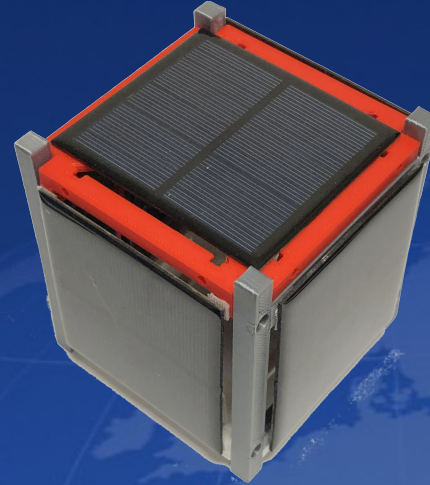


# Classroom Activities with the AMSAT CubeSat Simulator



**Fredric Raab, KK6NOW**  
**Adjunct Faculty**  
**College of the Desert, Palm Desert, CA**  
**[fraab@collegeofthedesert.edu](mailto:fraab@collegeofthedesert.edu)**

***[CubeSatSim.org](http://CubeSatSim.org)***

# Topics

- Who is AMSAT?
- Use of Amateur Radio by Educational CubeSats
- CubeSat Simulator
- Classroom Activities
- Q & A
- Acknowledgements



# Who is AMSAT?

- The Radio Amateur Satellite Corporation, or AMSAT, is a worldwide, volunteer, not for profit educational and scientific organization that has been designing, building and launching small satellites for more than a half century.
- These satellites have typically been used by amateur radio operators for voice communications.
- Some included digital packet communications and slow scan television



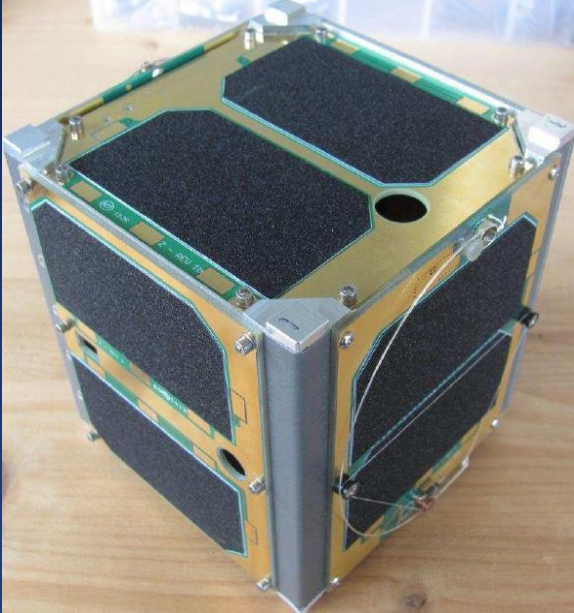
# OSCAR

## Orbiting Satellite Carrying Amateur Radio



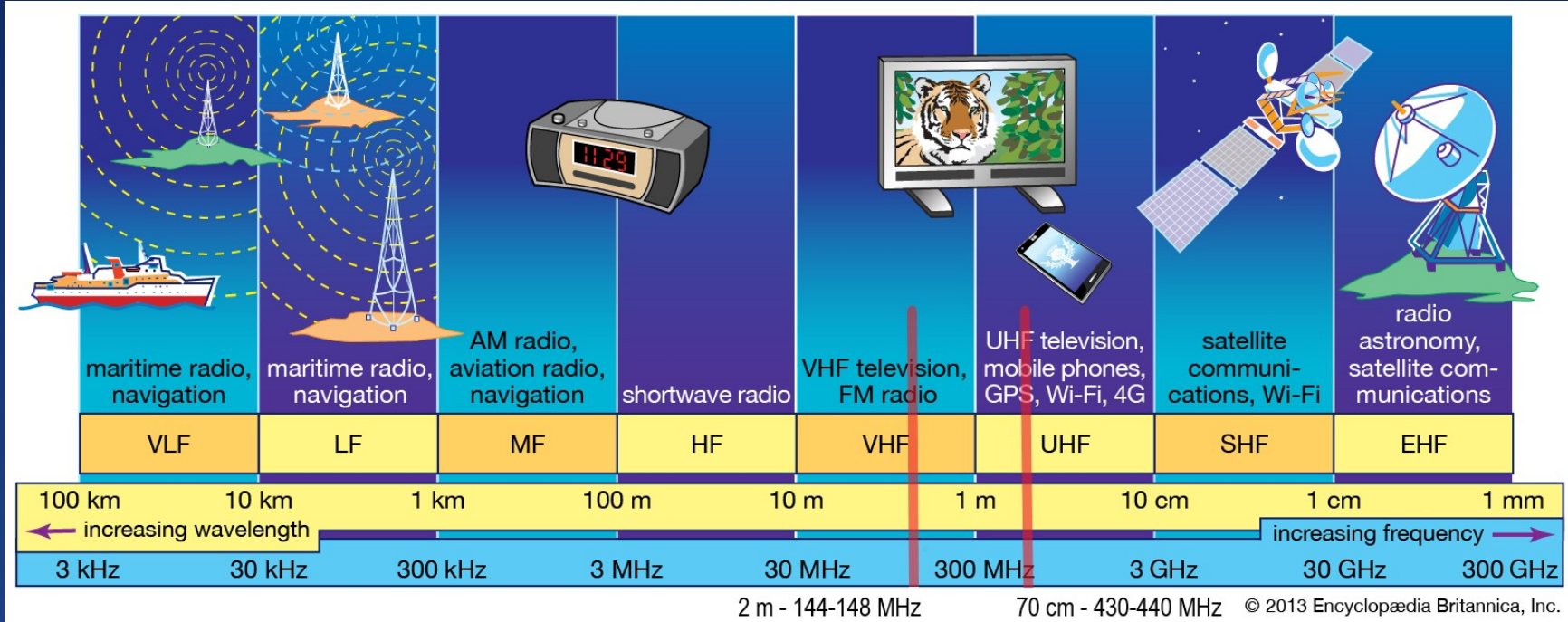
Lance Ginner, K6GSJ with OSCAR 1 launched 1961

# FOX Series – Five 1U CubeSats



First launched Oct 2015 & Nov 2017  
All carried experimental university payloads.

# Use of Amateur Radio by Educational CubeSats



# Use of Amateur Radio by Educational CubeSats

Please note that for performance reasons, some statistics may not be real time.

866

Total Satellites

Satellites

1574

Total Transmitters

Transmitters

86.85%

Alive Transmitters

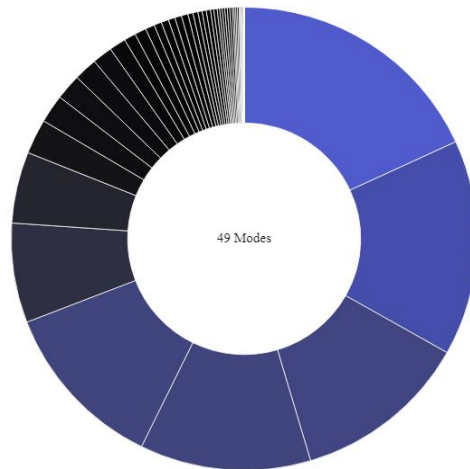
Transmitters

145839978

Total Data

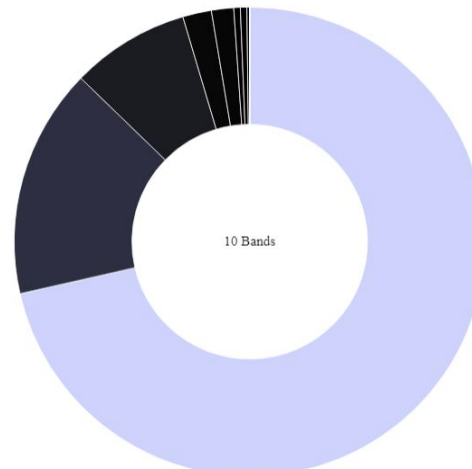
db.satnogs.org/stats  
20 June 2022

Transmitter Modes



|                   |     |
|-------------------|-----|
| FM                | 319 |
| CW                | 280 |
| BFPSK             | 211 |
| GMSK              | 205 |
| FSK               | 205 |
| AFSK              | 120 |
| GFSK              | 86  |
| USB               | 42  |
| LoRa              | 34  |
| FSK AX.100 Mode 5 | 31  |
| MSK AX.100 Mode 5 | 28  |
| LSB               | 24  |
| QPSK              | 20  |
| FSK AX.25 G3RUH   | 14  |
| FMN               | 14  |
| SSTV              | 11  |

Transmitter Bands

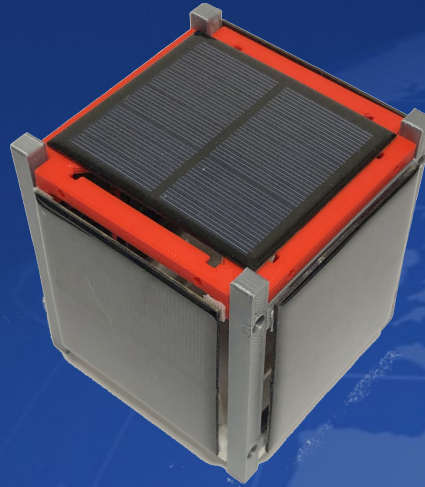


|     |      |
|-----|------|
| UHF | 1123 |
| VHF | 249  |
| S   | 128  |
| X   | 31   |
| L   | 24   |



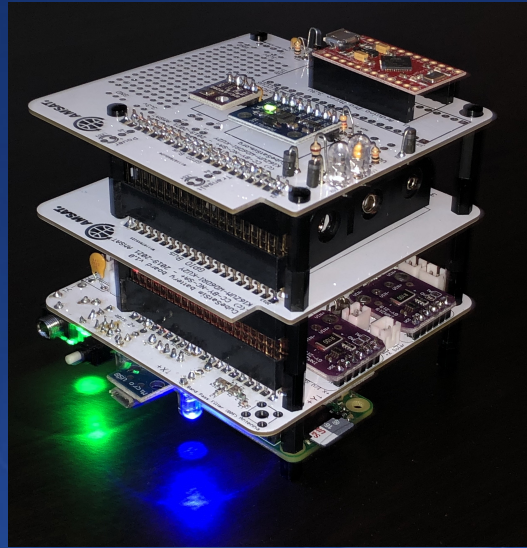
# What is a CubeSatSim?

- A low-cost (\$350) satellite emulator that runs on solar panels in sunlight, batteries in eclipse, and transmits UHF radio telemetry using the most commonly used transmission modes and protocols.



# What is a CubeSatSim?

- Uses a 3-board stack that contains a Raspberry Pi single board computer, an Arduino compatible microcontroller, rechargeable batteries, voltage/current sensors, and environment sensors.



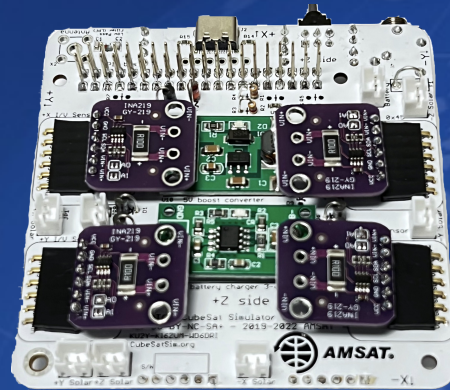
# CubeSatSim Features

- 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
- Loaners available for educations and demonstrators



# Technical Details

- Main Board
  - Plugs into Raspberry Pi Zero
  - 8 Voltage/Current Sensors
  - 1 Charge Controller for Batteries
  - 1 Boost Converter/Regulator



**CubeSatSim Project**

# Technical Details

## ■ Battery Board

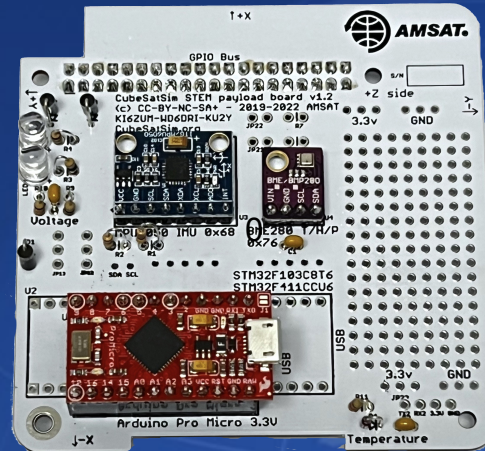
- 3 AA/AAA Nickel Metal Hydride (NiMH) Batteries for safety
- Can operate in demo mode for 3 hours
- Charged with USB-C cable



# Technical Details

## ■ STEM Payload Board

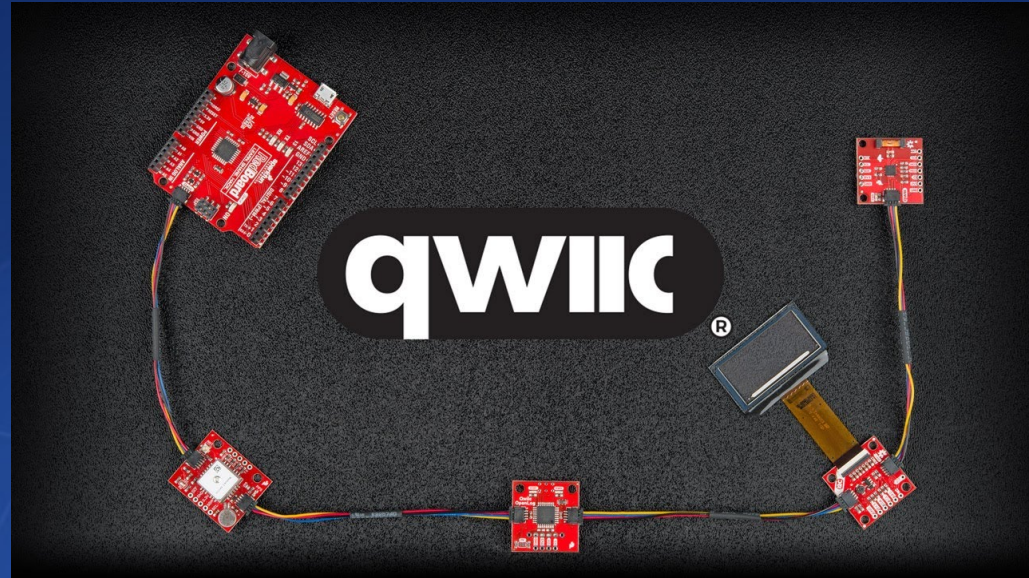
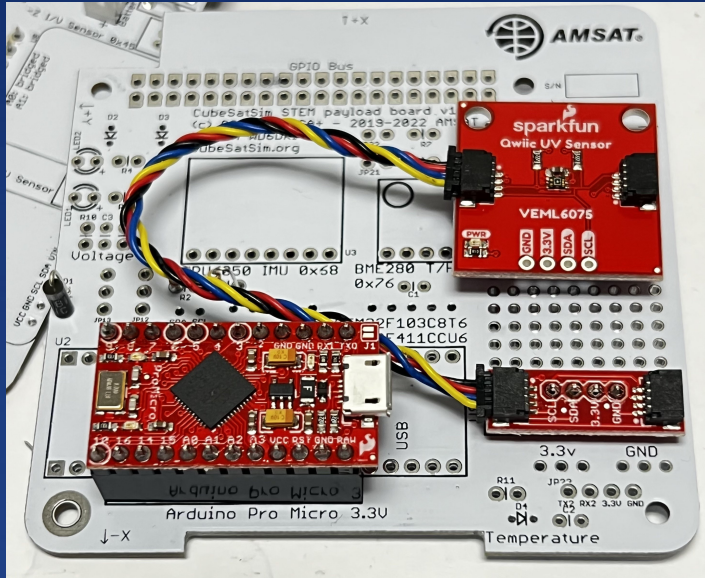
- 1 Arduino compatible microcontroller
- 1 Temperature/Pressure/Humidity Sensor (BME-280)
- 1 3-Axis Accelerometer/Gyroscope (MPU-6050)



**CubeSatSim Project**

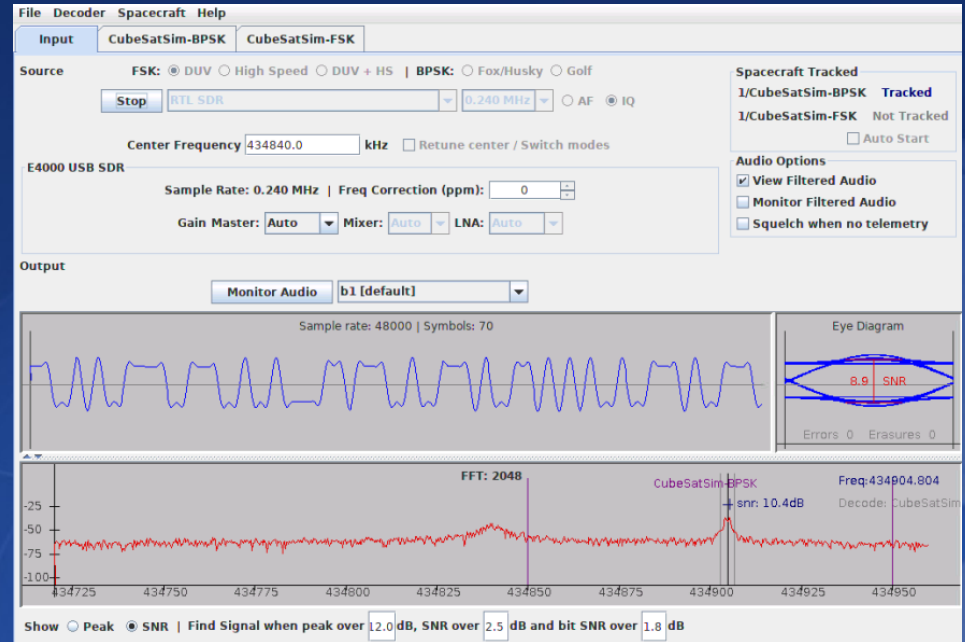
# Technical Details

- STEM Payload Board
  - Extendable via QWIIC boards from Sparkfun & Adafruit



# Ground Station Software

- FoxTelem for Windows, Mac & Linux receives, decodes, visualizes and records telemetry data from Fox CubeSats via a \$35 RTL-SDR



# Ground Station Software

## ■ Ground Station

- Pre-built Software Stack (Fox-in-a-Box)
- Or, install on your own PC

## ■ Software:

- FoxTelem
- Direwolf
- QSSTV
- OpenWebRX
- CubicSDR
- RTL-TCP
- Gpredict
- KLATracker

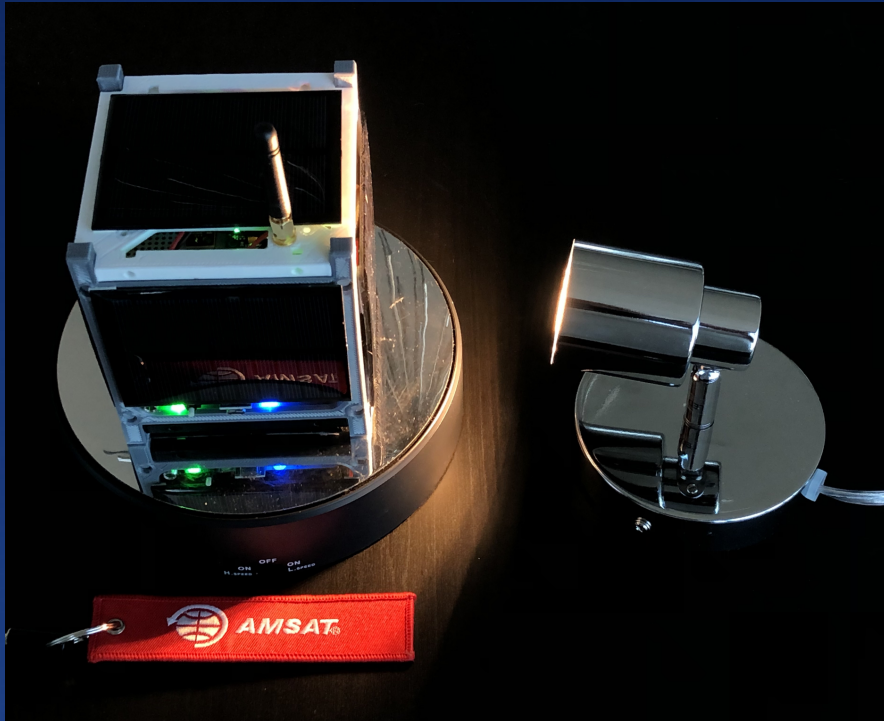


# Loaner Kits Available

- Includes CubeSat Simulator, ground station, turntable, LED lamp



# Classroom Activities

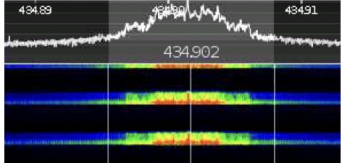
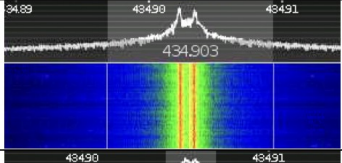
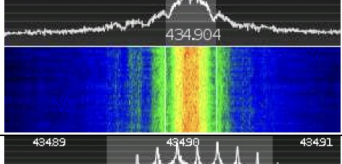
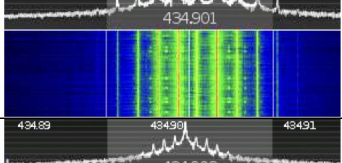


# Classroom Activities

- CubeSat Radio Communications
- Solar Cells & Power Management
- CubeSat Orientation & Spin Rates
- STEM Payload Sensors
- Software Enhancements



# CubeSat Radio Communications

| Blinks | Mode | Description                                                                                                                                                                                      | Decoding                                                                                                                                                                                                                            | Command                | Audio                                                  | Waterfall (Cubic SDR)                                                                |
|--------|------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------|--------------------------------------------------------|--------------------------------------------------------------------------------------|
| 1      | APRS | Automatic Packet Reporting System. This digital mode sends a packet of data with AFSK or Audio Frequency Shift Keying modulation.                                                                | Windows: <a href="#">SoundModem</a> or <a href="#">Direwolf</a><br>Raspberry Pi/Linux: <a href="#">OpenWebRX</a> or <a href="#">Direwolf</a> with spreadsheet <a href="http://cubesatsim.org/telem">http://cubesatsim.org/telem</a> | <code>config -a</code> | <a href="http://CubeSatSim.org/a">CubeSatSim.org/a</a> |   |
| 2      | FSK  | Frequency Shift Keying. This mode transmits a continuous signal that makes a rumbling sound that emulates the AMSAT Fox CubeSats such as Fox-1C or AO-95. Also known as DUV or Data Under Voice. | Windows/Raspberry Pi/Linux: <a href="#">FoxTelem</a>                                                                                                                                                                                | <code>config -f</code> | <a href="http://CubeSatSim.org/f">CubeSatSim.org/f</a> |   |
| 3      | BPSK | Binary Phase Shift Keying. This mode transmits a continuous signal that sounds like noise that emulates the AMSAT Fox-1E or HuskSat-1 CubeSats. You need to demodulate using USB.                | Windows/Raspberry Pi/Linux: <a href="#">FoxTelem</a>                                                                                                                                                                                | <code>config -b</code> | <a href="http://CubeSatSim.org/b">CubeSatSim.org/b</a> |   |
| 4      | SSTV | Slow Scan TeleVision. This mode transmits stored images in Scottie 2 format which sounds like a series of tones.                                                                                 | Windows: <a href="#">MMSSTV</a><br>Raspberry Pi/Linux: <a href="#">QSSSTV</a>                                                                                                                                                       | <code>config -s</code> | <a href="http://CubeSatSim.org/s">CubeSatSim.org/s</a> |   |
| 5      | CW   | Continuous Wave or Morse Code. This mode transmits a FM modulated tone at 20 words per minute Morse Code telemetry.                                                                              | Windows/Raspberry Pi/Linux: <a href="#">fdigi</a> with spreadsheet <a href="http://cubesatsim.org/telem">http://cubesatsim.org/telem</a>                                                                                            | <code>config -m</code> | <a href="http://CubeSatSim.org/m">CubeSatSim.org/m</a> |  |

# Solar Cells & Power Management

- Measure and record differences in solar panel output
- Measure battery voltages and currents
- Measure power consumption and generation under different levels of sunlight
- Determine when processor will shutdown
- Determine how long CubeSat will operate in eclipse
- Observe voltage and current changes as CubeSat enters and leaves eclipse
- Determining solar panel failures or performance issues



# CubeSat Orientation & Spin Rates

- Determine orientation using accelormeter
- Determine orientation using solar cells
- Determine spin rate using gryoscope
- Determine spin rate using solar cells
- Determine camera direction
- Simulate mission scenarios

# STEM Payload Sensors

- Additional sensor support via QWIIC
  - IR / UV sensors
  - Environmental
- On-board sensor processing
- GPS support



# Software Enhancements

## ■ Flight Software

- Power sensor calibration
- Active power management (transmitter control)
- Automatic communications mode switching
- Improved camera scheduling
- On-board storage of sensor data
- Scheduled transmission of sensor data

# Demo



# CubeSatSim Project Team

## ■ Leadership

- Alan B Johnson, PhD, KU2Y  
VP, Educational Relations,  
AMSAT

## ■ Hardware

- Jim McLaughlin, KI6ZUM
- David White, WD6DRI

## ■ Educational Materials

- Paul Graveline, K1YUB
- Fredric Raab, KK6NOW
- Mark Samis, KD2XS
- David White, WD6DRI

## ■ Beta Builders

- Kerry Bonin, KJ7HTG
- Jim Nagle, KF4OD
- Virginia Smith, NV5F
- Chris Thompson, G0KLA/AC2CZ
- Randy Standke, KQ6RS,
- Christine Mehner, MD, PhD,  
KO4EWG
- Sopwith, N1SPW
- Kai Ji, AC3EN

## ■ Documentation

- Alan B Johnson, PhD, KU2Y
- Sopwith, N1SPW

## ■ Students

- Villanova University, Villanova, PA  
CubeSat Club and Spring 2019  
and 2022 ECE 1205 Freshman  
Projects classes
- Bishop O'Connell High School,  
Arlington, TX DJO ARC students  
and teacher Melissa Pore,  
KM4CZN

## ■ CAD

- Lindsay White, KI6LZN
- Low Pass Filter Design  
and Testing
- Randy Standke, KQ6RS



# Acknowledgements

- Thanks to Mark Spencer, WA8SME, for his trailblazing work on CubeSat simulators and to Bob Bruninga, WB4APR, for ideas and inspiration from his undergrad “LabSat” developments.
- Pat Kilroy, N8PK, was instrumental in getting the CubeSat Simulator project going again.
- We would also like to acknowledge all the open source hardware and software that is a part of the AMSAT CubeSatSim.
- Photos from CubeSatSim.org and AMSAT.org websites
- Finally, we would like to acknowledge the support of the AMSAT Board of Directors and the members of AMSAT for their support and encouragement of this project.



# Q & A

Contact Fredric at [fraab@collegeofthedesert.edu](mailto:fraab@collegeofthedesert.edu)  
or [FredricRaab@yahoo.com](mailto:FredricRaab@yahoo.com)

<https://CubeSatSim.org>

<https://www.amsat.org>

<https://github.com/alanbjohnston/CubeSatSim/wiki>

