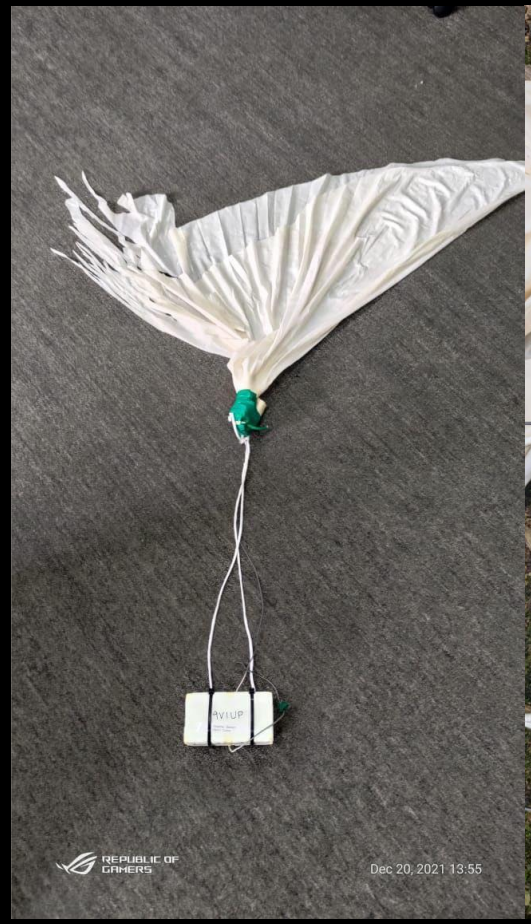
BEAR-4 Report

By Payload Specialist: Lih Wei (9V1LW)

Previously-on BEAR-3

- Great success! Full flight tracked from launch to landing
- Only premature descent probably due to balloon defect
  - Also payload still got lost in the mail in the end =(



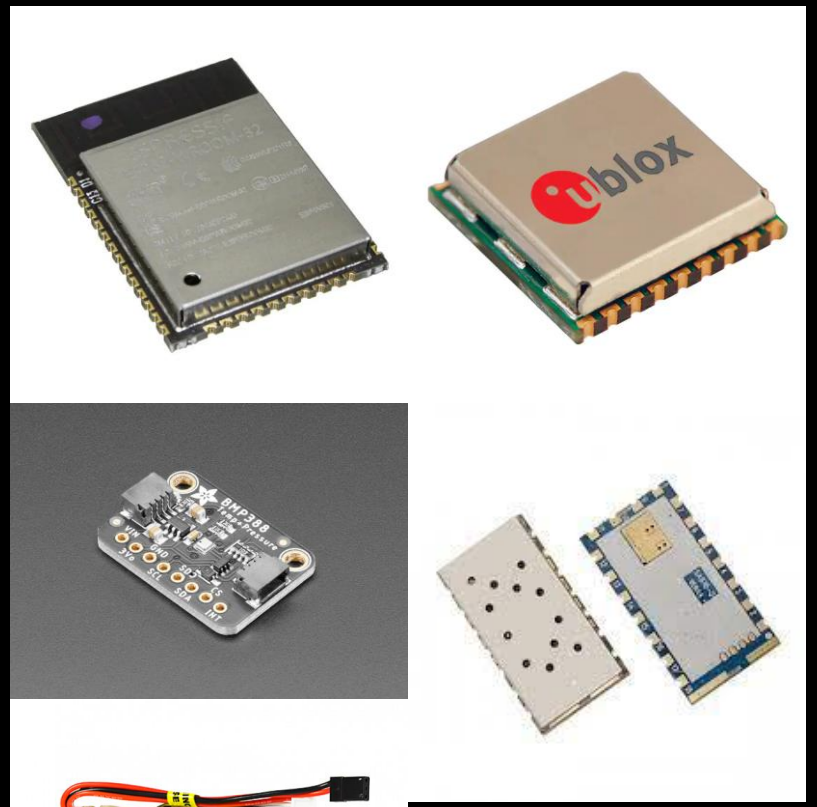
BEAR-4

- Try to roll our own payload
  - Resolve GPS blinding problem
  - More expandability for more sensors
  - Quality-of-life improvements
  - Better battery life (haha)
- Let’s transmit more things
  - Aim for having camera-based SSTV as end goal

Targets

- Own-capability based off LightAPRS
- Additional SSTV (non-camera) for TX lockout demonstration
- Improvements
  - Integrated heater control MOSFET
  - Better RF shielding between TX and GPS
  - U.FL connectors for better and remote antenna options
  - ESP32-based for wireless sealed debugging
  - Integrated battery connector with charge protection and remote charge
  - Option for remote one-wire based pressure and temp sensors
- Weight (w/o battery & heater resistors): 47g
- Total weight: 113g (BEAR-3: 109g)

Bill-of-Materials

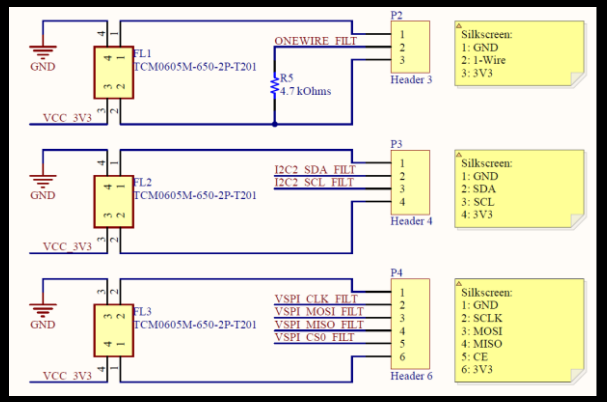


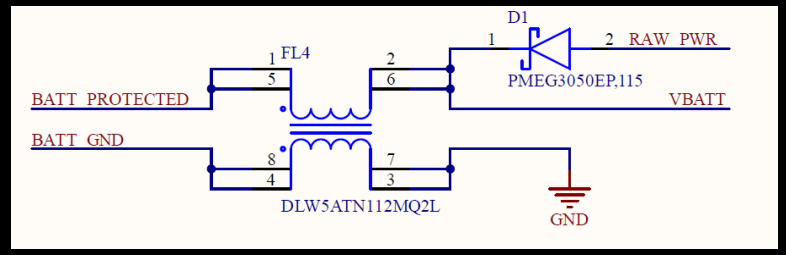
- Main Components
  - MCU: Espressif ESP32-WROOM
  - GPS: U-Blox MAX-M8Q
  - Sensor Suite: Bosch BMP388*
  - Radio: Dorji DRA818V
  - Accel: InvenSense MPU6050*
- Support Components
  - Charge Protection: AP9214L
  - Battery: ZIPPY Compact 700mAh 6.6V 5C LiFePo4 Receiver Pack
  - Regulator: APXS003A0X

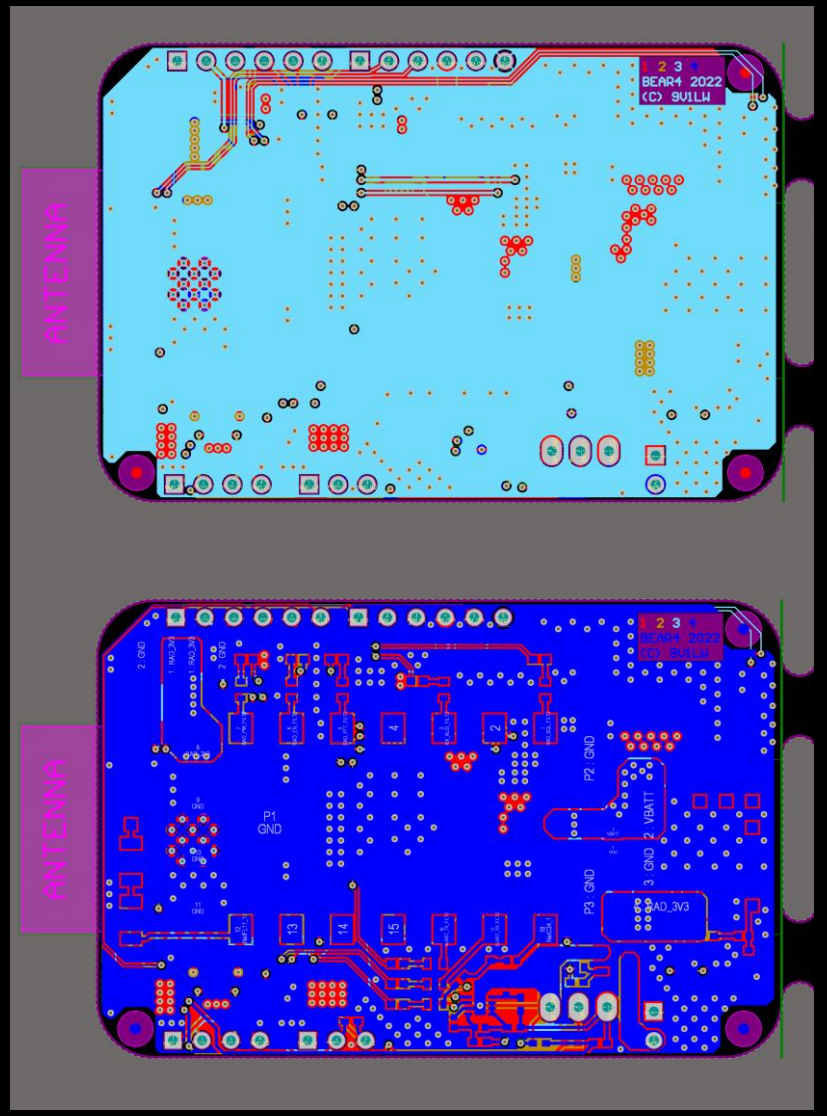
*1 Extracted from breakout board, e.g.: https://www.adafruit.com/product/3966
*2 Extracted from breakout board, e.g.: https://www.mouser.sg/ProductDetail/DFRobot/SEN0142?qs=sGAEpiMZZMvShe%252BZiYheiiZG96itCpFCVwvMfnWNB%2FY%3D

Addressing RF Interference

- Split power supply for GPS and main PSU
- Dedicated PCB GND layer to shield DRA818V
- Common choke for long battery input leads and any external interfaces (future use)







Addressing RF Interference

- Extensive EMI filters to reduce conducted interference from DRV818V
- LPF for DRA818V to remove harmonics that may reach GPS

Mini-Circuits

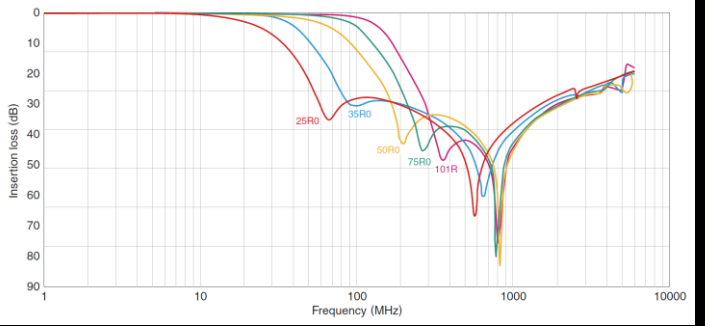
Low Pass Filter LFCN-160+

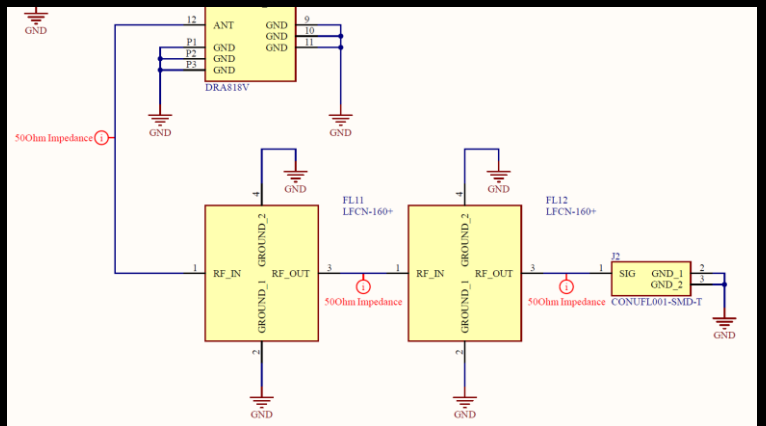
TYPICAL PERFORMANCE DATA AT 25°C

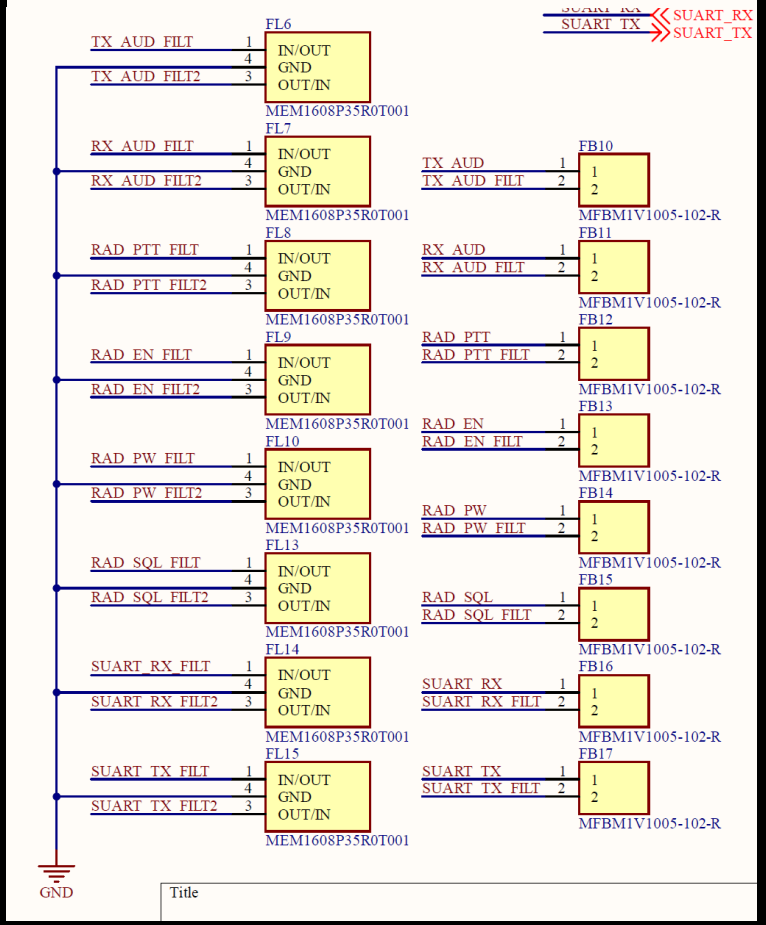
Frequency (MHz)	Insertion Loss (dB)	VSWR (:1)
40	0.29	1.07
100	0.53	1.07
150	0.77	1.09
160	0.85	1.11
210	1.60	1.41
230	2.50	1.74
260	5.92	2.80
280	10.64	3.89
310	21.67	5.22
330	30.84	5.74
350	37.58	6.13
480	39.25	12.26
1000	54.13	59.91
2700	41.64	56.04

MEM1608P type

INSERTION LOSS VS. FREQUENCY CHARACTERISTICS

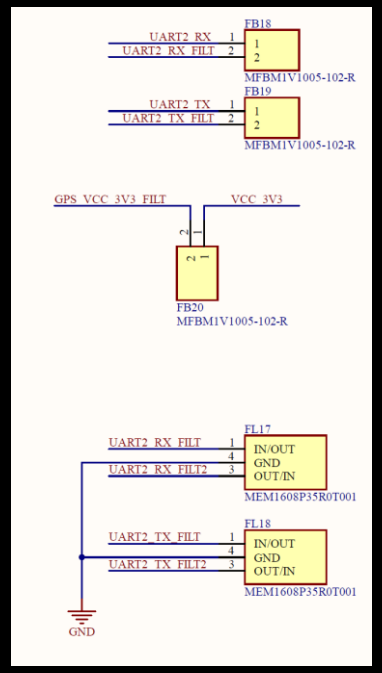






Addressing RF Interference

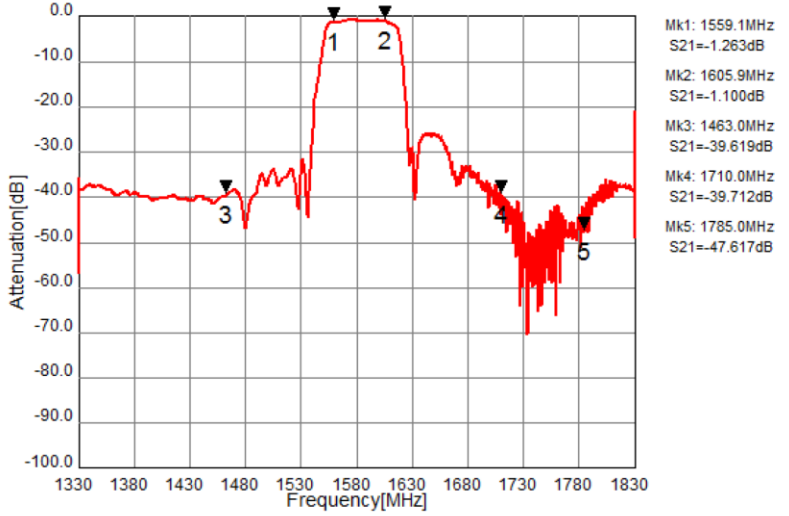
- Onboard LNA and SAW filter for GPS input
- Power and signal lines filtering



Customer Name	Standard	TAIYO YUDEN Mobile Technology Co., Ltd.	
System	GPS + GLONASS + Galileo + Compass	Date	Dec. 19, 2018
Part Number	F6QA1G581M2QZ	Version 2.2bB	Final

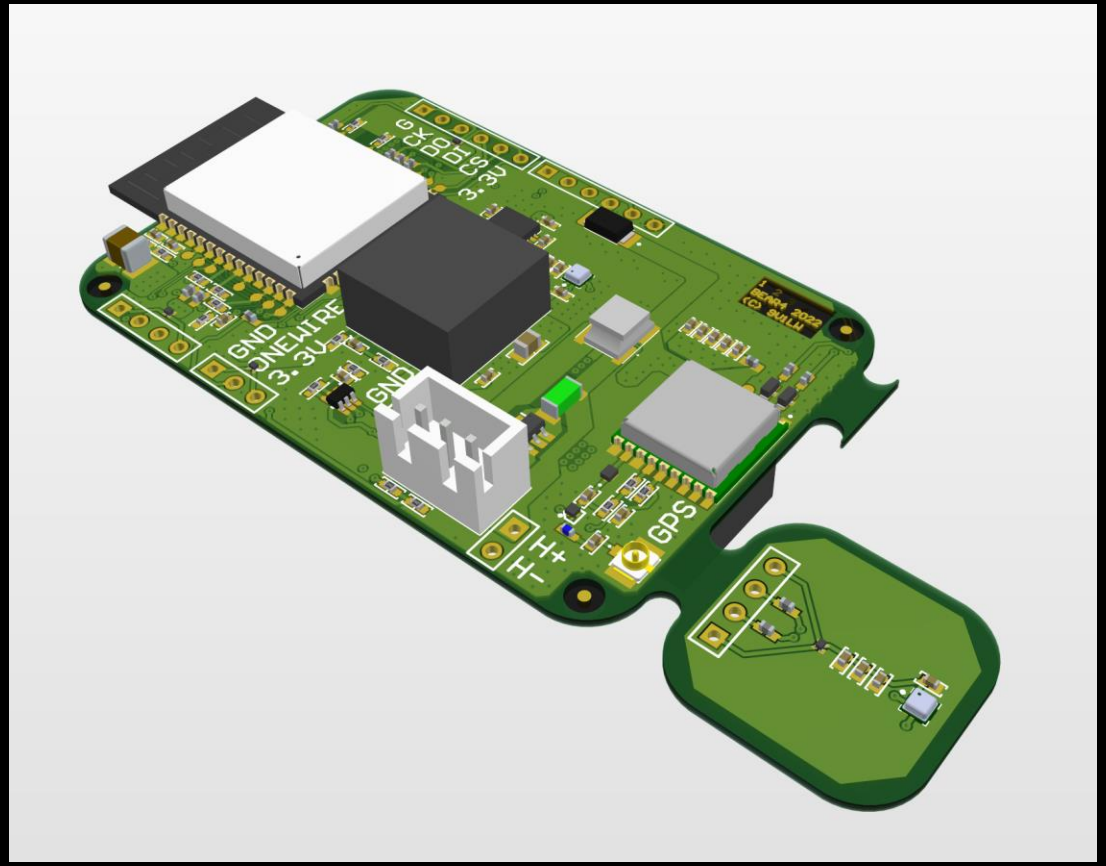
Electrical Characteristics

Passband



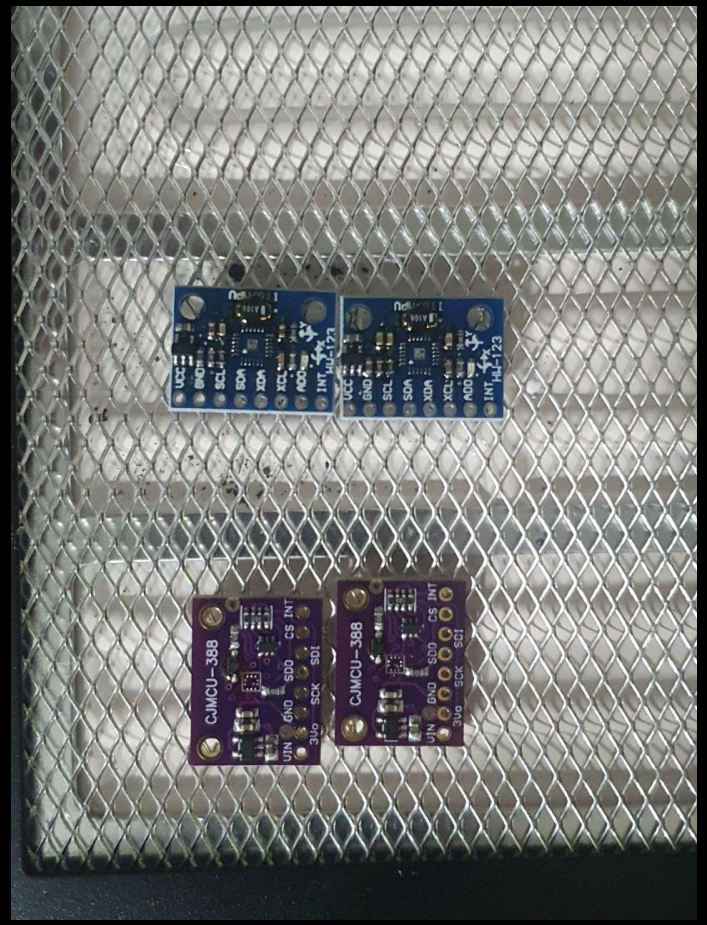
Final Board Design

- 60x40mm (excluding ESP32 antenna protrusion)
- Remote BMP388 board with CM filter for future use (sensor in balloon for burst detection)

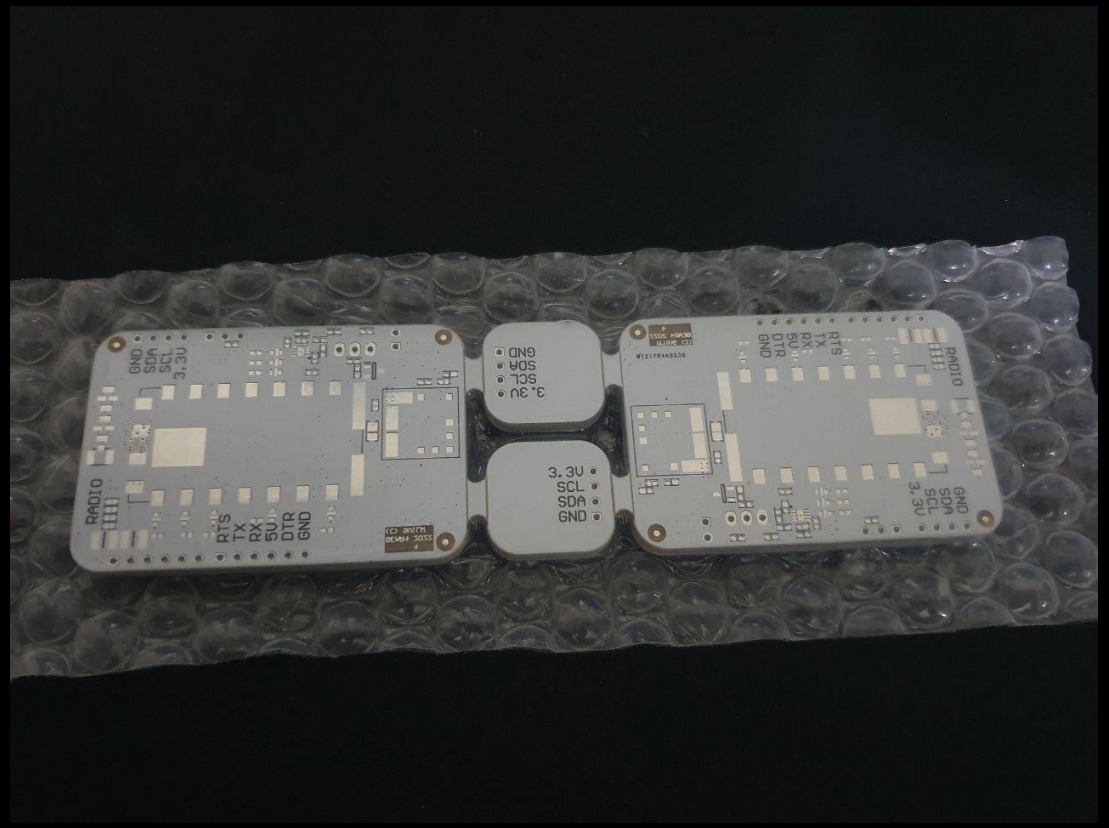


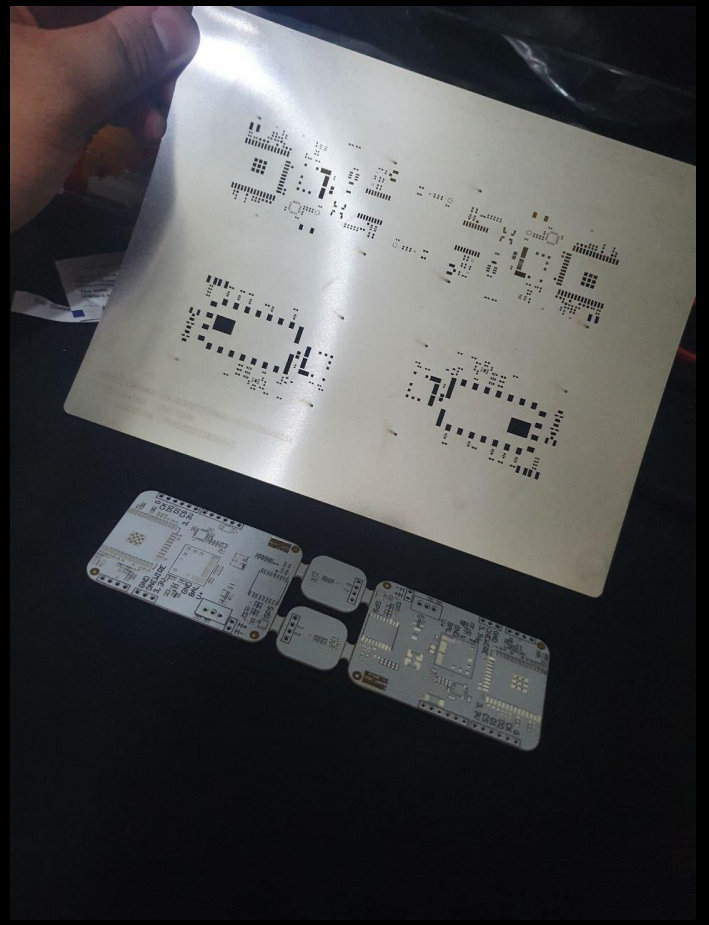
Assembly

Scavenging Sensors

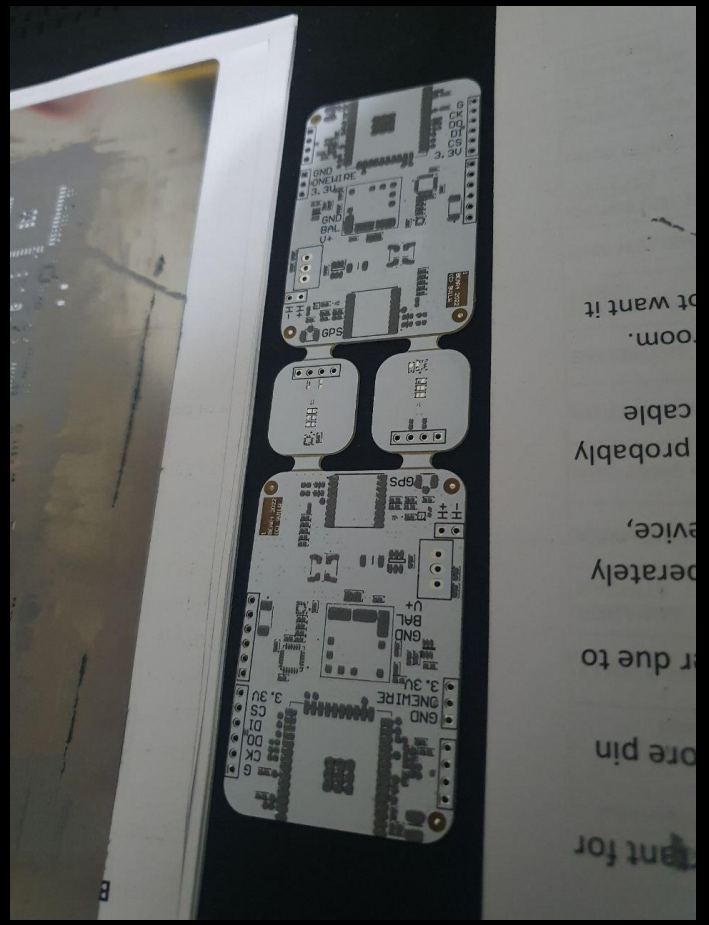


Stencilling

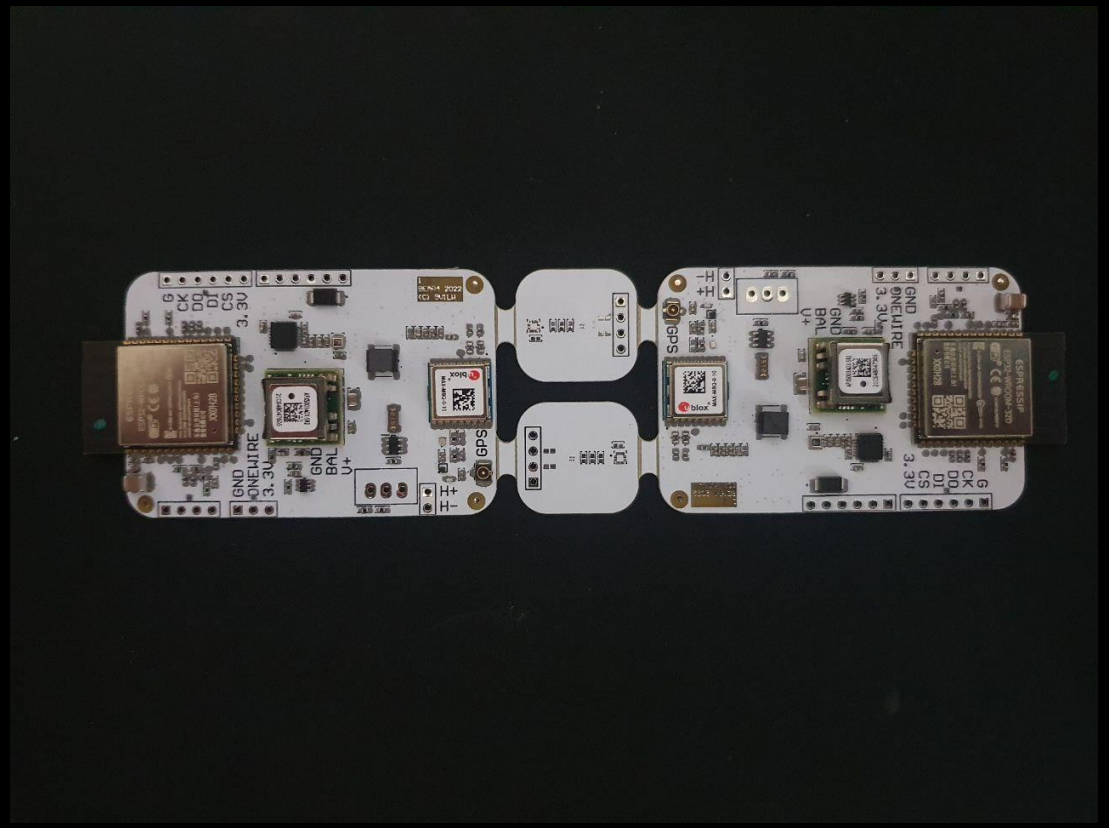


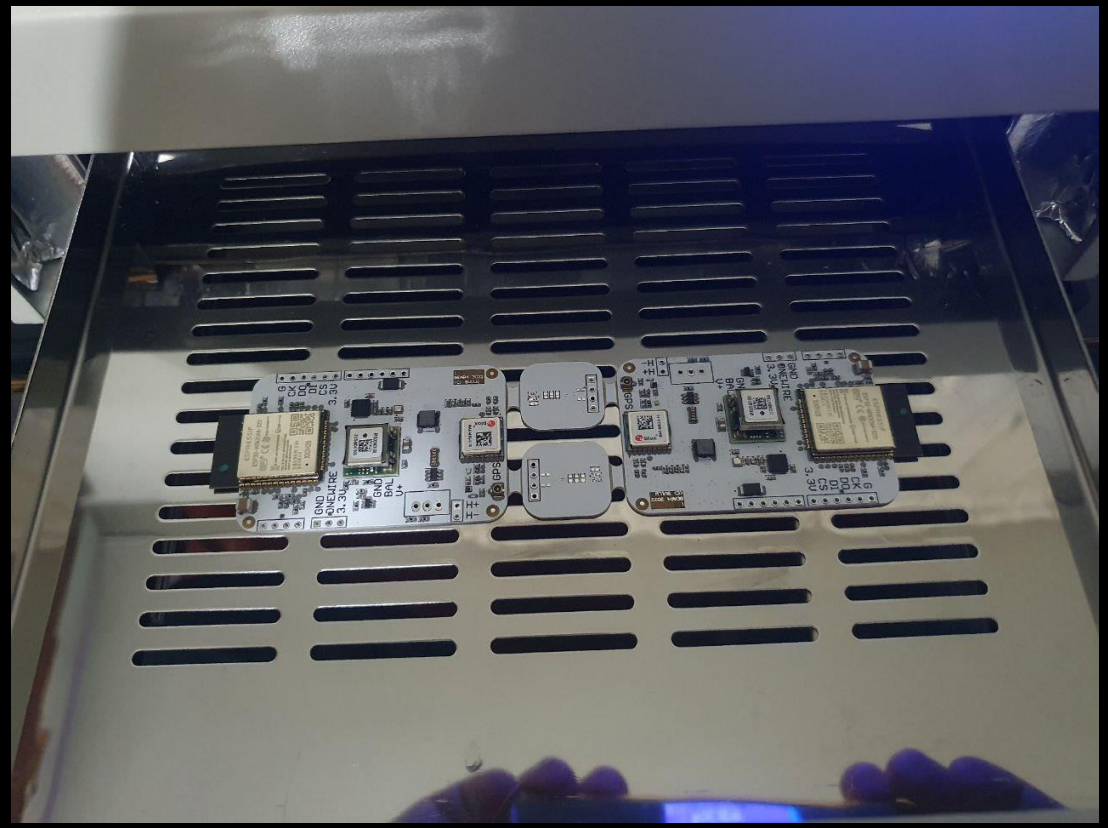


Stencilling

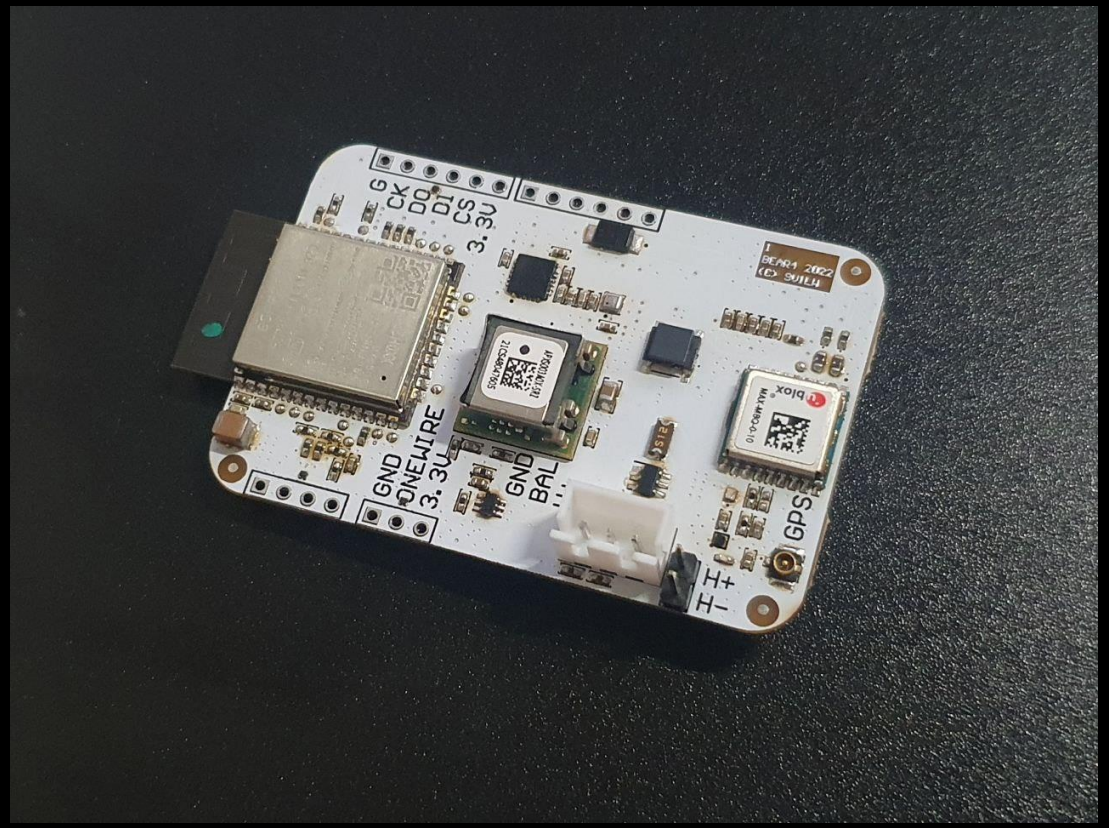


Component Placing & Reflow

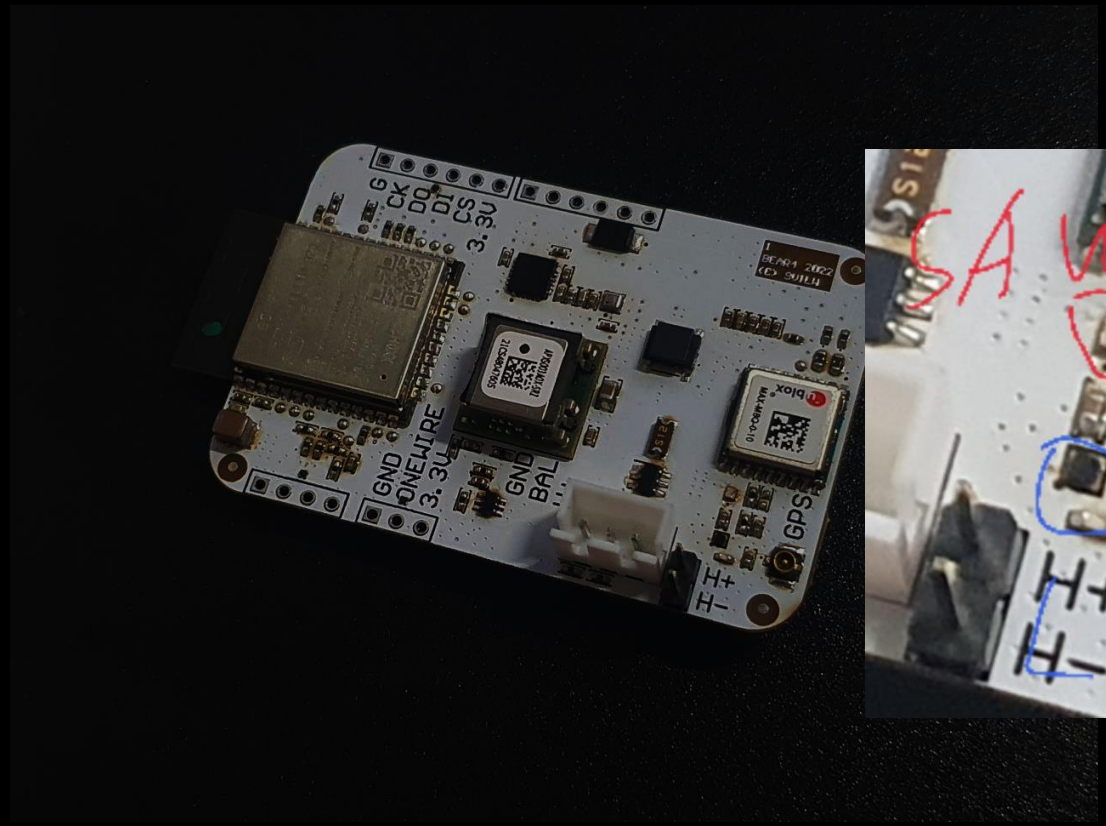


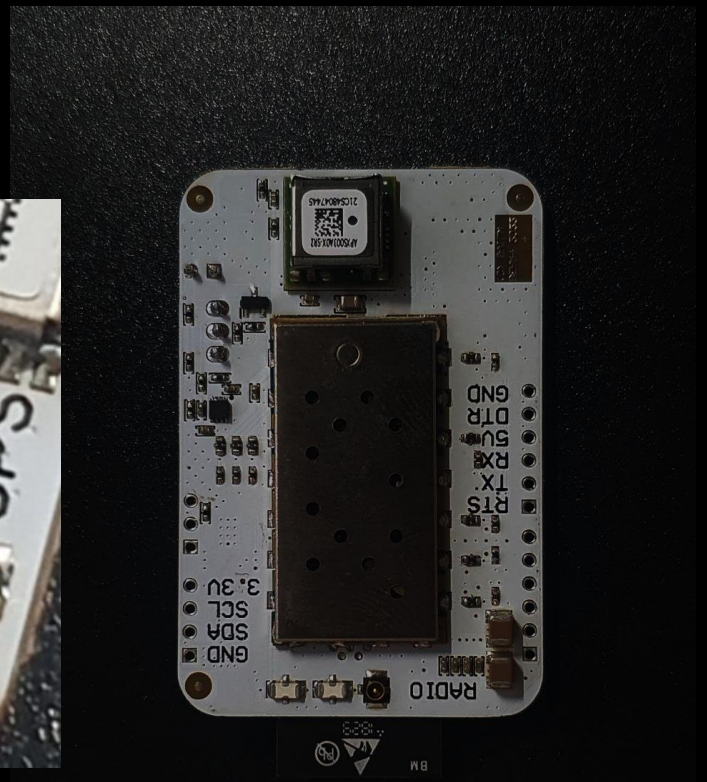


Assembled Board



Assembled Board



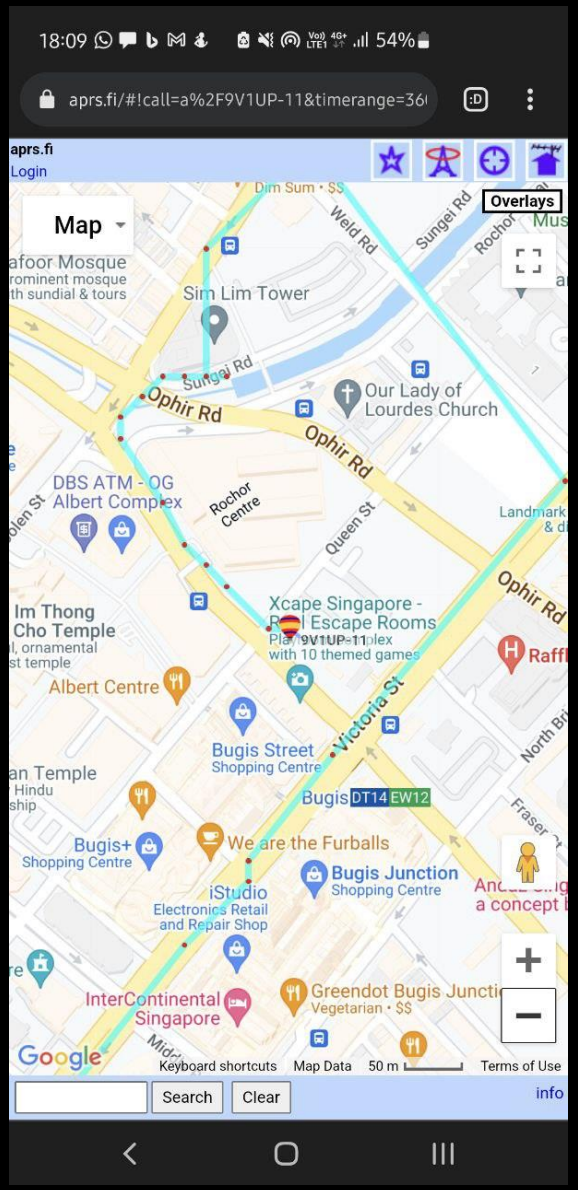


RF Interference Results

Don’t have the right equipment, so just simple qualitative results

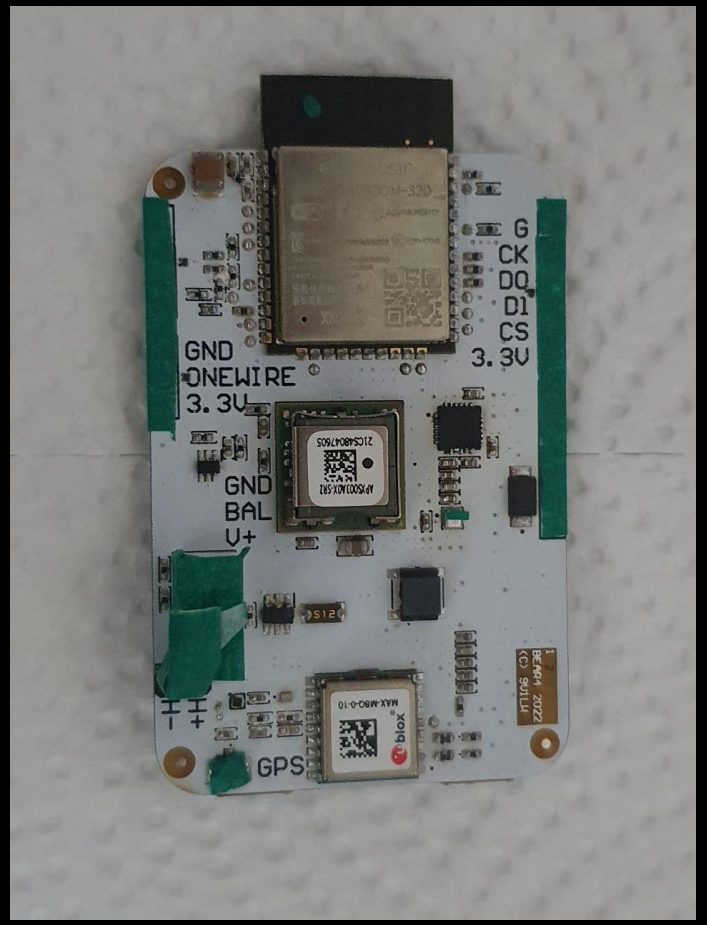
RF Interference Results

- 9 GPS lock indoors (near window)
- 17 GPS lock in clear sky
  - Instant lock (<5s) from cold start using GPS assist data
  - Usual 2min from cold start without assist data
- 10dB drop in SNR during TX, but acceptable for outdoor
  - No loss of lock during TX
- No loss of GPS or lock issue during launch (except at end)



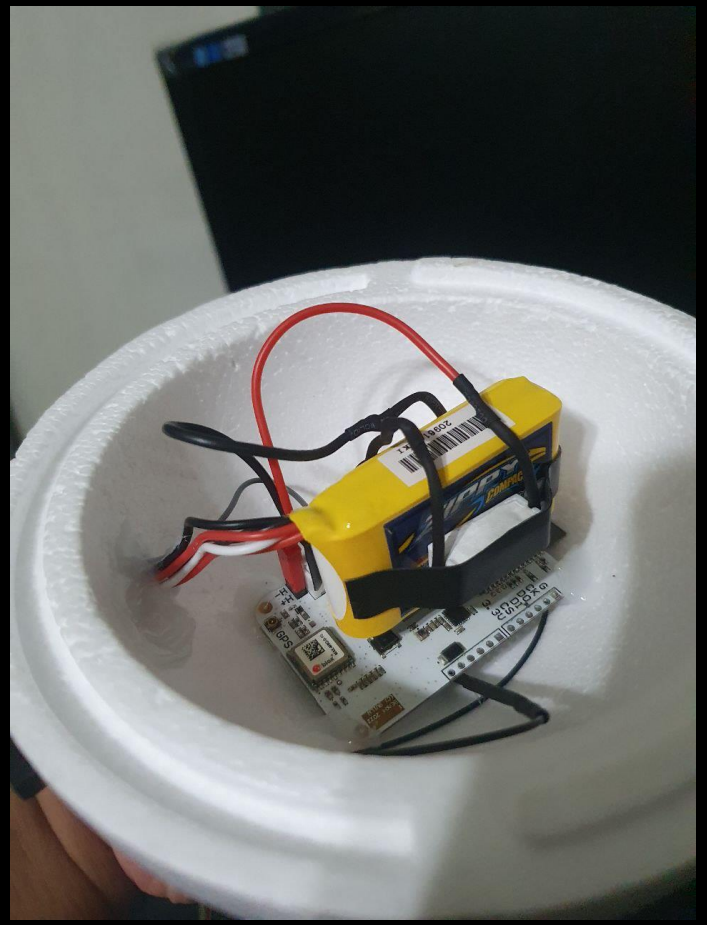
Sealing & Harness

- Sprayed with polymer-based waterproof conformal coat
  - Acrylic would be nicer but could not find one in time



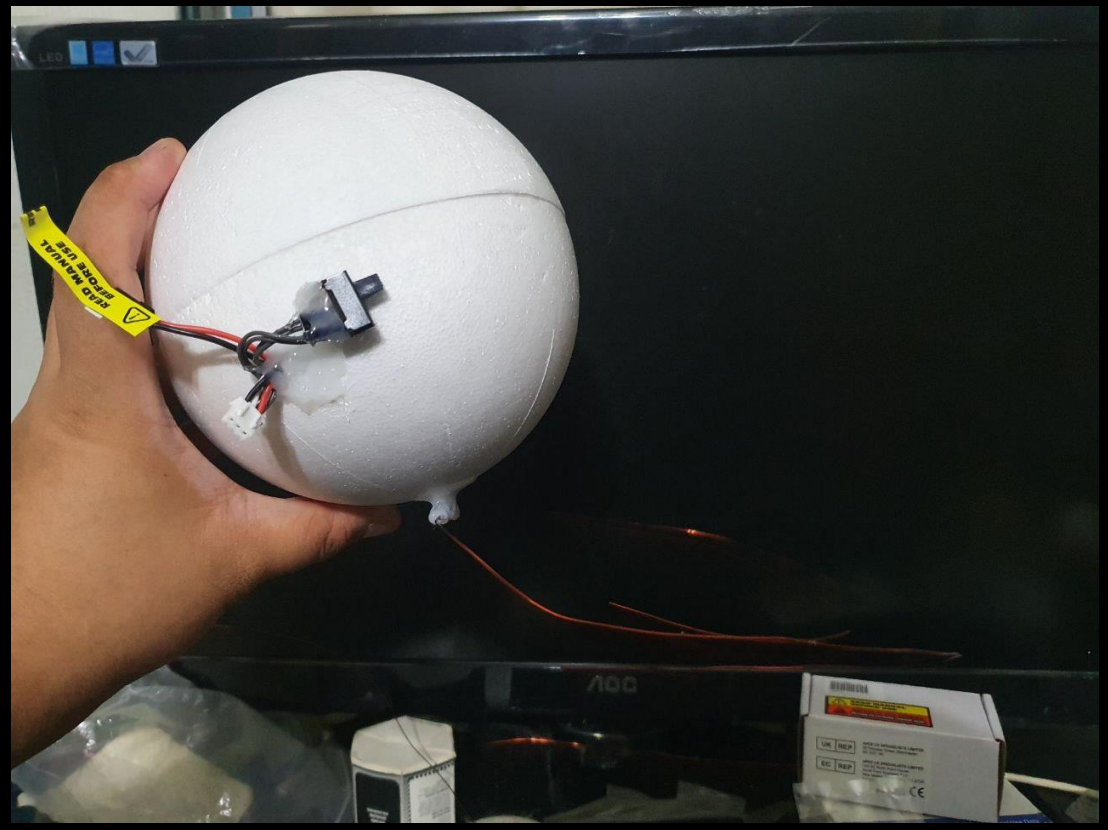
Sealing & Harness

- Sprayed with polymer-based waterproof conformal coat
  - Acrylic would be nicer but could not find one in time
- PL, battery, heater, GPS antenna hot-glued inside Styrofoam ball
  - Light coat of acetone sprayed on outer surface to seal natural Styrofoam gaps
  - Followed by same polymer waterproof conformal coat



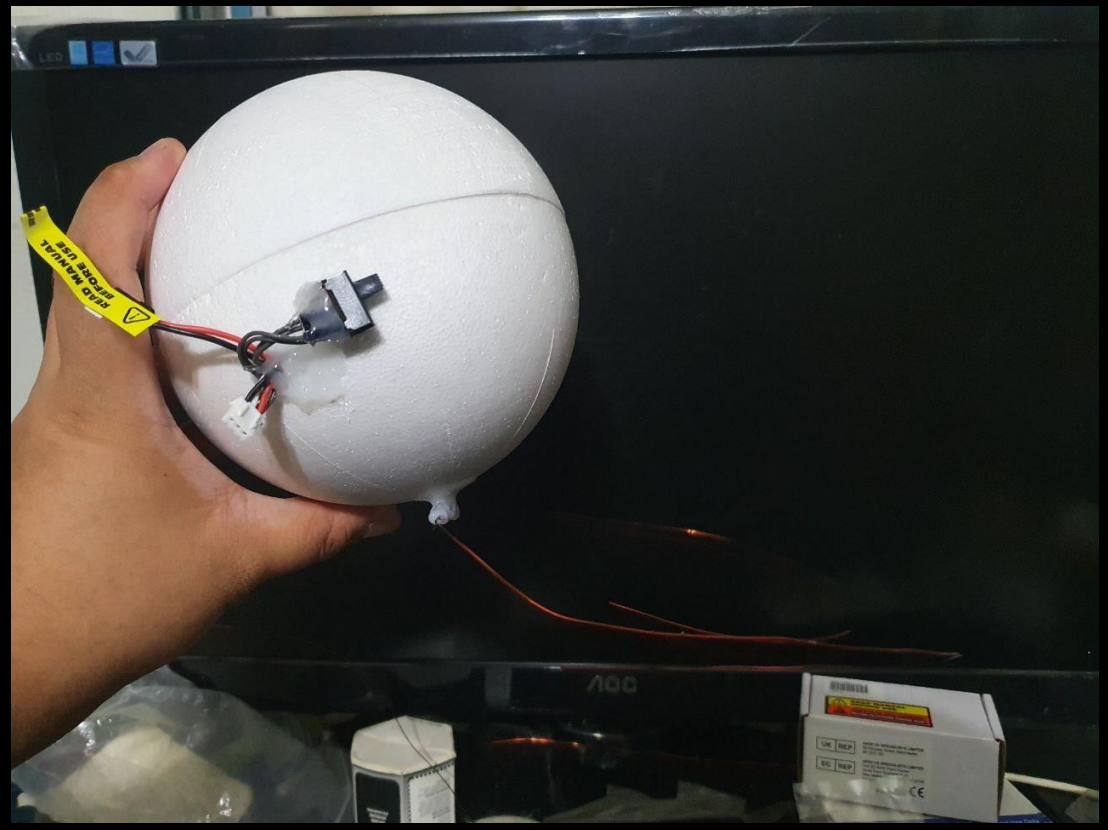
Sealing & Harness

- Rigged external power switch and charge port
- Quarter wavelength dipole VHF antenna made from 1mm copper wire



Sealing & Harness

- Rigged external power switch and charge port
- Quarter wavelength dipole VHF antenna made from 1mm copper wire
- Comment from 9V1ZV:



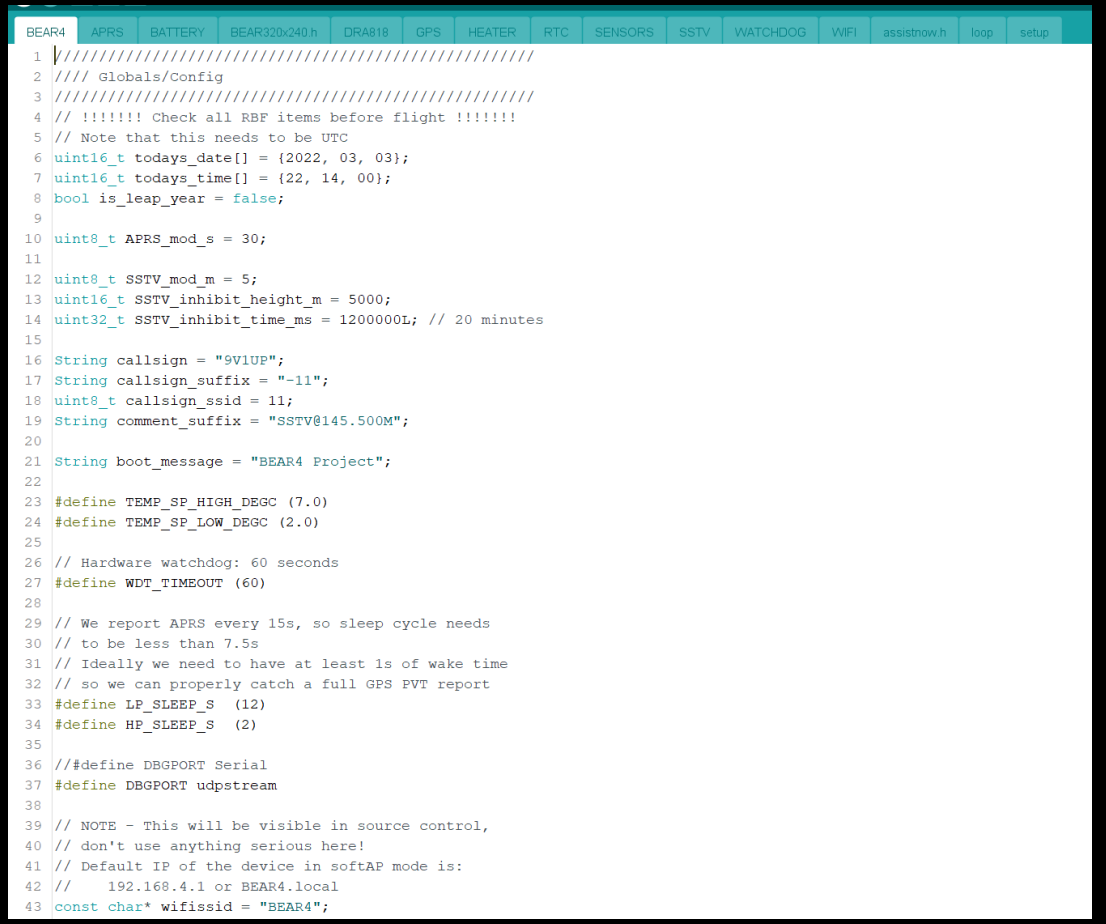
Sealing & Harness

- Ingenious harness by 9V1YP
- Payload before launch modelled by 9V1FH

Software

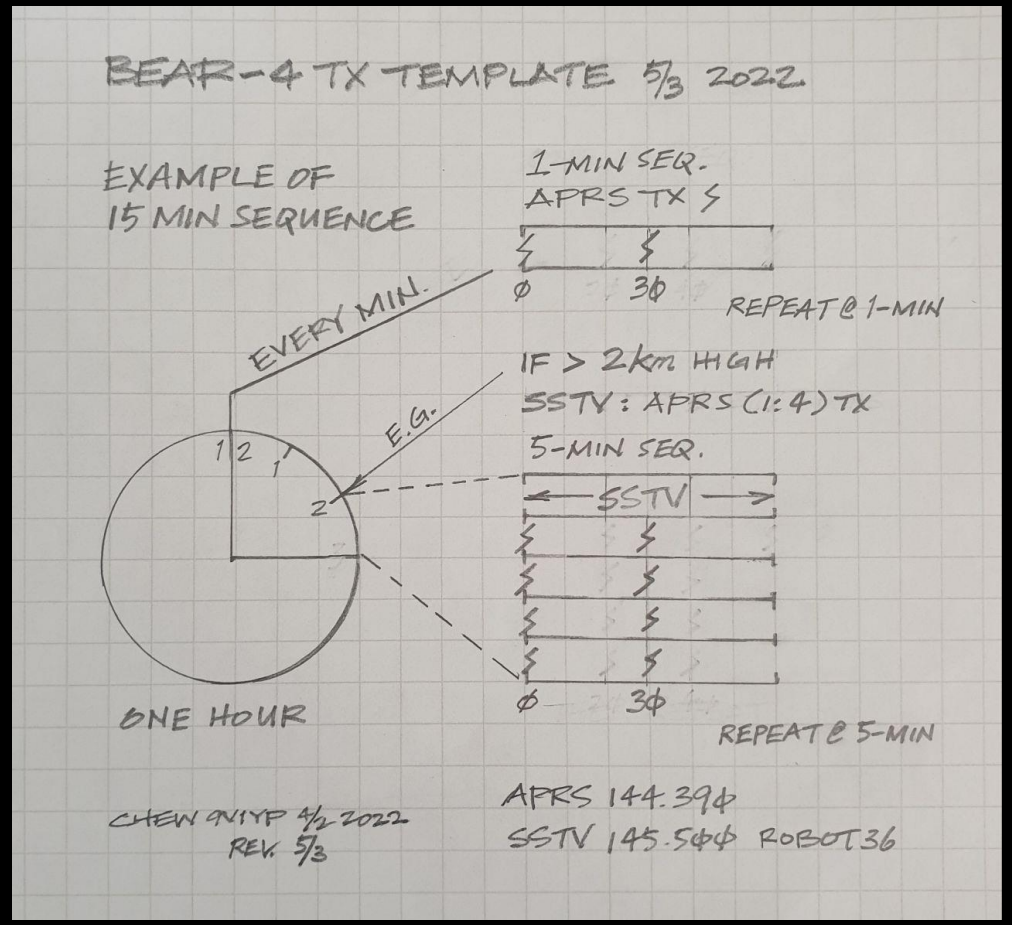
Software

- Written from scratch in Arduino
- Tasked-based cooperative multi-tasking
- ROBOT36 SSTV modulator written from spec
  - Uses ESP32's built-in tone generator so no need for CORDIC
  - Built-in time and altitude-based inhibitor
- Loads GPS assist data for better GPS performance
- Wi-Fi enabled for 60s on boot to allow remote code load and debug
  - Custom UDP-print allows drop-in Serial replacement for remote debug
- Uses MPU6050's internal free-fall detector to detect balloon burst



Software

- Emulated RTC allows tracking time even when GPS lock is lost (for TX scheduling)
- Transmit schedule based on time
  - SSTV every 5-min @ 00, 05, 10, etc
  - APRS every 30s @ 00s & 30s
  - APRS higher priority than SSTV and will transmit first



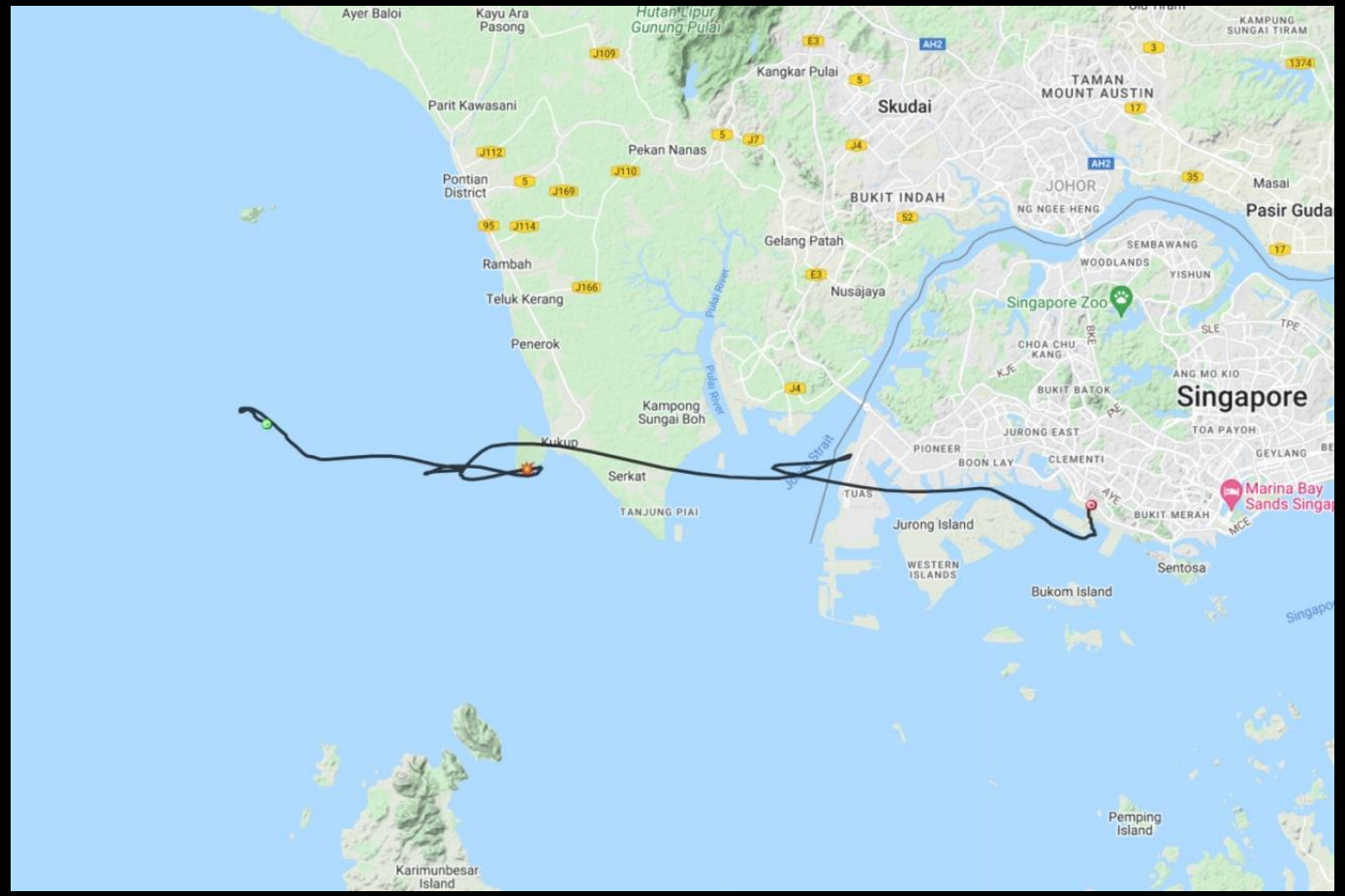
Open Source (MIT License)

https://github.com/xieliwei/BEAR4-hardware

https://github.com/xieliwei/BEAR4-firmware

Launch

Projected Flight Path (Courtesy 9V1ZV)



Set-Up

Launchpad (Photo by 9V1ZV)

NTU Team (Photo by 9V1BN)

Set-Up

Launchpad (Photo by 9V1YP)

NTU Team (Photo by 9V1BC)

Set-Up

Launchpad (Photo by 9V1YP)

NTU Team (Photo by 9V1DE)

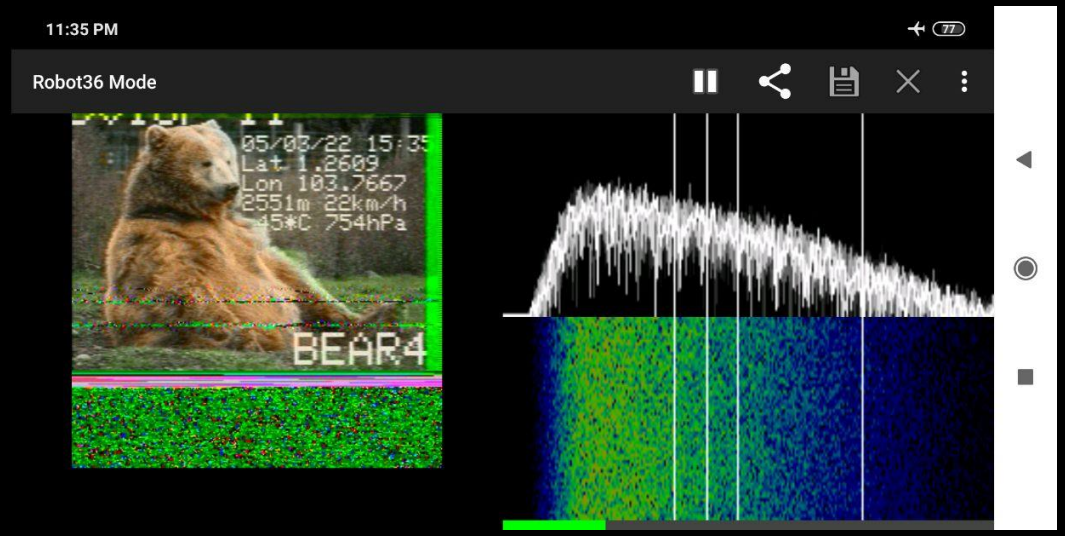
Launch Photos by 9V1KB

Launch!

SSTV Receives

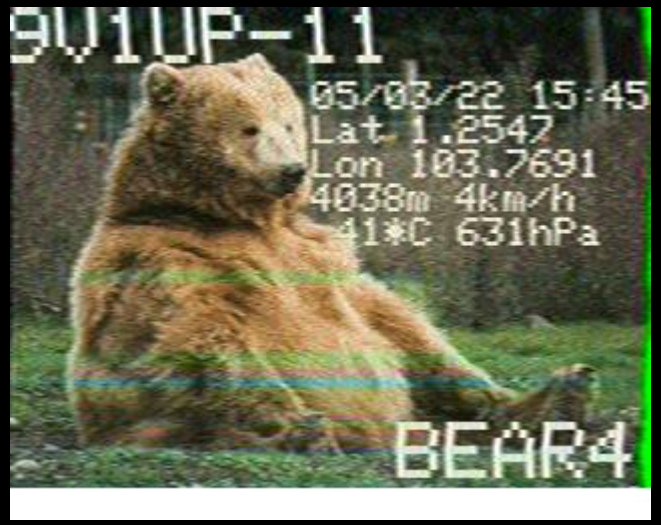
9V1HH (11:35pm)

9V1BX (11:35pm)



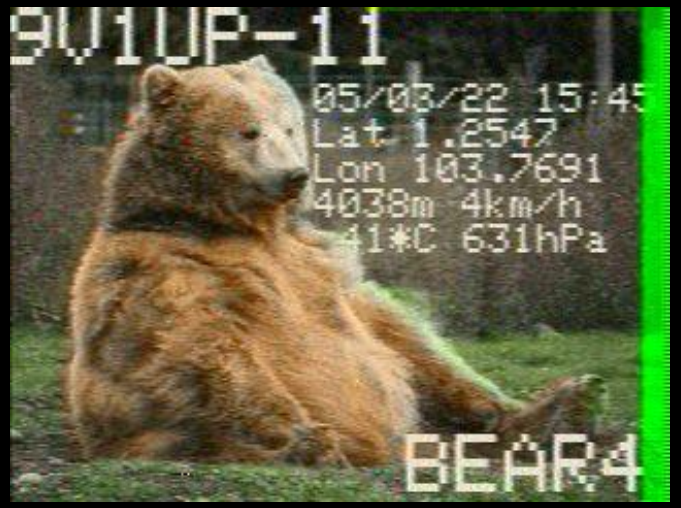
SSTV Receives

9V1HH (11:45pm)



9V1LD (11:45pm)

9V1BX (11:45pm)



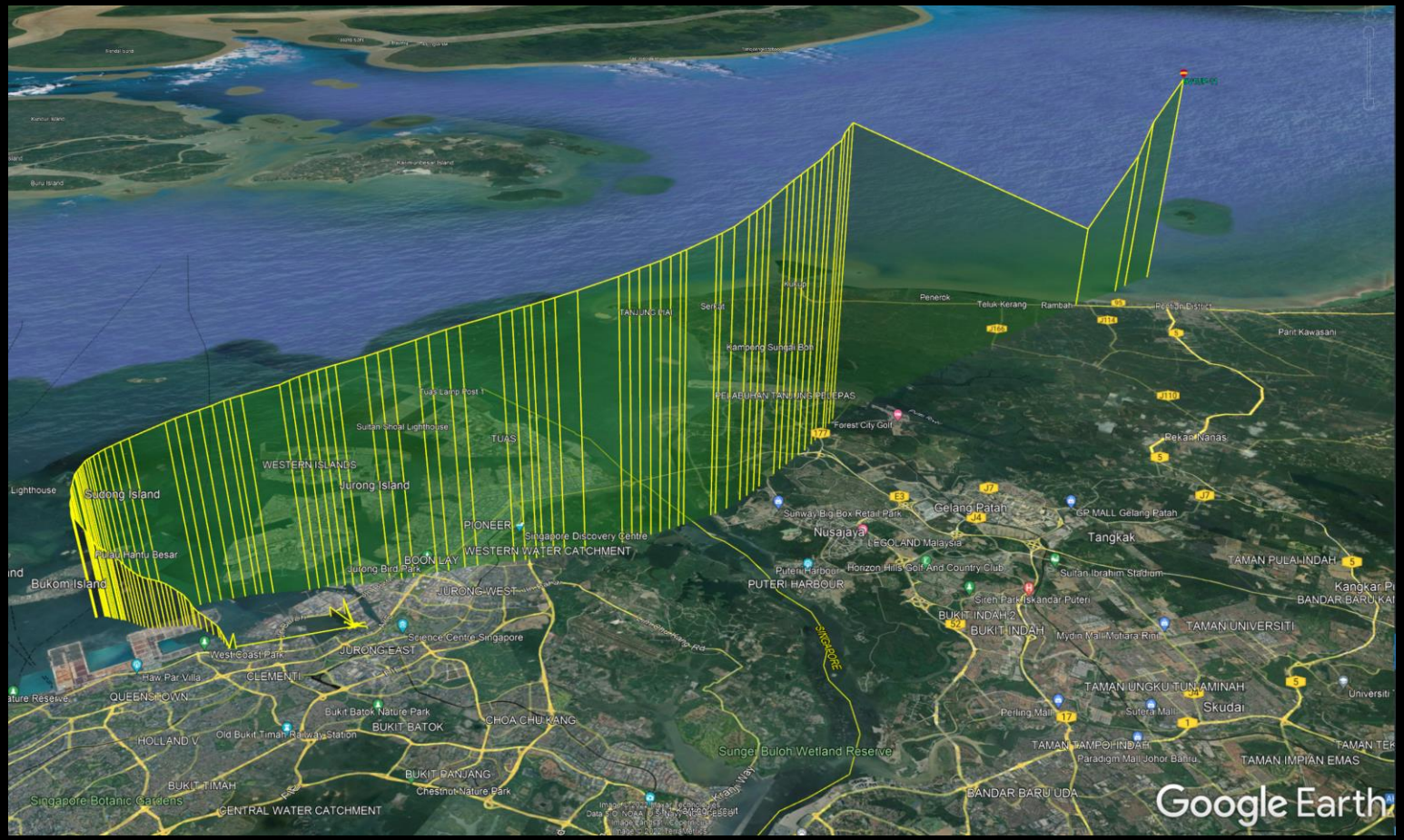
SSTV Receives

9V1ZV (12:35am)

9V1HH (12:35am)

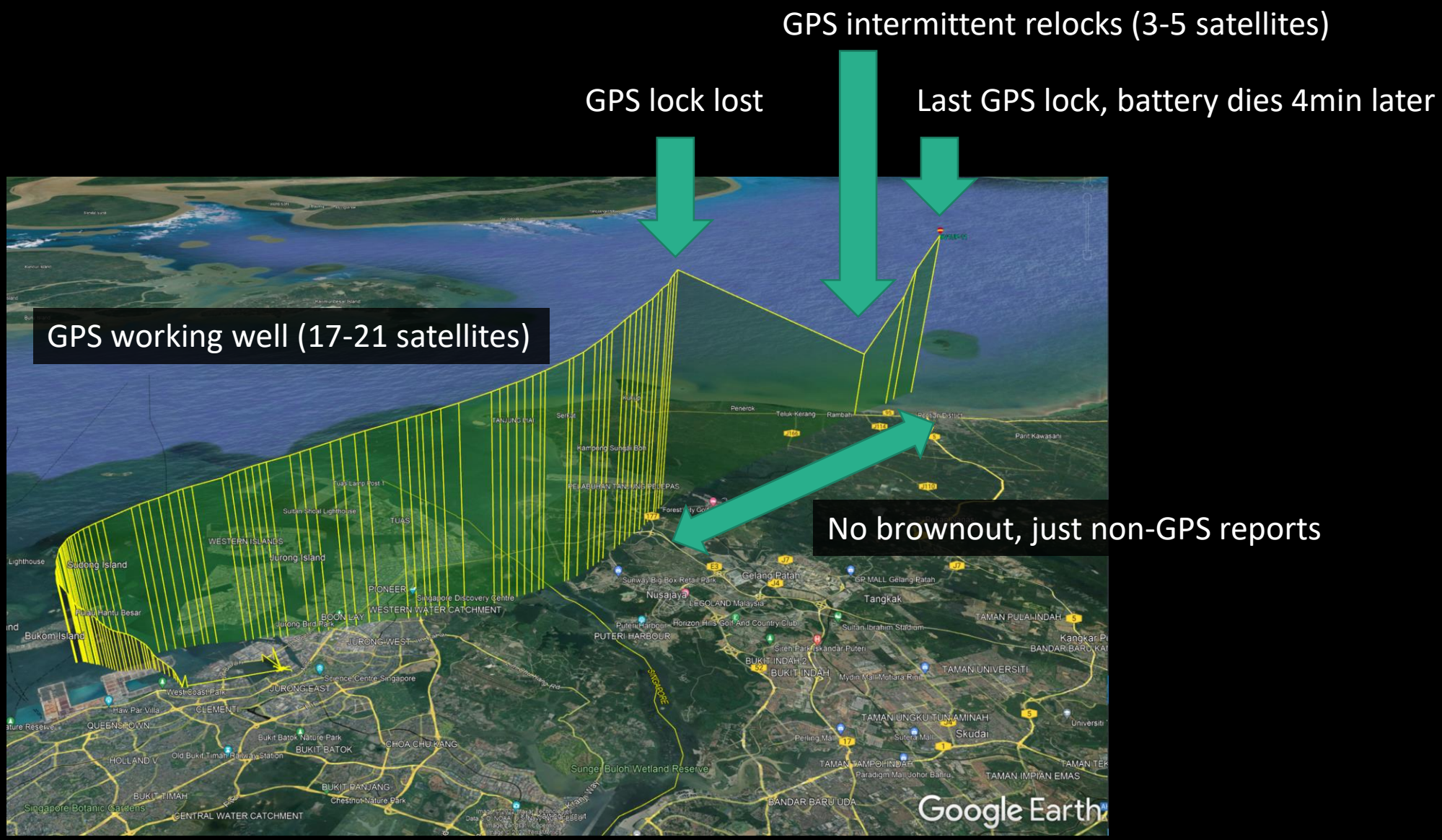
Also 9V1ZV (12:35am)

Path


Sudong Island
Jurong Island
WESTERN ISLANDS
TUAS
PIONEER
WESTERN WATER CATCHMENT
BOON LAY
JURONG WEST
JURONG EAST
CLEMENTI
QUEENSTOWN
HOLLAND V
BUKIT BATOK
CHOA CHU KANG
BUKIT PANJANG
BUKIT TIMAH
CENTRAL WATER CATCHMENT
Singapore Botanic Gardens
Sungei Buloh Wetland Reserve
PUTERI HARBOUR
Nusajaya
Gelang Patah
Tangkak
BUKIT INDAH
BUKIT INDAH 2
TAMAN UNIVERSITI
TAMAN PULAI INDAH
Skudai
TAMAN IMPIAN EMAS
BANDAR BARU UDA
Google Earth

Post Mortem

Path


GPS intermittent relocks (3-5 satellites)
GPS lock lost
Last GPS lock, battery dies 4min later
GPS working well (17-21 satellites)
No brownout, just non-GPS reports
Google Earth

Mystery

- Possible theories
  - Odd GPS malfunction at A >= 40000ft
    - Last GPS report before malfunction was 39591ft
    - Next report should be >40000ft
    - Later GPS reports are when GPS thinks it is <40000ft
    - Why?
  - GPS Assist data messed things up
    - Possible, can also explain A >= 40000ft failure
  - Low battery voltage affecting GPS operation
    - Unlikely, happened when beacons could still happen for another 20min or so

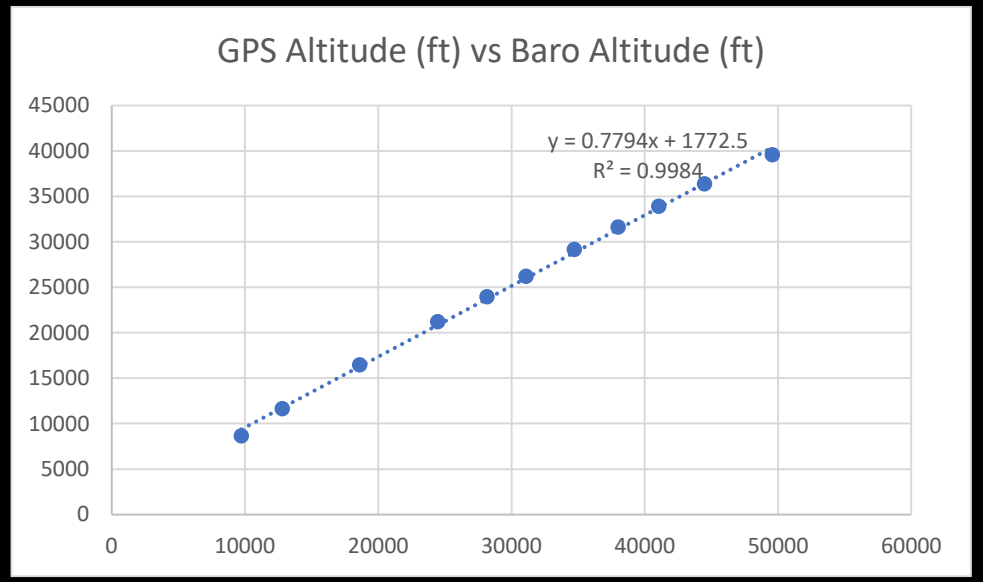
Final Reported Altitude

- We can correct the barometer value against GPS altitude
- Final barometer altitude:
  - 71768ft @ 1:03am

```
2022-03-06 01:03:13 +08: 9V1UP-11>BEACON,WIDE1-1,qAS,9W2DCW-4:>051703/A=071768 000201TxC -13.07C 102.32hPa 5.22V 00S SSTV@145.500M
```

- Corrected altitude:
  - 57708ft => 17590m => 17.6km

- Last contact @ 1:06:20am
- Launch @ 11:15:06pm
  - Alive for 1hr 51min 14s

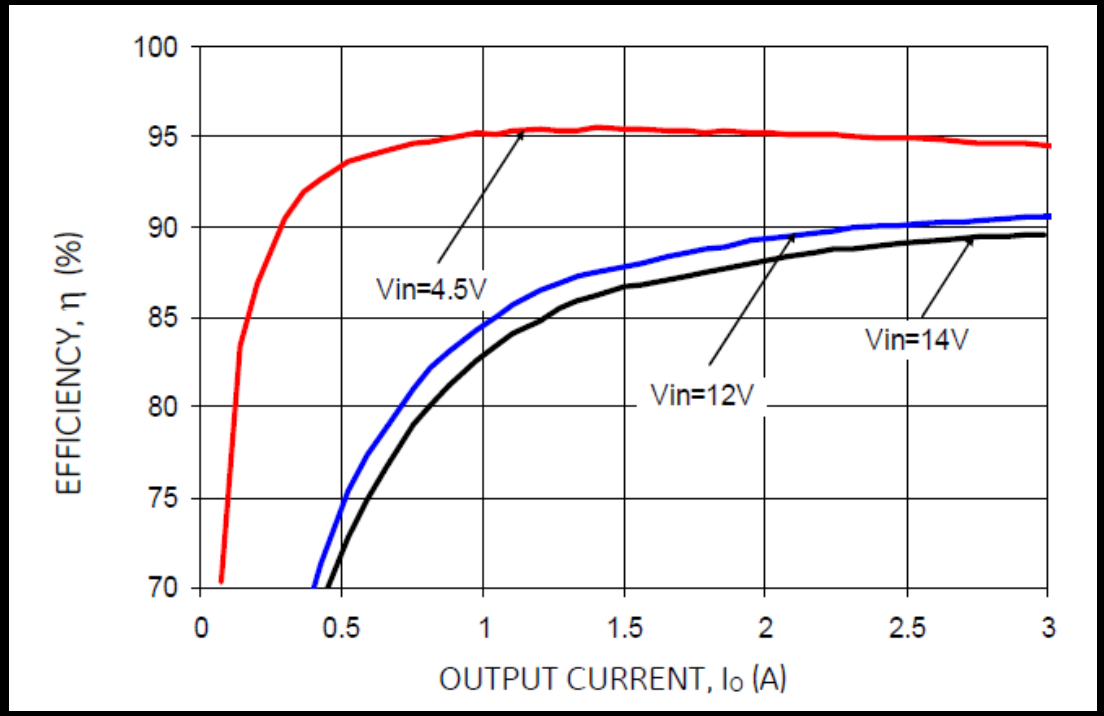


Recovery?

- Haha no
- Too excited for launch, forgot to attach dog tag

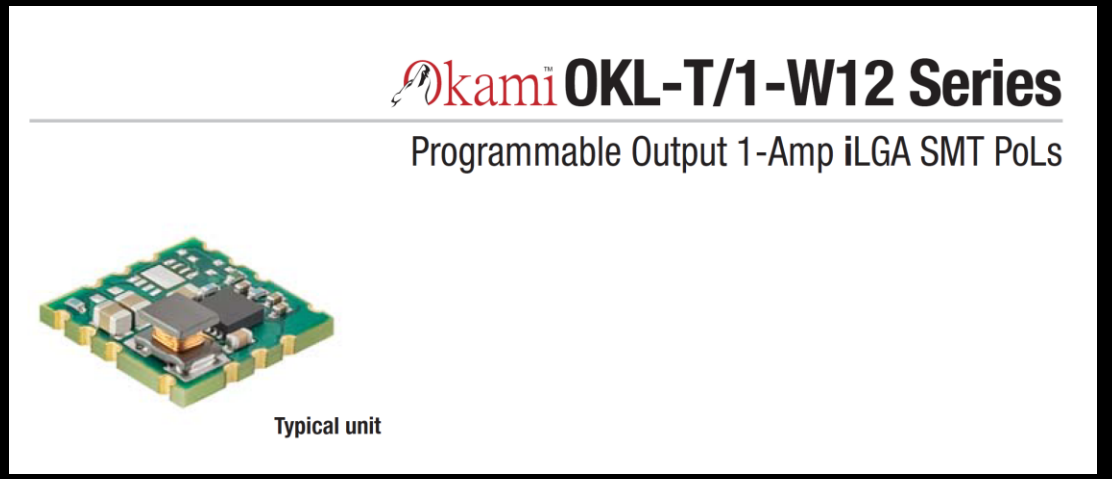
Design Flaws

- Poor regulator choice
  - Selected based on peak current for DRV818V and ESP32 requirements
  - Did not check efficiency @ low currents
    - No-load current: 55mA @ input
  - Since we have two regulators
    - At least 110mA @ input was being burned constantly
    - 220mAh of 700mAh battery wasted
    - At least another 50min of runtime
      - Actual is more as the 220mAh will be efficiently converted to target voltage



Design Flaws

- Poor regulator choice
  - Luckily, common iLGA footprint
  - Replacement regulator has 10mA no-load current
    - EOL product as of Mar 2022
    - Already bought for BEAR-5
  - Other parts can easily be found



Design Flaws

- ADC not usable when Wi-Fi is on
  - DRV818V RX audio is attached to ADC2, not usable when Wi-Fi is on
- TX audio too loud for DRV818V
  - DRV818V only accepts up to 0.3V
- ESP32 reset pin floating
  - Thought there was internal PU, there isn’t

- Pin remapped to work with ESP32-S3 (only S3)
- Voltage divider inserted
- Pull-up resistor inserted

BEAR-5

BEAR-5

- Scheduled for 28 May 2022 (1 month from today)

- Same hardware with flaws patched
- Advocate for camera use!

- Hardware ready, software WIP

- Other possible uses:
  - Sensor in balloon for burst sending and correct temperature reading

Recruiting Now!

- Need better shell design
- Want to mount camera
- RX stations
- More software & hardware review

- Contact 9V1LW @xieliwei on Telegram or in chat group