The AMSAT® Journal

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Spotting IMAGE

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10605 Concord St., Suite 304
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AMSAT Announcements

2018 AMSAT Space Symposium, November 2-4

AMSAT announces that the 2018 36th Annual AMSAT Space Symposium and General Meeting will be held on **Friday through Sunday, Nov. 2-4, 2018, in Huntsville, Alabama**. Location will be at the U.S. Space and Rocket Center, One Tranquility Base, Huntsville, Alabama (www.rocketcenter.com). Hotel accommodations will be next door at the Marriott at the Space & Rocket Center, 5 Tranquility Base, Huntsville, Alabama. Feature include:

- Space Symposium with Presentations
- Operating Techniques, News, & Plans from the Amateur Satellite World
- Board of Directors Meeting open to AMSAT members, to be held at the Marriott at the US Space and Rocket Center.
- Opportunities to Meet Board Members and Officers
- AMSAT Annual General Membership Meeting
- Auction, Annual Banquet, Keynote Speaker and Door Prizes !!

Our keynote speaker this year will be announced at a later date.

- Multiple activities/attractions in the Huntsville area.
- Huntsville Botanical Garden, Monte Sano State Park
- U.S. Veterans Memorial Museum, Von Braun Center
- Tours of Redstone Arsenal and Marshall Spaceflight Center (TBD).

The Marriott is located at 5 Tranquility Base, Huntsville, AL. Amenities include: Free parking for attendees., complimentary WiFi.

Hotel reservations may be made by attendees directly with Marriott reservations at 1-(800) 228-9290 or (256) 830-2222. Please mention the Radio Amateur Satellite Corporation (AMSAT), Reference Number M-BIHHXTA.

Attendees may also make their reservations online at **amsat.org**.

AMSAT's Mission

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

AMSAT's Vision

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

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Apogee View

Joe Spier, K6WAO
President

As I write this installment of Apogee View, I am less than 24 hours from boarding my flight to Hamvention 2018. I'm looking forward to meeting all my AMSAT friends and making new acquaintances at the Greene County Fair Grounds in Xenia, OH. I guess there is something to be said for getting together with 30,000 of your closest friends, and the Dayton Amateur Radio Association (DARA) always puts on a great event. AMSAT has some important announcements. The GOLF program is beginning its development, and ARISS is kicking off its fundraising efforts to pay for the construction and launch of the Interoperable Multi-Voltage Power Supply (MVPS) and Kenwood radios for the International Space Station.

Another important announcement is this year's 36th Annual AMSAT Space Symposium and General Meeting, to take place on November 2-4, 2018 in Huntsville, Alabama, at the US Space and Rocket Center, One Tranquility Base (www.rocketcenter.com/). Hotel accommodations will be next door at the Marriott at the Space & Rocket Center, 5 Tranquility Base, Huntsville, Alabama.

The 2018 AMSAT Space Symposium and Annual Meeting will feature:

- Space Symposium with Amateur Satellite Presentations
- Operating Techniques, News, & Plans from the Amateur Satellite World
- Board of Directors (BoD) Meeting open to AMSAT members at the Marriott at the U.S. Space and Rocket Center
- Opportunities to Meet Board
- Members and Officers
- AMSAT Annual General Membership Meeting
- Auction, Annual Banquet, Keynote Speaker and Door Prizes!!

The keynote speaker will be announced at a later date. Other activities and attractions include:

- Huntsville Botanical Garden
- Monte Sano State Park
- U.S. Veterans Memorial Museum
- Von Braun Center
-

We are working on tours of Redstone Arsenal and Marshall Spaceflight Center.

The Marriott at the U.S. Space and Rocket Center is located at 5 Tranquility Base, Huntsville, AL, 35805.

Hotel Reservations for the Symposium may be made by individual attendees directly with Marriott reservations at (800) 228-9290 or (256) 830-2222 or at **www.amsat.org/amsat-symposium/**.

Attendees may also make their reservations

On the education front, Dr. Alan B. Johnston, Ph.D., KU2Y, has been appointed as AMSAT Vice President, Educational Relations. Educational outreach is critical to the mission of AMSAT. AMSAT continues to create the structure for fulfilling our mission component regarding education with projects such as the CubeSat Simulator, ARISS, and outreach to primary, middle, high school, and university programs. Alan has agreed to help AMSAT establish and coordinate an education initiative program and serve as AMSAT's senior point of contact with outside organizations regarding educational outreach.

The increasing importance of fulfilling education goals as justification for launch opportunities is essential for AMSAT. Alan is aptly suited for this position as he is currently an instructor at Rowan University in the Electrical and Computer Engineering department and has previously taught at Seattle University, Illinois Institute of Technology, and Washington University in St Louis. Alan is interested in using amateur radio satellites to teach on various engineering and scientific topics, and he thoroughly understands the teacher perspective. He holds an Amateur Extra class license and is also a published author.

From April 30 to May 2, I had the pleasure of attending the 15th Annual CubeSat Developer's Workshop at Cal Poly in San Luis Obispo, CA. This a premier event that brings together universities, K-12 educators, commercial vendors, commercial space opportunities, and the public from all over the globe. AMSAT had a table this year, and traffic was steady. The successes of AMSAT's AO-85, AO-91, and AO-92 show that Amateur Radio Satellites work well. I must commend AMSAT's Vice-President, Engineering, Jerry Buxton, N0JY, for laying the groundwork with the CubeSat community.

AMSAT is perceived as an equal among the many university CubeSat programs and is being sought out for partnerships for amateur radio communications in future CubeSats. I was reminded that the 1784 definition of the noun "amateur" comes from the French amateur or "lover of," and from the Latin amatorem (nominative amator) "lover," in this case "lover of the radio art." The highest compliment AMSAT received was from one of the exceptional professionals from the 18th Space Control Squadron (18 SPCS), formerly JSpOC or NORAD, who described AMSAT as "a responsible spacefarer."

The discussions about FCC licensing and the FCC Part 25 Notice of Proposed Rulemaking (NPRM) were lively. Many presentations covered propulsion with all the varying methodologies, including electrical ion drives, cold, and green gas thrusters, all of which are made to fit in CubeSat spaceframes. With the launch of NASA's first interplanetary MarCO (Mars CubeSat One) CubeSat the following Saturday from Vandenberg AFB, CubeSats are not just for LEO anymore.

AMSAT is working with the ARRL to provide comments to protect Part 97 Amateur Radio Service spectrum. We must realize that the NPRM is about Part 25, Satellite Communications or generally Commercial Satellites. The FCC is attempting to "streamline" the process that has been used to license large geostationary satellites to allow non-geostationary orbit (NGSO) commercial CubeSats access to frequency and licensing for short duration missions. There is an approach to standardize size (no smaller than 1U) and number (10 per license) to limit network swarms of CubeSats. Part 97 Amateur Radio Service and Part 5 Experimental Radio Service are only mentioned in the notes of the NPRM and not in the actual Part 25 proposed rules. Even so, AMSAT and the ARRL will be diligent in our respective reviews and comments.

After I return from Hamvention 2018, I'll be at SEA-PAC June 1-3, "The Northwest's Largest Ham Convention" or the ARRL Northwestern Division Convention in Seaside, Oregon. I'll have an AMSAT table and will give a presentation for amateur satellite enthusiasts in the Pacific Northwest. If you're in the area, please stop by, say hi, maybe renew your membership and find out the latest AMSAT goings on. I'll be back in Reno, Nevada, for NVCON at the Boomtown Casino Hotel, July 20 through 22. I'll have an AMSAT table, a presentation on "Satellite Operating 101," and Anthony Marcin, W7XM, promised me dinner if I gave the keynote address at the Saturday evening banquet. Further out towards September 21-23, I'll be one of the hosts for the AMSAT Academy at the 2018 Duke City Hamfest/ARRL Rocky Mountain Division Convention in Albuquerque, New Mexico. If you're in the area for any of these events and would like to help, please send me an email.

Elsewhere in the *AMSAT Journal*, you should find relevant updates about the Engineering and Human Spaceflight, or ARISS, projects. Any dollars you can contribute to these projects will go to good use.

A few words on AMSAT Policies... The Executive Team has been working on updating several policies to bring AMSAT current with the prevailing standards of doing business. The AMSAT BoD already has approved a harassment policy on, and work has begun on a comprehensive social media policy. AMSAT is hiring a consultant to assist with this comprehensive assessment, but the BoD already has determined that the corporation shall own all its social media.

On the long-awaited EAR/ITAR Policy, I missed my own deadline for completing the policy before Hamvention. But as policy work has continued, our AMSAT engineers have asked for another chance to review the policy. Since this policy directly affects the engineers, I have promised them the additional review time. Complex requirements remain to comply with the federal regulations, but I think AMSAT has found a methodology to not only comply with EAR/ITAR but also potentially have the ability to work with some of the other AMSAT organizations around the globe. I hope to share a complete explanation in a future issue of the *Journal*.

I'll close on a simple but important note borrowed from Tom Wolfe's book and made into a motion picture, (RIP Tom Wolfe 5/14/2018). "Do you know what makes your bird go up? Funding. No bucks, no Buck Rogers." It takes real dollars to build and launch our satellites, so please give what you can. 73-Joe, K6WAO

Engineering Update

Jerry Buxton, N0JY
Vice President, Engineering

We have three Fox-1 CubeSats in orbit right now. The first is the Fox-1A, AO-85, launched in October 2015. Fox-1B, AO-91, went up in November of last year, and Fox-1D, AO-92, was launched in January of this year. Fox-1Cliff is pending launch later this year, and so is Fox-1E. Fox-1Cliff will go on a Spaceflight launch, an SSOA mission. Fox-1E, known as RadFxSat-2, has a linear transponder and will fly on a Virgin Orbit launch sometime this fall (Figure 1).

Figure 1.

The first four of the Foxes had single-channel FM transponders. AO-85 started out a little bit hard of hearing. It was difficult to work with five watts and essentially an Arrow antenna as an "easy sat." I have explained the reasons for that in various places. Three of the four have an AFC built into the receiver with a UHF uplink and the generally 5 kHz steps that you get on an HT. The Doppler on the 70 cm downlink was plus or minus 9 kHz during the pass. The AFC was designed to help that.

As you know, the AFC locks onto your signal. However, as it locks onto only the strongest signal, you have to be the top dog in the pileup to capture it. However, it provides a little assist on the Doppler tuning. We disabled it on Fox-1Cliff because, before we had determined the cause of Fox-1A's problem, we weren't sure if the AFC may have been part of it. With Fox-1C and -1D pending an earlier launch at that time, we decided to disable it on -1Cliff so that we could determine whether or not that was the problem. Of course, those launches got postponed, and we figured out what was wrong before they ever went up. So, when you work Fox-1Cliff, you will need to pay a little more attention to Doppler tuning.

Both Fox-1Cliff and -1D have the L-band downshifter, and that provides the opportunity to have L-band, a 1.2 GHz uplink, again on FM. The sensitivity of 1.2 GHz receiver is excellent, as well as the 70 cm receiver on -1D right now. Some HTs have L-band, which provides a great opportunity to get into some microwave work. Essentially, what it does is receive the 1.2 GHz signal and converts it down to the 70 cm input frequency, and then passes it on to the existing receiver. Meanwhile, the telemetry simultaneously transmits with the transponder voice signals — the "train" sound you may hear of Data Under Voice.

Fox-1E was not part of the original plan of four Fox CubeSats. Using "spare parts" from the previous CubeSats to create a new Fox, we decided to experiment by developing Fox-1E with a 30 kHz linear transponder. We flipped the mode to V/u, so it has a 2 m uplink and 70 cm downlink. We figured that could allow up to 10 SSB QSOs at a time, depending on how friendly you are with your signal. So, that will create some transponder activity in low Earth orbit (LEO). Fox-1E also will use a separate telemetry downlink channel. The downlink will be 1200 bpsk on a separate frequency so that users will have the whole transponder available for communications.

The first three Fox CubeSats do live up to the claim of "easy sats." You can work AO-85, AO-91 and AO-92, and whatever Fox-1Cliff will be called, with a handheld and a quarter-wave commercial off the shelf antenna, even on L-band. We've solved the sensitivity problem we had on AO-85 with AO-91 and -92, and we've found that L-band is just as sensitive.

We've seen many new people trying out the satellites. And the reason these satellites are designed the way they are is to provide an opportunity for many hams to work an "easy sat." Anyone with a Technician license, an HT and a simple antenna can try them out and see if they like satellites. It's a cheap test drive.

I have been producing some videos both on YouTube (**www.youtube.com/n0jy**) and live streaming on Twitch (**www.twitch.tv/n0jy**). My perception as V.P. Engineering is that we say we're going to build a satellite, go away for four years, and then come back with a built spacecraft. In the meantime, everybody wonders what's going on, and actually, a lot is going on. To get something that is space-worthy with a high likelihood of success in our terms and that will last a long time takes a lot of work.

If you want to tune into the videos, some are long, but you can speed them up or skip through them. A two-hour video is just one slice of a required test. I've also produced a few 15-minute videos to talk about specific topics. I did one on the Foxes in general and RadFxSat-2, as well as "The Good and the Bad with AO-91," about its trials and tribulations. Even though we've built five "identical" satellites in a sense, every one of them has its own string of problems. They are very complicated and fitful, and they will drive you nuts right to the end.

The GOLF program is our next step in AMSAT's satellite program, which means we will do more than one as we did with the Fox-1s. It's a better return on investment because, with the components and other things that it takes to build one, it's cheaper to buy more of them at one time.

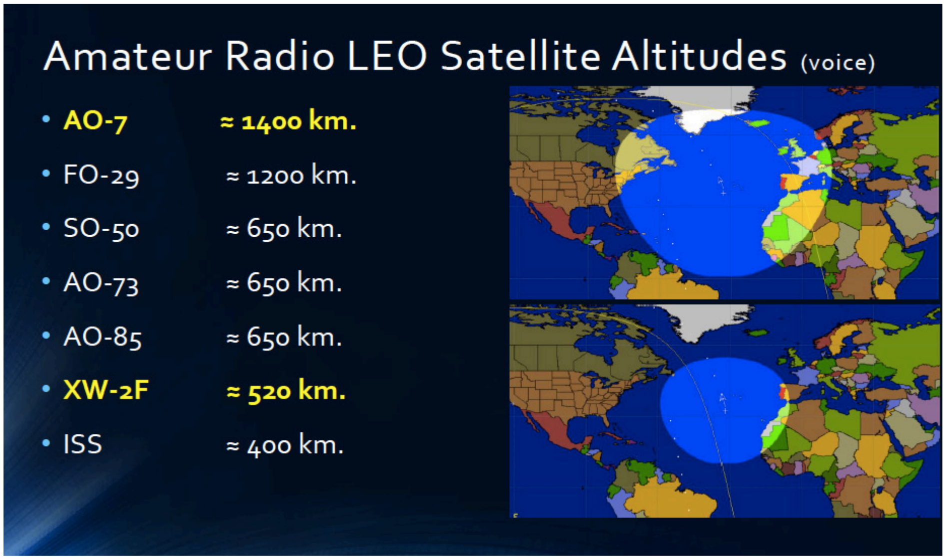

Figure 2.

GOLF is the phonetic following Fox, and we've made it an acronym for Greater Orbit Larger Footprint. The higher the orbit, the larger the coverage. As Figure 2 shows, with AO-7 at an altitude of 1400 km, you see the larger size of the footprint in the top right image as compared with the XW-2F, a typical LEO satellite with the smaller footprint shown in the lower right. With the GOLF series, we're working our way back up to high elliptical orbit (HEO), and getting there requires a bit of knowledge (Figure 3).

The Fox series of satellites all were 1U CubeSats and, in part, a learning tool for AMSAT Engineering because we had built all sizes and shapes of satellites but never anything that small before. Trying to reduce the electronics into something that size, and enable it to function in the environment affected by thermal conditions, vibration and the radiation of space was a challenge. We learned from that and did very well. So now, we're going to get a little bit bigger with a 3U platform, and incorporate Attitude Determination and Control (ADAC) for stabilization of the satellite, deployable solar panels, ability to point antennas, and possibly propulsion in the future. Deployable solar panels will be needed for more power. Software-defined radios (SDR) require more power but also provide more flexibility. With propulsion, in the future, as we go higher, we also need to be able to de-orbit. By law, to minimize orbital debris, you must de-orbit or place your satellite in a "parking orbit" within 25 years after the end of your mission. Typically, with satellites like Fox, we launched them into a decaying orbit that will last only six to eight years before re-entry. Once we get up to orbits like those of AO-7, 1300-1400 km, we have to be able to bring the satellite back down.

GOLF-"TEE" (Technology Exploration Environment) will be the first one and already has been "recommended" by the NASA CubeSat Launch Initiative (CSLI) last February, which means CLSI will manifest us for a launch. GOLF-TEE primarily will test the ADAC and deployable solar panels. It also will include the Fox-1E-type linear transponder, a proven technology, which provides us with the opportunity to maintain effective communications so if we have any trouble with ADAC and the deployable solar panels we can issue commands and understand what's going on. It's also the backup or failsafe so that, if all else fails, we will still have a working amateur radio satellite.

With the SDR, we'll start moving to the "five and dime"—the C-band/X-band plan, with a minimum of an X-band high-speed telemetry downlink. That doesn't mean we're not going to do more than that, but that is the minimum requirement we set as a target.

With the VHF uplink for the V/u transponder, and also can downlink it to X-band. We may be able to use VHF and X-link on the downlink. In addition to the ADAC and deployable solar panels, we'll also test a radiation-tolerant IHU (Integrated Housekeeping Unit). With the Fox IHUs, we went with the commercial off-the-shelf (COTS) units because they are cheaper. As you go higher, you get more radiation, and it's going to upset the spacecraft more. Fox-1's IHU was relatively "dumb," so that if it went through the South Atlantic Anomaly, for example, and experienced a radiation upset, the IHU simply would reboot and pick up where it left off. The radiation hardened IHU is looking to use technology that will protect against those kinds of upsets as well as backing it up with logic. We hope to implement the most robust IHU for the cheapest cost.

GOLF-TEE also will carry a Vanderbilt University radiation experiment. This is a continuation of the same experiment that Vanderbilt conducted on several of the Fox-1 satellites and will help provide a baseline by comparing the radiation at higher orbit with the LEO radiation to which Fox satellites are exposed.

Figure 3.

GOLF-1 is targeted for delivery in the fourth quarter of 2020. We're shooting for a 1300 km orbit, somewhere up in the area of AO-7 and FO-29, with an SDR transponder with "five and dime," 5 GHz up and 10 GHz down. We'll also have the capability of a V/u linear transponder because, as we go higher, we need to transition to microwave bands for volume purposes as much as anything else. Putting high-gain antennas on CubeSats is not easy. It's much easier with shorter wavelengths to incorporate patch arrays, for example.

And with an SDR transponder, other bands and modes are possible. As we do more missions moving back up to HEO, we can do HF, 1.2 GHz, and other things.

Albuquerque Public Schools has partnered with Virginia Tech and us to take one of the Virginia Tech camera designs used in Fox-1C and -1D to provide its own weather observation experiment. Vanderbilt University has more radiation experiments to fly which are useful to AMSAT as well because they will help us learn about the effects on COTS parts. And this will require a de-orbit capability. So, we need to find a certified de-orbit device to be able to bring us back 25 years after a mission.

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.

ARISS Update

Frank Bauer, KA3HDO
Vice President, Human Spaceflight
Chairman, ARISS

To refresh everyone's recollection about what we provide on the International Space Station, ARISS radios are located both in the Columbus Module and the Russian Service Module. We have VHF and UHF capabilities located in the Service Module and VHF available in the Columbus Module. We also provide Slow Scan TV and HamTV.

What I want to convey to you is how comprehensive our program is. You might hear a lot of talk about going to Mars and now to the Moon, but internationally the focus is on the Deep Space Gateway, which is between the Earth and the Moon. This is a way to "gateway" missions from Earth to the Moon or Mars. We are working both on the European side and the U.S. side with our respective space agencies to make sure they understand that amateur radio has done these kinds of things before in space, having included receiving Voyager and Cassini signals. So, we submitted a request for information that came out of the European Space Agency (ESA) on the European side. On the U.S. side, we've conducted several conversations with NASA about the Deep Space Gateway.

Regarding funding, CASIS (Center for the Advancement of Science in Space) provides support for our operations that amounts to $150,000 per year. The amateur radio leadership from AMSAT and ARRL are two tremendous partners. And Kenwood has been, and continues to be, a primary sponsor, as well as Dayton Amateur Radio Association, QCWA, and the YASME Foundation.

Our next ARISS International meeting will be October 18-20, 2018, at College Park, Maryland, in the Washington, D.C. area. We'll have a two-day education summit, and NASA tours in the afternoon of Tuesday, October 18. The ARISS International meeting will take place Wednesday through Friday. And, on Saturday, October 20, we'll have hardware development discussions. It's an opportunity to meet the ARISS International team and have fun.

Since we talked last, we established an education committee. We have 22 U.S. members who are educators and support the proposal process for the contacts. They staff our booths all over the U.S. for CASIS and NASA SCaN (Space Communications and Navigation organization). They are interested in mentoring our educators, the teachers, and helping with lesson plans. We're trying to make our program even more comprehensive from an education perspective.

Among our educational accomplishments, last year we directly touched about 170,000 people, both students and the general public. That means people in the auditoriums during our ISS activities. Our contact events included a group of Tuskegee airmen students, youth in aviation students and we had five astronauts on stage with them before, and after, the contact. We also engaged with the Girl Scouts of America, which involved an entire week of activities culminating in the contact. Plus this occurred in the rain, and the girls didn't care because they wanted to be involved in the contact. Those are just three of the 81 contacts conducted last year. We're approaching 12,000 contacts since we started in December 2000.

ARRL sponsored the development of a pre-contact video to get students and the general audience aware of amateur radio in a more in-depth way and what's going to happen before the contact. So, we wanted to make that similar from contact to contact.

Antietam Elementary School represents another significant contact. One of our education committee members who attended, Kathy Lamont, KM4TAY, has a daughter, Hannah, who was nine years old and obtained her Technician Class license when she was eight, just upgraded to General.

Slow Scan TV gets more exciting every time we do this. We've had 6,000 images uploaded to the website. People like it, and we're going to try to provide it more often. Plus it will be even better once we have the interoperable radio system installed.

Concerning the onboard status, we're pretty much where we were last year. The Kenwood TM-D710 currently onboard in the Service

Module is a stock radio operating in kind of a kludge mode — not the way we want to operate it. However, it is a powerful unit. Our digital died, as everyone knows. So, we're not doing APRS, but we had a design change with the interoperable radio system. We thought we were going to launch in October, but it now looks like we're going to launch in January of February. With the additional downtime, we worked with NASA and decided we're probably going to launch one of our flight back-up packet modules and spend the time to get that certified and flown. We expect to get the paperwork completed before July and will probably fly in early October on either the Soyuz or Progress resupply ship. Moreover, if we can get an earlier flight, NASA will put us on the payload.

You might have seen our press release about the HamTV system. The transmission capability has been out for several weeks, and we've been doing substantial trouble-shooting with the astronauts. Unfortunately, when ESA built the HamTV system, they did not build a flight back-up. So, we need to bring the old one down, repair it, and send it back up. We're working pretty aggressively on that. We want to make sure that ESA is entirely on board because they own the hardware, and we're the custodians of it.

We will get HamTV back in operation as soon as we can. One of the most significant challenges we've had is with the down-converter and the availability of down-converters.

I want to say more about the interoperable radio system. We're using a Kenwood TM-D701GA with a power supply for VHF, UHF, voice and packet, and Slow Scan TV. We've modified the transceiver to operate in constant repeater mode, which is something hams would love to see, as well as APRS capability in both the Russian segment and the U.S. segment. The multi-voltage power supply is our future because it will allow us to connect four different systems with multiple devices at the same time. We're going to use it for the VCH-1. We have 6-volt, 13.8-volt and 28-volt capability with this power supply. We're very proud of the effort. Lou McFadin, W5DID, is the leader and Kerry Banke, N6IZW, has been doing the actual electronics development. The radio is ready, but we can't fly it because we need 13.8 volts.

We have to build 10 units. We need two of them onboard. And these are about $15,000 apiece when you include all the costs. That equates to approximately $150,000 total to produce. We'll deliver the first one in the Columbus Module because we need it most there. Then, we'll deliver the next one in the Russian Service Module.

We just kicked off a fundraiser. We're looking for $150,000 to support the new capabilities as well as student outreach activities, with various donation levels starting at $100. Donors receive different benefits for each level. At the"Astronaut" level, you are entitled to a behind-the-scenes tour of either the Johnson Space Center or Goddard Spaceflight Center.

ARISS is also involved with experimentation. One is "Marconista," which means radio amateur in Italian. This experiment is a spectrum analysis using a LimeSDR, as well as antenna analysis, to be launched on SpaceX to ISS in the middle of this year.

Our Russian colleagues will be flying CubeSats, another set of the Tanusha formation-flying satellites in August.

We need both financial and volunteer support, including electrical and mechanical mentors and ground stations for HamTV. We started this program 21 years ago — me, Bill Tynan, Lou McFadin, and Rosalie White. The teamwork has made it happen, with all the space agencies. Also, we want to go beyond low Earth orbit. We have this opportunity with Deep Space Gateway. Since November 2000, we've supported AMSAT in "keeping amateur radio in space," and we want to do that beyond low Earth orbit, too.

Recovering NASA's IMAGE Satellite Using the Doppler Effect

Scott Tilley, VE7TIL

As any radio amateur knows from their very first experiences monitoring an OSCAR (Orbital Satellite Carrying Amateur Radio), a distinctive frequency shift occurs in the satellite's radio transmissions during the evolution of the pass over a given ground station. Known as the Doppler effect, most operators consider this an annoyance or perhaps an additional challenge to overcome to allow for effective communication over a satellite path. However, some consider it an invitation to study the orbit of the object or even tell you what the object might be. As we will see, this and a lot of time spent listening, analyzing, researching and cataloging resulted in the recovery of NASA's lost IMAGE satellite.

A broad swath of microwave radio spectrum on S-band (2200-2300MHz) is set aside for space-to-Earth communications using routine telemetry, tracking, and control of spacecraft (TT&C). While the signals found here are often weak and very uninteresting upon a casual glance, they provide a wealth of targets to study orbital dynamics, space history and even Geo-politics.

The Doppler effect is the change in pitch of a signal caused by the relative velocity of the receiver in relation to the transmitting object. The frequency of the signal can be directly related to the relative velocity of the receiver and transmitter. One can then take expected relative velocities of objects and predict the effect of their motion on a signal source moving relative to a receiver. One can also take anticipated velocities and compare them to observed signal frequencies converted to velocities and then find the best match in a catalog of objects expected to move over a receiver.

The station here uses two primary means of obtaining S-band Doppler data, an omnidirectional search antenna and a small 60cm dish for positional and deep space monitoring. The station is arranged as noted in Figure 1. The software used is called Sattools RF written by Dr. Cees Bassa and is freely available on Github. Amateurs developed this software over the years specifically to study and track satellites using

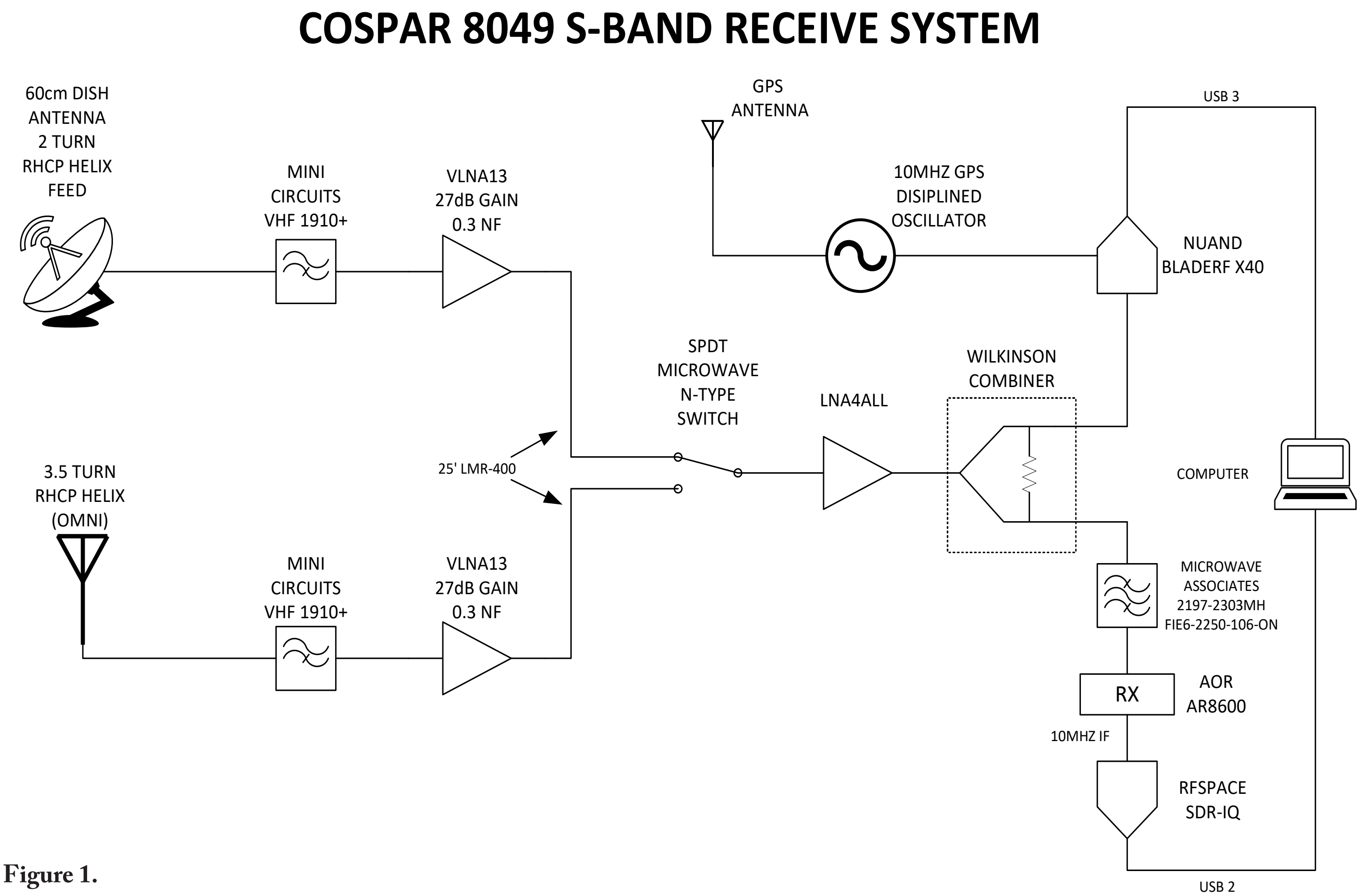

Figure 1.

the Doppler effect. A view of the station's S-band dish and omni search antenna is provided in Figure 2.

While searching for something entirely different from IMAGE, frequency versus time data was collected from an unknown signal as shown in Figure 3. This data was later studied manually to identify a signal not noted in the catalog of known emitters after many years of monitoring. Next, the data was extracted from the background noise and plotted for analysis. At this point, an algorithm in software was used to conduct a brute force search by taking each object published daily by the Joint Space Operations Center (JSpOC) and the amateur classified orbital catalog maintained by Mike McCants. The software compared the data to each unique set of orbital elements for all objects known to be in Earth orbit one by one.

The algorithm looped through the provided orbital catalogs and converted each object's orbital elements from the catalog into a velocity at the time the data was sampled and then conducted a curve fit to compare the actual data against the calculated data for the object being compared. The curve fit routine outputted an RMS (root mean square) error value, and this was used to filter objects out that produce high residuals. Objects with low residuals were displayed, and the object with the best RMS fit was offered as the best fitting satellite.

The technique is far from perfect. Not all of the orbital elements can be uniquely constrained from a limited amount of data. As with any data analysis, routine careful collection of data over time allows for a better chance of obtaining a reliable output. Also, good old research of the object after the routine collection provides a best guess and offers critical insight into the correct identification of unidentified targets.

In the case of IMAGE, once the routine provided its best guess as being object 26113, a search of the object number revealed it was IMAGE in human understandable terms. This was reassuring as it wasn't debris. A rocket booster or some other object cluttering Earth's orbit would surely not be emitting radio signals. But another mystery emerged. All the published articles on IMAGE at the time of the recovery referred to IMAGE in the past tense and, after some further reading, noted that it had been lost in space since 2005. The work wasn't completed at this point as IMAGE was supposed to be dead, and no specifics mentioned the spacecraft's RF characteristics.

After some additional research, the NASA failure review board report for IMAGE was obtained. This provided an excellent reason why IMAGE may be transmitting. NASA considered that the most likely failure mode for the mission was a single event upset that caused an electronic circuit breaker feeding the communications system to open. They figured that after the spacecraft experienced an extended enough eclipse, it would reboot into its default configuration and restart the radio communications system. Unfortunately, this didn't happen in 2007 as hoped and NASA gave up. But it appeared to have happened years later as these observations revealed. Meanwhile, more Doppler data was being recorded, and the fit was getting better. The moment we realized that this was a potentially significant

Figure 2.

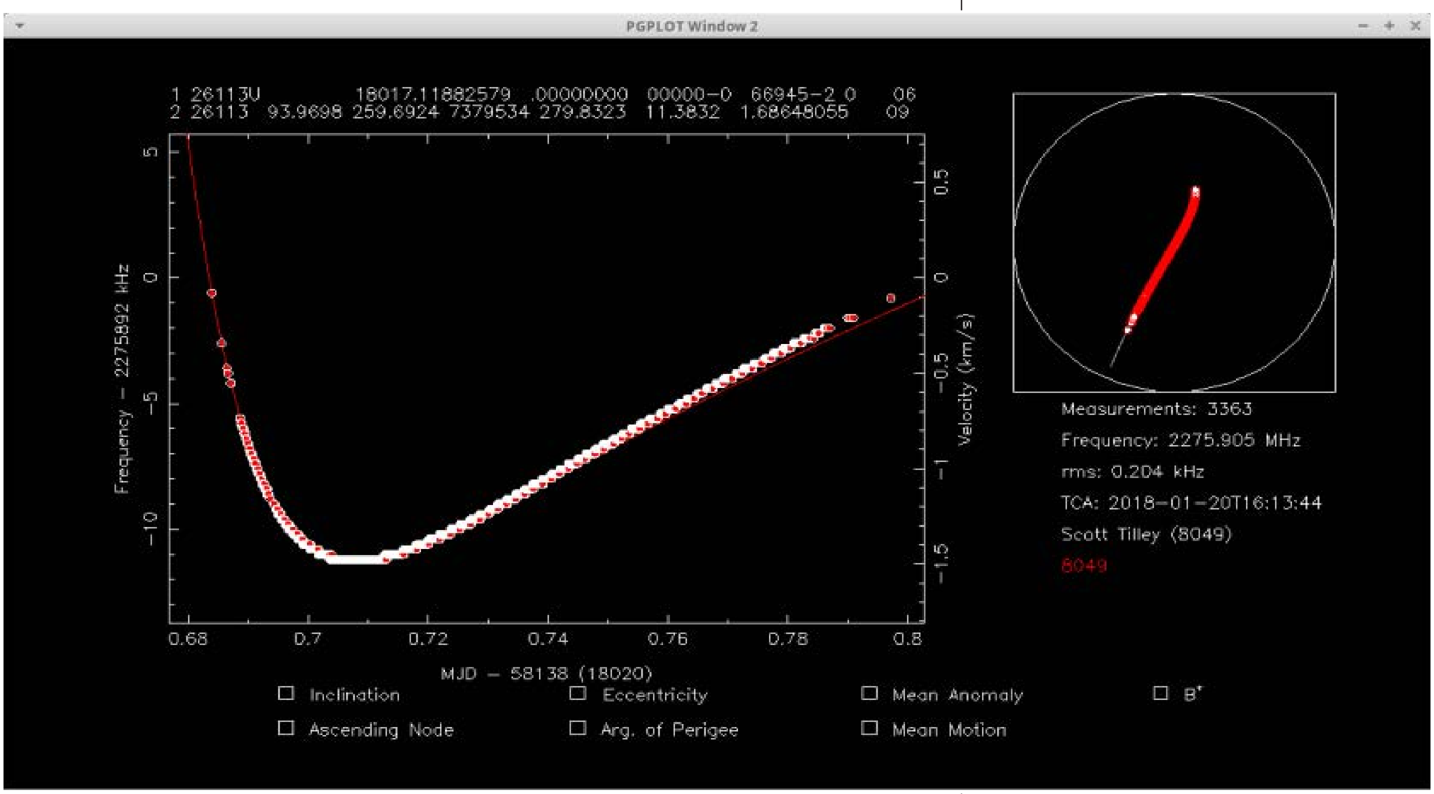

Figure 3.

observation was very emotional.

Like all good amateurs, the observations were written up and ultimately sent to the mission's Principal Investigator, Dr. James Burch of the South West Research Institute (they QSL right?). Dr. Burch followed up by sending the report to NASA and having NASA confirm my observations by initially noting that the carrier frequency and data sidebands observed in my data were consistent with IMAGE. Later, NASA was able to decode telemetry blocks and obtain the spacecraft ID, definitively identifying the satellite as indeed IMAGE.

This wasn't the first time that the Doppler effect was used to identify, track and or locate a satellite in space by amateurs. Some recent examples include the tracking of The Planetary Society's mission, Lightsail. Amateurs assisted in following the spacecraft to final reentry by studying the Doppler effect on the mission's signal on 70 cm. Amateurs also helped in the recovery and tracking of the Manfred Memorial Moon Mission (4M) that was lost track of after its first encounter with the Moon. Study of the Doppler characteristics produced the final orbital elements of the mission before its battery died and it ended.

Amateurs can contribute significantly by studying the Doppler characteristics of satellite emissions as software and hardware techniques have evolved to the point this is now practical for amateur observers. The amateur's ability to monitor large parts of the spectrum with no bureaucratic restrictions on their interests allows for many research projects to be within their purview.

The methods touched on here can be employed to identify unique satellites launched in clusters, in search of missions that may have experienced technical difficulties but later came back to life (like IMAGE), and to provide critical tracking data to on-orbit experiments in low orbits or deep space orbits or active satellites that are about to reenter. It also shows that amateurs can contribute real science using the tools and equipment that adorn their shacks.

A Whole Orbit Data Simulation Based on Orbit Prediction Software

Carl E. Wick, D.Sc., N3MIM

Abstract

Most satellites, including AMSAT Fox satellites, collect important satellite state and experimental data at periodic intervals throughout an orbit. A complete orbital history of satellite data can be extremely important in not only determining the continuing health of a satellite but also in determining reasons and corrective action when anomalies are observed. Acquiring and maintaining historical data implies that there must be a system to not only collect sufficient and timely data at the satellite, but also to ensure that a complete record of this data is received at control points on Earth. In this paper, I discuss a simulation method that was used to help answer some critical satellite systems design questions concerning the collection, retention, transmission and ultimate reception of whole orbit data at an Earth control point.

Introduction

Except in very rare instances, once a satellite is launched, the only possible view of its current state of operation is through specific health-related data periodically sent earthward. Though each single data set provides valuable information, it is only through complete histories of the data (so-called whole orbit data) that trends may be noted or subtle anomalies may be discovered. Therefore, in the design of satellites that record and transmit internal system data, we need to consider a complete picture, from the generation of the data, to queuing on the satellite, to transmission schemes, to reception by ground stations, to final collation of all data at a control point. Because a satellite is typically not recoverable to analyze, rebuild and relaunch, it is important to consider all collection, transmission and re-assembly factors as thoroughly as possible at design time.

When designing whole orbit data systems, we want to be able to precisely model and predict in advance what will happen as a satellite collects data and then sends the data to ground stations while it orbits the Earth. Equally important is to have a model that is as faithful as possible to actual operating conditions and one that makes minimal assumptions. Given the remote nature of space, such prediction can often be performed only through carefully constructed simulations.

One type of simulation commonly used that accurately depicts the position of a satellite with respect to the Earth is an orbit prediction model, typically called a satellite tracker. Such a model can not only predict the location of a satellite in real time but also can project a satellite orbit in time to show future satellite positions. When the location of a satellite in orbit is known, that location can then be used to determine which portion of the Earth could receive the data, how much data could be collected at a given transmission rate, etc. Predicted positions will also reveal portions of an orbit in which no reception is likely, for example when the transmission footprint of a satellite is over an ocean or a relatively unpopulated region. Such knowledge will help in deciding how much data a satellite must retain during an orbit to have reasonable assurance that all orbit data would be received somewhere on Earth.

The simulation described in this paper has at its base a standard orbit prediction program. The code was modified by the author to not only track a collection of satellites, but also to maintain an extensive database of Earth stations that routinely provide satellite telemetry data to AMSAT. The program can determine satellite viewing parameters at each station and use this information to determine the likelihood that data from a satellite would be received. By knowing orbital satellite positions and ground station locations, various data assembly and transmission schemes at a satellite can be devised, tested and tuned iteratively to produce a well-functioning design.

Simulation

The orbit simulation program used in this study began from one constructed by the author several years prior as a way of answering similar types of questions in the design of a commercial communications satellite system. The orbital prediction portion of this simulation is based on a standard NORAD low Earth orbit prediction model (NORAD SGP4). For those interested, details of the SGP4 model, including FORTRAN code, may be found at www.celestrak.com/NORAD/documentation/spacetrk.pdf. The SGP4 Fortran code was translated by the author to equivalent C++ and was then placed in a C++ Builder graphics shell. The addition of a graphics shell allows projected satellite positions and ground stations to be viewed on a three-dimensional near-Earth representation, and it will enable controlling variables from a graphics screen. In normal operation, satellite positions are tracked in real-time at a one-second rate, but projecting future satellite positions can be made at substantially higher rates, requiring only about one second per orbit to calculate all ephemeris and communications parameters. Orbit prediction of operational satellites relies on data from standard satellite orbital element sets, which are easily found on the internet. Correct operation of the orbital portion of the simulation was verified by comparing operational satellite positions with other existing prediction models and by verifying with beacon signals from operational satellites.

A substantial Earth station model was added to the satellite orbit prediction simulation. In this addition, at each orbit point the Earth footprint (Earth area from which satellite is visible) of the satellite in question is calculated. A database of ground stations is then queried to determine which ground stations fall within the footprint and at what azimuth and elevation the satellite is seen by each. This database was populated by a collection of ground stations that regularly contribute telemetry to the AMSAT server. Positions of all ground stations in the database are shown on the 3-D Earth graphic during operation.

Further modification to the simulation is code to simulate, on a second-to-second basis, data generation, queuing and transmission from a satellite like AO-85 or future Fox satellites to the collection of Earth stations. The probability of reception by any one station is determined through Monte Carlo statistics based on observed satellite elevation. As a particular simulation progresses, several files are generated to record the progress of a satellite's orbit and to record other relevant factors such as the number of ground stations that see the satellite, amount of data in satellite queues, how much data has been successfully received by ground stations, etc. These data are saved in such a form that they can be viewed in other data viewing and processing programs. I used MATLAB for further processing and data viewing.

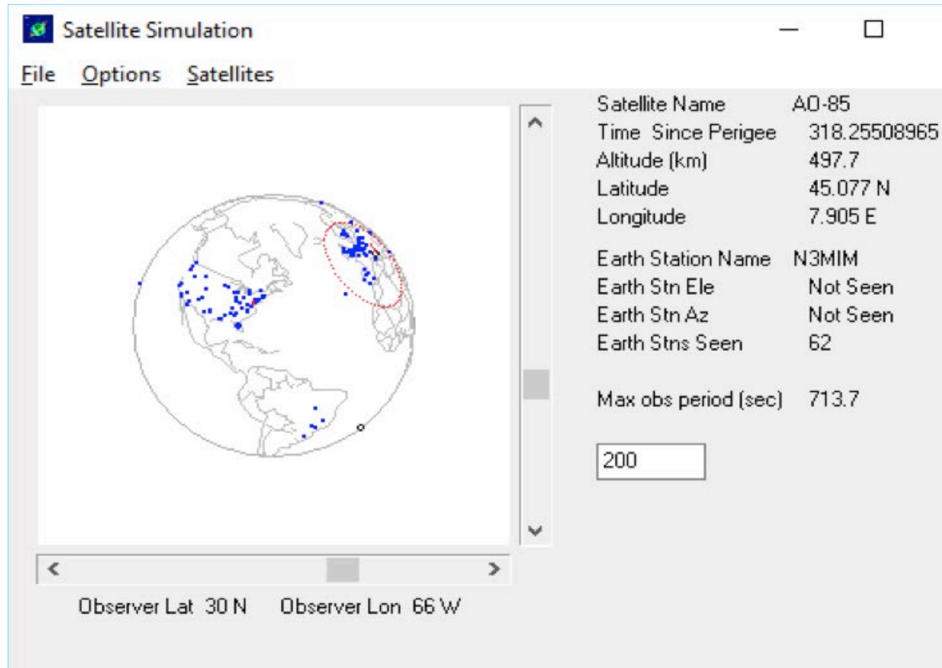

Figure 1 — Snapshot of the subject satellite prediction program in operation. The circular footprint of the satellite of interest (AO-85) may be seen over the European continent. Note the simulation indicates that satellite can be seen by 62 AMSAT contributing Earth stations there (dots). The program can simultaneously track multiple satellites; a secondary (no footprint shown) fictitious polar orbiting satellite may be seen as a small circle on the Earth limb just off South America. Also shown here is an edit box shown on the lower right, which allows satellite queue size to be changed in simulation runs (current size is 200). In this way parameters can be optimized.

Some design questions and simulation answers

Once this software tool was established, I then used it to answer some critical design questions related to future AMSAT satellites. Even from the limited view shown in Figure 1, we can make several observations. The first is that the collection of AMSAT contributing Earth ground stations is highly localized to a relatively few geographic areas. In the displayed view, America and western Europe show a heavy concentration of receiving stations; a few receiving stations are located along eastern South America and almost none elsewhere. During a satellite orbit, sometimes data passed to the ground will have a high probability of reception because many stations are under the footprint; at other times, long stretches occur where few or no receiving stations are available.

The first question that arises is, in the likely orbital path of a satellite like AO-85, for how much of an orbit will the satellite be out of range of any telemetry receiving station? The answer can be valuable in determining how much data must be retained at a satellite in a queue so that a complete history might be received during one or more orbits. We might answer that question in part by projecting a satellite over an orbit similar to AO-85 for an extended period of time (one day was chosen in this study).

During the projection of the satellite track, each Earth station is queried each second to see if it falls within the footprint. Counters are then incremented to show periods of time that no Earth station is under the footprint of the satellite, and other counters are incremented to indicate when at least one station is under the footprint.

Since AMSAT satellites (and most CubeSats) do not intrinsically know what land mass they are operating over at any given time, the data they generate must be held in some type of a queue. This queue must be of sufficient size so that when data is sent from the queue on a continuing basis, all data may eventually be observed by a collection of ground stations. The size of this queue is directly related to the maximum length of time the satellite is without a suitable receiving station under its footprint. Some results of a simulation of this type can be seen in Figure 2. We can see that a satellite in an inclined orbit like that of AO-85 experiences significant periods of time during which the satellite is not in range of any of the database telemetry receiving sites.

The longest period during the 24 hours simulated for an orbit like AO-85 is over 5100 seconds (85 minutes). Other outage times of 2000+ seconds are very common. If

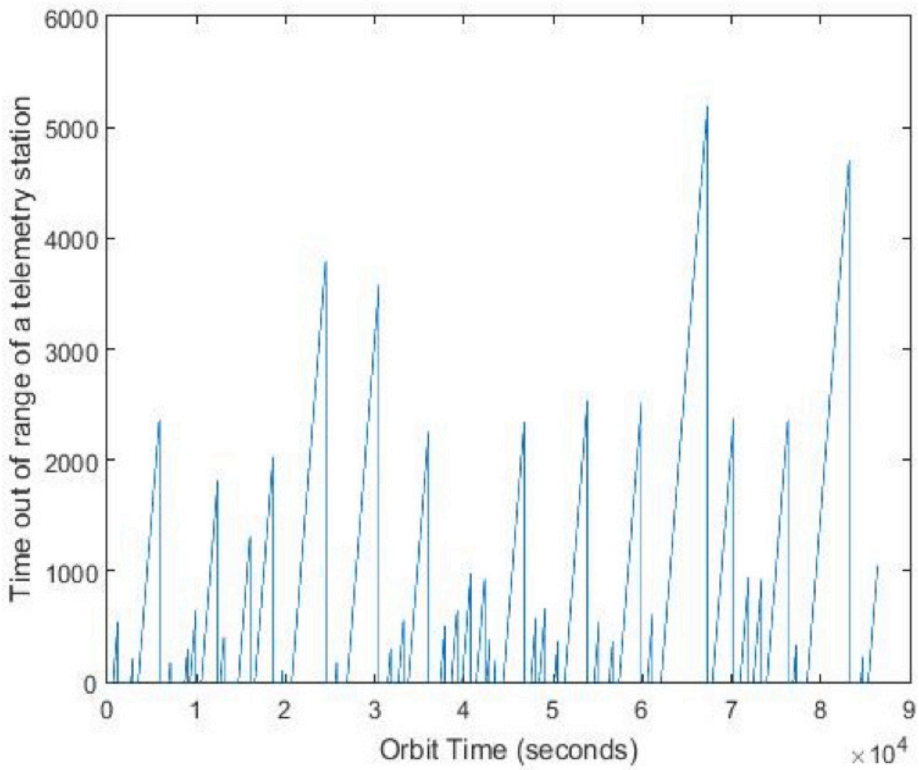

Figure 2 — Results of a simulation of an AO-85 orbit over existing AMSAT telemetry receiving ground stations.

a ground station receives a complete record of data at some point, then a satellite data queue would have to hold at least enough data to cover the most considerable outage period it might encounter, so that it might be able to send the total collection of historical data to the ground piecewise later.

Interestingly, the results of this type of simulation are slightly dependent on orbital plane. For example, an inclined orbit northwest to southeast (like AO-85) can encounter a significant stretch of ocean area, particularly in the Pacific Ocean due to the distribution of land masses, where polar orbits may result in shorter stretches of ocean. Whether this orbit-dependent factor is important also has to do with the geographic concentration of ground stations around the world.

Another question we might ask is can periodic data be held and retransmitted to available ground stations such that all data can eventually be recovered on the ground? That is, can at least one ground station retrieve at least one sample of every data set generated by the satellite? This is a complicated question that has several variables. They include: how often data is generated by the satellite, the size of data packets to be sent, the data queuing scheme used, the rate data can be transmitted by the satellite to Earth, the number of stations under a footprint, and the probability that a viewing ground station can successfully receive a complete data packet.

To answer this question, a separate model of proposed satellite queuing strategy was programmed into the simulation as a subroutine. In this queuing strategy, a satellite pushes data packets of a known size into an onboard satellite queue at a predetermined sample rate (2 packets per minute in this study). The spacecraft then sends data blindly to Earth round-robin from the queue at a rate that can be supported by the modulation method used for telemetry and the physical size of the packets to be sent (1200 baud and approximately one data packet per second).

The satellite must continually send packets in circular buffer style because it has no knowledge of when it is over stations that may receive the packets. It must rely on having a queue that is large enough and transmission rates fast enough that all the data will be collected by some station somewhere. Imperfect ground reception was accommodated by using a probability distribution based on satellite elevation at the time packets are sent from the satellite. This distribution function (0 to 1) assigns low probability when the satellite is near the horizon and high probability if a satellite is near zenith from a receiving station. Monte Carlo techniques are used to determine if a message makes it from satellite to ground station. A random number between 0 and 1 is chosen by the computer for each station falling under the satellite footprint. If the random number is less than the distribution value for the satellite elevation seen, reception is said to have occurred, otherwise reception does not occur. If reception happens at any station for a packet, then the item in the satellite queue is marked as "sent."

As the simulation runs, new data packets are continuously pushed onto the queue at a low sample rate. Once a packet has reached the length of the queue, it is considered lost unless it has been received at some point by some ground station and marked as "sent." In a simulation run, the queue is checked to see if more unreceived packets remain than the projected length of the queue. If this happens, data is presumed lost. By running simulations and adjusting queue sizes to reduce or eliminate lost data, a more-or-less optimum size can be chosen for a particular queuing and communications strategy.

From simulations done to answer questions about queue size, an interesting observation emerged. If queue sizes are too small, data routinely will be lost because not enough data is accumulated over extended areas of outage and leave the queue before it can be retransmitted and received by a ground station in a populated area. But large queue sizes also lost data. In this case, the problem is that the available ground stations are too concentrated in relatively small geographic areas and insufficient time is available during a pass to get substantially through a large queue circularly transmitting data (at medium data rates). Essentially, the satellite has moved beyond reception range of any ground station before it can get completely around a large queue.

Summary

This paper has outlined how a low Earth orbit tracking simulation was modified and used to begin to answer some fundamental satellite whole orbit data system design questions. These simulations are based on actual orbital positions taken from existing or proposed orbital element sets, as well as on the real locations of contributing ground stations. Furthermore, the resulting simulation duplicates the communications functions of a target satellite design and uses actual ground station locations to predict the likelihood that various systems parameters and schemes will or will not work in an operational environment.

Evolution of the VITA 74 Standard (VNX) for "SpaceVNX" CubeSat Applications

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Abstract

A new standard is working its way through the standards community. This standard defines the module functionality, interface and packaging concepts for small form factor (SFF) embedded computers, I/O modules, power supplies, backplanes and chassis building blocks. This new standard was recently ratified by the VITA Standards Organization (VSO) and has been published by ANSI and released as a joint ANSI/VITA standard known as AV74.0-2017. This new standard is referred to as "VITA 74", also known by its trade name as "VNX." The VITA 74.0 Compliant System Small Form Factor Module Base Standard has been created to meet the growing needs for improved size, weight and power (SWaP). The standard features a rugged, low cost, fast serial fabric interconnect based plug-in module, while leveraging many proven features of existing ANSI, VITA and other military and commercial standards.

A specific implementation of VITA 74 is being developed to address the specific needs of the CubeSat and SmallSAT marketplace, and this implementation will be specifically referred to as "VITA 74.4" or "SpaceVNX." This paper will describe the essential elements of VITA 74, and discuss current plans to evolve the baseline VITA 74.0 standard to VITA 74.4, SpaceVNX.

Foreword

The VITA 74.0 standard describes both mechanical and electrical standards required to implement a SFF system utilizing compliant VITA 74 modules. The standard addresses a need for a unified approach to small-scale systems to be used in a variety of MIL-Rugged applications. The standard encourages multiple vendors to supply components to be used in SFF systems at various levels; i.e., modules, backplanes, enclosures and complete solutions. The goal is to allow vendor implementation flexibility, at the same time maximizing component interoperability.

To minimize development and schedule risk associated with creating a new standard, the developers agreed to take advantage of previous work. The VITA 46 (VPX) and VITA 65 (OpenVPX) standards have been used as a basis for the VITA 74.0 base standard, and VITA 78 (SpaceVPX and SpaceVPX Lite) will be used as the basis for VITA 74.4 (SpaceVNX). This standard takes many of the conventions and leverages the signal definitions from its larger and higher complexity cousins into a SFF environment. The standard adopts the signal definitions from the larger standards, introduces a new high-speed, low-cost connector, and reduces the number of serial fabric options. The result is a standard that has two primary serial fabrics, Ethernet and PCI-Express, but can evolve in the future to allow other high-speed fabric interconnects, such as Serial RapidIO and other similar fabrics which may be further developed. In the interest of keeping the system as simple to implement as possible, a single CPU root node is specified. There are no reasons why multiple CPU implementations cannot be accommodated and defined in a future "dot" standard.

The base standard gives details on the mechanical implementation of the system Plug-In Modules. Two module types are defined, 19 mm and 12.5 mm. Each type addresses a different set of functions. Fabrication of the module container is left to the vendor. Also, details are provided for the module base carrier board (traditionally referred to as a backplane), including connector location, assembly hole locations, and component keep-out areas. The 19mm module has ample room for a two-board stack with requisite heat spreaders. The inter-board connector selection is outside the scope of this standard. Suitable connectors are available from various manufacturers to meet the stacking height requirement, with consideration given to board thickness and component heights.

Finally, even though the standard doesn't specify a specific backplane implementation, details are provided as part of a reference design for a 4-slot backplane, available to VITA subscribers. This reference design may be used as a design starting point for a derivative implementation, with the specific implementation details defined by the application. Also, an example chassis design, with dimensional details, is available as a starting point from VITA. The chassis example may be reproduced in whole or modified as required depending on the requirements.

Introduction

The tactical embedded marketplace operates with unique requirements that drive SWaP to the extreme. Like the commercial counterpart, there are still requirements for high performance but at a much-reduced SWaP proposition. VITA 74 standard based products serve markets needing ruggedized products requiring Data Plane interconnect technologies that closely follow the industry state of the art. Switched serial technologies are available that provide significant benefits and scale over the long term. The benefits of these technologies are widely known with many products currently in the market incorporating one or more of these.

The VITA 74 standard provides a standardized electro-mechanical format for standardization of switched serial interconnects for ruggedized SFF applications. There are many candidate technologies for switched serial interconnects. These include Gigabit Ethernet and PCI Express. There is also the need for legacy I/O interfaces that provide connection to standard serial, discrete and analog devices.

The usage model for the plug-in modules described in this standard is very different than other plug-in modules in the VITA family of standards. plug-in modules are installed into an open frame backplane, and then the chassis walls are attached, as opposed to a typical VPX or VME implementation where plug-in modules are installed into a fixed wall chassis.

VITA 74 Objectives

The objectives of the VITA 74 standard are to:

- Define a 12.5 mm and 19 mm family of SFF plug-in modules
- Define a suitable high-speed connector family for use in plug-in modules
- Make provision for switched serial interconnects between plug-in modules
- Accommodate Open Standard technology for switched serial interconnects
- Make provision for additional I/O capability at the plug-in module level, and
- Define a mechanical standard for the plug-in modules.

Overview of the VITA 74 Family of Standards

The VITA 74 family of standards consists of this base standard, which defines: physical features of compliant components; protocol layer standards, which define specific serial or parallel interconnects used in a system implementation; and complementary physical or electrical standards.

At the time of publication, the following dot standards have been allocated, but not yet published.

- VITA 74.0 is the base standard and the primary definition of the vision. The standard describes a plug-in module designed for backplane systems with one or more modules communicating over the backplane. This is the base standard that will be first in the series published by ANSI. For marketing purposes, VITA 74.0 has been branded as "VNX."
- VITA 74.1: (Reserved)
- VITA 74.2 is the 74.0 rear transition module standard.
- VITA 74.3 is a set of slot profiles for CPU, I/O, storage and other specific modules. This standard will define pin assignments and signal characteristics that when used in conjunction with VITA 74.0, will serve to enhance module interoperability between vendors.
- VITA 74.4, also known as SpaceVNX, will be to generate additions to the baseline standards that will be equally applicable for high reliability and high availability avionic and flight control applications, as is the case with space applications. This standard is modeled after "SpaceVPX-Lite," currently in work by VITA.
- VITA 74.5 is a standard for VNX with an optical connection. This standard will bring optics through the backplane using existing VNX connector with adjacent auxiliary MT Ferrule.
- VITA 74.6 is a standard for VNX with one or more RF connections. This standard will bring RF through the backplane using existing VNX connector with adjacent RF connectors, as well as to provide standards for bringing RF from the front of the module.
- VITA 74.7 is a standard for VNX to facilitate high-performance cooling and packaging. This standard will utilize chassis-mounted wedge locks with VNX baseline modules for higher power applications when needed.

The VITA 74.0 base standard includes features drawn from IEEE 1101.2-1992, conduction cooled plug-in modules. These features are evident in the mechanical drawings provided.

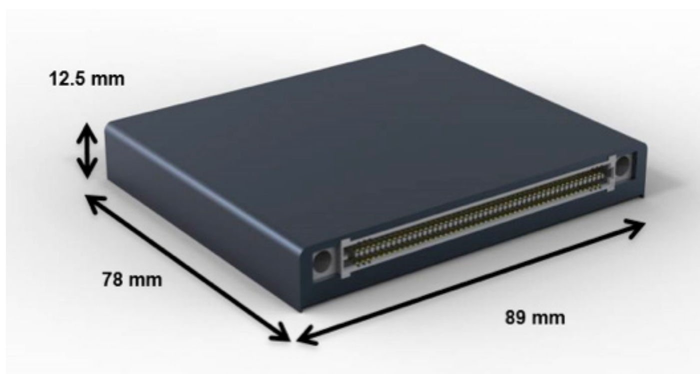
The VITA 74.0 base standard defines physical and electrical features on the VITA 74 compliant system plug-in module that enable high-speed communication in a compliant system. These features include a definition of two module sizes; a 78 mm x 89 mm x 19 mm module and a 78 mm x 89 mm x 12.5 mm module, both with high-speed differential and single-ended signals. The electrical signal definitions, differential, single-ended, power and maintenance are defined in the base standard as interconnects. The base standard includes a standard fabric type, PCI-Express. The PCI-Express fabric acts as the primary conduit for I/O internal to a system.

The base standard also defines alignment and keying features used to protect the connector system. The plug-in modules can only be oriented in one direction when being inserted into a slot. This keying is implemented in the module mechanical shell, its associated slot guide, the connector and its counterpart on the backplane.

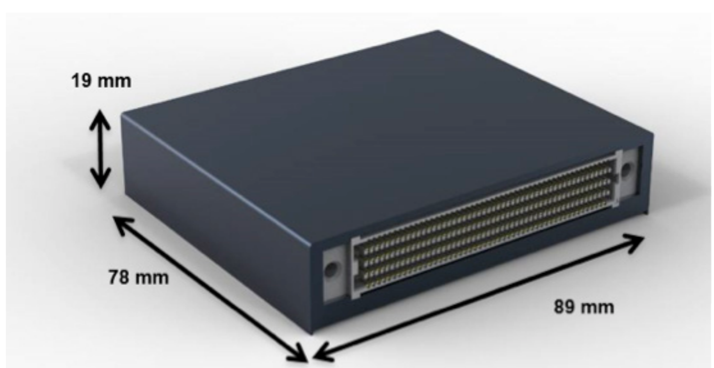
What makes a VITA 74 Module Compliant?

All VITA 74 compliant plug-in modules, backplanes, and systems incorporate the following key features:

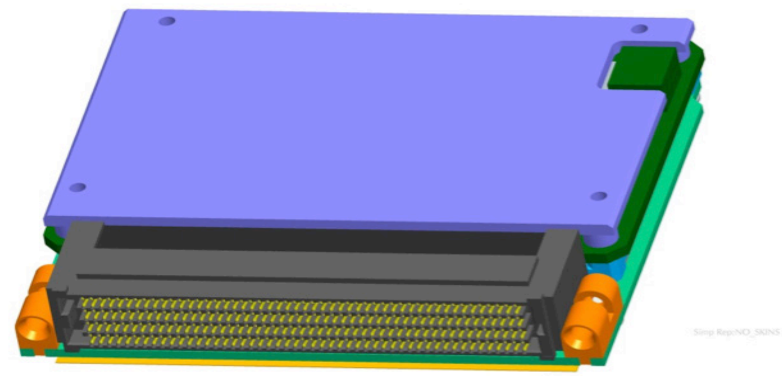
- Connectors/connector sets that meet the requirements of this standard
- Keying and alignment mechanism for all slots that meet the requirements of this standard
- Support for the VITA 74-defined power rails VS1, VS2, VS3, VS
- Support for the VITA 74-defined utility signals: geographical address pins,



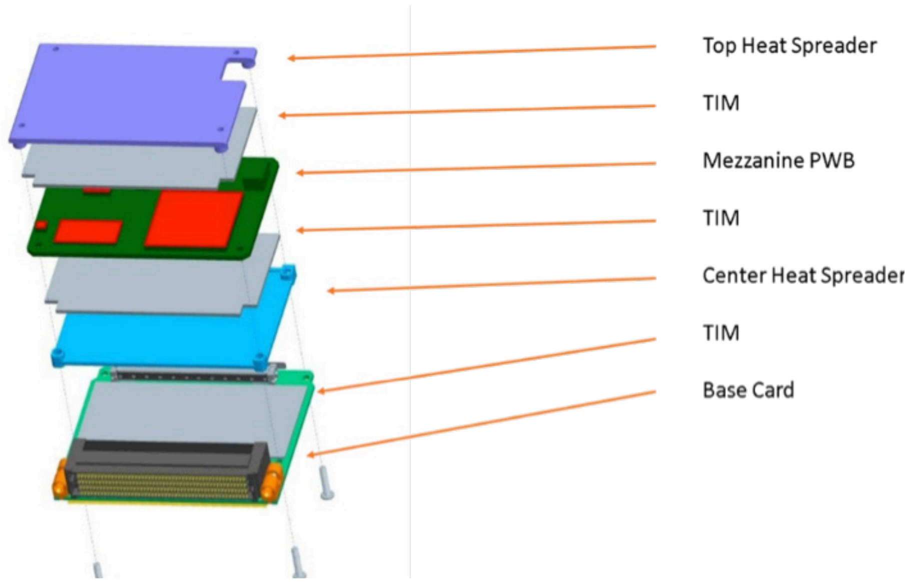
12.5 mm VITA 74 Compliant System Module.



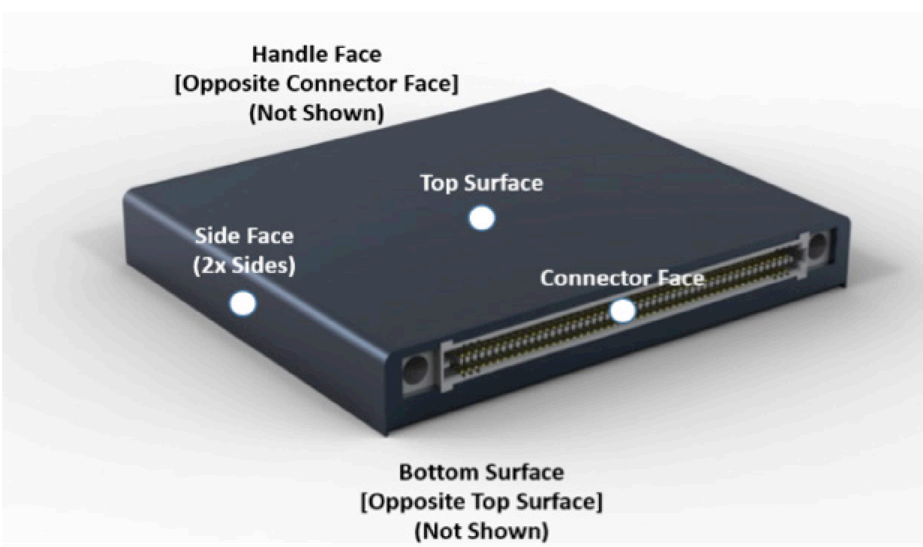
19 mm VITA 74 Compliant System Module.



VITA 74 Module without Cover.



VITA 74 Module Exploded View.



VITA 74 Naming Convention of Module Faces

PCI Express reference clocks, system management signals, Non-Volatile Memory Read Only (NVMRO) signal, SYSRESET*, reserved bussed signals, and reserved for future use (RFU) single-ended signals. The VITA 74.0 base standard reserves RFU signals; not the subsequent dot standards.

- Fabric provisioning for one or more of the various protocol layer standards, including the base protocol, PCI Express

VITA 74CubeSAT System Implementation Based on Reference Design

The purpose of this section is to describe how you can use modules that were designed per the VITA 74.0 base standard and integrate them into a normal conduction cooled system that would be appropriate for a CubeSat, as well as an avionic, vetronic, or rugged industrial application.

It should be noted that the images in this paper describe hardware that was intended for a rugged airborne or terrestrial application suitable for VITA 74.0. This paper is intended as a "thought piece" to discuss ways that this technology can be adapted in the VITA 74.4 SpaceVNX standard which is under development at present. To date, the VITA 74.4 SpaceVNX standard is still in development, but the time is right to make inputs to the designers of the standard to address the needs of the CubeSat community.

It is recognized that specific changes will need to be made in the standard to optimize it for the CubeSat marketplace, such as taking mass out of some of the metalwork, adding additional hold-down hardware to secure the modules into the chassis frame, and optimizing the thermal heat spreaders on the system.

VITA 74 System Reference Design

Along with the VITA 74.0 base standard, the authors of the standard have provided a reference design which is available to VITA members through the VSO website as well as those who purchase the standard. This reference design is intended to be used to illustrate how to accomplish a typical system design using VITA 74.0 modules. This design shows many of the essential constructs that are part of the standard, as well as many ideas on how the standard can be utilized to design and build complete system assemblies.

It should be noted that the VITA 74 reference design has been designed to be ideally sized for a 1U to 6U CubeSat application.

See the VITA 74 reference design for further illustration and information.

Definition of Terms

A VITA 74 module has six primary faces which are defined as illustrated below. The same face nomenclature will be used for both the 12.5 mm and 19 mm modules described in the standard, as well as discussed below.

VITA 74 Modules as Described in the VITA 74.0 Base Standard

Currently, two primary modules are described in the VITA 74.0 base standard. The module set consists of the 19 mm module and the 12.5 mm module.

Both the 12.5 mm and the 19 mm modules use the Samtec SeaRay series connector, with 200 contacts and 400 contacts respectively. The connectors have been qualified and shown to withstand the rigors of high vibration, extreme temperature environments. Both connectors have excellent frequency response characteristics, suitable for high-speed signaling, up to and including RF frequencies.

Typically, a 19 mm module will have two substantial boards (a base card and a mezzanine card) inside of its envelope. For many applications, such as an airborne mission computer, a 19 mm module is generally some sort of processing element, i.e. a high performance single board computer (SBC) or some other type of processor module, such as a field programmable gate array (FPGA) or video graphics processing unit (VGPU). A 19 mm module can also be an I/O card that requires a lot of user I/O pins, or a board with oversize components such as transformers, etc. For our CubeSat example, we will assume that a 19 mm module could be a crossband repeater with audio processing and control functions. A second 19 mm module could house a Telemetry and Command & Control radio.

The 12.5 mm module is typically some sort of module for a low powered processor (such as a PIC or an ARM processor), data bus I/O, serial communications, analog I/O, GPS/inertial measurement unit, or bulk persistent storage. Generally, this module has a substantial base card and is sized in such a way that it may contain two or more Micro Mezzanine boards such as a MiniPCIe, mSATA, or other custom form factors.

Hardware Configuration of Application Example

For purposes of this illustration, assume that the system described in this section will have the card slot assignments and payload modules shown above.

VITA 74 CubeSAT Application Example Slot Assignments

Slot	Module Function	Module Size
1	Crossband Repeater & Controller	19 mm
2	Telemetry & Command Processor	19 mm
3	System Processor	12.5 mm
4	Inertial Measurement & Power Control	12.5 mm

In addition to the four payload modules above, the system would also contain a few application-specific modules whose characteristics are not specified in this standard but are left to the system designer to develop and implement. Because of the similarity of VITA 74 (VNX) to VITA 46 (VPX), there are a lot of designs used in VITA 46 / VITA 65 (OpenVPX) that are usable as references for a VITA 74 system implementation. In a typical system, these modules and assemblies are defined and described below.

Power Supply Unit

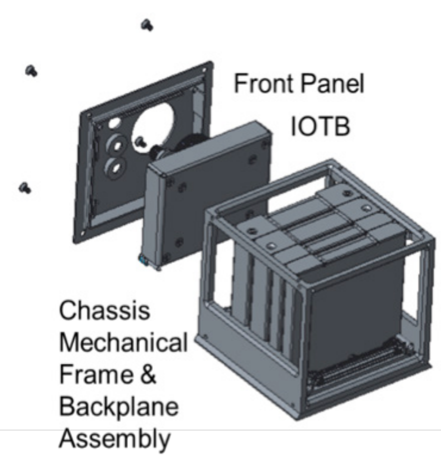
The power supply unit (PSU) interfaces with the primary power sources for the system (such as solar panels, batteries, and thermo-electric generators) with the rest of the system. The PSU converts the supplied voltages to those specific voltages required by the application, as well as the power rails required by the standard.

I/O Transition Board

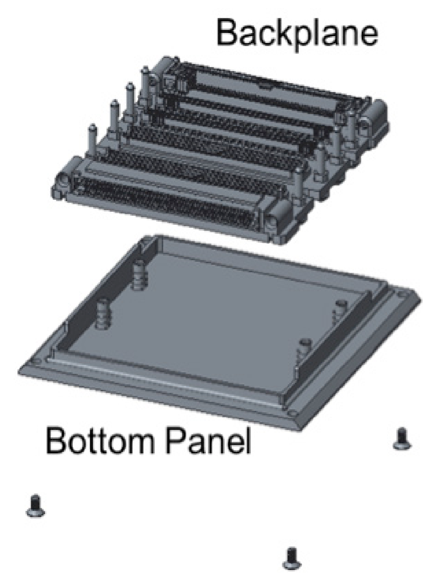
The I/O transition board (IOTB) is a printed wiring board (PWB) that functions as a connector panel for the interface to the outside world for those interfaces required for testing and I/O. As necessary, the IOTB also provides signal filtering and pin hardening. The IOTB plugs into the backplane through a connector with sufficient pins and bandwidth characteristics to allow the required signals to be routed from the backplane to the outside.

Backplane

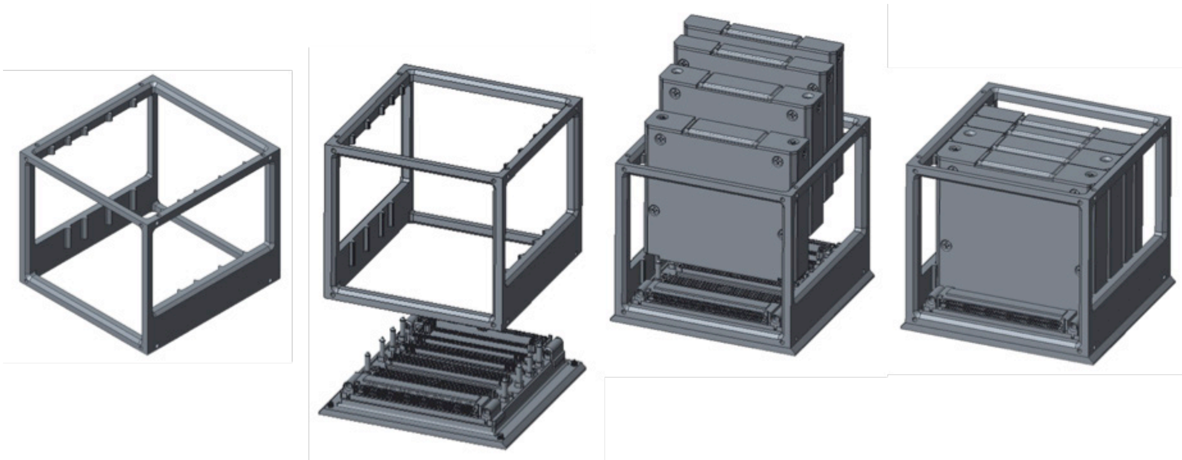
The backplane is a printed wiring board which mounts into an associated chassis mechanical frame assembly (CMFA). The backplane allows electrical connections from each module slot to interconnect to other slots, as well as to other modules described in this section. As in a VPX system, the backplane is divided into three main sections. These include a utility plane which provides power and control signals to each module, a serial fabric lane which routes data buses between slots, and user I/O plane between the modules as required,



Application Example (Terrestrial System) IOTB with Front Panel & Chassis.



VITA 74 Application Example Backplane & Bottom Panel



VITA 74 Application Example Chassis Mechanical Frame, Backplane & Payload Cards.

as well as from the modules to the outside world via the IOTB. The backplane also has the mechanical guide pins which ensure that the module connector face and the backplane receptacle are correctly aligned as they snap into position to mate the module and the backplane connectors.

Chassis Mechanical Frame Assembly (CMFA)

The CMFA is a mechanical structure which provides for correct card alignment and spacing in accordance with the VITA 74.0 standard. The CMFA is secured to the backplane. During assembly and operation, the CMFA holds all the modules in the correct orientation as the system is assembled and the side panels (which in a CubeSat application would mount to the solar panels) are installed.

Side Panels

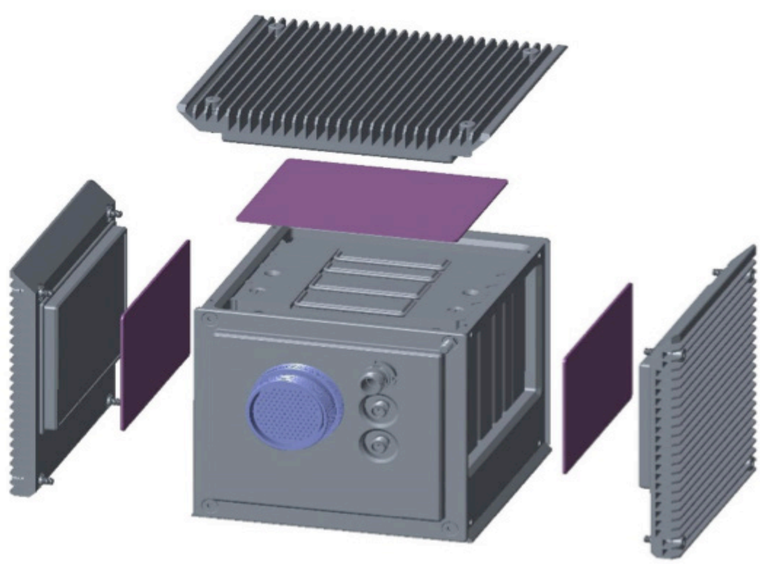
The side panels are the metal plates which mount to the sides and top of a typical VITA 74 system. The size of the any included fins and the capacity of the plates to conduct heat and spread it around the CubeSat will drive the total power dissipation capability of the entire system. The side panels are in direct contact with the side faces of the VITA 74.0 module, through a suitably sized piece of thermal interface material (TIM).

Assembly of a VITA 74 System

VITA 74 is a SFF system which is designed to be lightweight, optimally sized, and generally low power. To accomplish these ends, several design decisions were made early in the definition process that ultimately help facilitate the SWaP goals of the system designers.

One of the critical attributes of the module design driven by the VITA 74.0 base standard is that the modules do not require locking devices (generically known as wedge locks) to hold the modules in place or to facilitate thermal heat transfer. Instead, the modules are inserted into the CMFA/backplane assembly, in a manner that the module's connector face mates with the backplane. When mated correctly, an audible snap will be heard as the plugs and receptacles correctly join. The backplane connectors and guide pins, as well as the keying notches in the CMFA, keep the cards in the correct orientation and provide for optimal spacing. After insertion of all cards, TIM is cut into thin strips and put on the two side faces and the handle face of each VITA 74 module. Please note here that the top surface and the bottom surface do not contribute to taking heat off the module in a typical back-to-back slotted chassis design. No TIM is to be applied to either of these surfaces for conventional module installation. The system has a small gap between modules when the modules are positioned in the system correctly.

After positioning the TIM on all the three designated faces on the module, the chassis side heat spreaders and the top heat spreader are installed. General practice has been to connect the first side heat spreader using the provided screws, snugging the screws only finger tight. The opposite side heat spreader is installed the same way, still tightening the screws just finger tight. Last, the remaining side (the top heat spreader) is connected,



VITA 74 Reference Chassis Design Exploded View.

with the screws finger tight. After all three sides are loosely installed, then the screws on the heat spreaders are all sequentially tightened in such a way to cause the entire chassis cooling fin assemblies to compress evenly around the CMFA, forming a dense block of modules, heat spreaders, and TIM. It has been shown that the thermal transmissibility from any module, through properly cut and applied TIM, to the side heat spreaders is within 5% to 10% of an equivalent system modeled with wedge locks.

Adaptation of AV74.0-2017 for SpaceVNX Use

As a first step towards implementing a reliable, high-performance architecture for small spacecraft, a follow-on article will describe an approach to use highly capable commercial of the shelf (COTS) parts in conjunction with lower cost radiation hardened/tolerant supervision circuits/ICs to protect the system from latch-up events. This approach also would use the VNX architecture to provide redundancy to allow the system to continue operating even after one of these events.

The SpaceVNX community is designing an architecture that uses radiation hardened/tolerant components in the simpler but more critical subsystems of the spacecraft (e.g., housekeeping) while implementing redundancy and circumvention and recovery (when desired) in the most complex subsystems of the satellite (mission processing). The main enhancements to the existing VNX architecture are the radiation tolerant system controller supervision circuitry, the latch-up overcurrent protection methods integrated into the system controller and all other modules, and the inclusion of dual redundancy methods to allow the system to continue operating even after a module suffers a latch-up event. This new architecture will be further described in an upcoming article.

Conclusion

While many larger satellites have been built using standards-based hardware (such as VME, VPX and more recently, SpaceVPX), embedded computing standards have not been applied to the SmallSAT and CubeSat space, except for adaptations of PC/104, a standard generally used for convection cooled industrial applications. VITA 74 provides an opportunity to bring Small Form Factor, conduction cooled, highly reliable MIL-Rugged hardware into the mix of technologies to be considered for future CubeSat designs.

AMSAT Academy at Duke City Hamfest

AMSAT® and the Albuquerque Duke City Hamfest (DCHF) are collaborating on a day-long course aimed at giving participants a deep dive into the world of amateur-radio satellites. The course will provide the necessary knowledge, resources and confidence needed to leave the class ready to operate and make contacts in the fascinating world of amateur radio satellite communications.

Dubbed AMSAT® Academy, the course will run from 8 a.m. to 5 p.m. on Friday, September 21, the opening day of the three-day hamfest, which also is this year's host for the ARRL's Rocky Mountain Division Convention. The event will be held at the Isleta Resort and Casino's convention facility just south of the Albuquerque International Sunport.

AMSAT® Academy represents a natural confluence of interests, notes Bill Ripley, KY5Q, president of New Mexico Hamvention, Inc., the non-profit corporation that organizes the 71-year-old hamfest. For several years, the hamfest has been supporting local junior-high and high-school students working on a multi-year project to build and launch a CubeSat, according to Ripley. Students have earned Technician class and even General class licenses so that they can use amateur radio to acquire the satellite's data, track and monitor the orbiter's health, and communicate to others around the globe.

"DCHF has been involved in STEM education, and AMSAT® is interested in promoting STEM education through amateur-radio satellites," Ripley said. "Holding a full-day course at the hamfest/convention seemed like a natural fit."

AMSAT® Academy is the latest addition to a gradually expanding list of day-long courses DCHF has developed over the years.

"We felt that the trend towards all-day sessions on Friday could readily accommodate a session on AMSAT® and Satellite communications," Ripley explained. "This would provide a painless way for people to learn about amateur satellites and start making contacts and participating in the hobby, particularly as we go forward offering new satellites with more capabilities, with higher orbits and larger global footprints. The time is right to jump in with both feet."

Among the list of instructors are Joe Spier, AMSAT® president, Skyler Fennell, KD0WHB, who has hosted a Rocky Mountain Division AMSAT net and is a student at New Mexico Institute of Mining and Technology in Socorro, NM, and Ripley, a long-time satellite enthusiast and embedded-systems architect. Other instructors are being added. The tentative line-up of topics includes:

1. Introduction to AMSAT® and History of Amateur Radio Satellite Communications
2. The Basics of Amateur Radio Satellites and Current Communications Practices
3. Locating Amateur Radio Satellites and the Use of Satellite Tracking Hardware and Software
4. Amateur Radio Satellite Station Antennas, Radio Equipment and Accessories
5. Operating the FM "EZ-SATs," SSB/CW Satellites and Digital Modes
6. Status and Available Modes for Popular Amateur Radio Repeater, Transponder, and Telemetry Satellites
7. Hands-On Satellite Tracking and Communication Demonstrations, and
8. The Future of Amateur Radio Satellites.

The course admission fee includes breakfast and snacks, a soft copy of the book, Getting Started with Amateur Satellites, and a discount coupon redeemable at the AMSAT booth.

In addition, AMSAT's Spier is scheduled to speak at the "Farewell Breakfast Banquet" on Sunday, September 23. His talk will focus on AMSAT's outreach to young people via the ARISS program, as well as on trends in high school CubeSat development. Students will present slides and video about their "BalloonSAT" project, a prototype CubeSat flown on a high altitude near-space balloon during the hamfest. For more information on the hamfest/convention and to keep up with AMSAT® Academy's evolving program and instructor list, visit the hamfest website: **www.dukecithyhamfest.org.**

My Great Spring Rove 2018

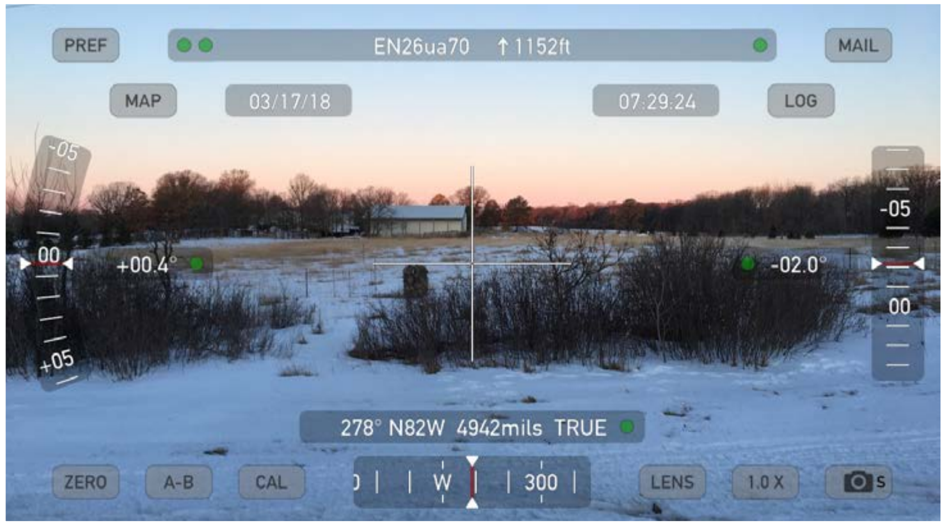
Paul Overn, KE0PBR

In early March 2018, my wife told me she had planned a "Girls Weekend" and would be gone over St. Patrick's Day weekend. After telling her just much I would miss her, I immediately started planning "The Great Rove – Spring 2018." Aside from what grids I activated, or where I went, I will focus on how I planned and executed my activation.

During this process, I often used Twitter to ask for help in finding tools and otherwise getting advice on how to conduct the trip. Once I knew the dates of my roving expedition, I shared my plans on Twitter (don't forget to #AMSAT in your Tweet), advising my followers that I would be roving the next weekend. I asked what grids near my roving location they might need. Three people replied with desired grids.

Next, I identified the locations I would be activating within the grids. In determining preferred locations, I consulted Patrick Stoddard, WD9EWK, who showed me a great tool, QTH Locator (qthlocator.free.fr/), to help me identify locations where I could activate more than one grid at a time. This tool uses Google Maps and shows the outline of a chosen grid. I just entered a grid square at the bottom of the page to display the grid outline. At the top of the page, I could change to satellite view. Using the satellite view, I zoomed in on the grid side that was shared with the adjacent grid I wanted to activate. I traced along that border until I found a suitable site unobstructed by trees and buildings with a large shoulder or parking lot and no big power lines. QTH Locator proved invaluable for helping me activate many grids at once.

I then needed to determine travel time between my chosen locations. Again using Google Maps, I created waypoints for the grid locations I planned to activate. I clicked on one of the locations I identified in QTH Locator, which displayed a box with the address on the bottom of the screen. I then clicked on the blue address, and a window appeared on the left. I then hit the "Save" button. After saving the location, I renamed it, designating my stops "1st Stop," "2nd Stop," etc. By creating these custom locations, I found you can do two things. First, if you set up Google Maps to sync with your other devices, the mapped locations will appear on your phone. Second,



EN25 & EN26 pass. [Paul Overn, KE0PBR, photos.]

EN17 & EN27 line.

Kenwood TM-V71, Arrow antenna and headset.

you can see travel times and distances between each stop.

After I established the activation locations, I opened my favorite satellite tracking program and created a list of all satellite passes that I could work. Since I was only working FM birds, my list was relatively short. I entered my schedule into Excel so that I could add other information. I included such information as whether the satellite was moving from North to South, the peak angle, if the pass was easterly or westerly, who requested the grid, and which location I would use for that pass. This information would prove very useful. While in the satellite tracking program, I also verified that the operators requesting the grid would be within the pass footprint. At this point, I had set up the grids I wanted to activate, created a pass schedule with the locations from which I would activate them, and calculated the travel times and distances between the locations. The next step was to determine from the pass schedule the approximate driving times and whether I could make it from one site to another in time for the desired pass. I found that if I arrived at a location a half hour early, I would have enough time to make sure the place was suitable and prepare for the pass. This also allowed me to stop for gas, grab a sandwich, etc.

Gathering all the information I needed regarding what grids I would activate, with which passes, and verifying that I could make it to those activation locations was the hardest part. I then tweeted everyone the plan. I usually try to do this three to four days ahead of time.

On the day before the trip, I made sure everything was ready — recorder charged, radio working, extra headset, spare radio, additional antennae. The first two grids were scheduled for about 11:00 a.m., which allowed me a few hours in the morning to check out my setup. Looking at my schedule, I found a SO-50 pass I could work to make sure everything was working. So, at 7:30 a.m. I made a few local SO-50 QSOs. Everything worked well, and I was on plan.

At the time, I was new to APRS, so I decided to take this opportunity to try it out. I tweeted that anyone could follow me on APRS.FI. I didn't think that anyone would. After the first stop, however, followers were asking why I stopped showing up on APRS.FI. I discovered that I was in such a remote location that I couldn't hit any repeaters. I switched to a cell-based APRS system, and all was good. I believe at least a few people enjoyed watching me drive all over the state to activate the grids.

At 10:00 a.m., I fired up the Jeep and used my phone map to guide me to the 1st stop. I arrived at my location about 20 minutes before the pass started. That left enough time to take a photo of my GPS display as evidence that I was on the line between two grids and another picture of the sky towards the pass starting point. I tweeted that I was ready and looking forward to the pass, and I uploaded the two photos.

Everything went well during the pass. I used my list of requested grids to begin calling the operators that had asked for them. Once people heard me, they started calling. After the pass, I sent a tweet thanking everyone for the QSOs and reminding them of the grids and times I was next activity.

I followed this routine two more times, and each pass generated more QSOs, more tweets about the trips and more interest. After my last planned stop, I realized that I could activate one more grid if I made a quick trip south. I tweeted this proposal and received many positive replies. KE4AL responded that he really wanted that grid but only had one-degree elevation. I found a large hill, and I think he stood on his car, but we pulled off the QSO!

After all the grids and passes were complete, I drove home. When I arrived home, I entered all the QSOs into LoTW. I also sent one last trip-related tweet thanking all who participated along with a list of stats, including the number of QSOs, operators and grids. Responses to that last tweet showed how much people enjoyed my rove and also reminded me how much fun I had. That last tweet generated the most interactions. Many operators liked knowing how productive it was.

I had a blast on this activation trip and learned some new tricks. Some were simple, like knowing what county you were in when activating. I learned that some sat guys chase both counties and grids. Maybe next time I will do a live feed on Periscope so people can see me working the pass. I saw KG5CCI do this. I also want to find someone to join me. It would have been great having another ham to talk to and share tips with as I was driving from location to location. I encourage all satellite operators to get out of their shacks, have some fun, activate some grids, and make some QSOs while improving your skills.

Wireless Autonomic Antenna Follower Rotator

Horacio Bouzas, VA6DTX

Introduction

In this article, I will describe a novel, economic and unsupervised device that allows precise and on-demand satellite antenna positioning while the satellite is visible. The device can control any rotator that allows movement in azimuth and elevation and reports its position, for each of the axes, using a variable DC voltage. The device retrieves the satellite position by communicating with a server that performs the orbit calculations real-time.

The satellite you wish to follow is selected by sending a message to the device using a simple web browser command. The service running on the server also provides satellite frequency and mode of operation, as well as orbit predictions. This information is returned in standard JSON formatting suitable for use within applications that wish to consume it.

Functional Description

The central part of the module is the Espressif WiFi enabled microprocessor ESP8266. The microprocessor connects to a WiFi network and automatically retrieves the azimuth and elevation of the satellite selected, based on the geographical position of the user. Satellite selection and location settings are changed by sending a command using a standard web browser from a computer or mobile device. Once the selected satellite is visible, the module reads the satellite azimuth and elevation from a web server and reads the voltages coming from the rotator. The module then varies the azimuth and elevation accordingly to match those of the satellite. This process is repeated every 10 seconds until the satellite is no longer visible.

The module will then go on standby and wait until the satellite is visible again or, if a change command is sent to the module, it will wait until the new satellite becomes visible and repeat the process described above.

This process also applies to the moon, sun and other celestial objects. The goal is to have a self-operated wireless rotator control based on object position.

Web Server

The service running on the web server automatically updates the two-line elements (TLE) of the objects, which are used to calculate the satellite position and are retrieved as they become available, so positions are always accurate.

The calculations involved are done at the server level, and interfacing with the web service is kept simple enough to avoid unnecessary drain of resources from the WiFi microcontroller. The module just gets the azimuth and elevation of the satellite based on user location coordinates and desired satellite or celestial object.

The web server is located at **www.hamsatspot.com**. To retrieve a satellite or celestial object per current azimuth and elevation, the operator needs only to send the following web browser command:

www.hamsatspot.com/get_sat_data.php/?name=satellite_name&lat=latitude&lon=longitude&ele=elevation&key=your_key

with:

name: a unique code name for the satellite whose position you want to retrieve. Valid names can be obtained using the 'list' command

lat: latitude of the observer (ex: 54:04:28.61)
lon: longitude of the observer (ex: -112:03:17.19)
ele: elevation of the observer in meters (ex: 798)
key: a valid access key (request your key using the form available at **www.hamsatspot.com**).

If you are doing this programmatically, you can also use a POST request as follows. First, connect to the server **www.hamsatspot.com** on port 80 and then send:

POST get_sat_data.php/?name=satellite_name&lat=latitude&lon=longitude&ele=elevation&key=your_key.

To retrieve the most current list of satellites, send an HTTP request as follows:
www.hamsatspot.com/get_sat_data.php/?name=list&key=your_key

with:
name: the code name 'list'
key: a valid access key (request your key using the form available at **www.hamsatspot.com**).

You can also use a POST request. First, connect to the server hamsatspot.com on port 80 and then send:

POST get_sat_data.php/?name=list&key=your_key.

All responses are sent back in JSON format.

Satellites and Celestial Objects Supported

Figure 1 lists the satellites and objects that are supported, however, this list is being frequently expanded and can also be expanded by request. Use the contact form at **www.hamsatspot.com** to request new items.

Connecting the Module to an Antenna Rotator

The module supports any rotator that has a control box that allows remote control. It is specifically designed for the Yaesu G5500, but it is easily adapted to other two axis rotators that accept left and right and up and down simple switch commands (switch to ground). It also sends analog voltage as an indication of the rotator current position.

The module allows for easy calibration of the voltages coming from the rotator using a resistor divider between the input voltage and the analog to digital input of the microprocessor. Figure 2 shows the module layout and components.

The rotor and control unit should be set up and calibrated according to the manufacturer's manual.

The module reads the satellite coordinates; based on these coordinates and the voltage received from the control unit on pins azimuth analog (AZA) and elevation analog (ELA), which indicate the position of the rotor, it then adjusts the rotor position by switching pins azimuth left (AZLR), azimuth right (AZRR), elevation down (ELDR) or elevation up (ELUR) to ground, as required by the external connection of a rotor control such as the Yaesu G5500. The process continues until the voltages measured on pins AZA and ELA indicate a rotor position aligned with the satellite position within one degree.

New satellite coordinates are pulled from the server every 10 seconds.

The module features individual calibration trimmers, so the voltage range is within the needed min and max of the microcontrollers ADC input. To calibrate the voltages going into the ADC, we need to ensure that the minimum voltage for both azimuth and elevation feedback is set to zero volts when the rotor is at the minimum position, usually zero degrees azimuth and zero degrees elevation.

AO-07
AO-73
AO-85
CUBEBUG-1
EO-79
EO-88
✓ FO-29
LILACSAT-2
NO-84
SO-50
UKUBE-1
XW-2A
XW-2B
XW-2C
XW-2D
XW-2F
ISS
Moon
Sun
Stand by
List all
Test

Figure 1.

We then move the rotor to its maximum azimuth and maximum elevation.

We connect the ground output positioning voltage from the rotor control box to the ground input of the module, i.e., ground from the control box to ground of module.

We connect the azimuth output positioning voltage from the rotor control box to the AZA input of the module.

Using a multimeter, we measure the DC voltage between the azimuth pin (+) and (GND), and we turn the corresponding trimpot until we get 1.1 V on the multimeter. Next, we measure the DC voltage between the elevation pin (+) and (GND), and we turn the corresponding trimpot until we get 1.1 Volts on the multimeter.

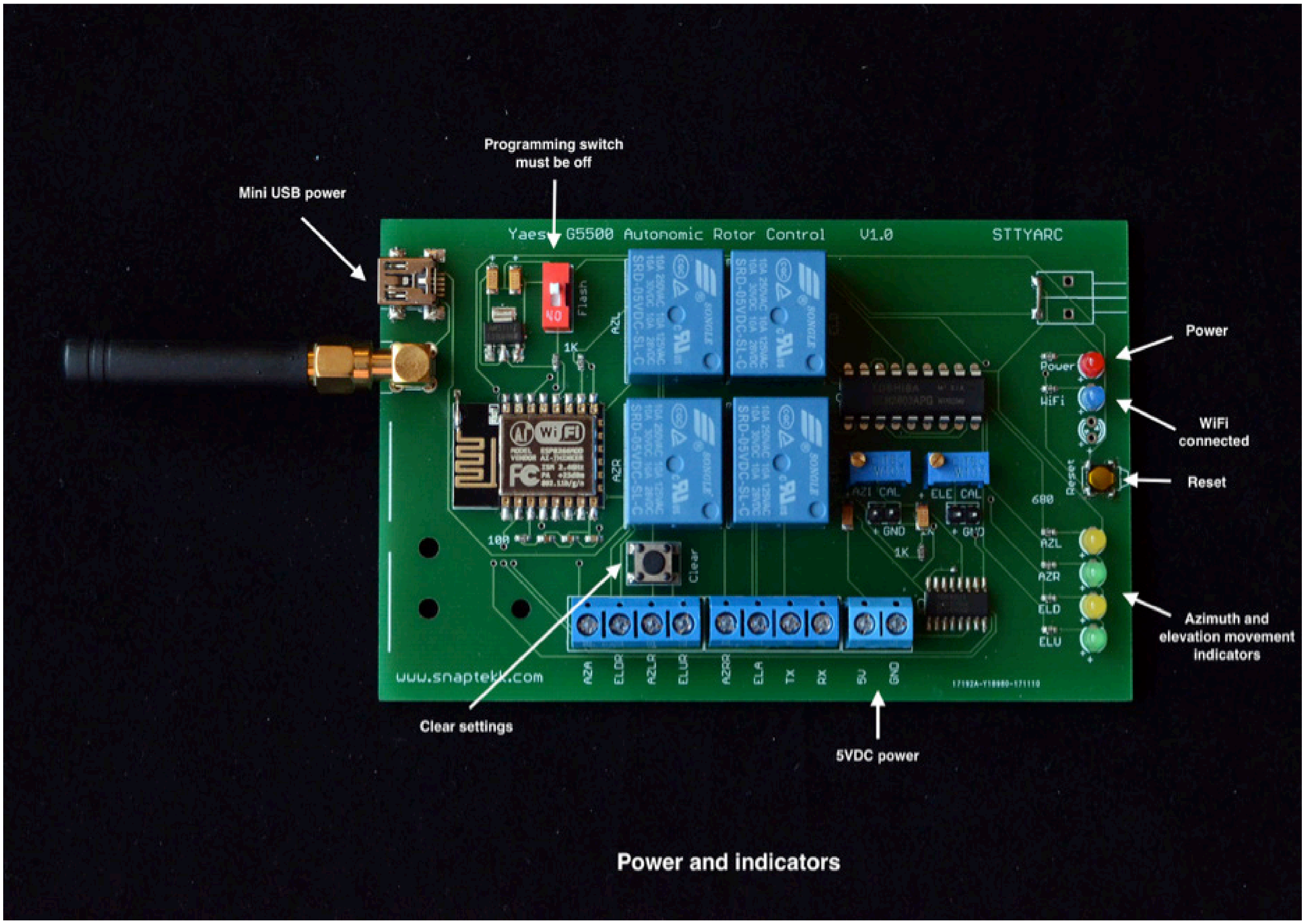


Figure 2.

LEDs indicate the direction of movement for both azimuth and elevation.

Continuous Operation of the Module

Once the module is connected to the WiFi network, configured, and then connected to the rotor remote control unit, and its voltages have been calibrated, we are ready to put it to work continuously.

The module works in an unsupervised mode, and all you have to do is instruct it to follow a satellite by issuing the web browser command (or use the public service): module_IP_address:9999/?name=satellite_name&lat=your_latitude&lon=your_longitude&ele=your_elevation.

The module will follow the satellite when it becomes visible. If you want to change the satellite to follow or the observer coordinates, just issue a new command with the new parameters. That's all.

Integration with MacDoppler Satellite Tracker

The MacDoppler satellite tracking and rig control application can easily be integrated with the autonomic module through the UDP messaging feature in MacDoppler. As an example, I am showing a python script that listens for UDP messages from MacDoppler, decodes them and instructs the autonomic module to change satellites as they become visible. With this arrangement, you can achieve a continuous satellite following system that is always tracking the desired satellites when they become visible.

As a bonus feature, the python code also implements a FlexRadio rig control based on UDP messaging from MacDoppler. This bonus feature allows for automation of frequency and mode tuning based on satellite data.

The Python code (still a work in progress) can be downloaded from **github.com/hbouzas/SatelliteControl.**

Conclusion

This article describes a novel and economic device that allows precise on-demand satellite antenna positioning while the satellite is visible. The device can control any rotator the allows movement in azimuth and elevation and reports its position, in each of the axes, using a variable DC voltage. It is autonomous and does not require supervision, apart from the target selection.

The device successfully integrates several modern technologies to solve a problem for hams. Furthermore, you can create a fully automated system if you integrate it with MacDoppler. The device significantly has helped my satellite operation. I hope it also helps other hams achieve their goals.

Please send any comments or suggestions to Horacio Bouzas, VA6DTX, **va6dtx@gmail.com** or **horacio@snaptekk.com.**

Greene County Fairgrounds, Xenia, Ohio. [Courtesy: Dayton Amateur Radio Association.]

Booth setup lunch at Nick's in Xenia, OH. [All photos, Keith Baker, KB1SF/VA3KSF, unless otherwise noted]

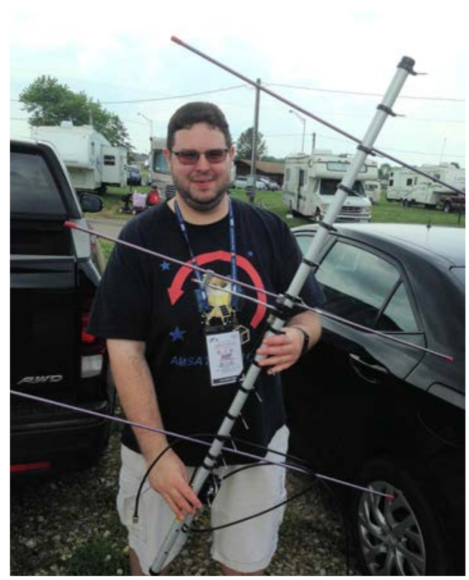
New members, old friends and helpful hints for working the birds.

AMSAT Executive Vice President, Paul Stoetzer, N8HM, conducting live satellite demos.

Spring fashions for satellite chasers.

(From left) ARISS Secretary, Rosalie White, K1STO, Chairman, Frank Bauer, KA3HDO, and Chet Latawiec, VE3CFK.

Chet Latawiec explaining the benefits of AMSAT membership.



Paul "Conan" Stoetzer, proudly brandishing his trusty antenna.

Despite the rain, enthusiasm at Hamvention was not dampened [Joe Kornowski, KB6IGK, photo].

Filtering out the wet "QRN."

Bob Bruninga, WB4APR, provided an update on the use of APRS, including its operation in packet satellites [Joe Kornowski, KB6IGK, photo].

Bob demonstrated a functioning digital satellite model transmitting on 145.825 MHz APRS/packet to attendees [Joe Kornowski, KB6IGK, photo].

AMSAT Treasurer, **Keith Baker, KB1SF/VA3KSF, served as moderator of** the AMSAT Forum [Joe Kornowski, KB6IGK, photo].

(From left) Keith Baker, **KB1SF/VA3KSF**, Frank Bauer, KA3HDO, Joe Spier, K6WAO, and Jeff Devoe, K8JTD.

Easy set-up for the AMSAT portable satellite demo station [Joe Kornowski, KB6IGK, photo].

Frank Bauer was interviewed by Ted Randall, WB8PUM, on QSO Radio live via shortwave station WTWW.

The Hamvention antenna farm [Joe Kornowski, KB6IGK, photo].

The annual AMSAT/TAPR Banquet was well-attended.

AMSAT President, Joe Spier, K6WAO, speaking at the AMSAT/TAPR banquet.

AMSAT President, Joe Spier, K6WAO, and banquet speaker, Jeri Ellsworth, AI6TK [Joe Kornowski, KB6IGK, photo].

Jeri Ellsworth, AI6TK, shared her insights on her life as an inventor and entrepreneur, as well as amateur radio and mentorship.

A fine feast with friends.

Frank Beafore, WS8B, and Jim Simpson, WB8QZZ.

(From left) Jack Gerbs, WB8SCT, Dr. (Colonel) Rick Allnut, USAF (Ret.), WS8G, Ron Cramer, KD8ENJ, Michael Kalter, W8CI.

The Dayton Amateur Radio Association presented Joe Spier with a $5,000 donation to AMSAT.

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.

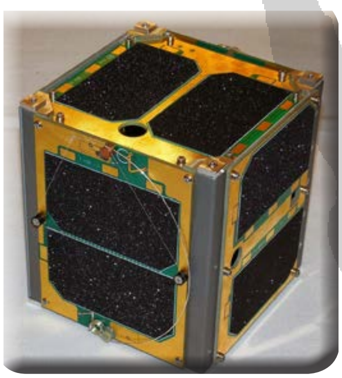
AMSAT has an immediate need to raise funds to cover both the launch and related expenses for Fox-1Cliff and Fox-1D. We have set a fundraising goal of $125,000 to cover these expenses and help us to continue to keep amateur radio in space.

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 early 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.

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

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 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 AMSAT – then click Volunteer.