

Adopt a Satellite: Using SatNOGS in the Classroom

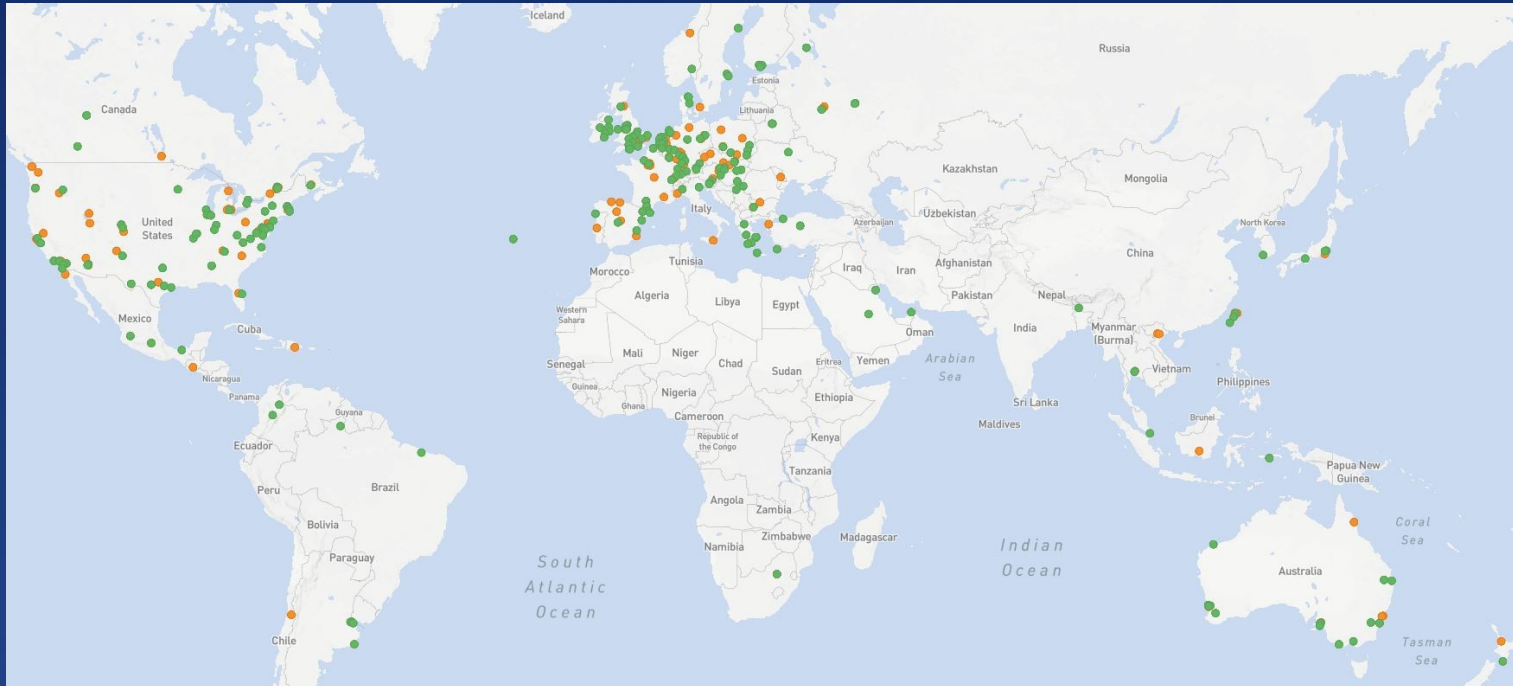
**SmallSat Education Conference
October 28-29, 2023
Kennedy Space Center**

**Fredric Raab, KK6NOW
Adjunct Faculty
College of the Desert, Palm Desert, CA
fraab@collegeofthedesert.edu**

SatNOGS.org

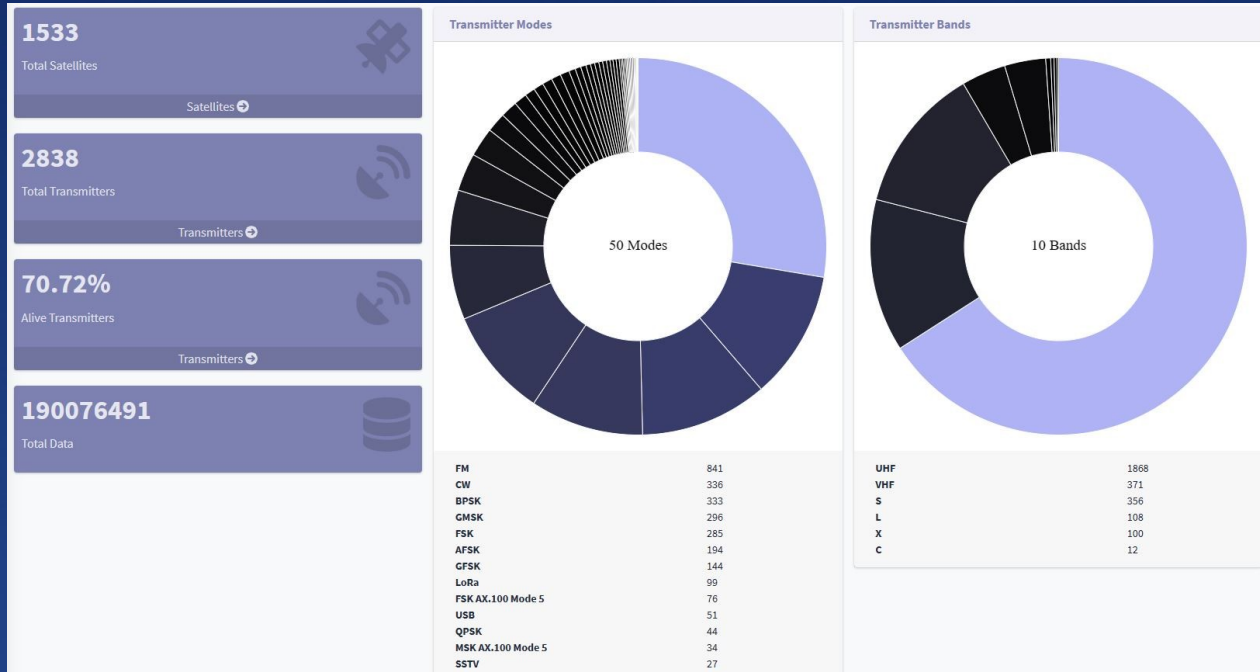
What is SatNOGS?

- Global network of open-source ground stations operated by educational institutions, hobbyists and space enthusiasts.



What is SatNOGS?

- It's an Open Access database containing more than 190 million observations from 1500+ satellites.



What is SatNOGS?

- Dashboards provide visual access to operational data
- Scientific data available from some satellites



What is SatNOGS?

- Access to DB and dashboards is free to everyone
- You can build an operating SatNOGS station for \$150 US
- As a station operator, you can schedule data downloads on any other station in the network worldwide



Why Adopt a Satellite?

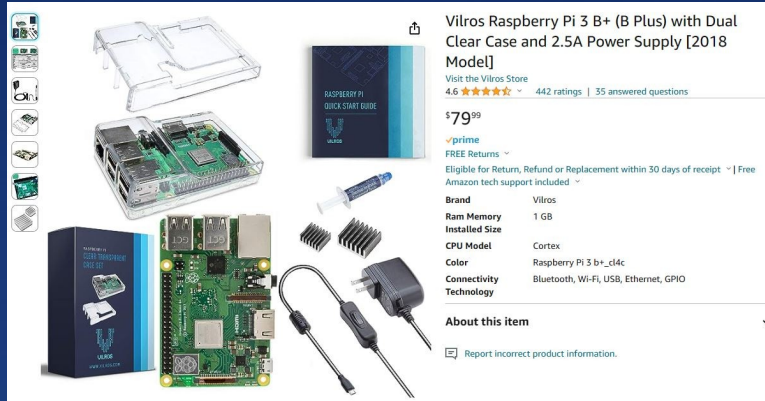
- Once a CubeSat is on-orbit, its operators need to continuously monitor its health and collect scientific data.
- By “adopting” an existing, on-orbit satellite, your students have the experience of being a satellite operator without the expense and risk of launching your own CubeSat.
- Using published information, your students learn about their “adopted” CubeSat, its mission and orbital path, the communications protocols used and data returned, etc.
- By using SatNOGS to schedule data downlinks & monitor the CubeSat’s dashboard over a 2 – 4+ week period, students learn about CubeSat communications, operations and performance.

How to Begin

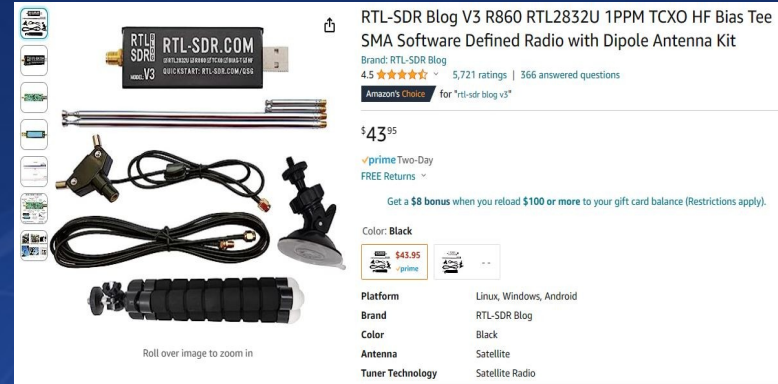
- Explore SatNOGS.org
- Assemble a minimum station and start scheduling observations
- Assemble students into teams of 3 - 5
 - Each team picks a satellite for adoption
 - They learn everything they can about their satellite
 - They schedule downlinks across the global network, monitor received data and compare data to historical data for the specified time period
 - They present their findings to the class.
 - Optionally, they track newly launched satellites (more to come...)

Assembling a Minimum Station

- Raspberry Pi 3B+ (or better) kit with micro-SD card

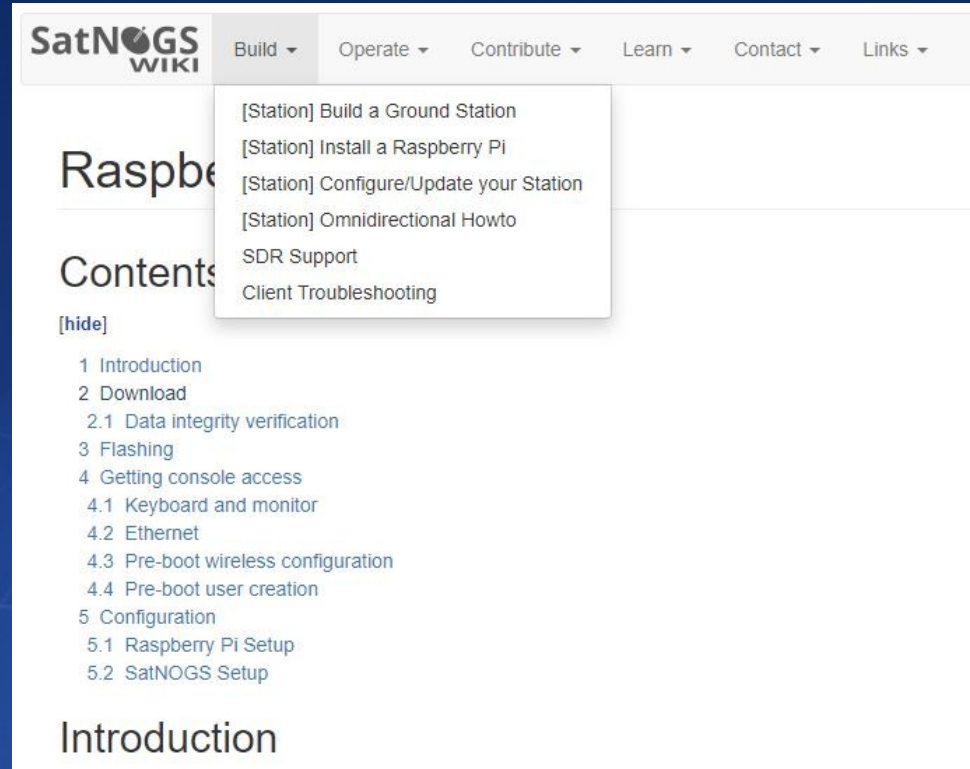


- RTL-SRD.COM SDR stick with antenna kit



Assembling a Minimum Station

- Follow the step-by-step instructions on the SatNOGS wiki
- Download and flash the SD card image
- Boot and configure
- You don't need keyboard and monitor to configure, but it helps.
- Once configured, use SSH to remotely access the Rpi (if necessary)



Ideal Satellites to Adopt

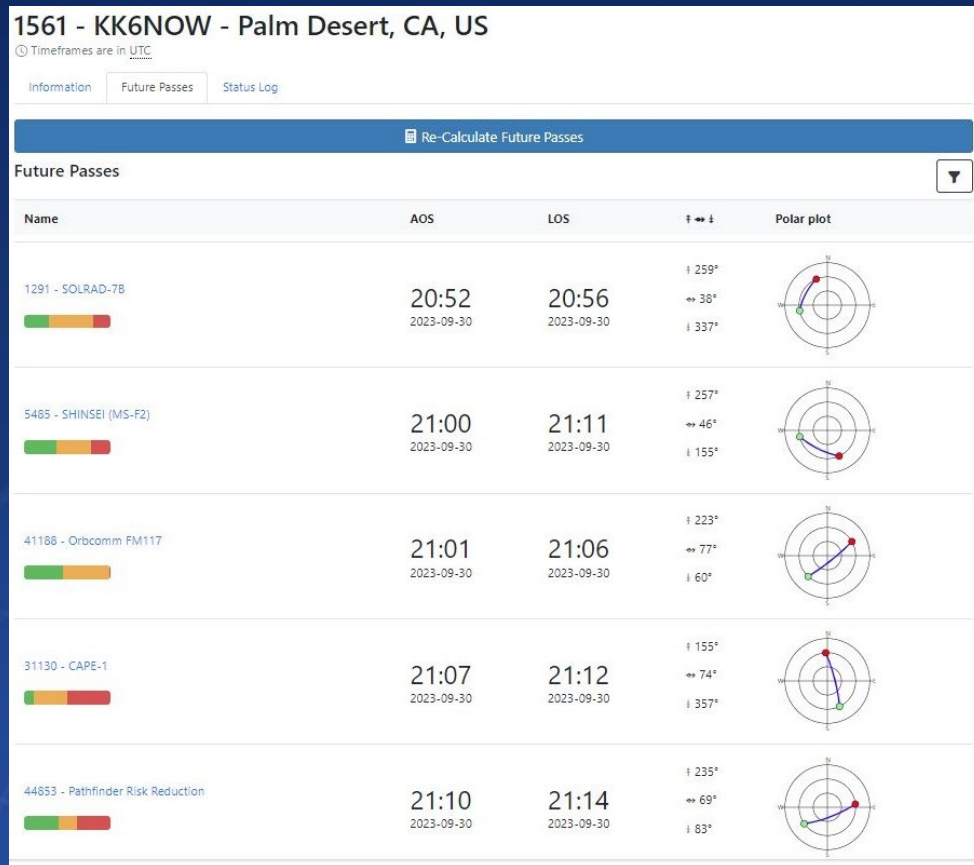
- Have a SatNOGS dashboard
- Are currently active
- Are successfully received by numerous stations
- You can easily find information about the satellite on the Internet
- Have more than 1 year of on-orbit data available
- Examples:
 - ISS (International Space Station)
 - CIRBE – lasp.colorado.edu/cirbe
 - GRIFEX – jpl.nasa.gov
 - CubeBel-1 & 2 – bsusat.com
 - UVSQSat – latmos.ipsl.fr

Overview of Classroom Activities

- SatNOGS observation scheduling
- Observation interpretation
- Satellite communications
- Decoding communications protocols – bits to data
- Interpreting dashboards and housekeeping data
- Satellite components
- Satellite operations
- Scientific missions
- Satellite predication and orbital mechanics
- Tracking newly launched cubesats

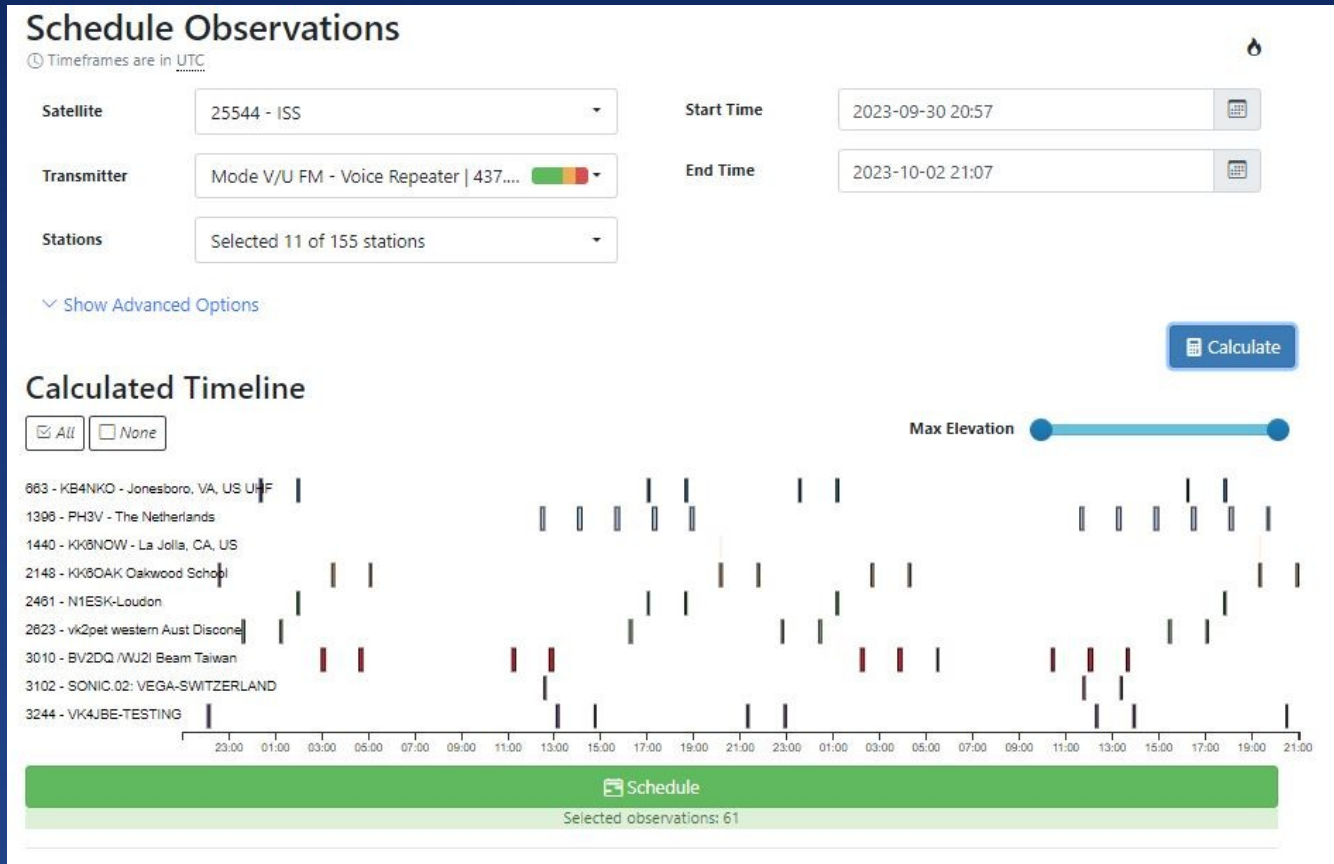
Observation Scheduling

- **Schedule by station**
- Notice how many are overhead is such a short period.
- You don't have to wait long to observe a satellite.



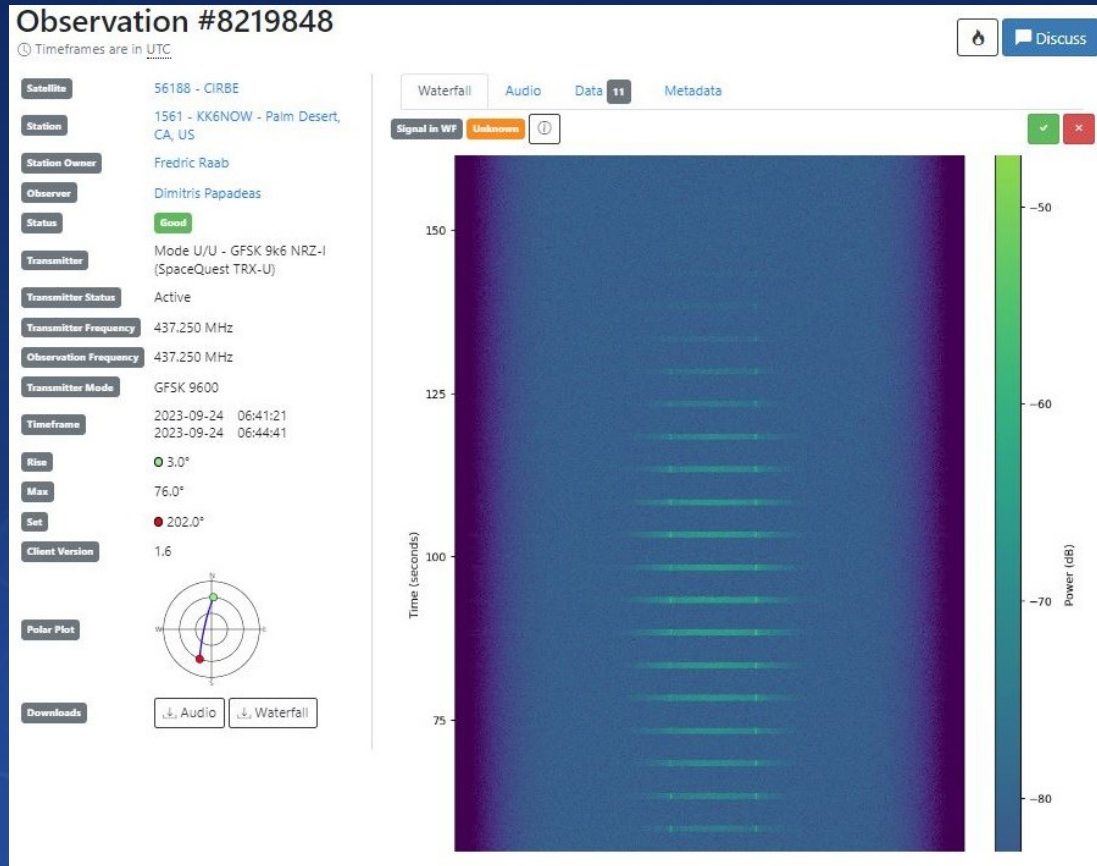
Observation Scheduling

- Schedule by satellite
- Up to 2 days in advance
- Across multiple stations
- Select “super” stations to provide global coverage.



Observation interpretation

- Waterfall provides a visual representation of the signal and strength over time
- Click green & red buttons (far right) to indicate good signals
- Use tabs to listen to signal, view data packet
- Left column provides metadata about the observation



Decoding Communications Protocols

- How are waterfall signals turned into bits?
- How are bits turned into data?
- How is data turned into information that can be displayed on a dashboard?

Observation #8219848

🕒 Timeframes are in UTC

Satellite

56188 - CIRBE

Station

1561 - KK6NOW - Palm Desert, CA, US

Station Owner

Fredric Raab

Observer

Dimitris Papadeas

Status

Good

Transmitter

Mode U/U - GFSK 9k6 NRZ-I (SpaceQuest TRX-U)

Transmitter Status

Active

Transmitter Frequency

437.250 MHz

Observation Frequency

437.250 MHz

Transmitter Mode

GFSK 9600

Timeframe

2023-09-24 06:41:21
2023-09-24 06:44:41

Rise

3.0°

Max

76.0°

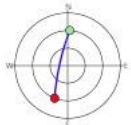
Set

202.0°

Client Version

1.6

Polar Plot



Downloads

📶 Audio

📶 Waterfall

Waterfall

Audio

Data 11

Metadata

Load More Data(1)

Load All Data(1)

ASCII

HEX

AX.25

data_obs/2023/9/24/6/8219848/data_8219848_2023-09-24T06-42-35

```
84 86 A8 40 40 40 60 86 92 A4 84 8A 40 E1 03 F0 08 50 E7 5C 00 D2 2C A2 96 FE 04 1E 05
00 00 CE 00 00 00 00 00 00 00 2F B3 26 F5 25 24 77 80 00 00 00 00 00 00 00 00 00
00 00 00 97 00 A6 2D 00 00 00 01 41 C6 51 48 7F 66 66 81 01 0F 10 30 1E C5 FB FC 0C 05
08 D5 E2 09 2F 17 88 A6 E5 76 F4 07 B6 F6 0A 37 C0 C9 C0 C6 D8 B7 F3 C8 EE 07 EC 26 01
00 48 C2 85 A9 30 62 42 8B F3 03 B0 4A 50 08 68 54 1F 00 95 6D 68 21 FE F1 F8 48 05 72
03 00 00 17 00 01 76 B8 EB AD 01 00 03 00 14 12 03 03 03 57 17 1B 9F 1B 9F 00 00 02 00
00 15 ED 55 F3 16 E9 95 11 3E 27 00 92 02 43 FF 98 00 16 17 00 F0 E2 35 00 00 00 00 0E
17 2F 00 00 00 01 00 00 00 34 00 08 00 01 C5 BC 2D 01 00 41 00 01 00 00 0D A5 21 28 00
01
```

data_obs/2023/9/24/6/8219848/data_8219848_2023-09-24T06-42-40

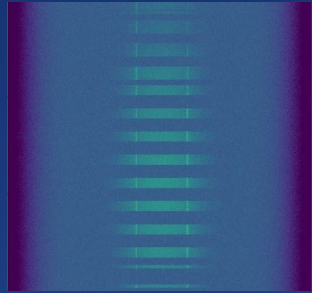
```
84 86 A8 40 40 40 60 86 92 A4 84 8A 40 E1 03 F0 08 50 E7 5D 00 D2 2C A2 97 03 04 20 05
00 00 D3 00 00 00 00 00 00 00 00 A2 F4 27 41 26 29 77 00 00 00 00 00 00 00 00 00
00 00 00 97 00 A6 2D 00 00 00 01 41 C6 51 48 81 E6 66 81 01 0F 10 3F 20 2E F8 F3 92 4F
00 BE 76 D0 2E B1 36 F0 E5 90 64 89 B6 A8 72 67 C1 07 C1 06 D7 F0 F3 E4 EE 41 EC 0D 01
00 49 87 CD A8 30 D5 4A 45 F3 FC 41 5D 4F 37 2A 4C 1F 00 95 6D 68 21 FE C8 FB 48 05 70
03 00 00 16 00 00 75 DE EB AD 01 00 03 01 13 12 03 03 03 57 17 1B 9F 1B 9F 00 00 02 00
00 15 ED D5 F4 A8 E6 9B 11 3E 27 00 89 02 34 FF 97 00 16 17 00 F0 E2 4E 0D 00 00 00 00
17 2F 00 00 00 01 00 00 00 34 00 08 00 01 C5 BC 2D 01 00 41 00 01 00 00 0D 08 21 28 00
01
```

data_obs/2023/9/24/6/8219848/data_8219848_2023-09-24T06-42-45

```
84 86 A8 40 40 40 60 86 92 A4 84 8A 40 E1 03 F0 08 50 E7 5E 00 D2 2C A2 97 08 04 00 05
00 00 D8 00 00 00 00 00 00 00 16 0F 27 E8 27 2E 77 80 00 00 00 00 00 00 00 00 00
00 00 00 97 00 A6 2D 00 00 00 01 41 C6 51 48 84 66 66 81 01 0F 10 4E 00 CA FB EB 20 C6
08 A6 F3 AA 2E 4A 87 0F E5 AA 0A 64 B6 61 6F 21 C1 41 C1 40 D7 3A F3 FF EE 79 EB F6 01
00 4A 49 63 DE 31 3D D2 E7 F4 EB 14 13 4E 63 8C 95 1F 00 95 6D 68 21 FE AC FB 3C 05 7C
03 00 00 16 00 00 B4 E6 EB AD 01 00 03 01 13 11 03 03 03 57 17 1B 9F 1B 9F 00 00 02 00
00 15 EF 18 F2 69 E7 D7 11 3E 27 00 8F 02 27 FF 84 00 16 17 00 F0 E2 67 0D 00 00 00 0E
17 2F 00 00 00 01 00 00 00 34 00 08 00 01 C5 BC 2D 01 00 41 00 01 00 00 0E 11 21 28 00
01
```

Satellite Communications

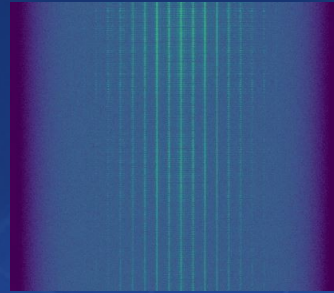
- Why do waterfalls look different?
- Answer: each is a different communications (RF) mode
- Why do satellites use difference (and sometimes multiple) modes to transmit data?



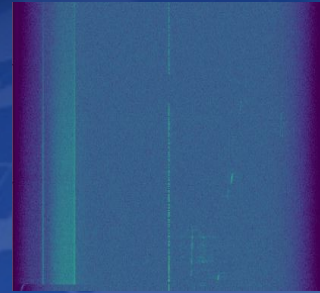
GFS 9K6



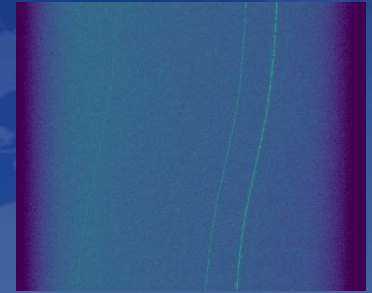
APRS



APT – Weather
Satellite



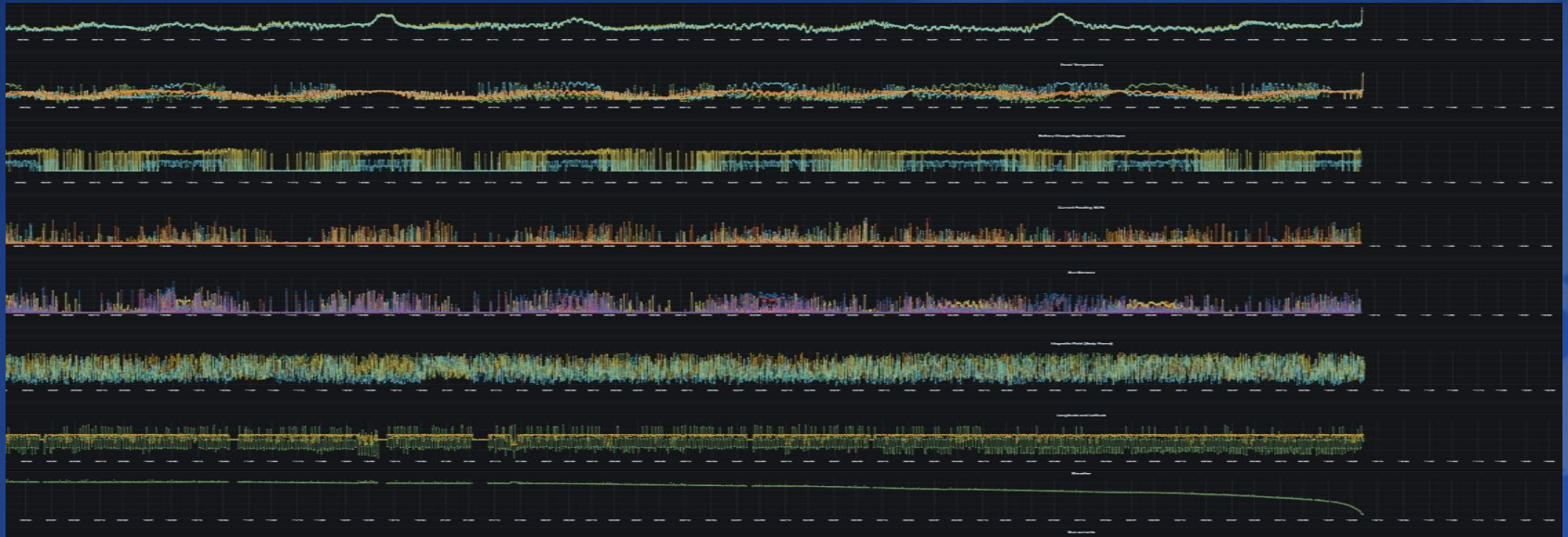
Morse Code
w Other Sats



Local
Interference
w Doppler Shift

Dashboards and Housekeeping Data

- Dashboards provide time-series data at a glance
- Shows patterns over time making it easier to detect anomalies
- What happened here? *Hint: bottom graph is altitude.*



Satellite Operations

- Schedule global observations for minimum coverage for at least 2 weeks
- Compare received signal strength of observations
- Solar cell performance: voltage & current on each panel
- Power management and battery performance
- Thermal management: multiple sensors within the satellite
- Observe voltage, current and temperature changes over time
- May be able to determine orientation and spin rate
- Use orbit predicative software to plot altitude
- These are some of the parameters you would monitor if this was your satellite.

- Use Gpredict, Orbitron, SatPC32 to show satellite orbits
- Smartphone software great for real-time, field use



Tracking Newly Launched CubeSats

- Deployments are announced on discussion boards
- Bragging rights to the first station or user to receive a signal
- Providing a valuable service to the CubeSat's owner
- Provides a level of anticipation and involvement for your students
- Fun but frustrating: expect many observations with no signals.

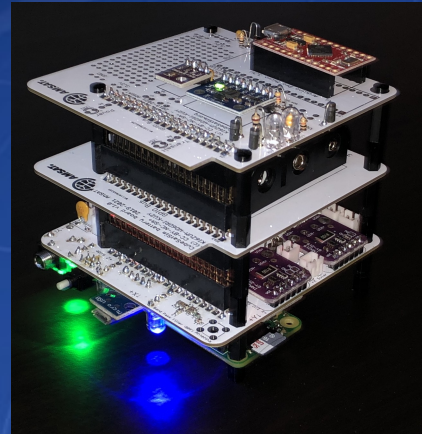
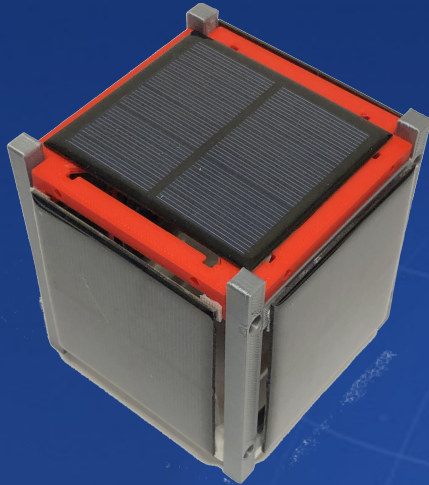
SpaceX F9 Transporter-8 - 2023-06-12 21:35 UTC

■ Satellites & Observations ■ Launches

Temporary NORAD ID	Satellite	Frequency	Notes	Deployed
COMMERCIAL UHF				
99258 ¹¹	GHOST-3	400.5 MHz		Directly
99098 ¹²	Otter Pup	400.5 MHz		Orbiter SN3
99081	Tomorrow R2	400.5 MHz	Former unknown satellite with the name "Transporter 8 Satellite B"	Directly
99082	Transporter 8 Satellite C	400.503 MHz	Merged with GHOST-3	Directly
99079	AI-DELTA	401.05 MHz	Former unknown satellite with the name "Transporter 8 Satellite E"	Unknown
99078 ²	Transporter 8 Satellite F	401.05 MHz	Unknown Satellite, possible match is AYRIS-2 according to the pre-launch TLE from Celestrak	Unknown
99192 ¹	Istanbul	401.075 MHz		ION SCV-011 - Alba Orbital Cluster 7

AMSAT CubeSatSim

- A low-cost (\$350 - \$500) satellite emulator using a 3-board stack that contains a Raspberry Pi with camera, an Arduino compatible microcontroller, solar panels and rechargeable batteries, voltage/current sensors, and environment sensors, transmitting UHF radio telemetry using the most commonly used transmission modes and protocols.



CubeSatSim Features

- Two processors: flight & payload
- Six solar panels, each with voltage & current monitoring
- Expandable payload via I2C sensors
- Raspberry Pi camera
- UHF radio using 5 telemetry modes
- Open Source hardware and software
- Open Source Raspberry Pi / RTL-SDR ground station
- **FREE loaners available for educators and demonstrators**



Q & A

Contact Fredric at fraab@collegeofthedesert.edu
or FredricRaab@yahoo.com

www.FredricRaab.com

SatNOGS.org

CubeSatSim.org

www.amsat.org

CubeSatSim Project

