

BIRDS-X Project

APRS Student Mission Ground Terminal

Volcano harm

- About 1500 active volcanos in the world
- There is volcano disaster it has victims every 10~30 years (only in Japan)
- Eruption affect to space (gas and particle generated by eruption causes unusual currents of extreme winds)

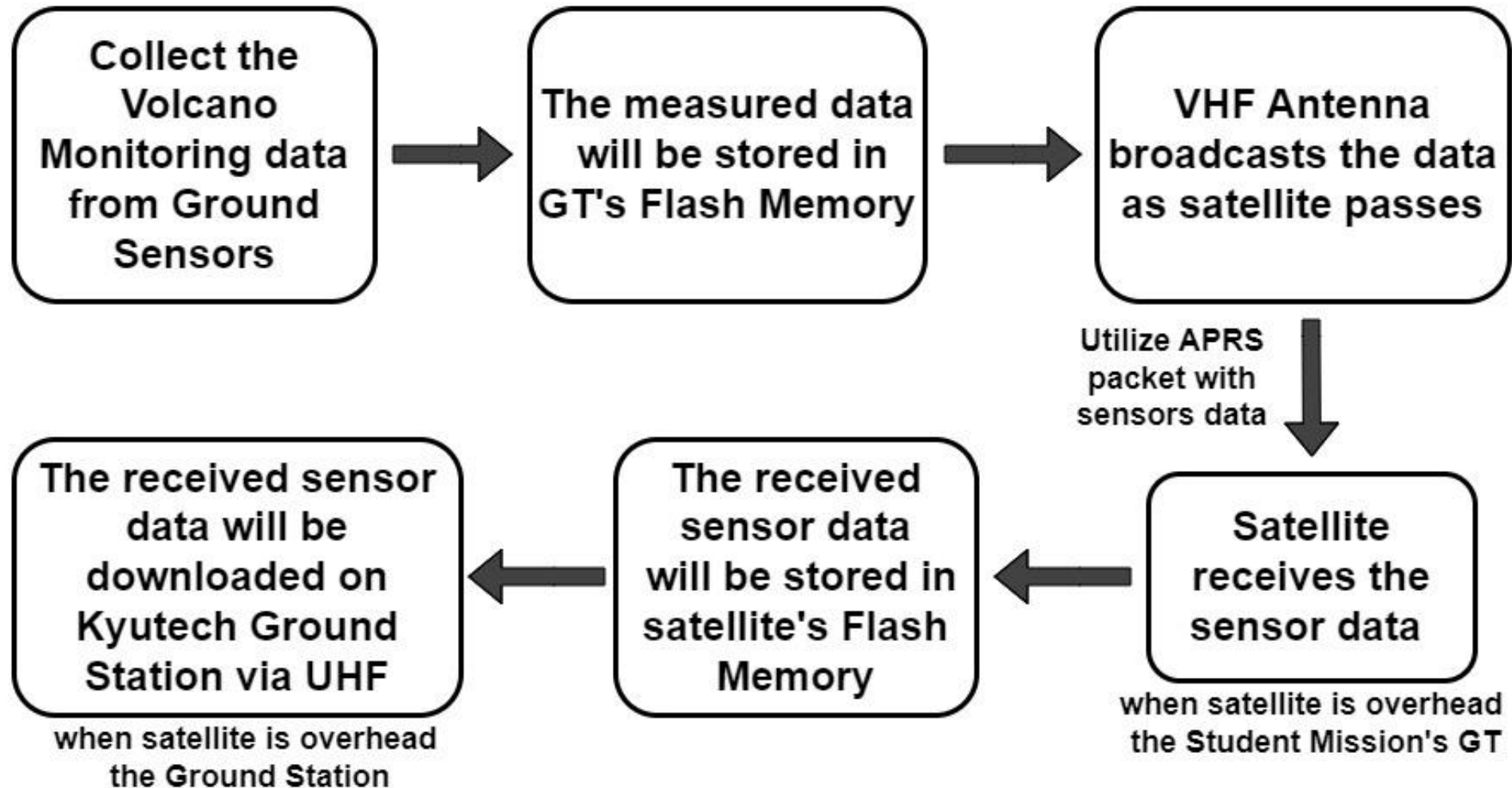
By monitoring volcano

- Predict volcano eruption
- Avoid disaster
- Understand earth activity



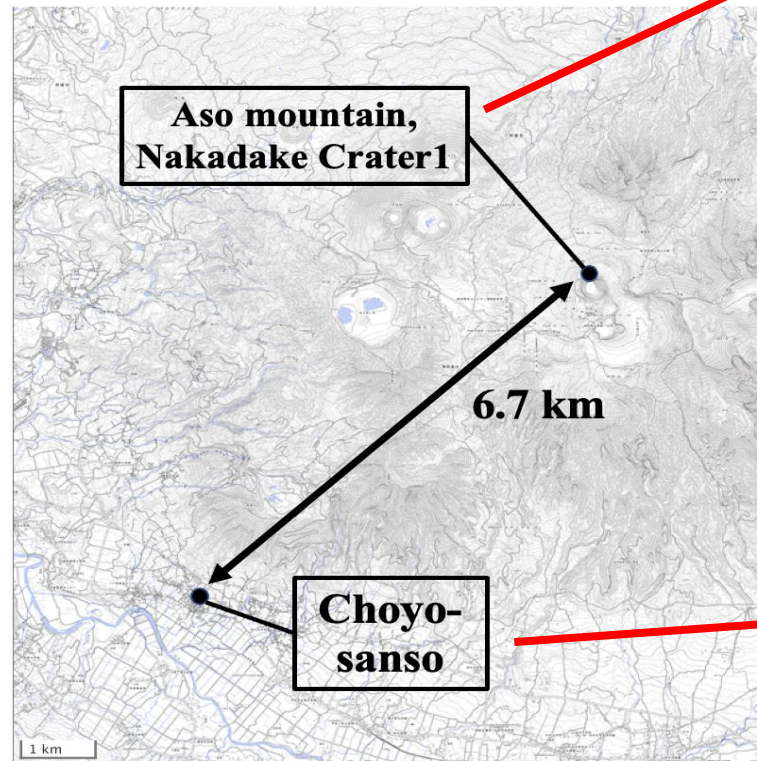
https://www.carsensor.net/contents/article_images/65319/eruption_bousai_01.jpg

- **Problem:** Difficulty in gathering the data from a remote area
 - No internet connection
 - Hard situation to observe by human
 - Difficult to get data continuously
- **Solution:** Use satellite as a platform to collect data from sensors for volcano monitoring
- **Mission objectives:**
 - To operate the satellite to store and forward data acquired from the remote area to the ground station.
 - To monitor the volcano activity and collect the data through our satellite by using APRS



EXPECTED LOCATION

- “Choyo-Sanso” Kyutech Retreat Facility near the Aso mountain
- Active volcano
- 6.7 km from the Nakadake Crater 1



Sensors for volcano monitoring:

1. Gas sensor



DF Robot SEN0470 (SO2)

(measures gas concentration of SO2)

Specification

- Detects: Sulfur Dioxide (SO2)
- Temperature: -20 to 50 °C
- Detection range: 0 - 20 ppm
- Protocols: I2C, UART

2. Weather windmeter



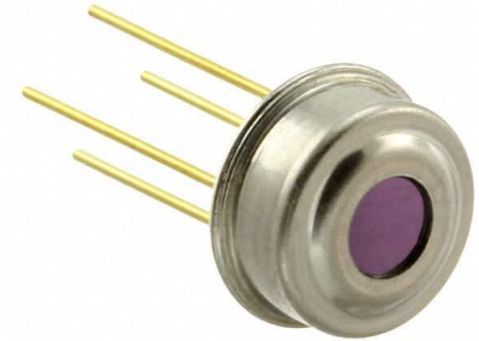
DS-15901

(measures speed and direction of wind in the vicinity of volcano)

Specification

- Detects: Wind speed & direction
- Including:
 - Wind vane
 - Anemometer

3. Thermal sensor



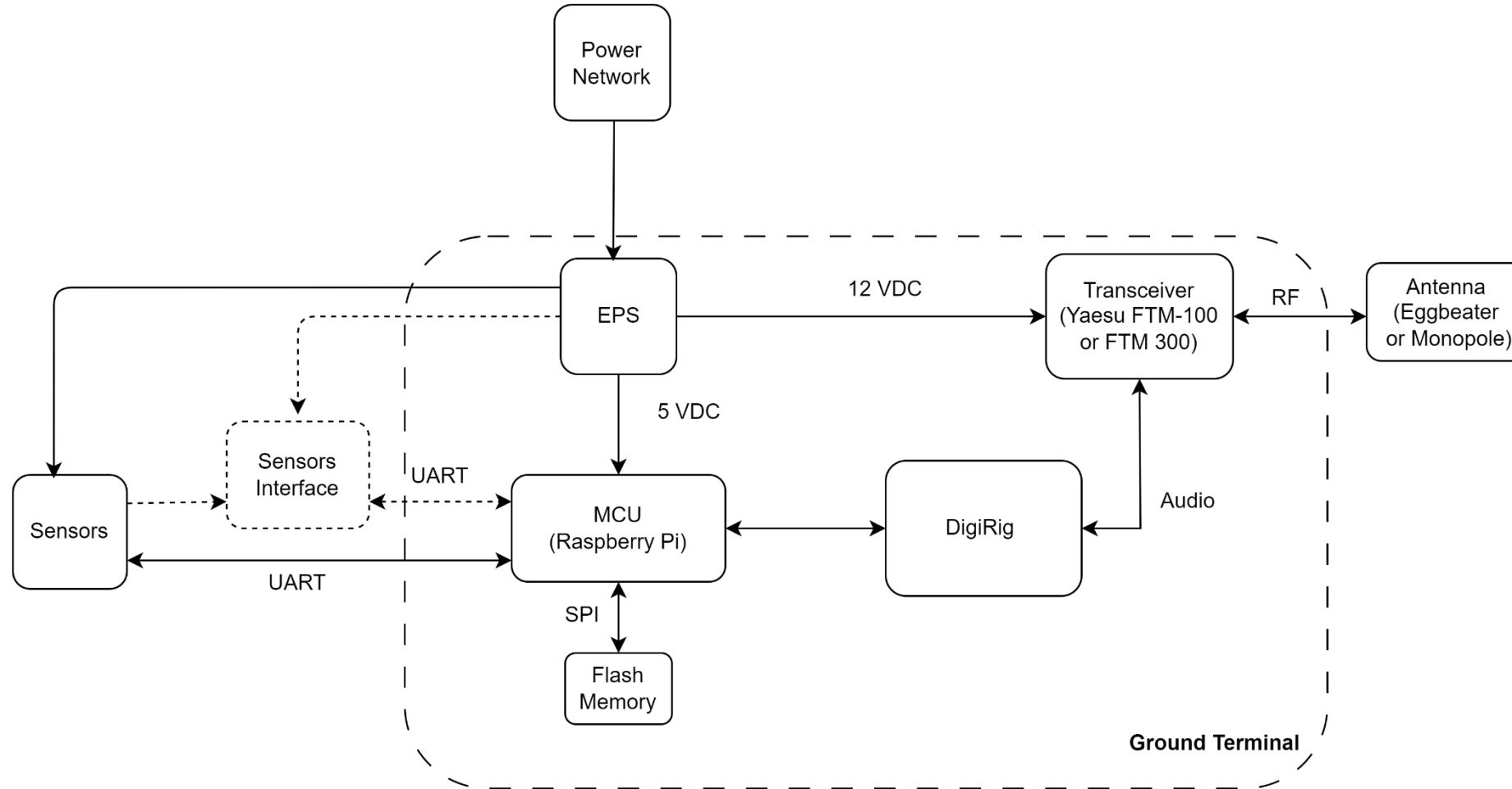
MLX90614ESF-ACK-000-SP

(measures change in temperature of volcanic vents)

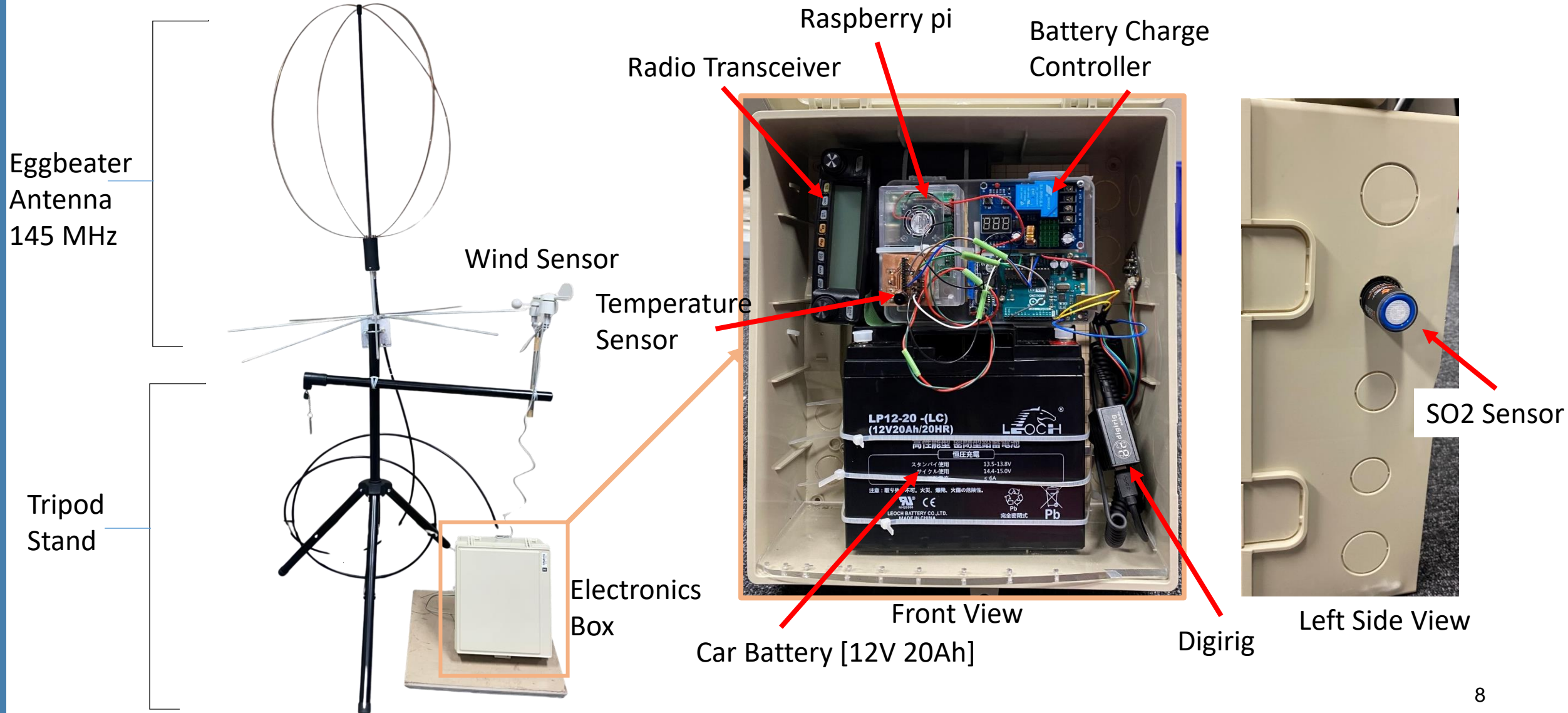
Specification

- Detects : Temperature change
- Sensing temperature (Local): -40°C to 85°C
- Sensing temperature (Remote): -70°C to 380°C
- Temperature resolution: 0.02°C

Ground Sensor Terminal Block Diagram



Ground Sensor Terminal (GST)



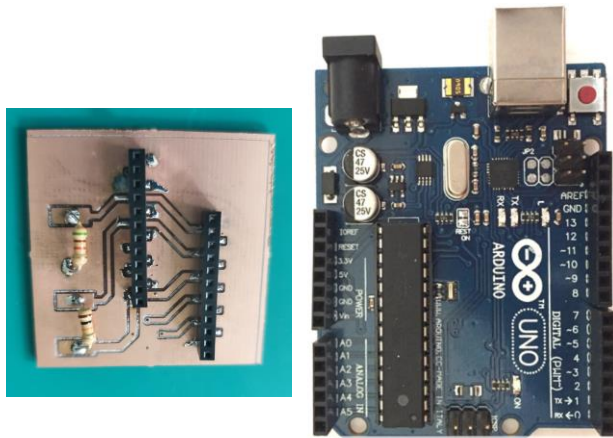
Components of the GST



**Microcomputer Unit
(MCU): Raspberry Pi 3B**



RF Transceiver: Yaesu FTM 100-DH



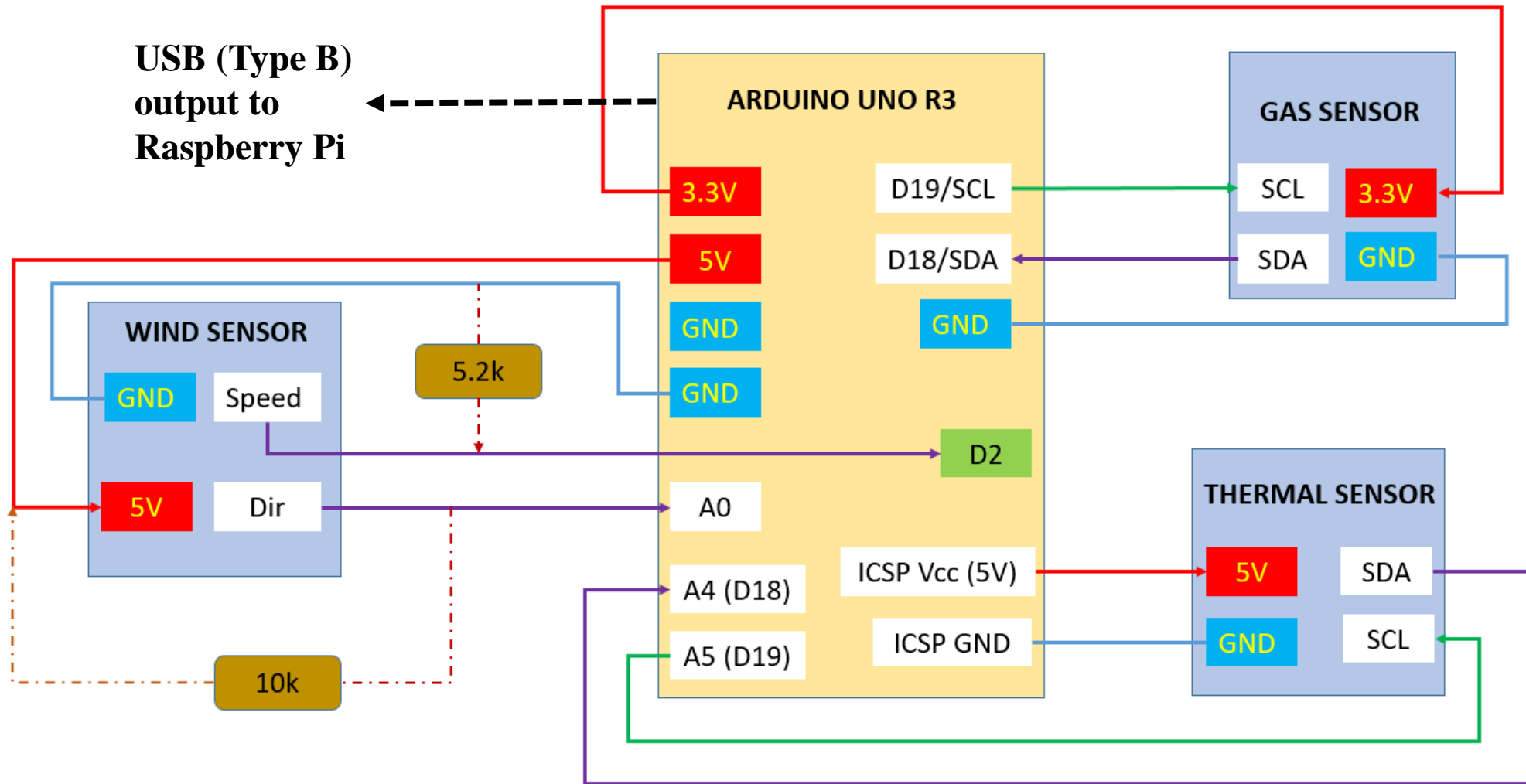
**Sensor board and Sensor
Interface (Arduino UNO R3)**



Digirig mobile

**Antenna:
Eggbeater antenna**

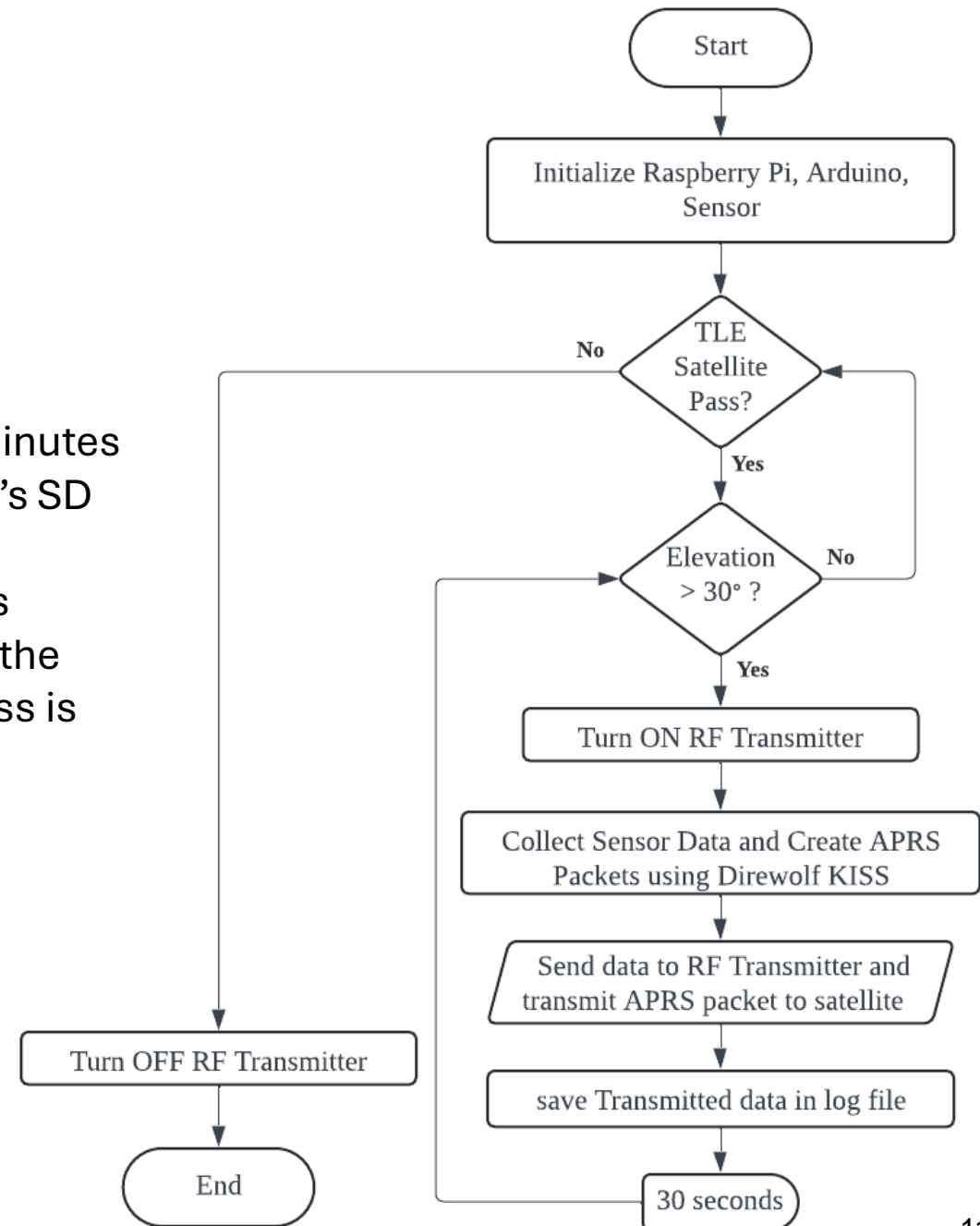




Sensors – Sensor Interface connection Block Diagram

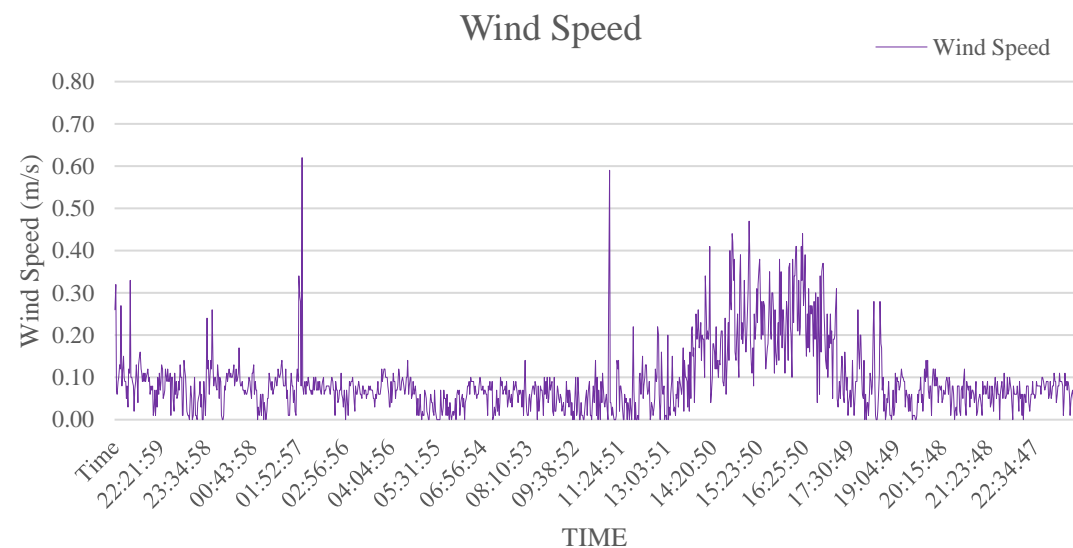
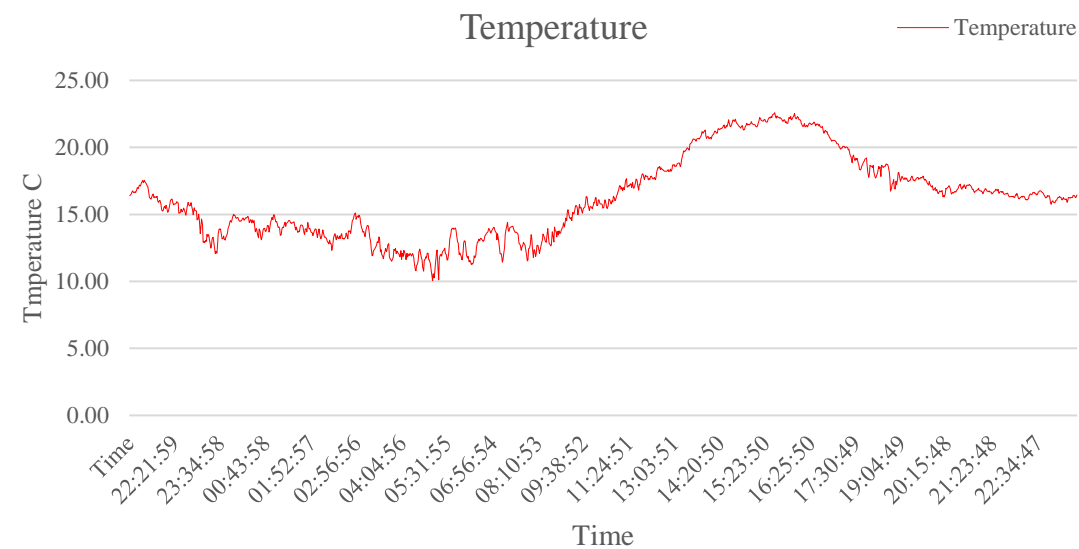
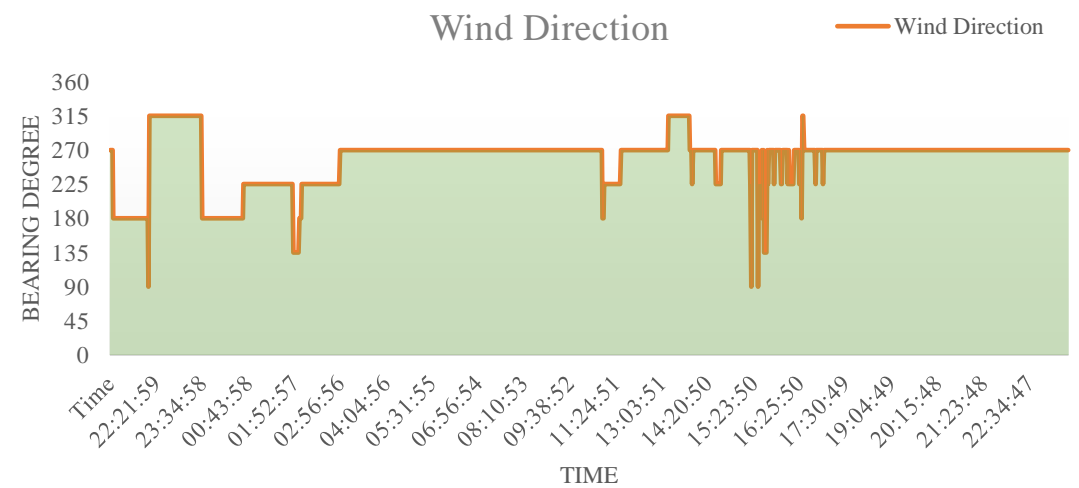
Operation Flowchart

- Raspberry Pi, Arduino, Sensors and DC/DC buck converter will be turned on all the time
 - Sensors will capture Volcano data every two minutes
 - Volcano data will be stored in the Raspberry Pi's SD card
- YAESU transceiver will be turned on around 10 mins before a satellite pass, and be turned off right after the satellite pass (assume that the duration of each pass is approximately 10 minutes)
 - The 15W transmission mode will be chosen as default TX mode
 - The transmitting time is **2 minutes**
 - Each transmission will be **30 seconds apart**



Data Collection Test

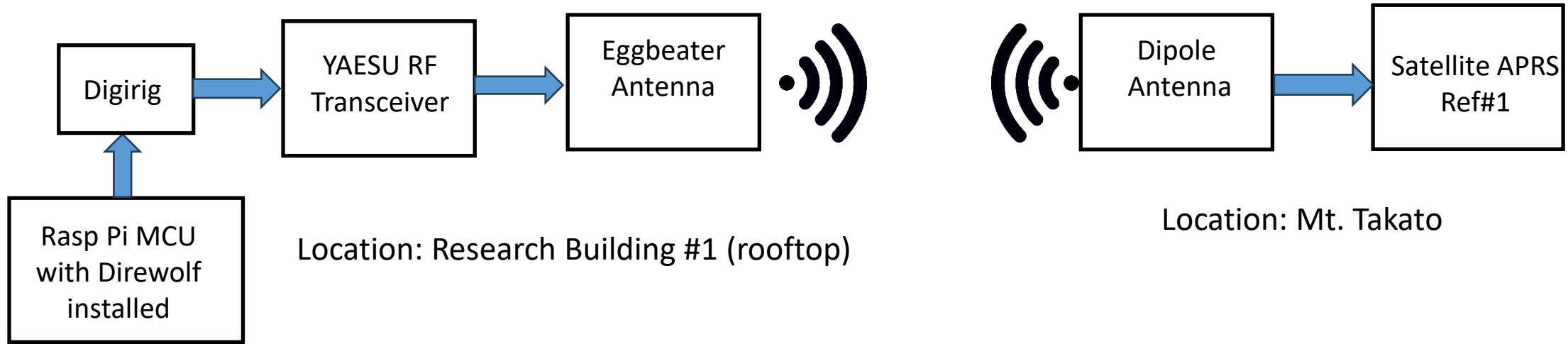
Duration: **26 hours 24 mins**



Summary of the data results

Sensor data	Max	Min	Avg
Temperature	22.59 °C	9.93 °C	16.07 °C
Wind Speed	0.62 m/s	0 m/s	0.07 m/s
	Most dominant wd		Duration
Wind direction	South West (270°)		18h 48m

RF Test (Long range)



- An APRS message was transmitted from GST to satellite's APRS REF#1 at VHF
 - Transmitted APRS message from APRS GST: APRSGT>JG6Y0W-11,WIDE1-1:@073557z4903.50N/07201.75W_090/002g000t025gas0.02{01
- Satellite received this message, then digipeated back to GST

RF Test (Long range)

```
birdsx@birdsx: ~  
File Edit Tabs Help  
JG6YOW audio level = 198(112/52) [NONE] ____|_|_|_|_|_  
Audio input level is too high. Reduce so most stations are around 50.  
[0.5] JG6YOW>APTT4,WIDE1-1:>Dragonfly Satellite APRS Digipeater 73 1  
Status Report, Tiny Track  
Dragonfly Satellite APRS Digipeater 73 1  
[0L] APRSGT>JG6YOW-11,WIDE1-1:@073557z4903.50N/07201.75W_090/002g000t025gas0.02{  
01  
Digipeater WIDE1 (probably JG6YOW) audio level = 199(113/52) [NONE] ____|_|_|_|_|_  
Audio input level is too high. Reduce so most stations are around 50.  
[0.5] APRSGT>JG6YOW-11,JG6YOW,WIDE1*:@073557z4903.50N/07201.75W_090/002g000t025g  
as0.02{01  
Weather Report, WEATHER Station (blue)  
N 49 03.5000, W 072 01.7500  
wind 2.3 mph, direction 90, gust 0, temperature 25, "gas0.02{01"  
JG6YOW audio level = 196(108/52) [NONE] ____|_|_|_|_|_:  
Audio input level is too high. Reduce so most stations are around 50.  
[0.5] JG6YOW>APTT4,WIDE1-1:>Dragonfly Satellite APRS Digipeater 73 1  
Status Report, Tiny Track  
Dragonfly Satellite APRS Digipeater 73 1
```

→ The transmitted APRS signal

→ The content of the decoded APRS signal

→ The digipeated message from satellite

Link Budget Analysis (VHF)

Parameters	Unit	EI	EI	EI	EI	EI	EI	EI	EI	EI
		0	10	20	30	40	50	60	75	90
Frequency	MHz	145.825	145.825	145.825	145.825	145.825	145.825	145.825	145.825	145.825
At the Ground Station Terminal side										
EIRP (5W)	dBm	20	26	32	36	38	39	41.5	41.6	41.62
EIRP (15W)	dBm	24.76	30.76	36.76	40.76	42.76	43.76	46.26	46.36	46.38
EIRP (50W)	dBm	30	36	42	46	48	49	51.5	51.6	51.62
TOTAL LOSS	dB	151.88	147.84	144.54	142.05	140.21	138.86	137.88	137.00	136.72
At the Satellite Side										
Rcv power at TRX (for 5W TX case)	dBm	-134.28	-124.24	-114.94	-108.45	-104.61	-102.26	-98.78	-97.8	-97.5
Rcv power at TRX (for 15W TX case)	dBm	-129.52	-119.48	-110.18	-103.69	-99.85	-97.5	-94.02	-93.04	-92.74
Rcv power at TRX (for 50W TX case)	dBm	-124.28	-114.24	-104.94	-98.45	-94.61	-92.26	-88.78	-87.8	-87.5
Required power at TRX	dBm	-105	-105	-105	-105	-105	-105	-105	-105	-105
LINK MARGIN										
* for 5W transmission scenario	dB	-29.28	-19.24	-9.94	-3.45	0.39	2.74	6.22	7.20	7.50
* for 15W transmission scenario	dB	-24.52	-14.48	-5.18	1.31	5.15	7.50	10.98	11.96	12.26
* for 50W transmission scenario	dB	-19.28	-9.24	0.06	6.55	10.39	12.74	16.22	17.20	17.50

Good values

Power Budget Analysis

Components		Current consumption (A)	Operating Voltage (V)	Power consumption (W)	Duty Cycle (h)	Energy per day (Wh)
Raspberry Pi, Arduino and Sensors		0.68	5	3.4	24	81.6
RF Transceiver (TX mode)	5W	2.24	12.8	28.67	0.033	0.06
	15W	4.12	12.8	52.74	0.033	0.12
	50W	9	12.8	115.2	0.033	0.26
	(RX mode)	0.58	12.8	7.42	0.33	2.45

Total energy consumption per day: **~84.3 Wh**

Data Budget Analysis

Data Budget in a day when there is a satellite pass

	Parameters	Values	Units	Notes
A	Mean time per satellite pass	476.6	s	STK access simulation
B	Effective time for data collection	238.3	s	Assume that is only 50% of A
C	Mean duration of each access with good communication	120	s	Analysis from the AER result, with respect to the condition $EI \geq 33^\circ$
D	Maximum amount of data that can be collected for each 30 seconds	67	bytes	Assume that the whole length of an APRS frame must be used
E	Maximum amount of data that can be collected when considering B	532	bytes	$= (B/30)*D$; corresponds to 7 APRS packets
F	Maximum amount of data that can be collected when considering C	268	bytes	$= (C/30)*D$; corresponds to 4 APRS packets

Data Dashboard

<https://birds-x.birds-project.com/>



About us

FAQs

ICD and Handbook

Members

Satellite Documents

Timeline

APRS Mission

APRS Volcano Monitoring Ground Terminal Dashboard

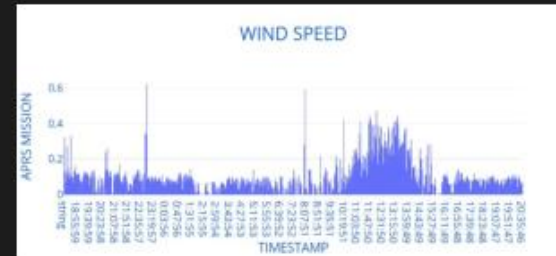
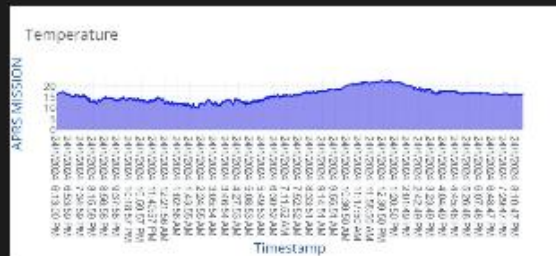
View only

Temperature

Wind
Direction

Wind
Speed

Data filter



Appendix

APRS Data Format

- Formatted the output sensor data in APRS format:
 - Chosen format: **Complete Weather report** (with normal Lat/Long, timestamp)

Complete Weather Report Format — with Lat/Long position and Timestamp									
/ or @	Time DHM / HMS	Lat	Sym Table ID	Long	Symbol Code	Wind Directn/ Speed	Weather Data	APRS Software	WX Unit
1	7	8	1	9	1	7	n	1	2-4

The results appear in the Direwolf's decode window:

```
APRSGT>JG6YOW-11,WIDE1-1:@092345z4903.50N/07201.75W_090/002g000t025gas0.02
Weather Report, WEATHER Station (blue)
N 49 03.5000, W 072 01.7500
wind 2.3 mph, direction 90, gust 0, temperature 25, "gas0.02"
```

APRSGT>JG6YOW-11,WIDE1-1:@092345z4903.50N/07201.75W_090/002g000t025gas0.02

COM5

```

000/g000t027gas0.00
2.579
000/g000t027gas0.00
3.643
000/g000t027gas0.00
3.961
000/g000t027gas0.00
3.013
000/g000t027gas0.00
1.232
000/g000t027gas0.00
0.361
000/g000t027gas0.00
000/g000t027gas0.00
000/g000t027gas0.00

```

Expected data for 1 APRS frame

Wind speed data

☒ Autoscroll ☐ Show timestamp

Sensor data collection by Arduino

```

225/g000t025gas0.00
Temperature increased !
000
225/g000t025gas0.00
003
225/g000t025gas0.00
Temperature decreased !
270/g000t025gas0.00
180/g000t025gas0.00
Temperature increased !
225/g000t025gas0.00
001
225/g000t025gas0.00
Temperature decreased !
003
225/g000t025gas0.00

```

Sensor data
received from
Arduino by Rasp Pi

```

output_data_APRS.dat - /home/birdsx/Desktop/APRS
File Edit Search View Document Project Build Tools Help
output_data_APRS.dat x ORBTTEST.py x test3.txt x output_format_rwrite_APRS7.py x
673 APRSGT>JG6Y0W-11,WIDE1-1:@113123z3250.49N/13101.47E_225/000g000t017gas0.00
674 APRSGT>JG6Y0W-11,WIDE1-1:@113128z3250.49N/13101.47E_225/000g000t016gas0.00
675 Stop Time: 11:31:29 25/11/23, Duration: 00:00:27
676
677 SESSION 52
678 Start Time: 11:45:28 25/11/23
679 APRSGT>JG6Y0W-11,WIDE1-1:@114533z3250.49N/13101.47E_000/000g000t016g0.00ta16.53wsa0.08
680 APRSGT>JG6Y0W-11,WIDE1-1:@114538z3250.49N/13101.47E_000/000g000t016g0.00ta16.51wsa0.17
681 APRSGT>JG6Y0W-11,WIDE1-1:@114543z3250.49N/13101.47E_000/000g000t016g0.00ta16.47wsa0.18
682 APRSGT>JG6Y0W-11,WIDE1-1:@114548z3250.49N/13101.47E_000/000g000t016g0.00ta16.43wsa0.10
683 APRSGT>JG6Y0W-11,WIDE1-1:@114553z3250.49N/13101.47E_000/000g000t016g0.00ta16.45wsa0.11
684 APRSGT>JG6Y0W-11,WIDE1-1:@114558z3250.49N/13101.47E_000/000g000t016g0.00ta16.47
685 Stop Time: 11:46:01 25/11/23, Duration: 00:00:33
686
687 SESSION 53
688 Start Time: 12:12:00 25/11/23
689 APRSGT>JG6Y0W-11,WIDE1-1:@121300z3250.49N/13101.47E_000/000g000t016g0.00ta16.19wsa0.11
690 APRSGT>JG6Y0W-11,WIDE1-1:@121400z3250.49N/13101.47E_000/000g000t016g0.00ta16.21wsa0.13
691 APRSGT>JG6Y0W-11,WIDE1-1:@121500z3250.49N/13101.47E_270/000g000t016g0.00ta16.39wsa0.26
692 APRSGT>JG6Y0W-11,WIDE1-1:@121600z3250.49N/13101.47E_270/001g000t016g0.00ta16.45wsa0.32
693 APRSGT>JG6Y0W-11,WIDE1-1:@121700z3250.49N/13101.47E_270/000g000t016g0.00ta16.51wsa0.07
694 APRSGT>JG6Y0W-11,WIDE1-1:@121800z3250.49N/13101.47E_270/000g000t016g0.00ta16.69wsa0.06
695 APRSGT>JG6Y0W-11,WIDE1-1:@121900z3250.49N/13101.47E_180/000g000t016g0.00ta16.71
696 APRSGT>JG6Y0W-11,WIDE1-1:@122000z3250.49N/13101.47E_180/000g000t016g0.00ta16.77wsa0.09
697 APRSGT>JG6Y0W-11,WIDE1-1:@122100z3250.49N/13101.47E_180/000g000t016g0.00ta16.65wsa0.10

```

The APRS-formatted data
stored in log file

```

aprs_output.txt x output_data.dat x orbttest.log x elevation_log.txt x ORBTTEST
1 APRSGT>JG6Y0W-11,WIDE1-1:@092122z3250.49N/13101.47E_000/000g000t022g0.00ta22.15wsa0.02
2 APRSGT>JG6Y0W-11,WIDE1-1:@092132z3250.49N/13101.47E_000/002g000t022g0.00ta22.15wsa1.05
3 APRSGT>JG6Y0W-11,WIDE1-1:@092142z3250.49N/13101.47E_000/002g000t022g0.00ta22.15wsa1.22
4 APRSGT>JG6Y0W-11,WIDE1-1:@092152z3250.49N/13101.47E_000/000g000t022g0.00ta22.21
5 APRSGT>JG6Y0W-11,WIDE1-1:@092202z3250.49N/13101.47E_000/000g000t022g0.00ta22.23
6 APRSGT>JG6Y0W-11,WIDE1-1:@092212z3250.49N/13101.47E_180/000g000t022g0.00ta22.25
7 APRSGT>JG6Y0W-11,WIDE1-1:@092222z3250.49N/13101.47E_180/000g000t022g0.00ta22.31
8 APRSGT>JG6Y0W-11,WIDE1-1:@092232z3250.49N/13101.47E_180/000g000t022g0.00ta22.35
9 APRSGT>JG6Y0W-11,WIDE1-1:@092242z3250.49N/13101.47E_180/003g000t022g0.00ta22.37wsa1.52
10 APRSGT>JG6Y0W-11,WIDE1-1:@092252z3250.49N/13101.47E_180/002g000t022g0.00ta22.43wsa1.25
11 APRSGT>JG6Y0W-11,WIDE1-1:@092302z3250.49N/13101.47E_000/001g000t022g0.00ta22.51wsa0.37
12

```

The APRS output file that extracts data from the log file

```

geany_run_script_19MJL2.sh
File Edit Tabs Help
Executing direwolf...
Dire Wolf version 1.6
Includes optional support for: cm108-ptt

Reading config file /home/birdsx/direwolf.conf
Audio device for both receive and transmit: default
Channel 0: 1200 baud, AFSK 1200 & 2200 Hz, E+, 44100
ERROR can't open device /dev/ttyUSB0 for channel 0 PT
No such file or directory
Note: PTT not configured for channel 0. (Ignore this
Ready to accept AGW client application 0 on port 8000
Ready to accept KISS TCP client application 0 on port
Virtual KISS TNC is available on /dev/pts/2
Created symlink /tmp/kisstnc -> /dev/pts/2
Executing kissutil...
Commands executed successfully.

Attached to KISS TCP client application 0...

Ready to accept KISS TCP client application 1 on port
File /home/birdsx/test/msg/new_file_1.txt created.
Processing new_file_1.txt for transmit...
APRSGT>JG6Y0W-11,WIDE1-1:@092122z3250.49N/13101.47E_0
sa0.02

geany_run_script_19MJL2.sh
File Edit Tabs Help
Weather Report, WEATHER Station (blue)
32 50.4900, E 131 01.4700
wind 0.0 mph, direction 0, gust 0, temperature 22, "g0.00ta22.23"
APRSGT>JG6Y0W-11,WIDE1-1:@092202z3250.49N/13101.47E_000/000g000t022g0.00ta22
.23
file /home/birdsx/test/msg/new_file_6.txt created.
Processing new_file_6.txt for transmit...
APRSGT>JG6Y0W-11,WIDE1-1:@092212z3250.49N/13101.47E_180/000g000t022g0.00ta22.25
[0L] APRSGT>JG6Y0W-11,WIDE1-1:@092212z3250.49N/13101.47E_180/000g000t022g0.00ta2
1.25
APRSGT audio level = 198(104/97) [NONE] |||||_
Audio input level is too high. Reduce so most stations are around 50.
[0.3] APRSGT>JG6Y0W-11,WIDE1-1:@092212z3250.49N/13101.47E_180/000g000t022g0.00ta
2.25
Weather Report, WEATHER Station (blue)
32 50.4900, E 131 01.4700
wind 0.0 mph, direction 180, gust 0, temperature 22, "g0.00ta22.25"
APRSGT>JG6Y0W-11,WIDE1-1:@092212z3250.49N/13101.47E_180/000g000t022g0.00ta22
.25
file /home/birdsx/test/msg/new_file_7.txt created.
Processing new_file_7.txt for transmit...
APRSGT>JG6Y0W-11,WIDE1-1:@092222z3250.49N/13101.47E_180/000g000t022g0.00ta22.31
[0L] APRSGT>JG6Y0W-11,WIDE1-1:@092222z3250.49N/13101.47E_180/000g000t022g0.00ta2

```

Direwolf reads the content in APRS output file and transmit to transceiver by KISS protocol and digital mode interface (Digirig)

1. The collected sensor data appeared in the Arduino IDE monitoring screen;
2. The collected data appeared on the Raspberry Pi's screen after running the Python Code
3. In the log file:
 - Each sensor data collection session will be recorded;
 - The start time, stop time and duration of each session will be recorded;
 - The avg data after 3 hours have been recorded to APRS output file, as well as the data trend, and anomaly (if it has)
4. In the output file:
 - Each row in each session is a complete APRS data frame (containing the mentioned avg data, data trend...) which is formatted in the Complete Weather Data report format.