calc STD * Sum=0 100 %

2:24 PM 9/13/2021

How to Launch

Choosing a good time and place is important. The balloons are easily lost.

The location should be open, no close trees or power lines

The weather should be calm and there should be no clouds to pass through

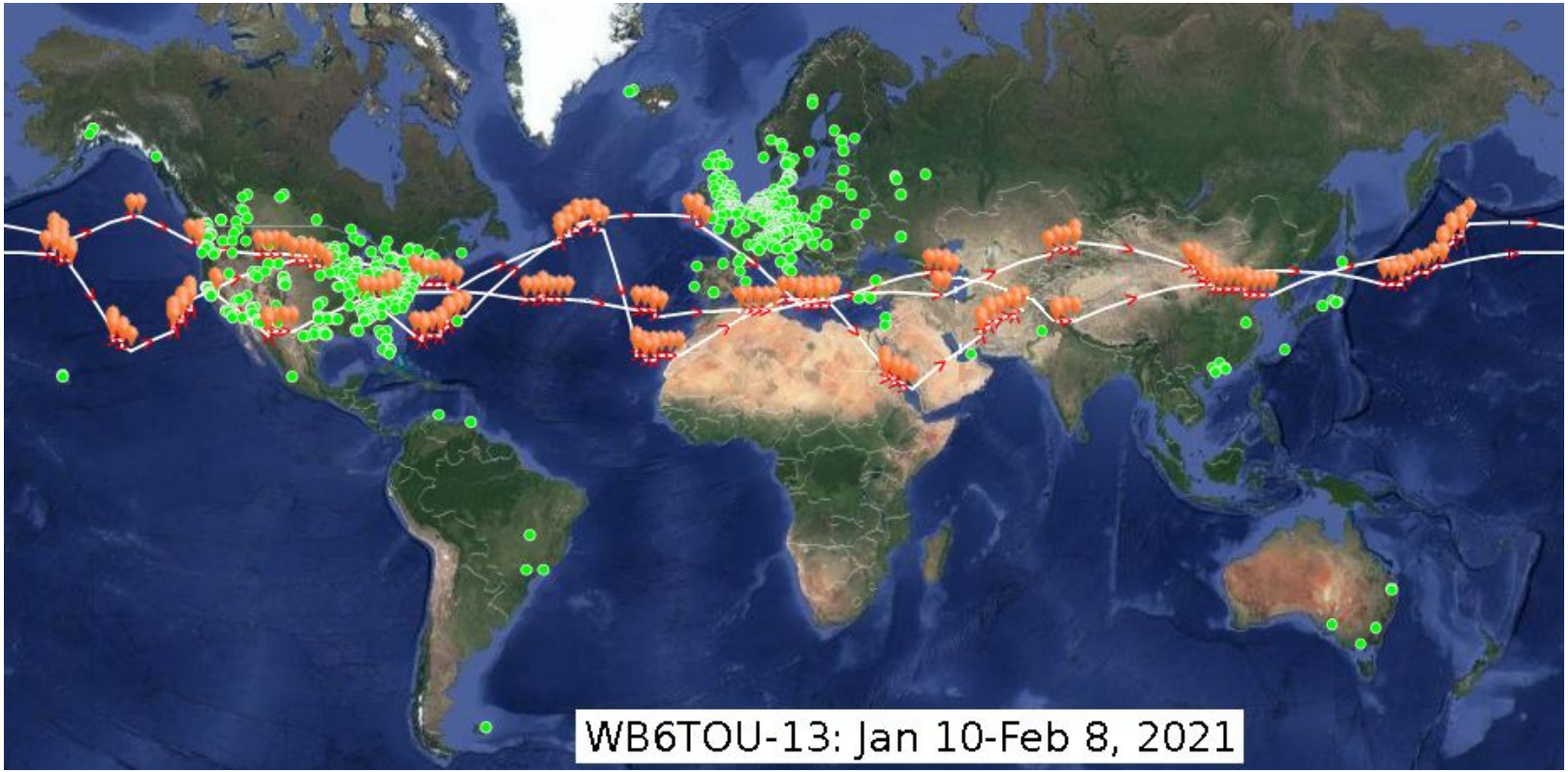
The expected altitude and course should not fly into clouds or above thunderstorms.

Winter favors circumnavigation. Summer favors interesting wandering trips.

The team releasing the balloons should practice as early or late release of the payload can result in problems.

Release a small trial balloon to be sure the air flow is OK.

WB6TOU-13: Around the World 2.5 Times



SBS-13 balloon, WB8ELK WSPR Skytracker

Different Types of Position Reporting

	Automatic Position Reporting System (APRS)	**Weak Signal Reporting System (WSPR)**
Network	ARPS.fi (APRS-IS)	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

Lightweight/Cheap DIY Trackers (vs Expensive COTS)

Tracker Hardware Building Blocks

- Power System (<$1 - $14, 3 g - 5g)
- GPS Receiver ($3.50 - $12, 0.5 g)
- Microcontroller ($2 - $4)
- Radio Transmitter(s) (<$1 - $ big bucks, Si5351 & TCXO = $3.65)
- Antenna System ($ pennies - $10, 2 g - many g)
- PCB - ($2), (0.8 mm, 3 g)

New Skills Developed/Improved During Covid

- Parts Selection (Eat or Starve)
- Schematic Design Entry (KiCAD -> EasyEDA)
- PCB Layout (KiCAD -> EasyEDA)
- SMT Soldering (Smaller Pitch)
- HW/SW Debugging (Work In Progress)
- L-Band QRM Debugging (Work In Progress)
- VHF “In The Shack” Glitch Debugging (Solvable)

Useful Tools

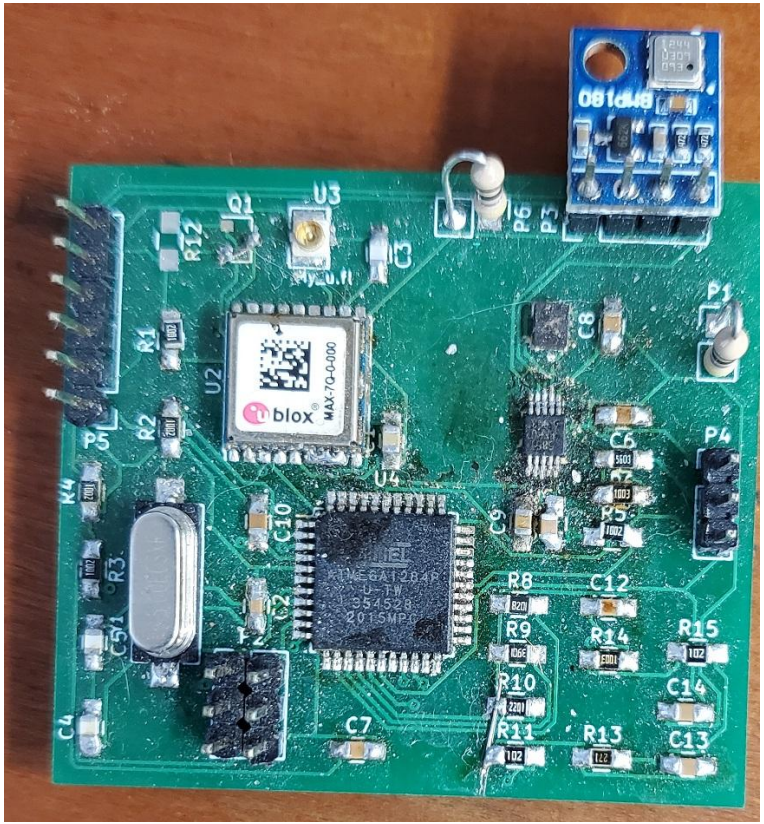
Inspection Microscope w/Light Ring

Hot Air Rework Tool

Mini Hot Plate Reflow Tool

SDR + Field Probes + SATSAGEN SW = Spectrum Analyzer

Old Tracker


U3
P6
P3
P1
U2
blox
MAX-7Q-0-000
P5
R2
P4
U4
C6
C10
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R8
C12
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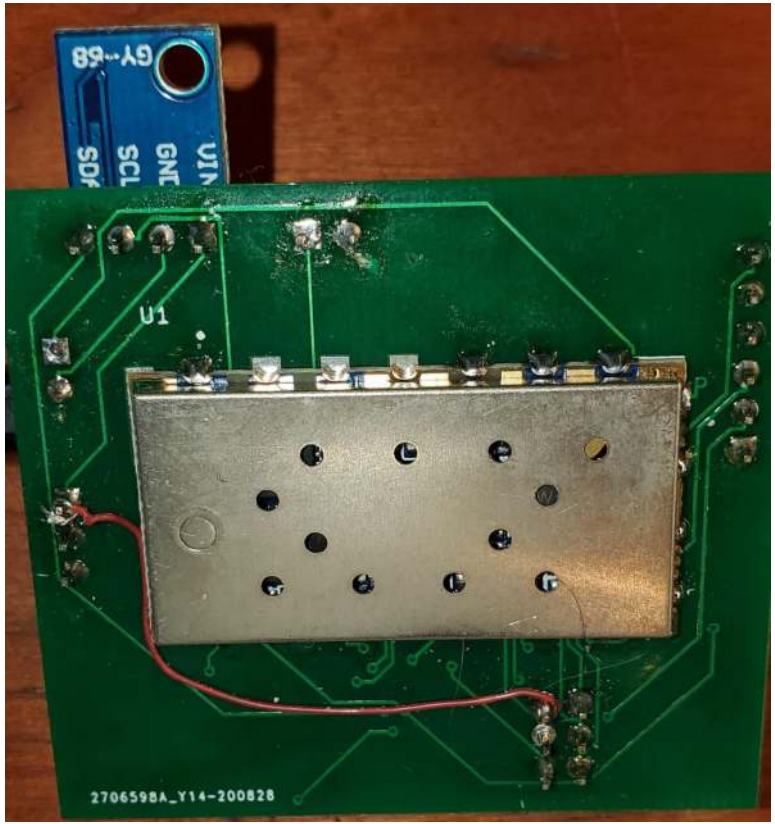
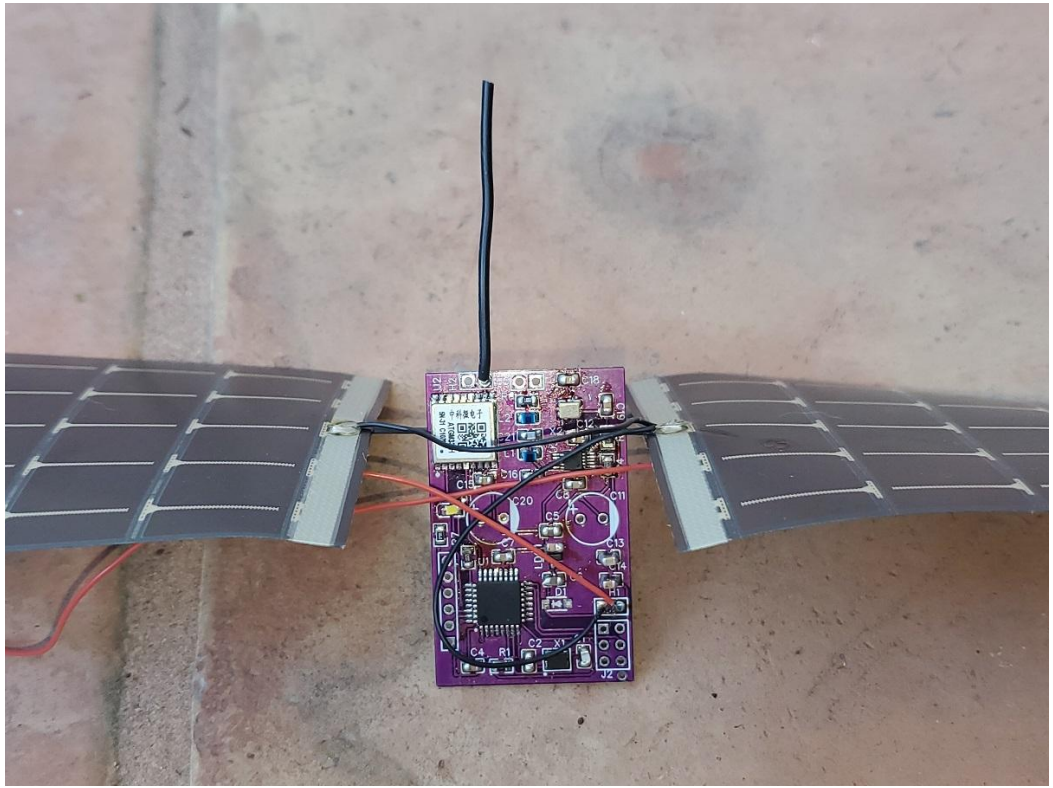
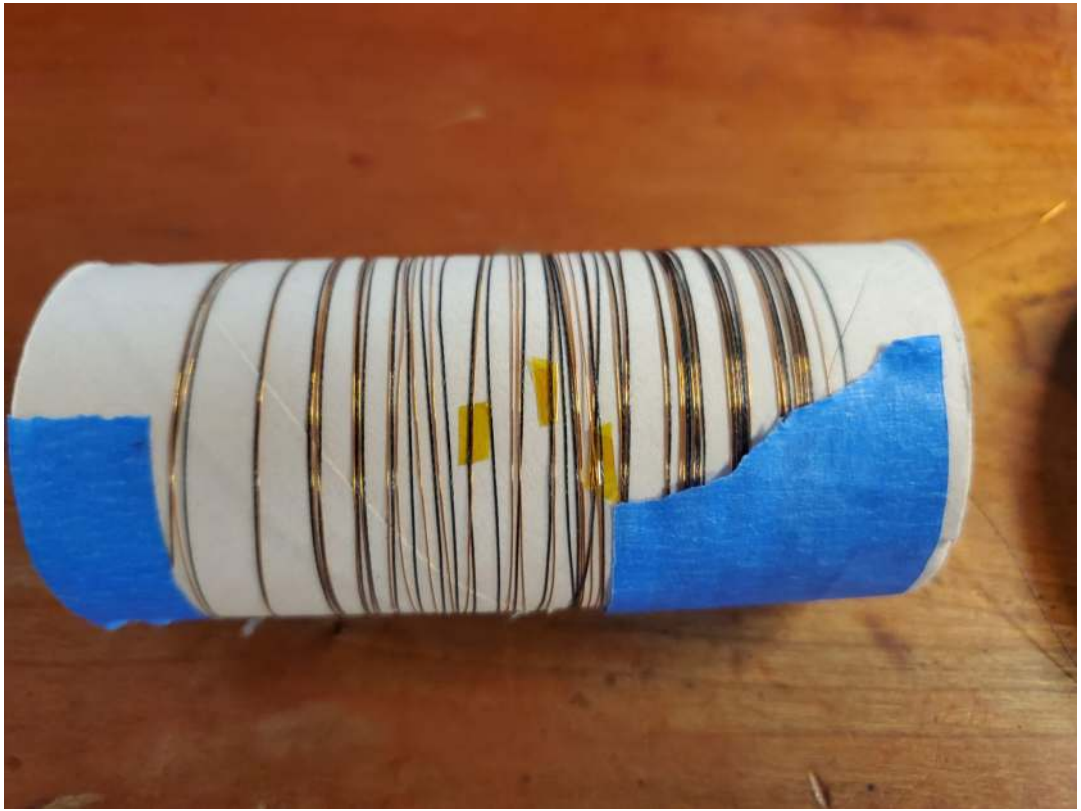
R15
R10
C14
C7
R11
R13
C13
C4


GY-68
U1
2706598A_Y14-200828

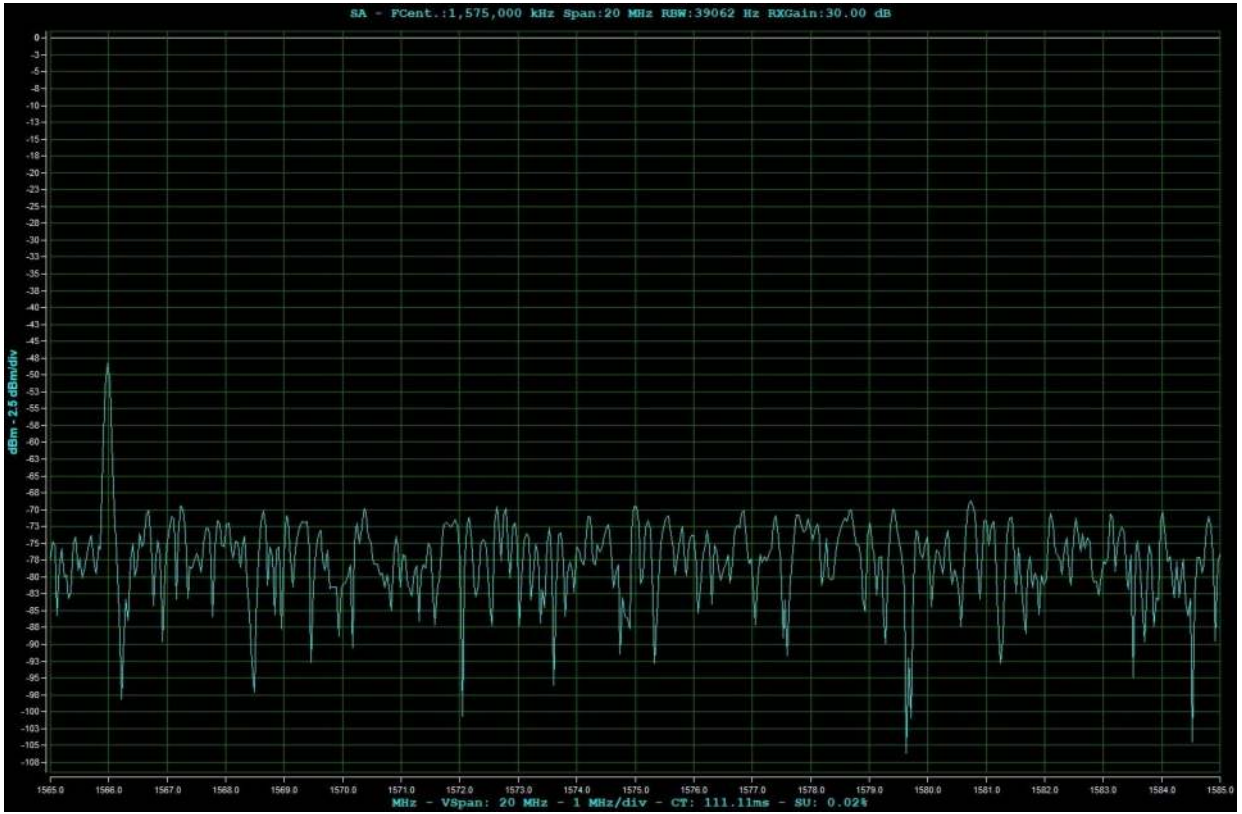
Current Tracker



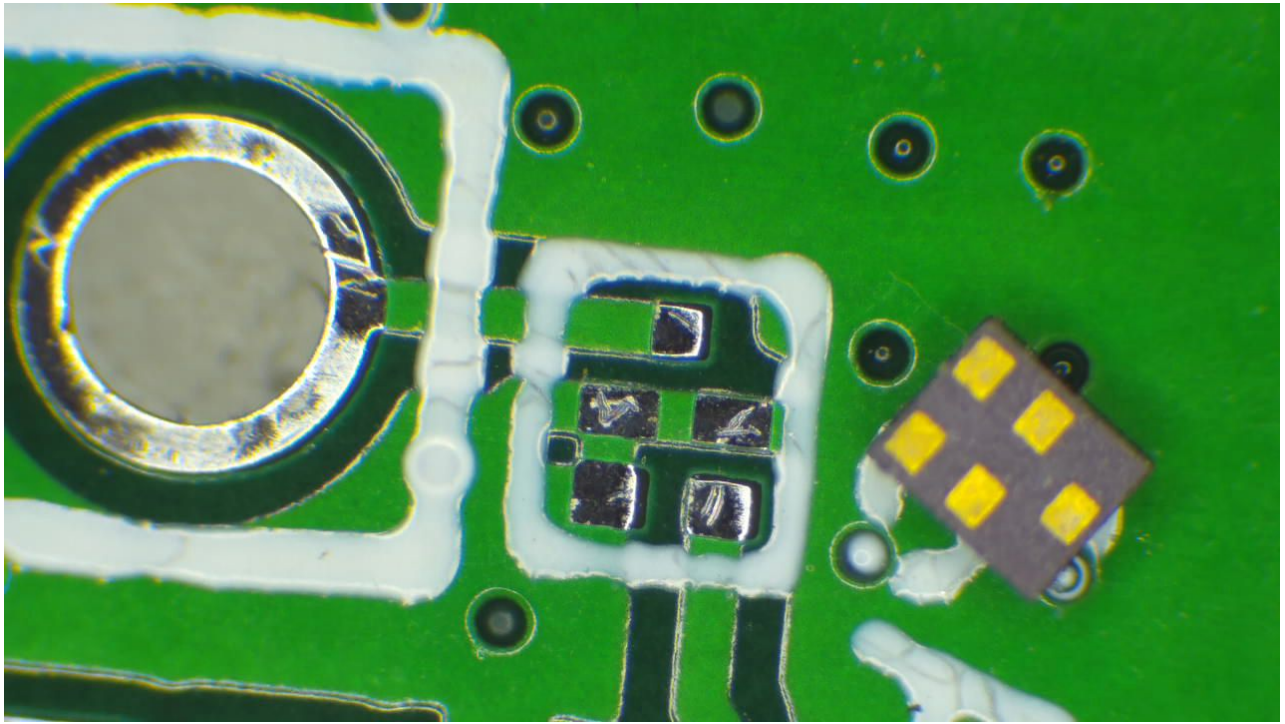
1.5 g/34 AWG/4 Ohm “Ladder Line” Driven Dipole Element

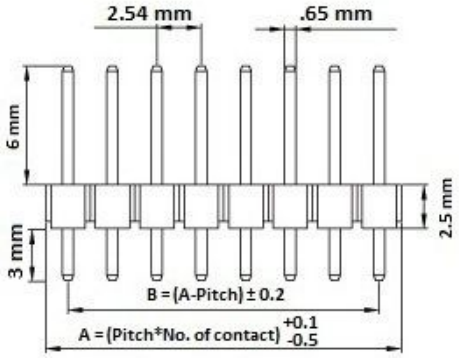


GPS QRM


SA - FCent.:1,575,000 kHz Span:20 MHz RBW:39062 Hz RXGain:30.00 dB
dBm - 2.5 dBm/div
MHz - VSpan: 20 MHz - 1 MHz/div - CT: 111.11ms - SU: 0.02%

Smallest Band-Aid (SAW Filter)





APRS Data

Station info - map view · info · telemetry · weather · raw · status · beacons · messages · bulletins · browse · moving · my account

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

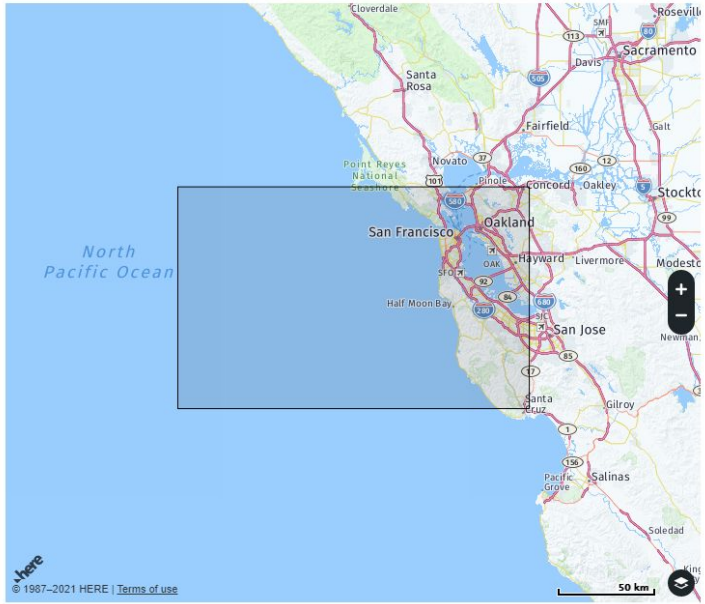
Other SSIDs: **K7HAK** K7HAK-7 K7HAK-9

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

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

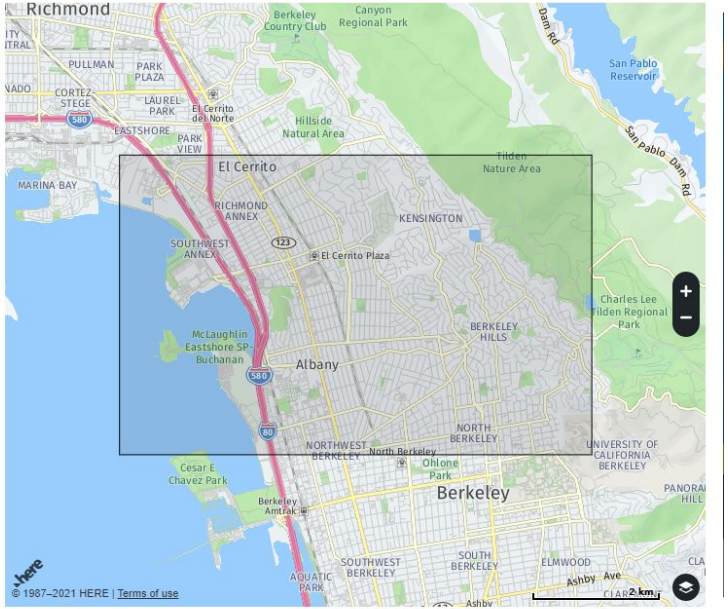
WSPR Position Reporting - Maidenhead Locator System

Grid Square: CM87



Other Ham Radio / Amateur Radio pages by K2DSL on Levinecentral

Grid Square: CM87uv

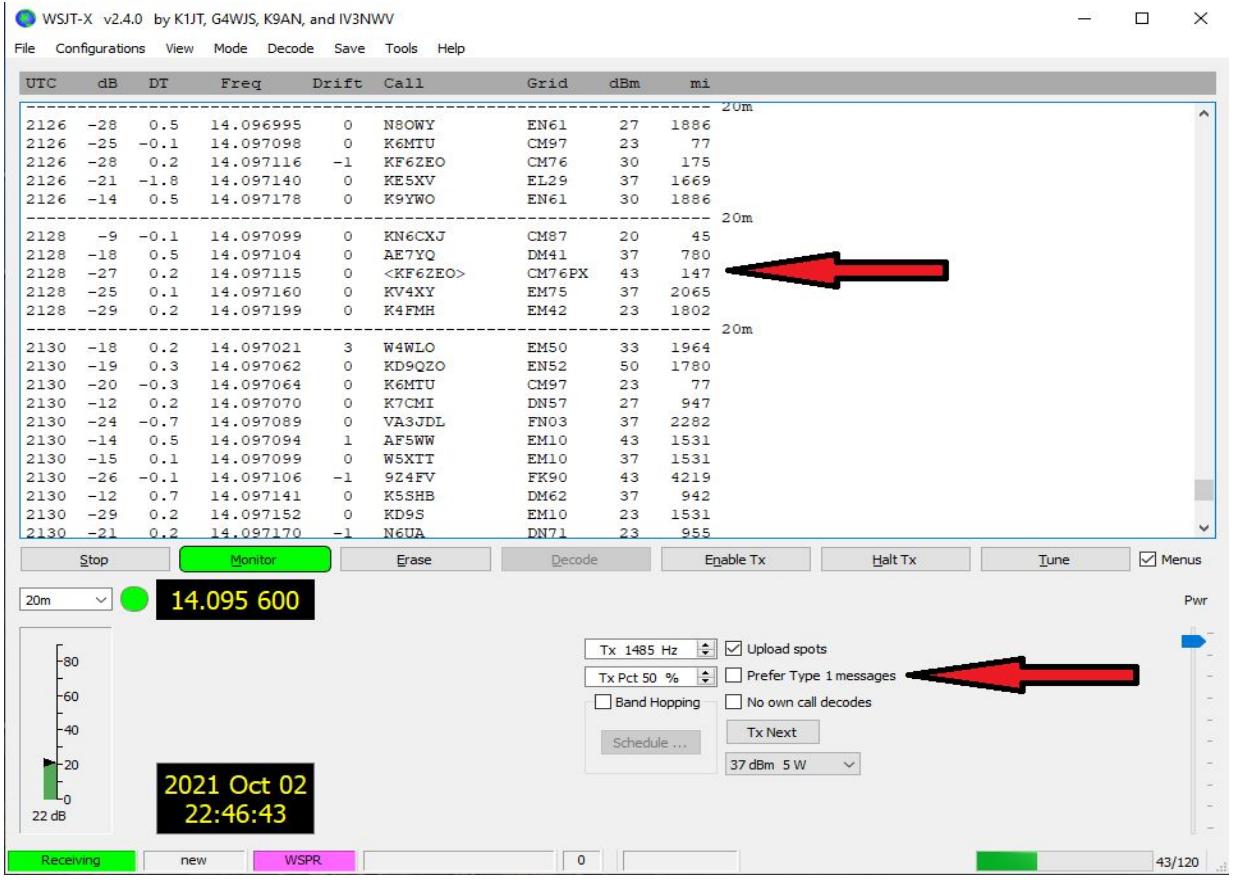


Other Ham Radio / Amateur Radio pages by K2DSL on Levinecentral

WSPR Altitude Reporting

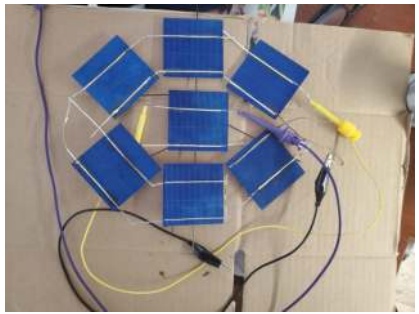
		Feet	Feet
Power dBm	Power Watt	Altitude Min	Altitude Max
0	1 mW	0	2953
3	2 mW	2953	6890
7	5 mW	6890	9843
10	10 mW	9843	12796
13	20 mW	12796	16732
17	50 mW	16732	19685
20	100 mW	19685	22638
23	200 mW	22638	26575
27	500 mW	26575	29528
30	1 W	29528	32480
33	2 W	32480	36417
37	5 W	36417	39370
40	10 W	39370	42323
43	20 W	42323	46260
47	50 W	46260	49213
50	100 W	49213	52165
53	200 W	52165	56102
57	500 W	56102	59055
60	1 kW	59055	

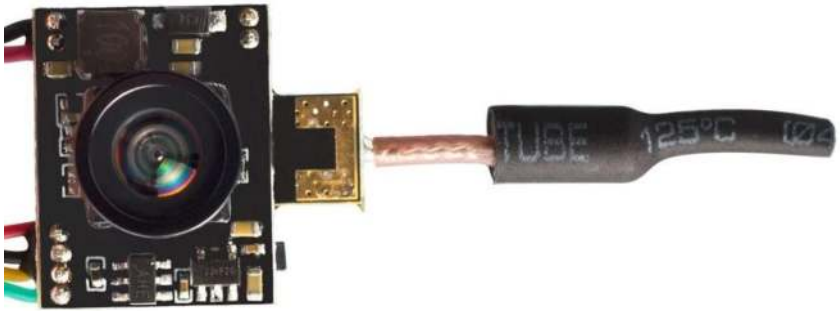
WSJT - WSPR “Precise” Reporting



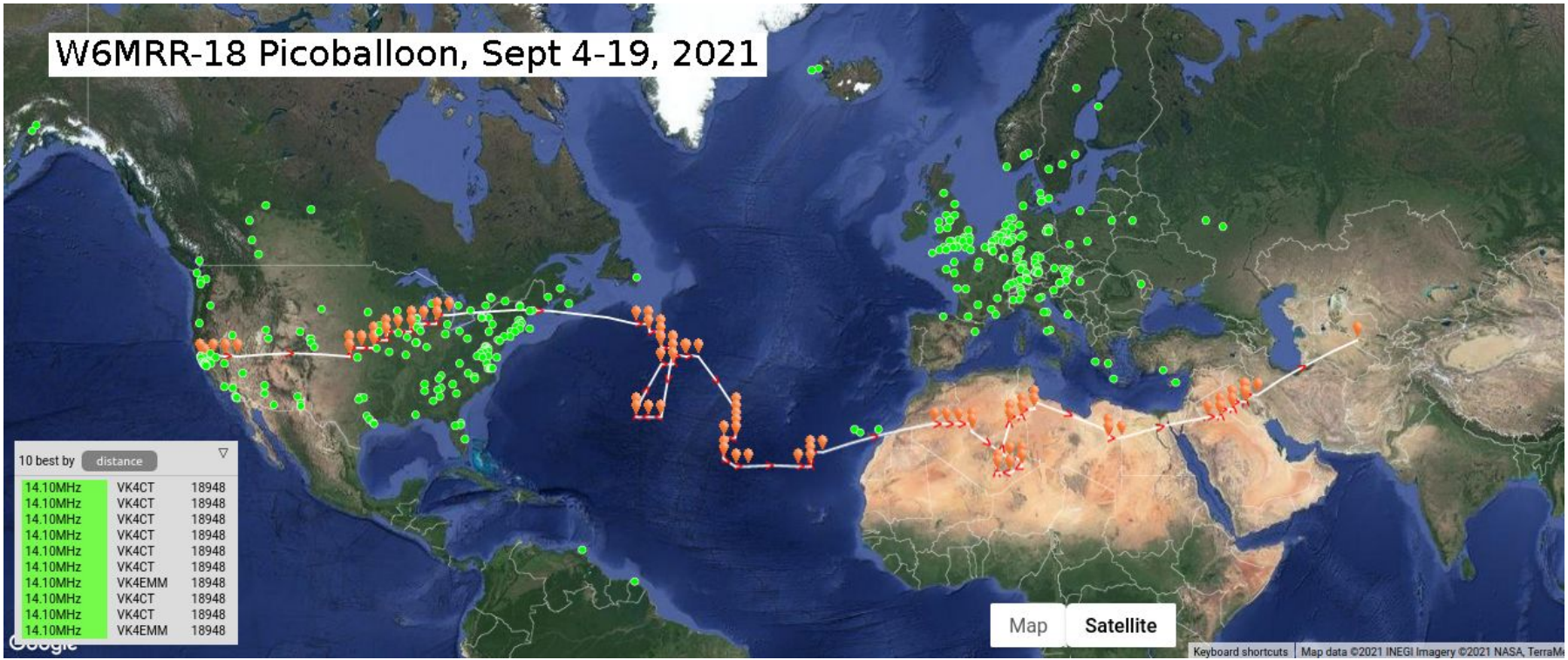
Help Wanted - Future Balloon Projects

- Interesting Pico Payloads - Cameras, Sensors,...
- Dual Gimbal Gyro Inertially Stabilized HAB payload
- VLF Downloader HAB
- Better Solution To Type 2 or 3 WSPR Message
- New Balloon Envelope Designs
- Controllable Altitude Balloon - Amateur Radio Loon?
- WSPR Buoys





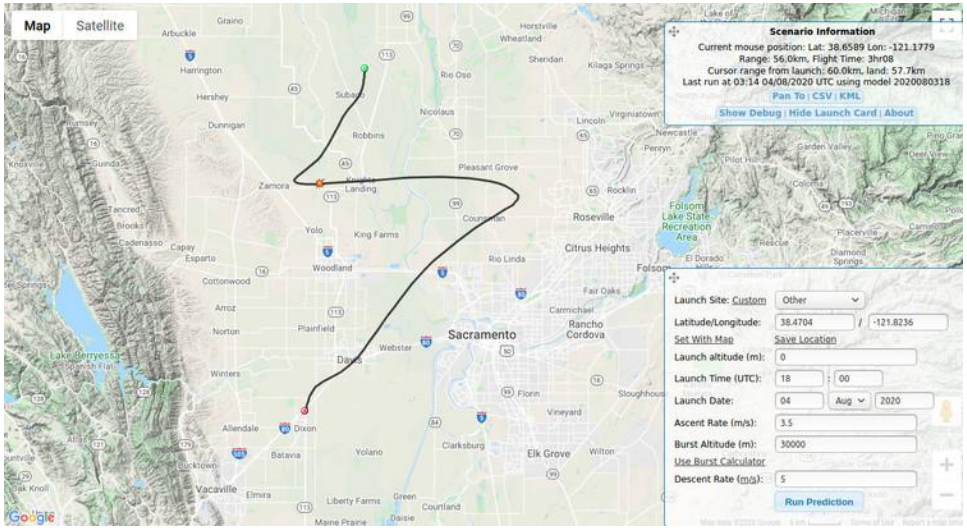
W6MRR-18: California to Turkmenistan



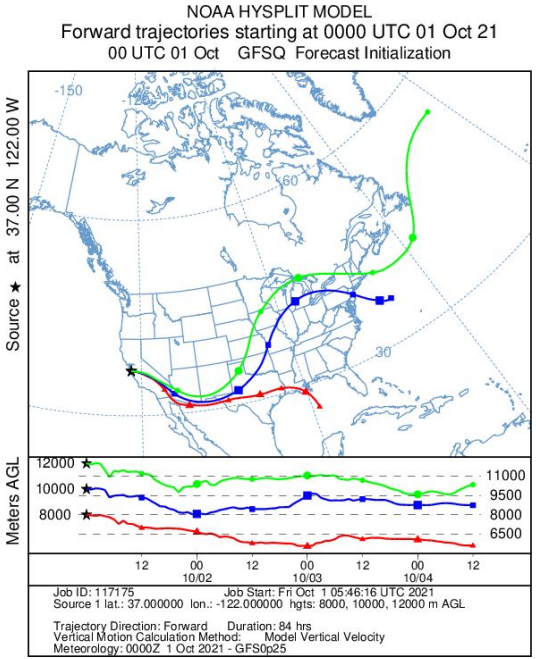
Two Ali Express balloons, custom WSPR transmitter

Flight Path Predictions

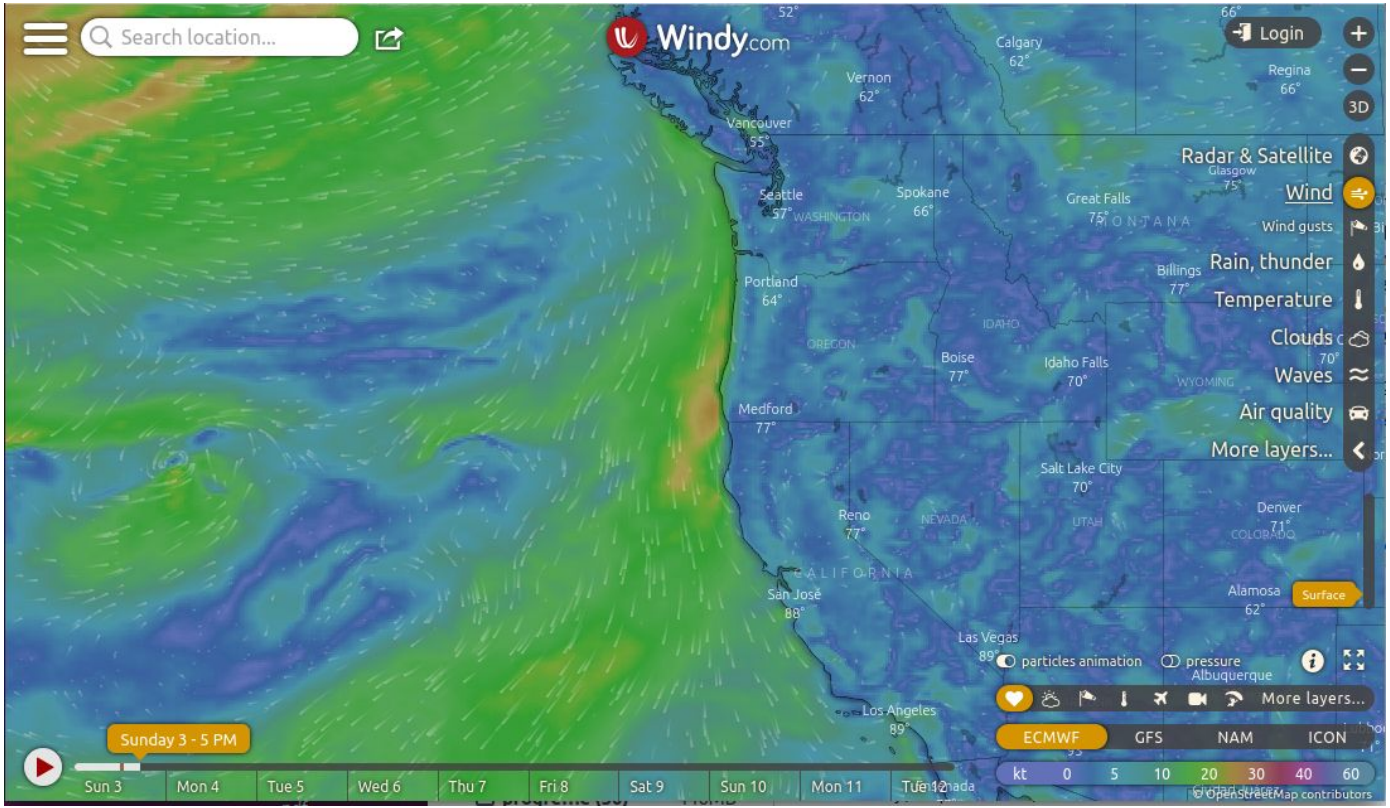
- How do you predict where a bursting Latex balloon will land?
- What direction will a superpressure Picoballoon float?
- Where does HYSPLIT get data from?



https://predict.habhub.org/

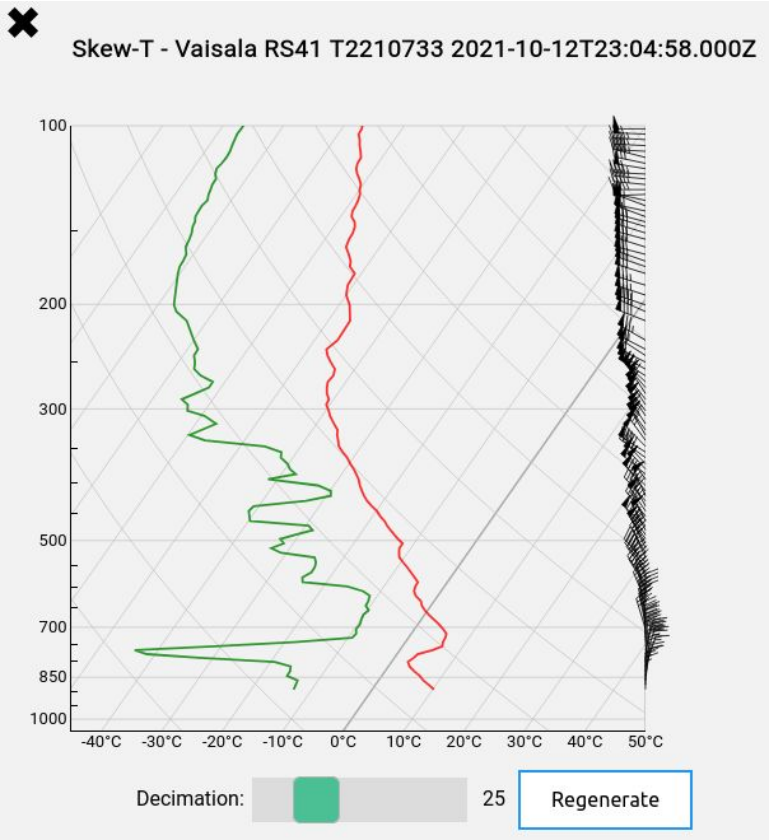


Where do these maps come from?



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

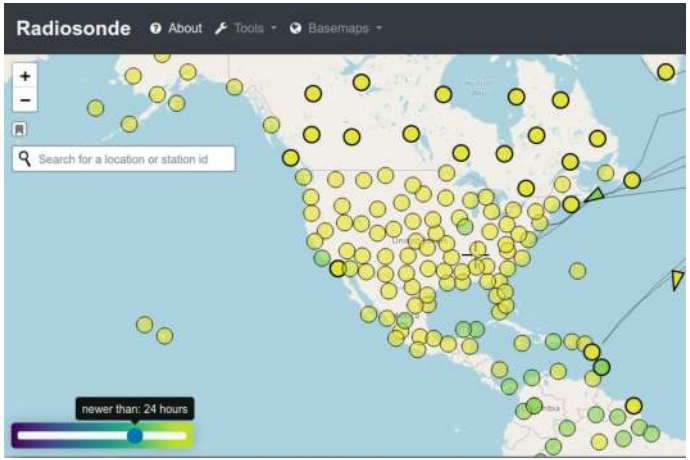
Radiosondes Directly Measure Upper Atmosphere Winds

- 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

Typical Radiosonde Flight

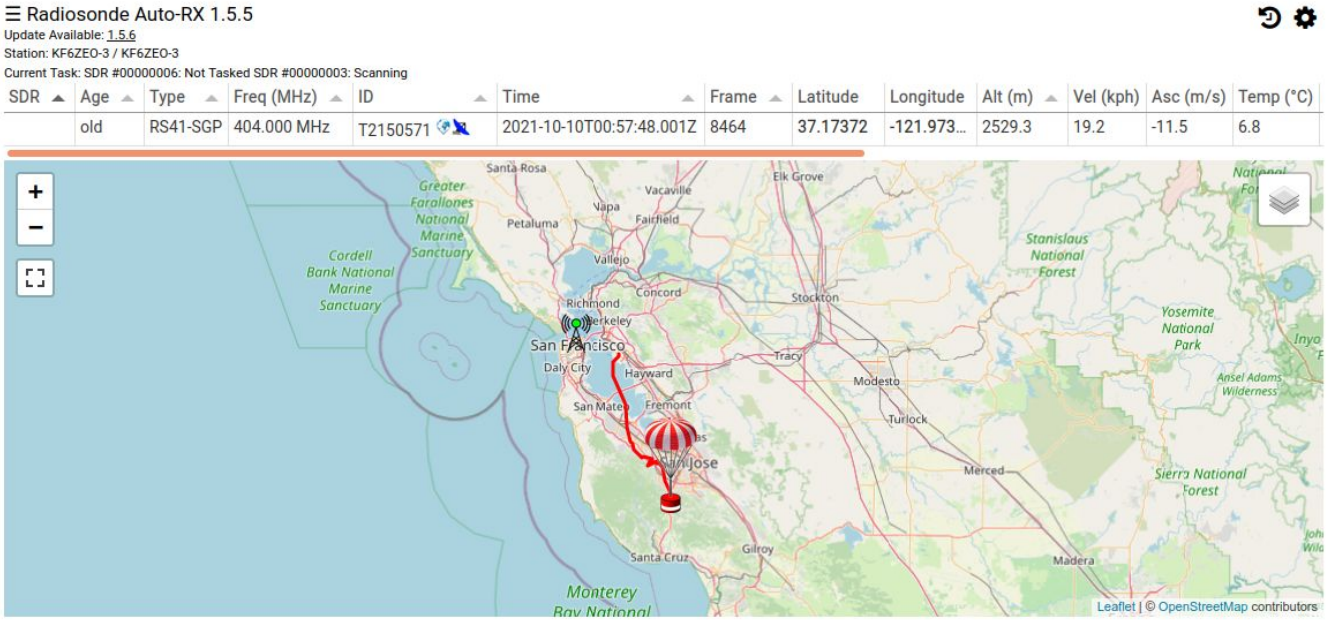
- Radiosondes are launched at 1100 and 2300 UTC every day
  - 4am and 4pm Pacific time (until DST ends soon)
- Balloon ascends at ~5 m/s for 90 minutes, up to ~30k meters (~100k feet)
- Balloon bursts, and free falls for 30 minutes until it hits the ground



Launch Sites in North America
https://radiosonde.mah.priv.at/dev/

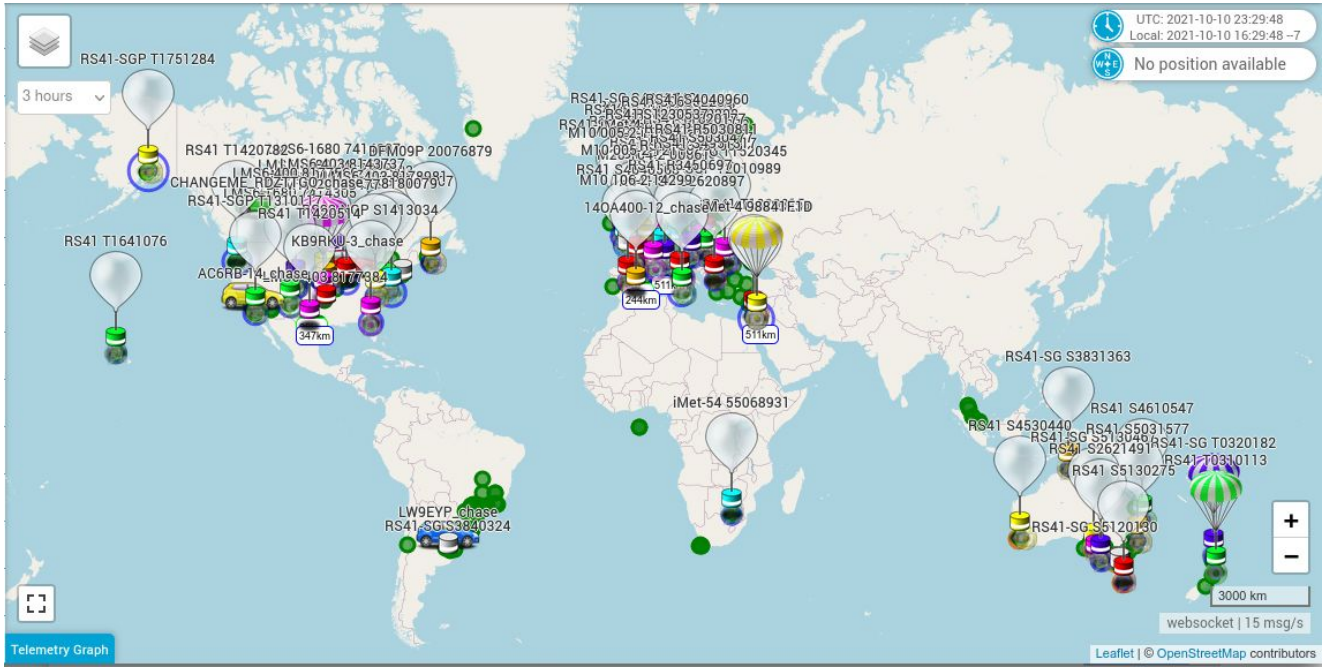
Radiosonde Receiving Software

- radiosonde_auto_rx runs on linux with a $25 RTL-SDR receiver
  - Runs in a docker container!
- rdzTTGOsonde runs on a TTGO LoRa ESP32 chipset

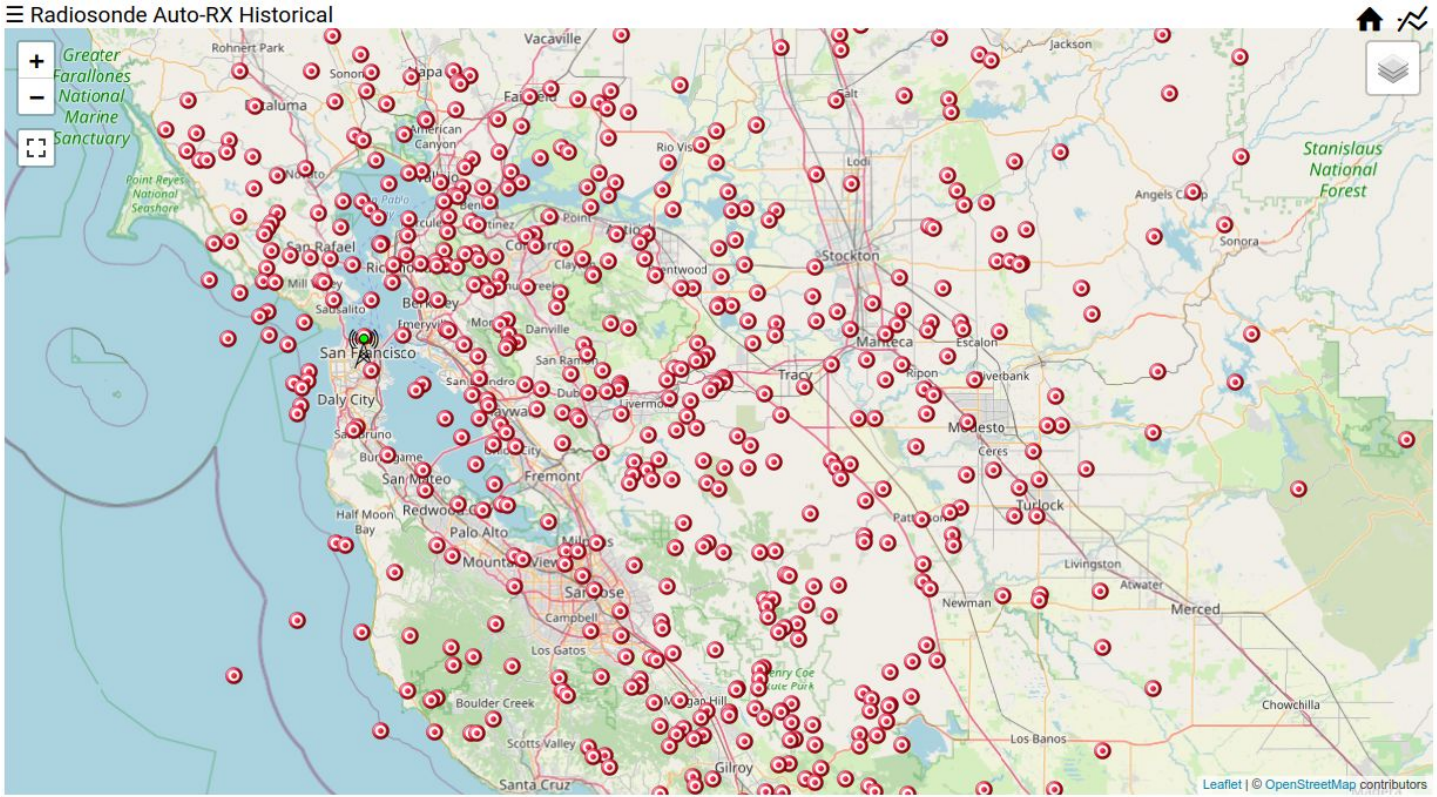


Worldwide Network of Radiosonde Receivers

- SondeHub collects all radiosonde_auto_rx telemetry
- Balloon tracking, real-time landing predictions, integration with Chasemapper



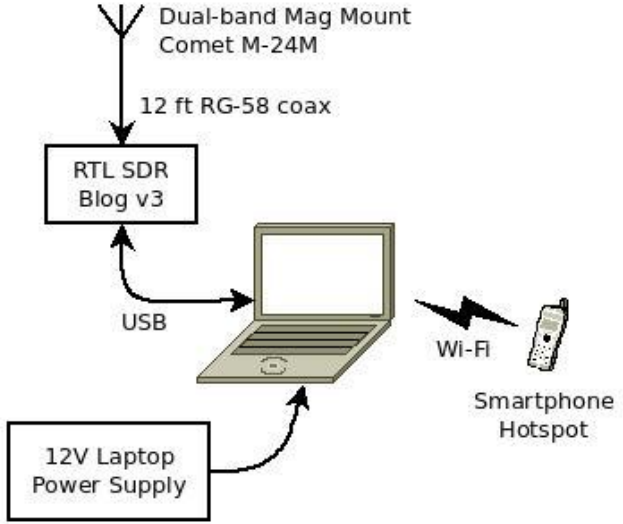
Where do Radiosondes Land?



Last radiosonde RX location, as received from my San Francisco station, Jan to Oct 2021

Chasing and Recovering a Radiosonde

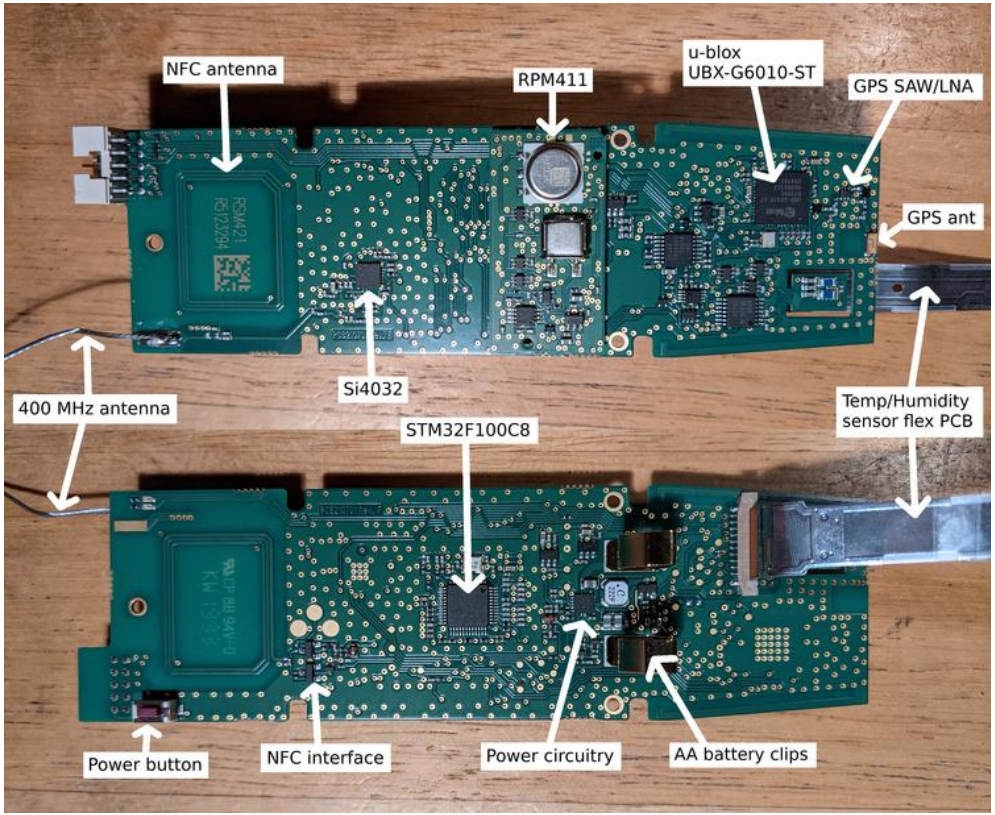
- Like amateur radio transmitter hunting
- Have someone else drive (so you can look at the screen and navigate)
- Ask for permission if it lands on private property
- Urban areas are more than 30% roadways and parking lots, so the odds are good
- Sondehub updates landing location during descent, you might be able to see it fall



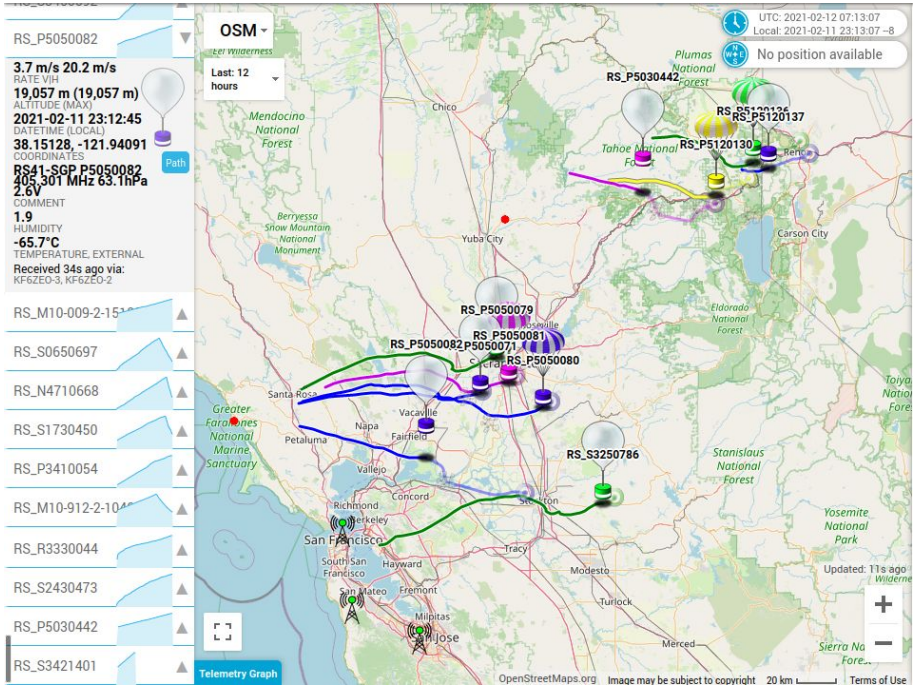
Radiosonde Recovery

What Can You Do With a Radiosonde?

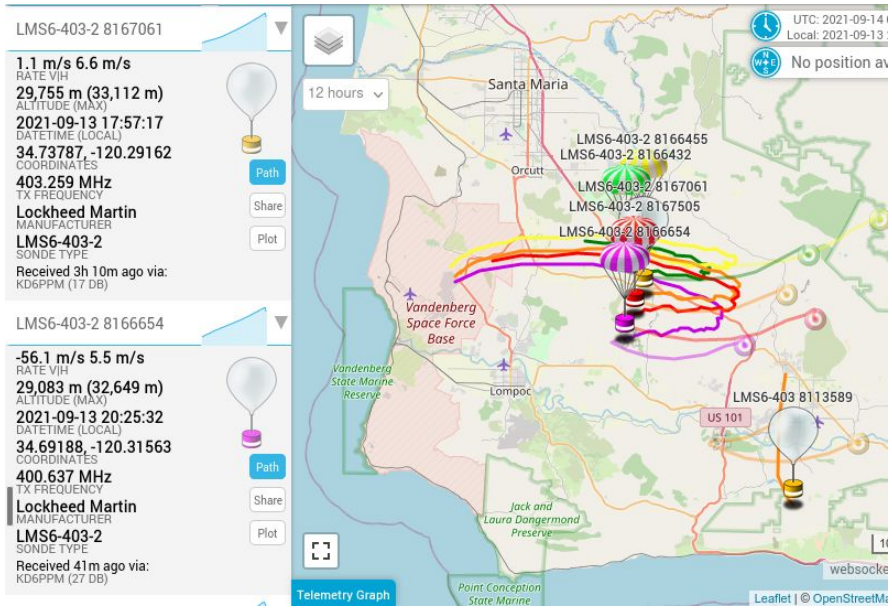
- Radiosondes are disposable, the NWS doesn't want them back
- Recycle/Reprogram:
  - Joseph OM3BC for 430 MHz APRS
  - DF8OE on github
- Scrap for parts:
  - Two AA lithium batteries
  - STMicroelectronics STM32F100C8
  - Silicon Labs Si4032
  - u-blox UBX-G6010-ST
  - Vaisala RPM411 pressure sensor



Special Radiosonde Launches

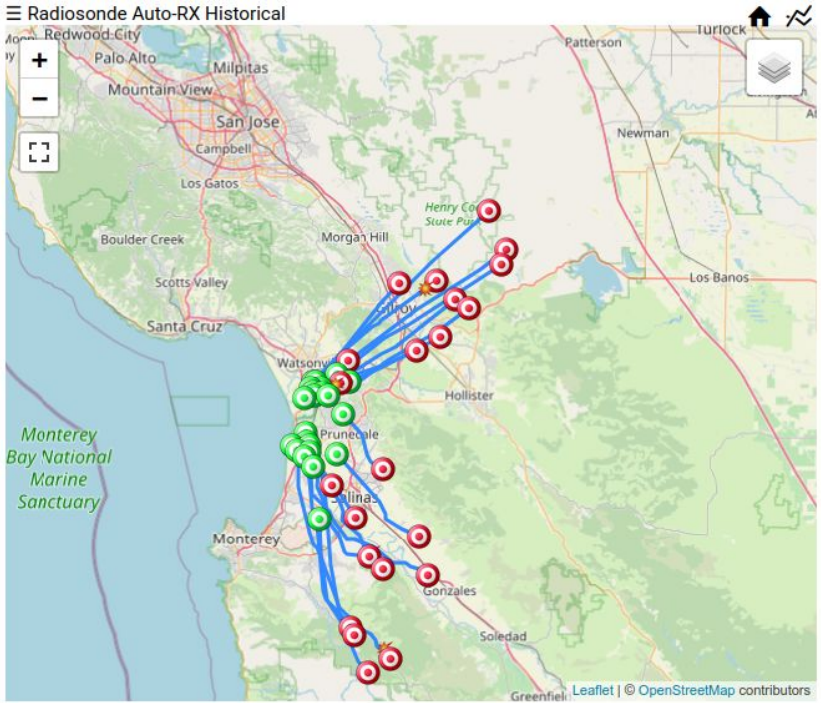


UCSD Atmospheric River Measurement

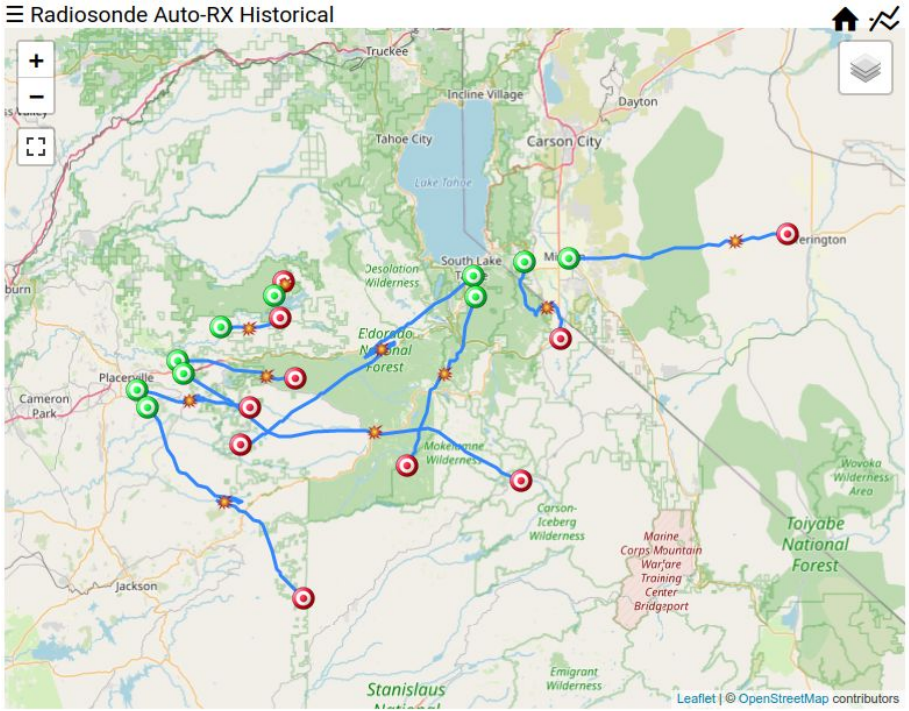


Falcon 9/Starlink launch from Vandenberg

Special Radiosonde Launches



Monterey Bay Weather Measurements



Caldor Fire Winds

Questions?

https://www.sf-hab.org