The AMSAT® Journal

Editor-in-Chief
Joe Kornowski, KB6IGK

Assistant Editors
Bernhard Jatzeck, VA6BMJ
Douglas Quagliana, KA2UPW/5
Paul Graveline, K1YUB

Volume 41, Number 6 **November/December 2018**

2018 William "Bill" Tynan Memorial AMSAT Space Symposium

in this issue ...

Periodicals
POSTAGE PAID
At Kensington, MD
and at additional
mailing offices

AMSAT
10605 Concord St., Suite 304
Kensington, MD 20895-2526

Support AMSAT Using your IRA

Those over age 70 1/2 may distribute up to $100,000 annually from their Individual Retirement Account (IRA) directly to qualifying charities, like the Radio Amateur Satellite Corporation (AMSAT), without first having to declare the distribution as income. That means your income will not increase, enabling you potentially to remain in a lower tax bracket for income taxes and possible Medicare premium surcharges. Donating directly from your IRA to AMSAT could have more tax advantages for you than a direct personal donation, depending on your personal tax situation.

To make this kind of donation, first contact the custodian of your IRA plan (e.g., the bank, mutual fund, brokerage, insurance company, etc.) that manages your IRA, and instruct that you wish to make a donation to AMSAT directly from your IRA.

The check from the custodian must be made payable to the Radio Amateur Satellite Corporation. Your custodian will then send you a 1099 form showing you, as the owner of the IRA, did not receive the income for your personal use. Most custodians will have you complete a direct donation form, and will mail the check directly to AMSAT.

AMSAT greatly appreciates any size donation from your IRA. Please call the AMSAT Office at 301-822-4376 for help with any information or mailing instructions required by your IRA custodian.

AMSAT strongly encourages those interested in supporting AMSAT through an IRA to consult with their attorney, accountant, and tax preparer or financial advisor to determine the implications and impact of such a gift on your personal situation. Thank you for supporting AMSAT!

The Amateur Radio Satellite Corporation, Inc., is an IRC 501(c)(3) organization (tax identification number 52-0888529).

Radio Amateur Satellite Corporation (AMSAT)
10605 Concord St., Suite 304, Kensington, MD 20895-2526
Telephone: 301-822-4376 – Toll Free: 888-322-6728
Facsimile: 301-822-4371
AMSAT Club Callsign: W3ZM
AMSAT Web site: http://www.amsat.org

The AMSAT Journal Staff
Editor-in-Chief: Joe Kornowski, KB6IGK, kb6igk@amsat.org
Assistant Editors:
Douglas Quagliana, KA2UPW/5
Bernhard Jatzeck, VA6BMJ
Paul Graveline, K1YUB
Circulation: Martha Saragovitz, martha@amsat.org

Editorial Office: Joe Kornowski KB6IGK, 5317 Musket Ridge, Austin, TX 78759. Please e-mail Journal submissions to: journal@amsat.org, Editor's telephone: 512-574-1233 (cell). Advertising Office: AMSAT Headquarters, 10605 Concord St., Suite 304, Kensington, MD 20895-2526, Telephone: 301-822-4376.

The AMSAT Journal (ISSN: 1407-3076) is published bi-monthly (Jan/Feb, Mar/Apr, May/Jun, Jul/Aug, Sep/Oct, Nov/Dec) by AMSAT, 10605 Concord St., Suite 304, Kensington, MD 20895-2526. Telephone: 301-822-4376, fax: 301-822-4371. Periodicals postage paid at Kensington, MD and additional mailing offices.

Postmaster: Send address changes to *The AMSAT Journal*, 10605 Concord St., Suite 304, Kensington, MD 20895-2526.

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

Joe Spier, K6WAO
President

For me, the past two months have been fairly intense. I attended the Duke City Hamfest in New Mexico, visited Gordon West in Costa Mesa, drove to Virginia and flew to Heathrow to be at the AMSAT-UK Colloquium in Milton Keynes, England, returned to Maryland for the ARISS-I Conference, spent a week in the AMSAT Office in Kensington, and then headed to the William A. Tynan W3XO Memorial Space Symposium and General Meeting in Huntsville, AL, before returning back out West for the holidays. My first year as AMSAT President has come to an end, and at the AMSAT Board of Director's meeting, I was elected to my second one-year term as AMSAT President. The BOD's main requests of me were to create a two-year, five-year and 10-year master plan. The two-year and five-year plans are to include the AMSAT Office, AMSAT's Golden Anniversary, and the GOLF projects. The 10-year plan will be quite flexible, basically suggestions to be refined and/or changed. Some of my major tasks this year will be to complete the member database update, promote international cooperation for both ARISS and AMSAT, policies, and AMSAT's Golden Jubilee at Hamvention and Symposium. The Huntsville team did a fantastic job this year at an exceptional venue, which everyone thoroughly enjoyed. Thanks go out to the Symposium team headed up by Chairman Robert Bankston, KE4AL!

I'll walk you through my extended tour starting with the Duke City Hamfest in Albuquerque, NM. Besides having an AMSAT booth presence, an all-day AMSAT Academy was hosted by me, Bill Ripley, KY5Q and Skyler Fennell, KD0WHB. We spoke on five topics: (1) AMSAT History 1957-1979, (2) AMSAT History 1980-2011, both of which included the Basics of Amateur Radio Satellites and Current Communications Practices, (3) Locating Amateur Radio Satellites and the Use of SatPC32 Tracking Hardware and Software / SatSat for iPhone, (4) Operating the FM "EZ-SATs," SSB/CW Satellites and Digital Modes which included Amateur Radio Satellite Station Antennas, Radio Equipment and Accessories, and (5) the Future of Amateur Radio Satellites. These presentations will become the foundation for a group of AMSAT approved PowerPoint presentations for the AMSAT Ambassadors program. Many thanks to Bill and Skyler! I also spoke at the farewell breakfast on Youth Outreach in AMSAT and ARISS.

On the way back to Reno, I stopped in Costa Mesa, California, for a visit with Gordon West, WB6NOA, and his lovely spouse, Suzy, N6GLF. Episode 369 of HamNation aired September 26th and may be seen at twit.tv/shows/ham-nation/episodes/. After a quick stop in Reno, Carolyn, KF6JQE, and I headed across country to Dulles International in Virginia for our flight to Heathrow Airport outside of London. I drove up to Milton Keynes where the Radio Society of Great Britain (RSGB) and AMSAT-UK were having their Convention and Colloquium. I spoke at the AMSAT-UK Colloquium on "50 years of AMSAT and Beyond." Among the many great talks over the next days were the European Student Earth Orbiter (ESEO) satellite, the FUNcube programs including ESEO & JY1Sat, Es'Hail-2, and other talks. Other activities included an ARISS Contact with Serena Aunon-Chancellor, KG5TMT on the ISS. I was also able to operate from the RSGB's National Radio Center (NRC) at Bletchley Park. The AMSAT-UK Banquet was great fun as were the animated discussions to the wee hours of the morning on all things satellite and space-related. Cheers go out to Jim Heck, G3WGM, Graham Shirville, G3VZV, Dr. Chris Bridges, M0IEB, Cairan Morgan, M0XTD, Dave Johnson, G4DPZ, Trevor Essex, M5AKA, and all the AMSAT-UK team, especially the Sargent-Major.

I returned to the U.S. on October 16th for the annual ARISS International Face-to-Face Meeting at the College Park Airport & Museum in College Park, MD. I attended the second day of the first-ever ARISS Education

Summit that was held at the facility.

At the international meetings, ARISS delegates and team members from around the world presented and listened to talks on all aspects of ARISS, from operations to education to hardware, current and upgrades to future projects. The team heard the latest news on HamTV, the Interoperable Radio System, and the antenna change-out required by the Bartolomeo platform, potential Astrobee activities, HamTV II, Radio-Pi projects, and crew scheduling. The team was particularly interested in a presentation by John Guidi, NASA Gateway Utilization Manager, who said ARISS is the only non-commercial entity whose ideas are being considered by the Deep Space Gateway program. Team members enjoyed viewing a live-streamed ARISS contact in Belgium. On the last day, an ARISS contact took place between meeting attendees and Serena M. Auñón-Chancellor, KG5TMT.

At the ARISS Education Summit, attendees included: educators from the U.S. and other countries; ARISS-US Education Committee members; and STEM educators from College Park Airport Museum, NASA Goddard Space Flight Center (GSFC), Space Communication & Navigation (SCaN) & NASA GSFC Education Office; NASA HQ SCaN; CASIS/SSE leaders; ARISS-I delegate/attendees, SCaN-sponsored educators from the mid-Atlantic region; and University of Maryland educators and students. They saw a demo of ARISS Slow Scan TV and several ham satellite contacts. One of the ARISS-US Education Committee teachers brought eight of her students to give talks about their STEM studies. Other committee members were part of a panel session discussing educator perspectives on ARISS and gave presentations on the ARISS education proposal process and orbit prediction programs. Astronaut Paul Richards led a discussion on space and education. CASIS' Dan Barstow spoke on exploring with the ISS, and Jimmy Acevedo/SCaN presented on kit-based learning. Attendees toured Goddard Space Flight Center and the ARISS K6DUE ham radio station.

ARISS-I and AMSAT Vice President for Human Spaceflight Frank Bauer, KA3HDO, ran an excellent meeting with hosting a get together at his home and coordinated tours and banquets through the week. ARISS-I agreements with RosCosMos will fly one of the new modified Kenwood D710's no earlier than the Progress-72 Resupply Mission scheduled for February 2019. The replacement Packet Module flew on Progress-71 that was launched on November 16th and docked with the ISS on November 18th. ARISS hopes to have the packet module operational in the Columbus module shortly.

I then spent a week with Martha in AMSAT office in Kensington, MD. I reviewed various office processes and equipment, a new lease agreement, and the status of the needed database work. I also met with our accounting firm, interviewed some consultants and prepared the BOD Agenda for the BOD meeting the following week. I arranged to have dinner with Dr. Perry Klein, W3PK, AMSAT's Founding President and Paul Stoetzer, N8HM, AMSAT's Executive Vice-President. Perry provided me with the 2 m/10 M circuit board that Dick Daniels, W4PUJ(SK) designed for AO-6/7/8 that spent a little too long in environmental testing (Dick's oven) for our auction at the 50th Anniversary Symposium. After picking up the symposium proceedings book and the award certificates, Carolyn and I headed for Huntsville with a short trip through the Great Smokey Mountains National Park for the fall colors.

The AMSAT 36th Annual Space Symposium will always be remembered as the William "Bill" Tynan W3XO Memorial Symposium. The BOD meeting was held at the hotel with all directors and officers present. Unfortunately, our two alternates for the board could not attend. The BOD Meeting was pretty standard with financials, department updates, election of officers, and regular AMSAT business. We were able to pass the 2018/19 budget before adjourning.

The Symposium itself was held at the U.S. Space and Rocket Center Educator Training Facility (ETF) The talks were exceptional and, if you missed them, they are available on the web, as is the digital version of the 2018 proceedings (available on the AMSAT store). The Symposium also had an ARISS contact between meeting attendees and Serena M. Auñón-Chancellor, KG5TMT, making it my third ARISS Contact in four weeks. An APRS balloon launch followed the ARISS contact. The banquet under the Saturn V was truly memorable and included access to all the exhibits in the Davidson Center including the Apollo 16 Command Module. Justin Foley's (KI6EPH) presentation on the Mars 2020 Rover capped off the evening quite well. The final day included an AMSAT Ambassadors breakfast and tours of the U.S. Space and Rocket Center and Marshall Space Flight Center.

The Es'hail-2 satellite with AMSAT-DL's Phase-4A transponder was launched successfully on Thursday, November 15 from Launch Complex 39A (LC-39A) at NASA's Kennedy Space Center in Florida. I applaud the joint Qatar Amateur Radio Society (QARS) and AMSAT-DL's achievement, the result of six years of work. To be a first at something in space is indeed a rare honor. It is this type of honor that AMSATs around the world work on every day. I spoke with Peter Gülzow, DB2OS on November 17th and wished AMSAT-DL success with the next part of their mission to be the first amateur radio linear transponder in geostationary orbit.

AMSAT Fox-1Cliff launched on December 3 and is now in orbit as AO-95. The SSO-A mission successfully carried several amateur radio satellites, including AMSAT's Fox-1Cliff, FUNcube on ESEO, JY1-SAT, K2SAT, and ExseedSat.

As one of my assignments as President, AMSAT's Golden Jubilee at next year's Hamvention and Symposium will include a 1969 theme and an "OSCAR Park" display. Please make your plans now to attend Hamvention at the Greene County Fairgrounds in Xenia, OH on May 17-19, 2019, as well as our Symposium for 2019, which will be in the Washington DC/Baltimore area, tentatively planned for mid-October 2019. Our chairperson for next year's Symposium is Ms. Melissa Pore, KM4CZN. Any help to provide fun and distractions on the 50th Anniversary would be much appreciated.

AMSAT now has a Vice President of User Services, Robert Bankston, KE4AL, who was elected by the board on November 20, 2018. I want to welcome Robert to the Executive Team in filling a position that has been vacant for far too long. Robert has taken on the task of essentially providing the AMSAT membership with the services that our members expect in the 21st Century.
I look forward to working with him. The AMSAT Vice-President of User Services is the team leader for the AMSAT News Service (ANS), The AMSAT Journal, Dayton Hamvention, Contests and Awards, AMSAT Ambassadors, AMSAT Nets, AMSAT Website, and Electronic Communications.

I hope you all enjoyed the holidays and will participate with AMSAT on the satellites. I encourage you to do your part, whether that's operating the satellites, giving AMSAT or ARISS support, or bringing dollars or new members to our organization.

Engineering Update

Jerry Buxton, N0JY
Vice President, Engineering

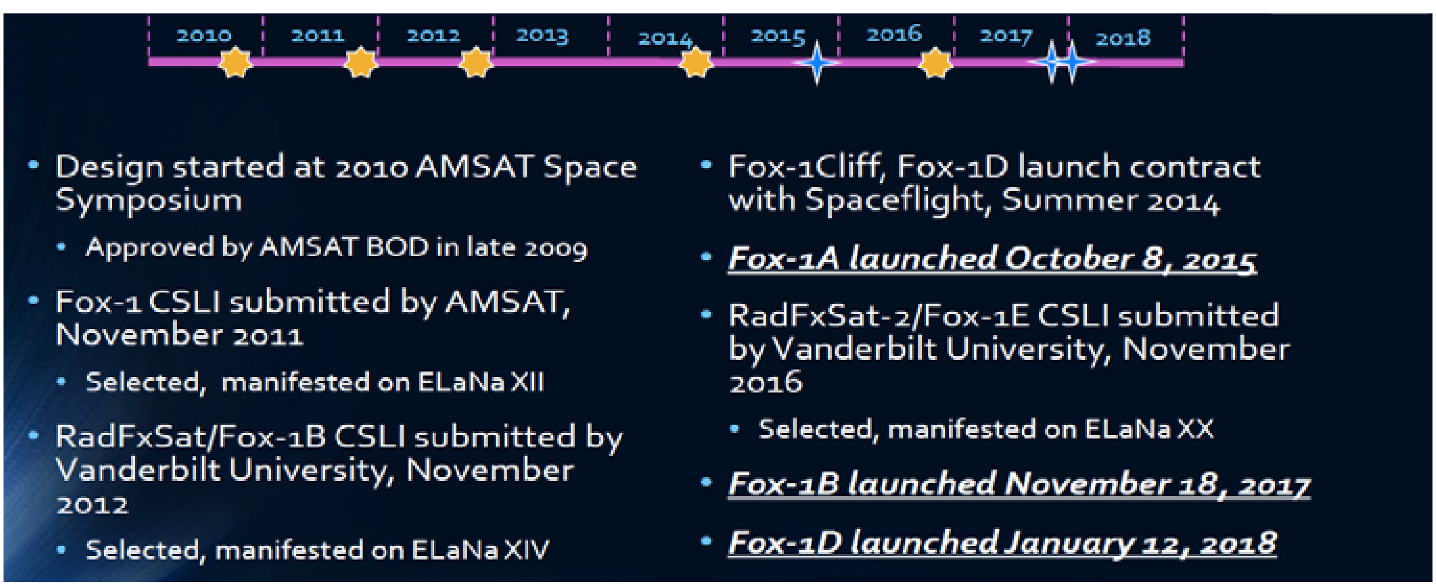
The level of what AMSAT Engineering produces is almost entirely driven by the engineers who volunteer their time and hard work toward a project. As with any ham radio organization, AMSAT is an organization of hobbyists, and the level of attraction and participation — the building-satellites kind — comes and goes as older volunteers taper off and younger volunteers come in with different capabilities and interests. Building the expertise and size of the team that we need to get a satellite into orbit is not easy. I think that behind the scenes is appropriately but unfortunately an unknown and misunderstood part of what goes on. You might certainly slap some components together and get a launch from ISS for something, but we all tend to like a spacecraft that is robust enough to survive in space for as long a life as possible, so it takes much more work that one might think at first look.

In addition, even within the engineers, differences of opinion arise over what we should do. The result has been some great moments with the production of a new or different type of satellite such as the pacsat and even the Fox-1 FM CubeSats. We have gone from LEO beepsats to LEO communication satellites to higher, Phase 3 HEO and then Pacsats and Microsats on to AO-40; and that had as much to do with the skills of the volunteer engineers as what we ham users wanted. Geostationary orbit is one of AMSAT's dream goals, but it may not be everybody's cup of tea, despite anyone's particular opinions or leanings. Es'hail 2 P4A is as much a product of opportunity and available skill as anything else AMSAT has produced, and happens to have been that opportunity that many have sought as the Holy Grail. Also, there have been occasions where AMSAT has been less than productive due to disagreement among the engineers over what or how it should be done.

The Fox-1 FM satellites were intended to be AMSAT's first CubeSat, which is the form factor of choice and affordability nowadays, and an EasySat that would bring the opportunity for more hams to explore and possibly get the satellite bug without a great investment. At the same time, we began with a new team of volunteer engineers and the opportunity to learn CubeSats while learning about the not-so-easy feat of engineering a viable and robust satellite. The idea wound up being very attractive and successful with partners wishing to fly experiments in our free science slots. That drove the rapid production of four Foxes, the growth of partner opportunities beneficial to AMSAT, and a fifth Fox from leftover parts that the engineering team had grown and extended to flying a linear transponder. The Fox-1 program is popular with many hams and was a necessary and important part of AMSAT at this time. It may not be what all of we wanted, but it is what we had the resources to create. And that grew an engineering team toward tackling bigger, higher, and much more complex projects such as GOLF.

One thing to keep in mind is that it takes a relatively long time to produce a GOOD satellite with a bunch of volunteer hams. The six years from approval to launch of Fox-1A may seem like forever to users waiting for a new bird, but it is hardly enough time to the volunteers giving as much free hobby time as they can, which can be a lot. DJ7WL pointed out that Es'hail P4A was years in the making and at least partially the result of essentially a lucky opportunity. The overall cost and scenario of Es'hail aside, the fact is that Bob McGwier and some others have worked tirelessly to find a hosted ride to GEO or get P3E to orbit, and for us in the U.S., it's going to cost an amount of money that has so far been unobtainable. I won't comment on the cost because I did not do any of the negotiating, so it's not my place. However, it is, in fact, single-digit millions of dollars. That's just the way it is right now.

On top of that, the current situation is that AMSAT-NA satellites have been proudly "Made in the U.S.A." because of ITAR and Export restrictions, not simply because we wanted to do it by ourselves. I am quite proud of what we have done by ourselves, but there would be a lot more volunteers, expertise, and money if we could undertake



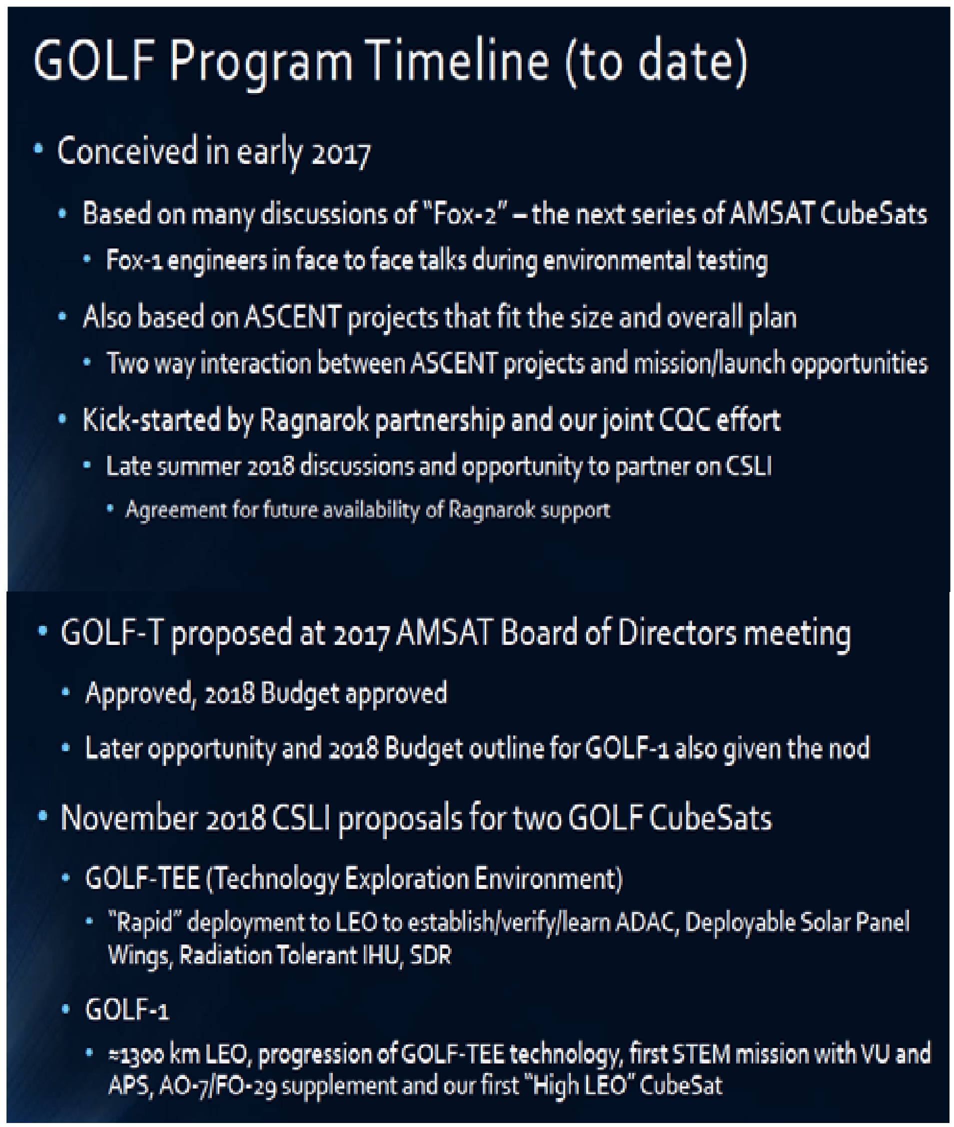
a multinational (multi-AMSAT) project like P3D again and that is what it currently would take to get to an AO-40 size HEO orbit again. AMSAT is working on being able to again have partnerships with other AMSAT chapters, and the amount of paperwork, time, money, and training needed on both sides of the agreement to achieve that is a bit of an undertaking, but we will get there.

In the meantime, as others have said, we are looking at many opportunities to get places, and that is not lip service. I know because I get to do a lot of looking and work in getting agreements. Competition is fierce with the abundance of CubeSat projects especially wanting to get a free ride, and that includes some government CubeSats. Everybody wants to take advantage of any offers of our (taxpayers) free money! Many things are going on that will remain unsaid until and unless something is concrete and that is for good reason. Witness P4B, the Virginia Tech pursuit of a GEO satellite, which AMSAT agreed as part of our MOU with VT to provide engineering support for if/when VT asked. Once word of a GEO satellite project was out, that quickly became AMSAT's pursuit of Phase 4B, and it was underway and would be launching in a year or two. People still ask when AMSAT is going to launch P4B and get disappointed with AMSAT when they find out that it won't be soon. And so AMSAT becomes the "can't do" organization overnight.

I try to share as much as I can in videos of the Fox-1 work, but a giant information void still exists for all who await a new bird without having updates properly and continuously streaming so everyone can know more. The current engineering talent and devotion by our volunteers are lined up to take us back to HEO and beyond, but until and unless the volunteer desires grow and the number of volunteers grows, that achievement will be a step by step process as we learn how to do it as we go along. I do not want to put even half a million bucks in a one-shot flight to HEO without having a very confident feeling that it will be successful. Would you like us to collect $500k in donations and screw it up to try to make we hams happy with a HEO bird real soon? So, it either means that nothing happens for many years while we build up our team and build this one-shot flight or we go along the way we have planned with the capability that we currently have to get there and still put up satellites along the way as we grow. I say "one-shot" flight because raising half a million is not as easy as you might think, and if it doesn't work then good luck trying to get another half million to try again. Look how many people bailed when AO-40 had an "oops." I will not call what we do rocket science because of personal semantics, but it is very much space science. And our volunteers are rightly proud of what they do. And nobody wants to screw up on their project whether it's a crystal radio or a HEO satellite.

As an AMSAT Director and VP of Engineering, I want to achieve all of the stuff that hams want to see, but as a Director and VP of Engineering, I also would be remiss if I told a group of volunteer engineers "this is what you are going to do." We're hams, not employees.

As always, we are happy to have new volunteers! Please do consider that, there does seem to be an unfortunate ratio of volunteer desire versus volunteer commitment. I can only be honest and say that the work is probably more than many think it is going in, and unless you have been in the satellite business it is understandably not what you might expect compared to building something in/for your shack. Though I've already acknowledged here the hard work of our volunteers, I'll just add that everyone is welcome to participate. Just please be honest about whether you actually can participate or not, and then if you are in let's have some fun! As a volunteer engineer, you can shape the future of AMSAT every bit as much as those who run the joint. ASCENT (our skunkworks, the Advanced Satellite Communications and Exploration of New Technology) is also an avenue for you to play in a sandbox and come up with new things for future satellites if you have the desire and time but do not fit into the current project. Several of the systems in GOLF are the result of ASCENT teams developing new ideas.



Educational Relations Update

Alan B. Johnston, KU2Y
Vice President, Educational Relations

Pat Kilroy, N8PK, and Alan Johnston, KU2Y, with the new AMSAT CubeSat Simulator at the 2018 AMSAT Space Symposium.

As I write this, I am back only a few days back from Huntsville after attending my first ever AMSAT Space Symposium. It was a great experience. Besides getting to meet my fellow AMSAT members and hams, experiencing a group ARISS contact with astronaut Dr. Serena M. Auñón-Chancellor, and having a close encounter with a Saturn V rocket, I got to present, along with Pat Kilroy, N8PK, the new AMSAT CubeSat Simulator.

The term "simulator" has a lot of different meanings in engineering depending on the context and who you talk to you. In this case, the CubeSat Simulator simulates many of the functions of a real CubeSat nano-satellite. For example, it transmits telemetry on UHF about actual voltages, currents, and temperatures that it senses. That telemetry can be picked up with a simple SDR (software defined radio) ground station and decoded, graphed, and analyzed in a spreadsheet. It also runs on batteries with solar panels to charge the batteries. The simulator also looks somewhat like a real CubeSat, with a 3D printed frame that mimics a 1U CubeSat.

Many of you will be familiar with the ARRL ETP CubeSat Simulator built by Mark Spencer, WA8SME, about ten years ago. The new simulator was designed to replicate many of those same functions but with a software and SDR focus to hopefully make it extendible and expandable.

In Huntsville, we enjoyed showing it off, even if I had a slight glitch in my demo (see photo).

For the details of the simulator, read the companion article in this month's Journal. The article is based on our 2018 AMSAT Space Symposium paper, but with a few new ideas based on feedback we received at the event. The article also includes the links to our GitHub repository which now includes WAV files of the telemetry and the spreadsheets used to analyze the telemetry. We hope to get more feedback from readers of this issue, as well. This CubeSat Simulator is not a finished product; instead, it is a proof of concept prototype, showing our vision and ideas. Over the next few months, we will work with beta builders and beta testers to refine our design. If you are interested in being a beta builder or beta tester, please email me **ku2y@amsat.org** or Tweet to me, **@alanbjohnston**.

Our goal is to manufacture four prototype units in time for Hamvention, where we will officially kick off our CubeSat Simulator program. These units will be loaned to schools and workshops and hamfests to help AMSAT fulfill its educational mission. We also hope that the CubeSat Simulator will be a way to engage the maker community in amateur radio and satellites.

One new idea from symposium feedback relating to the CubeSat Simulator is the CubeSat Simulator Lite concept. While Pat and I had been focusing on the maximum functionality out of the simulator, we had some requests for a minimum cost, minimum functionality simulator. To build a CubeSat Simulator Lite, all you need is a working Raspberry Pi, any version (the cheapest complete kit I've found is a Pi Zero W kit containing a Pi, micro SD card, and power supply which sells for about $35) and a piece of wire as a transmitter. Open source software is available for the Raspberry Pi that turns a GPIO pin into an FM transmitter. Using this software with an audio recording of actual telemetry from the CubeSat Simulator enables telemetry reception on any FM radio, and reception and decoding on any PC with a $20 RTL-SDR USB dongle.

We will monitor the level of interest in the CubeSat Simulator Lite going forward! In future Journal articles, Pat and I will discuss in detail what we can do with the CubeSat Simulator, besides the exercises outlined in Mark Spencer's article about his original simulator.

I am also taking this opportunity to start building an AMSAT Education Committee. The first task of this new committee is to act as a steering committee for the CubeSat Simulator program. In the future, the group will also plan and execute other educational programs. If you are interested in participating, please let me know.

Overall, I'm delighted so far with the reception of the community to the CubeSat Simulator. Thank you to everyone who has provided feedback and encouragement. Look for more to come in future months!

New AMSAT CubeSat Simulator

Alan B. Johnston, KU2Y
Vice President, Educational Relations
Assistant Professor, Villanova University
ku2y@amsat.org

Pat Kilroy, N8PK
Flight Systems Integration & Test (I&T) Engineer
NASA Goddard Space Flight Center
n8pk@amsat.org

Introduction

The AMSAT CubeSat Simulator is a new tool for education and demonstrations that can be used in a classroom or training setting to introduce the basics of satellites. Other uses include teaching STEM (Science Technology Engineering and Math) concepts or serving as a stepping stone in a project to build and launch an actual flight model CubeSat.

Too many CubeSats have been "DOA" upon deployment on orbit, which is a shame given the time, effort, and expense invested in them. An important use of the CubeSat Simulator is to help new CubeSat builders learn to "crawl before they walk or run." With the assistance of AMSAT, a new group embarking on a CubeSat mission would not start with a real flight model (FM) structure, but instead, first learn or practice by producing either an engineering test unit (ETU) or, before that, this CubeSat Simulator.

The simulator provides a real benefit to any groups who wish to have a simple, operating, "flight-like" model for education purposes. We believe that educators and AMSAT Ambassadors will be our primary users, but others will take notice as well.

We have built a proof of concept prototype of the AMSAT CubeSat Simulator, or CubeSat Sim. We received useful feedback after we presented and demonstrated it at the 2018 AMSAT Space Symposium. Additional feedback and suggestions will help us move ahead with the project. The current version is a work in progress prototype. We are working from high-level design considerations and architecture. Once the design is finalized, we will publish complete schematics and details.

ARRL ETP CubeSat Simulator

About ten years ago, Mark Spencer, WA8SME, developed a CubeSat simulator, which is the foundation and inspiration for our new simulator. *The AMSAT Journal* published his substantial results in two significant articles which are available online: **www.arrl.org/files/file/ETP/CubeSat/CubeSat-Pt1-SepOct09.pdf** and **www.arrl.org/files/file/ETP/CubeSat/CubeSat-Pt2-NovDec09.pdf.**

One of the most notable features of the ETP CubeSat Simulator was its lessons on Attitude Determination and Control (ADAC), which is a subsystem of most satellites big and small, not just CubeSats. Mark placed a solar cell on each of the six sides of the cube structure. Instead of implementing a battery charging circuit, and without an ADAC subsystem on board his "spin-stabilized" model, he pursued a clever lesson for students on how to determine a CubeSat's pointing position in low earth orbit. From the simulator's received Morse Code telemetry numbers, he plotted the output voltage measurements of the cells in a spreadsheet, knowing the voltage peaks would correlate to a given cell facing the sun. This procedure was meant to determine the spatial orientation and the rotation rate of the CubeSat to the source of illumination, and thus reveal its current attitude with respect an observer on the Earth. (Were a camera on board, for example, this would help answer the question of where it was looking.) These lessons served as a crude, but correct, educational method for a series of inquiries and challenges for students to investigate.

Mark not only successfully designed and built the original hardware, but he developed a wise philosophy on how to effectively present the material and hardware to teachers, students, fellow amateur radio operators and community groups. His goal was (and still is) to promote and facilitate the advancement of space technology literacy. In doing so, Mark cautions that in a school classroom, we must allow the teacher to do the teaching, and to make the connections to the education standards and benchmarks. Thus, AMSAT and the hams ought only to provide instruction to these teachers and the hardware, but should be ready to advise and assist.

Goals and Requirements

The primary goal of the project is to replicate as much as possible the functionality of the original ETP CubeSat Simulator. We have tried to use modern materials and utilized software and general-purpose hardware as much as possible, leveraging software defined radio (SDR) concepts. We sought to balance cost with performance, usually compromising on the performance to keep the cost of the CubeSat Sim low. Other goals include:

· open source all software and hardware developed
· a robust design that makes maintenance simple
· a look and feel that is as close to a CubeSat engineering model as possible
· functionality that emulates a real CubeSat in earth orbit
· a modular design that allows different subsections to be swapped out for alternatives
· a community to support and extend the design

We believe that the proof of concept described here has met most of these goals, but we hope to improve upon this design before moving forward with our educational plan for 2019.

Simulator Design

We want our simulator to simulate or act like a real spacecraft in low earth orbit as much as possible. Therefore, to the CubeSat design engineer, our simulator ought to look like the standard spacecraft as shown in Figure 1 and described briefly in Figure 2. So, we shall strive to maintain the subsystem correlations between the standard Spacecraft Block Diagram and our CubeSat Simulator Block Diagram.

The subsystems of the prototype CubeSat Simulator are shown in Figure 3 and described in the sections below. The prototype board stack is shown in Figure 4.

The Control Subsystem serves as the Command and Data Handling (C&DH) subsystem, also known as the Internal Housekeeping Unit (IHU), and is implemented as a Raspberry Pi Zero W single board computer (**www.raspberrypi.org/products/raspberry-pi-zero-w/**). The Pi Zero controls all functions of the CubeSat Sim. The software is available on GitHub at **github.com/alanbjohnston/CubeSatSim** and documentation at **github.com/alanbjohnston/CubeSatSim/wiki**. It collects data on the operation and status of the CubeSat Sim, formats the data as telemetry, and transmits it to the ground station for display and analysis. The General Purpose Input Output (GPIO) header allows the boards to be stacked and provides access to the various buses. The stacked

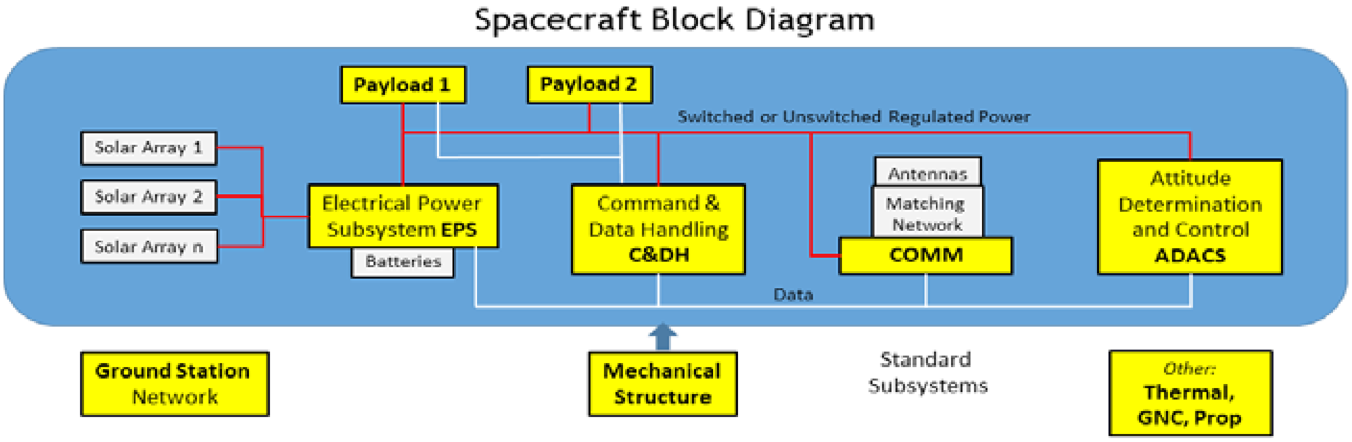


Figure 1 — Spacecraft block diagram.

TEN SUBSYSTEMS OF A SPACECRAFT

1. MECH: Mechanical Structure: houses the PC/104 standard, PCB stack, interlayer connections, standoffs, fasteners, microswitches, deployables, interfaces P-POD
2. EPS: Electrical Power Subsystem: solar cells, batteries, recharging, power regulating, distribution, grounding, fusing
3. C&DH or IHU: Command & Data Handling or Internal Housekeeping Unit: On Board Computer (OBC), FSW processing, scheduling, housekeeping, storage, more
4. COMM: Communications Subsystem: receivers, transmitters, processor, memory, TT&C formatting, beacons
5. ADAC: Attitude Determination & Control: multiple sensors, memory, computation
6. THERM: Thermal subsystem: Temp sensing, heat transfer, computation, control
7. GNC: Guidance, Navigation and Control: GPS, RTC, time-stamping data, timing/1 PPS
8. PROP: Propulsion: for structure translation and/or rotation
9. PAYLOAD: The reason for the mission. Cannot fly without these VIPs!
10. GROUND STATION: All too often an afterthought. Don't ever let it happen to you!

Figure 2 — Subsystems of a spacecraft.

boards are shown in Figure 5.

In this image, the order of the boards from the bottom is the Solar Power Management board, the Control System board, the Battery Management board, and the Transmitter board. The Electrical Power Subsystem (EPS) is comprised of these two management board units and the solar cells. The Communications (COMM) subsystem includes our Transmitter board, feedline and antenna.

The Battery Management unit, implemented using the MoPower V2 UPS (Uninterruptible Power Supply) (**www.allspectrum.com/mopower/**), charges and monitors the Nickel Metal Hydride (NiMH) batteries using power from the Solar Power Management Subsystem, and communicates with the Control Subsystem using the GPIO. Battery voltage and current and charging status are reported to the Control System. It also

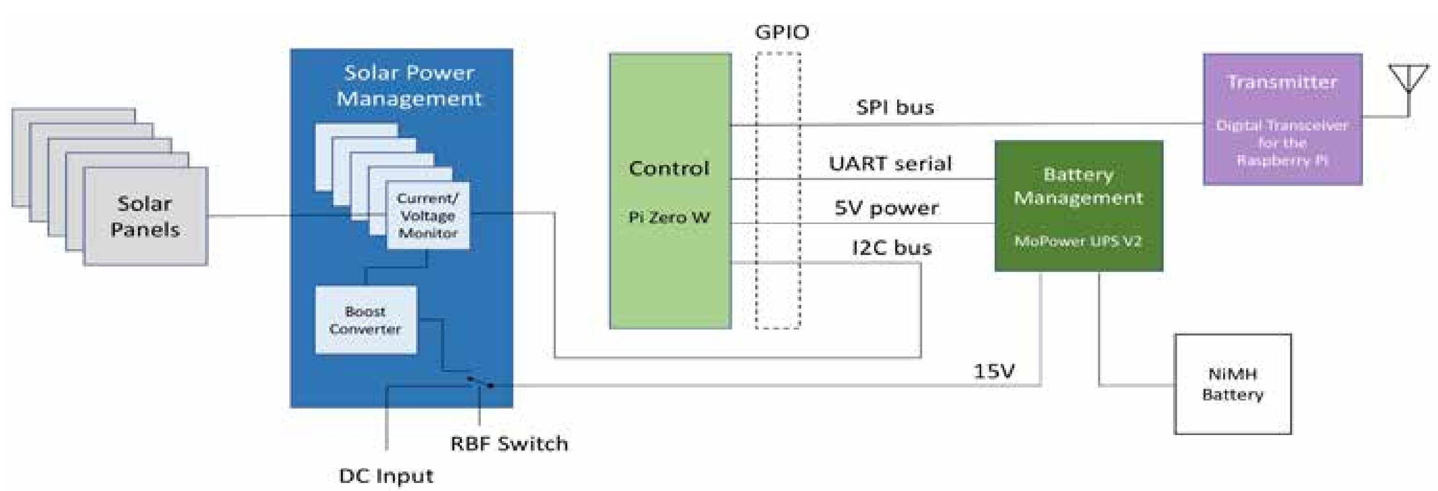
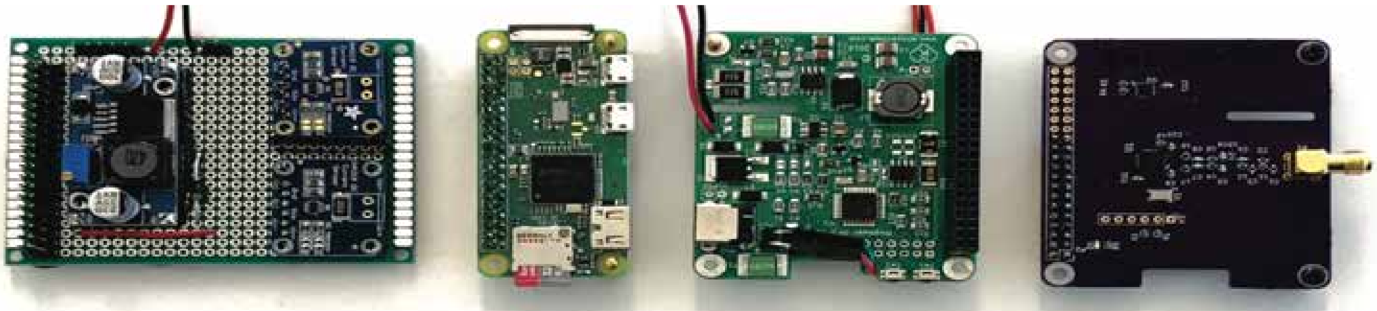


Figure 3 — CubeSat simulator subsystem block.



Solar Power Management	Control	Battery Management	Transmitter
Custom Circuit Board	Raspberry Pi Zero W	MoPower UPS V2	Brandenburg 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.

Figure 4 — Proof of concept prototype boards and functions.

Figure 5 — Proof of concept prototype stack.

sends shutdown and reboot commands to the Control Subsystem based on button presses. The Solar Power Management unit, implemented as a custom circuit board, takes up to five solar panels and combines their outputs, and then boosts the voltage to 15 V to charge the batteries. It also switches between solar power and DC input power supply to the Battery Management unit. Voltage and current monitoring are provided to the Control System over the GPIO connector. Solar cells provide power to the Solar Power Management unit.

The Transmitter subsystem, implemented as a Digital Transceiver for the Raspberry Pi board (**brandenburgtech.wordpress.com/**), transmits a 70 cm band telemetry beacon and is configured and controlled by the Control System over the GPIO connector.

The ground station, implemented as a PC with a RTL-SDR USB dongle and free software, receives and decodes the CubeSat Simulator telemetry. The data can be imported into a spreadsheet (such as either Microsoft Excel or LibreOffice Calc), where it can be analyzed, plotted and used to teach satellite or STEM concepts.

Each of these subsystems is described in more detail in our paper presented at the 2018 AMSAT Space Symposium (**countingfromzero.net/amsat/CubeSatSimPaper.pdf** and **countingfromzero.net/amsat/CubeSatSimulatorPresentation.pdf**).

Ground Station

The ground station can be any radio receiver capable of receiving FM and CW on the 70 cm band. Given that a PC is required to decode the telemetry, a great option is to use a software defined radio (SDR) dongle such as an RTL-SDR (**www.rtl-sdr.com $20 on Amazon.com**) or the FUNcube Dongle made by AMSAT-UK at (**amsat-uk.org/funcube/funcube-dongle-sdr**) and a PC. Any SDR software could be used including the freeware SDR# (pronounced "SDR sharp") at (**airspy.com/download/**) or HDSDR at (**www.hdsdr.de/**), or the open source Gqrx at (**gqrx.dk/**). Figures 6 and 7 show SDR# tuning the CW and the AFSK telemetry.

Other software is needed to decode the telemetry information. For the CW telemetry, there are various decoding programs such as CwGet (**www.dxsoft.com/en/products/cwget/**). For the AFSK, the open source Qtmm AFSK 1200 (**sourceforge.net/projects/qtmm/**) works well. Note that some kind of speaker-to-microphone audio patching software is needed to transfer the audio output from the SDR software into the microphone input of the decoding software. For Windows, we have used VB-CABLE Virtual Audio Device, which is licensed as donationware (**www.vb-audio.com/Cable/**). The raw telemetry is then copied and pasted into a spreadsheet to decode and display the actual telemetry values. For fun, we chose the OSCAR AO-7 telemetry format (e.g.hihi, 1aa 1bb 1cc 1dd 2ee … where aa, bb, cc, and dd are two decimal digits that encode Channel 1 data, etc.). Other formats can be added in the future, providing emulation for other satellites.

We have uploaded audio WAV files of telemetry from the CubeSat Simulator on GitHub which can be used to test out the decoding software, audio patching, and spreadsheet analysis. The AFSK signal is available at **github.com/alanbjohnston/CubeSatSim/blob/master/wav/afsk.wav?raw=true**, and the CW signal is **github.**

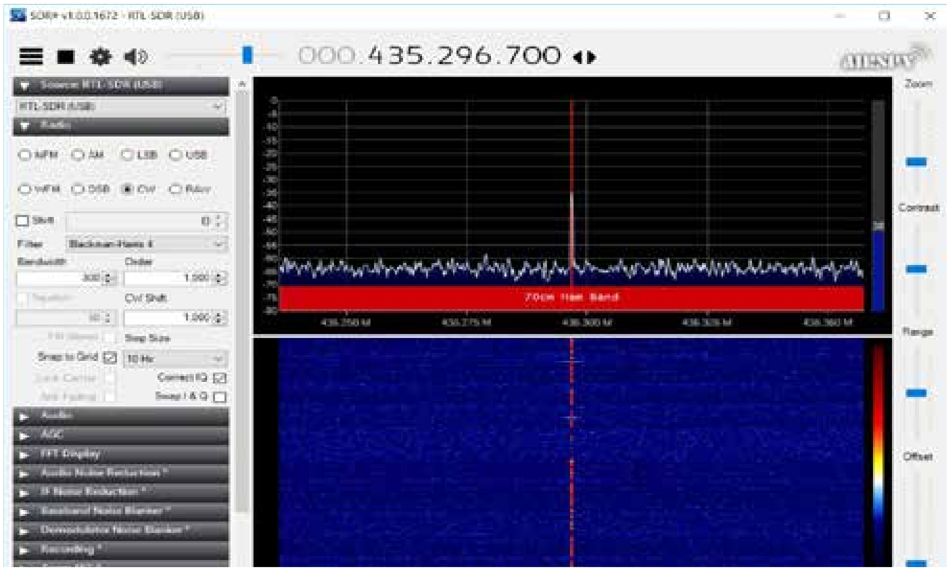


Figure 6 — SDR# decoding CW telemetry.

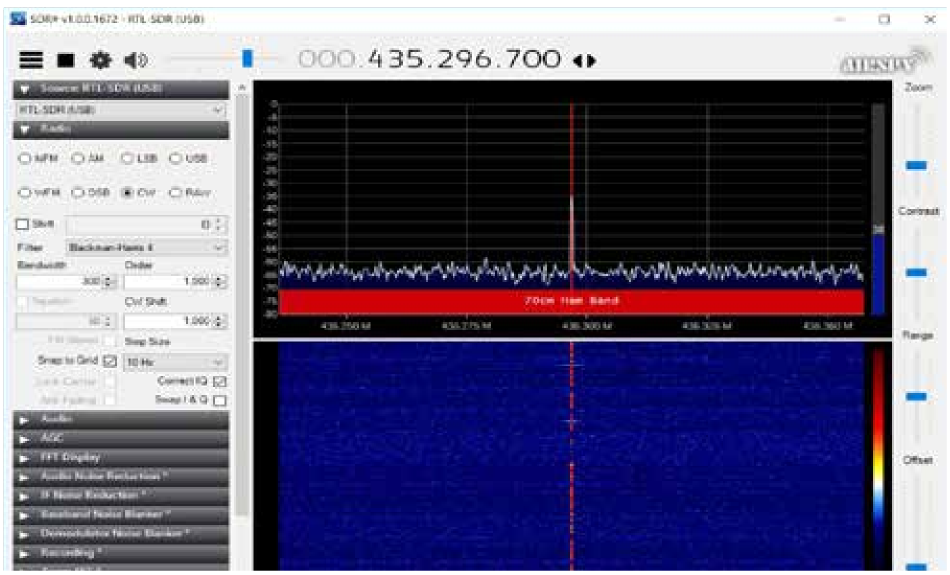


Figure 7 — SDR# decoding 1200 bps AFSK X.25 telemetry.

com/alanbjohnston/CubeSatSim/blob/master/wav/cw.wav?raw=true.

Note that the spreadsheet that we use is a modification of the actual "Morse Code Telemetry Frame Decoder for AMSAT-OSCAR-7," by Jan King, W3GEY, and Jim White, WD0E. Figure 8 shows actual solar panel and battery current graphs generated by the CubeSat Simulator. Formulas added to the spreadsheet take pasted telemetry frames and separates (parses) them into channels for display, then decoded into actual values. Most of the telemetry values in the AO-7 format are used by the CubeSat Simulator. Spreadsheets are available on GitHub at **github.com/alanbjohnston/CubeSatSim/tree/master/spreadsheet**.

This ground station option requires the installation of SDR dongle drivers on a user's PC, which is a manual process. Among the possible ways to avoid doing this is to use a Raspberry Pi 3B or 3B+ with either a Digital Transceiver for the Raspberry Pi board configured to act as a receiver, or a Pi with an RTL-SDR dongle. This Raspberry Pi could be used directly with a monitor, keyboard and mouse, or it could be accessed via a PC using a VNC connection over a network, or a direct USB serial connection.

Another interesting variant would be to build a ground station with a Linux OpenWrt Wi-Fi router (such as the low-cost GL-AR150 which sells for about $27), running a rtl_tcp server (**osmocom.org/projects/rtl-sdr/wiki/Rtl-sdr#rtl_tcp**) with an RTL-SDR dongle. The rtl_tcp server software allows a PC connected to the Wi-Fi network to connect to the RTL-SDR radio using SDR# and receive the IQ (In-phase and Quadrature) data in a stream which can then be demodulated and decoded on their own PC. This would also have the advantage of a Wi-Fi network that the CubeSat Sim would always connect to, making access and configuration easy. Plugging in the Ethernet of the Linux Wi-Fi router to the internet would allow software updates and even remote access to the CubeSat Sim.

CubeSat Simulator Mechanical Structure

This proof of concept prototype has concentrated on functionality, with form and fit taking a lower priority to date. Also, as electrical engineers, we have stayed in our comfort zone of electronics and software rather than spending a lot of time and energy on the physical design.

We have produced two frame structures to house the board stack. One is based around 3D printed 1U CubeSat parts from Thingiverse (**www.thingiverse.com/thing:27300**). We used fully threaded 3 mm steel rods as the posts, and clear plexiglass shelves and panels for mounting boards and solar panels. The Raspberry Pi stack was housed in this frame and is shown in Figure 9 below. In future structures, we would like to more closely approach the PC/104 standard (**pc104.org/**) for printed circuit boards (PCBs), stacking the PCB layers and electrically and mechanically interconnecting these layers. That is the standard used in many CubeSats in orbit today.

Applications and Uses of the CubeSat Simulator

Various educational exercises with a CubeSat Simulator are described in Mark Spencer's papers. The new CubeSat Sim can be used in many of these exercises. Also, we anticipate that the CubeSat Simulator will be useful to teams planning to build a CubeSat to gain experience. Also, we hope that emulation for additional satellites will provide practice and training in copying telemetry from new and existing satellites in a classroom setting. We plan to write more articles in *The AMSAT Journal* describing activities and exercises with the CubeSat Simulator.

For network savvy persons, users without an RTL-SDR radio and antenna can participate in demos using only an internet-connected PC. If a remotely accessible SDR server is receiving the CubeSat Simulator

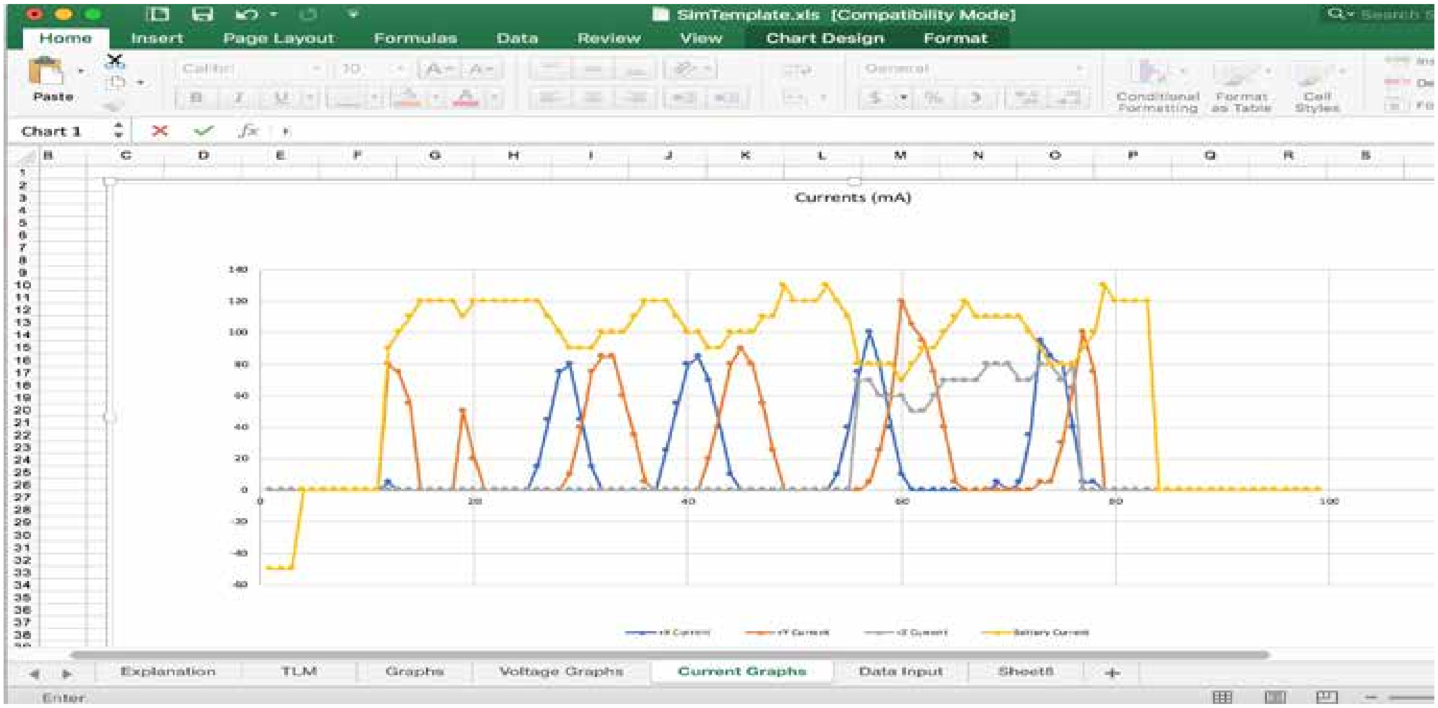


Figure 8 — Morse Code telemetry frame decoder for AMSAT-OSCAR-7 spreadsheet with CubeSat Simulator data.

transmissions, other users can connect to the server and then do their own decoding of the telemetry. For example, open source SDR server software (**sdr.hu/openwebrx**) that allows web users to connect to the server and demodulate and decode on their own PC could enable multiple participants in a room to do this, or even for remote participants on a web conference, for example, if the network access was configured correctly.

Currently, the CubeSat Sim supports two telemetry modulation schemes: CW and AFSK 1200 bps AX.25. In both cases, the telemetry is formatted in AO-7 format. In the future, support for additional telemetry modulation schemes and telemetry formats can be added. One highly valuable new feature to consider would be to implement the Data Under Voice (DUV) 200 bps FSK telemetry used by the AMSAT Fox satellites, or the new Fox-1E BPSK (Binary Phase Shift Keying) telemetry format. This "Fox emulation mode" would allow the use of the FoxTelem software to decode the telemetry. Also, in the future, developers of a new CubeSat could contribute an emulation mode for an upcoming satellite. This would allow amateurs to practice decoding telemetry and using the telemetry analysis tools before launch, avoiding the scramble after a CubeSat is launched and potential loss of initial telemetry data. At AMSAT, we can also ensure that we provide a "GOLF emulation mode" as our next generation of satellites are developed, providing excitement and training on telemetry reception before launch.

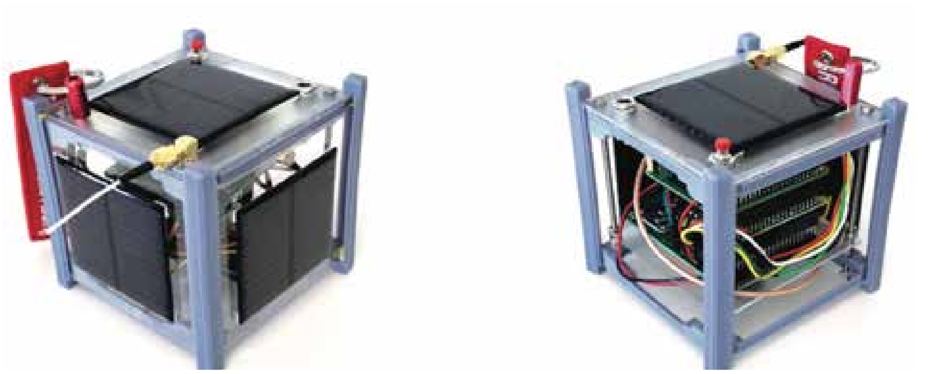


Figure 9 — CubeSat Simulator 1U frame using 3D printed parts.

Feedback from 2018 Space Symposium

We presented and demonstrated the CubeSat Simulator at the 2018 Space Symposium in Huntsville, Alabama. We received very favorable feedback on the look and functionality of the CubeSat Sim from the attendees. One suggestion we received was to investigate ways to possibly lower the cost of building the simulators, even if the functionality is reduced.

To achieve this, we have come up with a number of different configurations for the CubeSat Simulator that leverage the modular design which we will describe in a future article. One and only one of the series that we will share here is an idea for a "CubeSat Simulator Lite" which only requires a Raspberry Pi; no additional hardware is needed. Utilizing open source software which turns a GPIO pin on the Raspberry Pi into an FM transmitter, we have shown how an audio WAV file of actual telemetry (either CW or AFSK 1200 bps AX.25) from the CubeSat Simulator can be played, which can then be received on any FM radio receiver.

A piece of wire needs to be attached or soldered to a GPIO pin as an antenna; no transmitter board for the Raspberry Pi is required. Of course, the telemetry received is not actual generated currents, voltages, and temperatures, but it can be realistic data which can provide learning opportunities to decode and interpret. We imagine that some different WAV files can be provided, and selected randomly, providing interest in decoding and figuring out what is going on. This reduces the cost from a few hundred dollars to as low as $35 for a Raspberry Pi Zero W kit (Raspberry Pi W CPU, 16 GB micro-SD Card, and micro-USB power supply). Software and instructions for this CubeSat Simulator Lite are available on GitHub **github.com/alanbjohnston/CubeSatSim/wiki/CubeSat-Simulator-Lite**.

Next Steps

Our next steps are to get additional community feedback on the design and implementation. We are particularly looking for improvements to the space frame to make it sturdy and easy to build.

We plan to fully document hardware and software online and publish in the AMSAT Journal so that others can build their own. Immediately, we are also looking for beta testers to test it out in public demonstrations and classroom exercises and provide feedback. Please contact us directly if you are interested, at ku2y@amsat.org and n8pk@amsat.org. Teachers are encouraged to write and share example lesson plans at specific age and grade-appropriate levels to help educators incorporate the simulator in classrooms and extracurricular activities.

AMSAT also plans to build a set of AMSAT-owned CubeSat Simulators and make them available to educators by shipping them around. To support this, we will document presentations and activities to be used with the CubeSat Sim. Ultimately, we hope to grow a community of satellite simulator enthusiasts who continue to improve and extend the CubeSat Sim, adding additional functionality and satellite emulation modes.

Acknowledgments

We would like to thank Jonathan Brandenburg 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, and to Bob Bruninga for ideas and inspiration from his undergrad "LabSat" developments. 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.

L/v Mode Enhancement to SDR Satellite Station

Ronald G. Parsons, W5RKN

At about the time my FlexRadio FLEX-6600 implementation of my satellite station was published, AO-92 was commissioned and opened for amateur radio use. In addition to its U/v FM transponder, AO-92 also contained an L-band downshifter. When this mode is commanded, L-band uplink on 1267.359 MHz with downlink on 145.880 MHz is enabled. The initial implementation of my FLEX-6600 station did not provide capability for the L/v mode. I decided to investigate enhancing my system by adding L/v capability in a minimalist way. Ross Bigger, ZL1WN, has greatly assisted in the testing of the concepts described here.

In addition to AO-92, AMSAT's Fox-1Cliff and FUNcube on ESEO (European Student Earth Orbiter) both launching on the SSO-A mission, will have L-band uplinks when launched in late 2018. The L band is Earth-to-space only under the ITU Radio Regulations.

Supporting only uplink on the L-band greatly simplified the necessary design changes. In U/v mode, the transmit output from the FLEX-6600 is on port XVTR-B. This port is connected to the U-band transverter on its TXIF input. For this enhancement, a coax relay is inserted into this line with the NC connector going to TXIF, while the NO connector is connected to a transverter input with L-band output. The revised block diagram of the interconnections is shown in Figure 1. The parts in bold are changes from the paper in footnote 1. The output frequency of the FLEX-6600 XVTR ports is limited to 54 MHz, so an output of 28 MHz was chosen. The box labeled "1266-28 XVTR" stands in for a generic transverter with an input of 28-30 MHz and output of 1266-1268 MHz.

The added relay is controlled by a USB-8 relay control board using W0DHB's FlexRadio-oriented satellite control program, FlexSATPC. The relay is energized when the uplink frequency is in the satellite uplink part of the 23 cm amateur allocation. A SmartSDR XVTR band named L/V is defined as shown in Figure 2. The XVTR L/V defines the relationship between the final RF frequency and the transverter LO frequency, as well as the maximum power output from the XVTR-B port on the FLEX-6600. This enables SmartSDR to be able to display the actual uplink and downlink frequencies as shown in the slice flags in Figure 3.

Finding a "1266-28 XVTR" would seem simple, but we were unable to find a commercially-available transverter with those specifications in current production. Most transverters with L-band output have input on 144 MHz. Down East Microwave, Inc. (DEMI) has a transverter, L23HP, which has input on 28 MHz but covers only 1280-1300 MHz on output. However, good news awaits just over the horizon.

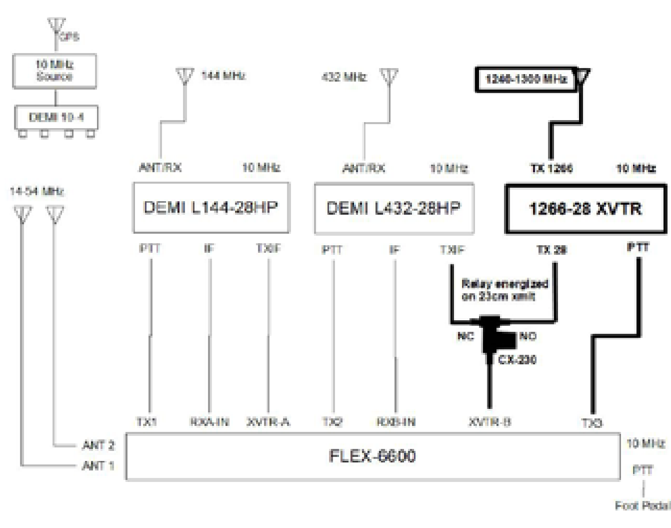


Figure 1 — Block diagram of the interconnections. The parts in bold are changes from the paper in footnote 1.

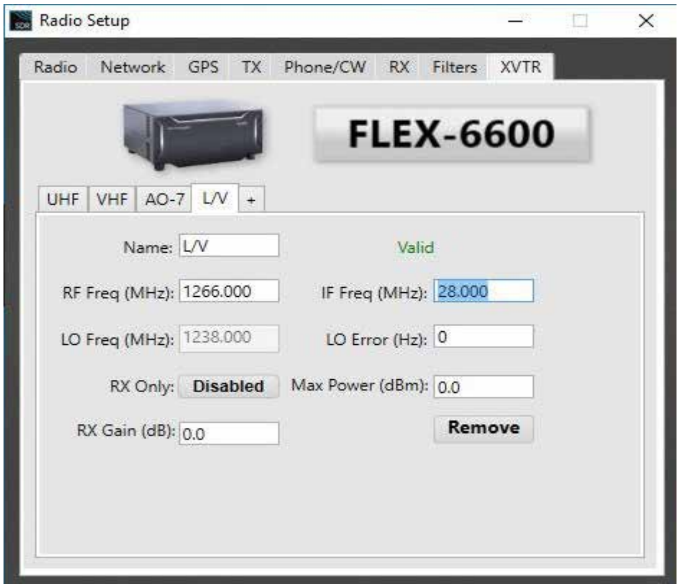


Figure 2 — FlexRadio SmartSDR XVTR definition for L/v mode.

Figure 3 — FlexRadio SmartSDR Slice Flags showing actual frequencies.

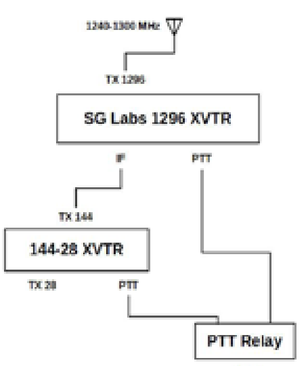


Figure 4 — W5RKN implementation of a 1266-28 transverter using two transverters

DEMI has in its R & D department a 23 cm upconverter for the worldwide recognized satellite band. It will be capable of producing 20 W and may utilize many different IF drive signals such as 10 m, 6 m, 2 m and 70 cm by merely selecting the LO frequency of the synthesizer. This converter will have the option of being a mast mountable unit if desired. Also, they are in the process of developing separate up and down multi-band converters. The TX converter will be at a low level (100 milliwatts or so) but will cover the uplink bands 2 m through 6 cm. The down converter will do the same including the 3 cm band. They will all have multiple IF band selections. These future products have an expected release date of late spring/early summer next year. The basic ideas of this enhancement article apply to these new DEMI products.

Implementations

Lacking ready availability of a 1266-28 transverter, ZL1WN and I implemented this transverter function in similar but distinct ways, somewhat guided by what was readily available. The block diagram of the transverter in my implementation is shown in Figure 4.

Without a 1266-28 transverter, I substituted two transverters in series – first a 144-28 followed by a 1296-144. The 144-28 component is available from www.transverters-store.com in Ukraine. It requires 1-50 mW (0-17 dBm) input power and has up to 15 W output. The 1296-144 component is available from SG Labs in Bulgaria. It covers 1240-1300 MHz, accepts input power from 0.2 to 5.0 W and has output power from 2 to 3 W. The PTT Relay in Figure 4 is a small DIP relay that separately grounds the PTT's of the two transverters.

I added an M2 23 cm antenna 23CM22EZA to my satellite rotator cross boom. It is a new design, with the elements stamped from sheet metal in two sections, making assembly extremely simple. It is rear mounted, 70" long, covers 1250-1300 MHz and has 18 dBi gain. The beam width is 24°. ZL1WN uses a different, but similar, 144-28 transverter, and added an SG Labs 23 cm amplifier after the 1296-144 transverter.

Operation

Operation is straightforward. I assume most users will want to have both the U/v and L/v modes of AO-92, for example, programmed into their system. All that is required to do this is to have both modes entered into the Doppler.SQF file, assuming you are using SatPC32. Since I am using the SmartSDR control software on my FLEX-6600, I needed to define Global Profiles for both modes, with FlexSATPC, named SATAO-92 and SATAO-92_1. To switch from the U/v mode of AO-92 to the L/v mode, open the CAT menu of SatPC32, and select the L/v line. FlexSATPC takes care of all necessary switching. To go back to U/v, just select that line in the CAT menu.

Real World Results

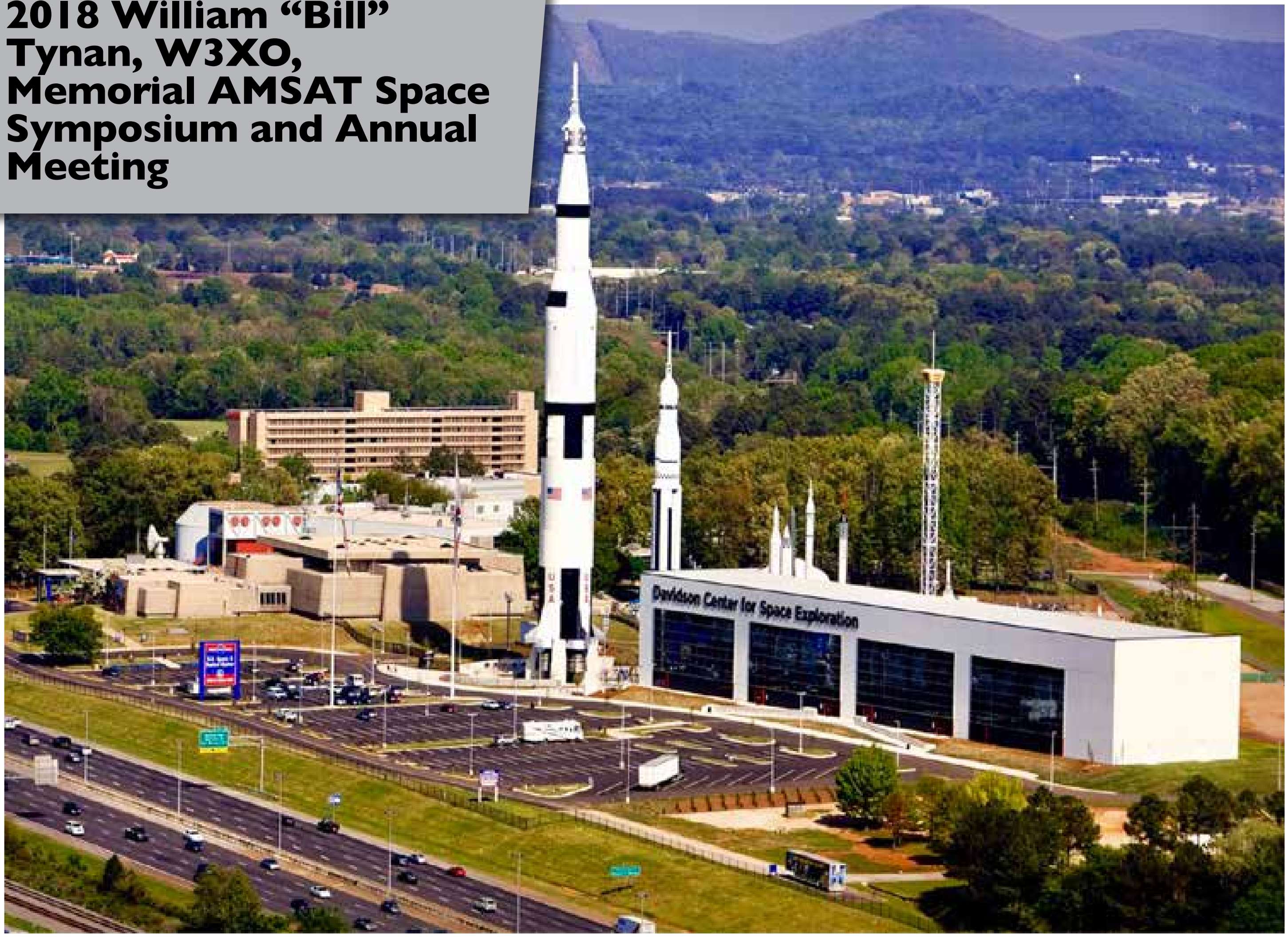
On the first AO-92 L/v pass at my location after finishing the upgrade, I was pleased (and perhaps a little surprised) by how well the upgrade worked. The pass had a maximum elevation of 50 degrees, and I was able to hear my own downlink well before closest approach. I was able to work three stations and heard another. All too soon I stopped hearing my downlink and noticed the elevation was down below 10 degrees. The pass was almost over. The next morning on another 50-degree pass, I was able to work four more stations. I requested signal quality reports from several contacts, and they were all complimentary. I was concerned about any possible interference or desensing of the downlink signal since its frequency is close to the output frequency of the 144-28 transverter. This concern was unwarranted.

My output power was 2-3 W, an estimated 5 dB loss in the feedline, and an antenna gain of 16 dBd.

Conclusion

While L/v mode will not be a major mode of operation for me, the simplicity and ease of the enhancement made it all worthwhile.

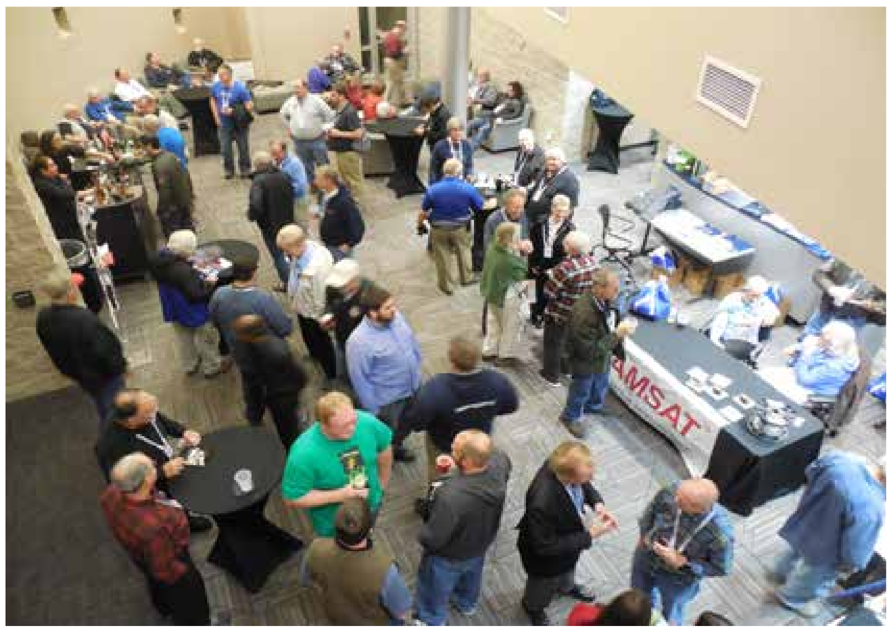
2018 William "Bill" Tynan, W3XO, Memorial AMSAT Space Symposium and Annual Meeting



U.S. Space and Rocket Center, Huntsville, AL. [All photos courtesy of Keith Baker, KB1SF/VA3KSF, unless otherwise noted.]

[Joe Kornowski, KB6IGK, photo.]

Presentations held in the Educator Training Facility were well-attended.



The Friday evening reception and auction at the Educator Training Facility provided an opportunity to catch up with old friends and put faces to call signs.

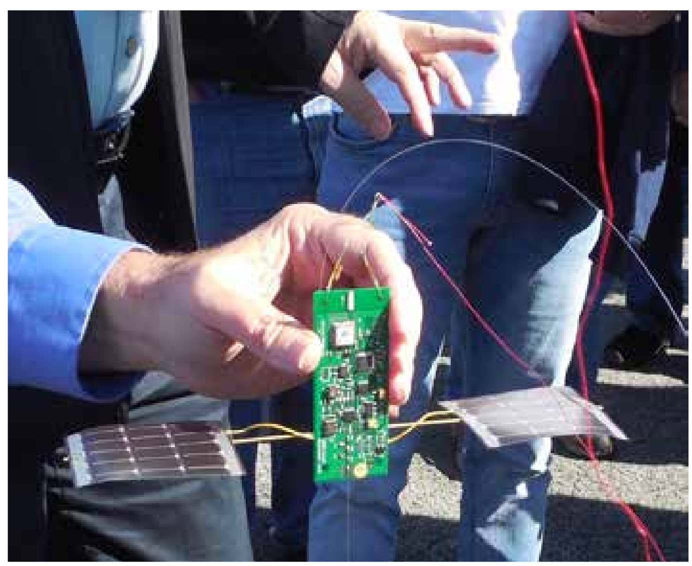
A diversity of items was available at auction for discriminating tastes.

Drew Glasbrenner, KO4MA, was clearly pleased with his winning bids.

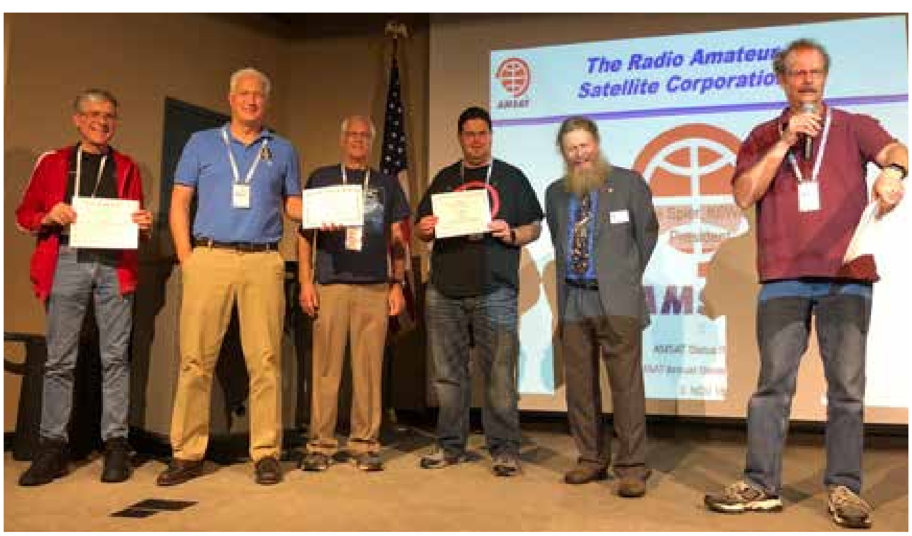
Scheduled ARISS contact with astronaut Dr. Serena M. Auñón-Chancellor, NA1SS, resulted in several QSOs.

Shaila Panyam, KC9ZJG, calling ISS astronaut Dr. Serena M. Auñón-Chancellor, NA1SS.

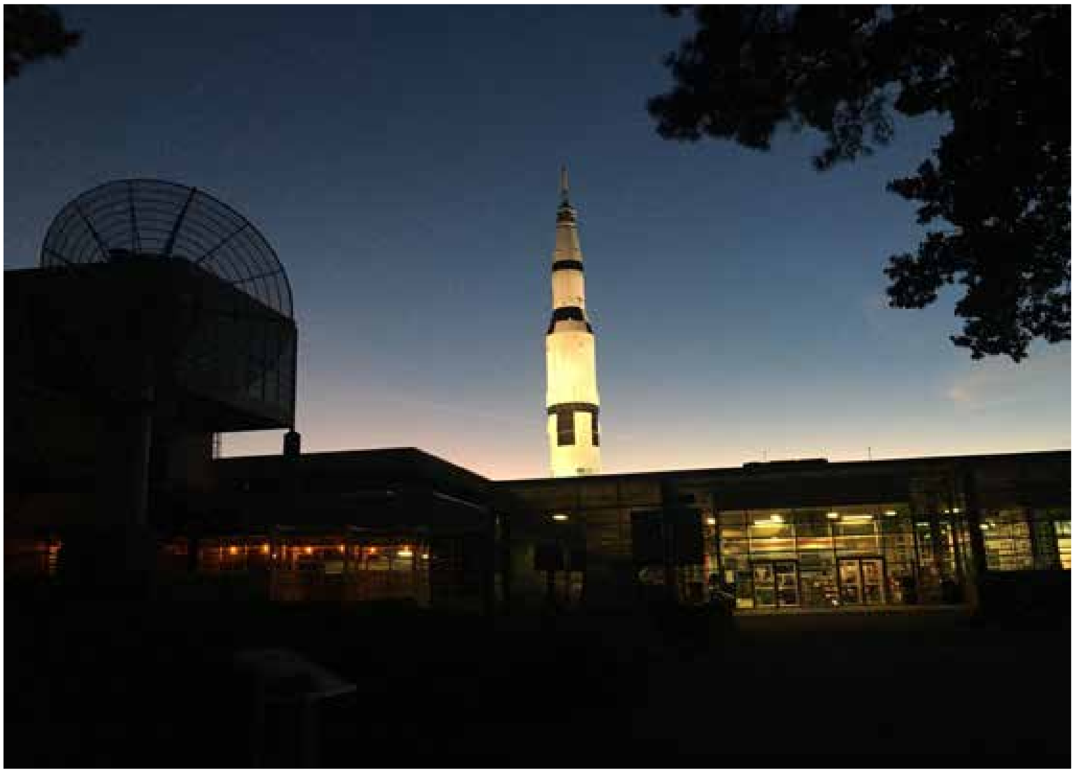
APRS balloon launch.



APRS digipeater balloon payload.



Thanks to the many AMSAT volunteers whose service and contributions allow AMSAT to succeed — both in space and on Earth!



The Symposium banquet took place in the Saturn V Hall.

Keynote speaker, Justin Foley, KI6EPH, System Engineer, JPL.

The AMSAT Journal Needs Your Words and Wisdom

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" (see below).
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® AMATEUR RADIO IN SPACE

The Two Meter EZ Lindenblad Revisited

Tom Planer, KJ9P
Grant Zehr, AA9LC

The Lindenblad antenna is a well-known design which lends itself to use for satellite communication and also works well as a general-purpose VHF antenna. Properly constructed, the antenna provides circular polarization and omnidirectional coverage, with gain near the horizon and good omnidirectional coverage at higher elevations. Historically this design has been used at airports for VHF communications with aircraft and is well suited to that task. Tony Monteiro, AA2TX (SK), outlined the history of the Lindenblad antenna in "An EZ-Lindenblad for 2 Meters," published in the August 2007 issue of *QST*. In that article, Monteiro described a practical way to build a Lindenblad antenna using four transmission line impedance transformers constructed from 75-ohm RG-59 cable. This allows the antenna to be fed with 50-ohm transmission line familiar to radio amateurs.

When the Central Illinois Radio Club was asked to help with a local ARISS contact (at Chiddix Jr. High School in Normal, IL), we looked carefully at the AA2TX design and decided to build a similar antenna for use with our ARISS backup station. Although the ARISS program only requires a vertical antenna, we knew that a Lindenblad would perform better as a backup antenna.

Our first antenna worked very well indeed. It was tested while monitoring transmissions from the ISS during other school contacts, during Slow Scan TV transmissions from the ISS and while monitoring the ISS downlink during our actual ARISS contact. While the Lindenblad was not needed during our ARISS contact, we feel confident that it would have worked well for that contact if needed.

Although the Lindenblad design has been around for many years, and the EZ Lindenblad design makes construction easier, there is still some confusion about constructing this type of antenna and getting it to function predictably. Building a Lindenblad just looks hard. We would like to share some of the features of our design, which might help others build a successful antenna.

Antenna Development

Tom Planer, KJ9P, did the initial work on our design and built our first antenna using 1 1/8 inch diameter tubing for the crossarms and dipoles and CPVC plumbing fittings for the tee connections (see Figure 1). The crossarms were fastened to a large diameter tubular aluminum mast. Multiple small L brackets were used to stabilize the crossarms where they attached to the mast. This provided a very sturdy antenna structure. A matching network was built using RG-11/U coaxial cable. This became the backup antenna for our ARISS contact and worked well.

While tuning this antenna, two important facts became apparent. First, the junction of the four matching sections and the SO-239 antenna connector is a critical point. The SWR of our antenna could be changed by positioning the antenna connector closer to or further from the matching network. Changing that geometry by ½ inch made very noticeable changes. Secondly, the length of the dipole elements also affected the tuning of the antenna. We found best results with antenna elements a little shorter than in the AA2TX design. Our RG-11/U matching sections were somewhat longer than AA2TX's. After adjusting these elements, an antenna was built which had good omnidirectional coverage and an SWR of 1.5:1 or less across the entire 2-meter band.

A second antenna was then built using more readily available parts, to determine if the design could be reproduced. With some minor changes, the second antenna also performed well and is discussed here.

Figure 1 — 2-meter Lindenblad used for our ARISS backup station.

Construction

Before beginning construction, the reader is encouraged to carefully read "An EZ-Lindenblad for 2 Meters," as many of the techniques used here are similar. This antenna can be built with ordinary hand tools. A tubing cutter or hacksaw with miter box is recommended for accurate tubing cuts. A tap tool with a bit for 10-32 machine screws is needed to connect the coaxial cables to the dipole elements.

1 1/8-inch diameter aluminum tubing from DX Engineering (DXE AT-1485) is used for the dipoles and crossarms. This tubing is available in either three-foot or six-foot lengths. Less material is wasted when six-foot sections are used, but the extra cost of shipping six-foot lengths is significant and should be considered when placing your order. The tubing can be obtained from other suppliers but be sure to obtain thick walled (.058") tubing so that the material can be tapped for insertion of machine screws. Care should be taken to cut the tubing at right angles, so the dipole ends are square and the crossarms fit accurately into the CPVC fittings. Either a miter box or tubing cutter can be used.

This size tubing fits perfectly into standard 1-inch size plastic CPVC plumbing fittings. Note that these are not the usual schedule 40 PVC fittings used in many amateur antenna designs. The CPVC fittings are designed for use in higher pressure water supply systems and have different dimensions. They are available in most large home centers. Four 1-inch size CPVC tee fittings are used, one at the midpoint of each dipole.

Begin with construction of the antenna crossarms. These are cut to 24 ¼ inches. Find the center of each cross arm and carefully drill a hole for a 2 ½ inch #6 machine screw which will join the two crossarms and ensure that they stay centered during construction. A section of 1 ½ inch aluminum angle stock about 22 inches long serves as the vertical mast for the antenna. The crossarms are then attached to the mast. We used ¾ inch angle stock to support the crossarms (see Figure 2). The crossarms can be connected to the angle stock with #6 or #8 machine screws or pop rivets.

Cut 8 half-dipoles from 1 1/8 inch aluminum tubing. Cutting each half dipole element to 13 5/8 inches results in a dipole 28 ½ inches long (including the CPVC fitting). Measure carefully to be sure this number works for your CPVC fittings and be sure both half dipole elements are the same length. The dipole elements should be driven firmly into

Figure 2 — Crossarms are connected to the mast using short pieces of ¾' aluminum angle stock and machine screws.

CPVC fitting until they are seated against the molded stop inside the fitting.

A dipole with its CPVC tee fitting is attached to each end of the two crossarms. When inserted into the CPVC fitting a small (1/8") space is allowed rather than driving the tubing into the stop position inside the fitting. This results in a cross arm with a dipole center to center spacing of 25 ¾ inches. The crossarms will be tight in the CPVC fittings but can still be turned enough to adjust the dipole angle.

Use a drafting triangle or simple homemade gauge to adjust the angle of each dipole to 30 degrees from horizontal. Looking at a single dipole from outside the antenna, you need to rotate the dipole on the cross arm 30 degrees in a counter-clockwise direction (for right-hand circular polarization). Carefully drill through the CPVC fitting and cross arm tubing and tap the CPVC and aluminum to accept a ½ inch long #10-32 machine screw. Use care to preserve the 30-degree angle during this step. This will secure the base of the tee fitting to the antenna crossarm (see Figure 3).

Figure 3 — Machine screw on top of insulator holds dipole at 30 degrees from horizontal.

Next, build the impedance matching transformers. RG-11/U cable (DX Engineering DXE 11U) is used rather than the RG-59 specified by AA2TX. RG-11/U has copper shielding (unlike many modern versions of RG-59), provides lower loss at VHF, and can handle more transmit power. We found the larger size cable easier to work with than the smaller diameter RG-59.

Each cable is cut to 27 inches. On one end of each cable cut back the black vinyl covering to a length of 1 3/8 inches. Spread and separate the shield braid and form it into a single lead. Attach ring terminals (that can accommodate #10 machine screws) to the shield and center conductors. These should be crimped and soldered in place. Heat shrink tubing over the leads provides some protection against weather and solar UV. The terminals will be connected to the dipole elements later.

At the other end of the cable 1 ½ inch of black insulation is removed. One-quarter inch of shield (adjacent to the insulation) is tinned with solder. A large iron is needed but take care to avoid overheating and melting the foam dielectric. The shield and foam dielectric are then cut away, leaving one-quarter inch of tinned braid in place and the rest of the center conductor bare. A small rotary tool with circular cutting attachment can be used to make this task easier. If your cuts are accurate, this will result in 24 3/8 inches of cable with the shield still in place, with shield and center conductor separated at each end. The four cables are grouped together and joined as shown in Figure 4. The shields are wrapped with copper wire or soldering wick braid and soldered together. The center connectors are joined together, soldered, and then connected to the center pin of a SO-239 chassis connector (Amphenol # 83-1R). The SO-239 connector is mounted on a short piece of aluminum angle stock, which is attached to the antenna support mast (see Figure 5). A short jumper wire connects the bonded shields to a ground lug on the SO-239 connector. Keep the center connector and shield connections as short as possible, as shown in Figures 4 and 5.

A Fair-Rite brand ferrite sleeve (Fair-Rite part number 2631102002) is used on each RG-11/U cable as a choke balun. It should be positioned over the cable near the connection to the dipole (see Figure 6). It can be held in place with a cable tie.

The terminals on the free end of each RG-11/U cable are attached directly to the dipole elements. Each terminal is connected to the

Figure 4 — Shields of the four RG-11/U matching sections are bonded together and connected to ground by a short lead.

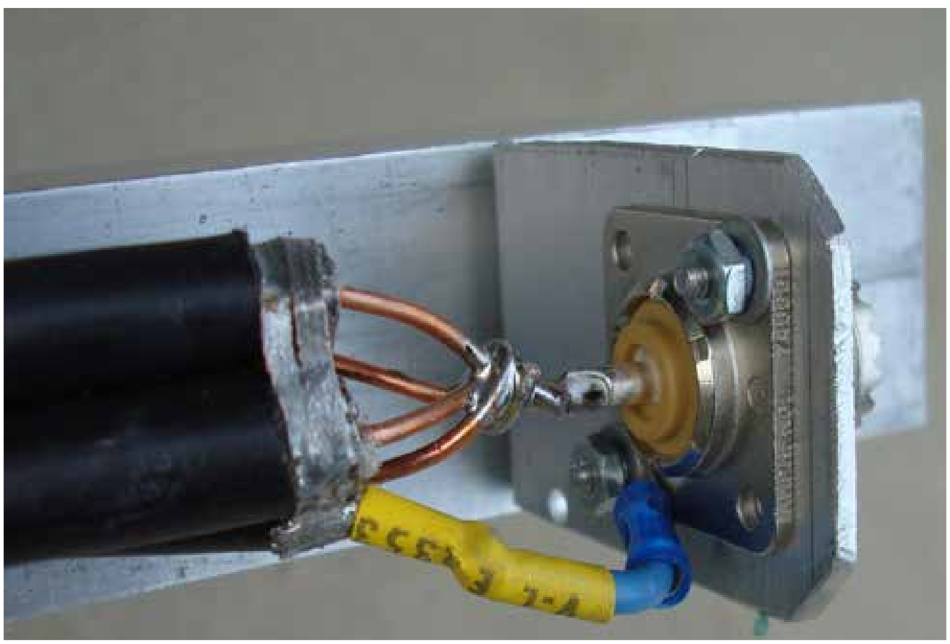


Figure 5 — Center conductors of the four RG-11/U matching sections are connected. One center conductor continues and is connected to the center pin of a SO-239 chassis connector..

antenna by drilling through the tee fitting and tapping the CPVC and aluminum tubing inside for a ½ inch long #10-32 machine screw. The number 32 specifies 32 threads per inch, which is preferred over #10-24 hardware with 24 threads per inch. With more threads per inch, #10-32 screws will provide more surface area and better electrical contact into the aluminum tubing. The CPVC material is also threaded, with provides needed mechanical strength and secures the screw in the aluminum tubing. Sheet metal screws will not provide a solid contact and should be avoided.

NOALOX or a similar anti-oxidant compound is used on each screw connection to prevent oxidation and improve conduction. The center conductor attaches to the end of the dipole, which is angled upward, and the shield to the end of the dipole, which slants downward. If you have turned your antenna over to access the bottom surface, be careful to select the correct end!

The cables making up the matching network should be attached to the crossarms and main mast. Cable ties can be used. We built a bracket from two pieces of ¾ inch angle stock to secure the RG-11/U cables to the antenna mast.

CPVC caps are used for the top of each dipole to prevent water from entering the system. The lower end of each dipole can be left open. If caps are used on the lower ends (to prevent entrance of insects and debris), be sure to leave a drain hole at the lowest point to avoid collecting water there.

Before final installation, be sure to waterproof the electrical connections. We used inexpensive hot glue from the Home Center. Fill in the area around the antenna connector and cover the screws attaching the coaxial cable to the dipole elements. Alternatively, you can use your favorite acid-free silicone sealer. Painting the CPVC fittings is prudent to avoid UV damage from sun exposure.

After the antenna has been constructed, mount it temporarily about 10 feet above the ground and check the SWR across the desired portion of the band. This is easily done with a modern antenna analyzer such as the Rig Expert AA-600 which was used here. A carefully constructed antenna should have an SWR of 1.5:1 or better across the 2-meter band.

In case of problems, if the SWR is higher than 2:1 carefully examine the connection between the matching coaxial cable transformers and the SO-239 connector. Shortening or bending the wires there may improve the SWR since you will be adjusting the stray inductance and capacitance at that connection.

If the antenna is nicely resonant, but above or below the two-meter band, the dipole elements can be adjusted to shift the resonant frequency. The dipole elements can be cut to a shorter length if the resonant frequency is too low. If the resonant frequency is too high, short lengths of aluminum tubing can be inserted into each dipole element and held in place with #6 screws. The outer tubing can be drilled and tapped to secure short #6 screws which hold short (2-3 inch) segments of 1-inch tubing (DXE 1498) in place (see Figure 7). This allows fine tuning of the antenna, so the resonant point can be centered in the two-meter band. Be careful to change each dipole half the same amount.

Figure 6 — CPVC tee fittings serve as center insulators for dipole elements, here viewed from the bottom of the antenna.

Figure 7 — If it is necessary to tune the antenna to a lower frequency, adjustable sections can be added to each dipole element.

We found that changing the length of each half-dipole by ½ inch moved the resonant frequency about 3 MHz. When a desired setting has been found, pop rivets can be used to secure the setting or new elements can be cut to the correct length. We were able to achieve an SWR of less than 1.3:1 across the entire 2-meter band (see Figure 8-9).

Antenna Modeling

We created an EZNEC model of our Lindenblad antenna to see its radiation pattern. Two of the dipoles were moved 1.125 inches lower than the other pair to duplicate the offset created by our construction method. The typical omnidirectional pattern expected with a Lindenblad antenna resulted, with no detectable change caused by the vertical offset (see Figures 10-11).

Results

The Lindenblad array antenna described here performs well on the two-meter band. We monitored many transmissions from the ISS leading up to our ARISS contact and always had good reception. We were able to hear the ISS with good signals at the horizon, although full quieting did not occur until the space station was at 5-7 degrees elevation. Using a conventional amateur transceiver

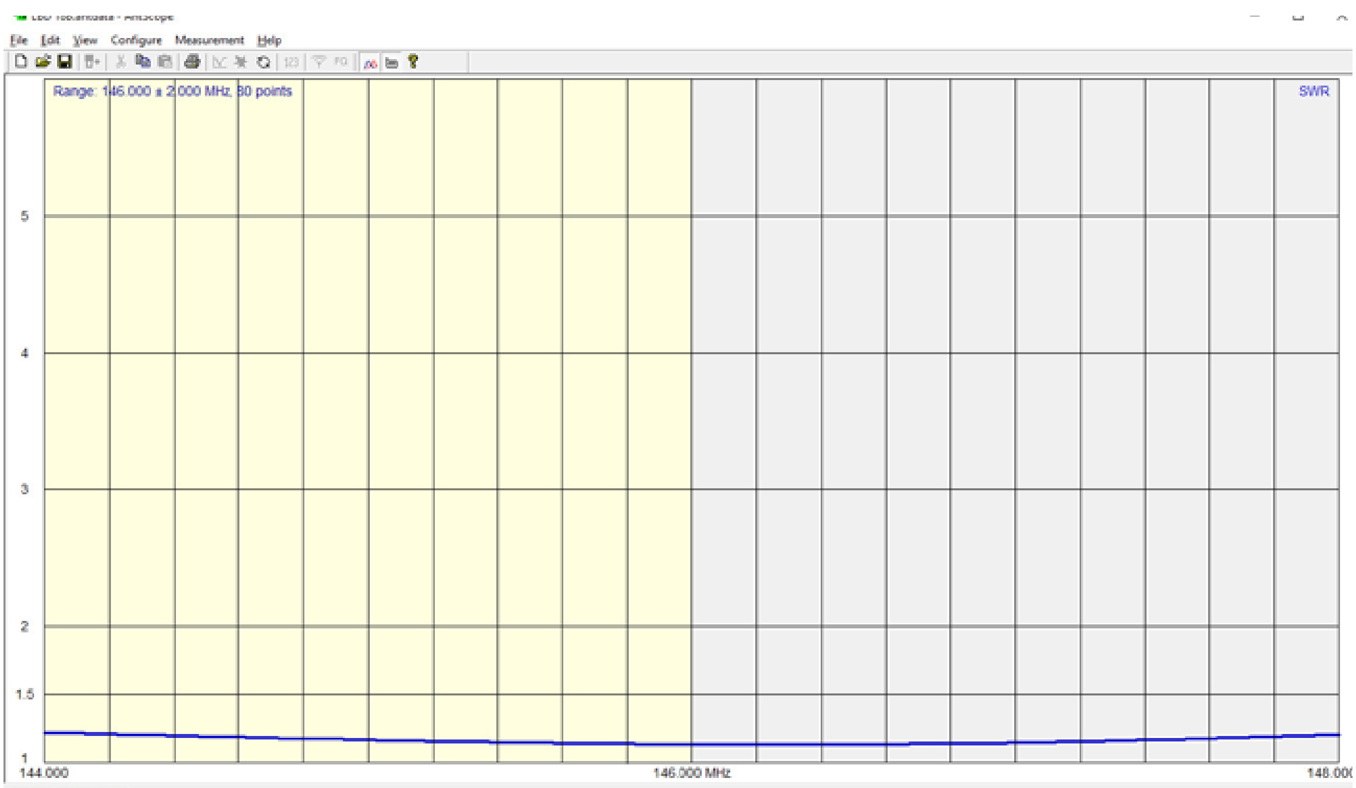


Figure 8 — SWR from 144 to 148 MHz is less than 1.5:1.

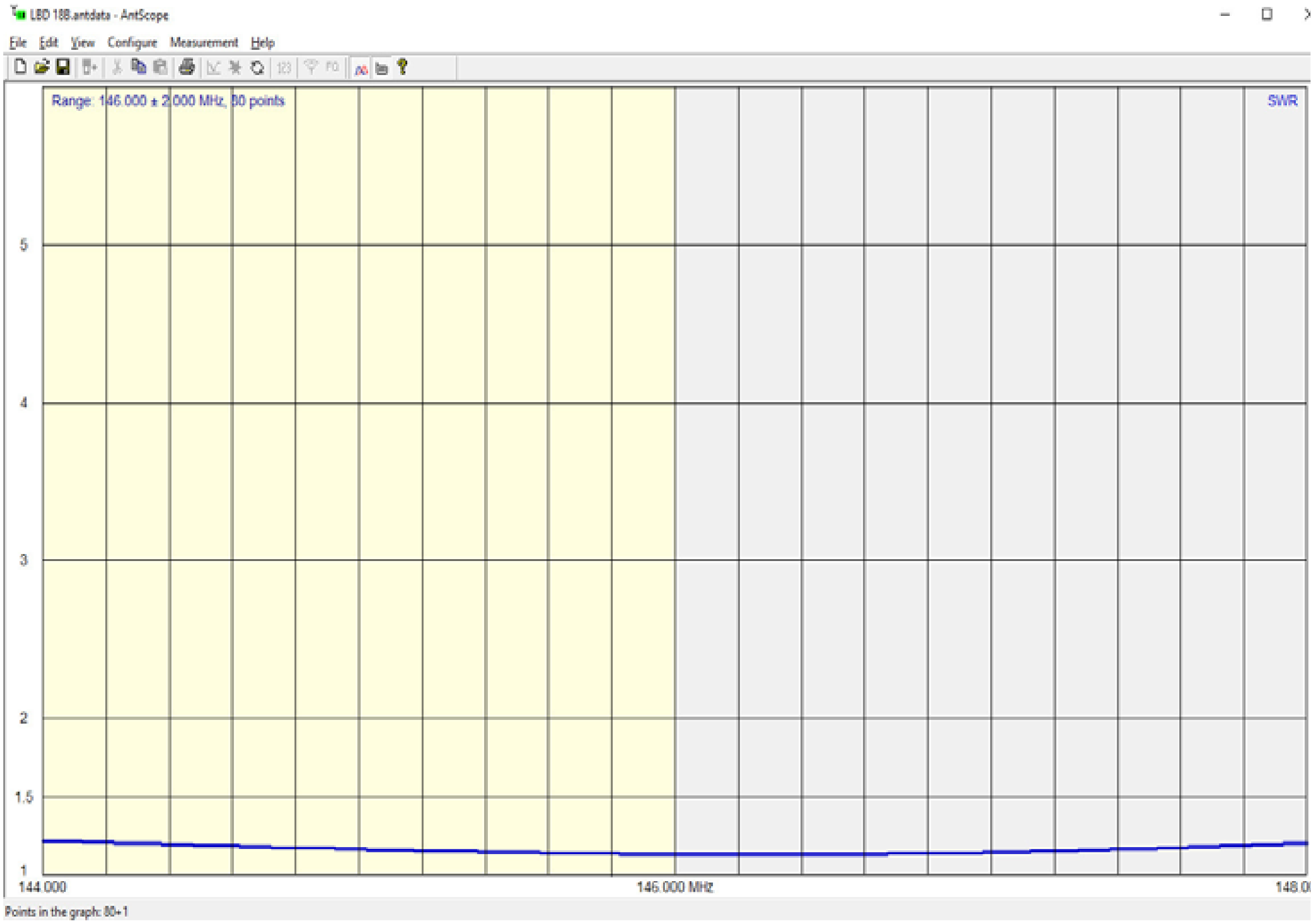


Figure 9 — SWR from 136 to 156 MHz is less than 2.5: 1.

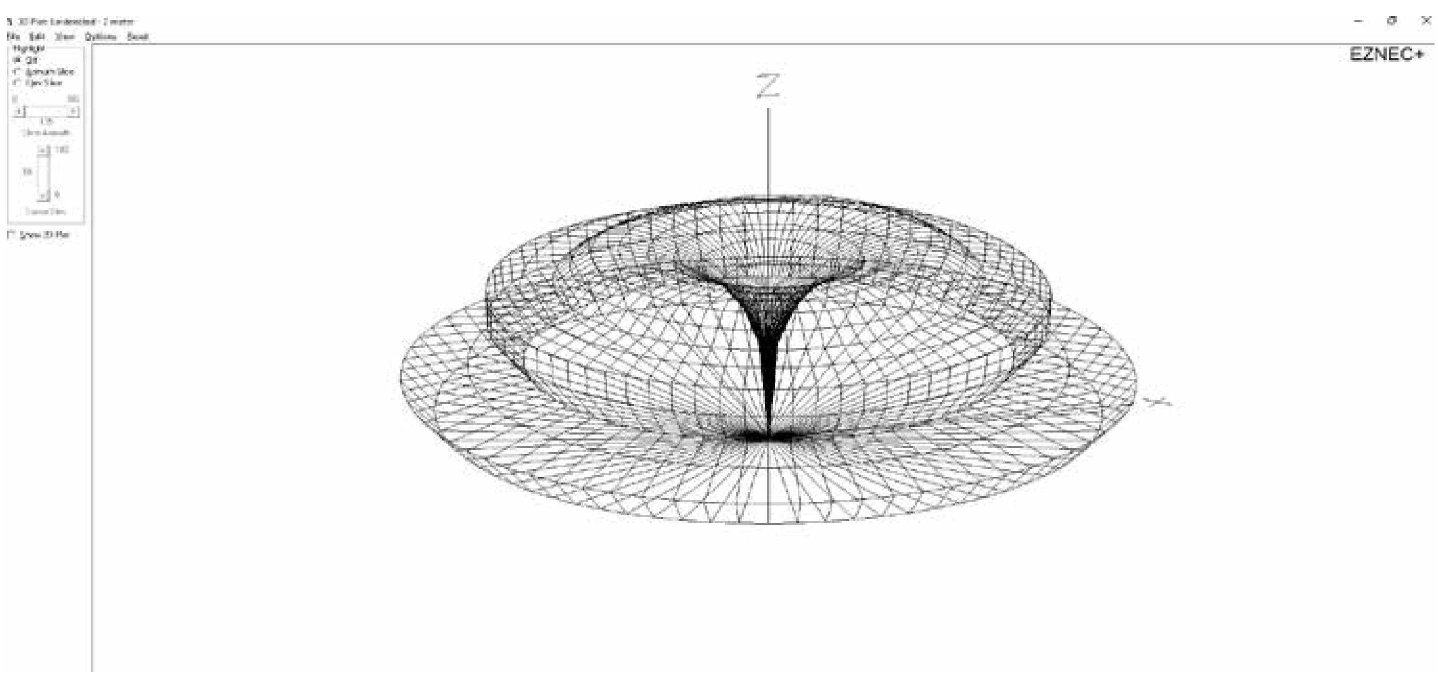


Figure 10 — Lindenblad radiation pattern.

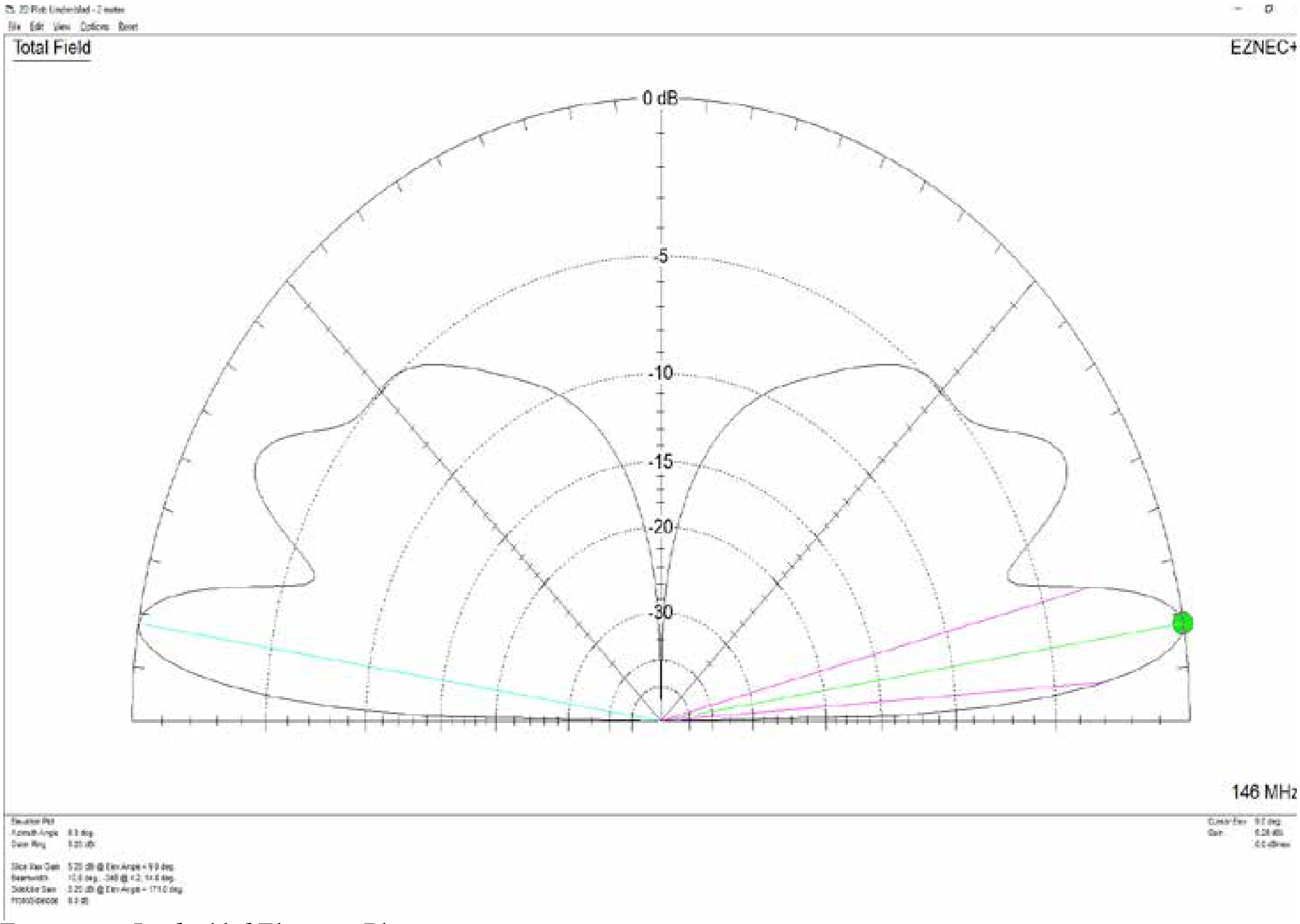


Figure 11 — Lindenblad Elevation Plot.

Figure 12 — Final antenna mounted for testing.

and amplifier (as suggested by ARISS) this antenna should provide solid uplink signals to the ISS from horizon to horizon, ideal for a backup station. Many QSOs on amateur satellites have been made from the station of AA9LC using this antenna, and it is an excellent choice for amateurs who do not wish to install a steerable AZ/EL gain antenna for the satellite operation on two meters.

Thanks again to Tony Monteiro, AA2TX, for his excellent original design. We have enjoyed building and using this rugged antenna (see Figure 12) and hope that our experience will encourage others to build a Lindenblad for their station or as a backup station antenna for an ARISS contact.

Materials:

- Aluminum tubing – 1.125" outside diameter, .058" thickness
- Either: DXE-AT 1485, 1.125 in. 6-foot length, quantity 3
- or: DXE-AT 1499, 1.125 in. 3-foot length, quantity 6

- Schedule 40 CPVC 1-inch tee fitting, quantity 4 -NIBCO brand available at Menards Home Center #T00202C
- Schedule 40 CPVC 1 inch cap, quantity 4 – NIBCO brand available at Menards Home Center # T00225C
- 1 ½ inch angle stock 1/8 x 1 ½ inch x 36 inches long – available at Menards Home Center
- ¾ inch aluminum stock – 1/16 x ¾ inch x 36 inches long – available at Menards Home Center
- RG-11/U coaxial cable – DX Engineering DXE 11/U – 10 feet
- Ferrite chokes – Fair-Rite brand PN 2631102002 – available from Mouser Electronics
- Panel mount SO-239 connector – Amphenol 83-1R – available from Mouser Electronics
- Ring terminals, uninsulated 12-10 gauge for 8-10 stud, quantity 8
- Machine screws # 10-32 x 1/2" long, quantity 12
- Machine screw # 6 x 2.5 inches, quantity 1
- Machine screws # 6 or # 8 or POP rivets as preferred to secure crossarms to the antenna mast
- NOALOX .5 oz. anti-oxidant compound for electrical connections

Contact information:

Grant Zehr AA9LC
9781 Old Sawmill Rd.
Bloomington, IL 61705
Email: grant@dzehr.com

or

Tom Planer KJ9P
2354 Callard Lane
Normal, IL 61761
Email: kj9p309@gmail.com

Phase 4 Ground Update

Michelle Thompson, W5NYV

Phase 4 Ground is a project supported by open source hardware and software technology. The goal of the Phase 4 Ground project is a modular and reusable "five and dime" (5 GHz uplink, 10 GHz downlink) ground station for amateur radio space and terrestrial use. Phase 4 Ground uses the digital video broadcast satellite second revision (DVB-S2) standard as a downlink. The project also supports an extension to DVB-S2 that includes functions to improve reception of very low signal to noise (VLSNR) ratios. The extension is called DVB-S2X. We refer to the combined standards as DVB-S2/X.

The mission of Phase 4 Ground is to create a re-usable affordable amateur radio ground station that provides a frequency-division multiple access uplink (~100 channels of 4-ary minimum shift keyed access) that are combined in the payload into one-time division multiplexed downlink (DVB-S2/X). Any payload that complies with the air interface can use this system!

The primary tool for all this digital waveform radio design is GNU Radio (https://www.gnuradio.org). GNU radio is a free and open source toolkit for software defined radio (SDR) and digital signal processing (DSP). GNU Radio is known and used across the amateur radio community. ARRL's QEX started covering what we would recognize as SDR in the late 1990s. QEX articles over the past two decades cover a variety of tools and techniques, including but not limited to GNU Radio.

The most common introductory radio design for SDR is a frequency modulation (FM) broadcast receiver. GNU Radio blocks have inputs or outputs or both. When the output from a block is connected to another block's input, the data flows from one block to the other. Each block does a task, such as filtering or amplifying. GNU Radio provides a graphical user interface for connecting blocks.

When the flow graph is ready for testing, the "play" button is pressed, and data begins to flow. Data can be sourced from a file, a TCP/UDP socket, live radio signals, or generated by mathematical constructions. Various graphical user interface elements can be placed in the flow graph to see the results. Time and frequency visualizers provide oscilloscope and spectrum analysis. Waterfall displays, constellation diagrams, baseband results, filter representations, and many other visuals can be attached to the flow graph.

Specially formatted computer software functions define each graphical drag-and-drop block. These functions work underneath the user interface. The functions are written in either Python or C++. In general, a Python block is easier to get up and running, and a C++ block has higher performance. A common practice is to experiment with different algorithms in Python. Once the right series of steps is determined, that algorithm is implemented in C++.

GNU Radio is one of the most recognizable and most advanced software defined radio prototyping tools available. Like any other powerful tool, it has a learning curve. Here is what we recommend for learning how to use GNU Radio: **wiki.gnuradio.org/index.php/Tutorials#Guided_Tutorials.**

Generic Stream Encapsulation (GSE) is a standard from DVB. It's important for amateur communications over DVB-S2/X, as it enables any data stream, not just MPEG, to be transported over the communications link. Current efforts include integrating IP Multicast, Real Time Protocol (RTP), and GSE into a powerful distributed radio architecture.

A correlation block has been written by a contributor from Libre Space Foundation and Low Density Parity Check (LDPC) forward error correction code donation from active community members. The DVB-S2 specific correlation block is another step forward in broadband digital multiple access protocols. The LDPC code donation is state of the art.

GNU Radio has block creation boilerplate that helps set up the directory and template structure to get a block done. We also plan to develop an FPGA based radio. We have secured funding for the development boards.

As of today, complete DVB-S2 transmitters are available in GNU Radio, but GNU Radio does not have complete DVB-S2 receivers. Progress on getting complete receivers working has been good, but it is an ambitious goal. Amateur radio is worth the effort! Imagine having a powerful multiple-access broadband digital system that can be used for both terrestrial and space applications.

DVB-S2 receiver flow graphs are composed of open source blocks that implement commonly available and well-understood digital communication functions. These flow graphs will be available for use for both terrestrial and space projects. Development is done in the open using freely available DVB documentation from **www.dvb.org**.

Fun, affordable, broadband digital microwave systems are within our grasp and will enable communications that equal or exceed commercial and proprietary options. It's up to those of us that want to see this happen to come together, collaborate, and contribute in the best traditions of open source. Phase 4 Ground is here to enable and support your journey to learn these technologies and develop systems that make a difference in amateur radio. For further information, please email **mountain.michelle@gmail.com**.

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.

Sometimes we are getting rid of our old equipment, sometimes selling something new. In any case, please consider giving a piece of the pie to a new satellite and choose AMSAT for your eBay Charity.

Member Footprints: Share Your Experiences as an AMSAT Member

As a way to better serve our readers, *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 *The 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**).

Support AMSAT

AMSAT is the North American distributor of SatPC32, a tracking program for ham satellite applications. Version 12.8c is compatible with Windows 7, 8/8.1 & 10 and features enhanced support for tuning multiple radios.

Version 12.8c features:

- SatPC32, SatPC32ISS, Wisat32 and SuM now support rotor control of the M2 RC-2800 rotor system.
- The CAT control functions of SatPC32, SatPC32ISS and Wisat32 have been expanded. The programs now provide CAT control of the new Icom transceiver IC-9100.
- The accuracy of the rotor positions can now be adjusted for the particular rotor controller. SatPC32 therefore can output the rotor positions with 0, 1 or 2 decimals. Corrections of the antenna positions can automatically be saved. In previous versions that had to be done manually.
- The tool "DataBackup" has been added. The tool allows users to save the SatPC32 program data via mouse click and to restore them if necessary. •
- The rotor interfaces IF-100, FODTrack, RifPC and KCT require the kernel driver IOPort.SYS to be installed. Since it is a 32-bit driver it will not work on 64-bit Windows systems.
- SuM now outputs a DDE string with azimuth and elevation, that can be evaluated by client programs. Some demo files show how to program and configure the client.

Minimum Donation is $45 for AMSAT members, $50 for non-members, on CD-ROM.
A demo version may be downloaded from http://www.dk1tb.de/indexeng.htm

A registration password for the demo version may be obtained for a minimum donation of $40 for members and $45 for non-members. Order by calling 1-888-322-6728. The author DK1TB donated SatPC32 to AMSAT. All proceeds support AMSAT.

AMSAT Fox-1Cliff & Fox-1D $125,000 Launch Initiative Goal

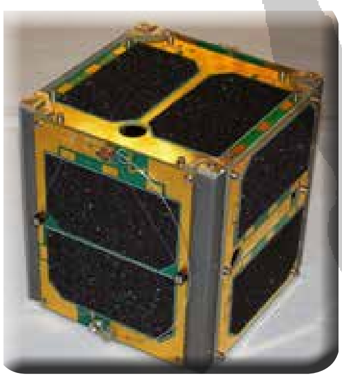
AMSAT is excited about the upcoming launch opportunities for the Fox-1Cliff and Fox-1D CubeSats. Fox-1Cliff and Fox-1D will provide selectable U/V or L/V repeater capabilities on separate frequencies once in orbit, and will be capable of downlinking Earth images from the Virginia Tech camera experiment.

AMSAT has an immediate need to raise funds to cover both the launch and related expenses for Fox-1Cliff and Fox-1D. We have set a fundraising goal of $125,000 to cover these expenses and help us to continue to keep amateur radio in space.

Fox-1Cliff will launch on Spaceflight's SSO-A dedicated rideshare mission aboard a SpaceX Falcon 9 scheduled to launch from Vandenberg Air Force Base in California in 2018.

Fox-1D rode to orbit on an Indian PSLV vehicle launched from Satish Dhawan Space Centre in Sriharikota, India on January 12, 2018.

Donations may be made through the AMSAT webpage at **www.amsat.org**, by calling (888) 322-6728 or by mail to the AMSAT office at 10605 Concord Street, Kensington, MD 20895, USA. Please consider a recurring, club, or corporate donation to maximize our chance of success with this mission.



Your help is needed to get the AMSAT Fox-1Cliff and Fox-1D 1U Cubesats launched.

For the latest news on Fox-1 watch our website at www.amsat.org, follow us on Twitter at "AMSAT", or on Facebook as "The Radio Amateur Satellite Corporation" for continuing news and opportunities for support.

AMSAT President's Club
Support Fox-1Cliff and Fox-1D

Contribute to AMSAT directly through easy, automatic charges to your credit card. Since AMSAT is a 501(C)(3) organization donations may be USA tax deductible. (Check with your tax advisor.) To join contact Martha at the AMSAT Office by phone (888) 322-6728 in the US, or (301) 822-4376; e-mail **martha@amsat.org**.

Titanium Donors contribute at least US $400 per month	❐ $400 / month ❐ $4800 one time
Platinum Donors contribute at least US $200 per month	❐ $200 / month ❐ $2400 one time
Gold Donors contribute at least US $100 per month	❐ $100 / month ❐ $1200 one time
Silver Donors contribute at least US $50 per month	❐ $50 / month ❐ $600 one time
Bronze Donors contribute at least US $25 per month	❐ $25 / month ❐ $300 one time
Core Donors contribute at least US $10 per month	❐ $10 / month ❐ $120 one time

AMSAT is Amateur Radio in Space
... and YOU are AMSAT!

Seize opportunities to launch your amateur radio experience to new heights!

AMSAT Ambassadors - NEW

AMSAT Ambassadors program is looking for satellite operators to share enthusiasm for Amateur Radio in Space with others by:

- Promoting AMSAT at in-person events, practical demonstrations, online, or in written communications
- Offering personal mentoring and coaching to new enthusiasts either in-person or via online means
- Connecting members and potential enthusiasts with proper resources at AMSAT.

To volunteer, send an e-mail to Clayton Coleman, W5PFG at: **w5pfg@amsat.org**

AMSAT Internet Presence

AMSAT's information technology team has immediate needs for volunteers to help with development and on-going support of our internet presence:

- Satellite status updating and reporting.
- Add/delete satellites to ANS and the web as needed.
- Research and report satellite details including frequencies, beacons, operating modes.
- Manage AMSAT's Facebook and Twitter presence.

To volunteer, send an e-mail to Drew Glasbrenner, KO4MA at: **ko4ma@amsat.org**.

AMSAT Engineering Team

AMSAT Engineering is looking for hams with experience in the following areas:

- Attitude Determination and Control, and Thermal Engineering, to help in the design of high orbit CubeSats.
- Power systems, for CubeSats from 1U through 6U and LEO to HEO.
- Help with solar, power supply, and battery design for both LEO and HEO missions.
- Logistics, for parts procurement, inventory, and distribution.
- Documentation, for designs, tests, and public relations.

To volunteer, please describe your expertise using the form at **www.amsat.org/contact-amsat-engineering/.**

AMSAT User Services

AMSAT is looking for an on-line store co-manager to update and refresh the AMSAT Store web page when new merchandise becomes available or prices and shipping costs change.

- Add new merchandise offerings
- Delete merchandise no longer available
- Update shipping costs as needed
- Add periodic updates for event registrations
- Interface with the AMSAT Office.

To volunteer, send an e-mail to Joe Kornowski, KB6IGK at: **kb6igk@amsat.org**

AMSAT Educational Relations Team

AMSAT's Educational Relations Team needs volunteers with a background in education and classroom lesson development ...

- Engage the educational community through presentations of how we can assist teaching about space in the classroom.
- Create scientific and engineering experiments packaged for the classroom.
- Create methods to display and analyze experimental data received from Fox-1.

To volunteer send an e-mail describing your area of expertise to Joe Spier, K6WAO at: **k6wao@amsat.org**.

ARISS Development and Support

AMSAT's Human Space Flight Team is looking for volunteers to help with development and support of the ARISS program:

- Mentors for school contacts
- Support for the ARISS web
- Hardware development for spaceflight and ground stations
- Help with QSL and awards certificate mailing.

To volunteer send an e-mail describing your area of expertise to Frank Bauer at: **ka3hdo@amsat.org.**

Find more information at amsat.org. Click Get Involved, then Volunteer for AMSAT.