The AMSAT® Journal

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Record Broken in Saba

[James Lea, WX4TV, photo.]

in this issue ...

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

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AMSAT Announcements

2017 AMSAT-NA Board of Directors Nomination Notice

It's time to submit nominations for the upcoming AMSAT-NA Board of Directors election. Four directors' terms expire this year: Barry Baines, WD4ASW, Jerry Buxton, N0JY, Drew Glasbrenner, KO4MA, and Bob McGwier, N4HY. In addition, up to two Alternates may be elected for one year terms.

A valid nomination requires either one Member Society or five current individual members in good standing to nominate an AMSAT-NA member for Director. Written nominations, consisting of the nominee's name and call, and the nominating individual's names, calls and individual signatures should be mailed to:
AMSAT-NA, 10605 Concord St, #304
Kensington, MD 20895-2526.

In addition to traditional submissions of written nominations, whichis the preferred method, the intent to nominate someone may be made by electronic means. These include e-mail, fax, or electronic image of a petition. Electronic petitions should be sent to **martha@amsat.org** or faxed to (301) 822-4371.

No matter what means is used, petitions MUST arrive no later than June 15th at the AMSAT-NA office. If the nomination is a traditional written nomination, no other action is required. If it is other than this, i.e. electronic, a verifying traditional written petition MUST be received at the AMSAT-NA office at the above address within 7 days following the close of nominations on June 15th.

ELECTRONIC SUBMISSIONS WITHOUT THIS SECOND, WRITTEN VERIFICATION ARE NOT VALID UNDER THE EXISTING AMSAT-NA BYLAWS.

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

Barry Baines, WD4ASW
President

Spring has Sprung! I write this column the week of March 20 with major league baseball starting up in two weeks (April 2) and Hamvention taking place in only eight weeks (May 19-20). Along with the coming of spring, I'd like to share with you some interesting developments taking place for AMSAT.

Fox-1C/D News

First, we are making progress on the launch of Fox-1Cliff and Fox-1D. AMSAT signed an amended contract with Spaceflight, Inc., on March 10 that changes the flight arrangements for our two CubeSats in response to changing circumstances concerning our original agreement with Spaceflight. The opportunity to place our two satellites on the same F5 Launch is no longer available.

Spaceflight is now making arrangements to fly our satellites on two different launchers: Fox-1Cliff will fly on a SpaceX Falcon-9 SSO-A launch sometime between late Fall 2017 and early 2018, and Fox-1D will fly on a PSLV launch in late Fall 2017 from India.

Our revised agreement maintains our relationship with Spaceflight, where they will provide launch integration services as well as handle export control requirements to allow Fox-1D to be flown from a launch facility outside the United States. Additional details concerning these recent developments appear in Jerry Buxton's article in this issue of *The AMSAT Journal*.

When we signed the original launch agreement with Spaceflight in July 2014, we did not expect that the road to actual launch of Fox-1Cliff (and later amending the contract to include Fox-1D) would take the twists and turns that it has over the past year. These developments are beyond AMSAT's control and of course all of the participants are impacted by "events" that drive actual launches. Under the leadership of VP-Operations Drew Glasbrenner, KO4MA, and VP-Engineering Jerry Buxton, N0JY, who have been the primary interfaces with Spaceflight, we have been able to secure revised launch opportunities that will serve us well in providing suitable orbits for our two CubeSats. My thanks to both Drew and Jerry for working so diligently with Spaceflight to secure alternative launches.

Hamvention

Under the guidance of Steve Belter, N9IP, AMSAT is preparing for the 2017 Hamvention that will be at a new venue: The Greene County Fairgrounds in Xenia, OH. Along with the new venue is an opportunity to make a different "first impression." We're expanding our commercial exhibit space to include eight commercial booths, which will give us additional room to highlight our engineering programs (such as the "five-and-dime" ground station development), education and ARISS. Our booth location will be in the first aisle in Building One. AMSAT will occupy the entire aisle 1 area (booths 1007-1010 and 1107-1110). This arrangement will provide not only more space but allow us to tailor the area to our needs without potential interference from other vendors. A drawing of the exhibit spaces for Building One may be found at **hamvention.org/wp-content/uploads/2017/01/Booths-Building-1.pdf.**

Just as important, the satellite demo area (led by Paul Stoetzer, N8HM) will be located just outside Building One on the same side of the building as our exhibit space. In essence, the demo area will be sharing the front wall with the AMSAT exhibit area, making it easier to direct people to demos and providing potential opportunities for improved support services for the satellite demo team.

Our social activities will continue as we've done during previous Hamventions. Activities include an informal social get together at Ticket's Pub in Fairborn on Thursday night. The annual AMSAT-TAPR (or TAPR-AMSAT) dinner takes place at the Kohler Presidential Center Friday evening, as in the past. TAPR President Steve Bible, N7HPR has invited Carl Laufer of Auckland, New Zealand, to be our banquet speaker. Carl is the creator and author of the extremely popular RTL-SDR Blog, author of the book, "The Hobbyist Guide to RTL-SDR," and supplier of the RTL-SDR dongle. The RTL-SDR dongle is a low-cost, receive-only SDR receiver that hobbyists around the world are using for a variety of radio receiver projects, and Carl blogs about them at http://www.rtl-sdr.com/. Details about Carl's talk already should be posted on the TAPR and AMSAT websites. Those wishing to attend the dinner will need to purchase their tickets via the AMSAT Store (**store.amsat.org).**

An AMSAT Forum is scheduled Saturday morning from 1045-1215. Our moderator is AMSAT VP-Educational Relations Joe Spier, K6WAO. We're currently finalizing our speaker/presentation list. Expect presentations concerning the Fox Program, ground station development, ARISS, educational outreach, and operational news/updates. I'm sure it will be a jammed-packed 90 minutes.

AMSAT will offer new materials at the booth this year, including the 2017 edition of Getting Started with Amateur Satellites, as well as the latest in "satellite fashions." We'll once again provide a "Beginner's Corner" where questions will be answered about amateur radio satellites and amateur radio satellite communications.

Hamvention is amateur radio's premier gathering in North America. AMSAT's presence is important because it not only provides a venue to interact with our members and those interested in amateur radio satellites, but it also provides an opportunity to engage those that may not currently be active with satellites. Our mantra is "Keeping amateur radio in space," but we also need to be diligent about that mantra in front of thousands of amateurs who attend Hamvention. Our Hamvention presence builds awareness, generates revenue, and lays the foundation for future support.

Strategic Planning

In a previous "Apogee View" column (Sep/Oct 2016) I noted that the AMSAT leadership would be undertaking a Strategic Planning process in 2017. As I noted in that article:
"As the Board is responsible for the strategic direction of AMSAT (while the President and Senior Leadership Team handle day-to-day 'tactical' affairs), there is a need for the Board to step back and take time to take a serious and reflective look at the future using a strategic planning process that encompasses a variety of areas. The AMSAT organization that exists today is not the same organization that existed in 2008 when I became President. Indeed, most of the Board and Senior Leadership Team members that serve today were not in those positions of responsibility back in 2008.

Adding to the need for such a process is that the Fox-1 program will soon complete the last of the series (as currently planned) in late 2017 or early 2018. While Engineering is working towards creating the 'five and dime' ground terminal that has potential application in a variety of uses (including Phase-4B, CubeQuest Challenge with Ragnarok Industries, and a HEO 6U CubeSat concept), it is certainly appropriate for the Board to take time in the coming year to establish a multi-year plan that builds on our accomplishments and encourages the organization to 'push the envelope' subject to the resources and capabilities that currently exist within AMSAT as well as recognizes the perceived impact of externalities that influence the organization. The last thorough Strategic Plan was established in 2004 with an update in 2009 when the Board made the decision to accept the recommendations of the Engineering Task Force (led by VP-Engineering Tony Monteiro, AA2TX) to establish the Fox-1 program. Given that it has been seven years since the Board took the time to think through a strategic plan, it is time to focus on it again."

After the Board discussion in Galveston, we considered how best to manage the strategic planning process. A key consideration was finding an outside facilitator to help guide the conversation and establish the process for the Board to utilize as a means of coming to a consensus on what's important for AMSAT.

We selected Tony Silbert, MSOD of Spartina Consulting, to serve as our facilitator. See: spartinaconsulting.com. Two aspects of Tony's approach were important to us: (1) building on our strengths and our 47 years of distinguished history, and (2) creating "ownership" for making the strategic plan successful. In other words, those that are fully engaged in the creation of a strategic plan are more likely to make the commitment for implementation. A key consideration was finding someone who could encourage full participation by those in attendance and to create the environment that would encourage frank and honest conversation and to exchange ideas by all participants. The end result is "buy-in" by those who participate.

Those familiar with strategic planning development will remember "SWOT" (Strengths, Weaknesses, Opportunities, and Threats) as the mechanism for evaluating internal and external considerations. Typically, most time is spent evaluating the negatives as defined by "weaknesses" and "threats." In essence, that means looking at past problems and barriers that can stymie creative thinking and innovation.

Tony's approach was a little different. He calls it SOAR (Strengths, Opportunities, Aspirations and Results). Its focus is on the desired future, building upon the organization's recognized capabilities. Focusing on the positives enhances creativity and possibility thinking so more sustainable ideas will be created and shared within the strategic planning process. It also creates mechanisms for moving forward and measuring the results to evaluate overall success:

Strengths: What are our greatest assets?

Opportunities: What can we improve, even innovate?

Aspirations: What is our preferred future?

Results: How do we know it; how do we see it? (measurable results)

The AMSAT Strategic Planning Kickoff meeting was held in Orlando, FL, the weekend of March 3, 2017. A planning team was assembled — Keith Baker, KB1SF, Drew Glasbrenner, KO4MA, Paul Stoetzer, N8HM, and Clayton Coleman, W5PFG — in early February to work with Tony Silbert on developing the agenda for the two-day session and to ensure that key outcomes and topics were identified and shared with Tony in advance of the meeting. They also worked with Tony on developing the materials to be used by the participants during the two-day session.

An anonymous benefactor made a donation to AMSAT to cover Tony's consulting fee. Along with the board (including Alternates) and senior officers who are not board members, we also invited several additional participants. Two of our invitees from outside of AMSAT (but who are well recognized in the amateur or satellite community) were subsequently unable to attend, but we did benefit significantly from the participation of Joe Kornowski, KB6IGK (AMSAT Journal Editor) and Gould Smith, WA4SXM (former board member and former VP-User Services), along with Joe Spier, K6WAO (VP-Educational Relations) and Dave Taylor, W8AAS (ARISS International Delegate). Dave filled in for Frank Bauer, KA3HDO (VP-Human Space Flight), who could not attend, as it was important that ARISS be represented in this process.

I also invited Dave Jordan, AA4KN, to attend the sessions as our "scribe," responsible for capturing all of the thoughts/outcomes that were discussed, as well as ensuring that any ideas put into the "parking lot" were not lost. Significant details captured on boards needed documenting. Dave spent two weeks after the meeting putting together a document for the participants to use as a reference of what transpired in Orlando. My thanks go to Dave for his diligence in documenting a very intense and fast-paced weekend of activity.

Six basic areas were identified during our strategy kickoff session:

1. Satellite Innovation
2. Membership Engagement & Communication
3. Developing Revenue Streams

4. Education/Partnerships
5. IT and Web Development
6. Succession Planning

Each area has a team leader, and I expect those team leaders will be reaching outside the senior leadership to ask individual AMSAT members to participate in their respective teams.

As I write this, the Planning Group will be meeting with Mr. Silbert to review the document that Dave created and ensure that we place proper focus on next steps and establishing expectations.

My perception is that everyone who participated at the Orlando meeting was impressed by the process used and thought that the session was time and money well spent. Feedback about the weekend was very positive regarding how well Tony led the process, as well as how participants departed the meeting feeling energized and excited about the future of AMSAT. The challenge is to take the momentum that was generated at Orlando and amplify it with your support. Translating ideas into milestones and results requires focus and significant effort. In future issues of *The AMSAT Journal*, we will share progress that is being made as well as how you can engage and contribute to the future of AMSAT.

Engineering Update

Jerry Buxton, N0JY
Vice President, Engineering

A rather common way to describe what AMSAT does is, "we build and launch amateur radio satellites." Of course, that is not exactly true. If we did have our own launch vehicles, it would certainly be handy, but probably quite a costly business and a regulatory mess. Saying that "we build and seek launches for amateur radio satellites, then operate them when they are on orbit" would be more accurate but not quite as sweet or easy as the former statement.

The CubeSat format allows for access to a variety of launch vehicles because of the design standard. The five Fox-1 satellites will ride on five different launch vehicles to get to their orbit. That capability and the variety of launches available are pretty amazing when you think about it. The CubeSat design and the commercial space industry are making a big impact on the ability to get to orbit.

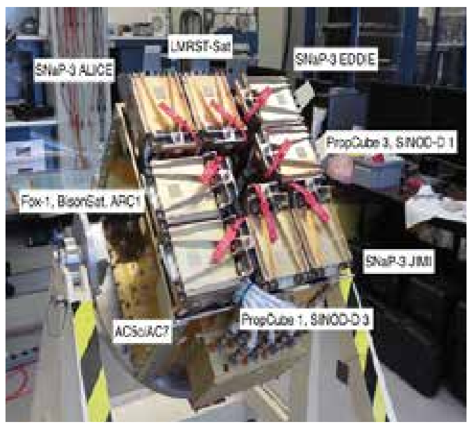

Figure 1 — NPSCuL with P-PODs. [Photo courtesy of California Polytechnic State University.]

Fox-1 CubeSats are integrated into a few different types of dispensers: the Cal Poly P-POD; Integrated Solutions In Space (ISIS) Quadpack; and Xtenti FANTM. While each has some unique characteristics based on their designs for various vehicles and competitive advantage, they all share the same general characteristic relevant to this discussion by holding 3U of CubeSat (3 x 1U, 1 x 3U, or other combinations of 1U, 1.5U, and 2U). With a spring-driven platform at the "bottom" end and a door or other securing device at the "top" end, the CubeSats are held captive until the securing device is activated. Once released the CubeSats are pushed out of the dispenser at a pretty good rate to clear the launch vehicle and are in orbit.

Fox-1A rode on a United Launch Alliance (ULA) Atlas V EELV (Evolved Expendable Launch Vehicle) launched from Vandenberg Air Force Base in October 2015. That launch was an interesting and the roughest ride any of the Fox-1 satellites will experience. The CubeSat secondary payload dispensers were loaded into a NPSCuL (Naval Postgraduate School CubeSat Launcher) which is a box-like structure holding eight P-PODs for this launch. The NSPCul is then attached

Figure 2 — NPSCuL being mounted.

to the Aft Bulkhead Carrier on the Centaur upper stage very close to the engine bell. Figures 1 and 2 show the NPSCuL with the P-PODs, and the NPSCuL being mounted to the Centaur.

Once the primary payload of the mission was deployed the Centaur stage was lowered to an orbit height that would clear the primary as well as satisfy the orbital debris requirement that the secondary payloads re-enter within 25 years of launch, and the deploy of the CubeSats began. One by one the P-PODs were opened with a delay between each P-POD deployment as well as some repositioning of the Centaur for collision mitigation. [See video, "Fox 1A Deploy." which can be found at **youtube.com/c/n0jy** or search YouTube for Jerry Buxton.]

RadFxSat (Fox-1B) will ride on a ULA Delta II ELV (Expendable Launch Vehicle). This will be the next to the last of the venerable Delta II rockets. The launch is currently scheduled for August 29, 2017, at Vandenberg Air Force Base. We will perform integration of RadFxSat into the P-POD at Cal Poly in San Luis Obispo, CA in June 2017. The ride is a bit better than on the Atlas V, with the P-POD inside the payload fairing and near the bottom of the payload adapter. Photo 3 shows an example of the P-POD (circled in red) carried on a Delta II. As with the Fox-1A launch, once the primary JPSS-1 payload is deployed the rocket stage will be repositioned to a lower

Figure 3 — P-POD (circled in red) on Delta II. [Photo courtesy of Tyvak Nano-Satellite Systems, Inc.]

Figure 4 — Virgin Orbit LauncherOne launched from a Boeing 747-400. [Photo courtesy of Virgin Galactic.]

orbit to clear the primary and satisfy orbital debris requirements, then the CubeSats will be deployed.

By now you have probably heard of the change to the Fox-1Cliff and Fox-1D launches. They both have been rebooked from the original Spaceflight Formosat-5/Sherpa mission aboard a SpaceX Falcon 9 onto two separate new launches. This will afford some margin for the risk of launch and deployment for each satellite rather than having them both on the same mission.

Fox-1D will now ride to orbit on an Indian PSLV (Polar Satellite Launch Vehicle) scheduled to launch from Satish Dhawan Space Centre in Sriharikota, India in late 2017. Spaceflight Inc., which AMSAT contracted for the launch of Fox-1Cliff and Fox-1D, will have us do integration of Fox-1D into the dispenser in Tukwila, WA and then ship it to India for integration on the launch vehicle. The PSLV carries the dispensers inside the fairing with the primary payload as does the Delta II and the ride should be similar. This will be our first non-U.S. CubeSat launch vehicle but the requirements for imager licensing and FCC approval are still necessary because the satellite was produced in the United States.

Fox-1Cliff is now manifested on the Spaceflight SSO-A mission, a dedicated rideshare launch on a Falcon 9 rocket. Spaceflight is preparing a dedicated CubeSat interface for the deployers, and unlike our other launches, this mission will go directly to the target orbit to deploy our CubeSat. This launch will also be from Vandenberg Air Force Base, and we will deliver Fox-1Cliff to Spaceflight for integration in Tukwila, WA.

By our choice of the available launches for their specific orbits, Fox-1D and Fox-1Cliff should both have an orbital lifetime of about 6.5 years.

Our final Fox-1 CubeSat launch variety will be RadFxSat-2 (Fox-1E) which will be riding on a new vehicle, the Virgin Orbit LauncherOne. While still flying on a rocket, the LauncherOne is a departure from a typical rocket launch because the rocket itself is a payload, aboard a Boeing 747-400 aircraft. The aircraft takes the rocket to an altitude of 35,000 feet and releases it, to fire its engine and continue to orbit. See Photo 4[4]. The rocket (in our case) is designed exclusively to handle CubeSats with deployers similar to the P-POD. Once the rocket reaches the target orbit height, the CubeSats are slowly released as with the other missions, for collision mitigation. RadFxSat-2 will be flying on the maiden (commercial) launch of LauncherOne in December 2017.

The times are exciting in the choices available for launching a CubeSat and the various requirements, testing, and compliance needed for each launch. Once all five Fox-1 satellites are in orbit, AMSAT will have established a record of successful CubeSat design and implementation in a variety of launch options.

Designing and Operating a Portable Satellite Station in an Urban Environment

Paul Stoetzer, N8HM
Secretary and Alternate Board Member

[Originally presented at the 34th Space Symposium and AMSAT-NA Annual Meeting, November 2016]

Figure 1 — Paul Stoetzer giving his presentation onboard the Carnival Liberty at the 2016 Space Symposium.

I first became interested in satellites in 2011, having been licensed since 1989. I had read articles in *QST* about satellite operations and the ARISSat-1 satellite. So, I bought an Arrow antenna, listened to a few passes, and then put it on the shelf for about a year. In 2012, on Labor Day weekend — I live in Washington, D.C. — I drove to my parents' house in the upper peninsula of Michigan. I brought my Arrow with me and made my first contact from EN75 on AO-27 and several additional contacts the next day.

After that, I got more into it. And then, after a couple of weeks, AO-27 died, and that left SO-50 on FM. I had and FT-817, and I thought, "What else can I do with this?" So, I looked into the linear satellites.

One of the big challenges I have is that I live in an apartment building in southwest Washington, D.C. — not the best environment for amateur radio at all. In fact, a bit of trivia, my building is listed as AMSAT's address on the original AMSAT articles of incorporation because one of the incorporators, Perry Klein, lived there in 1969. Over the next year to year and a half, I read a lot and tried to figure out how best I can operate in this difficult environment.

One of the articles that inspired me was a presentation that PA1IVO gave at the AMSAT-UK Colloquium in 2011 about a multi-purpose portable station setup (**ivok.home.xs4all.nl/pa1ivo/portable_satellite_setup.html**). He put two Yaesu FT-817s together in a bag. He built a custom bracket to hold the 817s together along with fuses, etc. — a real nice design. It's a little bit much regarding the work involved to put it all together but very nice. And that inspired me.

So, the first thing I tried was a Kenwood TH-F6A handheld transceiver as the receiver with the FT-817 as the output transmitter. I strapped it all together and carried it outside. That didn't work too well. In the urban environment, the TH-F6A got swamped. The front end is wide open, and it just gets swamped with RF.

The next thing I tried was an ICOM ICR-10, which was a much better receiver, but it lacks sensitivity especially on UHF. I ended up making several hundred contacts with it before I got a second FT-817.

Figure 2 shows Patrick Stoddard, WD9EWK, working VO-52 with two 817s from his backyard in a YouTube video. Patrick likes to tweet pictures of his setup.

Figure 3 is a photo of me using my setup. That was taken on the 45th parallel in northern Michigan back in January 2015. I was operating on the EN84/EN85 gridline, precisely. So, my portable setup is two FT-817s in a camera bag. I also have preamps and an amplifier. The amplifier is a Microset VUR 30 dual-band UHF/VHF. It puts out 30 W VHF and 22 W UHF.

Figure 5 shows the portable satellite station. The top radio is a FT-817 I got on eBay. The guy said it seems to work, but it doesn't transmit. Of course, everyone knows that in the original 817s the finals got unstable because they are connected directly to the battery. The finals would virtually destroy themselves when the battery voltage got too low. That happened to quite a few of them, but that also made it a great deal on eBay

Figure 2 — Patrick Stoddard, WD9EWK, working VO-52.

Figure 3 — The author on the EN84/EN85 gridline in northern Michigan.

Figure 4—The author activating a NPOTA site in Banneker Circle, Washington, D.C.

Figure 5 —The author's portable satellite station.

because it can't transmit. But I don't need it to transmit; it's a receiver.

On the right side is a High Sierra Microwave preamp powered by a small lithium polymer battery. The amplifier is in the front pocket. The battery to power the amplifier is in the left pocket. Each 817 has an internal battery.

I've got just a regular computer headset, a Logitech gaming headset. In the front top pocket is a digital audio recorder. I also have a Belkin Rockstar splitter so I can do demos, use headphones, a digital audio recorder, and hook up an external speaker,

The one thing about holding two 817s and an amplifier close to your body with shoulder straps while also holding an Arrow is that often you get desense, especially when transmitting on VHF and receiving on UHF. So, what I do is have an MFJ-936 for both 817s.

Let me give you a sense of what I'm dealing with. I use shoulder straps that are designed for carrying two SLR cameras. I hook them onto the bag so I can operate the controls in front of me. Since I live in an apartment building, I have a balcony that is south facing. That means I have substantial coverage to the south for southern passes. It works great for the Caribbean, Central America, and South America. But that doesn't work great for Europe or stations north of me.

So, I can't really set up a station in my apartment. Well, I could, but I'd essentially only be able to work passes to the south. That's why I designed a station that I can just strap on my shoulders, walk outside with the antenna and operate the passes. So, I can either run outside with my gear to work all the passes or sometimes I'll just work the southern passes from my balcony. That's why I designed this whole portable satellite station. It works great. As long as I can see the satellites and don't have too many challenges, I can work down to the horizon without a problem. The trees and the noise and buildings are my only real limitations.

I've worked over 430 of the 488 grids in the United States, as well as quite a few European stations, to Asia, up to Alaska, and South America. I'm up to 71 DXCCs. I've worked 49 states, but Hawaii remains a challenge. Each side of the best passes between D.C. and Hawaii only gets one and a half degrees on AO-7.

It takes a lot of effort to work each pass, and I miss quite a few just because sometimes I won't want to grab my gear and walk outside, or I have to switch my setup from mode J and the satellite about to come over is mode B. In Europe, I worked a couple of grids in Poland, Germany, Italy, Denmark, Sweden, Norway, France, Spain, Portugal, the Azores, Faroe Islands, and Iceland. When FO-29 is near apogee over the Atlantic, it's pretty easy to work Europe from Washington, D. C.

I like to keep statistics. I note all the satellites I've worked and all the various using my QSOs, grids, grid fields, states, Canadian call areas, continents, DXCCs, CQ zones, and then total entities for the OSCAR Century Award. It breaks down as follows:

938 grids
50 grid fields
49 states
13 of the 14 Canadian call areas
71 DXCCs
15 CQ zones
4 continents

N8HM - Washington, DC (FM18) - Satellite QSOs

Satellite	QSOs	%	Uniques	Grids	Fields	States	Canadian Call Areas	DXCCs	Zones	Continents	OSCAR Awards Entities
FO-29	1738	33.89%	435	536	41	48	7	52	14	4	104
SO-50	1487	28.99%	469	385	26	48	11	35	11	3	92
AO-73	514	10.02%	138	133	18	33	5	9	8	2	45
AO-7B	458	8.93%	170	185	35	41	5	24	12	4	68
AO-85	418	8.15%	154	122	14	37	8	7	7	2	49
XW-2F	126	2.46%	72	72	13	29	4	7	7	2	38
VO-52	89	1.74%	53	51	9	27	1	3	4	1	29
XW-2A	63	1.23%	45	40	8	20	2	5	4	2	25
XW-2C	63	1.23%	44	40	12	16	4	5	5	2	22
CAS-3H (FM)	47	0.92%	29	27	8	17	0	2	4	1	18
XW-2E	45	0.88%	27	23	5	14	1	2	2	1	15
UKube-1	21	0.41%	16	16	6	12	1	3	4	1	14
LO-78	21	0.41%	12	12	4	11	0	1	2	1	11
EO-79	17	0.33%	14	14	5	12	0	2	3	1	13
XW-2B	6	0.12%	5	5	3	5	0	1	1	1	5
ISS Repeater	5	0.10%	4	4	4	4	0	1	2	1	4
XW-2D	3	0.06%	3	3	3	3	0	1	2	1	3
AO-27	2	0.04%	2	2	2	2	0	1	2	1	2
ISS Packet	2	0.04%	2	2	2	2	0	1	2	1	2
AO-7A	2	0.04%	2	2	1	1	0	1	1	1	1
CAS-3H (Linear)	2	0.04%	1	1	1	1	0	1	1	1	1
Total	5129	100.00%	877	847	48	49	12	68	15	4	126

Figure 6 —The author's satellite QSO statistics (as of the presentation date).

Adaptive Coding and Modulation for Phase 4 Ground

Michelle Thompson, W5NYV
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Phase 4 Ground provides digital radio solutions for any payload that complies with the Phase 4 Ground Air Interface document. These projects currently include but are not limited to Phase 4B Payload, Cube Quest Challenge (CQC), Phase 3E, and terrestrial groundsats.

An Introduction to Coding and Modulation

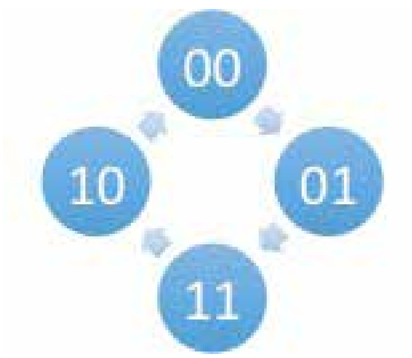
In analog wireless communications, continuously varying signals are sent from transmitter to receiver. Voice, for example, is directly encoded in an analog transmission by a proportional relationship between baseband and carrier. The changes in audio that make speech intelligible to the ear are proportional to changes in either the frequency (FM), amplitude (AM), or phase (PM) of a transmitted carrier signal.

In digital wireless communications, data such as voice is represented by the digital symbols 1 and 0. Coding is the process of removing unnecessary redundancy in a signal and adding the right type of redundancy. Removing unnecessary redundancy is compression. Adding useful redundancy is channel coding. The type of channel coding we're most interested in is forward error correction coding. This is a way of coding the data where we can recover corrupted parts of the signal.

When we talk about code rate, we are talking about the ratio of how many bits go into the forward error correction coder, or encoder, over how many go out. A 2/3 rate code takes in two bits and produces three. The extra bit is produced with mathematics especially designed to make the signal more durable as it travels from transmitter to receiver. The more bits you add, the smaller the ratio. Rates up to 1/9 are common. For a 1/9 rate code, for every bit that goes into the encoder, nine come out. As you'd expect, the more coding, the more durable the transmitted bits are against noise and interference. However, there's a cost. If you compare two signals that are transmitted at the same rate, the one with more extra bits to protect it needs more time to get through. The data rate is lower. It takes longer to transmit the same amount of data.

After the data is channel coded, the resulting bits are transmitted. The simplest type of digital waveform has two distinct states. One state corresponds to a 1, and the other state corresponds to a 0. Each of these ready-to-transmit values is called a symbol. When we send one bit at a time, we have two symbols from which to choose. An example of this type of modulation is Binary Phase Shift Keying (BPSK). The modulation order is the number of symbols we have to choose from. For BPSK it's two.

This simple BPSK modulation scheme can be dramatically improved. Sending one bit at a time is a great start, but we can do a lot better. If we use four distinct states in our transmitted waveform, then we can send binary data two bits at a time. We now have four symbols instead of two. An example of this type of modulation is Quadrature Phase Shift Keying (QPSK). The modulation order has doubled to four.



How about 8? 16? 32? Yes, to all, and more, all the way up to 256, 512, and even 1024! Sending 1024 bits in a single sample sounds amazing. So, why don't we just send 1024 bits in a single sample all the time?

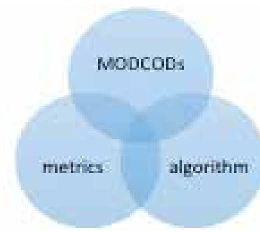
Engineering is all about trade-offs, and there's another one right here in front of us. The higher the modulation order, the more power required. This means that the signal carrier power for transmitting two bits at a time must be twice that of transmitting one bit at a time, assuming that we are transmitting at the same symbol rate. We pay for the doubling in information capacity by having to provide double the power. As long as you have enough power, you can use more powerful modulations. If you have too much noise or not enough power, then you have to drop down to a lower modulation order.

Coding and Modulation Techniques in DVB

Traditional communications design assigns a fixed modulation and forward error correction coding (MODCOD) to a link. The MODCOD is selected to provide reliable communications under worst case conditions. For example, a microwave link that points down off a mountain is often designed to be good enough to work through rain fade and summer foliage. During clear conditions in the fall with no leaves, plenty of excess link margin is available, but a fixed system designed to work through summer thunderstorms cannot take advantage of this margin. In the Digital Video Broadcasting (DVB) world, this technique is called Constant Coding and Modulation (CCM). Phase 4 Ground uses many DVB protocols and techniques due to their high quality and widespread use in industry. Adapting these protocols to amateur radio is part of our mission.

Since it makes sense to adjust our link to better match observed conditions, one can design a system that uses a variety of MODCODs. An operator can then observe the link and then adjust the MODCOD to take advantage of better conditions. This technique is called Variable Coding and Modulation (VCM). VCM requires intervention of some sort to accomplish. Generally, no feedback path exists from the receiver to the transmitter, and a human is involved. But what if there was a feedback path from the receiver to the transmitter?

Adaptive Coding and Modulation (ACM) is a technique where the modulation and forward error correction are automatically changed in response to link conditions. As the link improves, higher order modulations and less coding allow increased throughput. Throughput can increase to take better advantage of available link margin. Challenging link conditions are responded to by lower order modulation and more coding. The throughput will decrease, but the link is maintained. The adaptation is enabled by establishing the set of MODCODs to be used, listing the metrics that control the decision to change MODCODs, and defining the algorithm that produces the decision. These three ingredients make up ACM.



With a CCM system, severe fades can cause total loss of the link and zero throughput. VCM can address some of the challenges of severe fades, but ACM automatically turns fade margin directly into capacity. Maximizing throughput is highest with ACM.

Adaptive Coding and Modulation in Phase 4 Ground

The first challenge to an amateur-radio-centric version of ACM is that all existing implementations of ACM are proprietary. ACM is used in landline modems, 802.11, terrestrial microwave communications, and satellite links. When you are making money with subscribers, leaving margin on the table is not ideal. More efficient links mean more capacity, and more capacity means more subscribers, and more subscribers mean more profit.

Most commercial ACM links only connect amongst themselves. No reason exists to create and maintain an open standard. Therefore, outside of the limited advice given in the implementation guidelines for DVB and a few white papers from a few companies, no open standard exists for ACM that we can simply adopt. For Phase 4 Ground, we have to develop our own implementation of ACM, document it fully, and adjust it as we learn more in the field.

This is a great opportunity for amateur radio. Documenting the engineering trade-offs made in an advanced digital wireless system provides enormous educational opportunity for a wide variety of people, from interested amateurs to engineering students, to satellite startups, to people interested in machine learning and cognitive radio. Providing a working open-source implementation of ACM that other amateur projects can consider for adoption is a valuable engineering service.

The particular radio problem that has to be solved for space payloads is relatively straightforward. The geostationary and lunar and beyond radio environments are well-characterized. The available modulation schemes and coding rates are drawn from an established set described in the DVB standards (freely available from https://www.dvb.org). Advice exists from commercial and academic sources.

The particular radio problem that has to be solved for terrestrial groundsats is also relatively straightforward. Groundsats are terrestrial versions of space-based payloads. They provide all the functions of an orbiting platform but are on the ground. The control loop for terrestrial ACM has to be able to respond faster than for space. This is still well-characterized, and advice exists from commercial and academic sources.

DVB allows an extreme resolution of MODCODs. Each and every frame can have a different MODCOD. This enables a link to respond very rapidly. For receiving transmissions from space, rapidly changing links are not the norm. The primary challenge is weather and rain fade or dishes not quite pointed right. For terrestrial links, changes in link quality can be more rapid, especially for mobile stations. Terrestrial links have multipath, obstacles, noise, signal interference, and can also have rain fade and pointing problems.

There is a simple equation for ACM. In DVB, and for ACM in particular, the symbol rate is fixed. This greatly simplifies the communications system design. After a symbol rate is determined, a set of MODCODs is selected. The bit rate expression is therefore:

Bit rate = symbol rate * modulation order * code rate

Many MODCODs are available to choose from in DVB. For space projects, the DVB-S family is the standard to reference. For terrestrial, we look to DVB-T. S stands for Space, and T stands for terrestrial (think "television").

Phase 4 Ground uses DVB-S2X and DVB-T2. The 2 in DVB-S2X and DVB-T2 stands for second generation. Second generation DVB-T2 and DVB-S2 is backwards compatible (with some effort) to the first generation DVB-S and DVB-T. Second generation standards provide substantial improvements over first generation.

DVB-S2X is an extension to DVB-S2 that provides additional MODCODS and some additional mechanisms. Of compelling interest to us are the additional MODCODs at the lower end of the spectrum that provide enhanced very low signal to noise (VL-SNR) operation. For CQC, VL-SNR operation will provide needed support. For Phase 4B Payload, VL-SNR allows for reasonably sized dishes and opens up the possibility of patch arrays.

A large advantage gained in choosing DVB standards is that the receiver is explicitly told, frame by frame, exactly what MODCOD has been chosen. The receiver does not have to do anything extra to use ACM. The complexity of ACM is in the transmitter.

The second challenge to an amateur-radio-centric version of ACM is that ACM assumes exactly one intended receiver. If the transmission is a QST or CQ, or intended for a roundtable talk group, or is merely open to monitoring by silent listeners, modifications to the standard ACM scheme will be needed.

Maximizing The Bit Rate

A very important distinction exists between analog and digital systems and how to interpret the guidance for best-operating practices as set out in part 97.

A principle of conservation of power applies in analog communications in amateur radio. The least amount of power should be used to ensure reliable communications in normal operations.

Part 97: Sec. 97.313 Transmitter power standards
(a) An amateur station must use the minimum transmitter power necessary to carry out the desired communications.

Obviously, emergencies may require a different practice. In digital communications, the spirit of this guidance is best achieved by maximizing the bit rate, or throughput. Maximum bit rate ensures that the communications are achieved in the most efficient manner by providing maximum capacity. If this means transmitting at a higher power than is necessary simply to maintain a communications link, then so be it. It's better to transmit for 450 milliseconds and then almost immediately allow someone else to then use the channel than to transmit for 450 seconds on minimum power using maximum coding and the lowest modulation scheme before relinquishing that particular channel. We equate bit rate with power and assert that this complies with the spirit of part 97.

We want to maximize throughput. This means maximizing the bit rate. In order to get to maximum bit rate, the professional advice is to start out with a stable link and work upwards. Here's an excerpt from Work Microwave's website.

Start conservatively, approach the optimum: When setting up a link it is wise to start with very conservative settings to have a stable link running in the first place. Even if the "first shot" has not the desired bandwidth efficiency, an incremental approach will be the best way to optimize the link once it is up and stable. Due to numerous parameters and conditions affecting the Es/N0, the best settings will be reached by trial and error and can hardly be predicted beforehand.

"ACM Dos and Don'ts." Work Microwave, 13 Mar. 2016, https://work-microwave.com/acm-dos-donts/

The Es/N0 value is a big clue. It's a critical metric for ACM. It stands for energy per symbol divided by the noise power spectral density. We already know what symbols are. A symbol is the distinct states of the modulator. The simplest one transmits 0 and 1. Two symbols can be transmitted, so the modulation order is 2. Next most complex is 00, 01, 11, and 10. Four symbols can be transmitted, so the modulation order is four. Next most complex is 000, 001, 010, 011, 100, 101, 110, 111. Eight symbols are available to be transmitted, so the modulation order is eight. An example of this type of modulation scheme is 8PSK.

Energy Per Bit

Es/N0 is commonly used in the analysis of digital modulation schemes, but we're going to dig deeper and look at a quantity called Eb/N0. This is the energy per bit divided by the noise power spectral density. Eb/N0 is the normalized signal to noise ratio of our link, and this value is what drives the adaptation decisions in ACM. Think of Eb/N0 as the signal-to-noise (SNR) per bit. The energy per symbol and the energy per bit are related by the following expression.

Es/N0 = Eb/N0 * Log2(modulation order)

So for the modulations that we listed above, we have the following relationships.

Es/N0 = Eb/N0 * Log2(2) two symbols to choose from
Es/N0 = Eb/N0 * Log2(4) four symbols to choose from
Es/N0 = Eb/N0 * Log2(8) eight symbols to choose from

This gives us:

For modulation order 2: Es/N0 = Eb/N0

The energy required to transmit a symbol of 0 or 1 is the same as required to transmit 0 or 1 bits. Makes sense!

For modulation order 4: Es/N0 = Eb/N0 * 2

The energy required to transmit a symbol of 00, 01, 10, or 11 is twice as much as required to transmit a 0 or 1. Still makes sense.

For modulation order 8: Es/N0 = Eb/N0 * 3

The energy required to transmit a symbol of 000, 001, 010, 011, 100, 101, 110, 111 is three times as much as required to transmit a 0 or 1. We see the pattern.

In ACM, we have to be able to decide when we can afford to move on up to the higher order modulation schemes, which allows us to transmit more bits at once. If all the power we have available to us amounts to about as much power as required to transmit one bit, then we are stuck transmitting one bit at a time in BPSK. If our metrics tell us that we have more than three times the power required for a single bit available to us, then we can transmit a symbol that stands for three bits at once. We can go with 8PSK.

Within the modulation schemes are sets of coding rates. We've seen how spending power can increase the bit rate. How does coding fit in?

Coding Gain

There are two major types of coding. Source coding removes unnecessary redundancy so that source data can be more efficiently stored and handled. For example, digital music and video is source coded for compression. Otherwise, the directly sampled files would be enormous.
Channel coding puts back in the right type of redundancy to make the transmitted signal resilient. Forward error correction puts in additional bits that allow for both the detection and correction of errors. Better than magic!

In DVB-S2X, the forward error correcting code is called LDPC-BCH. It's an advanced concatenated block code. Block code means that groups of bits are gathered up and then mathematically modified with extra bits. Other types of codes operate on continuous streams of bits. Those types of codes operate bit-by-bit as long as there are bits in the pipeline. Each block stands alone and is decoded separately. Concatenated means that two different codes are used. The reason these two different codes are used together in DVB-S2X is that using them together cancels out weaknesses. Taken together they make a very high-performance code.

Coding gain is the measure of the difference between the Eb/N0 levels of an uncoded system when compared to a coded system when both systems are required to provide the same bit error rate. We have the same signal energy available in either case. Coded signals allow us to correct errors, which allows us to transmit at less power.

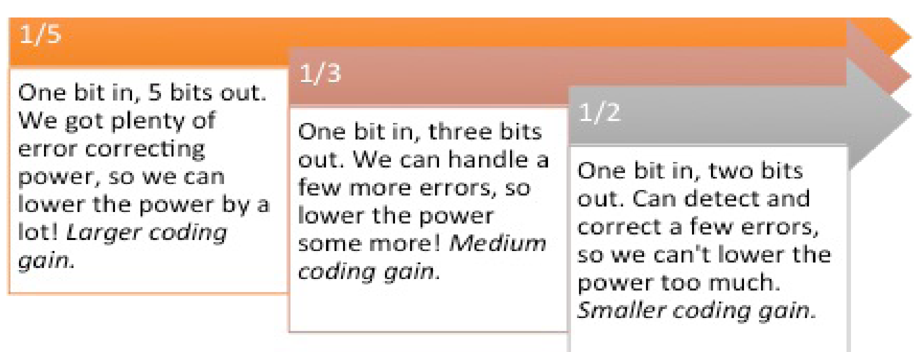
What can we do with this extra gain? In ACM we can put it right to work in maintaining target bit error rate performance. If we know what Eb/N0 we need, and we know which codes consume that much Eb/N0 to maintain a particular performance level, then we can select the code that maximizes bit rate while minimizing bit error rate.

We do this by measuring Eb/N0 at the receiver. This tells us how strong the signal is. Eb/N0 is reported to the ACM controller, and the right modulation and coding are selected for that receiver. In commercial satellite, the ACM controller is centralized and is usually on the ground. For Phase 4B Payload and for groundsats, it's planned that the controller will be onboard the satellite.

Changing the modulation is the coarse-grain control knob in ACM. Changing the code rate is the fine-grained control knob in ACM.

Putting Metrics, MODCODs, and Algorithms Together

For ACM to work, the modulator must send which MODCOD is being used at the start of each frame. The receiver must be able to handle an arbitrary change in MODCOD without any advance knowledge. The receiver must be able to work fast enough to process the packet or frame without corrupting or dropping it. This puts a lot of pressure on the receiver. This pressure can be alleviated in several ways. One example is using standardized mechanisms in DVB



such as time slicing. See Wally Ritchie's paper "Using DVB-S2X and Annex M to implement low-cost Phase 4B Earth Station Terminals" (AMSAT Journal, Jan/Feb 2017, p. 26) for ideas on time slicing.

Another requirement is that the receiver needs to be able to measure or calculate an estimate of the link quality (Eb/N0) and then communicate this estimate to the payload. The payload must be able to process this reported metric and then adapt the data rate and change the MODCOD sent to the receiver. This maximizes the data rate, complies with the spirit of part 97, and is sparkling with efficiency and style.

Reacting to changes in channel quality makes sense. But can there be additional improvement? Yes, there can! A large body of research shows how throughput and bit error rate performance change when using linear prediction to estimate the future state of the channel based on past measurements.

Practical limits constrain how quickly an ACM system can respond. In general, about 1dB per second is achievable. If something happens and the demodulator comes unlocked, then it's a good idea to go back to the lowest MODCOD. This way, you're starting over with the highest probability of re-connecting and then working your way back up to maximum bit rate.

Assuming that the receiver has acquired the satellite and done all necessary chores to receive the downlink, and assuming the receiver has the necessary authentication, and assuming the receiver can successfully determine which channels are free for transmission to the payload, the receiver now needs to determine what MODCODs it is capable of receiving.

The dish might not be pointed correctly. The receiver might be a bit noisy. The local oscillator might not be rubidium quality. There might be some atmospheric conditions that attenuate the signal. Someone could have dented the dish. A connector could be loose. Some of these factors change very slowly over time, and some of them change more quickly. All of these factors affect receive capability, and all of them can be automatically accommodated with ACM.

The standard model of ACM has the receiver monitor and report its Eb/N0 to the controller. In our case, the controller can be in the payload. When Eb/N0 falls below a setpoint, the receiving station is sent a lower MODCOD. The setpoints are configured to provide a minimum level of performance. When going to a lower MODCOD, throughput is reduced, but the link is maintained. Eb/N0 reports can be part of the frame structure.

Digital communications performance can be defined by maximum allowable bit error rate. DVB is designed to provide very low error rates. The standard of performance for DVB is called quasi-error-free. DVB allows one uncorrected error per hour of video broadcast viewing. This is a very high standard that works out to a bit error rate of about 1*10-10 to 1*10-11.

When you establish the values for Eb/N0 that you're going to allow, they have to be made based on what bit error rate you can tolerate. Quasi-error-free bit error rate in DVB is many orders of magnitude lower than, say, the maximum bit error rate for GSM (1*10-3) and lower than the data-centric maximum bit error rate for 3G data (1*10-6). Voice is more forgiving than data which is more forgiving than digital video broadcasting. Selecting a baseline bit error rate of 1*10-6 is not out of line.

Once you have a bit error rate that you want to keep below, then you calculate a table of Eb/N0 values that would cause you to move to a better MODCOD. "Better" could mean higher or lower depending on whether you were doing great or having trouble with the link.

Anyone that's ever worked with set points knows that there's a potential for oscillating when the measured value is very close to the set point. A common approach with ACM is to put in 0.3dB or more of hysteresis. Going up requires a bit more SNR than coming down. This doesn't just prevent oscillating between two MODCODs but can also help maintain demodulation lock. You don't want your radio to work any harder than it has to.

We want the operator to see as much information about the metrics and the link as they desire. Our goal is to provide quality presentations of signal-to-noise ratios, states of lock, channel occupancy, system status, user synchronous log visualizations, symbol rate, modulation constellation, data rate, bit error rate, and more. Metrics such as these and more are presented by an application that can be run or not, depending on the preferences of the operator. Some systems provide a bit error rate tester as an application. This can help debug situations of synchronization loss, unexpected bursts of bit errors, or other problems. If the operator doesn't want to see any of this, then they don't have to. It should "just work" without intervention, and provide clear error or failure messages if anything goes wrong.

When a higher MODCOD is selected, the available data rate is increased. This usually isn't a problem. When a lower MODCOD is selected, the available data rate is decreased. This can be a problem. Congestion control must be considered and implemented to avoid losing packets or frames. Buffers and FIFOs to the rescue!

Is maximizing the bit rate enough? What about latency? While ACM considered in the abstract doesn't minimize or maximize latency, the use of DVB-S2X can offer some relief over DVB-S2. Latency will be one of the biggest challenges to operator experience on the Phase 4B Payload. It is impossible to go faster than the speed of light, and the round-trip delay of at least 240mS is substantial. There are things that we can do to mitigate latency such as reducing buffer size and using shorter frame lengths. Providing voice memo as an alternative to real-time voice is another.

Proposed Adaptive Coding and Modulation Scheme

Here's the current proposal for MODCODs, metrics, and algorithm for ACM for Phase 4 Ground. This is an open design that is going into prototyping and testing. The expectation is that this proposal will be reviewed, refined, and retuned to maximize bitrate and avoid commonly encountered challenges. Some challenges are anticipated and have been mentioned above. Others we will certainly discover along the way.

There are choices of frame size in DVB-S2 and DVB-S2X. The CCSDS (Consultative Committee for Space Data Systems) RF Modulation and Channel Coding Workshop, among other individuals and groups, recommends the short frame size for near space-earth transmissions. A selection of the short frame size MODCODs that we believe will work best for Phase 4B Payload is presented in the table below. Short frame size is 16200 bits. Frame size and the presence or absence of pilot signals is communicated in the TYPE field of the physical layer header. Each MODCOD has an identification code. The decimal value of that code, which goes into the PLS field of the physical layer header, is the first column. Ideal Es/N0 is ideal energy per symbol divided by the noise power spectral density in dB to achieve a frame error rate of 10-5. This is quasi-error-free operation with no impairments. In other words, very ideal!

PLS Code	MODCOD Name	Rate	Ideal Es/N0
1	QPSK code rate ¼	1/4	-2.05
2	QPSK code rate 1/3	1/3	-1.00
3	QPSK code rate 2/5	2/5	0
4	QPSK code rate ½	½	1
5	QPSK code rate 3/5	3/5	2
6	QPSK code rate 2/3	2/3	2.8
7	QPSK code rate ¾	¾	3.7
8	QPSK code rate 4/5	4/5	4.38
9	QPSK code rate 5/6	5/6	4.9
10	QPSK code rate 8/9	8/9	5.9
216	QPSK code rate 11/45	11/45	-1.46
218	QPSK code rate 4/15	4/15	-2.24
220	QPSK code rate 14/45	14/45	-1.46
222	QPSK code rate 7/15	7/15	0.60
224	QPSK code rate 8/15	8/15	4.71
226	QPSK code rate 32/45	32/45	7.54
12	8PSK code rate 3/5	3/5	5.2
13	8PSK code rate 2/3	2/3	6.3
14	8PSK code rate ¾	¾	6.7
15	8PSK code rate 5/6	5/6	7.7
16	8PSK code rate 8/9	8/9	10.4
228	8PSK code rate 7/15	7/15	3.83
230	8PSK code rate 8/15	8/15	6.93
232	8PSK code rate 26/45	26/45	7.66
234	8PSK code rate 32/45	32/45	9.81

When we look at a chart of these MODCODs, we can see the effect of modulation and coding. We get about 12 dB of range just using QPSK and 8PSK. We haven't yet listed the VL-SNR codes that can bring the Es/N0 down to -10dB. They require some additional care and work to implement.

We need to select enough different MODCODs to give the performance we want, but not so many that we have a situation where the algorithm is flailing about making unnecessary changes. The starter list of MODCODs is the following. This gives a MODCOD at about every 2-3 dB.

QPSK 4/15 (identification number 218) -2.24
QPSK 2/5 (identification number 3) 0
QPSK 2/3 (identification number 6) 2.8
QPSK 4/5 (identification number 8) 4.38
8PSK 5/6 (identification number 15) 7.7
8PSK 8/9 (identification number 16) 10.4

All measurements have error. There are multiple sources of error and noise. The set of target Es/N0 (or Eb/N0) numbers need to be far enough apart to where link performance instead of noise is the main trigger of an ACM decision.

If three MODCODs turn out to be the best match, then it means we use three MODCODs. If we can use more, then we use more.

Once the MODCODs are selected, hysteresis is applied, and the metrics are monitored. Then the choice of which MODCOD to apply to which frame can be usefully made.

While the underlying mechanism is straightforward, there are many problems to solve. Decisions must be made about flow control and the type of service quality. The DVB implementation guidelines give a great start for ACM and describe ways to set up Generic Stream Encapsulation (GSE) to help implement ACM.

This is where we stand today. We're writing policy management code in Python to simulate ACM. We are learning the details of how to create DVB frames and predict the performance of the DVB physical layer components.

The next big step after the design, document, simulate, and test stage is to implement what works using GNU Radio with the USRPs donated by Ettus Research. This allows bench testing and then testing over the air as a groundsat.

Want to help? You're welcome to join Phase 4 Ground!

Apply at http://**www.amsat.org/?page_id=1096**

For Phase 4 Ground, you do not have to be a U.S. citizen.

We have an announcement email list **phase4@amsat.org**
a Slack team at **phase4ground.slack.com**
and documentation at our GitHub **github.com/phase4ground**

There are about 100 people on the Phase 4 Ground email list, and 52 members on the Slack team, and about 50 on GitHub. Not all members are active on the project, and not all members are active in each phase.

We have an enormous variety of work available, from art design to antenna design. Our mission is to create an open, digital, modular microwave radio that is fun, teachable, and affordable, that will support terrestrial and space communications. You are welcome to join and contribute however you are able!

Frank Bauer, KA3HDO, Named 2017 Dayton Hamvention Amateur of the Year

The Dayton Hamvention has announced the winners of the 2017 Hamvention Awards. Each year, the Dayton Hamvention honors radio amateurs who have made major contributions to the art and science of amateur radio. AMSAT Vice President for Human Spaceflight Frank Bauer, KA3HDO, was named 2017 Amateur of the Year.

The award citation reads:
"Frank serves as the Amateur Radio on the International Space Station (ARISS) international chairman. In the mid-1990s, Bauer proposed a GPS reception experiment on the AMSAT Phase 3D satellite (AO-40). The experiment was to measure the signal strength of the GPS satellite constellation while Phase 3D was in high-Earth orbit (HEO). The AO-40 experiment subsequently has often been cited in aerospace literature, as it remained the most comprehensive above-the-constellation data source for nearly a decade and led to changes in the system's specifications and applications. The results of the AO-40 experiment jump-started a game-changing transformation in navigation at HEO/GEO altitudes, enabling new and exciting missions in these orbits.

Bauer holds bachelor's and master's degrees in aeronautics and astronautics from Purdue University. His career in aerospace spans four decades within NASA and in private industry.

Bauer has been licensed since 1974. In 1983, in preparation for the space mission of Owen Garriott, W5LFL, he was responsible for setting up and operating the worldwide retransmission of Space Shuttle air-to-ground communications from Goddard Amateur Radio Club station WA3NAN. This initiative provided a critical conduit of information to hams attempting to contact astronaut-hams in the pre-Internet era."

The 2017 Dayton Hamvention Award winners are listed at **hamvention.org/event-details/awards/**.

Share Your Experiences as an AMSAT Member

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

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

- Your Name
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- Reasons You Are an AMSAT Member
- Favorite AMSAT Memory (a satellite contact, symposium, engineering project, event that would never have happened without AMSAT, etc.)
- Favorite Topics Appearing in *The AMSAT Journal* (could include things like building a homebrew antenna, assembling a ground station, using tablets and smartphones, news of upcoming launches, portable operations, ARISS, etc.

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

2017 AMSAT Field Day

Bruce Paige, KK5DO
Board Member

It's that time of year again; summer and Field Day! Each year the American Radio Relay League (ARRL) sponsors Field Day as a "picnic, a campout, practice for emergencies, an informal contest and, most of all, FUN!" The event takes place during a 24-hour period on the fourth weekend of June. For 2017 the event takes place during a 27-hour period from 1800 UTC on Saturday, June 24, 2017, through 2100 UTC on Sunday, June 25, 2017. Those who set up before 1800 UTC on June 24 can operate only 24 hours. The Radio Amateur Satellite Corporation (AMSAT) promotes its own version of Field Day for operation via the amateur satellites, held concurrently with the ARRL event.

This year should be easier than many years since we have about 10 transponders and repeaters available, with more possible before Field Day. Users should check the AMSAT status page at **www.amsat.org/status/** and the pages at **www.amsat.org/?page_id=177** for what is available in the weeks leading up to field day. To reduce the amount of time to research each satellite, see the current FM satellite table at **www.amsat.org/?page_id=5012** and the current linear satellite table at **www.amsat.org/?page_id=5033**

If you are considering ONLY the FM voice satellites like SO-50 for your AMSAT Field Day focus, do not, unless you are simply hoping to make one contact for the ARRL rules bonus points. The congestion on FM LEO satellites is always so intense that we must continue to limit their use to one-QSO-per-FM-satellite. This includes the International Space Station. You will be allowed one QSO if the ISS is operating voice.

It was suggested during past field days that a control station be allowed to coordinate contacts on the FM satellites. Nothing in the rules would prohibit this. This is nothing more than a single station working multiple QSO's. If a station were to act as a control station and give QSO's to every other field day station, the control station would still only be allowed to turn in one QSO per FM satellite while the other station would be able to submit one QSO.

The format for the message exchange on the ISS or other digital packet satellite is an unproto packet to the other station (3-way exchange required) with all the same information as normally exchanged for ARRL Field Day,
e.g.:
W6NWG de KK5DO 2A STX
KK5DO de W6NWG QSL 5A SDG
W6NWG de KK5DO QSL

If you have worked the satellites on Field Day in recent years, you may have noticed a lot of good contacts can be made on some of the less-populated, LEO satellites like FO-29, AO-7, AO-73, EO-88 (NAYIF-1) NO-84 or the XW satellites. During Field Day, the transponders come alive like 20 meters on the weekend. The good news is that the transponders on these satellites will support multiple simultaneous contacts. The bad news is that you can't use FM, just low duty-cycle modes like SSB and CW.

THE 2017 AMSAT FIELD DAY RULES

The AMSAT Field Day 2017 event is open to all Amateur Radio operators. Amateurs are to use the exchange as specified in ARRL rules for Field Day. The AMSAT competition is to encourage the use of all amateur satellites, both analog and digital. Note that no points will be credited for any contacts beyond the ONE allowed via each single-channel FM satellite. Operators are encouraged not to make any extra contacts via theses satellites (e.g., SO-50). CW contacts and digital contacts are worth three points as outlined below.

1. Analog Transponders

ARRL rules apply, except:

- Each phone, CW, and digital segment ON EACH SATELLITE TRANSPONDER is considered to be a separate band.

- CW and digital (RTTY, PSK-31, etc.) contacts count THREE points each.

- Stations may only count one completed QSO on any single channel FM satellite. If a satellite has multiple modes, such as V/u and L/s modes, turned on, one contact each is allowed. If the PBBS is on - see Pacsats below, ISS (1 phone and 1 digital), Contacts with the ISS crew will count for one contact if they are active. PCSat (I, II, etc.) (1 digital),

- The use of more than one transmitter at the same time on a single satellite transponder is prohibited.

2. Digital Transponders

We have only APRS digipeaters and 10 m to 70 cm PSK transponders (see Bob Bruninga's article in the March/April 2016 issue of *The AMSAT Journal*).

Satellite digipeater QSO's and APRS short-message contacts are worth three points each but must be complete verified two-way exchanges. The one contact per FM satellite rule does not apply to digital transponders.

The use of terrestrial gateway stations or internet gateways (i.e., EchoLink, IRLP, etc.) to uplink/downlink is not allowed.

Sample Satellite Field Day Greetings File:

Greetings from W5MSQ Field Day Satellite station near Katy, Texas, EL-29, with 20 participants, operating class 2A, in the AMSAT-Houston group with the Houston Amateur Television Society and the Houston QRP club. All the best and 73!

Note that the message stated the call, name of the group, operating class, the location (the grid square would be helpful) and how many operators were in attendance.

3. Operating Class

Stations operating portable and using emergency power (as per ARRL Field Day rules) are in a separate operating class from those at home connected to commercial power. On the report form simply check off Emergency or Commercial for the Power Source and be sure to specify your ARRL operating class (2A, 1C, etc.).

Finally, he Satellite Summary Sheet should be used for submission of the AMSAT Field Day competition and be received by KK5DO (email or postal mail) by 11:59 PM CDT, Monday, July 10, 2017. This is earlier than the due date for the ARRL submissions. The preferred method for submitting your log is via e-mail to kk5do@amsat.org or kk5do@arrl.net.

You may also use the postal service but give plenty of time for your results to arrive by the submission date. Add photographs or other interesting information that can be used in an article for the Journal.

You will receive an email back (within one or two days) from me when I receive your email submission. If you do not receive a confirmation message, then I have not received your submission. Try sending it again or send it to my other email address. If mailing your submission, the address is:

Bruce Paige, KK5DO
Director of Awards and Contests
PO Box 1598
Porter, TX 77365-1598.

Certificates will be awarded for the first-place emergency power/portable station at the AMSAT General Meeting and Space Symposium in the fall of 2017. Certificates will also be awarded to the second and third place portable/emergency operation in addition to the first-place home station running on emergency power. A station submitting high, award-winning scores will be requested to send in dupe sheets for analog contacts and message listings for digital downloads.

You may have multiple rig difficulties, antenna failures, computer glitches, generator disasters, tropical storms, and there may even be satellite problems, but the goal is to test your ability to operate in an emergency situation. Try different gear. Demonstrate satellite operations to hams that don't even know the HAMSATS exist. Test your equipment. Avoid making more than ONE contact via the FM-only voice HAMSATS or the ISS, and enjoy the event!

[This form is designed to allow for easy editing in a Word Processor.]

AMSAT Satellite Summary Sheet - 2017

Satellite and number of Voice QSO's
AO-27 1 (example)

Satellite and number of CW/RTTY/PSK31 etc. QSO's
AO-07 5 (example)

Satellite and Up/Downloads
UO-11 3 (example)

Score Calculation
Total Voice QSO's x 1 =
Total CW/RTTY/PSK31 QSO's x 3 =
Total Up/Downloads x 3 =
Grand Total =

Please provide the following information

Your Field Day Callsign

Your Group Name

ARRL Field Day Classification
ARRL Section
Power Source (Select 1)
Emergency
Commercial

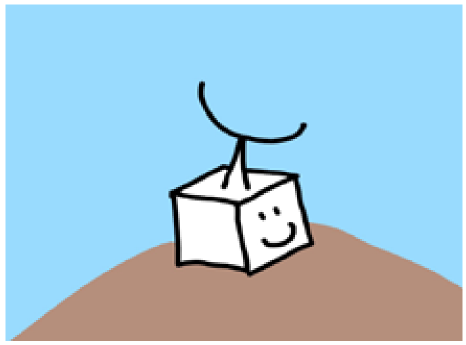
Your name and home call

Home address

Any Comments

Designing a Ground Station for P4 and P5 Satellites

John P. Toscano, WØJT/5
Member, AMSAT ASCENT Skunkworks



This article will describe some of the considerations that are going into the design of ground stations (ground terminals) for the upcoming P4 and P5 satellites.

Phase 4 or P4 refers to a satellite in geosynchronous or geostationary orbit, about 36,000 Km above the surface of the Earth. AMSAT is partnering with several other entities to "rideshare," i.e., to add an Amateur Radio package as a "piggyback" payload supplement to an existing satellite that is planned for Geosynchronous Orbit.

ITAR restrictions limit what this article can say about the details of the satellite itself. Instead, the focus will be on the ground stations that amateur radio operators will use to access the satellite. Satellites in geostationary orbit, such as those used by commercial satellite TV broadcasters, have a period of revolution around the Earth which is the same as the rate at which the Earth itself is rotating below, giving the appearance that the satellite is hovering motionless in the sky. A geosynchronous orbit, on the other hand, is one where the satellite appears to trace a "figure 8" pattern in the sky and returns to the same sky position (azimuth and elevation) at the same time every day. Relatively small amounts of azimuth and elevation motion are needed during a 24-hour period, and typically once a ground antenna is pointed correctly, it does not need to be re-positioned very frequently.

The orbit can be selected to favor either the northern or southern hemisphere. Our rideshare for P4 is to geosynchronous orbit. In addition to the relatively small amount of re-positioning of antennas required, another advantage of GEO orbits is that the satellite "footprint" covers nearly an entire hemisphere of the Earth at once. This means that if the satellite is positioned over the continental United States (as planned), amateur radio operators throughout most of North and South America can all "see" it and work it if they have the required equipment.

Phase 5 or P5 refers to a satellite in Lunar Orbit or beyond. AMSAT is working on a P5 satellite as part of the NASA-sponsored Cube Quest Challenge (CQC). This contest is designed to stimulate innovation in small satellite technology by requiring that competitors work on solving the problems of operating small satellites far above the Earth's surface. At such distances, radio signals become very weak; navigation cannot rely on the Earth's magnetic field or GPS satellites, radiation exposure levels are much higher, etc.

AMSAT is partnering with the Ragnarok Industries Nano-Satellite Company on the development of an entry in this contest. AMSAT is providing the radio technology, while Ragnarok is designing the satellite spaceframe, propulsion, navigation, power generation, etc. Once the CQC is over, AMSAT will take possession of the 6U CubeSat in lunar orbit.

One property that P4 and P5 satellites will share is their much greater distance from the surface of the Earth than current amateur satellites. Therefore, some innovations in radio technology will be needed for optimum success in communicating through them. AMSAT has committed to designing ground station equipment for both P4 and P5 satellites.

We expect that *at least three* different designs for P4/P5 ground terminals will evolve:

1. The first is a complete, ready-to-go system, ready to run "out of the box," with no assembly required, for those hams with more money than time or assembly skills.

2. The second is an inexpensive terminal for budget conscious hams, possibly a complete kit containing all of the needed components ready to be assembled, or at least a detailed BOM (Bill Of Materials) for the ham to use for sourcing his/her own parts.

3. The third is a guide for those folks who wish to "roll their own" ground terminal, mostly from commonly available modules. The documentation that will be provided by Phase 4 Ground will be as full, helpful,

and dynamic as possible, hoping to make the recipe section as challenging as following something from the Good Housekeeping Cookbook — in other words, not very.

The specifics of design implementation continue to evolve. However, at this point, some attributes have been determined with pretty good certainty after considerable deliberation. For example:

1. The uplink from the ground stations to the satellites will be in the amateur satellite sub-band of the C-band, namely 5650-5670 MHz.

2. The downlink from the satellites to ground stations will be in the amateur satellite sub-band of the X-band, namely 10450-10500 MHz.

3. The ground station will need one or two parabolic dish antennas. In a typical home station or homebrew station, using two dishes allows the 5 GHz uplink antenna to be easily positioned several feet away from the 10 GHz downlink antenna, which provides considerable protection of the downlink from desense by the uplink.

4. For emergency communications applications, or for many portable setups in general, a single dish with a dual-band feed would be preferred, since there is less work needed to erect the station, only a single dish to point, etc. Current estimates are that a 1-meter diameter dish should be sufficient for P4, but a 1.8-meter diameter (or larger) dish will more likely be needed for P5. AMSAT is attempting to design a dual-band cross-polarized feed horn to illuminate a parabolic dish, keeping as much isolation of the transmitter (C-band) from the receiver (X-band) as possible. The plan includes a design goal of 100 dB or more of isolation. If this does not succeed, an alternative plan being considered is a combination dish/patch antenna system.

5. Some operational situations may require direct (simplex) communication between one ground terminal and another. This option is being planned for selected ground terminals, which would have a full transceiver on X-band instead of only a receiver. Such terrestrial communication would likely occur in the 10440-10450 MHz sub-band which is designated for terrestrial broadband digital communication. These choices would comply with IARU regulations on the Amateur Satellite Service and both FCC regulations and ARRL band plans for the Amateur Radio Service.

6. DVB-S2x modulation and demodulation of RF signals will be used for communications between a ground terminal and the P4 or P5 satellite. DVB-S2x is a relatively recent industry standard that has been very well-received in the satellite TV industry and seems to be a good fit for our digital data aspirations.

7. DVB-S2x VLSNR (Very Low Signal-to-Noise Ratio) modulation may also be needed, especially for P5. This satellite will be much further away from the surface of the Earth, causing greater path loss between the satellite and the ground station. At the same time, since P5 will be squeezed into a 6U CubeSat (approximately the size of two reams of paper), its antennas will be smaller (have less gain), and its solar panels will be smaller (produce less DC power). Thus, its X-band power amplifier will have a lower power output (weaker downlink signal).

8. While the DVB-S2x VLSNR standard appears to be a good one, it has yet to gain much traction in the satellite TV industry. This is an area where AMSAT is on the "bleeding edge" of implementing the technology, rather than depending on a plethora of COTS (Commercial, Off-The-Shelf) solutions from which to choose.

9. DVB-T2 modulation will be used for those ground terminals having the optional capability of terrestrial (non-satellite) simplex communication. DVB-T2 is optimized for radio signals pointed at terrestrial stations (and subjected, for example, to multipath interference) instead of being pointed into the sky (where multipath interference should be non-existent).

10. Since we intend to pass a lot of different types of digital data, rather than only video signals, we will use a standard known as GSE or Generic Stream Encapsulation as a wrapper around the data packets. GSE has much less overhead than using the MPEG wrapper commonly used by satellite TV video streams, without precluding the

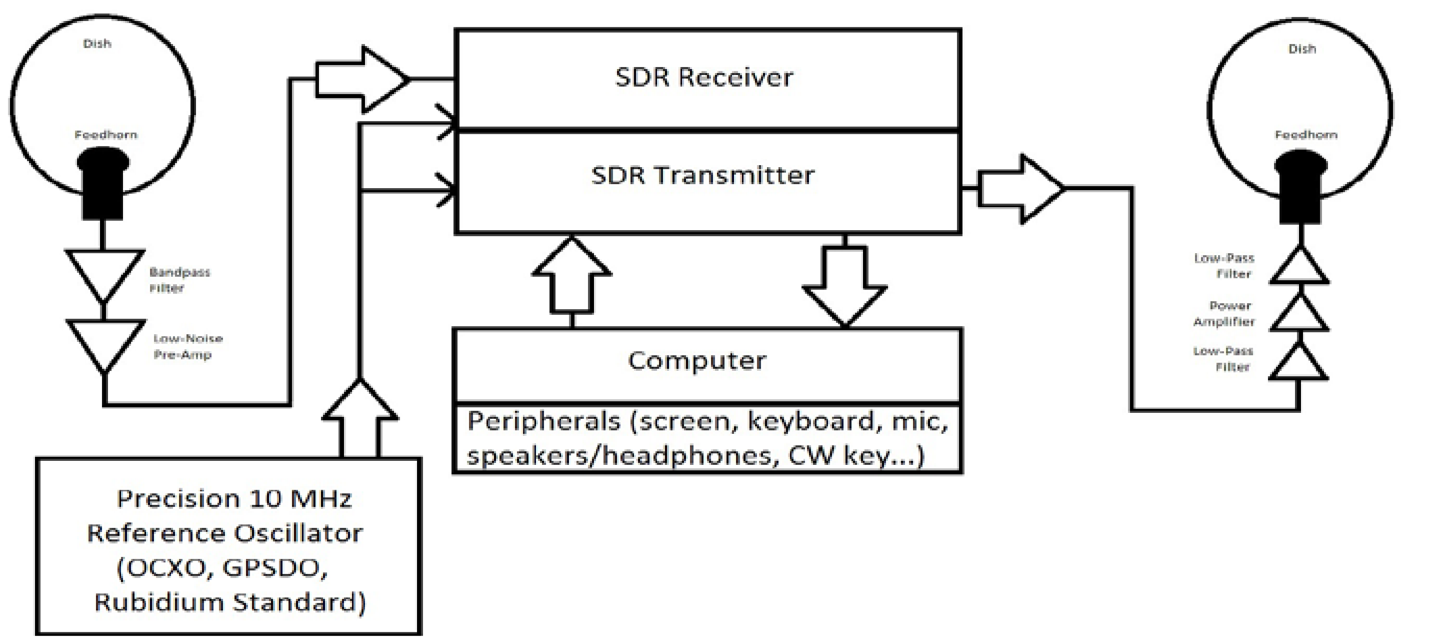


Figure 1 — Block diagram of typical entry-level AMSAT Ground Terminal for the P4 and P5 operations.

transmission of television signals at all.

11. AMSAT plans to support only a digital transponder on these satellites with its ground terminal design. P5 possibly could offer a C/X analog transponder on a part-time, scheduled basis, using some of the circuitry planned as a failsafe backup system. However, no plans exist to incorporate this capability in an AMSAT ground terminal, so such operation would remain in the realm of well-equipped microwave EME station operators who design and build their own ground station.

12. Both P4 and P5 will be launched with a SDR (Software-Defined Radio) transponder. This will enable the RF channel specifications to be re-defined even after the satellites are launched. Naturally, that capability would be meaningless unless the ground terminals were also capable of re-definition to match. So the AMSAT ground stations will also use SDR technology, which will allow the ham to "re-create the radio design" with a simple firmware download and installation.

Figure 1 is a block diagram showing the design of a typical, entry-level AMSAT ground station for the P4 and P5 satellites. The ovals at the top left and top right of the drawing represent offset feed parabolic dishes, possibly discarded/re-purposed satellite TV dishes. The receiving dish feedhorn sends its signal through a bandpass filter to eliminate as much out-of-band noise as possible, particularly the second harmonic of the transmitter signal, and then to a low-noise pre-amplifier, before being routed to the SDR receiver. It may be possible to substitute an inexpensive PLL-based COTS Satellite TV LNB for the feedhorn, filters, and preamp assembly for stations that will have X-band receive-only operation, as discussed further below. It should be pointed out that no existing SDR's can directly receive X-band signals, so if the LNB solution is not being used, then a full transverter or at least a receive-converter will be needed to translate the X-band signals to a lower frequency that the SDR can handle.

The SDR transmitter is shown sending its output signal through filtering and then to power amplification hardware. All existing SDRs produce too little RF power (on the order of only about 10 milliwatts) to make a useful satellite transmitter by themselves, and many of them are incapable of generating frequencies as high as C–band. Both problems can be addressed by the use of a transverter on the output side, or at least a transmit converter. However, if the chosen SDR is one that can reach C-band directly, then filtration and power amplification between the SDR and the dish feedhorn can be sufficient.

Figure 1 shows the inclusion of a precision 10 MHz reference oscillator as part of the design. The reference oscillator is essential for ground stations that wish to participate in the CQC because extremely precise frequency control is needed to perform ranging and velocity calculations necessary for navigation of the 6U CubeSat into lunar orbit. It might be argued that a precision frequency standard is "only recommended" for working P4, but locking your SDR's frequencies to a highly precise standard will make it easier to tune into the satellite. Microwave operators have known for years that locking their radio systems to a precise frequency standard makes it far easier to tune to the actual frequency that you are trying to tune, in order to work another station that expects you at a particular frequency. An OCXO (Oven-Controlled Crystal Oscillator) can often be found at a reasonable price on the surplus market. A GPSDO (Global Positioning Satellite Disciplined Oscillator) is typically a TCXO (Temperature-Controlled Crystal Oscillator) or OCXO that provides higher precision by repeatedly adjusting its crystal oscillator to match the extremely precise Cesium standards on the constellation of GPS satellites. A rubidium standard can also be acquired on the surplus market for a bit more money and is more precise than an OCXO, but less precise than a Cesium standard. So it too might be GPS-disciplined. In any case, it is likely to need replacement sooner than a GPSDO if used heavily because of aging of the internal rubidium standard.

Of course, Figure 1 also points out that a computer of some sort is going to be required to operate the SDR by running the specific software that defines how the radio works. We'll have a little more to say about that later in this article.

This brings us to a discussion of the choice of SDR to use for the ground terminal. Your first idea might be to use the same SDR that is flying on the P4 and P5 satellites, to ensure the maximum compatibility of hardware and software. So, what is the SDR flying on P4 and P5? It is the AstroSDR by Rincon Research Corporation, shown in Figure 2.

The problem with using the AstroSDR for the ground station is cost. How expensive is it? As the expression goes, "If you have to ask how much it costs, you can't afford it." Remember that this SDR is designed to be tolerant of the high radiation levels and extreme temperature swings that will be encountered in high Earth orbit or in lunar orbit, which is overkill for a ground station. We can use something much more affordable. Nevertheless, not just any SDR will do the job.

Among the needed capabilities for the ground stations which are not present in all SDRs is:

1. The ability to operate at C-Band and X-Band. If the SDR cannot reach these 5 and 10 GHz frequencies directly, then an additional up-converter and/or down-converter will be needed.

2. Full-duplex (simultaneous transmit and receive) operation also is needed, where the satellite's downlink is received concurrently with the uplink transmission by the ground station. If the SDR cannot operate in full-duplex mode, then a separate SDR might be used for each of the transmit and receive functions.

3. One early concept for the ground station SDR was to use a HackRF board as the 5 GHz transmitter SDR (this board is half-

Figure 2 — The SDR flying on P4 and P5.

Parameter	HackRF One HackRF Blue	Ettus B200	Ettus B210	BladeRF x40 or x115	RTL-SDR	LimeSDR
Frequency Range	1 MHz – 6 GHz	70 MHz – 6 GHz	70 MHz – 6 GHz	300 MHz – 3.8 GHz	22 MHz – 2.2 GHz	100 KHz – 3.8 GHz
RF Bandwidth	20 MHz	61.44 MHz	61.44 MHz	40 MHz	3.2 MHz	61.44 MHz
Sample Depth	8 bits	12 bits	12 bits	12 bits	8 bits	12 bits
Transmitters	1	1	2	1	0	2
Receivers	1	1	2	1	1	2
Duplex	Half	Full	Full	Full	N/A	Full
Interface	USB 2.0	USB 3.0	USB 3.0	USB 3.0	USB 2.0	USB 3.0
Programmable Logic	64 cell CPLD	75K FPGA	100K FPGA	40K or 115K FPGA	N/A	40K FPGA
Chipset	MAX5864 MAX2837 RFFC5072	AD9364	AD9361	LMS6002M	RTL2832U	LMS7002M
Open Source?	Full	Schematic, Firmware	Schematic, Firmware	Schematic, Firmware	No	Full
Transmit Power	-10 dBm to +15 dBm	10 dBm+	10 dBm+››	6 dBm	N/A	0-10 dBm
Price	$299.00	$686.00	$1,119.00	$420 or $650	~$10	$299.00

Table 1 — Adapted from the LimeSDR CrowdSource documents, summarizing salient features of 8 different SDRs that have received scrutiny by the ASCENT team.

duplex only, but can operate directly up to 6 GHz), and an inexpensive RTL-SDR dongle plus a COTS satellite TV LNB for the receiver. The LNB would drop the frequency of the satellite downlink from around 10.5 GHz to around 600 or 700 MHz, well within the range covered by the RTL-SDR dongle. Unfortunately, the bandwidth of the RTL-SDR is far too narrow to work in our ground station.

4. Our early testing suggests that a high-speed I/O channel between the SDR's RF front end and the computer performing the DSP operations to encode and decode signals is needed. USB2 seems to be too slow. USB3 or Gigabit Ethernet might be needed. An FPGA (Field Programmable Gate Array) that is tightly coupled to the digital data stream could also work, but FPGAs are usually expensive and are more difficult to program than general-purpose microcomputers. This I/O limitation probably rules out the HackRF also.

As can be seen from Table 1, the SDR that comes closest to meeting all of the needs of a ground station is the Ettus B210. It can transmit in the 5.7 GHz C-band, it is full duplex, it uses USB 3.0 for its interface to the computer, and has a large FPGA that may be programmed to perform the difficult, time-consuming computations needed to encode and decode DVB signals. The main problem with the Ettus B210 is its price of $1,119. The LimeSDR is almost as capable, for about ¼ the price ($299 instead of $1,119). It cannot transmit in the 5.7 GHz C-band without assistance, which is its main shortcoming for the P4/P5 ground terminal. But Lime Micro has announced its intention to produce an expansion board that will boost its top frequency capability to 12 GHz, making it the only SDR of this bunch that could receive and transmit on both the 5.7 GHz C-band and the 10.5 GHz X-band. This is very exciting! Of course, it does not exist today, so we can't put all our eggs in that basket (yet).

No existing SDR can do the whole job without some assistance. SDRs are designed to receive and transmit over a very wide frequency range, but their receive sensitivity is low, as is their ability to receive weak signals in the presence of other strong signals and their maximum transmit power. Spurs can be a significant problem. Filtration and signal amplification will be needed. On the C-band uplink, low-pass and/or bandpass filters plus a power amplifier will be required for a clean, strong signal. On the X-band downlink, high-pass and/or bandpass filtration plus a low-noise pre-amplifier will be necessary to clearly receive weak signals. The uplink and downlink filtration not only is needed to prevent out-of-band transmission and to exclude environmental out-of-band signals that could overwhelm the receiver but also to maximize the isolation of the 10.45 GHz receiver from the 5.6 GHz transmitter. This is especially an issue because of the nearly 2:1 ratio of the two frequencies. If the ground station needs only to receive X-band signals (i.e., it will not be transmitting X-band signals for simplex communication with another ground station), it may be possible to use an inexpensive COTS satellite TV LNB in place of discrete filters and pre-amplification. On the other hand, for ground stations with the optional terrestrial X-band simplex operation mode, the inexpensive LNB can't be used. In addition to filtration and a low-noise preamp, it will be necessary to add a power amplifier, additional output filtration, T/R (Transmit/Receive) switching, and in most or all cases, signal downconversion to a lower IF (Intermediate Frequency). A full transverter would perform all of these functions, particularly if the SDR is unable to reach X-band frequencies on its own, but it is not inexpensive.

Computing hardware will be mandatory to perform the software-defined RF signal modulation and de-modulation, the digital data encapsulation and extraction, and more. Nowadays, most ham shacks have a laptop or desktop computer, and this may be adequate for the "budget" home fixed station. For portable stations in general and EMCOM stations in particular, a self-contained microcontroller or microcomputer will be highly desirable, to make the ground station self-contained, easy to deploy, and stingy with its battery power drain. At this point, the minimum computational ability of the external or embedded computer has not been determined. Will it need to be an Intel quad-Core i7 CPU, or will an ARM Cortex processor be sufficient? Perhaps an ARM processor with additional GPU computational cores, like the Nvidia Jetson TK1, which combines four powerful Cortex-A15 cores, one low-power core, and 192 CUDA GPU cores for parallel processing, will work. Testing continues.

To attract many hams to operate on the P4 and/or P5 microwave satellites, the ground terminal needs to be affordable. Some things that we are doing will help keep the price down:

1. We are actively investigating the LimeSDR for its fine capabilities in its present form, and are especially hopeful that the LMS8001 expansion becomes available soon at an affordable price so that it can operate all the way up to 12 GHz without any other additional up-converter or down-converter.

2. We also are evaluating the possibility of using a reasonably inexpensive FPGA (Field Programmable Gate Array) for the time-sensitive, computation-intensive functions that demand a high I/O transfer speed. The more of the digital signal processing that an FPGA can do, the less powerful (less expensive) the computer that is needed.

3. We are evaluating the possibility of using ASIC's (Application-Specific Integrated Circuits) to alleviate the computation burden and I/O transfer burden. Some ASICs exist for the DVB-S2x demodulation standard since they are used in millions of satellite TV set-top boxes. Some of them claim to implement the VLSNR portions of the DVB-S2x standard, but to date, we have not found an ASIC that fully supports VLSNR properly, so we are still searching. Of course, satellite TV is currently one-way (i.e., receive-only) for the consumer, so ASICs to handle the DVB-S2x modulation standard for the ground station uplink are, not surprisingly, non-existent at this time. However, this is a rapidly-changing field, and we are keeping our eyes on the marketplace for new chips that may make the ground terminal simpler and cheaper. We are even investigating the possibility of using a COTS satellite TV tuner, which has DVB-S2x built in, to provide the demodulation of the P4/P5 downlinks, since some such tuners operate at frequencies immediately adjacent to the Amateur Satellite X-Band.

4. If you have been active on the 5760 MHz terrestrial weak-signal band, you know that linear power amplifiers for this band are expensive and low-powered. Ideally, we'd like our ground stations to be able to transmit with at least 5 to 10 watts of power to get a clean signal into the satellites. So the search is on for ways to generate more RF power on the 5 GHz C-Band. With the advent of Gallium Nitride technology, some power amplifier transistors for the 5 GHz band have finally become available, but the prices are quite high. TriQuint offers a 1 watt part for over $40 each, making it quite expensive to reach the desired power level. It also offers a 40 watt part, but it costs over $800 for the chip alone, not including all the support circuitry it would require. We have found an inexpensive C-band power amplifier board (not just the chip) that has been measured to produce 3.5 watts before the onset of compression, available for only $30 - $40. Needless to say, this caught our interest. The board uses two Skyworks SE5004L 2.5 watt chips in parallel. It would be possible to plumb two of these boards in parallel, but an even better solution would be to design our own circuit board that parallels 4 of the Skyworks chips with all splitting and combining circuitry on board, along with appropriate filtration to remove spurs and the first harmonic of the signal being transmitted. Once again, this is a work in progress.

5. Already mentioned is the possibility of dealing with the very high downlink frequencies using SDRs that are unable to operate at X-band frequencies on their own, using an inexpensive (~$30) COTS satellite television LNB (Low Noise Block down-converter). New PLL (Phase-Locked Loop) LNB models have sufficient stability for this application. Even though they are designed for the satellite TV frequencies above the amateur satellite sub-band, testing has shown them to be satisfactory all the way down to the bottom of the 10 GHz amateur radio sub-band, which is well below the bottom of the amateur satellite sub-band.

6. AMSAT is working with the GNU Radio community to accelerate the development and refinement of software for DVB-S2x encoding and decoding. Before AMSAT's selection of a modulation format for P4 and P5, GNU Radio software blocks already existed for DVB-S and DVB-T which were provided by Ron Economos,

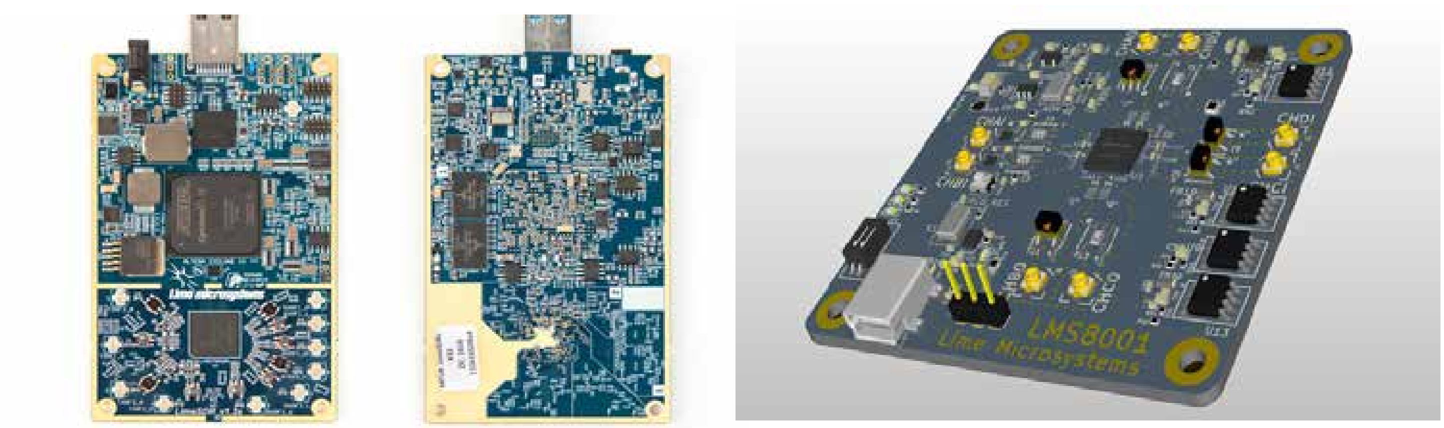


Figure 3 — The LimeSDR and LMS8001 expansion.

W6RZ. At the request of AMSAT, Ron has also developed GNU Radio blocks for DBV-S2x. Seeing renewed activity in the GNU Radio community with respect to DVB-S2x is very encouraging, particularly because some portions of the standard in which we have a lot of interest (such as the VLSNR extensions) have not been widely implemented yet. That means AMSAT may end up being on the leading edge (some would say, "the bleeding edge") of this technology's more widespread development and use.

Much of the complexity of the P4/P5 ground station results from the software that still needs to be written:

1. Although there are some free, open-source software programs like PowerSDR, SDR#, etc., for performing the DSP functions that an SDR needs for modulation and demodulation of CW, SSB, and FM signals, precious little SDR software support exists for the DVB-S2x modulation schemes. Fortunately, AMSAT's activity in this regard has stimulated a re-awakening of interest in this area, so the situation there is rapidly changing. GNU Radio can do it today, but a dedicated program would be desirable.

2. The P4 satellite will be visible to nearly half of the planet at any time. Even though the transponder is expected to support more simultaneous QSO's than any prior amateur satellite, a great deal of interest exists in preventing abuse of the transponder bandwidth by implementing a system of user identification, authentication, and confirmation of authorization. This will be especially important if the satellite is used during a crisis such as a severe weather disaster that brings down conventional communication channels. During such an emergency, we would want to reserve some or all of the transponder bandwidth for emergency traffic by authorized users, rather than to allow idle chatter or even signals originating with unlicensed persons. We currently envision using the ARRL's LOTW (Logbook of the World) database of subscribed users as a tool that can help us identify who is trying to use the (large, but still not unlimited) resources of the satellite transponder and decide whether or not to allow them to have access.

3. Work needs to be done on the channelization and sub-channelization process that will allow us to support an unprecedented number of simultaneous users.

4. Thinking outside of the box a bit, if the authentication of users is going to be assisted by accessing LOTW, it makes sense that QSOs can be automatically logged because the system will "know" the callsigns of each of the persons involved in a QSO. Much of this software development is actually done already.

5. Although tracking P4 and P5 will be far easier than tracking the fast-moving LEO satellites, it would be very convenient if automatic satellite tracking were built into the P4/P5 ground stations. Automatic tracking, or at least performing the computations if not re-pointing the antenna(s), is a pre-requisite for automatic Doppler shift frequency correction. Since the X-band microwave downlink frequencies are 72 times as high as the frequencies in the 2 meter VHF band on older satellites, the Doppler shift is 72 times as large for any given range rate. Fortunately, these satellites will have very slow range rates, appearing to hover nearly motionless in the sky, which offsets the high Doppler shift that otherwise would be experienced. Nevertheless, for optimal digital signal integrity, keeping each user within the assigned channel or sub-channel will be much easier with automatic Doppler correction. Orbital prediction of P4 will be simple, using existing tools. Tracking P5 accurately will be a bit more challenging because it will be using on-board thrusters to change its trajectory en route to lunar orbit, and because existing mathematical models of satellites in orbit around the Earth don't work for satellites in orbit around a satellite of the Earth (the Moon). However, simply pointing at the Moon (an easy computation) may be good enough, as was demonstrated by the Parkes Observatory Radiotelescope which had to quickly re-acquire a TV signal from Apollo 11 after a brief power outage reset all of their tracking computers.

The bottom line is,
If you are an RF Engineer or a Computer Software Engineer...
Volunteers are Still Wanted!

For more information:
github.com/phase4ground
phase4ground.slack.com
www.youtube.com/playlist?list=PLavdGnjBLuiX97DAKk32NJ1bCF1a0cv01

Building a Microwave Transceiver: The Path to My Own Five-and-Dime Ground Station

Jonathan Brandenburg, KF5IDY

When the partnership between AMSAT and the Hume Center for National Security and Technology[1] led to the announcement of an amateur radio geostationary satellite, I was excited. Then, when the AMSAT Phase 4 ground terminal project[2] launched in April 2015, I knew I wanted to get involved. I wanted to build my own ground station capable of transmitting at 5 GHz and receiving at 10 GHz, the five-and-dime concept.

First Steps

Given my utter lack of experience in the microwave bands, I talked to my mentors and friends in amateur radio. It seemed using a transverter to bring the frequencies into the range of my existing transceivers was the way to go. I'm sure it will not surprise the reader to hear I ended up looking at Down East Microwave's[3] product catalog. Upon contacting Down East Microwave to order the 5760-144[4] and the 10368-144[5] kits, the kind folks gently suggested I order the assembled product. Although I'm looking forward to building my own microwave components in the future, it seemed a small price to pay if the assembled product eliminated a lot of frustration and pain from my journey.

More Components

With the central component of my station ordered, it was now time to identify and acquire the other pieces of my station. I knew I needed a 10 MHz clock source. I went the GPS disciplined oscillator route, ordering a "Trimble Inside GPS Receiver GPSDO 10MHz 1PPS GPS Disciplined Clock with GPS Ant" from eBay[6]. I was pleased with that device as it seemed to lock relatively quickly and I could see the desired signal clearly on my oscilloscope.

I soon realized I needed a sequencer to switch between the transmit and receive transverter circuits and ensure I wasn't accidentally transmitting into the receive side of a transverter. A quick visit to Down East Microwave's website led to the acquisition of the "4 Step, 8 I/O, TR sequencer" kit[7]. The kit was very easy, and fun, to assemble but I admit to being a little intimidated with all the flexibility in configuring the connectors to be high or low. But a little time experimenting quickly yielded a "sequencer matrix" ensuring all my station components were in receive mode by default and properly switched to transmit mode when activating my push-to-talk switch.

I still needed an antenna and elected to obtain a 60 cm dish with a dual 5.7 GHz and 10 GHz dish feed from Directive Systems & Engineering[8]. Having decided to use a single antenna and with the transverters having separate receive inputs and transmit outputs, I'd need a relay to switch between them. This was probably my single biggest challenge as I was put off a bit by the expense of microwave relay switch. I have now found sellers at local hamfests with used relays, but I instead ordered a new relay, the BM14061, from Bracke Manufacturing[9].

That relay led to another purchase. The relay was designed to operate at 28 V dc, and I intended to operate my station on a single power supply at 13.8 V. Another visit to Down East Microwave addressed that issue with the "28V Relay Driver" kit[10], a cool device that provides enough voltage to initially engage the relay and then hold the relay active at 13.8 V.

Putting It Together

With all the parts acquired, I only needed to build some cables to connect everything together and test it. After all the previous work and research, this assembly went very smoothly! I did make one change late in the assembly process. Folks with the North Texas Microwave Society suggested I would benefit from a waterfall display of the spectrum. Given the narrow beamwidth of the dish and the possibility of frequency drift, they advised that a visual indication of any signals would be extremely helpful. So, I reconfigured my newly assembled station to use the Elecraft KX3 and PX3[11] rather than the initially planned Yaesu FT-817ND.

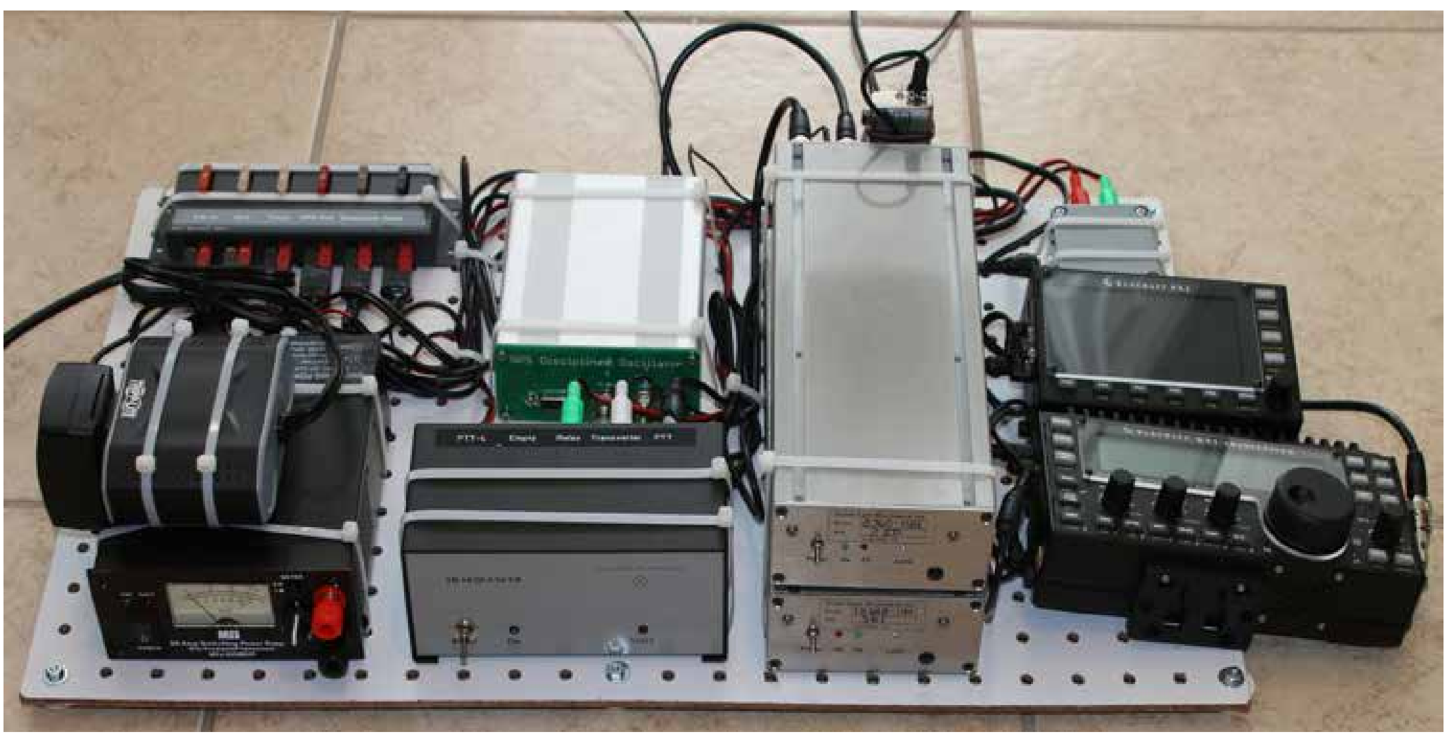
The final station, mounted to pegboard to keep it somewhat organized and neat, has worked extremely well in initial testing (see photo below). I have an incredible sense of accomplishment, and my excitement for working the microwave bands keeps growing!

What's Next

The current version of the station is only using the 5 GHz transverter for both transmit and receive. I certainly want to add the 10 GHz transverter into the station. I expect that addition will pose little challenge. But, I also want to make contacts on the microwave bands. The local community boasts several hams that are active on the microwave bands. I know I'll learn a lot about the behavior of my station as I work those stations. This experience is where I'm confident I'll learn more about the techniques to successfully make contacts over the microwave band amateur satellites as those incredible satellites are launched.

Notes:

1. www.hume.vt.edu/geo/
2. www.amsat.org/?p=4945
3. www.downeastmicrowave.com/
4. www.downeastmicrowave.com/product-p/5760-144.htm
5. www.downeastmicrowave.com/product-p/10368-144.htm
6. www.ebay.com/itm/GPSDO-Trimble-Inside-GPS-Receiver-10MHz-1PPS-GPS-Disciplined-Clock-with-GPS-Ant-/172148560746
7. www.downeastmicrowave.com/product-p/trsck.htm
8. directivesystems.com/2304-mhz-above/6-cm-3-cm-5-7-ghz-and-10-ghz/dsedbfeed/
9. storefront.brackemfg.com/storefrontCommerce/itemDetail.do?itm_id=12712
10. www.downeastmicrowave.com/product-p/rvd-1.htm
11. www.elecraft.com/



QSL Delta Mike Three Four

Faith Hannah Lea, PJ6/AE4FH

The Dave Kalter Memorial Youth DX Adventure, otherwise known as the YDXA, takes youth, each with a guardian, to other countries to operate ham radio. I was chosen to go with them to the island of Saba in the Dutch Caribbean as part of the PJ6Y team in August 2016. The team consisted of our host Jeff, NM1Y, the two leaders Don, N6JRL, and Jim AB8YK. The youth and their guardians included Ruth, KM4LAO, and her mom Sharon KM4TVU, Morgan, KD8ZLK, and his friend Joe, KD8YPY, and me, Faith Hannah, AE4FH, and my dad, James, WX4TV.

Daddy and I went to Sint Maarten a day early so we could get the first flight of the day to Saba the next morning. It got boring sitting on the beach, so we decided to work the SO-50 satellite. We worked my siblings and Fernando (NP4JV) who lives near Tucson, AZ. Soon after the pass, Fernando told us that we almost broke the SO-50 distance record. We missed it by about 54 miles. We decided to try to break the record while we were on Saba.

When we arrived on Saba the next morning, we were picked up by Jeff. He now owns the same house we used to live in when we lived on Saba! We made a few satellite contacts with our family and a few other hams as PJ6/AE4FH and PJ6/WX4TV while we waited for the rest of the team to arrive. Later in the day, the rest of the team arrived, and we set up the HF stations and antennas.

Unfortunately for us, Fernando, NP4JV, was not able to get far enough away to break the record without going into Native American burial grounds. Also, a station on Guadeloupe wanted to break the record with him. Luckily for us on Saba, they were not able to make contact. But we had a dilemma: how could we break the record if we couldn't do it with Fernando?

Fernando offered a possible solution. He asked Patrick, WD9EWK, if he would get out into the desert far enough to break the record, and Patrick agreed to give it a try. We had two opportunities: the first on the afternoon of August 6th, and then again early in the morning on August 7th. We tried to work him on the 6th, but we couldn't hear anyone else on the satellite even though we thought we heard our downlink. We quickly changed the coax to the receiver to see if that would help, but when we changed it out we only heard part of his reply before he lost the satellite. We thought there might be a problem with our setup, but we were not sure what it could be.

The next morning, we got up at 03:00 AST to try to fix whatever problems we had on the previous attempt. We found that we heard the third harmonic of our uplink instead of our downlink. We discovered this by pointing the antenna away from the satellite and transmitting. When we did this, we heard my transmission! We think we heard our third harmonic because we were running 50 watts since the satellite would be just below the horizon in our attempts to break the record.

As we waited for the next pass, we were treated to a star and meteor show that I will never forget. When it was time to make the contact, I started calling Patrick when the satellite was 5 degrees below the horizon, and on the recording that NP4JV made, you can hear him calling me back. I would say, "WD9EWK, this is PJ6Y, fox kilo eighty-seven," and he would reply "we did it Faith Hannah, QSL delta mike three four!" I didn't hear him at first, but as I kept calling him, I soon could hear in his voice that he was nervous that we wouldn't make the contact.

At 06:07 AST, with the satellite below the horizon, I finally heard his reply. He was in DM34we, and we were in FK87ip. We broke the record!

The entire PJ6Y team worked to break the record by practicing satellite passes, going to different parts of the island to scout out the best place to attempt to break the record, and staying behind to work HF (we made over 4,000 HF QSO's). On the day of the record break, Sharon videotaped the contact, Jeff made sure the radio was working correctly, Patrick drove out into the desert to get far enough away, Daddy held the antenna, and I was at the mic. All I had to do was say, "QSL delta mike three four!"

We have an Arrow antenna, but we left it at home so that my family could try to work us while we were in the Caribbean. A friend let us borrow his Arrow antenna to take to Saba (if you are reading this AE4TG, thank you). We used a Yaesu FT-60R for the receiver and a Yaesu FT-857D for the transmitter. We chose to use the FT-857D instead of another handheld because we wanted to make sure that we had enough power to get into the satellite when it was below the horizon. We powered the FT-857D with a battery from Jeff's generator.

The entire PJ6Y team and WD9EWK ended up with a good story to tell, but most importantly, we all now hold a world record!

Faith Hannah Lea, AE4FH, Ruth Willet, KM4LAO, and Morgan Croucher, KD8ZLK, operating an FO-29 pass from the rooftop in Saba. [James Lea, WX4TV, photo.]

Sharon Willet, KM4TVU, Faith Hannah Lea, AE4FH, and Jeff Jolie, NM1Y, minutes after breaking the record with WD9EWK. [James Lea, WX4TV, photo.]

DIY Arduino Based Satellite Tracking Pointer

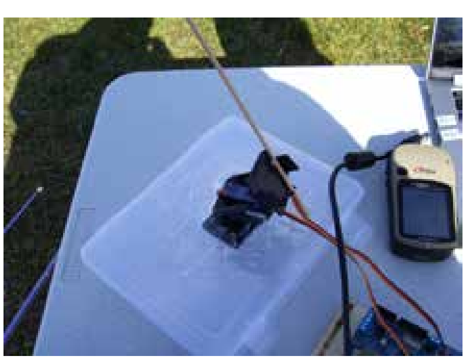
John Stockman, KC2THY

If you use a handheld satellite antenna and are having trouble judging the position of the satellite, or its progress across the sky; or, if a fully motorized azimuth/elevation rotator and control box is not in the budget, you may find this simple Arduino based pointing device helpful.

This device will point a wooden dowel at the point in the sky where the satellite is located and will track it up to 180 degrees on entirely Easterly or entirely Westerly passes (low to medium angle passes). All one has to do is keep the handheld antenna parallel to the dowel as the dowel follows the path of the satellite. Field testing shows that it is quite accurate. Another characteristic is that one can put the antenna down to attend to something else for a minute or two and then one can simply re-orient the antenna parallel to the dowel and regain the bird's signal.

The parts list is short: One needs an Arduino Uno or equivalent, a USB cable, the pan/tilt device available from Adafruit.com and a narrow wooden dowel about 18 inches long. The pan/tilt device comes fully assembled and contains two micro server motors and their connecting cables. I also use an Adafruit motor shield because it has two convenient three-pin servo connectors. However, it is not difficult to connect the signal lines directly to digital pin 9 and 10 on the Uno. The servo power lines can be connected directly to the Uno's ground and power ports, or you can supply power from a separate source.

Developing this device was largely a software challenge. Investigation with user guides and internet searches revealed that AMSAT's SatPC32 satellite software output a serial ASCII character stream in a fixed format which provided azimuth and elevation position information. It outputs this stream at regular intervals. The stream is transmitted to the Arduino via the USB cable at 9600 baud. Firmware that I developed captured this stream and loaded it into a character array variable in the Arduino's processor memory.



The real challenge then became, how to parse out the azimuth and elevation characters and convert them to integer values which could be passed as variables to the Arduino language's servo library function. When using the Arduino servo library function, all one needs to do is pass an integer angle number to the function, and a servo.write instruction will then move the servo motor to that degree angle. There are several ways to convert characters to integer values. The C programming language, on which the Arduino language is based, has a "canned" function called "atoi()" which will do the conversion. I was having great difficulty getting this to work properly. Ultimately I went to the Arduino programming forum and asked for help. One of the members replied with five lines of code which solved the problem completely. That member suggested the use of a pointer to the character array. Pointers are really just variables which contain the memory address of data being stored in the processor. Once I started using the pointer, I stopped receiving the "invalid type conversion" compiler error messages which had plagued my efforts.

The pointer points to the first numerical character in the array, and the atoi function starts reading the numerical characters from that point until it encounters a non-numerical character, in this case, a decimal point. The atoi function then converts the characters to an integer value and assigns them to a variable called AZ or EL. The software then passes those variables to the servo library function, which moves the servo to the angle specified.

Operating the pointer

First a word on safety: WEAR EYE PROTECTION AT ALL TIMES, when testing or operating the pointer. The servo motors swing the dowel around very quickly, and it can hit you in the face if you are too close to it. Connect the USB cable to between the Arduino and the PC running SatPC32. In Widows device manager note the COM port number for the Arduino and enter that number on SatPC32's communication program's set up box. Also, set the baud rate at 9600 in the setup dialog box. Connect the signal lines from the servos to the Arduino digital pins specified in the microcontroller software (9 and 10) and provide power for the servo motors or use the Arduino board's power pins. Do not power the servos off the USB cable, they draw too much power when operating and can overload the cable. The pan will be 0-180 degrees, and because the dowel is pointed off the back side of the pan/tilt device you will need to orient the device with 180 degrees pointed true North for an entirely Easterly pass. For a Westerly pass rotate the pan/tilt device so that 180 degrees is pointed true South. The microcontroller software will sense Easterly and Westerly azimuth numbers and compensate the pointing accordingly, as long as the pan/tilt is oriented properly

Secure the dowel securely to the pan/tilt device. I found that two pieces of clear packing tape did the job. Secure the pan tilt to a weighted base. The servos generate a lot of torque, and the base will turn under the pan tilt device if it is not weighted. I used a plastic box to which I can add ballast.

Then just start rotor control with the SABERTrack protocol and wait for the pass to begin. Turn off the rotator control on SatPC32 before the azimuth numbers exceed 360 or 180 respectively. This will prevent the dowel from swinging around 180 degrees towards the end of the pass.

Limitations

The azimuth servo can only turn slightly less than 180 degrees so it may not catch the entire pass. It will catch most of an entirely Easterly or Westerly pass. The servo motors can drain a small 9V battery very quickly so have replacements ready

The main portions of the microcontroller Arduino software are listed in exhibit A and there are photos of the field station attached as well. Feel free to modify and improve the software. What I have provided is just the basics to get started. I am sure that software could be modified to enable turn points and other more traditional features of rotator control software. You can command the pointer to a given position using SatPC32 command dialog box.

Advantages

This is a very cost effective solution compared to full-fledged satellite rotators and their control hardware and may be suitable for the occasional user or experimenter.

For a copy of the Arduino software in either RTF or Arduino format, email me at **JCS1@msn.com**.

On the Grids: Churchill MB EO28

Melvin C. Vye, W8MV

Polar bears are amazing animals. They have evolved in one of the harshest climates on earth. Some go eight months without eating. The best place to see polar bears in the wild is Churchill MB.

In the spring of 2016, I was at a weekly luncheon of hams and other technical types when I casually mentioned that I would like to go to Churchill and see the bears. Immediately Tom, KP2E, and one other person jumped on the idea. Along the way, we picked up a fourth, and we began planning the trip.

No roads lead to Churchill, so access is only by air or train. In mid-November, we flew to Winnipeg and then took Canadian VIA Rail to Churchill. Of course in the luggage was an HT and Arrow antenna.

Polar bears eat seals. The seals must be captured on ice. So in October and November, the bears wait in the vicinity of Churchill for the Hudson Bay to freeze. Since bears occasionally come into town, we were always on the lookout. If a bear comes into town during the day, a person in a truck with a shotgun attempts to scare the bear out of town. Night is much less secure, so Churchill maintains a curfew from 10 PM until daylight. It is against the law to lock your car in Churchill. If a bear wanders into town, someone else's car might be your only refuge.

That far north, SO-50 passes tend to cluster from about 1 AM until 10 AM. Since the sun rises around 8:30 AM, I was limited to one or two passes in daylight. One morning I noticed an optimal pass at around 7 AM. Should I chance it? It was still dark, and the curfew was in effect. I went outside; the temperature was -19C with a windchill of -32C and it was snowing. I passed. Later that morning at breakfast, a local said to me, "Did you see that polar bear this morning? He was two doors down from where you are staying." I lucked out again.

In spite of the harsh weather, I had a great time seeing many bears and giving a new grid to hams in the U.S. and Canada.

The Bloomington ARC Issues ARISS Challenge

The Bloomington Amateur Radio Club (BARC) in Indiana challenges clubs to beat its effort to help ARISS (Amateur Radio on the International Space Station) replace its failed radio. After learning of the failure, the club voted to give $100 to ARISS, then three members quickly matched that amount with their own checks, and others chipped in to make a total of $600!

BARC officers and others are: (from left, front row) Vice President Tim Day, AC9ML; ARRL ARISS Delegate Rosalie White, K1STO; President Jimmy Merry, KC9RPX; Board Member Richard Phillips, WA9MTH; (from left, back row) Board Member Ray Stevens, KB9LGS; ARRL Indiana Section Manager Brent Walls, N9BA; Secretary Bill Wootton, KC9ACL; Public Information Officer Carol Emmons, KD9BSJ; and Board Member Bill Evans, N9SYI. [Rob Hamros, KB9RNB, photo.]

Hamcation, Orlando

Dave Jordan, AA4KN, and Phil Parton, N4DRO, National Sales Manager for Kenwood JVC.

Hope Lea, KM4IPF, and her dad, James, WX4TV.

Matthew Stevens, KK4FEM, with his eggbeater antennas prize.

Michael Sprenger, W4UOO, and the M2 representative.

Drew Glasbrenner, KO4MA and ARRL CEO Tom Gallagher, NY2RF, bird hunting.

Houston Hamfest

Andy MacAllister, C6ACM/W5ACM, staffing the AMSAT booth. [All photos KB6IGK.]

Carl Kotila, WD5JRD, staffing the AMSAT booth.

Bustling hams early Saturday morning at the Fort Bend County Fairgrounds.

AMSAT Area Coordinator Allen Mattis, N5AFV, presenting an update on OSCAR satellites.

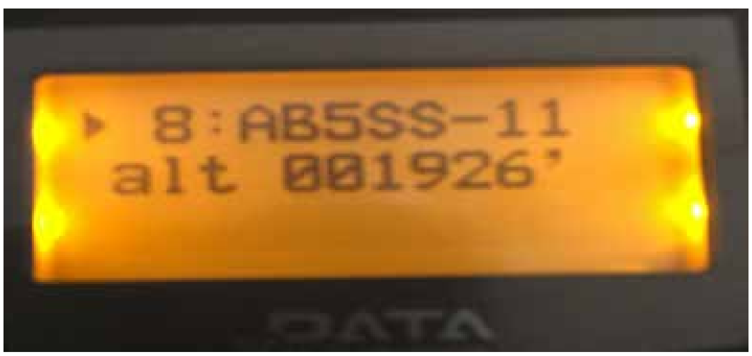
Andy fills BLT-48, a high-altitude party balloon — or "popper" — for a short flight carrying a repeater.

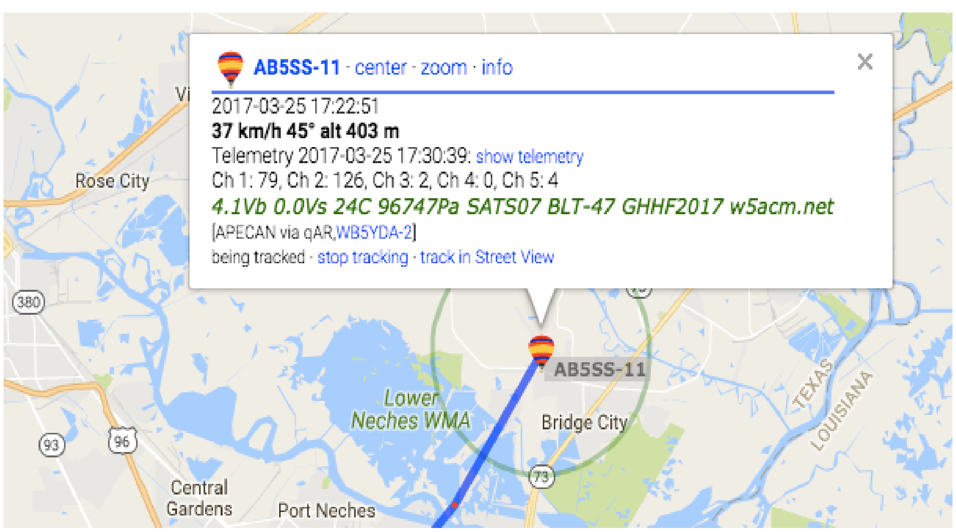
BLT-48's payload was a miniaturized cross-band FM repeater, 446.000 MHz up and 147.450 MHz down, with 500 mW.

The team launches BLT-47, a super pressure "floater," capable of circumnavigating the Earth, carrying APRS.

The lightweight APRS system used on BLT-47 (AB5SS-11) adjusts the output frequency appropriately for anywhere on Earth. Solar cells and a rechargable Li-Ion battery provides 50 mW for an extended period.

BLT-47 sending telemetry via APRS on 144.39 MHz shortly after launch.





BLT-47 tracking on aprs.fi

Support AMSAT

AMSAT is the North American distributor of SatPC32, a tracking program for ham satellite applications. For Windows 98, NT, ME, 2000, XP, Vista, Windows 7, 8/8.1 & 10.

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 main windows of SatPC32 and SatPC32ISS have been slightly changed to make them clearer. With window size W3 the world map can be stretched (only SatPC32).
- 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. After the program has been configured for the user's equipment the settings should be saved with 'DataBackup'. If problems occur later, the program can easily restore the working configuration.
- 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. On such systems the driver can cause error messages. To prevent such messages the driver can now optionally be deactivated.
- 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.

The AMSAT Journal Needs Your Words and Wisdom

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

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

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

After your article lands in members' mailboxes, and the kudos start arriving for your narrative payload, you can enjoy the satisfaction of knowing you've elevated the collective wisdom of AMSAT to a higher trajectory.

Send your manuscripts and photos, or story ideas, to: **journal@amsat.org**.

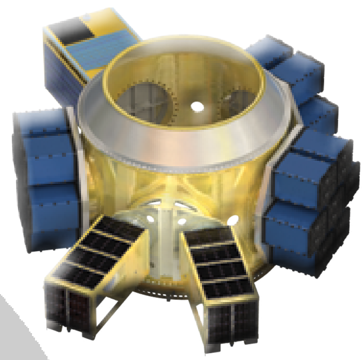
Our editors are standing by!

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

AMSAT is excited to announce a launch opportunity for **BOTH** the Fox-1Cliff and Fox-1D Cubesats. In response to a breaking opportunity, AMSAT and Spaceflight, Inc. have arranged for Fox-1D to accompany Fox-1Cliff on the maiden flight of the SHERPA system on a SpaceX Falcon 9 in the 1st quarter of 2016.

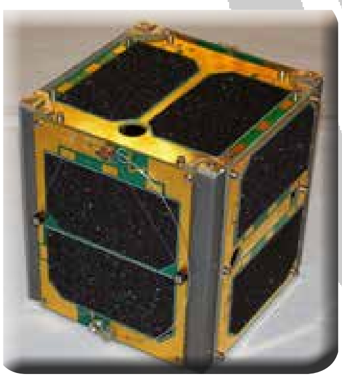
Fox-1Cliff and Fox-1D will provide selectable U/V or L/V repeater capabilities on separate frequencies once in orbit, and will be capable of downlinking Earth images from the Virginia Tech camera experiment.

AMSAT has an immediate need to raise funds to cover both the launch contract and additional materials for construction and testing for Fox-1Cliff and Fox-1D. We have set a fundraising goal of $125,000 to cover these expenses over the next 12 months, and allow us to continue to keep amateur radio in space.



Spaceflight's SHERPA will deploy multiple cubesat payloads on-orbit

ISIS QuadPack Nanosatellite Dispenser



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

Your help is needed to get the AMSAT Fox-1Cliff and Fox-1D 1U Cubesats launched on the Spaceflight's initial SHERPA flight.

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

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

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

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

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

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

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.**

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 **ww2.amsat.org/?page_id=1121.**

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**.

AMSAT Field Operations

AMSAT's Field Operations Team is looking for satellite operators to promote amateur radio in space with hands-on demonstrations and presentations.

- Promote AMSAT at hamfests
- Setup and operate satellite demonstrations at hamfests.
- Provide presentations at club meetings.
- Show amateur radio in space at Dayton, Pacificon, Orlando Hamcation.

To volunteer, send an e-mail to Patrick Stoddard, WD9EWK at: **wd9ewk@amsat.org**

You can find more information on the web:
www.amsat.org – click AMSAT – then click Volunteer