The AMSAT® Journal

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Write for *The AMSAT Journal*

The AMSAT Journal is looking for interesting articles, experiences and photos to share with other AMSAT members. Writing for the *Journal* is an excellent way both to give back to the AMSAT community and to help others learn and grow in this most fascinating aspect of the amateur radio avocation.

Find a quiet place, sit yourself down, get out your laptop or pick up a pen, and …

1. *Launch* your inner writer;
2. *Downlink* your knowledge and experiences to others by:
   -- Sharing your adventures in the "On the Grids" column or
   -- Describing your AMSAT career in "Member Footprints;"
3. *Transmit* lessons learned from operational and technical projects;
4. *Log* some of your more interesting passes across the sky; and
5. *Boost* others to a higher orbit of know-how and experience.

After your article lands in members' mailboxes, and the kudos start arriving for your narrative payload, you can enjoy the satisfaction of knowing you've elevated the collective wisdom of AMSAT to a higher trajectory. Send your manuscripts and photos, or story ideas, to: journal@amsat.org.

Our editors are standing by!

AMSAT's Mission

AMSAT is a non-profit volunteer organization which designs, builds and operates experimental satellites and promotes space education. We work in partnership with government, industry, educational institutions and fellow Amateur Radio societies. We encourage technical and scientific innovation, and promote the training and development of skilled satellite and ground system designers and operators.

AMSAT's Vision

Our Vision is to deploy satellite systems with the goal of providing wide-area and continuous coverage. AMSAT will continue active participation in human space missions and support a stream of LEO satellites developed in cooperation with the educational community and other amateur satellite groups.

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The AMSAT Journal staff is always interested in article submissions. Whenever possible, submissions should be sent via e-mail to journal@amsat.org using plain text or word processor files; photos or figures in TIF, GIF or JPG formats. Kindly do not embed graphics or photos in your manuscript. We prefer receiving those as separate files. AMSAT reserves the right to select material for *The AMSAT Journal* based on suitability of content and space considerations.

Apogee View

Robert Bankston, KE4AL
President

The AMSAT 40th Space Symposium and Annual General Meeting has come and gone. All I can say is WOW! It was nice to finally meet in person again, and the Crowne Plaza AiRE in Bloomington, Minnesota, located right between the Minneapolis-St. Paul International Airport and Mall of America was the perfect venue.

Our Board of Directors met on Thursday, October 20th, and the first half of Friday, October 21st. It was a very informative and productive meeting. First, our engineering, operations, education, youth initiative, ANS, Journal, information technology, contest & awards, and web store teams provided updates on what they have been working on during the year, what they have accomplished, and what they are working on in the coming year. Then, as we moved to new business, our directors approved a new Reserve Policy and an Export Control and Economic Sanctions Policy, as well as discussed the use of the Fox Plus program as a test flight platform to quickly test newly developed satellite systems in space and the impact of the new FCC pronouncement on orbital debris mitigation.

On Friday afternoon and Saturday, we were treated to some fantastic presentations. Stefan Wagener, VE4SW, shared with us "Building a Portable Station for QO-100, the Geostationary Satellite Es'hail-2 Carrying Amateur Radio." Randy Berger, WA0D, ARISS Director of Engineering, provided us with an update on "What's New, ARISS on ISS and mission to the moon with Lunar Gateway." Next, Heimir Thor Sverrisson, W1ANT, presented an interesting proposal on "OTA Software Update for LEO satellites," using multiple ground stations to reprogram or apply software updates in coordinated segments. Nick Pugh, K5QXJ, then filled us in on the work being done at the University of Louisiana at Lafayette. Nick's first presentation covered the university's approach to its education initiative. The second presentation provided an update on their Cape IV mission. Paul Graveline, K1YUB, updated us on AMSAT's CubeSat Simulator program. Kip Moravec, AE5IB, provided the current development status of AMSAT GOLF-TEE's electrical power system. Burns Fisher, WB1FJ, shared improvements made to AMSAT's Linear Transponder Module (LTM) power amplifier and the upcoming use of it in the University of Maine's MESAT-1 3U CubeSat mission. Next up was a fascinating presentation by AMSAT's Assistant V.P. of Engineering, Jonathan Brandenburg, KF5IDY, on his work, "Building a Helmholtz Cage for Dynamic Magnetic Field Generation and CubeSat Attitude Control Testing," followed by an update on AMSAT's reaction wheel assembly open project update, presented by Zach Metzinger, N0ZGO, and Jonathan Brandenburg, KF5IDY. The AMSAT 40th Space Symposium culminated with an AMSAT Engineering Update, provided by Jerry Buxton, N0JY, V.P. of Engineering. You could tell our presenters put a lot of time and effort into preparing these, for which we are truly thankful.

New FCC Ruling Presents a New Set of Challenges

What goes up must come down, and that applies to satellites. Until now, all spacecraft had to either deorbit or move to a disposal orbit no later than 25 years after the end of their mission. With the Federal Communication Commission's (FCC) new ruling, they must come down sooner.

The FCC's new orbital debris mitigation ruling, FCC 22-74, requires non-geostationary satellite operators that terminate satellite operations in or passing through the low-Earth orbit region (below 2,000-kilometer altitude) complete disposal as soon as practicable following the end of mission, and no later than five years after the end of its primary mission. The goal is to minimize the risk of collisions that would create debris.

The FCC defines "end of mission" to be "the time at which the individual spacecraft is no longer capable of conducting collision avoidance maneuvers," and, for spacecraft without collision avoidance capabilities, end of mission is defined as the point at which the individual spacecraft has completed its primary mission.

Furthermore, the FCC requires a demonstration that the probability of success of the chosen disposal method will be 90 percent or greater. This new rule-making will have a significant effect on AMSAT's future satellite operations and, as such, was a serious topic of discussion at our recent board of directors meeting. That discussion generated many questions.

- What does the FCC mean by disposal demonstration, and what constitutes a 90 percent or greater probability rate?
- What are licensable disposal methods, other than through natural decay?
- Will the FCC accept the National Aeronautics and Space Administration (NASA) orbit analysis report for naturally decaying orbits to meet the probability threshold?

Unfortunately, the FCC did not supply much implementation guidance in meeting these new requirements, so our next step will be to reach out to the FCC to define our requirements better and how we can meet those standards. We will keep you informed.

Export Control and Economic Sanctions Policy

One of the most exciting things to come out of this year's AMSAT Symposium, at least to me, was our Export Control and Economic Sanctions Policy approved by our Board of Directors.

Some of AMSAT's greatest achievements have come from working with our international AMSAT partners. Unfortunately, changes in International Traffic in Arms Regulations (ITAR) and Export Administration Regulations (EAR) and the enforcement thereof caused a self-imposed limit to our international participation.

The desire to return to the international development of satellites and related systems served as the impetus for our new policy.

This policy states, "The Radio Amateur Satellite Corporation (AMSAT) will comply with all U.S. export control and economic sanctions laws and regulations." While this, in and of itself, is no different than how we have been operating, specific provisions of the policy create an essential path to our return to international cooperation through the use of the public domain (ITAR) and publicly available (EAR) exclusions.

It is important to note that ITAR and EAR exclusions only apply to information related to the development of our satellites but not to the actual building of satellites. Exporting materials to non-U.S. persons, be it hardware or software, will still require an export license. On the other hand, importing materials to the U.S. is not restricted by ITAR or EAR.

Creating this policy was only the first step. We still need to develop and put in place the prescribed controls to ensure our compliance and establish a training program for our volunteers, all of which we hope to have accomplished in the next couple of months.

I am excited about the opportunities that lie ahead with being able to collaborate with our fellow AMSAT organizations around the world once again.

Please read our new Export Control and Economic Sanctions Policy, available on our website, along with our other organizational documents, policies, and financial disclosures, at www.amsat.org/about-amsat/. This is your organization, and together, we can accomplish great things.

Until the next time, Onward & Upward!

Smile for AMSAT at Amazon.com

When making purchases from Amazon, you can select a charity and Amazon will donate .5% of a qualified purchase towards that charity. Select smile.amazon.com when making your Amazon purchases and make Radio Amateur Satellite Corporation (AMSAT) your chosen charity.

Having selected a charity, when you go to amazon.com, you will be prompted to go to smile.amazon.com. However, you can put everything you want in your cart at the original amazon.com site, then leave the site and go to smile.amazon.com and all your items will still be in your cart.

Educational Relations Update

Alan Johnston, Ph.D., KU2Y
V.P. Educational Relations

Although I could not attend, I heard the 40th Anniversary AMSAT Space Symposium & Annual General Meeting was a success! Paul Graveline, K1YUB, was there and gave a well-received presentation about the work of the CubeSatSim Educational Materials team. I also recorded a short video that was played. You can watch it here on YouTube: **youtu.be/L8JLovCDCno**. You also can see a list of all my CubeSatSim and education videos here: **youtube.com/@ku2y**.

In this *Journal* edition, you can read my Symposium Paper, an education and CubeSatSim update over the past 12 months. We are looking forward to a great year in 2023! If you are interested, we offer many volunteer opportunities to help in education, STEM outreach, or the CubeSat Simulator project — get in touch with me.

For the latest CubeSat Simulator news, follow our dedicated Twitter account **@CubeSatSim**.

If you are interested in doing a demo for a group or school, I can ship you a loaner – contact me via email at **ku2y@arrl.net** or on Twitter **@alanbjohnston**.

eBay Sellers Donate to AMSAT

Are you an eBay seller? One item, ten items, or a full-time business you can donate a percentage of your winning bid to AMSAT.

To do so, do not list your item with the basic listing tool, select advanced tools. eBay will give you a warning message that it is for large volume sellers, however this is where the eBay for Charity tool is found.

You can "select another nonprofit you love" and search for either AMSAT or Radio Amateur Satellite Corporation. Choose the percentage amount of the sale you would like to donate to AMSAT, and boom!.

When your item sells and the winning bidder pays, eBay will deduct the percentage from your take and forward it to AMSAT.

AMSAT Education and CubeSat Simulator Project Update

[2022 AMSAT Space Symposium]

Alan Johnston, Ph.D., KU2Y
V.P. Educational Relations

Abstract — The AMSAT CubeSatSim is a small, low-cost spacecraft simulator that serves as a tool for academic education, public demonstrations and theory & design disciplines. CubeSatSim can be used in a classroom, lab or training setting to introduce the basics of satellite operations, or to teach STEM (Science, Technology, Engineering, Math) exercises. This article updates the CubeSatSim Project to October 2022 at the last AMSAT Space Symposium. The update includes classroom activities, events, high-altitude balloons, and overall project status.

Overview

The AMSAT CubeSatSim model is shown in Figure 1. The AMSAT CubeSatSim, or CubeSat Simulator, is a Raspberry Pi Zero-based, 3D printed, functional model of a 1U form factor CubeSat. It is designed to act, as reasonably as possible, as one flying in Low Earth Orbit (LEO) to demystify how satellites work. The construction plans and software are fully open-sourced, and information about building one is available at cubesatsim.org. Like real LEO satellites, this simulator is self-powered through onboard rechargeable batteries and solar panels. In addition, it transmits telemetry wireless on UHF in various formats. For details on the design and construction of the simulator, see our article in the March/April 2020 issue of *The AMSAT Journal* (**cubesatsim.org/content/CubeSatSimPaper5.pdf**). Additionally, a trove of good information appears on the CubeSatSim Project page, **cubesatsim.org**.

This article updates the CubeSatSim Project over the 12 months ending in October 2022.

AMSAT Education Update

With the situation in education starting to return to normal, there has been an increase in STEM outreach activity at AMSAT. This includes the continued development of the CubeSatSim, the CubeSat Simulator, High Altitude Balloon (HAB) activities, demonstrations at Hamvention, Hamcation, and other events, including the Orange County Maker Faire in Los Angeles. The CubeSatSim has also been used in several classrooms as part of engineering courses.

Figure 1 —The AMSAT CubeSatSim.

There is also an active Discussion Forum on Github for the CubeSatSim, which you can access at: **github.com/alanbjohnston/CubeSatSim/discussions**.

The current version of the CubeSatSim PCBs (v1.2) is available at the AMSAT Store and Hamvention. In addition, Raspberry Pi CubeSatSim SD cards and Fox-in-a-Box SD cards are also in the store.

A CubeSatSim Lite Beta version has appeared a few times in the AMSAT Store and at Hamvention and has received favorable feedback.

We published an article in *The AMSAT Journal* November/December 2021 issue on "Using High Altitude Balloons (HABs) in Science, Technology, Engineering and Mathematics Education," by David White, WD6DRI, Jim McLaughlin, KI6ZUM, Bernadette Lally, Alan Johnston, KU2Y.

At Villanova University, we flew a Beta CubeSatSim Lite board with a STEM Payload board on a high-altitude balloon (HAB), gaining helpful experience in how the CubeSatSim can be used with HABs.

We also published a follow-up article on repurposing Radiosondes: "Using Recovered National Weather Service RS-41 Radiosondes for Amateur Radio High Altitude Balloon," by David White, WD6DRI, Randy Standke, KQ6RS, Kerry Banke, N6IZW, Jim McLaughlin, KI6ZUM, Phil Karn, KA9Q, Gene Swiech, WB9COY, and Alan Johnston, PhD, KU2Y.

CubeSatSims in the Classroom

The AMSAT CubeSatSim has been used in a few classrooms in the past year.

At Villanova University, six CubeSatSims were built as part of an introductory electrical and computer engineering course for first-year students. An article — "Building AMSAT CubeSatSims in the Classroom" by Alan Johnston, KU2Y and Edward Char — in the July/August 2022 *AMSAT Journal*, describes the design and execution of the mini-project. Four of the CubeSatsSims are shown in Figure 2.

At the University of Colorado, Colorado Springs, the Mechanical and Aerospace

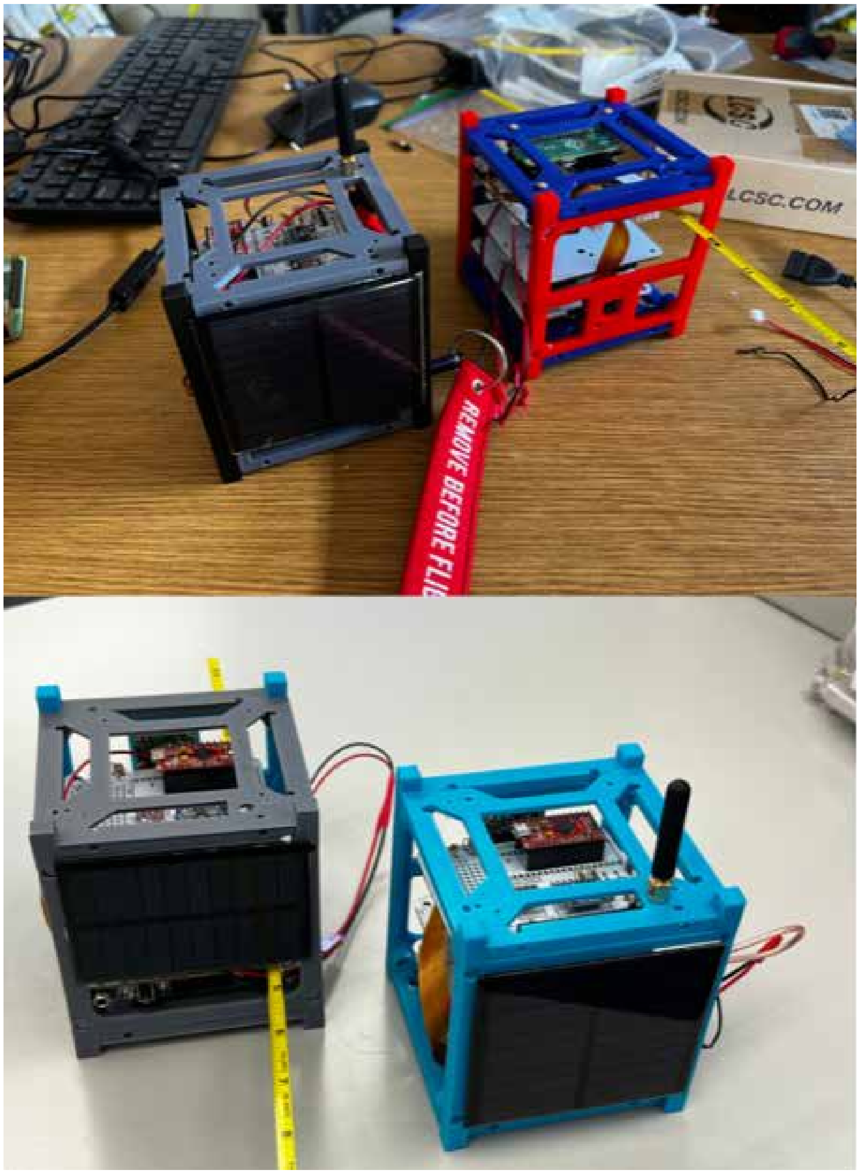

Figure 2 — CubeSatSims built by Villanova University students.

Engineering Department built five CubeSatSims in courses under Dr. Lynnane George, Senior Instructor. Her students borrowed and evaluated a CubeSatSim Loaner during the spring before building their CubeSatSims.

Other schools in Colorado and a university in Washington state are planning to build CubeSatSims.

CubeSatSim at Events

The CubeSatSim was present at Hamcation in February 2022 at both the ARISS (Amateur Radio on the International Space Station) booth and the AMSAT booth. The ARISS demo was thanks to Randy Berger, WA0D, ARISS Director of Engineering. The CubeSatSim Lite was shown off by Robert Bankston, KE4AL, AMSAT President, at the AMSAT booth.

Seeing many of you at Hamvention in May 2022 in the AMSAT booth was great. We had an education table staffed by three Villanova engineering students and Jack Spitznagel, KD4IZ. We demoed the CubeSatSim with an SSTV "selfie station," shown in Figure 3. In addition, we had a "Build Your own CubeSat" hands-on activity for kids, which was quite popular.

Tom Schuessler, N5HYP, and team again organized and ran an AMSAT table at the Frontiers of Flight "Moon Day" STEM event in Dallas, TX, in July 2022. This year, they showed off a CubeSatSim built by Virginia Smith, NV5F. Her CubeSatSim can be seen along with some friends in Figure 4.

Virginia also wrote an article for the July/August 2022 *AMSAT Journal* about her CubeSatSim building adventure: "My First Simulated Satellite" by Virginia Smith, NV5F.

Fredric Raab, KK6NOW, demonstrated classroom activities with the CubeSatSim at the Satellites & Education Conference XXXV at Cal State Los Angeles in July 2022. His presentation was titled "Classroom Activities with the AMSAT CubeSat Simulator."

Sopwith, N1SPW, organized and ran a CubeSatSim table at the Orange County Maker Faire in September 2022. He made contact with several groups. His table appears in Figure 5.

Jack Spitznagel, KD4IZ, borrowed a CubeSatSim Loaner and gave a presentation to the Southern Pennsylvania Communications Group/K3AE club based

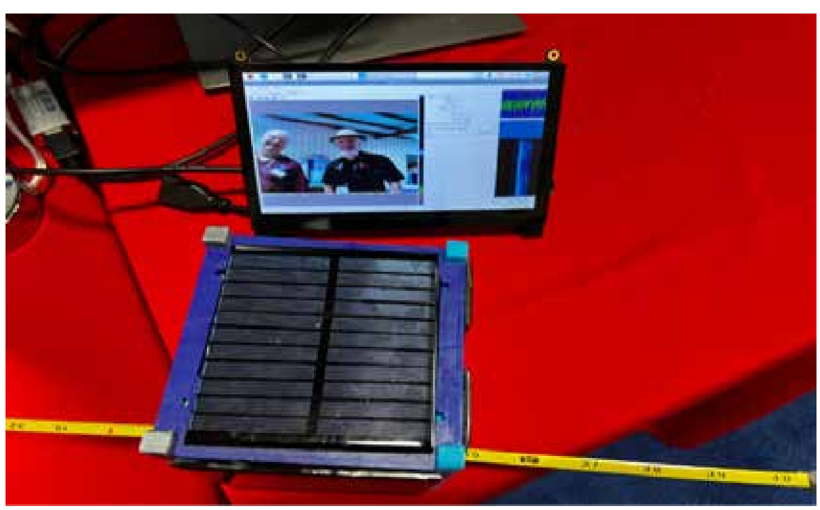

Figure 3 — Hamvention CubeSatSim SSTV "selfie" station using SSTV.

Figure 4 — CubeSatSims at the AMSAT table at the Frontiers of Flight "Moon Day" STEM event in Dallas, TX. Photo courtesy of Virginia Smith, NV5F.

Figure 5 — CubeSatSim table at the Orange County Maker Faire in California. Photo courtesy of Sopwith N1SPW.

in Shrewsbury, PA.

New Educational Materials Team

We have long recognized the need for educational materials such as lesson plans, how-tos and introductory materials and presentations. In 2022, a new educational materials team of volunteers was formed to develop these materials. The team members are:

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

We wrote an article in the May/June *AMSAT Journal* describing our plans: "Progress Report: Curriculum Development to Accompany The AMSAT CubeSatSim" by Paul Graveline, K1YUB, Alan Johnston, Ph.D., KU2Y, Fredric Raab, KK6NOW, Mark Samis, KD2XS, and David White, WD6DRI. You should start to see some of these materials in 2023.

We will need reviewers and proofreaders for this material. If you have an interest, please get in touch with me at **ku2y@arrl.net** for more information.

CubeSatSim Project Status

Well over a hundred CubeSatSims have been built to date. You can find many examples on social media with the hashtag #CubeSatSim.

The most significant challenge to the project in 2022 was global supply chain issues.

This has affected all manufacturing, especially electronics, as well as AMSAT Engineering. For the CubeSatSim, it has meant continually updating the Bill of Materials parts list with new parts sources. In addition, we had to make some substitutions as the availability situation changed. For example, we switched from purple INA219 current and voltage sensor boards to the larger blue INA219 boards. This resulted from low availability and high cost of the purple boards and an unacceptable failure rate of the purple boards.

The part availability we have yet to overcome is the unavailability of Raspberry Pi Zero single-board computers. The ground station can also use a Raspberry Pi 3B or 4B single-board computer, but any Windows or Linux computer can also be configured as the ground station. The CubeSatSim relies on the Pi Zero to run the software and act as the radio transmitter. So far, educational CubeSatSim projects have been able to continue using a stock of Pi Zeros that I accumulated in 2022, as it became clear that the availability of the boards was going to be an issue in the future.

Unfortunately, the supply disruptions of Raspberry Pi are likely to continue through at least 2023. As a result, the CubeSatSim Project Team has been working on new hardware and software that uses a Raspberry Pi Pico microcontroller instead of the Pi Zero. This has involved a significant redesign and rewrite as the Pi Zero software libraries are not generally available on the Pico. This work is still underway. A development version is shown in Figure 6.

Future Plans

We will continue making the CubeSatSim available for anyone to build and the loaners

Figure 6 — Development version of CubeSatSim using a Raspberry Pi Pico microcontroller instead of a Pi Zero.

available for any AMSAT member to borrow.

We hope the new Pico design will alleviate the Raspberry Pi Zero parts shortages while keeping the same functionality. We plan to have a Beta release at the start of 2023, with a full release in 2023.

We have also taken the opportunity of this redesign to plan for the availability of fully assembled CubeSatSims in 2023 - look for more info on this next year!

We also hope to make more educational materials available next year as the team releases documents.

Participating in the CubeSatSim Project

You can participate in the AMSAT CubeSatSim Project! Here are some of the ways:

- Document your CubeSat Simulator build and testing on social media.
- Offer to demonstrate your CubeSat Simulator to local schools, ham clubs, Makerspace or Hackerspace gatherings, or other STEM events.

The official CubeSatSim Project Twitter account is @CubeSatSim, and we use the hashtag #CubeSatSim to highlight our activities.

Conclusion

This paper updated the previous twelve months for AMSAT Educational activities and the CubeSatSim Project. Your suggestions and comments on improving the AMSAT CubeSat Simulator project are always most welcome!

Acknowledgments

We want to thank all the CubeSatSim Project team volunteers:

- Jim McLaughlin, KI6ZUM
- David White, WD6DRI
- Paul Graveline, K1YUB
- Fredric Raab, KK6NOW
- Mark Samis, KD2XS
- Sopwith, N1SPW
- Kerry Bonin, KJ7HTG
- Jim Nagle, KF4OD
- Virginia Smith, NV5F
- Chris Thompson, G0KLA/AC2CZ
- Christine Mehner, MD, PhD, KO4EWG
- Kai Ji, AC3EN
- Melissa Pore, KM4CZN
- Lindsay White, KI6LZN
- Randy Standke, KQ6RS

Thanks to Mark Spencer, WA8SME, for his trailblazing work on CubeSat simulators and the late Bob Bruninga, WB4APR (SK), 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.

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.

President's Club 2022 Members

REVISION A

The following members of the AMSAT 2022 President's Club have been added as of October 31, 2022. We thank them for their generous support and helping to keep Amateur Radio in Space!

The 2022 Year is rapidly coming to a close. If you have not yet joined, you can still earn your membership with distinctive five-color gold-finish coin, iron-on AMSAT logo patches and full-color certificate. Go to **www.amsat.org/join-the-amsat-presidents-club/** for more information.

Titanium ($4,800+)

Barry A. Baines WD4ASW
Alan P. Biddle WA4SCA
John D. Botti KC8OKB
William G. Brown K9LF

Platinum ($2,400+)

Ronald G. Parsons W5RKN (SK)

Gold ($1,200+)

Douglas Bessemer K0VPL
Burns Fisher WB1FJ
Joseph Lynch N6CL
John R. Kludt K7SYS
Glenn Miller AA5PK
Douglas B. Tabor N6UA

Silver ($600+)

John Boehme K4PRK
Warren Fugate W3WE
Mark Johns K0JM
Bruce Paige KK5DO
David A. Vine WA1EAW
Chuck Weaver W3VAR

Bronze ($300+)

Allen Kinney KK4K
Bruce Perens K6BP
Donald Pettigrew K9ECT
Scott Shaheen WB8OOJ
Thomas Talley K0CFI
Dave Taylor W8AAS
Ricky N. Walker

Core ($120+)

Oscar Alonso N6PAZ
Dwight Aussieker W9QJ
Steve Bachhuber K9SJB
Robert Brennan KC3CKV
Burlington Amateur Radio Club
George Carr WA5KBH
Michael Caughey N2BT

Jim Clary ND9M
Richard Dittmer KB7SAT
George Gallis AL7BX
David Grebe WA4LM
David Hartrum WA3YDZ
Stephen Howard AB0XE
Nels E. Knutzen W0PEC
Gailen Marshall N5GDM
Brendan McNeil ZL3BAM
Juan Munoz TG9AJR
Andrew Northam KE8FZT
Art Payne VE3GNF
Maxwell Rathbone W3POI
Jay Schwartz WB8SBI
Jason Schwarz N4JJS
Alton Simpson WA5TJB
Carl Starnes W4EAT
Paul Stoetzer N8HM
Christopher Wachs WA2KDL
Stefan Wagener VE4SW
Jeremy Wyatt KA2PFD

Share Your Experiences as an AMSAT Member

The AMSAT Journal is looking for you to share your satellite radio experiences, likes and dislikes, how you work the birds, and what you like about *The AMSAT Journal*. We'll publish a selection of responses in upcoming issues of the *Journal* under a column we're calling "Members Footprints." Photos are strongly encouraged! Thanks!

Please send the information requested below to journal@amsat.org --

- Your Name
- Call Signs Held
- Primary Grid Square
- Favorite Satellite Contact
- First Satellite Contact
- First Satellite Ground Station Description
- Current Satellite Ground Station Description
- Reasons You Are an AMSAT Member
- Favorite AMSAT Memory (a satellite contact, symposium, engineering project, event that would never have happened without AMSAT, etc.)
- Favorite Topics Appearing in T*he AMSAT Journal* (could include things like building a homebrew antenna, assembling a ground station, using tablets and smartphones, news of upcoming launches, portable operations, ARISS, etc.

Please Provide a Hi-Resolution Photograph (see www.amsat.org/?page_id=1709).

SatNOGS Ground Station at the School of Telematics

Omar Álvarez-Cárdenas, XE1AO;
Margarita G. Mayoral-Baldivia, XE1BMG;
Fermín P. Estrada-González, SWL;
José R. Herrera-Morales, SWL;
Armando Román-Gallardo, SWL;
Sara Sandoval-Carrillo, SWL.

Introduction

The University of Colima School of Telematics participates significantly in the TEPEU-1 mission. TEPEU-1 is a space project promoted by prominent educational institutions in Mexico, which consider the development of space technology for application in scientific and technological fields. This space project has the following objectives:

- A TEPEU space program will include the design, development, and integration of at least three missions: TEPEU-1, TEPEU-2 and TEPEU-3, for non-profit scientific research and technological development purposes.
- Development of a payload module to study the ionosphere layer and the space weather effects in this region.
- Integrate a ground station network based on amateur radio infrastructure to receive telemetry and scientific data.

The last objective of the TEPEU-1 mission is related to the ground segment of this project. Amateur radio stations worldwide will be invited to collaborate by receiving all the data of this space program. Most of the satellite ham radio operators have a local or mobile station to integrate the ground segment of the TEPEU-1 project (Mendoza-Bárcenas, et al. 2021). These satellite radio stations are composed of transceivers, low lost cable, Yagi antennas and rotors. All this equipment is not inexpensive nor easy to buy in most countries. The first TEPEU-1 satellite will include a ham radio FM voice repeater payload using VHF/UHF frequencies. This payload will send the primary telemetry and scientific information needed to integrate more ham radio ground stations worldwide. To increase the number of ground stations, the school of Telematics at Colima Mexico is testing low-cost ground station solutions to be integrated into the TEPEU space program.

The SatNOGS project is a global receive-only network of satellite ground stations. The network supports listening to most amateur bands with the ability to add custom bands and request to add new satellites to the schedule database (White, et al., 2018). With these facilities, the School of Telematics implemented an open ground station using the SatNOGS project.

SatNOGS

SatNOGS is an integral part of the Libre Space Foundation (LSF). The project aims to build a global network of satellite ground stations. It is designed as an open-source participatory project based on the users operating a ground station accessed via a web page for all the network users (satnogs.org/). A basic ground station can include commercial off-the-shelf components commonly available with a static omnidirectional antenna, with more complex stations adding multiple movable antennas (Nicolas, 2021). However, we can build our ground station using a non-rotator built with a simple RTL-SDR (USB software-defined radio) dongle and Raspberry Pi hardware (Szczerba, et al., 2020). With these options, we will get on the SatNOGS network quickly and easily to start scheduling satellite observations.

Once the client has been configured with information such as sampling rate, gain value, and geographical coordinates, the ground station is ready to be an operational asset and can be scheduled by the user and other operators on the network. The SatNOGS ground station at the School of Telematics will be ready to be included as a part of the TEPEU space program and the fourth ground station in Mexico on this platform.

Hardware setup

For the implementation of the SatNOGS network at our earth station, the following materials were used:

1. Raspberry Pi 3
2. 2.5A, 5.1V universal power supplies
3. 32GB Micro SD Memory
4. RTL_SDR Receiver R820T2
5. USB cable
6. Omnidirectional antenna
7. USB to microSD adapter

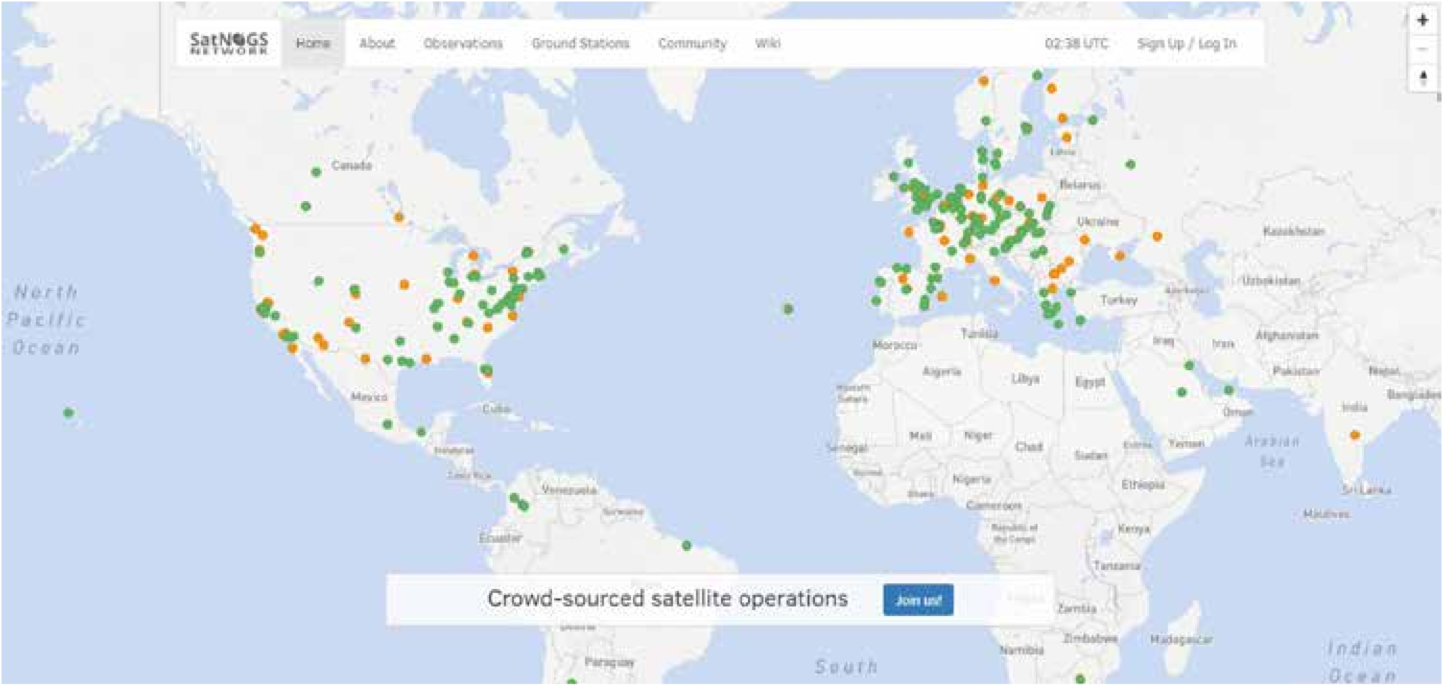

Figure 1 — SatNOGS Network Map.

The following programs implemented this practice:

- Tera Term (**bit.ly/3MeQ40J**)
- Raspberry Pi Imager (**bit.ly/3tbDZTw**) SatNOGS Network (**bit.ly/3NL6M8Y**)

Raspberry Pi Setup

The Raspberry Pi (v.3 or v.4) is the reference platform for SatNOGS. You can try using various distributions for this (Debian/Armbian, Arch, Fedora), but the one we suggest is our custom image based on the latest Raspbian. Download the latest Raspbian SatNOGS Image from GitLab. This image has the SatNOGS setup script installed, the SSH server enabled, and all required packages preinstalled. In addition, you will get an artifacts.zip file with the following content:

1. Zipped image files
2. Image info file;and
3. SHA256 checksum file.

To flash the SatNOGS image, we recommend following the instructions at [reference]. Once your Raspberry Pi is booted, log in with username "pi" and password "raspberry," and run: $ sudo raspi-config.

Be sure to:

- set a strong, unique password,
- Change localization settings:
- By default, the rpi locale is configured for EN-GB; change as appropriate (i.e.,

Setting	Description
SATNOGS_API_TOKEN	The API token is assigned to your ground station on the SatNOGS Network website, please do not share your API key as this can give access to anyone to upload and change things in network related to your station and its observations. To find your API token, log in to network.satnogs.org, click on the user icon at the top right corner and then click on the "Dashboard" option. On the top of the dashboard page right under the user icon click the button "API key" to show your API token.
SATNOGS_SOAPY_RX_DEVICE	If you are using an RTL-SDR, this is driver=rtlsdr. For other devices tested configurations can be found at [https://wiki.satnogs.org/Software_Defined_Radio]. See [https://github.com/pothosware/SoapyRTLSDR/wiki#modules] for other SDR modules (linked in the navigation bar at the right side of the page). If multiple devices are attached to your station you should also specify the serial of the desired device here, e.g. driver=uhd,serial=3164495.
SATNOGS_ANTENNA	If you are using an RTL-SDR, this is RX. For other devices tested configurations can be found at [https://wiki.satnogs.org/Software_Defined_Radio]. If your device has not been listed there yet, use SoapySDRUtil --probe 2>&1| grep Antennas to get available antennas.
SATNOGS_RX_SAMP_RATE	Specify the receiver sampling rate. Recommended value for RTL-SDR: 2.048e6 (for 2Msps), other devices will need different sample rates described at [https://wiki.satnogs.org/Software_Defined_Radio]. The command SoapySDRUtil --probe 2>&1 | grep Sample can be used to find all valid sample rates.
SATNOGS_RF_GAIN	RF Gain value for your SDR hardware. Run SoapySDRUtil --probe to see all possible gain values for your hardware. Example: For RTL-SDR without pre-amp, 32.8 is a good starting value. Follow [https://wiki.satnogs.org/Omnidirectional_Station_How_To#Setting_the_gain] to find a good gain value.
SATNOGS_STATION_ELEV	The height of your ground station above sea level in meters
SATNOGS_STATION_ID	The numeric ID assigned to your station in the SatNOGS Network site when the ground station was created.
SATNOGS_STATION_LAT	The latitude of your station. North is positive, south is negative.
SATNOGS_STATION_LON	The longitude of your station. East is positive, west is negative.

Table 1 — Basic configuration parameters.

Figure 2 — NOAA-18 Schedule Observation.

to EN_US.UTF-8)

- Set timezone (we recommend UTC)
- Set keyboard layout, again this is defaulting to a UK layout
- Expand the filesystem (under the Advanced menu)
- Configure network or WiFi
- Finish and reboot

SatNOGS Setup

Open an SSH connection to the Raspberry Pi with user "pi" and your new password. Before starting satnogs-setup, ensure the Raspberry Pi is up to date. This can be done with sudo apt update and then sudo apt upgrade.

To configure a SatNOGS Client system, follow the next steps:

1. SSH into the system and run sudo satnogs-setup to bring up the configuration menu
2. Set all options in Basic Configuration (see table 1 below)
3. Select Apply, and the Raspberry Pi will configure itself; this may take some time
4. Select Back to exit

Basic Configuration Table

If you want to optimize the station performance or enable support for additional features like antenna rotator control, the tables Advance Setup and Obsolete Setup Variables can be reviewed at **wiki.satnogs.org/SatNOGS_Client_Setup**.

Scheduling the first test observation

After completing these steps, you have set up your SatNOGS client successfully. Next, you must create an account on the SatNOGS main page and make a ground station, ensuring it displays ONLINE. Click on the name of your ground station and select the Upcoming passes tab. Look for a pass with a "schedule" button that isn't greyed out and click it. Make sure it is a good (high) pass of an operational satellite (check the color bar on the satellite). In the "New Observation" page that comes up, click the "Calculate" button, then click "Schedule." You should see a page for that observation in the "Waterfall" tab and "Waiting for waterfall." Now SSH to your ground station computer and run the following steps:

- Make SSH connection to your ground station.
- Follow the satnogs-client logs. Depending on your setup, this might be done with journalctl -f -u satnogs-client service or tail -F /var/log/supervisor/satnogs.log
- Before the observation is scheduled to start, you should see your client wake up once per minute to check for new jobs.
- At the scheduled time for the observation, you should see the client kick off the observation jobs.
- After the observation, you should see the client submit the data to the SatNOGS network.

In the SatNOGS Stage Environment, refresh the Observation page. You should now see a waterfall plot for your data. If that all worked, congratulations! You have just completed your first SatNOGS observation successfully. All the observations generate a collection of waterfalls with possible results according to the signals received. For example, if you receive a voice FM satellite signal, the waterfall will look like figure 3.

Conclusion

All low-orbit satellites need a ground station to receive telemetry and services (payload). Most ground stations are implemented with expensive and difficult-to-install equipment. Projects like SatNOGS, supported by the Libre Space Foundation (LSF), facilitate the implementation of low-cost ground stations to be used for free by any user. With this easy installation, the TEPEU-1 Space Mission will benefit from using the SatNOGS network as part of the ground stations that will be needed once the first of the satellites is in orbit. By the beginning of 2023, the School of Telematics will have implemented a ground station in the SatNOGS network to increase the number of stations of this type in Mexico. Additionally, it will be used

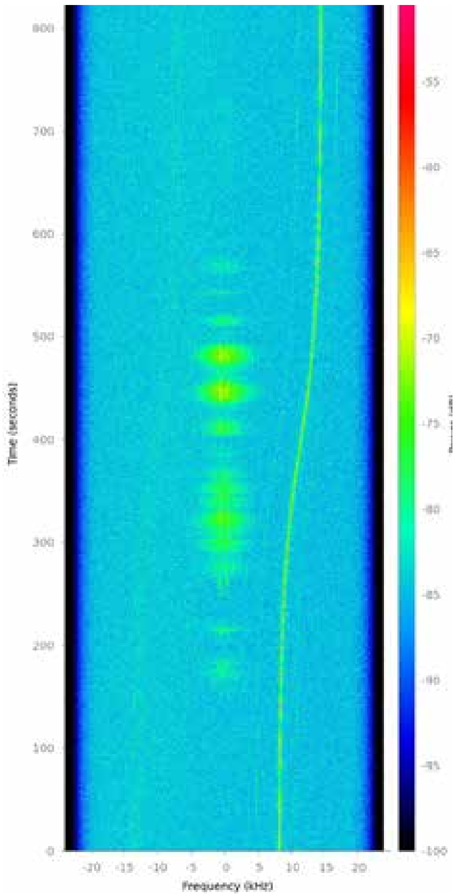

Figure 3 — Waterfall FM transmission.

within the TEPEU-1 project as a ground station with the capacity to receive the information generated by this Mexican space mission. You are invited to join this SatNOGS initiative by installing more ground stations worldwide.

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Tips for Starting ISS Satellite Operations

Shravika Pendyala, KQ4CUS

The Basics

- Call Sign used by American Astronauts: NA1SS
- Call Sign used by Russian Astronauts: RS0ISS
- Uplink Frequency = 145.990 MHz (PL 67)
- Downlink Frequency = 437.800 MHz
- ISS serves as a Cross-band repeater
- Supports Voice, Packet, and SSTV
- The ISS alternates every month between FM and CW/APRS. For example, September 2022 is for voice, October 2022 is for other modes, and November 2022 is for voice again.
- The ISS is not the only satellite that operates on a 2 m/70 cm cross-band
- Only a Technician license is required to work satellites!
- Unlike HF and VHF work, the ISS is not subject to poor propagation conditions.

The Set Up

- Because it is a cross-band repeater, you will need two antennas, one for each band. The most common setup is using a commercially bought antenna, but I have built my own Yagi antennas for both bands, so it is doable. Very commonly purchased antennas are the Arrow and Elk antennas ($130 - $170), both of which are cross-polarized--meaning both antennas are on the same boom, but the wires are perpendicular to each other. If you decide to build your own antennas, check out the bottom of this article for links to plans.
- Due to the cross-band nature, a full duplex operating mode is necessary. Ideally, you want to be able to listen as you are transmitting to ensure your signal is getting through, among other advantages. There are two methods of doing this, and both work just as nicely:

    1. Buying a full duplex radio
    2. Using two HTs, one on each antenna (one to listen and the other to transmit)

- If you choose to go the 2 HTs route, be aware that since the receiver and transmitter are so close to each other, they create a feedback loop into the mic. The easiest method of solving this is by using headphones for audio plugged into the audio jack of your radio.
- Avoid trees and terrain when possible; they absorb the signal on 70 cm. Ideally, an open field would be perfect, but if you're in the city, you can try the top of a parking garage to get a good elevation.

Tips Before Getting Started

- Get set up with satellite tracking software, whether it is from the AMSAT website (amsat.org/track) or n2yo.com. Find what works best for you, but either of these two links is an excellent place to start!
- Nevertheless, there are also a LOT of apps out there that can track satellites, and some even give you a 3D spatial view of the pass from your perspective. A good place to start might be Theodolite or GoSAT Watch for iOS users and AMSAT Droid for Android users.
- Before heading out to test, be sure to check the ARISS Current Status of the ISS page for updates on when the ISS will not be available for repeater operation due to maintenance, docking, experiments, etc.
- Understanding the Doppler effect: Because the ISS is moving at just about 17,000 mph, the Doppler effect significantly impacts the frequency usage for downlink and uplink. While it affects both the 2 m and 70 cm frequencies, it has a negligible impact on 2 m but a massive effect on 70 cm. An easy fix is to create memory channels, starting 10-15 kHz higher than the center frequency at AOS, and ending 10-15 kHz lower at LOS in increments of 5 kHz. Here is an example:
    - AOS: 437.81 MHz
    - A quarter of the time into the pass or upon starting to lose signal: 437.805 MHz
    - At Max Elevation Azimuth: 437.800 MHz
    - Descending: 437.795 MHz
    - LOS: 437.790 MHz

Tips for Operation

- In space, the ISS is constantly rotating and tumbling, meaning that the location of the repeater and its polarization changes. AKA polarization fading. To account for this, it is important to keep our antennas rotating to ensure the best polarization alignment. You will certainly find constantly rotating antennas if you check out videos of ham operators working satellites. It could account for almost a 20 dB drop if not done right.

- Logging Contacts: Due to the fast-paced nature of contacts using the ISS, it's easiest to record the entire pass so you can listen back and officially log them. Sometimes, you might find that you made more contacts than you remember!
- A commonly used and trusted recorder is the Sony PX470 digital recorder, which has a USB port and input audio line in. By pairing this with a headphone splitter plugged into your radio, you can have one line going to your headset and the other going to the audio recorder.
- A few minutes before the pass, mark the area around you: the AOS azimuth, Max El Azimuth, and LOS azimuth. One way to do this is by standing in a fixed location and marking the angles with chalk or traffic cones. This makes aiming very easy during the pass.
- If you prefer to avoid tracking the satellite's path and aiming your antenna just yet, an easy setup would be an omnidirectional antenna like an "egg beater" to start with.
- Once you hear yourself on the downlink, you can confirm that your setup works. This is another reason why having a full duplex mode is important.
- The Cardinal Rule for ISS Work: If you cannot hear anything, don't transmit. You will not hear yourself if you can't hear anyone using it as a repeater. Transmitting without a proper receiver can interfere with the existing contacts being made without you even knowing that you're making it through to the repeater. All in all, don't do this!
- If this is your first time working satellites as a whole, check out the AO-91 Sat. It is loud and clear with a wide footprint.
- It is very unusual for an astronaut to make ham radio contacts due to their hectic schedules; however, some astronauts are known to have fun with it when they can, so be on the lookout!
- Though the schedules of astronauts can vary, 8 pm UTC is when the astronauts get off work. If this happens to align with one of the passes over your area, pay extra attention, just in case.
- If you strongly seek an astronaut QSO, one strategy would be to leave out your antenna/radio set up all the time. That way, if an astronaut appears on the air, you have immediate setup access to get to work.

Etiquette

- Only transmit if you can hear the satellite first. Blindly calling disrupts contacts.
- Wait for your turn, and avoid stepping over existing contacts
- NEVER CALL CQ! It is very frowned upon.
- Use phonetics at all times--this saves a lot of time
- Minimize repeated contacts--give others a chance as well.
- Usually, a QSO lasts no longer than 10 seconds and involves an exchange of only a call sign and the grid square.
- Here is an example of what a standard QSO might look like assuming Person 1 call sign
  - = KQ4CUS; grid-square EM74 and Person 2 call sign = XXXXX, grid square = YYYY:
  - Person 1: KQ4CUS EM74 (call sign + grid square)
  - Person 2: KQ4CUS XXXXX YYYY
  - Person 1: YYYY Thank You/QSL
- Despite the short duration for each QSO, even getting in this bit of information becomes a challenge given the large number of people simultaneously trying to work the ISS. It is a fine line between aggression and avoiding stepping on other people's contacts.
- TIP: As soon as you hear the end of a QSO, announce your call sign along with the call sign of the person who just made the QSO.
- Due to the capture effect, the loudest signal usually wins in transmission. So even if you popped in your call right after a QSO, if someone else does it louder and stronger, their transmission will overtake yours. Just something to keep in mind.

Antenna Plans

- Just google Homebrew Antenna (DIY): WA5VJB Cheap Antenna Series. Many PDFs should appear.
- My personal antenna plans. I have previously scoured the web for designs, shortlisted them, simulated them using EZNec, and decided upon these. I added 30 mm extra to the length of each wire for both antennas to account for any losses and to make it easier to tune, which I did not need to do. Both operated nicely for the ISS frequencies using a simple 5 W HT.

My Story

I started my ham radio journey building antennas through our school's Science Olympiad club, where one of the competitions was WiFi antenna builds. I began with Yagi-Udas and Biquad Yagis for 2.4 GHz, and I only got into real ham radio when I attended one of the North Fulton Amateur Radio League's meetings by chance. I saw the sign posted outside while walking with a friend and got hooked on the idea. I received my Technician license in August and my General License in September, and I currently focus on Satellite operation but have yet to make a QSO on the ISS.

I look forward to exploring the many opportunities ham radio offers and am excited about what the future holds.

Acknowledgments

Thank you to all of my mentors at NFARL in Atlanta, GA. I couldn't have gone this far into ham radio without their help, mentoring, and guidance. Shout out to NV4C, K7SYS, KO4CUL, W4MSA, KO4VW, WE4AUB, N8SGZ, and W3WL for all their help on my journey! I could not have written this article without the help from K7SYS, and a huge thank you to N8SGZ for showing me the wonderful world of satellite operation.

No.	End 1				End 2		
	X (mm)	Y (mm)	Z (mm)	Conn	X (mm)	Y (mm)	Z (mm)
1	0	169.09	0		0	-169.09	0
2	145.8	162.18	0		145.8	-162.18	0
3	221.9	157.34	0		221.9	-157.34	0
4	341.1	153.825	0		341.1	-153.825	0
5	541.6	149.61	0		541.6	-149.61	0
6	752.8	149.795	0		752.8	-149.795	0
7	983.1	150.25	0		983.1	-150.25	0
8	1182	146.74	0		1182	-146.74	0

70 cm Antenna Dimensions: using a 2"x1" wooden boom and 10 AWG solid copper wire.

No.	End 1				End 2			
	X (mm)	Y (mm)	Z (mm)	Conn	X (mm)	Y (mm)	Z (mm)	Conn
1	0	-505.5	0		0	505.5	0	
2	260	-486.5	0		260	486.5	0	
3	465	-455.5	0		465	455.5	0	
4	985	-435	0		985	435	0	

2 m Antenna Dimensions: using a 2"x1" wooden boom and 8 AWG solid copper wire.

A Helmholtz Cage: Developing a "Time Machine"

Jonathan Brandenburg, KF5IDY
[2022 AMSAT Space Symposium]

Figure 1 — ISISPACE MagneTorQuer Board as listed on CubeSatShop.com (www.cubesatshop.com/product/isis-magnetorquer-board/).

Why?

This "presentation paper"[1] begins by describing the motivation that led my team to develop a seven-foot diameter Helmholtz cage. My employer, METECS, is briefly described later in this paper. For now, it is sufficient to say one METECS specialization is flight software, and METECS might want to develop and demonstrate flight software to control a satellite's orientation and orbit with a focus on CubeSats. In the CubeSat ecosystem, magnetorquers and reaction wheels are often used to control a satellite's orientation, and thrusters are evolving to change a CubeSat's orbit.

When developing software, an engineer must think about how the software will be tested and proven to function as expected. One way to test software is through unit tests, and algorithms may be further tested in simulation. For example, one may use Trick[2] to provide a simulation framework and EDGE[3] to provide visualization. A pure software simulation helps validate an algorithm but may not be sufficient to fully exercise hardware such as the aforementioned magnetorquers and reaction wheels. When interfacing with hardware, a hardware-in-the-loop simulation may be necessary. This paper will focus on the components for testing the magnetorquer detumbling algorithm.

What is a magnetorquer? A magnetorquer, also known as a torque rod, is an electromagnetic coil that can be energized to create a dipole that interacts with the Earth's magnetic field. In particular, an algorithm called B-dot uses the readings from a magnetometer to sense the Earth's magnetic field and create a resulting dipole using the magnetorquers to either attract or oppose the Earth's field to reduce the rotation of the satellite.

What?

How does one test an actuator that relies on the Earth's magnetic field in orbit? First, you create a device to reproduce an arbitrary magnetic field, including canceling the Earth's magnetic field, all while on the Earth's surface. The author saw such a device while touring the CubeSat lab at Cal Poly in San Luis Obispo and so knew the of existence and name of a Helmholtz cage.

A Helmholtz cage consists of three pairs of Helmholtz coils, with the three pairs of coils oriented along orthogonal axes. Each Helmholtz coil consists of two circular magnetic coils, with the distance between the coils and the radius of the coil being the same value.

One defining characteristic of a Helmholtz cage is its size. The field needs to stabilize, yielding a usable volume somewhat smaller than the size of the coils. A colleague of the author performed calculations and determined a volume consisting of an 18-inch cube would require coils with a diameter of approximately seven feet.

Another aspect of a Helmholtz coil is its desired field strength and the resulting requirement for power. The Earth's magnetic field ranges from approximately 0.25 to 0.65 gauss and is somewhat weaker at about 0.35 gauss[4] in low earth orbit.[5] Thus canceling the Earth's magnetic field at the surface and reproducing a magnetic field in low earth orbit requires the capability to generate a maximum of 1.0 gauss on each axis. Further calculations indicate a power requirement of 2 amps in 16 AWG magnet wire with 60 turns on each coil. The resulting resistance

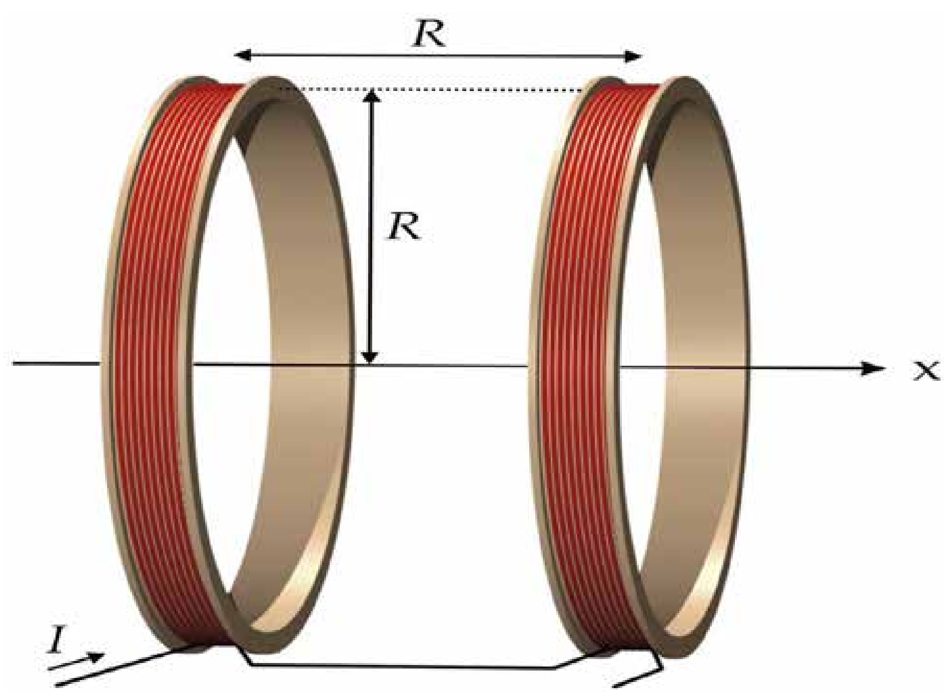

Figure 2 — Schematic of Helmholtz coil (en.wikipedia.org/wiki/Helmholtz_coil#/media/File:Helmholtz_coils.png)

Figure 3 — METECS Capabilities.

Figure 4 — 18" Helmholtz Cage.

on each coil was expected to range between 11.2 ohms and 11.9 ohms. The resistance of each pair of coils differs slightly as the coils are slightly different sizes to allow the coils to fit inside each other.

Who?

As noted earlier in this paper, the Helmholtz cage was a project undertaken by METECS, an aerospace engineering and applied technology company with a long history of providing high-fidelity simulation, software, robotics and analysis to NASA with contributions to the Space Shuttle, International Space Station, Orion, Lunar Gateway, and Artemis programs. In addition, METECS' customer base includes clients from many other industries, including agriculture, energy, construction, and sports marketing.

Admittedly, the author was a bit intimidated by the thought of building such an ambitious test fixture. So, what does he do? He assigns the work to summer interns! Jonathan Lephuoc and Adam Moore were two fantastic interns, and working with a tremendous mentor, Mike Zerkus, they tackled this project.

What, More?

To test the concept, the first effort was assembling a scale model Helmholtz cage, eighteen inches on a side. The build of the eighteen-inch Helmholtz cage was very successful, with only one notable surprise. When using the 16 AWG magnet wire, the resistance of the coils was less than would be experienced with the full-size cage making it a challenge to control the power in the coils using voltage-controlled power supplies. However, the discussion of the power system is generally beyond the scope of this paper.

The build of the full-size Helmholtz cage was a bit more challenging than the eighteen-inch Helmholtz cage, primarily because of mechanical aspects. In particular, the full-size cage proved challenging to strengthen and stiffen. As a result, the frame tended to "scissor," requiring careful reconstruction. In addition, the plastic wire trays used to hold the magnet wire sagged under the weight of the wire with the increased diameter of the coils. This issue was addressed by reinforcing the coils with fiberglass rods designed to create arches of netting in a garden. The result is quite impressive.

We faced one expected issue. The power supplies were only capable of generating positive voltage. What happens when we try to reverse the magnetic field as will be experienced in orbit? We considered a mechanism to switch the polarity of the power supply connections to the coils but eventually went with a power amplifier we could control from a LabJack[vii]. We decided to use PA74 amplifiers on the EK21 evaluation board from Apex Microtechnology[viii]. We're still assembling the power amplifiers but feel confident in the outcome.

One final piece of the puzzle remains. How does the satellite spin freely within the volume of the Helmholtz cage? Many ideas were considered. The most ambitious idea consisted of three concentric rings suspended by air bearings. Air bearings offer very little resistance and thus allow the rings to freely spin, subject only to air resistance.

Figure 5 — Full-Size Helmholtz Cage.

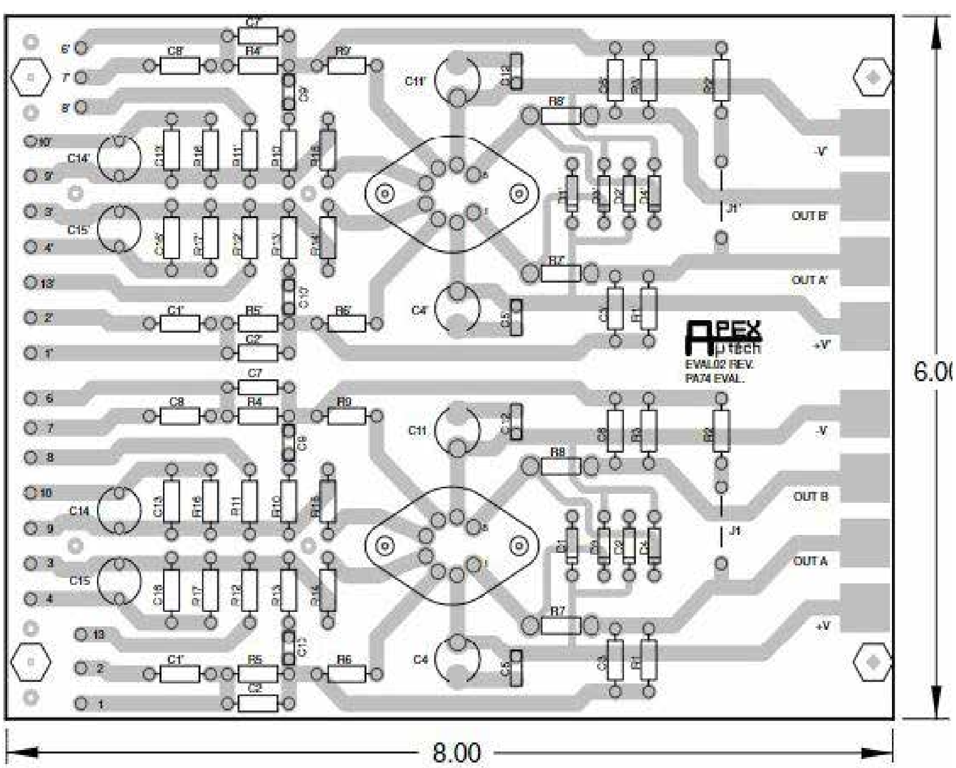

Figure 6 — Apex Microtechnology EK21 Evaluation Kit.

However, there was concern the inertia of the concentric rings would negatively impact the hardware-in-the-loop simulation and overwhelm the ability of the magnetorquers to slow the rotation of those concentric rings in addition to the satellite. A further issue was the challenge of routing air pressure to the interior rings to support the air bearings suspending the interior rings. In particular, we could not find a solution that would pass air through a rotating joint without adding substantial friction. Thus, the idea of three concentric rings was abandoned.

The current plan consists of a single air bearing holding the satellite allowing almost frictionless rotation around the vertical axis. A second, and potentially a third axis, will later be added using frames driven by motors with the motors controlled by a simulation controller. Extremely precise sensors monitor the torque driven by the satellite's actuators. The simulation controller reads this torque and changes the speed of the motors to simulate the effect on the satellite.

Time Machine?

John MacLean, the founder of METECS, printed a sign and placed it in front of the Helmholtz Cage (Figure 8).

Credits

METECS and the founder of METECS, John MacLean, deserve much credit for supporting this project and investing the necessary time, resources, and money in the development of this Helmholtz cage. Mike Zerkus deserves special mention as an extraordinary mentor.

Jonathan Lephuoc and Adam Moore, summer interns, were fantastic in their steady approach to identifying and resolving any issues experienced in constructing this Helmholtz cage.

Notes

1 The author uses "presentation paper" to describe a relatively informal paper light on prose that translates directly to a presentation.
2 **github.com/nasa/trick**
3 Engineering DOUG Graphics for Exploration, **software.nasa.gov/software/MSC-24663-1**
4 **www.ngdc.noaa.gov/geomag/faqgeom.shtml#What_are_the_magnetic_elements**
5 **image.gsfc.nasa.gov/poetry/ask/a10015.html**
6 **metecs.com/**
7 **labjack.com/**
8 **www.apexanalog.com/resources/products/ek21u.pdf**

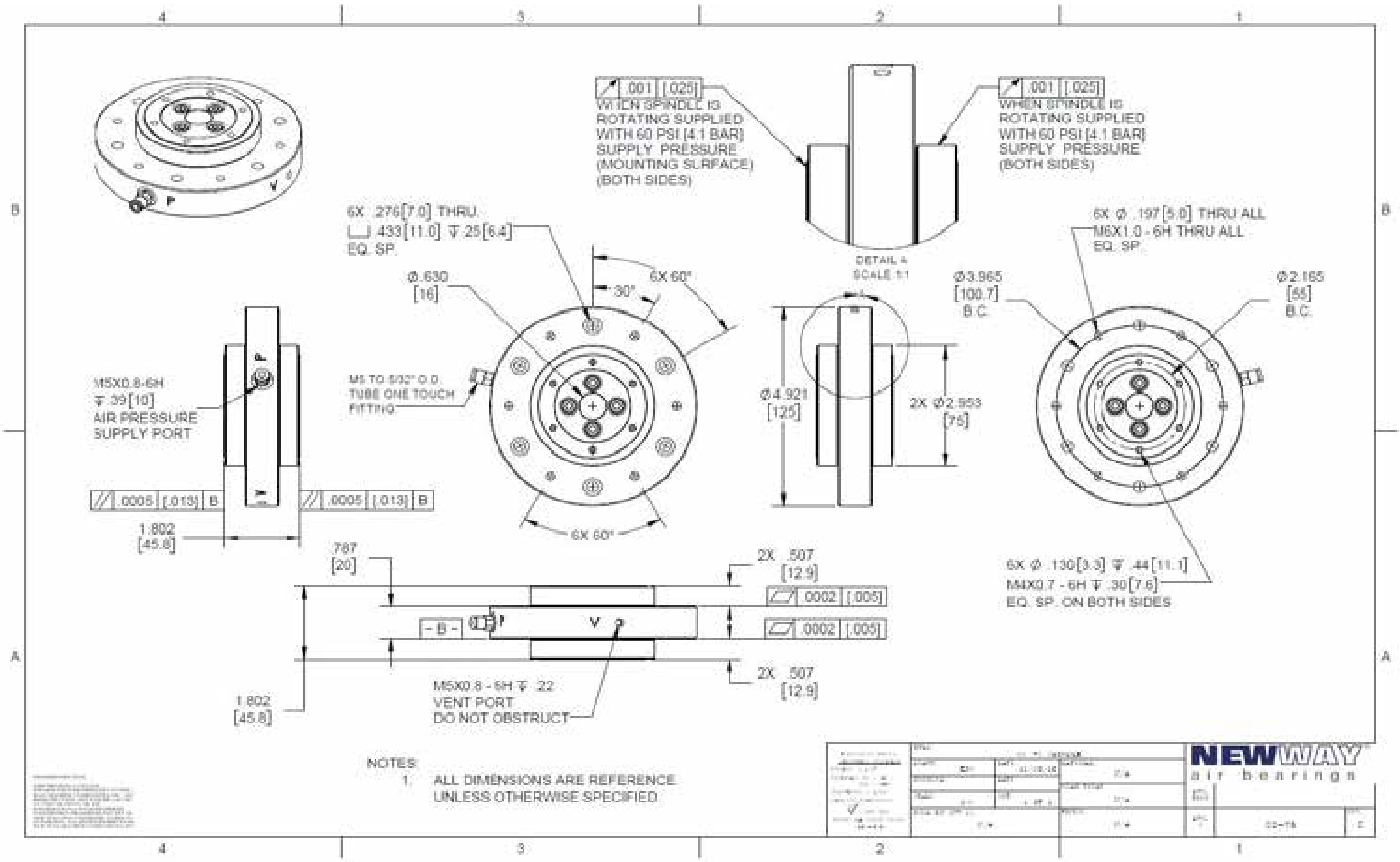

Figure 7 — New Way Air Bearings SS-75 - 75mm "T" Series Air Spindle (www.newwayairbearings.com/catalog/product/75mm-t-series-spindle-t-series-air-spindles/).

Figure 8 — Time Machine Warning.

Expediting the Deorbit of CubeSats

Bob Stricklin, N5BRG
[2022 AMSAT Space Symposium]

A longstanding Federal Communications Commission (FCC) ruling has required specific satellite missions to have a plan for deorbiting their hardware. Initially, the lifetime requirement for any spacecraft in low-Earth orbit was 25 years post-mission, or 30 years after launch if unable to be stored in a graveyard orbit[1].

The FCC recently made this requirement more stringent because of the growing proliferation of satellite missions. The FCC's new orbital debris mitigation ruling, FCC 22-74, requires non-geostationary satellite operators that terminate satellite operations in or passing through the low-Earth orbit region (below 2,000-kilometer altitude) complete disposal as soon as practicable following the end of mission, and no later than five years after the end of its primary mission.

This paper discusses a method to trigger a deorbit drag system that may be included in future AMSAT missions. The idea is to “make an effort” to support the deorbit requirements and hopefully show AMSAT and its partners can be good citizens in space.

There are two parts to this paper, first is to discuss a trigger mechanism to convert the space craft into deorbit mode. The second purpose is to suggest several methods to implement an expediting deorbit process.

Background

A satellite placed in orbit by the work of a rocket, providing kinetic energy, travels around the Earth at a velocity. While in motion, the satellite is exposed to several forces, including gravity (Earth, Moon, Sun, etc.), friction from the atmosphere, Lorenz–Mie solution of electromagnetic waves impinging on the body, and other forces. The Lorenz-Mie solution refers to light, mainly from the sun, which exerts a force on the spaceframe.

As a satellite goes through its lifecycle, each force will vary in contribution. However, gravity and atmospheric drag will be the most important.

This equation describing the satellite's motion because of atmospheric drag is shown in Equation 1.

$$\vec{a}_{\text{drag}} = -\frac{1}{2}\frac{c_D A}{m}\rho v_{\text{rel}}^2 \frac{\vec{v}_{\text{rel}}}{\|\vec{v}_{\text{rel}}\|},$$

Equation 1.

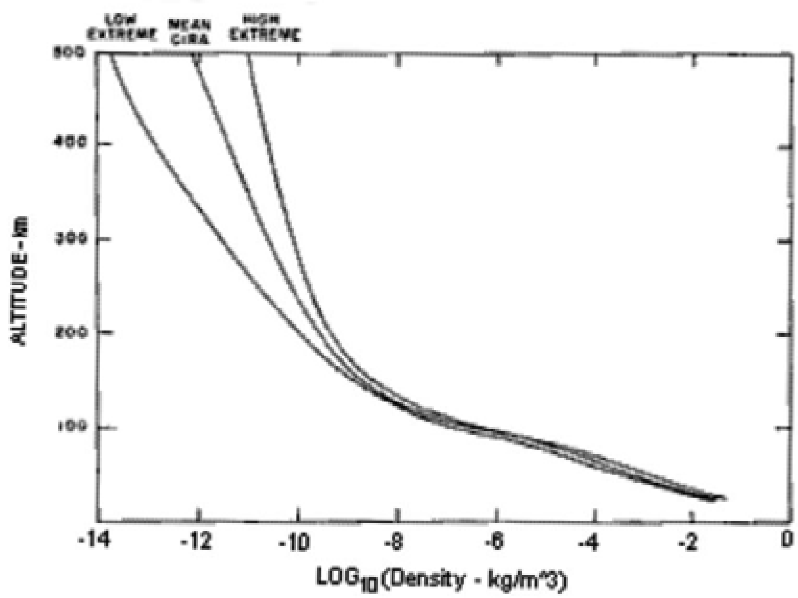

Figure 1.

Notice, if the mass is reduced, the drag will increase. If the exposed area of the surface is increased, drag will increase.

A deorbit concept can take advantage of the fact space is not a complete vacuum. Many need to realize there is a finite atmosphere of gas and other material which exist in the volume which makes up a typical low earth orbit (LEO) satellite orbital ballistic path. Existing CubeSats are hindered by this atmosphere. A graph of the Earth's estimated atmospheric density, known as the CIRA model, COSPAR International Reference Atmosphere, is shown in Figure 1.[7] COSPAR is the United Nations Committee for Space Research which was started in the early days of space exploitation[2]. The graph shown in Figure 1 includes the altitudes used by typical LEO satellites. The International Space Station ISS is at a mean altitude of 370 km and most of the AMSAT CubeSats are near or below this altitude.

Triggering FUSE

A passive method to take advantage of the drag or friction created by the atmosphere can be exploited if you can trigger the spacecraft to start the deorbit process and provide a method to increase your drag. For example, a way to begin the deorbiting process would be to take advantage of the degradation of plastic material properties when placed in space. The sun can be harsh and will bleach plastic-based materials causing them to lose their mechanical strength and eventually fail.

The proposal here is to study materials on Earth using accelerated testing with equivalent sun lamps and the sun. These types of tests are routinely done in quality assurance labs. Testing should also be added to future missions in space to correlate results.

Detailed studies on materials in space may also provide the information needed. Materials International Space Station Experiment (MISSE) is a program set up early in the ISS program to study materials. There is a detailed list of materials studied by NASA, and we can access some of this data[3].

Figure 2 illustrates a concept drawing of a CubeSat with a series of monofilament plastic lines placed on the corners. The idea

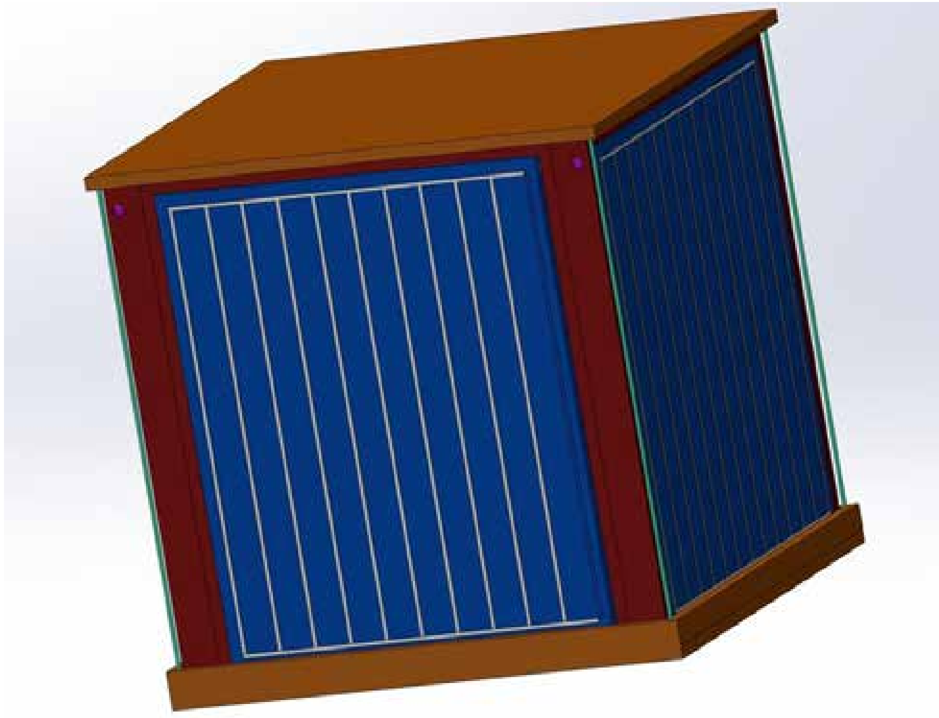

Figure 2A.

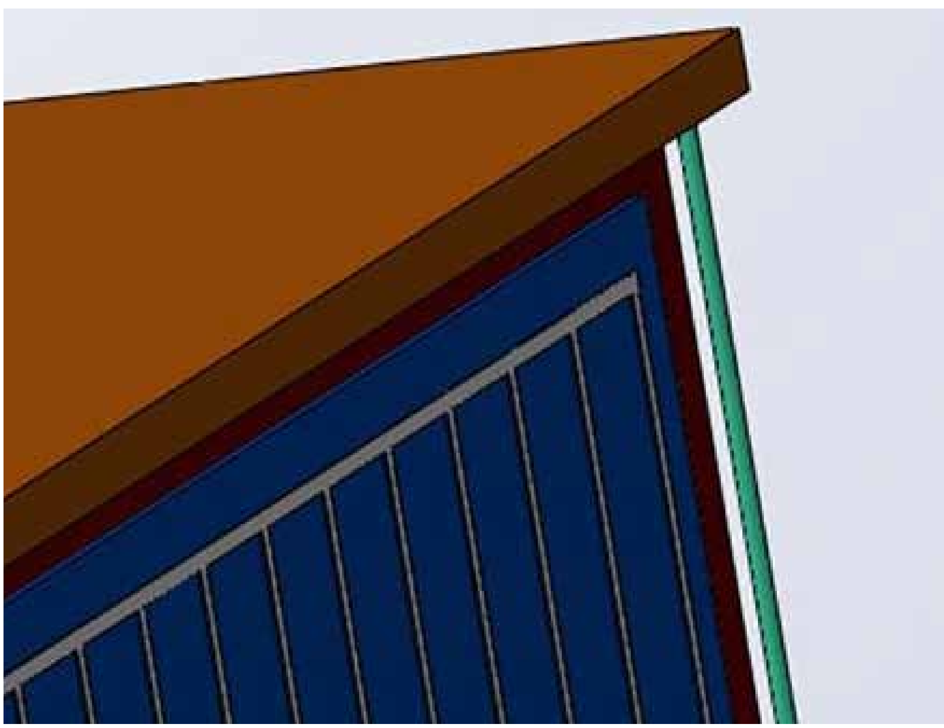

Figure 2B.

is to find the best material and determine the diameter needed along with stress on the line which will fail after years of operation. Essentially, build a trigger fuse. This system would not depend on the electrical systems of the spacecraft. Instead, the fuse would be self-triggering.

Each monofilament line would be threaded through the spaceframe of the CubeSat. Both ends of the line would be connected to a recoil torsion spring system to retract when the line fails.

These springs would also provide stress on the line, which will impact the time of failure. Finally, the line retraction would release a latch, allowing the CubeSat to expand or pop open like a jack-in-the-box.

A second method to trigger deorbit may be included, which can be triggered by the onboard electronics to expedite the deorbit plan if the CubeSat mission is considered complete or in danger of causing a problem.

Increasing Drag

A method being explored by others to expedite deorbiting involves increasing the drag of the spacecraft.

Flying through space with a known surface area and aerodynamics, which is the case with a CubeSat. After triggering a deployment mechanism, the surface area of the CubeSat needs to expand. One way of doing this, which is being studied, is to deploy a thin fabric that is tightly folded. The idea is to take up a minimum volume in the CubeSat. When the material surface is deployed, area and aerodynamics will increase significantly, and the possibility of affecting flight dynamics will increase, much like using a parachute.

Another approach would be to take advantage of the existing space frame by designing a mechanism to cause the frame to expand when the deorbit trigger fires. The idea would be to take advantage of the structure while preserving the precious volume. A method to do this would be to have the spaceframe expand. Figure 3 illustrates how the side walls holding the solar cells might hinge out based on a latch release and spring tension on the walls. The bottom plate, which may be cupped like a shoe box lid, will fall away from the main frame releasing the side walls and allowing some internal mass to separate from the base plate.

Then we have two bodies with different masses and different areas of atmospheric resistance.

After frame expansion, the surface area will be increased by a factor of four to five. Much of the area expansion would be in the main frame; however, the bottom section would be tethered to this main section and represent a different flying mass with added surface area. Referring to Equation 1, the result of expansion would be a 4 to 5 times increase in the deorbit acceleration, negative acceleration, or breaking due to the increase in area.

The effects of the atmosphere during the orbit will be nonlinear and complex. The most significant drag would occur at perigee on each orbit.

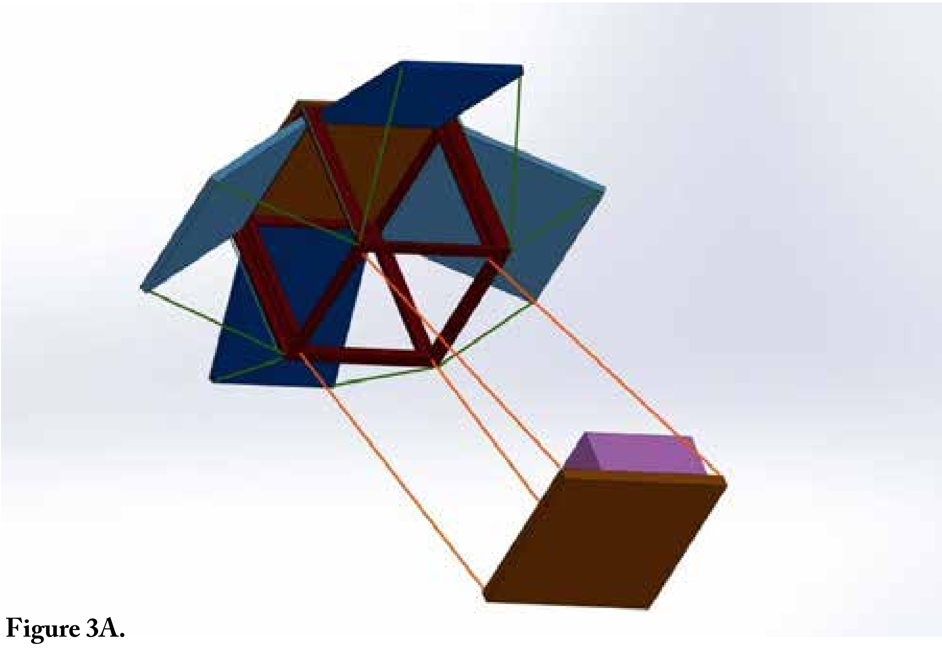

Figure 3A.

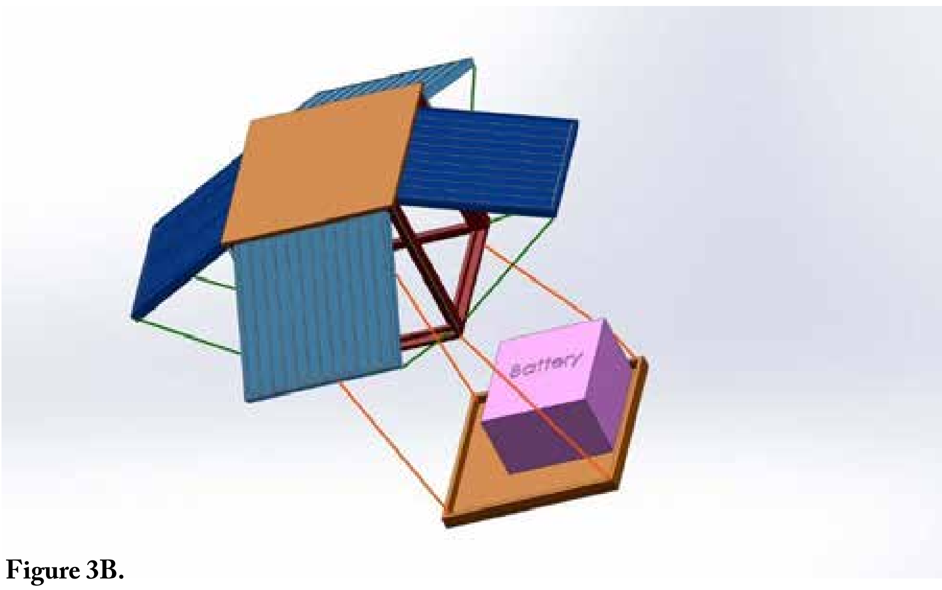

Figure 3B.

Additional secondary effects may be considered, like painting the underside of the frame, which folds out. If this underside has a net greater exposure to photons from the sun, moon and stars, then this surface may be painted white or made reflective to increase the deorbit forces on the spacecraft.

When the base's mass and the attached parts separate, this will remain tethered to the main frame. The idea is the craft must stay together as a single piece of space debris. The tether system would need a special design effort to ensure that, as the two bodies began to spin, the tether would succeed in doing its job correctly.

There may be an opportunity for aerodynamic designs on the main frame and have the tether pulling in an advantageous way to point the spaceframe down. The two masses will want to fall at different rates, and the larger frame will follow due to the larger area and increase drag resistance.[4] This should help keep the system capturing the maximum atmosphere and not tumbling.

Nowadays, you can find simulation software to test these ideas and tune a system like this. This would be a big project in itself.

This approach will require a lot of mechanical engineering design effort to build the hinging frame, latching system, spring design, and material study. Experiments to determine the best fuse material might include:

- Different diameters, spring tension, bends in material,
- Sun bleaching
- Earth-based testing
- Space-based testing
- Determine the statistical range of failure times.

Conclusion

AMSAT is working on getting CubeSats launched. While we may not want to consider deorbiting, we must address this issue proactively. Having a plan to help clean up our mess will get us into space.

A method was presented to trigger deorbiting and a second method to expedite deorbiting of a CubeSat satellite.

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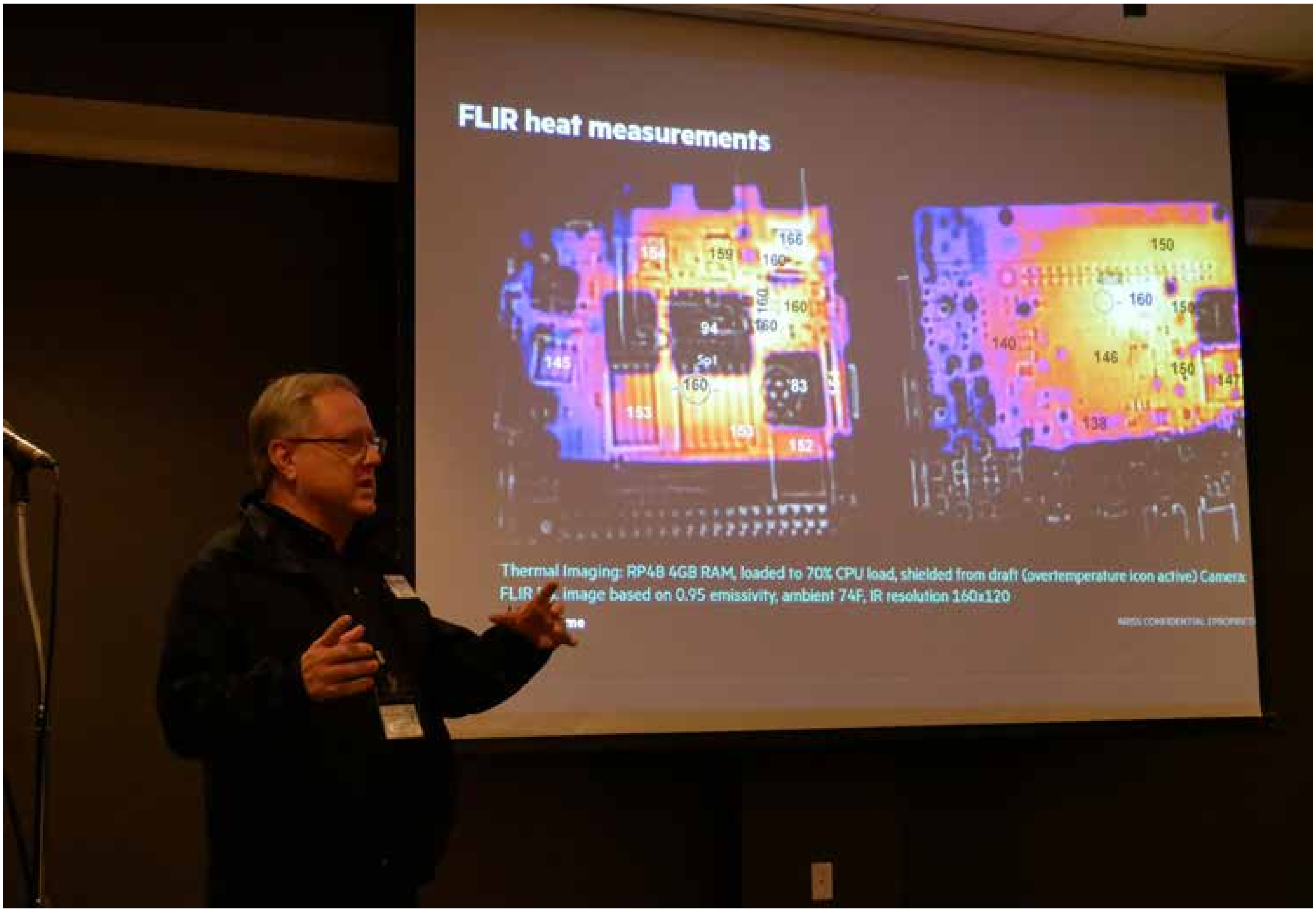
6. Jiaxiang Qin, Polymer Testing, **doi.org/10.1016/j.polmertesting.2020.106940.**
7. The graph presented can be found online. This is data provided by COSPAR under a CC license which may be found at c**reativecommons.org/licenses/by/3.0/legalcode**. No changes were made to the graph/data shown here. The data is provided to illustrate the potential impact of the atmosphere in space.

AMSAT-NA 40th Space Symposium and Annual Meeting

All photos courtesy of Jerry Buxton, N0JY


ARISS 2022 AMSAT SYMPOSIUM
Randy Berger
July 2022


FLIR heat measurements
Thermal Imaging: RP4B 4GB RAM, loaded to 70% CPU load, shielded from draft (overtemperature icon active) Camera:
image based on 0.95 emissivity, ambient 74F, IR resolution 160x120


LTM History – University of Washington
Radio Amateur Satellite Corp.
• First LTM University Partner
– HuskySat-1
– Taught us about the CAN bus (which we adopted for LTM)
• We updated the IHU board with CAN bus system
• We added CAN capability to LTM flight software
• They provided test boards to simulate their CAN messages for testing
• HuskySat-1 flew before Fox-1E (Launch Nov 2019)
– Mostly successful from UW point of view
– Command receiver flight proven
– Found AMSAT hardware and software problems
– Did not last long enough (power and/or transmitter) to spend time as a transponder


AIRE
MSP AIRPORT

AMSAT-UK North America Challenge

The QO-100 AMSAT-UK/BATC North American Challenge

AMSAT-UK and the British Amateur Television Club (BATC) announced a new amateur radio satellite service challenge, The QO-100 AMSAT-UK/BATC North American Challenge, during the AMSAT-UK International Space Colloquium in Milton Keynes, U.K. on October 8, 2022.

The QO-100 AMSAT-UK/BATC North American Challenge will recognize the first amateur radio station to successfully achieve a two-way QSO via QO-100 narrow band transponder while operating from North America, the first amateur radio station to achieve 100 QSOs via QO-100 narrow band transponder while operating from North America, and the first amateur radio station to achieve a successful two-way DATV QSO via QO-100 wide band transponder while operating from North America. In addition, subsequent operations from North America will also be eligible to apply for a special certificate.

The likely operating location from North America would be from St. Johns, Newfoundland, maidenhead grid square GN37qm (Lat/Long 47. 5204, -52.6262), which has a calculated viewing angle of -0.9 degrees elevation. Being below the horizon, it is expected that tropospheric ducting will be required for the first few miles, as demonstrated by Farid Farhan, YC1HVZ/P, during a recent QO-100 expedition in Indonesia, where he successfully operated through the QO-100 narrow band transponder from OI42de at -1.2 degrees elevation.

Detail of test being planned, general questions, and claims for trophies and certificates should be submitted to **awards@amsat-uk.org**.

Es'hail-2 / AMSAT Phase 4-A / Qatar-OSCAR 100, a joint project by the Qatar Satellite Company (Es'hailSat), the Qatar Amateur Radio Society (QARS) and AMSAT Deutschland (AMSAT-DL), is the first geostationary amateur radio transponder and links radio amateurs from Brazil to Thailand.

Es'hail-2/QO-100 carries two "Phase 4" amateur radio transponders operating in the 2400 MHz and 10450 MHz bands. A 500 kHz bandwidth linear transponder intended for conventional analogue operations and an 8 MHz bandwidth transponder for experimental digital modulation schemes and DVB amateur television.

[AMSAT thanks Graham Shirville, G3VZV, for the above information]

Join the 2022 AMSAT President's Club

And Help Return Amateur Radio to High Earth Orbit!

AMSAT is excited about developing and launching the next generation of Greater Orbit Larger Footprint ("GOLF") satellites. AMSAT has an immediate need to raise funds to cover development, launch and related expenses to *Keep Amateur Radio in Space*. We have set a fundraising goal of $125,000 to help keep AMSAT viable and effective in the competitive world of space communications.

GOLF-TEE (Technology Exploration Environment) is a rapid development satellite headed for LEO to fly and validate ADAC, deployable solar panel wing, radiation tolerant IHU, SDR and other technologies.

GOLF-1 is planned as a "High LEO" mission with a STEM payload in the progression of GOLF satellites.

With your membership, AMSAT is pleased to recognize your generosity. All members receive:

Commemorative Coin 2" with 4-color enamel accents and polished gold finish.

Full-color membership certificate

Embroidered 2.5" Iron-on AMSAT Logo Patch

Higher tier members receive even more benefits! You can join with a single payment or with twelve affordable monthly payments with your credit card. For payment by check or electronic transfer, contact Frank Karnauskas, VP-Development at N1UW@AMSAT.org.

Go to AMSAT.org/donate and join today!

Tier	Core	Bronze	Silver	Gold	Platinum	Titanium
Annual Donation	**$120 +**	**$300 +**	**$600 +**	**$1,200 +**	**$2,400 +**	**$4,800 +**
Journal Listing	X	X	X	X	X	X
Certificate	X	X	X	X	X	X
Coin	X	X	X	X	X	X
"RBF" Key Ring	X	X	X	X	X	X
Desk Plaque			X	X	X	X
TAPR/AMSAT Dinner @ Dayton				X	X	X
Symposium Admission					X	X
President's Symposium Lunch					X	X
Symposium VIP Recognition						X

Recognition items available for U.S. addresses only. For contributions from elsewhere please contact Frank Karnauskas, VP-Development at N1UW@AMSAT.org. AMSAT is a 501(c)3 corporation. Donations may be tax deductible. Check with your tax advisor. President's Club membership does not include AMSAT Annual Membership.

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