Amateur Radio Ballooning in The Bay Area With SF-HAB

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2025 ARRL/Pacificon San Ramon, CA

www.sf-hab.org

The Law(s)

PV=nRT

Density = Mass/Volume -> Float Altitude

FAA FAR 101 …

FCC Rules …

ITU Radio Regulations -> QRT Over Some Places (UK, NK,...)

ITAR (CoCom) Regulations -> Makes Your GPS Stop

Thermodynamics ->Heat Transfer Not Always Easy

Economics -> Beer Budget vs Champagne

From HABs to Picos

Types of Balloons

	HAB (Strechy)	Superpressure (Inelastic)
Flight duration	1-4 hours	Days to Months (to Years)
Goal	High altitude	Around the world Long endurance
Altitude	Up to ~120k feet, then down	Constant at 40 K - 60 K feet
Payload mass	Up to 12 lbs	10 to 40 Grams
Gas Needed	Large Tank	0.5 L
Comms	APRS / LoRa / 4FSK	WSPR / APRS
Payload recovered?	Yes (usually)	No
Balloon material	Latex	Multilayer plastics
Power	Batteries	Photovoltaic (New! With Batteries)
Science opportunities	Short duration tests	Developing for long duration

Future Developments

Battery Powered Picos

Controllable Altitude

Payload Inertial Stabilization

HAB Networks

Homemade Balloons

Balloon Preparation/Launch

HABs:
Recycle NWS end plug
Handle with gloves
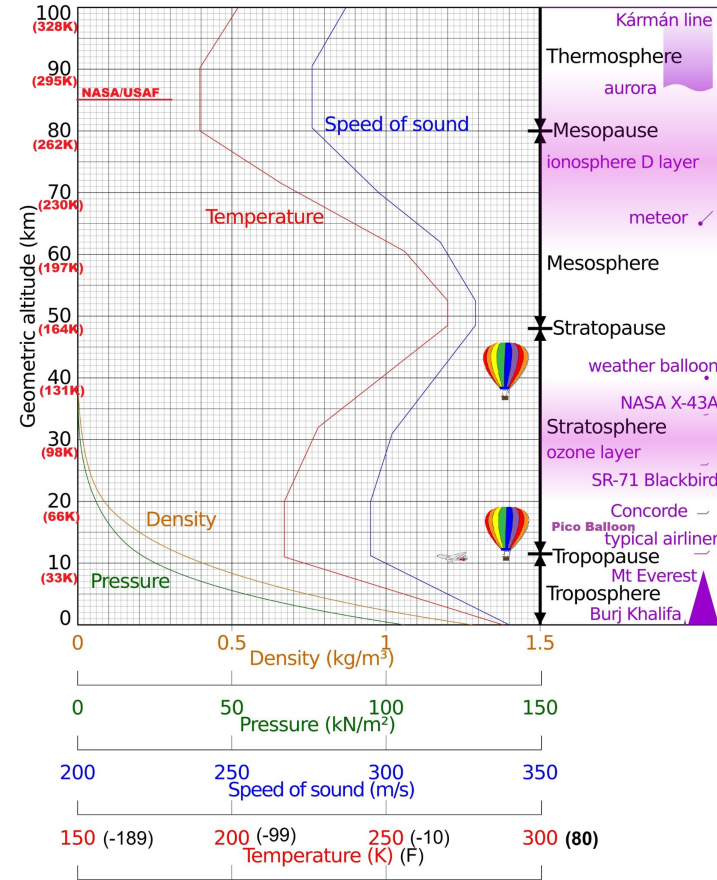Balloon filling/wrangling

Picos:
Pressure Test
Stretch
Fill

Launch:
Picos need low winds
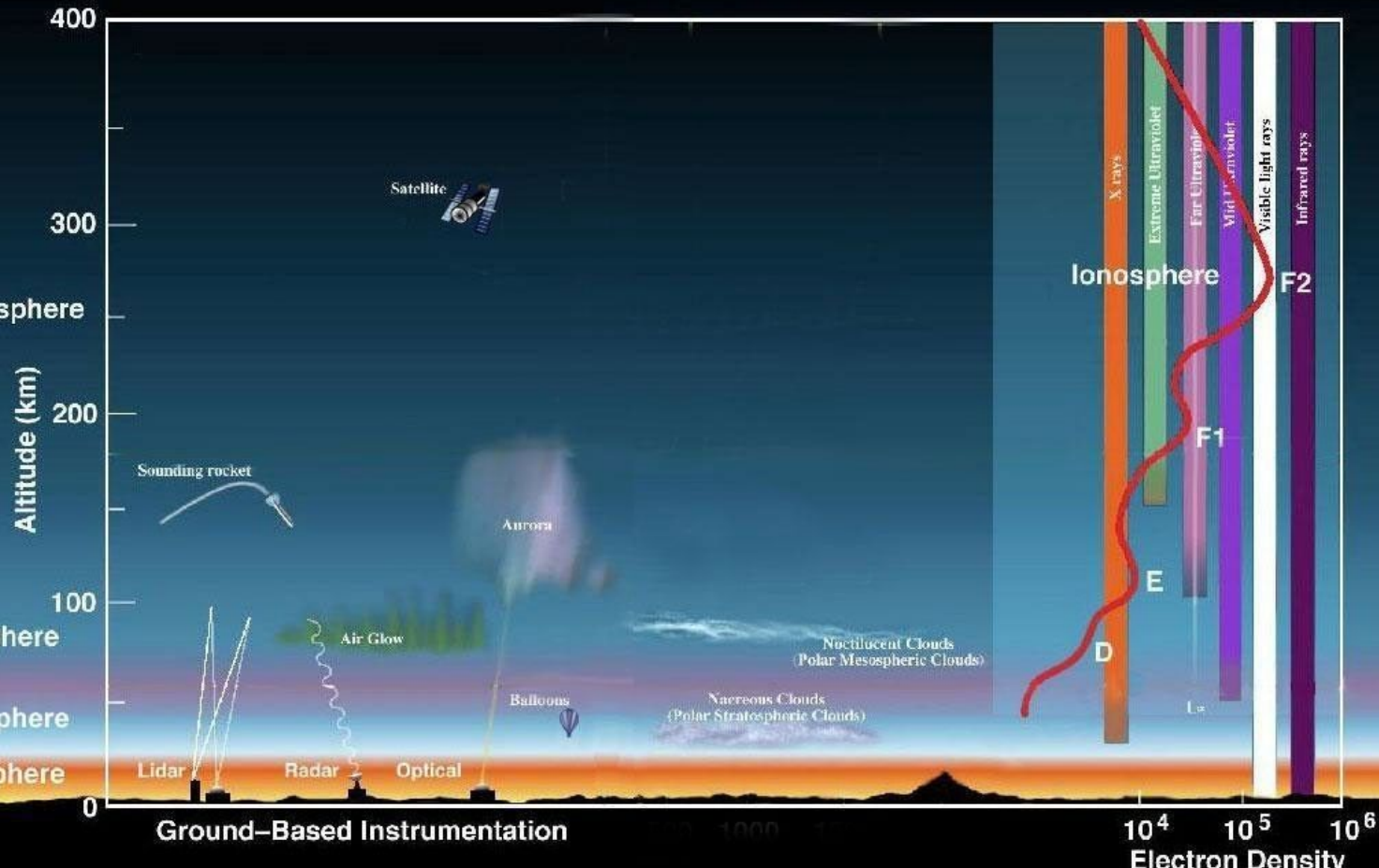Beware of balloons magnetic attraction to trees

Where we fly

Sondehub HAB burst calculator

CUSF/Sondehub HAB Flight Prediction

Balloon Burst

Flight path

Ascent rate: 2.3, descent
rate: 5.0, with burst at
33000.0m.
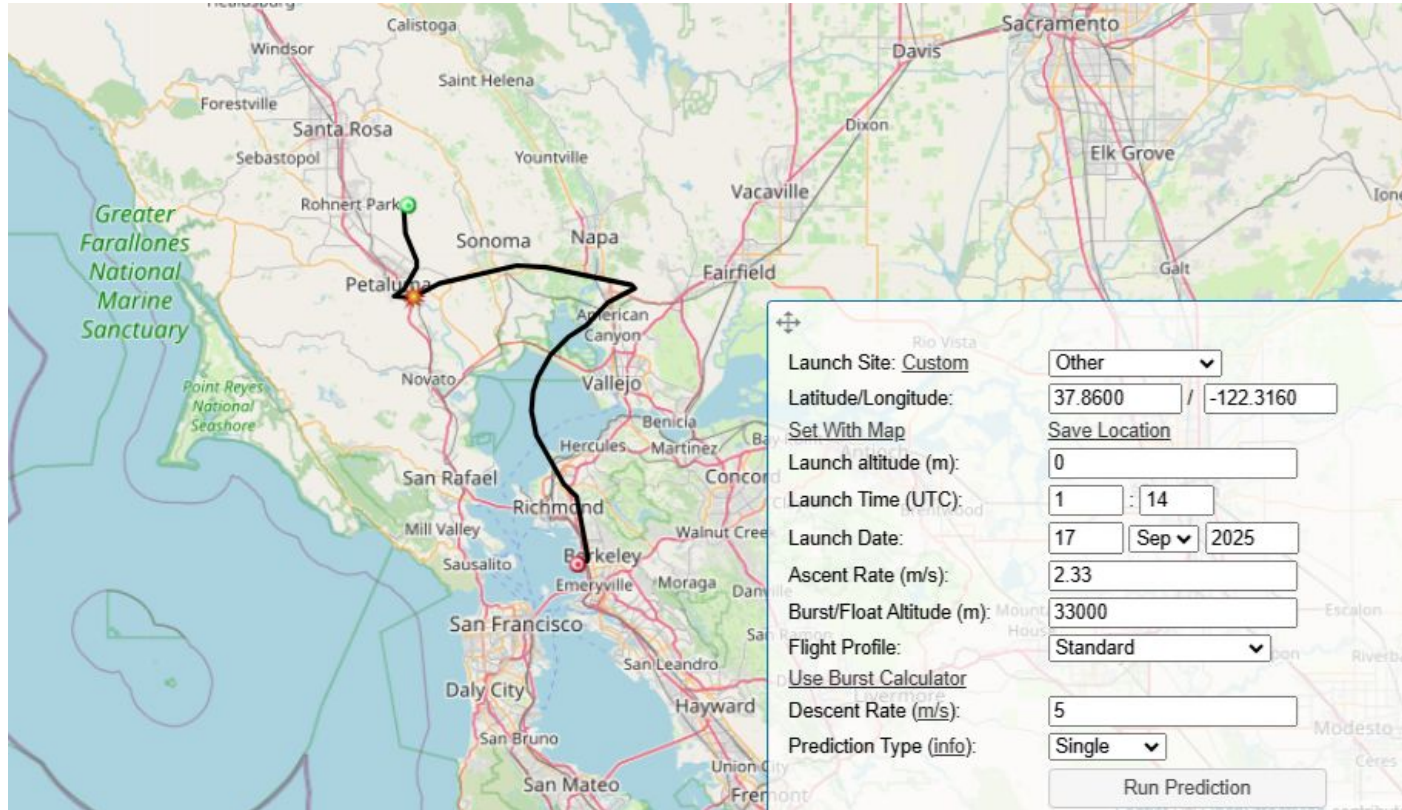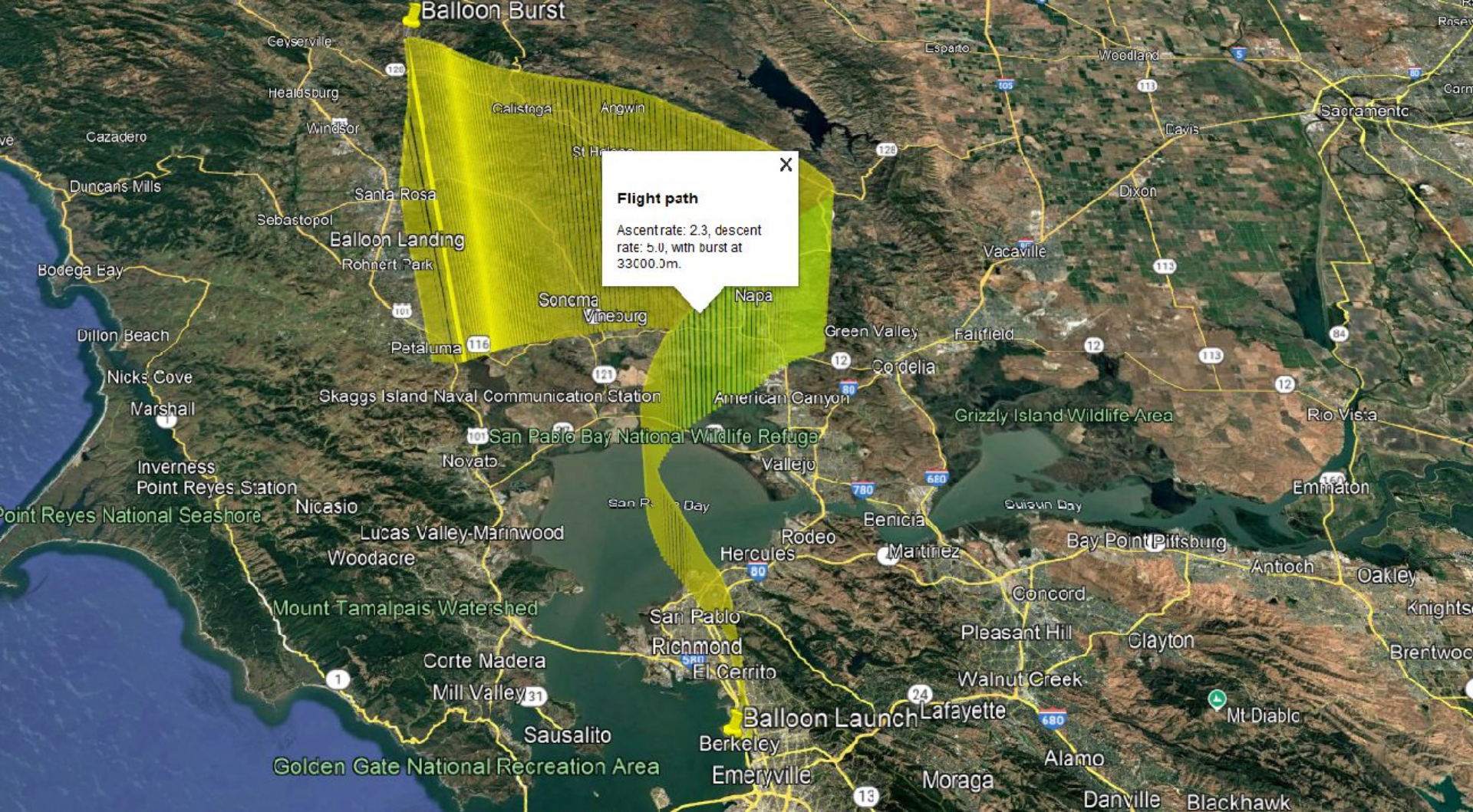
Balloon Launch

National Weather Service - Radiosonde Flights

- Radiosondes are launched at 1100 and 2300 UTC every day
- 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

# 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)
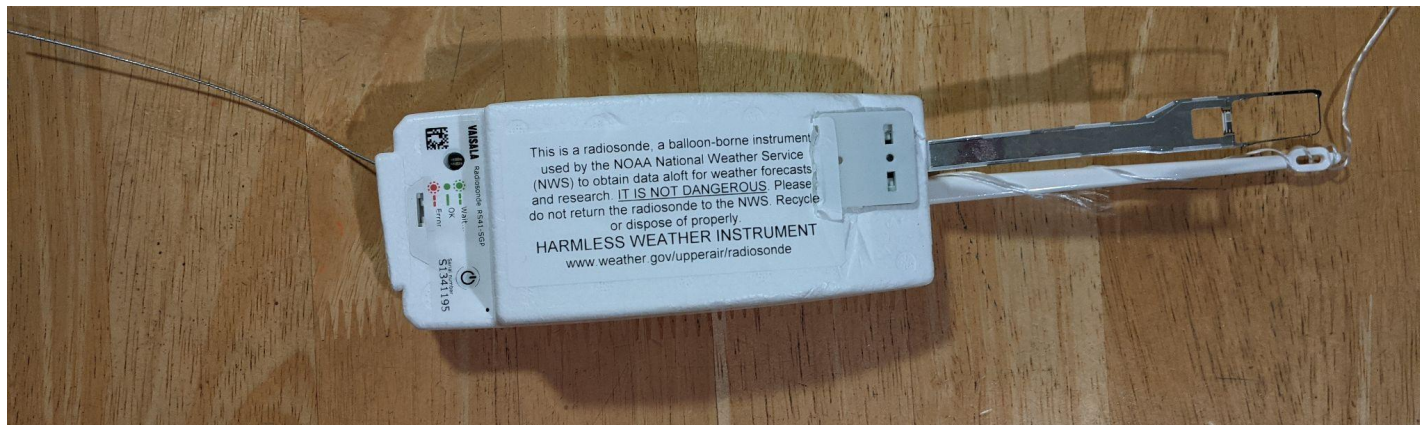
Vaisala RS41-SGP

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 radioso
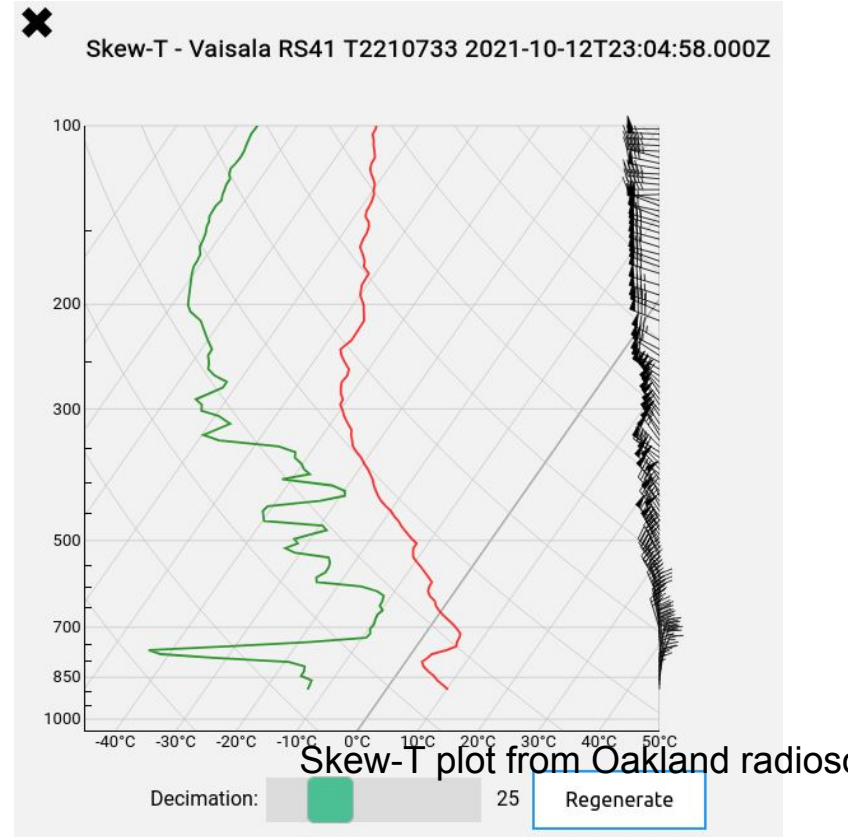
Where do the radiosondes land?

2025 OAK Landings
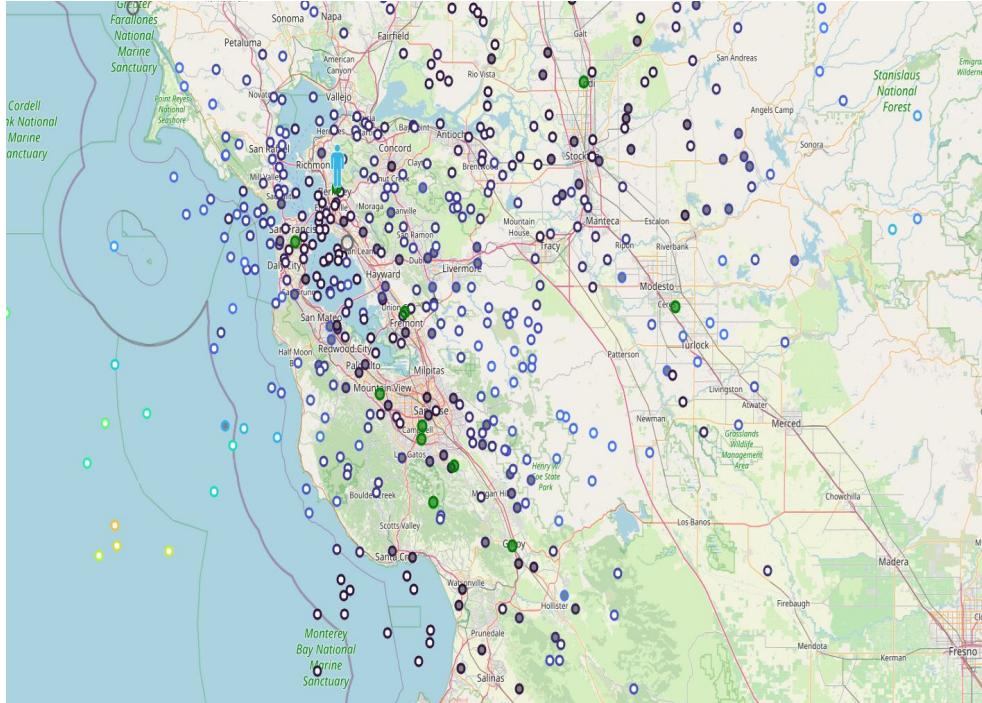
Radiosonde Recovery

NWS Radiosonde Hunting Is A Thing

- Email Alerts For Nearby HAB landings
- Sondehub Map Shows Flight Predictions & Chase Cars (sondehub.org)
- MySondeGo - ESP-32/433 MHz LoRa, Smartphone App
- RTL-SDR & FOSS Software

Design a pico balloon tracker

Hardware, Software and Protocol

Design Challenge

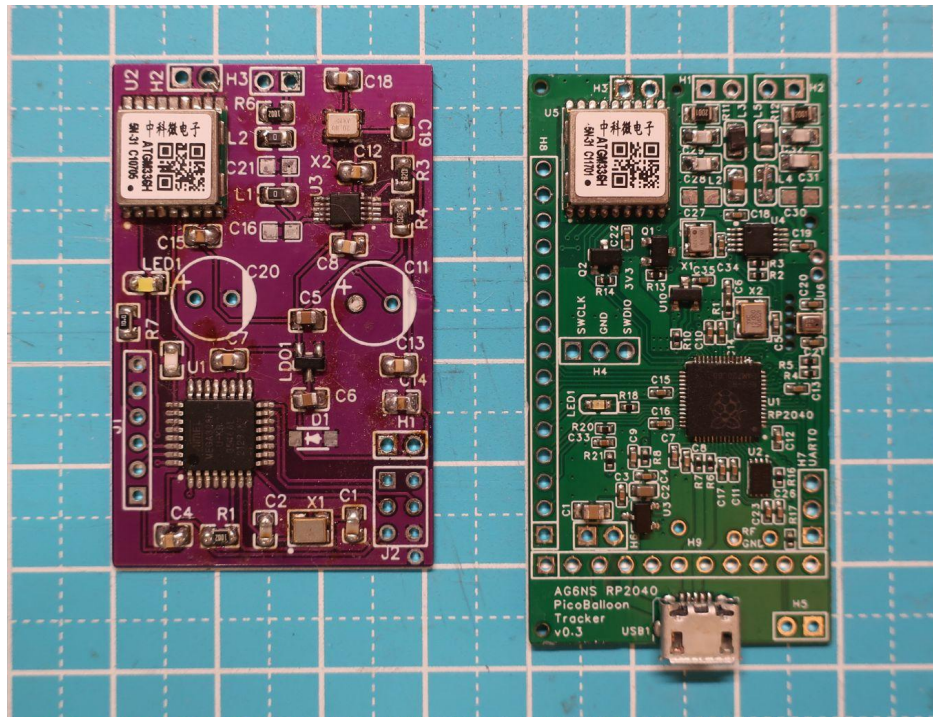- Functionalities v.s. Weight
  - More Sensors = More Weight
- Data Size v.s. Distance
  - More Data = Shorter Distance
- Weight v.s. Altitude
  - Heavier = Lower Altitude

Goal:

- Less weight
- Less power consumption
- Less data

Tracker PCB

Wire Dipole Antennas

GPS

0.6~1.4V to 3.3V
boost converter

1.0V

UART

RP2040
Dual Core
Arm
Cortex-M0+

I2C

Si5351A
Clock
Generator

20m LPF

2m LPF

PicoBalloon RP2040 v0.41

Schematic1 — P1

| Update Date | 2025-08-24 |
| Create Date | 2023-01-16 |

Drawn: EasyEDA Pro v1.8.39

| VER | SIZE | PAGE | OF |
| 2025-05-10 | A3 | 1 | 1 |

AG6NS Kazu Terasaki
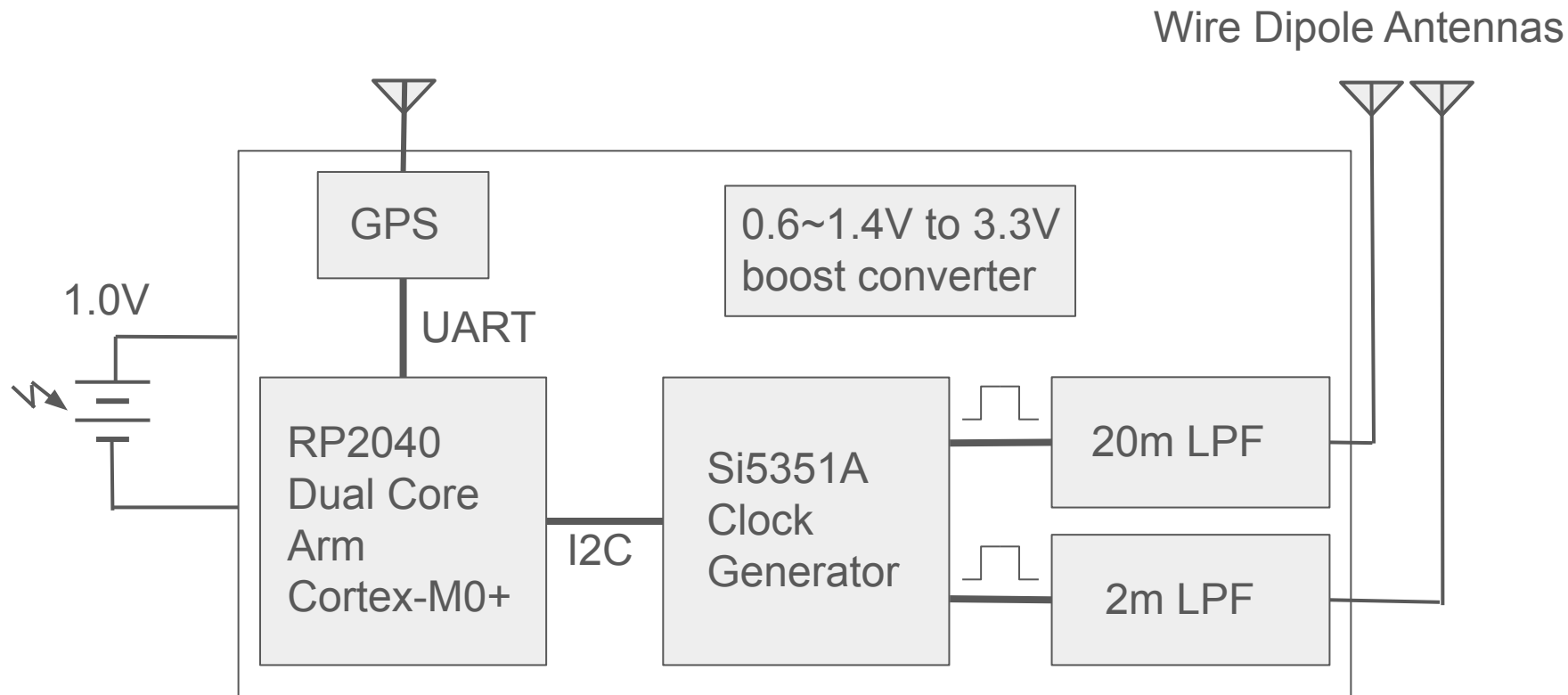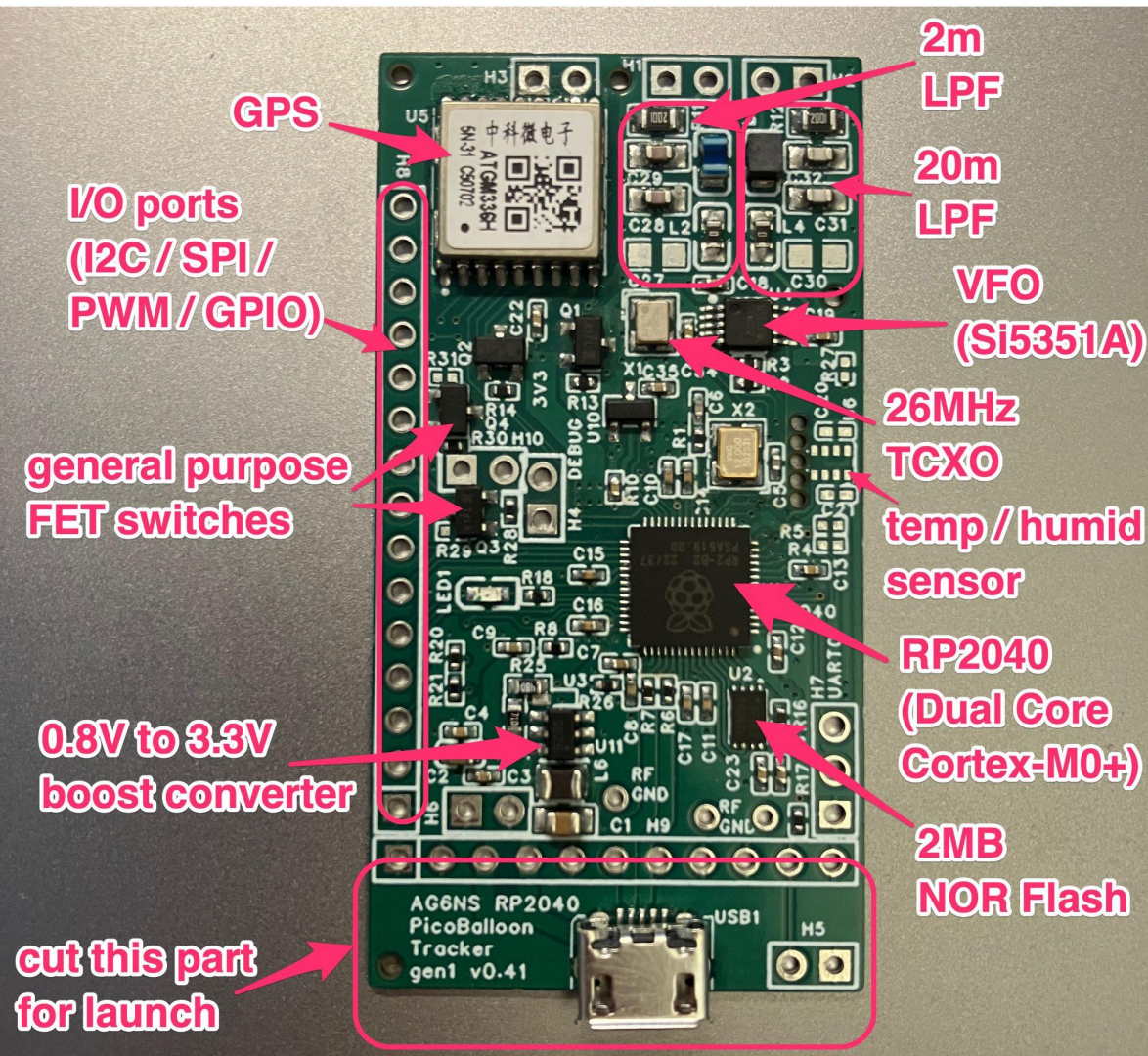
Software

- Target: Raspberry Pi RP2040 MCU
  - Arm Cortex-M0+
  - Clock:
    - 12MHz (WSPR)
    - 48MHz (APRS, SSTV)
  - Price: less than $1.00
- Programming Language: C (RP2040 SDK)
- Operating System: Bare-metal (no OS)
- Supported TX protocols:
  - WSPR, APRS, SSTV, CW

Software hacks

- Overclocking Si5351A I2C (400kHz → 1MHz)
  - To generate APRS (1200bps 2AFSK over FM) and SSTV signals
- Enhanced RTC (micro-seconds accuracy)
  - Calibrated with GPS 1PPS signal
  - For all the software timings
- Pseudo NV-RAM (Non Volatile RAM)
  - Preserve data during BOD resets (caused by unstable solar cell output)
- Auto resume WSPR after power interrupts
  - Receiver stations can't tell the WSPR signal was interrupted during the 110sec. TX

Protocols

- WSPR
  - 20m (or any HF frequency)
  - 6 digits Grid Locator, altitude, solar cell voltage, temperature
- APRS
  - 144.390MHz 1200bps 2AFSK over FM
  - 3D GPS coordinate (lat/lon/alt), solar cell voltage, temperature, humidity, …
- SSTV (mode: Martin-1)
  - 20m SSB (14.230MHz USB)
  - 2m FM (145.500 / 145.600MHz)
  - Mode: Martin-1 (114 sec. transmission length, 256 lines, color)
- CW
  - HF ~ 2m

Piggyback on WSPR protocol

- Use two consecutive WSPR frames (at same frequency offset)
- 1st frame:
  - Callsign (e.g. AG6NS)
  - Grid Locator (4 digits, e.g. "CM97")
  - Power Level (used as Altitude, e.g. 0m = 0dBm, 1000m = 3dBm, 2000m = 7dBm, …)
- 2nd frame:
  - Callsign (6 letters, e.g. "000AAA", "0A1BCD", "Q23EFG", "QZ9ZXX")
    - 1st letter: "0" or "Q" (fixed for a flight)
    - 2nd letter: Temperature and # of GPS Satellites (0~9, A~Z)
    - 3rd letter: Channel (0~9, fixed for a flight)
    - 4th letter: Solar Cell Voltage
    - 5&6th letter: 5&6th digit of 6 digit Grid Locator (e.g. "AS" if "CM97as")
  - Grid locator (same as 1st frame, e.g. "CM97")
  - Power Level (used as Altitude Offset, e.g. +0m = 0dBm, +60m = 3dBm … +960m = 53dBm)

Now you know why wsprnet.org has mysterious checkbox

SSTV from Balloon

AG6NS Balloon
250501190824z
Lat:43.1029N
Lon:76.3987W
Alt:12762m
Temp:-21.0C
Pw:10mW AG6NS

Martin1 Mode

AG6NS Balloon
250915195823z
Lat:37.1180N
Lon:121.6979W
Alt:8464m
Temp:-3.3C
Pw:10mW AG6NS

AG6NS Balloon
250918210632z
Lat:28.5389N
Lon:83.2142W
Alt:14721m
Temp:-15.6C
Pw:10mW AG6NS
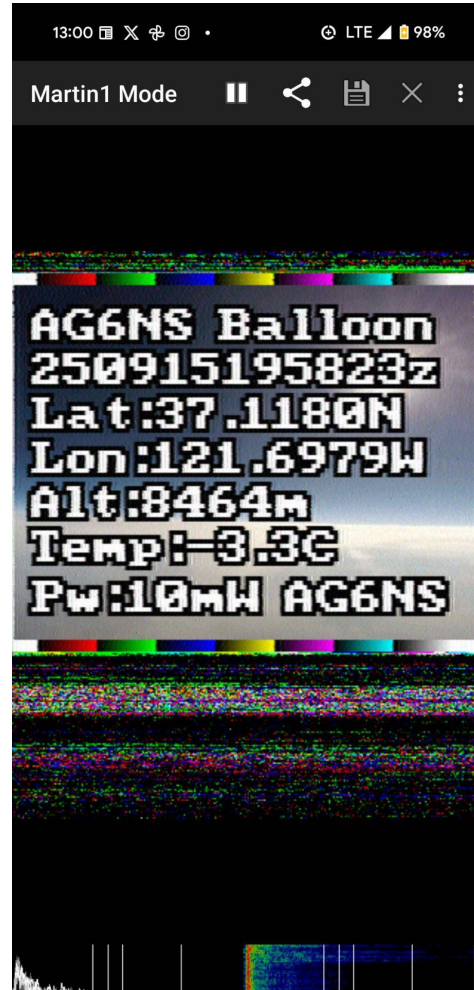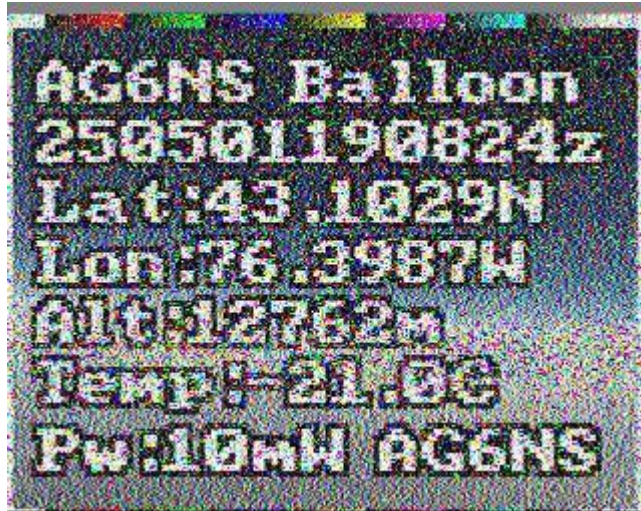
Future improvements

- Rechargeable battery
    - Transmit data 24/7
    - Good for failure analysis
- Sensors
    - IMU, Magnetic sensor, Particle sensor, Camera
- More Data bandwidth
    - HF: Data over FreeDV (e.g. FreeDATA)
    - V/U/SHF: LoRa, 9600bps APRS
- Higher RF output
    - Low voltage, high efficiency PA
- RX
    - digipeater, receive commands, OTA firmware update

For more info:

SF-HAB group:
  https://sf-hab.org/
  https://groups.io/g/sf-hab
  https://groups.io/g/sf-hab-chatter

Realtime Balloon tracking map:
  https://amateur.sondehub.org/

Pico Balloon community (world wide):
  https://groups.io/g/picoballoon

SF-HAB Open Hardware Pico Balloon Tracker project:
  https://github.com/kaduhi/sf-hab_rp2040_picoballoon_tracker_pcb_gen1