

AMSAT and the CubeSatSim: The AMSAT CubeSat Simulator

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About AMSAT

- The Radio Amateur Satellite Corporation, or AMSAT, is a worldwide group of Amateur Radio Operators (Hams). It was formed in the District of Columbia in 1969 as an educational organization.
- For over 50 years AMSAT groups in North America and elsewhere have played a key role in significantly advancing the state of the art in space science, space education, and space technology. The work now being done by AMSAT volunteers throughout the world will continue to have far-reaching, positive effects on the future of both Amateur Radio, as well as other governmental, scientific and commercial activities in Space – The Final Frontier.

AMSAT CubeSat Simulator <http://CubeSatSim.org>



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Amateur Radio at Villanova University



- Villanova University Amateur Radio Club is now reformed
 - 3YP callsign issued to Villanova College in 1921 – 100 years ago this year!
 - President Terry Yuan KD2UCB
 - Trustee Alan Johnston KU2Y
 - Grant from College of Engineering to build a satellite and HF station in Wireless Communication Laboratory in CEER Building (original repeater on roof of Tolentine Hall)
- Villanova University CubeSat Club formed in 2019
 - SatNOGS Station <https://network.satnogs.org/stations/1159/>
 - High Altitude Balloon Launch (HAB) in May 2021
 - AmbaSat-1 sprite mission sometime in 2022



AMSAT CubeSat Simulator <http://cubesatsim.org>

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AMSAT Mission

- AMSAT's goal is to foster Amateur Radio's participation in space research and communication. The Organization was founded to continue the efforts, begun in 1961, by Project OSCAR, a west coast USA-based group which built and launched the very first Amateur Radio satellite, OSCAR, on December 12, 1961, barely four years after the launch of Russia's first Sputnik.
- Today, the "home-brew" flavor of these early Amateur Radio satellites lives on, as most of the hardware and software now flying on even the most advanced AMSAT satellites is still largely the product of volunteer effort and donated resources.
- Though we are fond of traditions our designs and technology continue to push the outside of the envelope.

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AMSAT's Current Operating Satellites

AO-7 launched November 15, 1974 by a Delta 2310 launcher

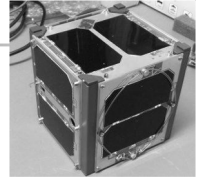
~~**AO-85** (Fox-1A) launched on NASA ELaNa flight on October 8, 2015~~

AO-91 (Fox-1B/RadFxSat) launched by a Delta II on November 18, 2017
(suffering battery issues, sometimes functioning)

AO-92 (Fox-1D) launched aboard Indian PSLV-C40 on January 12, 2018
(suffering battery issues, sometimes functioning)

AO-95 (Fox-1Cliff) launched via SpaceX Falcon 9 on December 4, 2018 (receiver non-functioning)

AO-109 (Fox-1E) launched via Virgin Galactic LauncherOne on January 17, 2021
(commissioning)



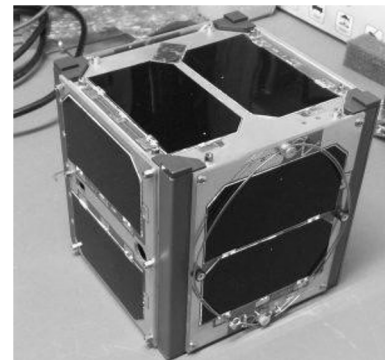
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Fox-1 [A,B,C,D,E] CubeSat Satellite Overview

- 1U CubeSat 10 x 10 x 10 cm (4 inch cube)
 - Standardized Space Frame
 - Fixed Solar Panels
 - Deployable Antenna
- Low Earth Orbit (LEO)
 - Nominal 600- 800 km, circular, depending on launcher.
- Single channel FM transponder; Mode U/v
- Fox-1C and D include L-Band "downshifter" Mode L/v
- 500 mW EIRP
- Experiments
 - Radiation/Gyroscope/Camera
- Data Under Voice (DUV) FSK telemetry



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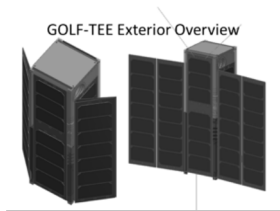


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AMSAT's Upcoming Satellites

GOLF-TEE (Technology Exploration Environment)

- 3U CubeSat with unfolding solar panels with ADAC (Attitude Determination And Control)
- Will serve as testbed for future missions and include Fox-1E linear transponder + new "five and dime" 5 GHz uplink / 10 GHz downlink SDR transponder
- Manifest on ELANA-46, launch NET (No earlier than) mid 2022



GOLF-1

- Will aim for higher LEO orbit as the first official "Greater Orbit, Larger Footprint" AMSAT CubeSat. Launch TBD



<https://www.amsat.org/greater-orbit-larger-footprint-an-introduction-to-the-amsat-golf-program/>

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AMSAT Education Outreach

- Takes many different forms including:
 - Outreach within the ham radio community and the public by AMSAT Ambassadors
 - ARISS (Amateur Radio on the International Space Station)
 - Partnerships with Universities
 - CubeSatSim Program
- Contact VP Educational Relations about any aspect of Educational Outreach for AMSAT

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Why a CubeSat Simulator?

- To demystify and reveal the inner workings of a Satellite
- To support educators and provide demonstrations to the public
- To help CubeSat developers be successful
- To share amateur radio and satellites with the maker community

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The AMSAT CubeSatSim



- Raspberry Pi Zero W-based, 3D-printed frame structure, functional model of a "1U" CubeSat
- Designed to act as if in Low Earth Orbit (LEO)
- Runs on rechargeable battery power and solar cell panels
- Transmits housekeeping telemetry on the 70 cm ham band using AFSK (Audio Frequency Shift Keying), FSK (Frequency Shift Keying), or BPSK (Binary Phase Shift Keying), and also transmits SSTV (Slow Scan TV) images
- Placed on a rotating turntable in front of a lamp or in the sun -- simulates a naturally spinning satellite in space

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Simulators at STEM/Robotics Events



- CubeSat Club attended two events in Philadelphia area:
 - Robotstock 2019
 - Philly Mini Maker Faire 2019
- Showed off Simulator and Sim Lite, live satellite tracking on a monitor, tape measure Yagi-Udas
- Also interactive “Assemble a CubeSat Simulator” activity



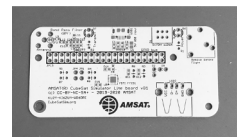
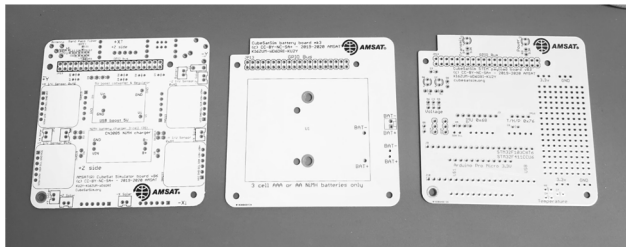
Looking forward to attending Maker Faires in 2021!

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Two CubeSatSim Versions



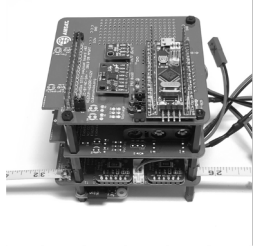
- CubeSatSim
 - 3 board stack plugs into Pi Zero W
 - Costs about \$200 to build, requires basic soldering and Raspberry Pi skills, about 10 hours for beginner
 - Transmits real telemetry in 70cm ham band and SSTV
- CubeSatSim Lite
 - Single board, plugs into any Pi
 - Entry level, lowest cost
 - Available assembled in the future
 - Transmits simulated telemetry and SSTV

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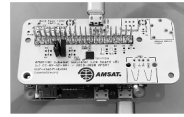
Two CubeSatSim Versions



- CubeSatSim
 - 3 board stack plugs into Pi Zero W
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 - Transmits real telemetry in 70cm ham band and SSTV

AMSAT CubeSatSim Project <https://CubeSatSim.org>

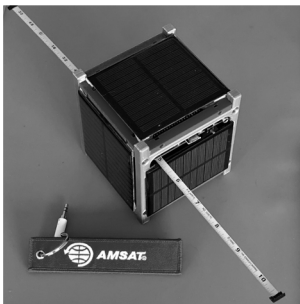
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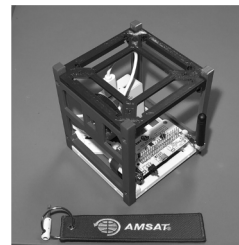
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- CubeSatSim Lite
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 - Transmits simulated telemetry and SSTV

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Ready for a Demo?



RBF Tags are Available on the AMSAT Store!

AMSAT CubeSatSim Project <https://CubeSatSim.org>

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Live CubeSatSim SDR Demo

In any browser go to:

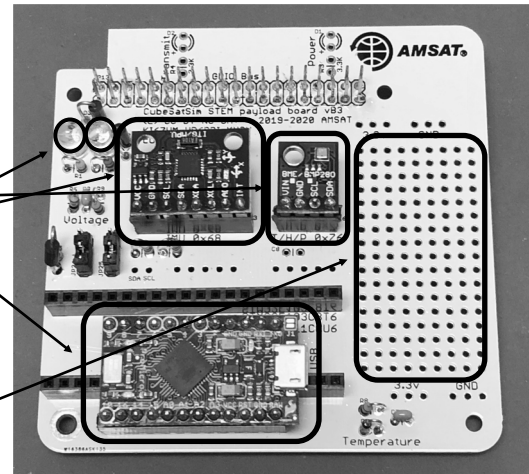
<http://proxy16.rt3.io:32011/>

(only works live on 5/20/21)

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STEM Payload Board

- Arduino-compatible microcontroller
 - Sparkfun Pro Micro, or
 - STM32 “blue pill”
- Pressure/Temperature/Humidity Sensor
 - BME280 sensor
- 3-Axis Gyro, 3-Axis Accelerometer
 - MPU6050 sensor
- Blue and Green LEDs
- Diode temperature circuit
- Resistor Divider voltage circuit
- Space for soldering other sensors!
- Useful for a balloon launch?



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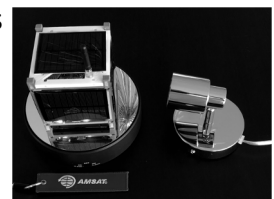
Build or Borrow?

Build One!

- All plans and designs are open source available on GitHub
 - <https://cubesatsim.org/wiki>
- Parts cost about \$200
 - You can also build a **CubeSatSim Lite with** any Raspberry Pi!
- 3D printed frame can be ordered on Thingiverse if you don't have a 3D printer
- Takes about 10 hours for someone with basic soldering skills to build

Borrow One!

- If you don't have the time or money to build one, AMSAT Education has five CubeSat Simulators available to borrow
- Use it in your classroom or seminar!
- Show it off at your next club meeting or hamfest!
- Take it to a Maker Faire
- See Alan KU2Y for details



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ARISS Radio Pi



- Raspberry Pi Image with Radio Software Pre-Loaded
- Uses \$20 RTL-SDR
- Software
 - Web SDR (OpenWebRX)
 - Satellite Tracking (Gpredict)
 - SDR (CubicSDR)
 - APRS (Direwolf)
 - SSTV (QSSTV)
 - Telemetry Decoding (FoxTelem)

<https://github.com/alanbjohnston/CubeSatSim/wiki/Radio-Pi>

AMSAT CubeSatSim Project <https://CubeSatSim.org>

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Participation in the CubeSatSim Project

- You can participate in the AMSAT CubeSatSim Project!
 - Document your CubeSatSim build and testing on social media
 - Offer to demonstrate your CubeSat Simulator to local schools, your ham club, Makerspace or Hackerspace gatherings, or other STEM events

The official CubeSatSim Project Twitter account is
 @CubeSatSim <https://twitter.com/CubeSatSim>

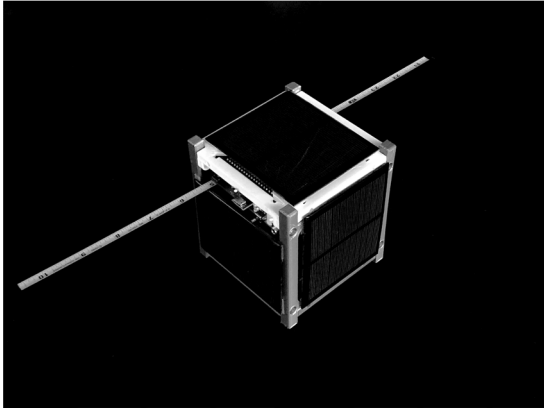
We use the hashtag #CubeSatSim to highlight our activities.

AMSAT CubeSatSim Project <https://CubeSatSim.org>

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Conclusions



- Status of Amateur Radio Satellites:
 - <https://amsat.org/status>
- For info on the AMSAT CubeSatSim Project visit
 - <https://CubeSatSim.org>
- You can participate!
- Read our paper “A Guide to the AMSAT CubeSatSim” for more details on all these topics

AMSAT CubeSatSim Project <https://CubeSatSim.org>

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New Papers at CubeSatSim.org

A Guide to the AMSAT CubeSatSim

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Figure 1 — The AMSAT CubeSatSim with tape measure dipole antenna.

AMSAT CubeSatSim Activities with FoxTelem

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Introduction
In the previous issue of the AMSAT Journal (March/April 2020), we introduced new design updates to the AMSAT CubeSatSim

as an improved tool for education and demonstrations. In this article, we will describe several educational activities that can be enjoyed with the CubeSatSim using FoxTelem, the free telemetry analysis software used by AMSAT members for on-orbit CubeSats. Some of these activities were also applied to the original design of the CubeSat Simulator in the Jan/Feb 2019 issue of the AMSAT Journal (<http://cubeatsim.org/content/CubeSatSimIntro2019>) based on the educational activities proposed for the original ARES EIP CubeSat Simulator by Mark Spencer, W4SME, in the AMSAT Journal, November/December 2009 issue (<http://www.amsat.org/Article/CubeSat-CubeSat-FoxTelem>).

First, we will describe how to download and configure the FoxTelem software for the CubeSatSim. For those without an AMSAT CubeSatSim model at hand, we posted several WAV files that can be downloaded to get experience with real-time analysis of telemetry from the CubeSatSim. Next, we will discuss various activities that can be done and describe how to proceed step by step using FoxTelem.

Background
The AMSAT CubeSatSim, our CubeSat Simulator, shown in Figures 1, 2, and 3, is a Raspberry Pi Zero-based, 3D-printed, functional model of a UJ form factor CubeSat. The simulator is designed to act as

Figure 1 — The AMSAT CubeSatSim is shown on a rotating turntable in front of a sun simulator LED lamp, with FoxTelem running on a laptop and an RTL-SDR USB dongle serving as the ground station receiver. The tape measure monopole antenna is

[A Guide to the the AMSAT CubeSatSim](#)

[AMSAT CubeSatSim Activities with FoxTelem](#)

AMSAT CubeSatSim Project <https://CubeSatSim.org>

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Coming Soon: New AMSAT Youth Initiative

Your future is looking up!



- KidszSat will provide a unique set of experiments for boys and girls, young men and women from fifth through twelfth grade
- KidszSat will call to a broad student audience by demonstrating how satellites work to solve problems that are important to today's youth such as:
 - climate change, pollution control, environmental protections, preservation of natural habitat, protecting wildlife...

AMSAT CubeSatSim Project <https://CubeSatSim.org>

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Join AMSAT

Membership includes the AMSAT® Journal and discounts on purchases made through the AMSAT store. Membership also supports many AMSAT activities including:

- OSCAR satellite operations
- Amateur Radio on the ISS
- Educational support
- Hamfest forums
- Beginner materials
- Technical achievement awards
- Future satellites



<https://www.amsat.org/join-amsat/>

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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.

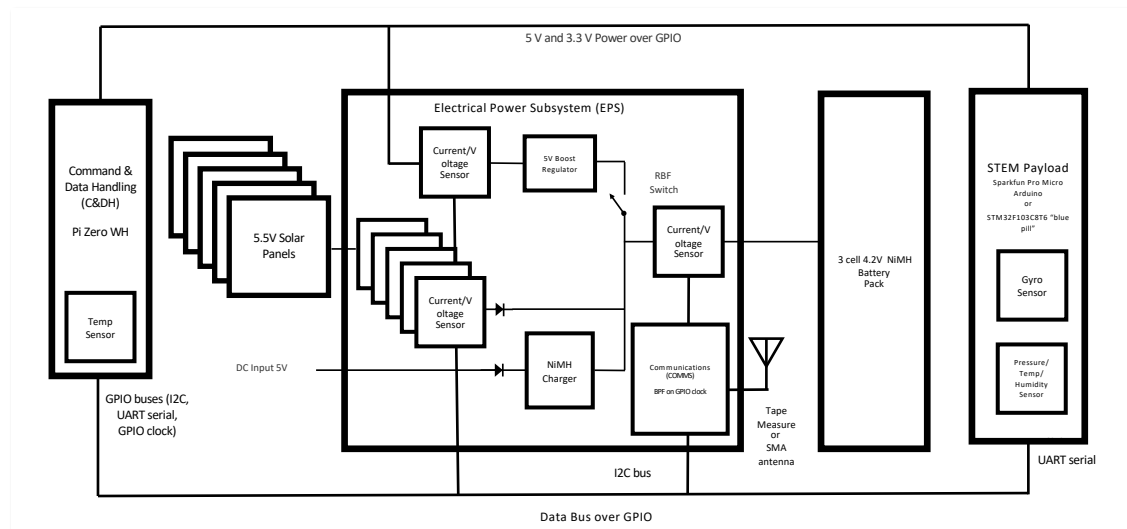
Thanks to our Beta Builders of 2020 especially Christine Mehner, MD, PhD, KO4EWG, "Sopwith", KN6CXD, and Kai Ji, AC3EN. Also thanks to the Villanova University Spring 2019 ECE-1205 Freshman Projects class. Thanks to Melissa Pore, KM4CZN, and the DJO ARC students. Thanks to Lindsay White, KI6LZN, for CAD work on the frame.

We would also like to acknowledge all the open source hardware and software that is a part of the AMSAT CubeSatSim.

Finally, we would like to acknowledge the support of the AMSAT Board of Directors for their support and encouragement of this project.

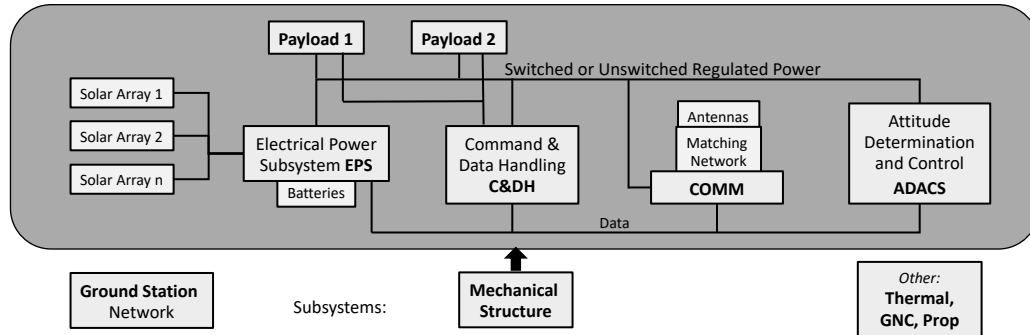
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AMSAT CubeSat Simulator Block Diagram



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Typical Spacecraft Block Diagram



1. Mechanical Structure: PC/104 standard, PCB stack, interlayer connections, standoff, fasteners, microswitches, deployables
2. EPS: solar cells, batteries, recharging, power regulating, distribution, grounding, fusing
3. C&DH: On Board Computer (OBC), FSW processing, scheduling, Housekeeping, storage
4. COMM: receivers, transmitters, processor, memory, TT&C, beacons
5. ADAC: multiple sensors, memory, computation
6. Thermal: Temp sensing, heat transfer, computation, control
7. GNC: GPS, RTC, time-stamping data, timing/1 PPS, computation
8. Prop: Propulsion, if we are so lucky, for translation, possibly attitude rotation
9. Payloads: The reason for the mission: Cannot fly without these VIPs!
10. Ground Station: Some seemed as an afterthought. Don't ever let it happen to you!

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