Adopt a Satellite: Using SatNOGS in the Classroom

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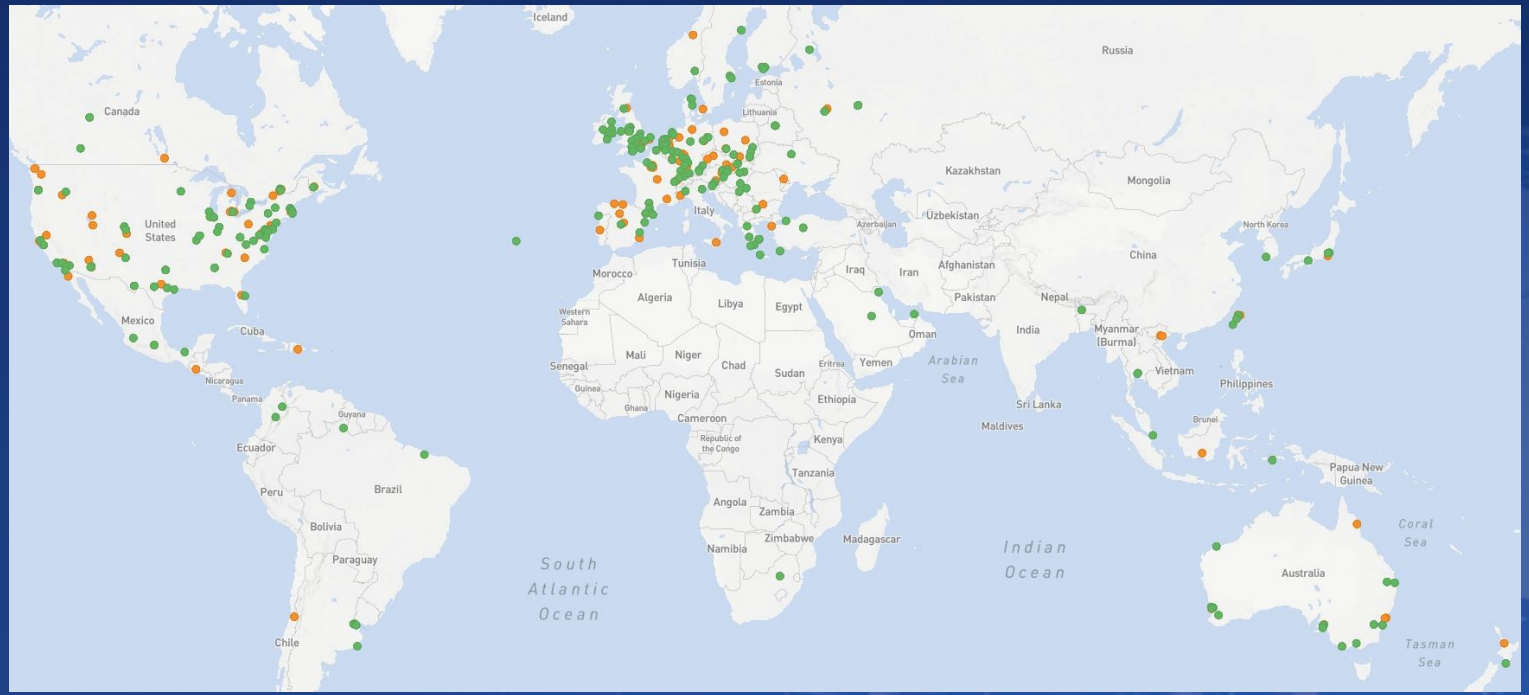
SatNOGS.org

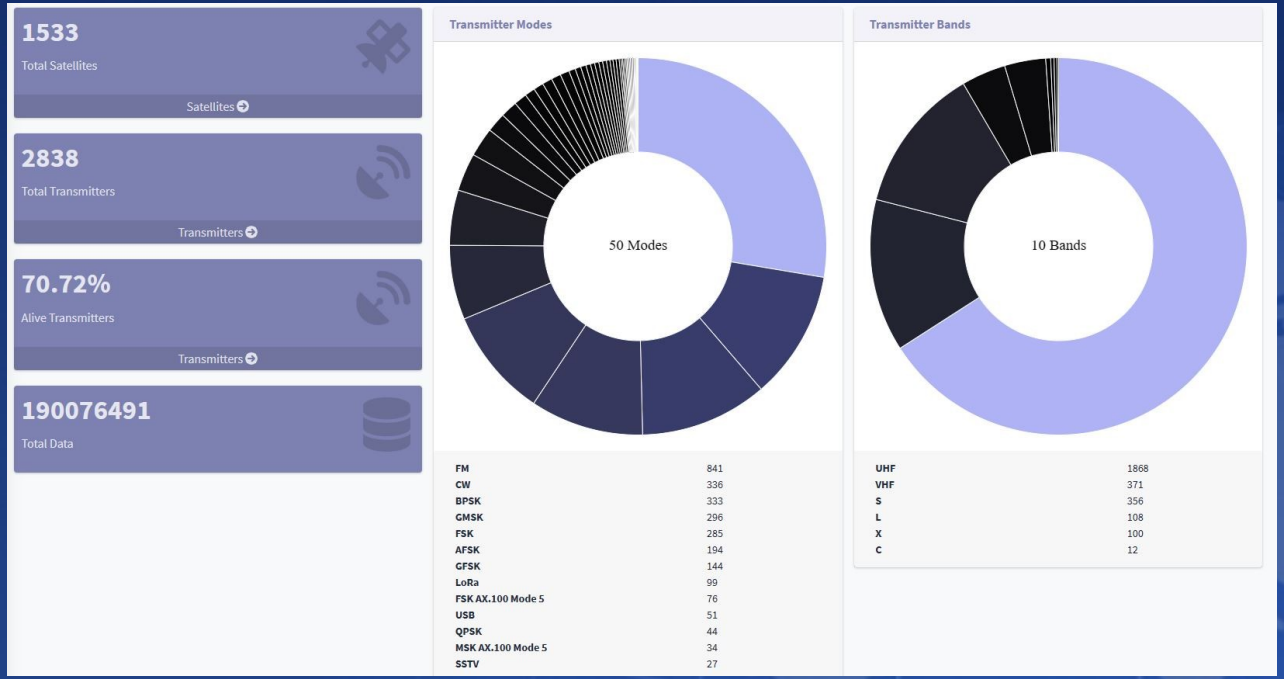
What is SatNOGS?

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



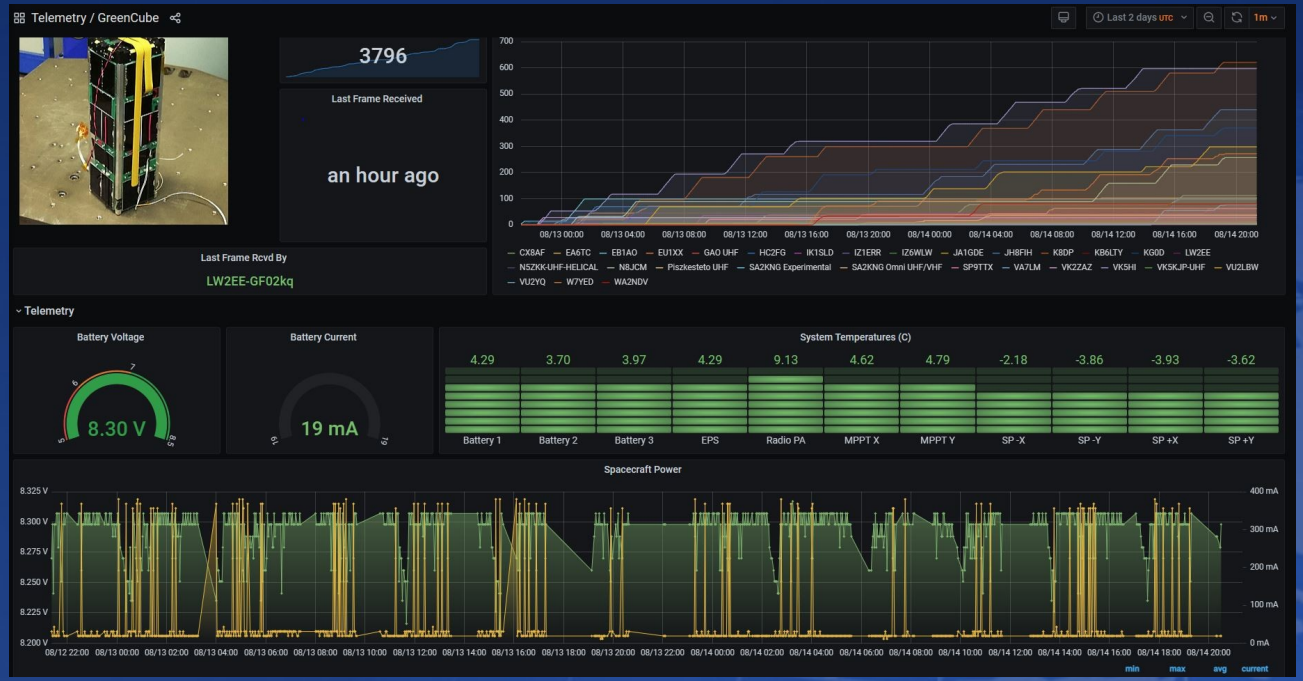
What is SatNOGS?

- 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.

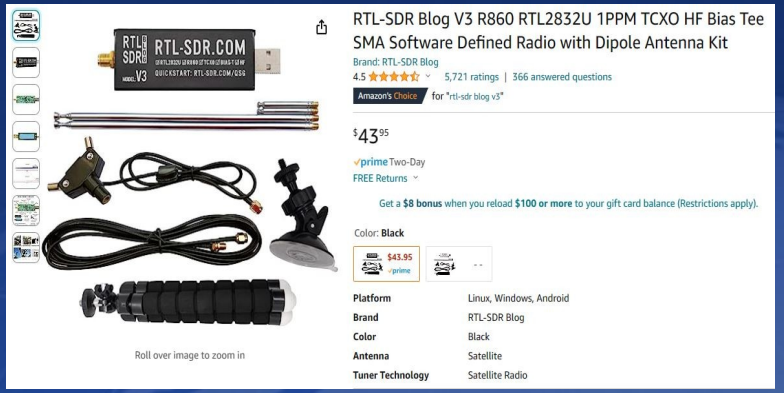
How to Begin

- 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 schedules 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

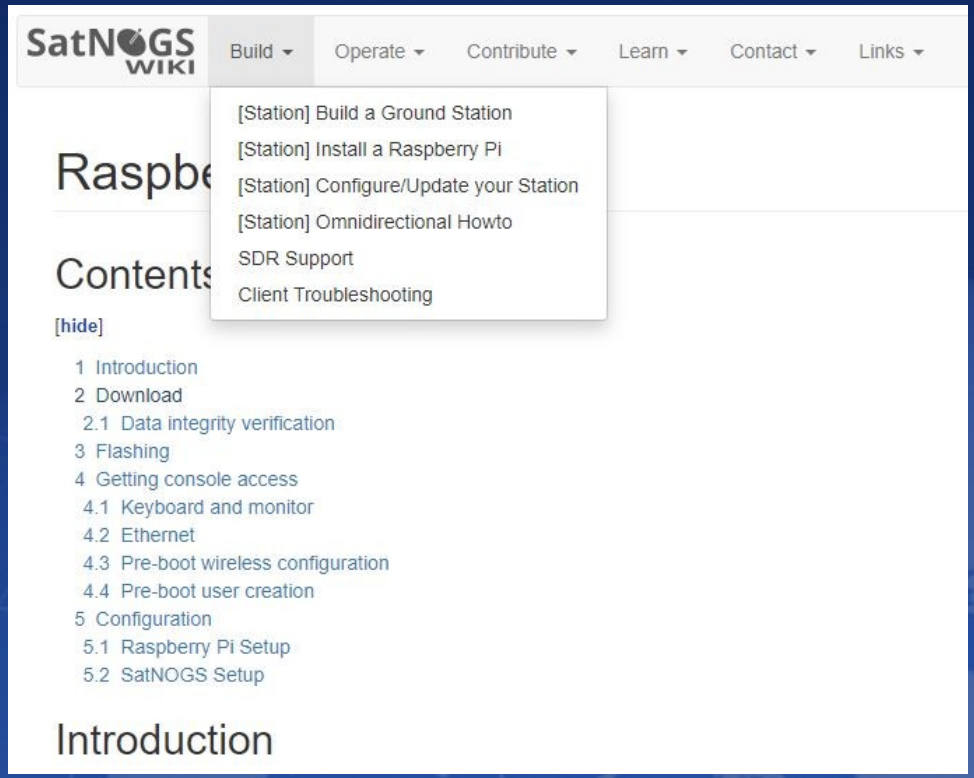
- Raspberry Pi 3B+ (or better) kit with micro-SD card

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

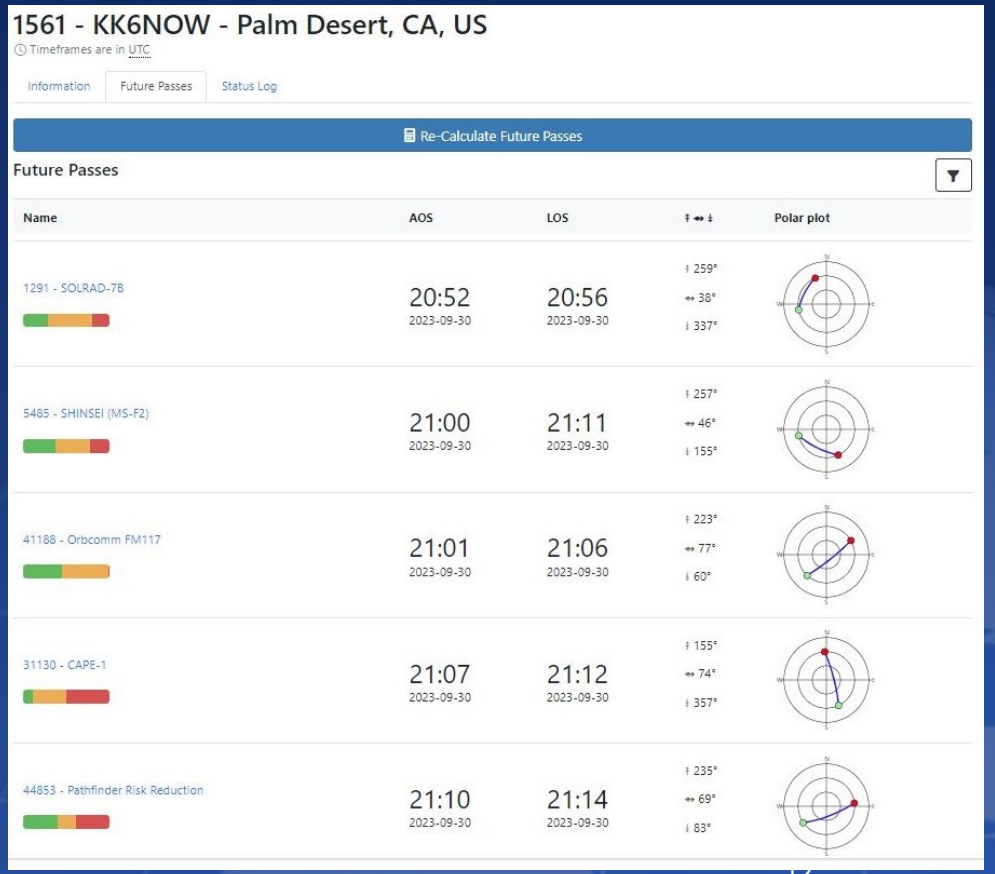
- Have a SatNOGS dashboard
- Are currently active
- Are successfully received by numerous stations
- You can easily find information about the satellite on the Internet
- Have more than 1 year of on-orbit data available
- Examples:
  - ISS (International Space Station)
  - CIRBE – lasp.colorado.edu/cirbe
  - 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

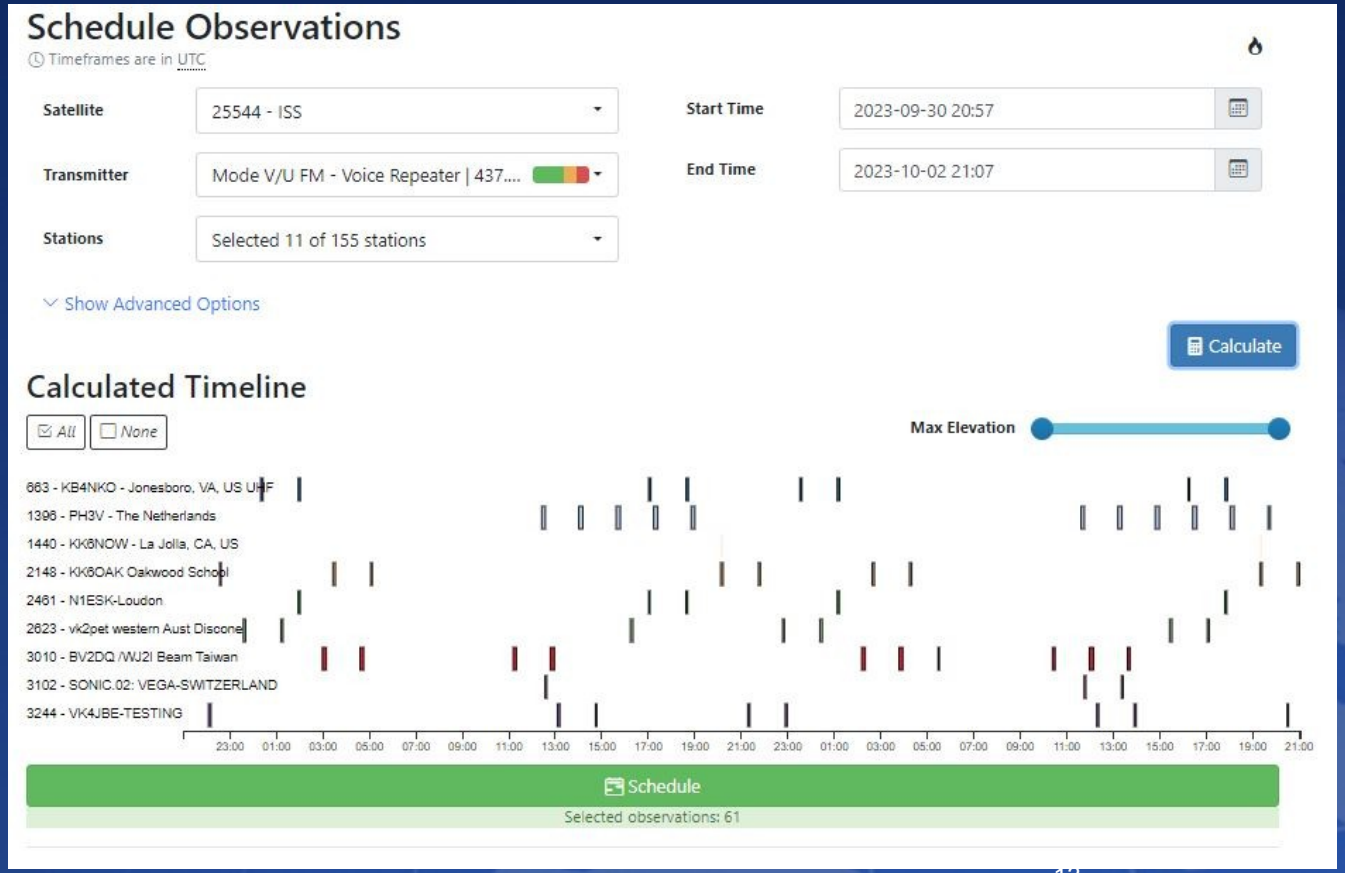
Observation Scheduling

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



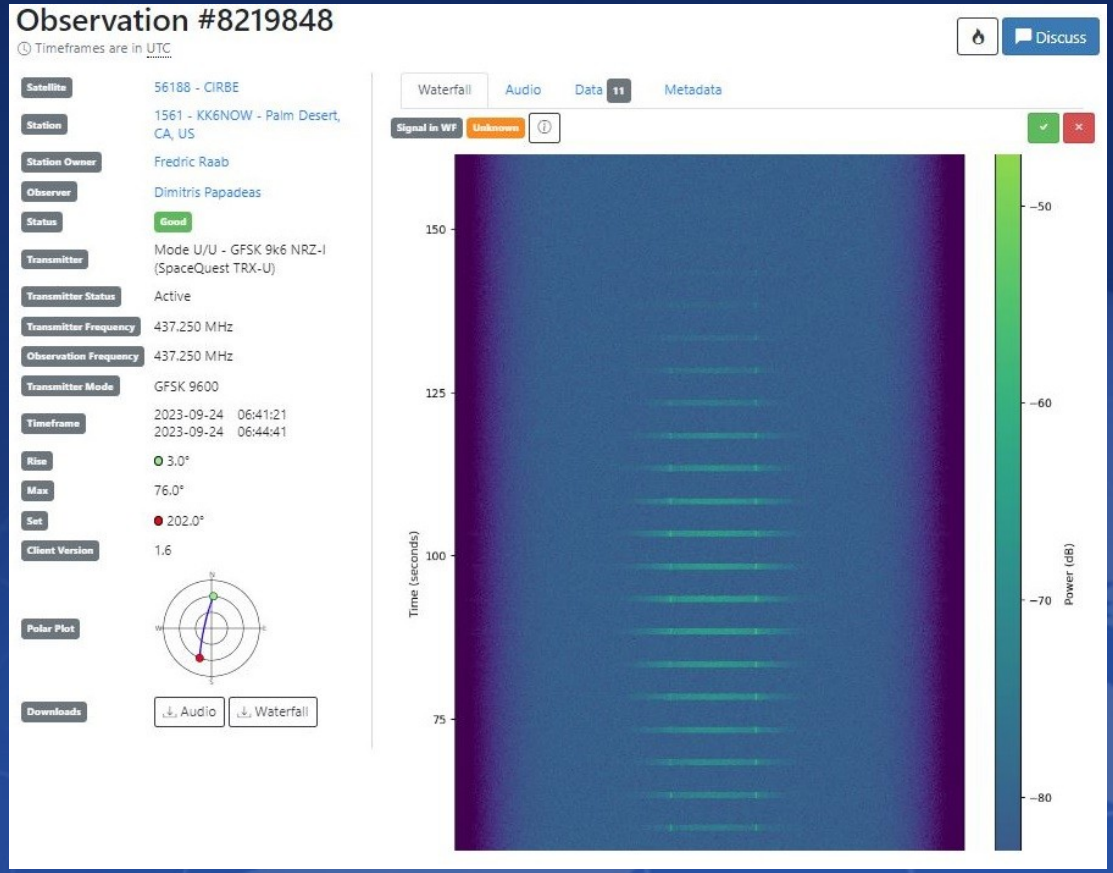
Observation Scheduling

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



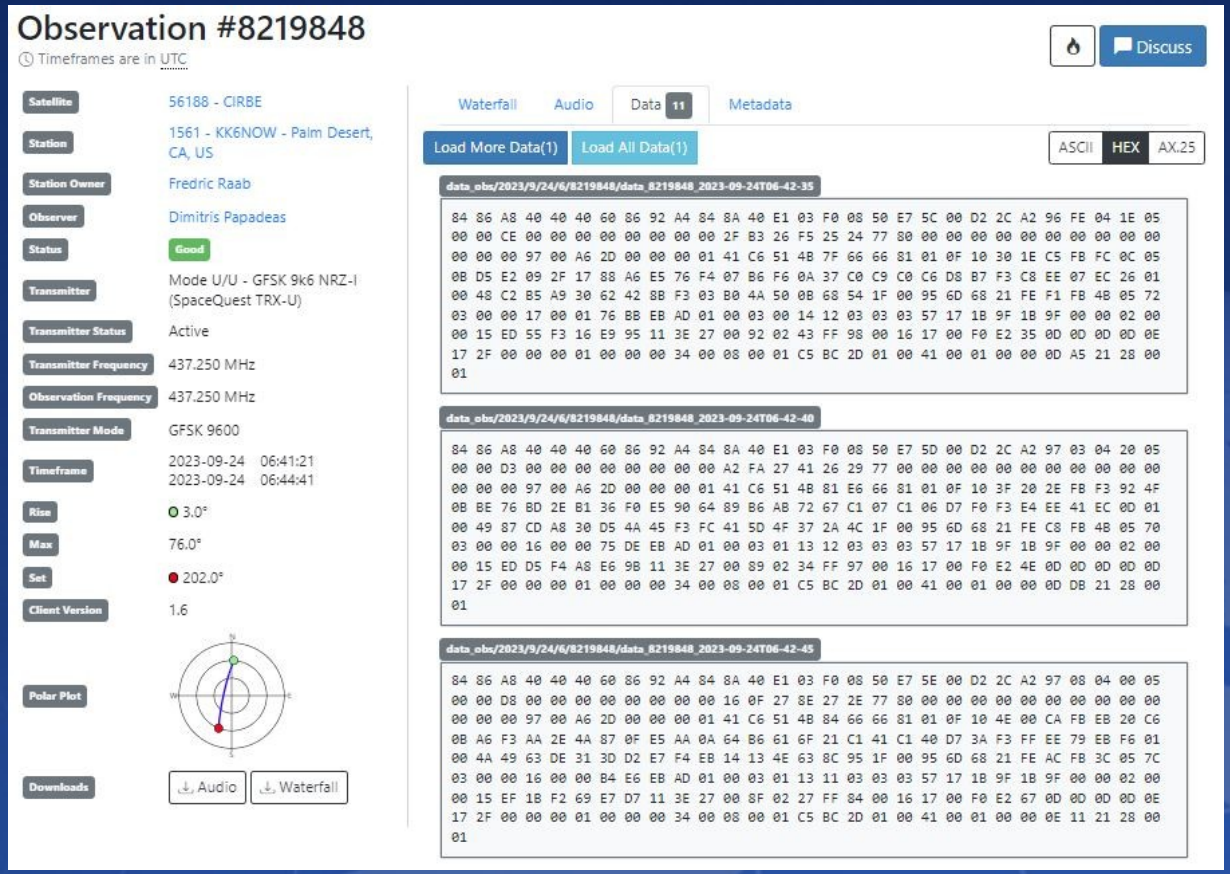
Observation interpretation

- 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



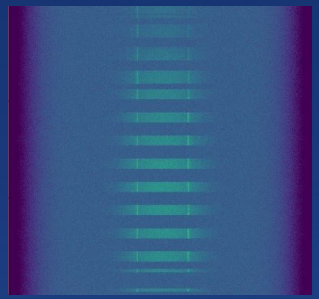
Decoding Communications Protocols

- 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?



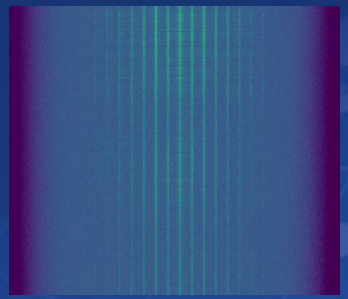
Satellite Communications

- 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?

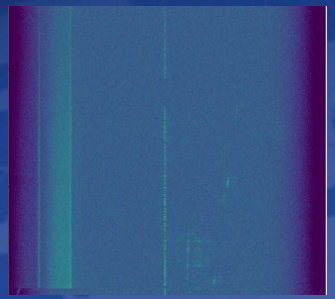


GFS 9K6

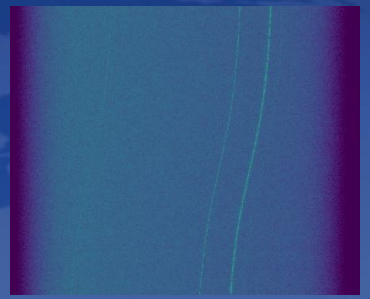
APRS



APT – Weather Satellite



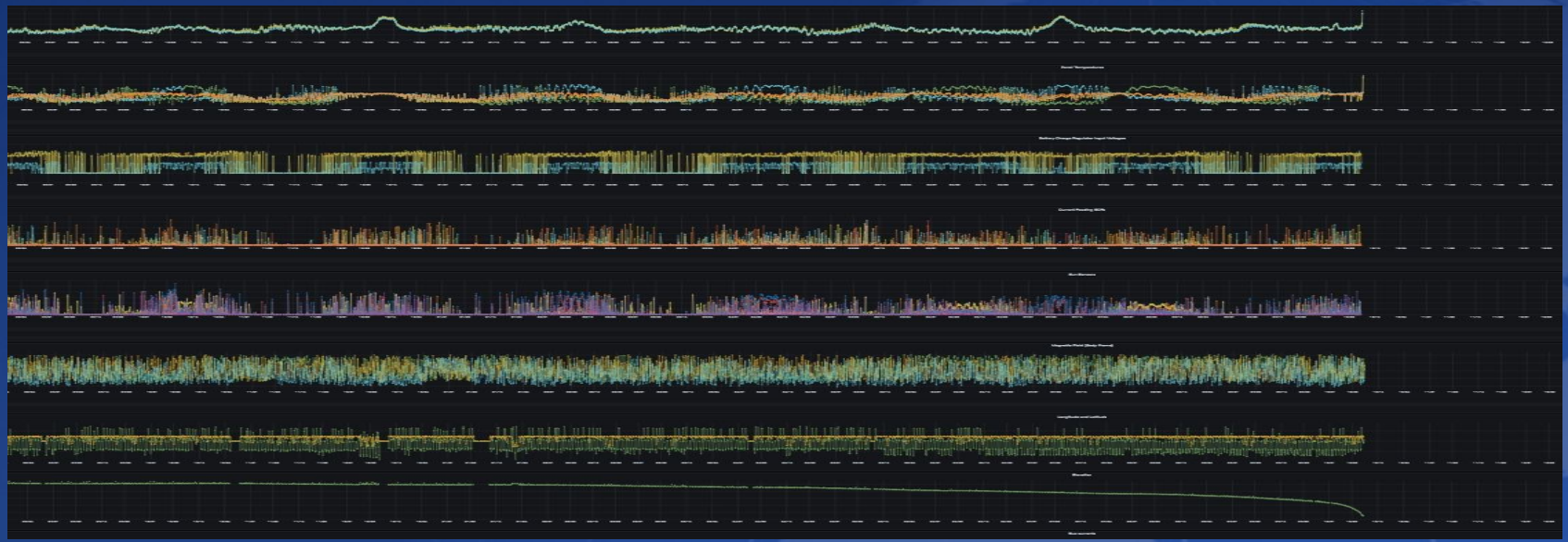
Morse Code w Other Sats



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.*

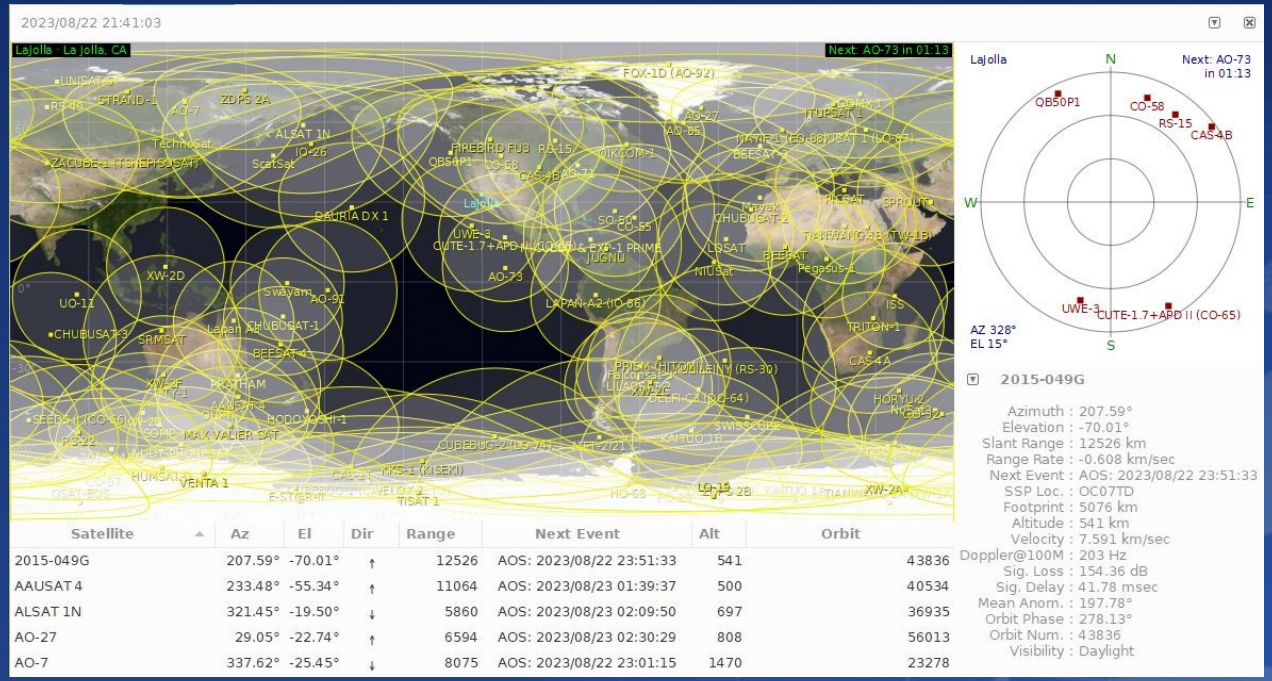


Satellite Operations

- 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.

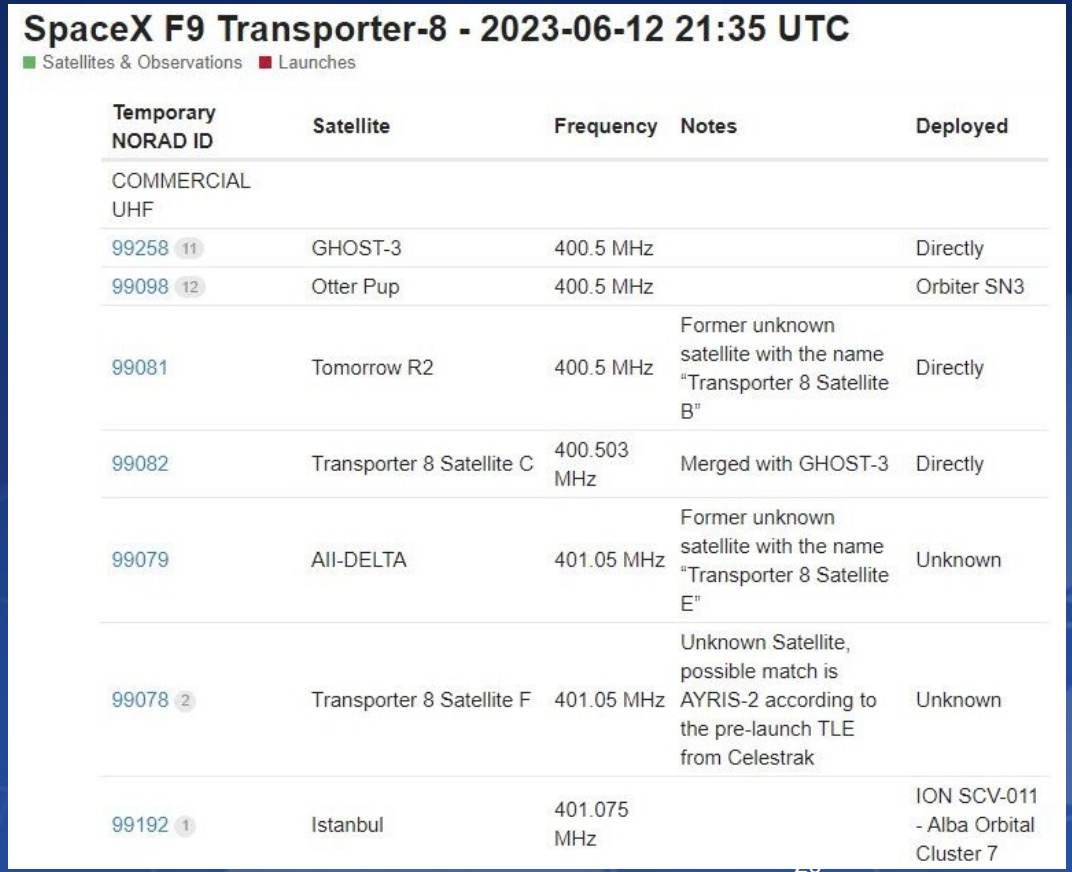
Satellite Predication & Orbital Mechanics

- 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.



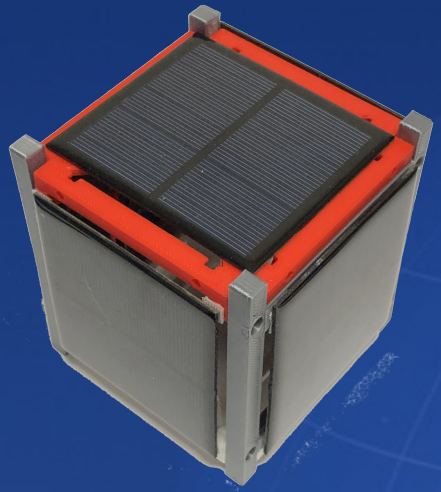
SpaceX F9 Transporter-8 - 2023-06-12 21:35 UTC

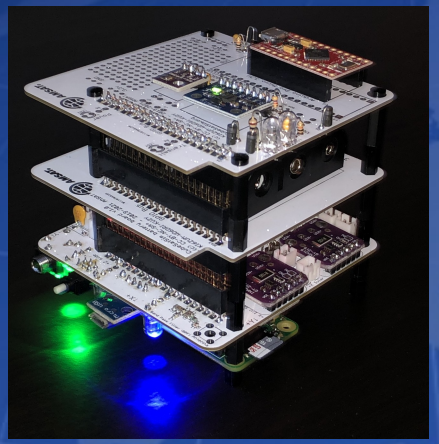
Satellites & Observations ■ Launches

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	AII-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

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www.FredricRaab.com

SatNOGS.org

CubeSatSim.org

www.amsat.org