Introducing the AMSAT CubeSat Simulator: A Satellite in Your Hand

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Tune to 440.390 MHz FM to hear the Simulator transmit when launched!

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
  - CubeSat Simulator Program
- Contact VP Educational Relations about any aspect of Educational Outreach for AMSAT

ARISS Education's Tie to AMSAT

ARISS-US Education Committee: 20 educators (including me!) and other AMSAT folks

- Education--a big component of ARISS: many ARISS youth learn about satellites and get to make satellite QSOs. ARISS is developing a project that can be a step leading youth to the new CubeSat Simulator Program.
- A hearty *THANK YOU* goes to AMSAT and AMSAT members for their fine support of ARISS!

School in Antietam

School in Massachusetts

School in Delaware

Why a Satellite Simulator?

- To demystify and reveal the inner workings of a Satellite
- To support educators and provide demonstrations to the public
- To help CubeSat builders / developers be successful

One Small Step (at a Time)

- PROBLEM: Too Many CubeSats “DOA” upon LEO deployment *
- SOLUTION: Build Levels of Competence & Confidence in Satellite Technology

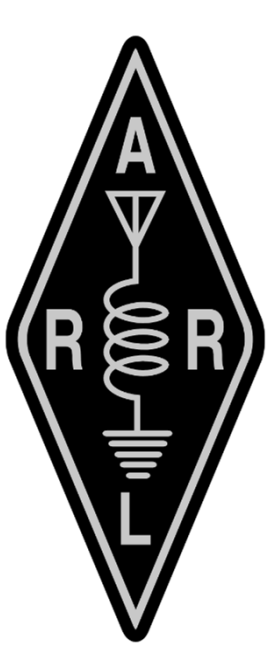
CRAWL	...	Amateur Radio: opportunities & benefits
WALK	...	AMSAT CubeSat Simulator
RUN	...	Engineering Model (EM) or Test Unit (ETU)
FLY	...	Flight Model (FM), Flight Spares & Testing

Original ARRL ETP CubeSat Simulator

Built by Mark Spencer, WA8SME, ARRL Education & Technology Program Coordinator

Described in The AMSAT Journal September/October 2009 and November/December 2009 issues

http://www.arrl.org/files/file/ETP/CubeSat/CubeSat-Pt1-SepOct09.pdf
http://www.arrl.org/files/file/ETP/CubeSat/CubeSat-Pt2-NovDec09.pdf



Education with a Satellite Simulator

ETP CubeSat Simulator (Part 1, the technical part)

by Mark Spencer, WA8SME, mspencer@arrl.org
ARRL Education and Technology Program Coordinator

During my interaction with classroom teachers involved in the ARRL's Education and Technology Program (ETP), I encourage the teachers to develop a portfolio of space related activities for use in their classrooms. These activity suggests include, for example, the use of Amateur Radio satellites, NOAA weather satellites, an ARISS contact, Radio JOVE, INSPIRE, and radio astronomy. During the Teachers Institute (http://www.arrl.org/FandES/tbp/ti.html), one afternoon of the 4-day institute is dedicated to bring space into the classroom with hands-on demonstrations of these suggested portfolio activities. Details of many of these activities have been highlighted in *The AMSAT Journal*, *QST* and *CQ VHF* magazines and there have been positive responses to these articles among the non-teacher ham population. This year I had the fortunate opportunity to pilot a Teachers Institute-2 (TI-2) course that focused entirely on using Amateur Radio satellites, particularly satellite telemetry,

Figure 1: CubeSat Simulator satellite.

in the classroom (Figure 2). This initiative proved very successful and it will serve as a model program that is being developed to provide a training course and resources for teachers that are preparing for a scheduled ARISS contact so that the teachers are better prepared to use the ARISS contact, and other space borne resources, in their classrooms long after the ISS has gone LOS.

In preparation for the TI-2, I wanted to develop an affordable classroom resource that teachers could add to their portfolio of space related activities to demonstrate satellite fundamentals in a controlled and predictable way so that the more tenuous live on-the-air satellite activity would be more effective as an instructional tool. The result of this effort, the CubeSat Simulator, is described here. This article, part one of the description of the simulator, will focus on the technical side. . In part two of this article, I will list a growing list of possible CubeSat Simulator activities that can be used in the classroom.

This effort really isn't re-inventing the wheel. Professor Bob Bruninga, WB4APR, of the Naval Academy has develop some exceptional hardware for teaching satellite fundamentals, and his work was (and is) inspirational. However, Bob's target audience is the Naval Academy Cadet, a uniquely talented audience. Another readily available satellite simulator resource, EyasSat, is a frequent advertiser in the *Journal*. This simulator is a very comprehensive and capable resource, unfortunately for my program, it has a price tag to match and again the target audience is the university and working professional level.

The target audiences for the ETP are primary, middle, and high school teachers and students. The instructional materials and associated instructional resources for this audience need to be scaled appropriately (appropriate level of rigor, depth, detail, scope, and in today's economic environment, it must be affordable). Also based on my experience with developing other instructional resources, many of the resources developed for schools also have found a piece of interest among the general ham population. I anticipate that the CubeSat Simulator will also peak the interest of some readers of the Journal.

The criteria upon which the CubeSat Simulator was developed include:

1. A resource that simulates a satellite operating in orbit as closely as possible in a classroom environment.
2. A resource that can be used to demonstrate the most basic fundamentals of satellite operations.
3. A resource with an open architecture that is easily constructed, modified, adapted, expanded, contracted, explored and used by students and teachers in the typical public school classroom.
4. A resource that is flexible enough to be used at some level by all students.
5. A resource that is rugged and easy to pull off the shelf and get working with minimum preparation time.
6. A resource that will not break the bank.

The CubeSat Simulator is made up of four basic component parts or blocks, each block will be described separately (Figure 3). These component blocks include the CubeSat itself, a 70 cm transceiver used for

Figure 2: TI-2 participants in the antenna farm.

Top 5 Reasons:
Why a Simulator is Better than a Real Satellite

1. You can keep a Simulator on your desk or shelf to show off, and it will never burn up on re-entry!
2. You don't have to pay a lot of money and wait years for a launch -- a Sim can be "launched" in any classroom or hamfest on the spot!
3. A Simulator is available anytime, not just on certain passes at certain times of day
4. You don't need a full ground station to receive telemetry, just a PC with an SDR dongle
5. You can build your own by soldering & 3D printing for about $400

Who will use a Satellite Simulator?

- Educators
  - In a classroom setting to do exercises that teach aspects of STEM and encourage technical careers
- Presenters
  - Those who wish to do public demonstrations and training, including AMSAT at Hamvention
- Builders
  - Teams who desire an early risk-reducing step in building a CubeSat flight model
- Makers
  - Hobbyists who just like to build things and enjoy the Raspberry Pi single board computer and the related simple interfaces

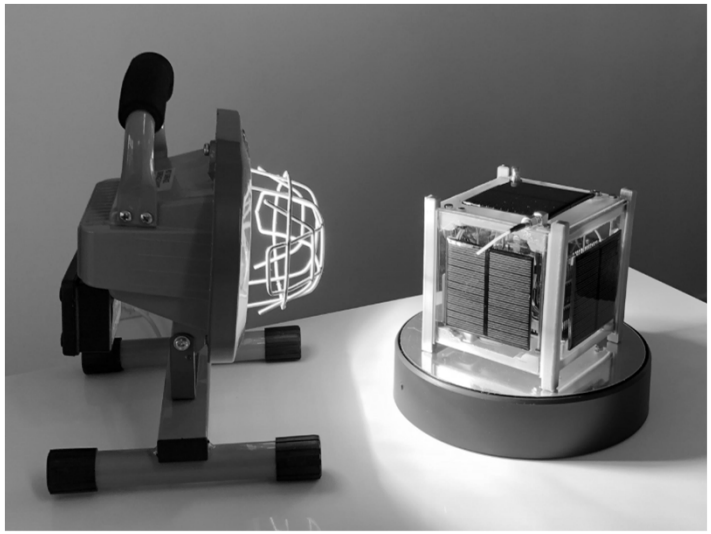
CubeSat Simulator Project Plan

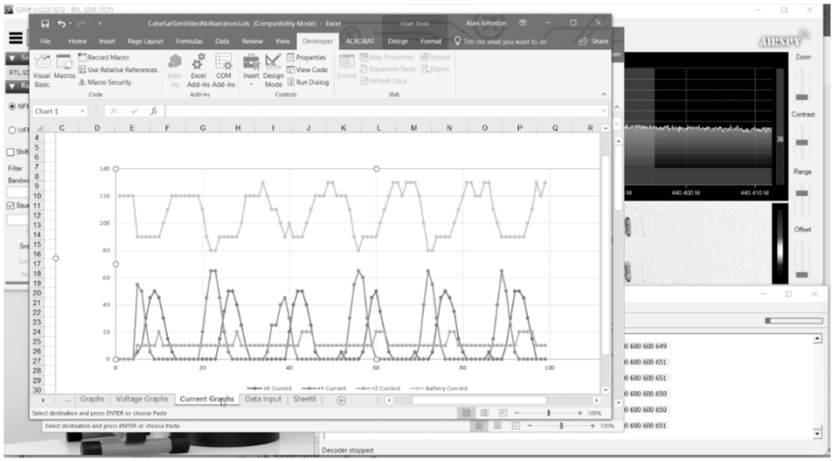
- ✓Build prototype and demo at 2018 Space Symposium
- ✓Get feedback from Beta Builders

  Thank you: Tom Dougherty, N0TJD, Ken Ernandes, N2WWD, Bob Koepke, AA6TB, Robert Smibert, VE6SMI
- ✓Build 4 Simulator Loaners for AMSAT
- ❑ ”Launch” at Hamvention 2019
- ❑ Get Simulators into the Classroom


REMOVE BEFORE FLIGHT

Launch!





In the Classroom

- Villanova University
  - Freshman Projects Course built 6 Simulators – Alan Johnston, KU2Y
- University of Tennessee Knoxville
  - Senior Design Course - Gould Smith, WA4SXM
- University of Texas at El Paso
  - Freshman Projects - Robert C. Roberts, KC8GOQ
- Fryeburg Academy, ME
  - CubeSat Mini Course - Warren Zeigler, K2ORS
- Grace Brethren Schools, Simi Valley, CA
  - Eric Tapper

What is Next?

Build One!

- All plans and designs are open source available on GitHub
  - https://cubesatsim.org/wiki
- Parts cost about $400
  - You can also build a **CubeSat Simulator Lite with** a Raspberry Pi!
- 3D printed frame can be ordered on Thingiverse if you don't have a 3D printer
- Takes about 20 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 four 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 or Pat for details

Acknowledgements

The Authors would like to thank Jonathan Brandenburg, KF5IDY for his help and assistance. His timely technical support on the Brandenburg Tech Digital Transceiver for the Raspberry Pi Board has been invaluable. Thanks to Mark Spencer for his aforementioned trailblazing work, to NASA summer intern student Nico Lagendyk at UMd-College Park, and to USNA's Bob Bruninga for ideas and inspiration from his undergrad "LabSat" developments.

Thanks to the Beta Builders and especially Villanova University Spring 2019 ECE-1205 Freshman Projects class

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

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

Questions? Comments?

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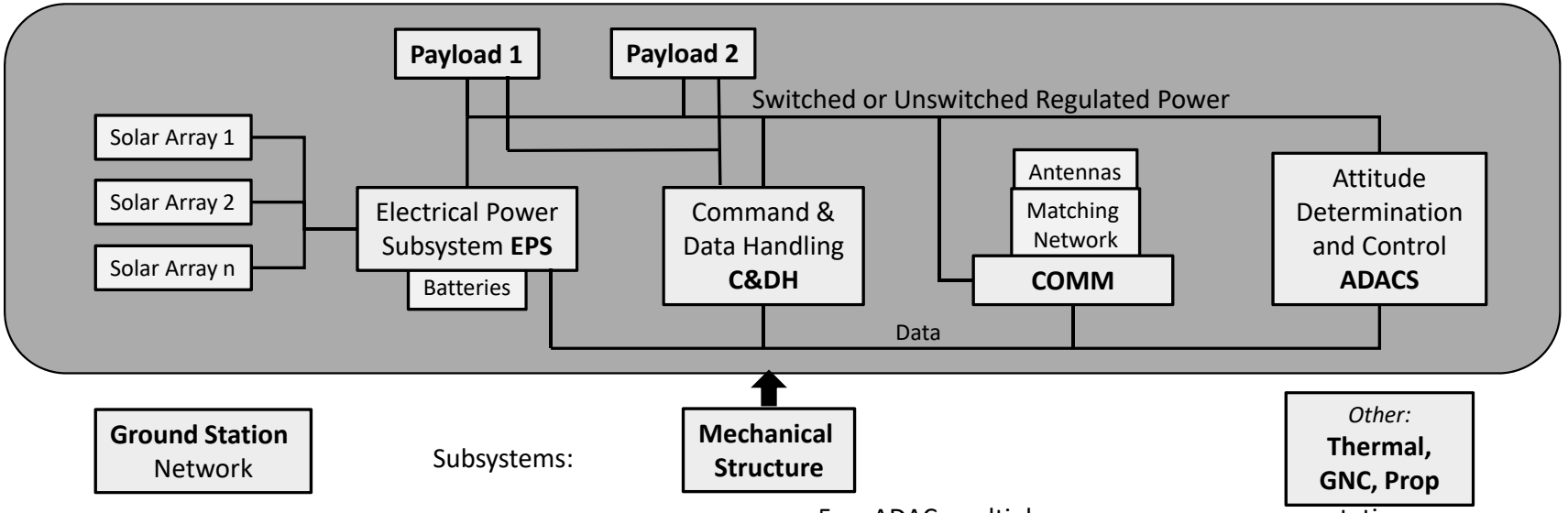
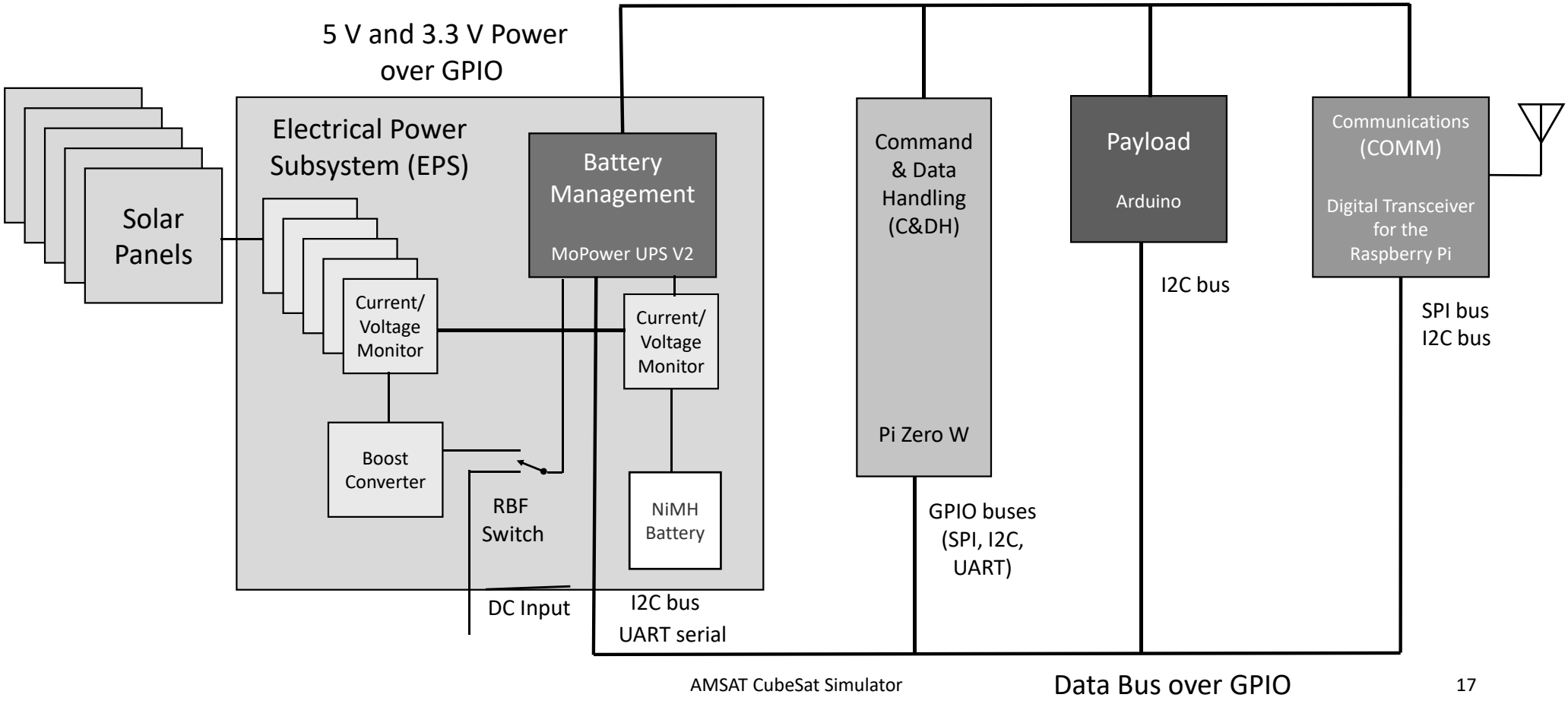
Typical Spacecraft Block Diagram

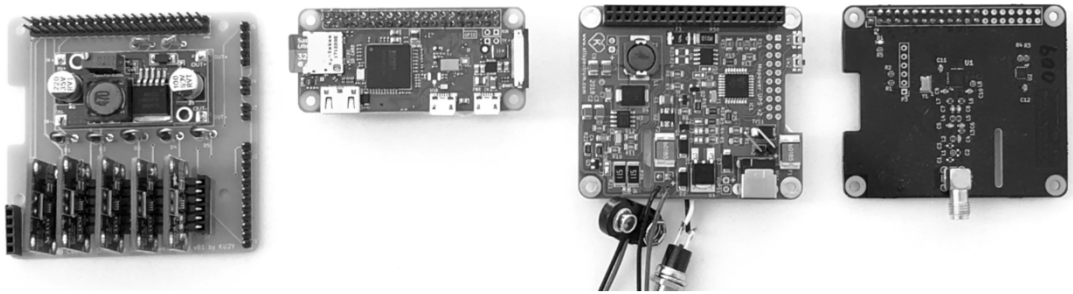


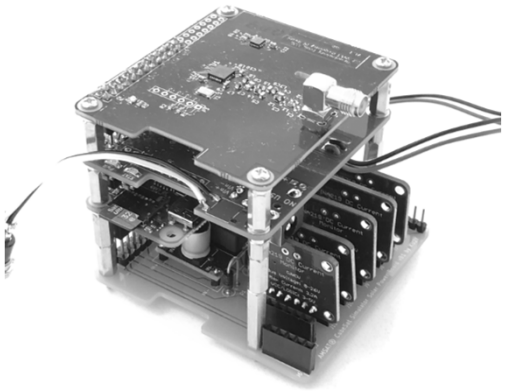
1. Mechanical Structure: PC/104 standard, PCB stack, interlayer connections,
   standoffs, fasteners, microswitches, deployables
2. EPS: solar cells, batteries, recharging, power regulating, distribution, grounding, fusing
3. C&DH: On Board Computer (OBC), FSW processing, scheduling, Housekeeping, storage
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!

AMSAT CubeSat Simulator Block Diagram



Boards in the Prototype





Solar Power Management (part of EPS)	C&DH	Battery Management (part of EPS)	Comm (Transmitter)
Custom Circuit Board	Raspberry Pi Zero W	MoPower UPS V2	Brandenburg Tech Digital Transceiver for the Raspberry Pi
Monitors solar panel current and voltages for telemetry. Boosts voltage to 15 V to charge batteries. Switches between DC input power and solar power.	Runs software to control simulator. Controls and communicates with other boards using the GPIO connector.	Manages charging of 9 V NiMH battery. Provides power on/reboot/shutdown button and automatically shuts down Pi if battery voltage is too low.	Transmits telemetry signal on 70 cm band using different modulation schemes.