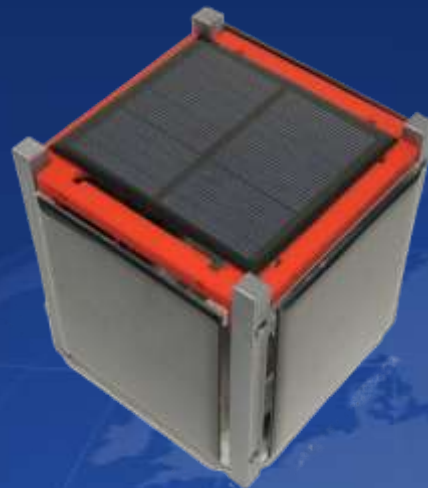


Classroom Activities with the AMSAT CubeSat Simulator



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CubeSatSim.org

Topics

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



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

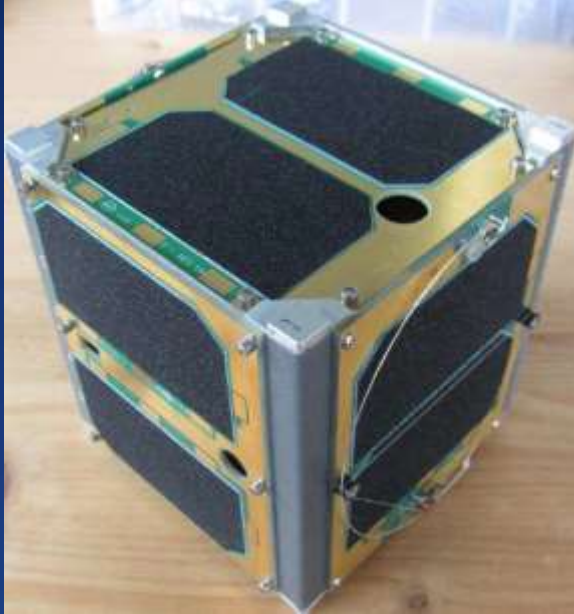


OSCAR Orbiting Satellite Carrying Amateur Radio



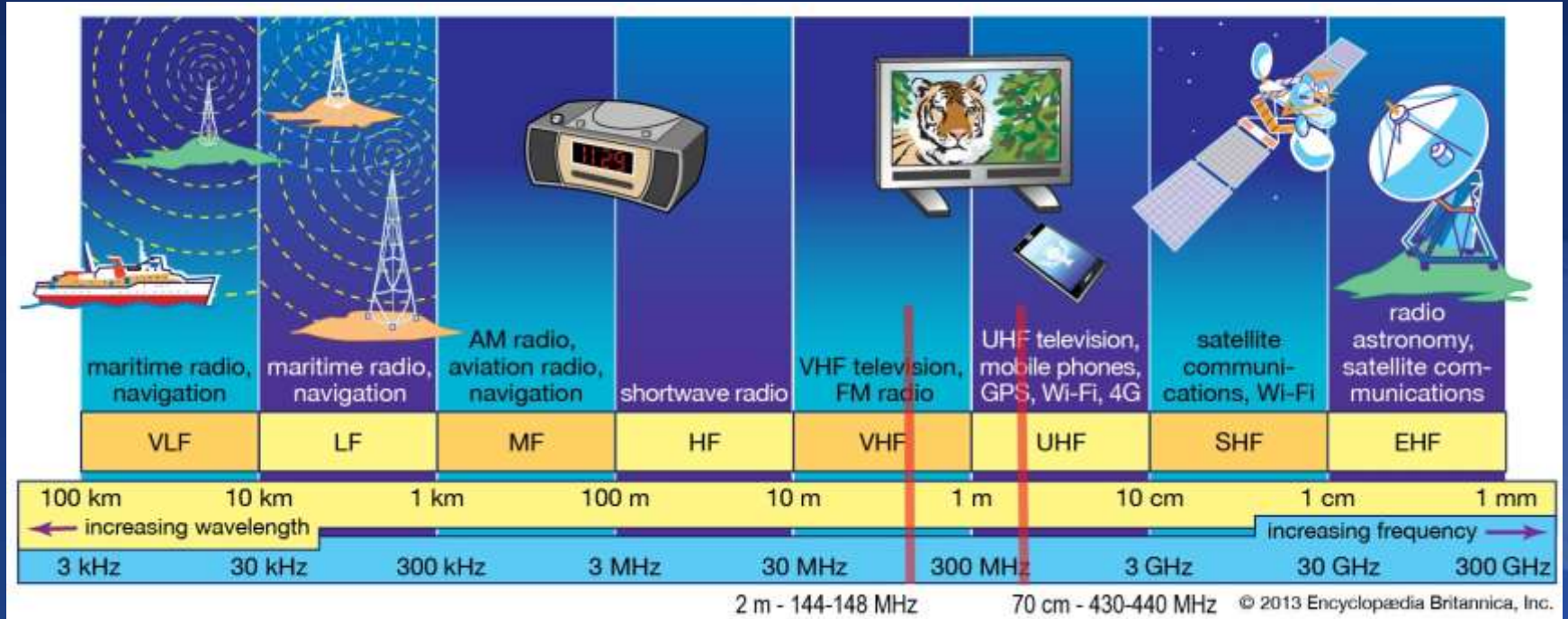
Lance Ginner, K6GSJ with OSCAR 1 launched 1961

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

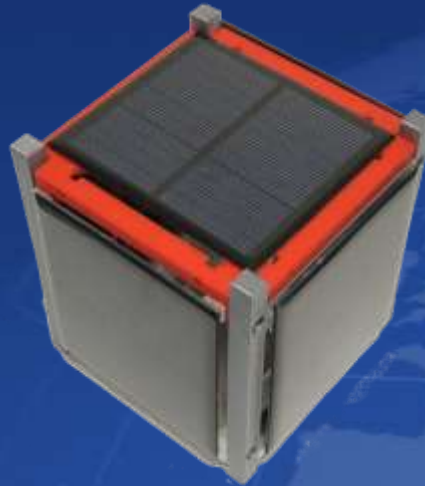


db.satnogs.org/stats
20 June 2022



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.



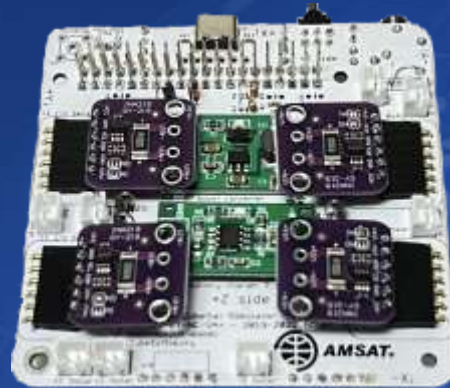
CubeSatSim Features

- 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



Technical Details

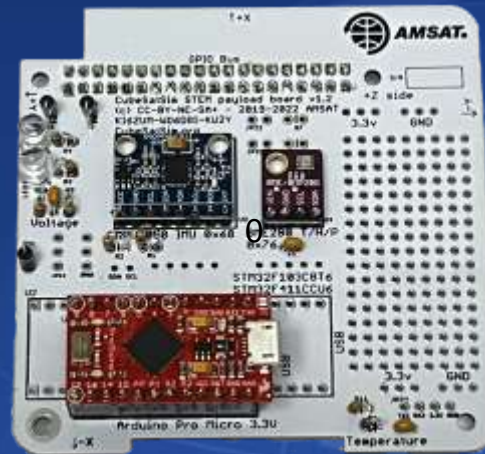
■ Battery Board

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



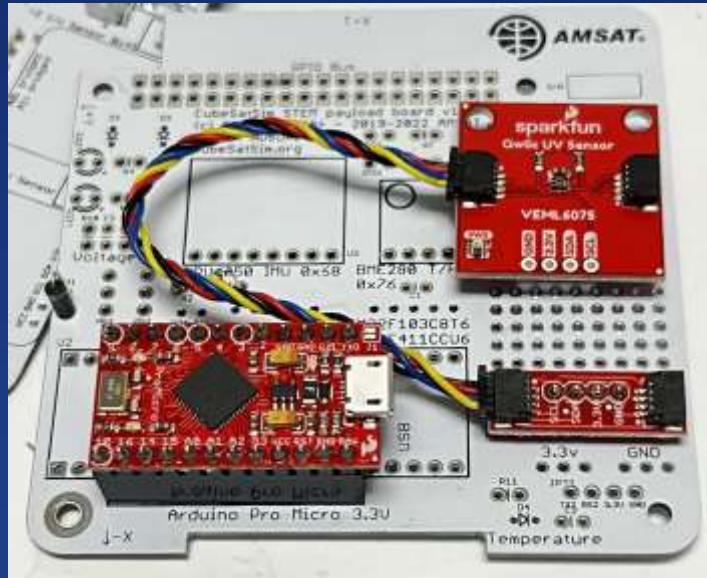
Technical Details

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



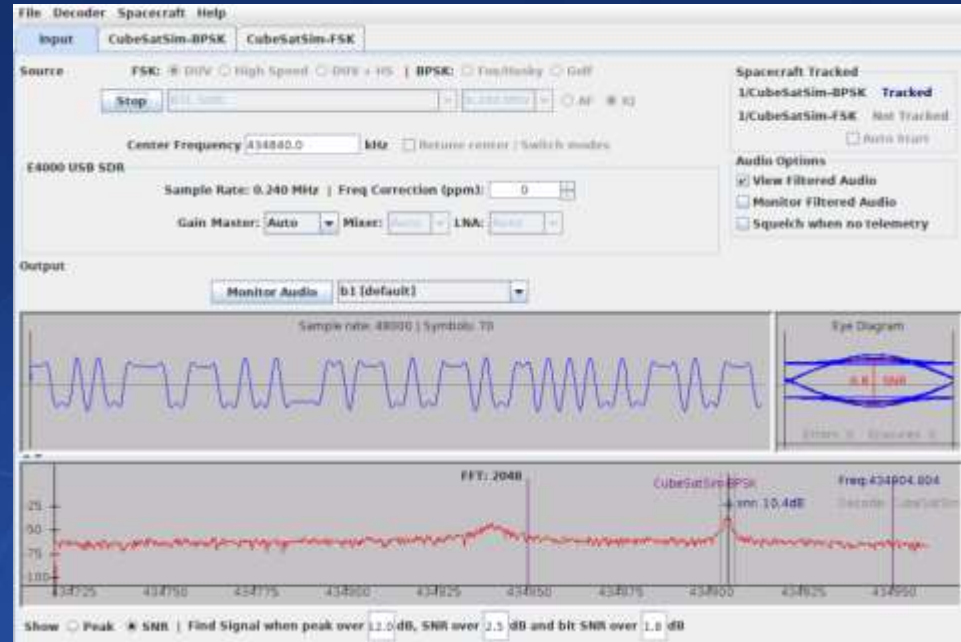
Technical Details

- 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

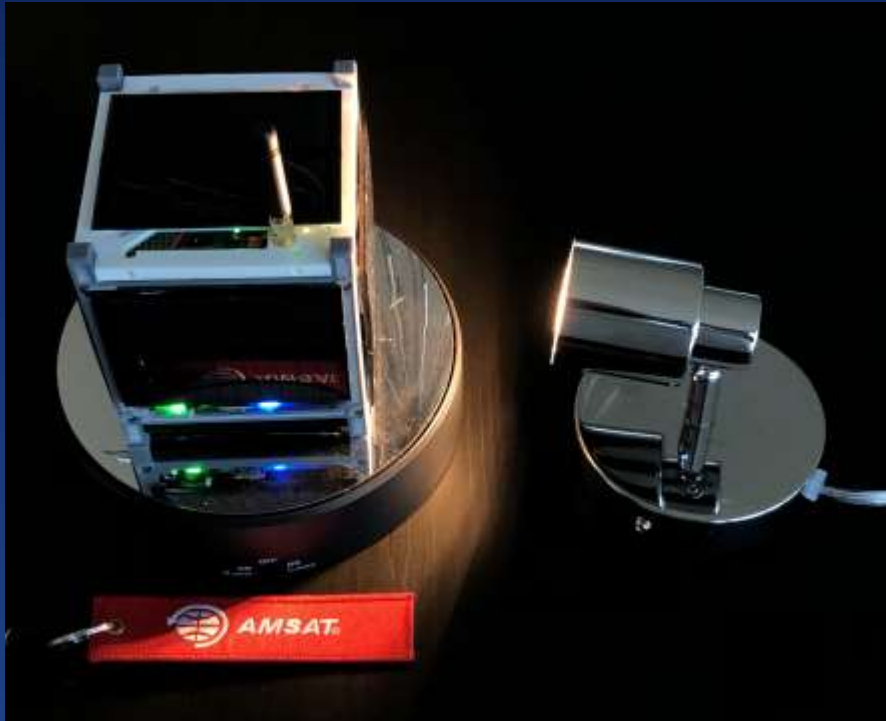


Loaner Kits Available

- 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: SoundModem or Direwolf Raspberry Pi/Linux: OpenWebRX or Direwolf with spreadsheet http://cubesatsim.org/telem	<code>config -a</code>	CubeSatSim.org/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: FoxTelem	<code>config -f</code>	CubeSatSim.org/f	
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: FoxTelem	<code>config -b</code>	CubeSatSim.org/b	
4	SSTV	Slow Scan TeleVision. This mode transmits stored images in Scottie 2 format which sounds like a series of tones.	Windows: MMSSTV Raspberry Pi/Linux: QSSTV	<code>config -s</code>	CubeSatSim.org/s	
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: fdigi with spreadsheet http://cubesatsim.org/telem	<code>config -m</code>	CubeSatSim.org/m	

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 gryroscope
- 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

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
or FredricRaab@yahoo.com

<https://CubeSatSim.org>

<https://www.amsat.org>

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



Demo



Input **AO-85** AO-91 AO-92 AO-95 **CubeSatSim-BPSK** **CubeSatSim-FSK** Fox-1E Husky

Source

FSK: DUV High Speed DUV + HS | BPSK: Fox/Husky Golf

RTL SDR 0.240 MHz AF IQ

Center Frequency kHz Retune center / Switch modes

R820T USB SDR

Sample Rate: 0.240 MHz | Freq Correction (ppm): Bias T

Gain Master: Mixer: LNA: VGA:

Output

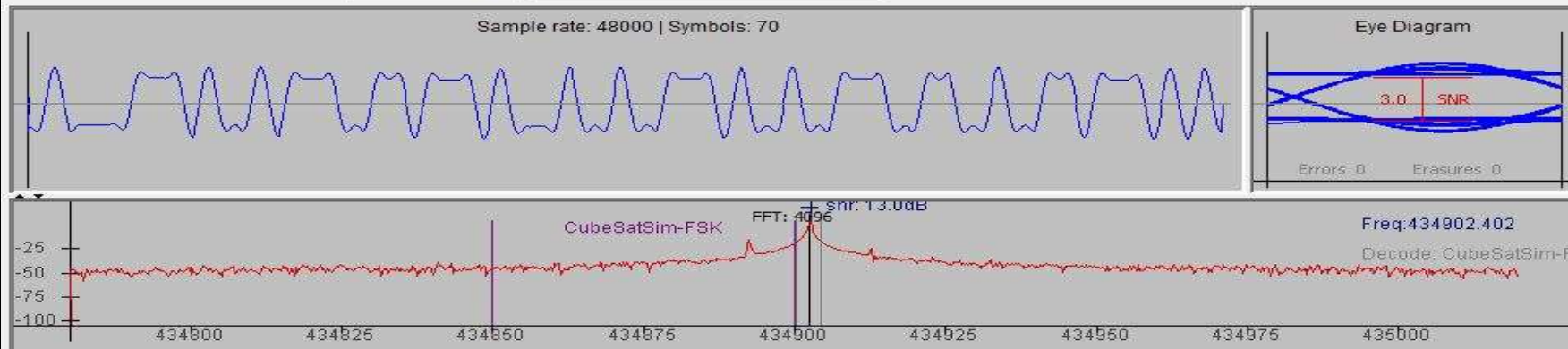
Spacecraft Tracked

1/AO-85 Not Tracked
 1/AO-91 Not Tracked
 1/AO-92 Not Tracked
 1/AO-95 Not Tracked
 1/CubeSatSim-BPSK Not Tracked
 1/CubeSatSim-FSK Tracked / No TLE
 1/Fox-1E Tracked / No TLE
 1/Husky Tracked / No TLE

Auto Start

Audio Options

View Filtered Audio
 Monitor Filtered Audio
 Squelch when no telemetry



Show Peak SNR | Find Signal when peak over dB, SNR over dB and bit SNR over dB

Input **AO-85** **AO-91** **AO-92** **AO-95** **CubeSatSim-BPSK** **CubeSatSim-FSK** **Fox-1E** **Husky**

 Health **Measurements**

 Satellite **CubeSatSim-FSK(EM) Mode: TRANSPONDER**

 Telemetry Payloads Decoded: **7115**

 Latest Realtime: **Resets: 163 Uptime: 222**

 Max: **Resets: 163 Uptime: 163**

 Min: **Resets: 153 Uptime: 374**
Radio

	RT	MIN	MAX
RSSI (dBm)	0	0	0
TX Antenna	Deployed		
RX Antenna	Stowed		

Computer Hardware

	RT	MIN	MAX
IHU Temp (Pi) (C)	36.9	34.7	35.8
I2C Bus 1	OK		
I2C Bus 3	OK		
Camera	OK		

Computer Software

	RT	MIN	MAX
Spacecraft Spin (rpm)	0.0	0.0	0.0
Safe Mode	OFF		
Ground Commands	0		
Simulated Telemetry	OFF		

Battery

	RT	MIN	MAX
Cell A+B+C Voltage ...	8.27	7.15	8.35
Current (mA)	26.0	471.0	115.0

PSU

	RT	MIN	MAX
Voltage (V)	4.96	4.78	4.96
Current (mA)	158.0	144.0	200.0

Experiments

	RT	MIN	MAX
STEM Payload Status	OK		
BME280 Temp (C)	0.0	0.0	0.0
BME280 Pressure (...)	0.0	0.0	0.0
BME280 Altitude (m)	0.0	0.0	0.0
BME280 Humidity (%)	0.0	0.0	0.0
Diode Temp (C)	107.3	105.3	107.3
Sensor 2 (signed s...	0.0	0.0	0.0

+X Panel

	RT	MIN	MAX
Voltage (V)	4.38	1.42	4.40
Current (mA)	91.0	0.0	92.0
Rotation (dps)	6	7	7
Acceleration (g)	-0.09	-0.06	-0.03

+Y Panel

	RT	MIN	MAX
Voltage (V)	4.40	3.19	4.52
Current (mA)	13.0	2.0	111.0
Rotation (dps)	1	0	1
Acceleration (g)	-0.01	-0.01	0.01

+Z Panel

	RT	MIN	MAX
Voltage (V)	0.00	0.00	0.00
Current (mA)	0.0	0.0	0.0
Rotation (dps)	9	0	11
Acceleration (g)	1.06	1.06	1.08

-X Panel

	RT	MIN	MAX
Voltage (V)	4.34	1.99	4.47
Current (mA)	3.0	0.0	72.0

-Y Panel

	RT	MIN	MAX
Voltage (V)	3.29	0.92	3.36
Current (mA)	10.0	0.0	82.0

-Z Panel

	RT	MIN	MAX
Voltage (V)	4.34	2.33	4.40
Current (mA)	72.0	0.0	118.0

 Current RT MAX MIN Display Raw Values Display UTC Time

 Last samples Captured: 2022/07/26 17:00:55

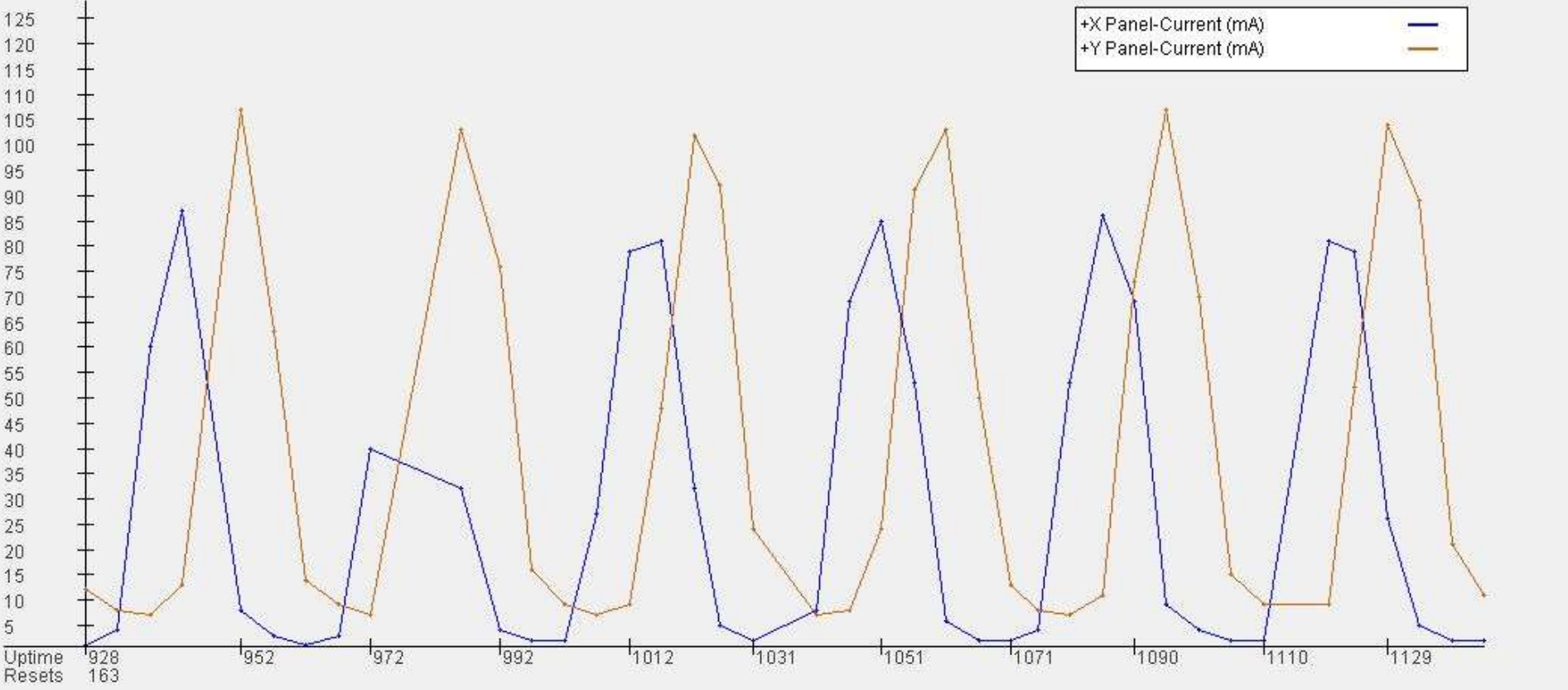
Battery-Cell A+B+C Voltage

UTC Uptime Continuous Lines Points Hide δx AVG

(mA)

CubeSatSim-FSK

+X Panel-Current (mA) — (blue line)
+Y Panel-Current (mA) — (orange line)



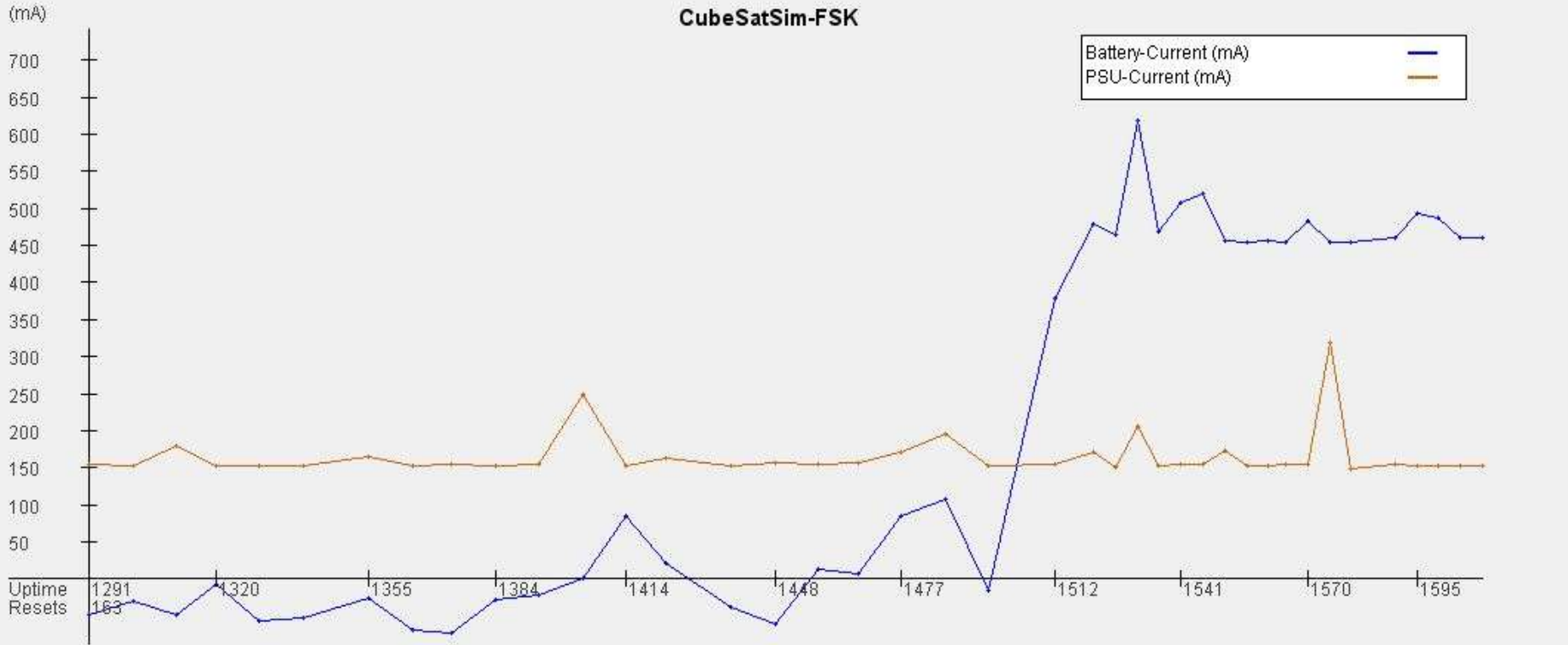
Round Labels Show Sun Last 40 samples



+ Battery-Cell A+B+C Voltage ▾

UTC Uptime Continuous Lines Points [List Icon] [Bar Icon] Hide [Print Icon] [Refresh Icon] [Save Icon] [Share Icon]

CubeSatSim-FSK

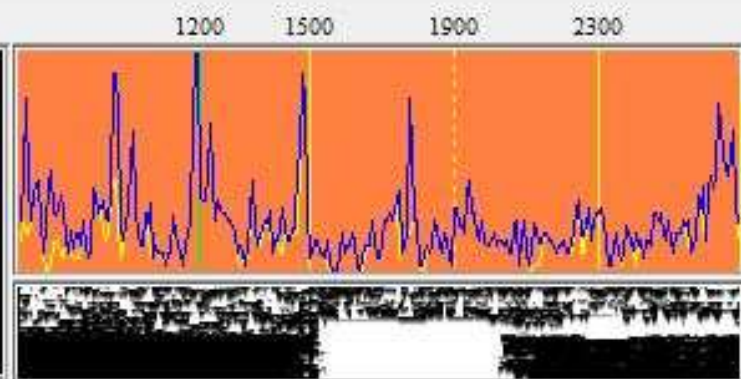


File Edit View Option PProfiles Program RadioCommand Help

Sync **RX** History TX Template



- RX Mode
- Auto
 - Robot 36
 - Robot 72
 - AVT 90
 - Scottie 1
 - Scottie 2
 - ScottieDX
 - Martin 1
 - Martin 2
 - SC2 180



DSP
AFC LMS

Log

Call His 595 My

Name Qth

Note

QSL RxID TxID

QSO Data Find Clear List 14.230

Lock ReSync Auto history

S.pix | S.templates 1 | 2 | 3 | 4 |

Show with template Draft 2/17

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