The AMSAT® Journal

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in this issue ...

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AMSAT Announcements

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's Mission

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

AMSAT's Vision

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

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

Apogee View

Paul Stoetzer, N8HM
Executive Vice President

Happy New Year! 2020 promises to be an exciting year filled with new satellites to work and significant progress towards our next generation of satellites. By the time you read this, HuskySat-1 should be in orbit and completing its science mission before being turned over to AMSAT for amateur radio use. I want to congratulate all those involved with this project both at the University of Washington and on AMSAT's Engineering and Operations teams who worked to make this mutually beneficial partnership happen. More details about HuskySat-1 and our partnership with the Husky Satellite Lab at the University of Washington can be found elsewhere in this issue.

While we look forward to the completion of HuskySat-1's primary mission, we also await the launch of the final Fox-1 satellite, RadFxSat-2 / Fox-1E, which is currently scheduled to launch no earlier than the first quarter of this year on the ELaNa XX mission. The ELaNa XX mission will fly on the second flight of Virgin Orbit's LauncherOne vehicle.

As the Fox project wraps up its series of five 1U CubeSats, progress continues on GOLF, the next generation of AMSAT satellites. A group of GOLF-TEE (Greater Orbit Larger Footprint – Technology Evaluation Environment) satellite prototype boards transmitted telemetry for the first time on Tuesday, January 14th. During the test, the boards were laid out on a bench as a "flat-sat" with interconnecting wires, bench power supplies, and a dummy load on the transmitter. The interconnected boards included:

• An early RT-IHU (Radiation Tolerant Internal Housekeeping Unit - i.e., computer) prototype,
• A CIU (Control Interface Unit) prototype, and
• A set of spare boards from HuskySat-1 that act as prototypes for the LIHU (Legacy IHU) and legacy VHF/UHF RF components.

Now that the team has reached this point, AMSAT Engineering has RF to use as a basis for developing a GOLF-TEE decoder for FoxTelem, our ground telemetry receiver software. Thousands of hours of work by many AMSAT volunteers have gone into the hardware and software that got us this far, with much work yet to be done before the assembly of flight units. The GOLF-TEE satellite is designed as a Low Earth Orbit (LEO) testbed for technologies necessary for a successful CubeSat mission to a wide variety of orbits, including MEO (Medium Earth Orbit) and HEO (High Earth Orbit).

The work on GOLF is intended for our CubeSat missions to higher orbits. However, much as the Fox-1E linear transponder was adapted as a payload for HuskySat-1, components developed for GOLF, such as the RT-IHU and the microwave SDR transponder, can be adapted to serve as the basis for a hosted payload on a commercial or government satellite in geostationary orbit or perhaps an educational CubeSat destined for MEO or GTO. Should an opportunity arise, the work being done on GOLF means that we will be ready to build such a hosted payload.

While we continue our work on these satellites, we face the prospect of regulatory roadblocks. Last year, we submitted comments on the Federal Communication Commission's Notice of Proposed Rulemaking regarding the mitigation of orbital debris. The proposed rules as worded would severely limit the

type of missions AMSAT could pursue. While the Commission has not yet issued final rules, we are hopeful that the near-unanimous opposition of commenters to the more harmful aspects of the rules, such as the requirement for satellite operators to indemnify the United States Government for any potential claims regarding their satellites, will limit the negative impact.

Another serious concern is our access to spectrum. While international threats that arose in the months before the 2019 World Radiocommunication Conference to the 144 MHz – 146 MHz and 1260 MHz – 1270 MHz amateur satellite service bands have subsided for the time being, other threats appear on the horizon. This past December, the FCC issued a Notice of Proposed Rulemaking that would delete the amateur allocation at 3.3 GHz – 3.5 GHz, including the amateur satellite service allocation at 3.4 GHz – 3.41 GHz. While that band has not yet been used for any amateur satellites as it is not available in ITU Region 3 (Asia & Oceania), it is still a potentially useful resource for a future amateur geostationary payload over the Americas.

Additionally, we know that many AMSAT members also use this band for other purposes, such as mesh networking, contesting, and EME communications. Access to microwave spectrum is crucial for many of our planned activities, including GOLF and amateur radio on the Lunar Gateway, and we must vigorously defend our spectrum allocations. AMSAT is currently drafting comments opposing this proposed rule, and, working alongside the ARRL, we continue to monitor potential legislative and regulatory actions that could limit or even preclude some of our current and planned activities.

On a final note, I wanted to let the membership know that AMSAT's servers will be migrating to a new operating system and a new hosting service later this year. This is necessary as the operating system currently running AMSAT's servers will reach its end of life in November. While AMSAT's capable IT team led by Joe Fitzgerald, KM1P, will do their best to minimize any disruptions to AMSAT services, this type of transition can often result in unforeseen problems. Continue to monitor the AMSAT-BB and AMSAT's Twitter and Facebook accounts for any updates.

Educational Relations Update

Alan Johnston, Ph.D., KU2Y
Vice President, Educational Relations

In this column, I will share news of CubeSat Simulators built in Europe, in Spain and France, as well as some domestic updates.

Carlos Rivera, Ph.D., from Madrid, Spain, shared this great photo of his CubeSat Simulator board stack, shown in Figure 1. He commented on his usage of the simulator:

I would add that the simulator is more than an educational tool. In fact, I am developing an advanced payload for a CubeSat, and I find the simulator very useful to test the integration of this system with the satellite bus. Of course, you have to "scale"/tweak some of its parts and design other critical subsystems (in particular, ADCS), but it is a good starting point, and you can save a lot of time. Moreover, I had identified the Raspberry Pi as a good candidate to work as OBC. Note that some architectures are using two Pis to improve reliability, and it has been tested under a few tens of krad(Si). Your project has really made the grade.

I look forward to hearing more about Carlos' work with the simulator in the future!

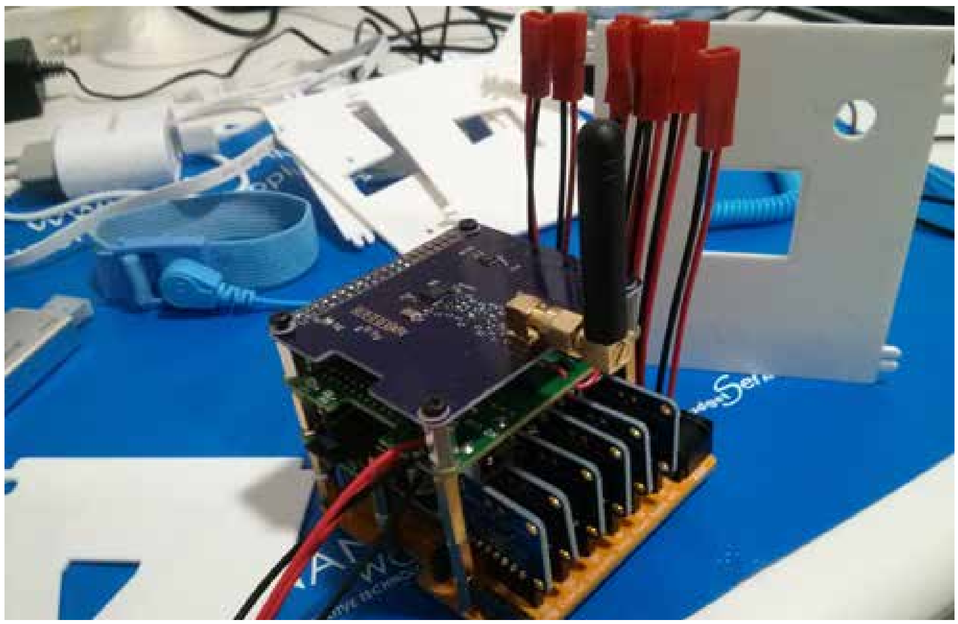
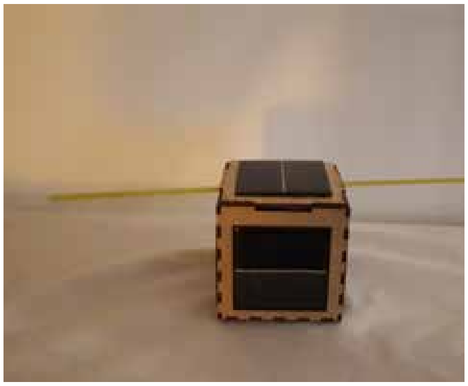


Figure 1 — CubeSat Simulator Board Stack built by Carlos Rivera, photo courtesy of Carlos Rivera.

Figure 2 — AMSAT-Francophone built CubeSat Simulator at Hamexpo 2019 in Le Mans, France, photo from Twitter,twitter.com/amsatf/status/1182954351070978049 ?s=20.



Christophe Mercier, President of AMSAT-Francophone, has built an exciting CubeSat Simulator. He and François Brulé, F4IFV, used a laser cut frame and a tape-measure dipole antenna, as shown in Figure 2. He has also written code to use UZ7HO Soundmodem to demodulate and InfluxDB and Graphana to display time-series telemetry. See their Wiki page (**code.electrolab.fr/xtof/josast/wikis/Cubesat%20Simulator) and open-source Java code (code.electrolab.fr/xtof/josast/tree/master/ModuleCubesatSim**). I'm looking forward to trying out their software soon!

AMSAT-FR has shown the simulator at several events, including Hamexpo in Le Mans, the Paris Maker Faire, and also at the F6KRK radio-club.

On this side of the Atlantic, we have been busy as well. Jim McLaughlin, KI6ZUM, of ZUM Radio, and David White, WD6DRI, are making major contributions to the next version of the simulator PCBs. Based on the simulator they built for the Mt. Carmel Amateur Radio Club, W6SUN, at Mt. Carmel High School in San Diego, CA, they contacted me, and we have been working closely together. Jim and Dave are experienced circuit designers and have knowledge and contacts that will help significantly reduce the cost of the simulator. Look for more on this soon!

The building of four more AMSAT loaner simulators will be underway soon — plenty for classrooms, club rooms, and STEM events. Contact me at **ku2y@amsat.org** to make arrangements if you would like one.

For Beginners – Amateur Radio Satellite Primer III

Keith Baker, KB1SF/VA3KSF, kb1sf@amsat.org

[Portions of this article were first published as "Working Your First Amateur Radio Satellite (Part III)" in the May 2010 issue of Monitoring Times Magazine*, Brasstown, NC. Thank you, MT!]*

I trust by now a number of you are up and running on our FM birds and having fun collecting new grid squares or working DX with this (for you) newfound part of our enjoyable hobby. However, my hunch is that your arm is probably getting tired while working these satellites using just a small, portable, handheld radio and a handheld Yagi antenna of some sort.

Now that warmer weather (in the Northern Hemisphere at least!) is upon us, my guess is that you'd like to begin investigating a more permanent antenna array for your satellite station. For beginners on a budget, I suggest you consider some form of omnidirectional antenna. That's because their use tremendously simplifies building your satellite station, as no rotators, cross booms, or rotator interfaces are needed. The use of omnidirectional antennas also greatly simplifies the satellite tracking part of this activity as it will allow you to concentrate fully on trying to hear, find and track your downlink signals while working the bird as it rapidly moves across the sky.

But, unfortunately, and as we have discussed, not all omnidirectional antennas are suitable for satellite work. So, in this edition of our satellite primer, I'll once again offer some tips to help you optimize your base station antennas for the satellites.

More Satellite Antenna Considerations

Contrary to what you might have heard from well-meaning veteran satellite ops, that only a cross-polarized set of multi-element Yagi antennas mounted on a non-metallic cross boom will do, I know from my own experiences that such talk is mostly bunkum. Just as with most other pursuits in amateur radio, while the "ultimate" satellite base station antenna array may sport one or more circularly polarized Yagi antennas all mounted on a fiberglass cross boom and turned by an expensive commercial alt-azimuth rotator, you can usually still get excellent results on the LEO birds for a whole lot less time, money and effort.

If you already have a VHF and UHF base station set up for scanning or use on the amateur bands, you probably also have an external VHF or UHF antenna of some sort connected to it. Unfortunately, the gain of most of these terrestrial antennas occurs at the point in a satellite's orbit where it is farthest away from you (at the horizon) and its downlink signal is at its weakest.

What's more, as the satellite rises above your horizon, it will gradually move outside the beamwidth of most terrestrially optimized antennas to the point that, when it is at its closest approach to you (i.e., directly overhead) you may not hear the satellite, and it may not hear you, at all!

Remember, too, that amateur radio satellites are both tumbling and spinning in space. As I've discussed in previous columns, cross-polarizing linear antennas results in a considerable loss of gain. This means that, if the antenna on the satellite is horizontally polarized and your antenna on the Earth is vertically polarized (or vice versa), you may not receive much of anything on the ground, no matter how much power is being transmitted to or from the satellite.

In the past, and to help minimize these problems, satellite builders routinely incorporated what are called "circularly polarized" antennas into their satellites. Building circularly polarized antennas into a satellite helps minimize the effects of antenna cross-polarization losses on the ground as the satellite moves through space. That's because the difference between right-hand circular polarization and left-hand circular polarization is only about 3 dB.

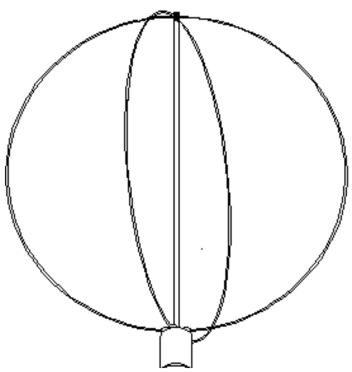
Unfortunately, today's small CubeSat satellites simply don't have enough surface area to mount circularly polarized antennas. Most incorporate just single whip antennas for transmitting and receiving. As a result, you'll often notice deep fades in their signals as the satellite tumbles in orbit over your station. However, using circular polarized antennas at your station will still help (but not completely eliminate) most of these effects.

Thankfully, a couple of relatively simple, omnidirectional antennas are also specially designed to achieve this high angle, circular signal polarization pattern without also costing you a fortune or making your home look like a NASA tracking station!

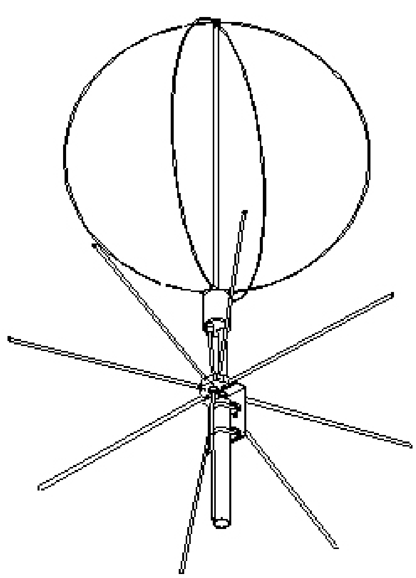
Scrambled Eggs, Anyone?

One relatively inexpensive omnidirectional base station antenna that is useful for LEO satellite work is called an Eggbeater. The Eggbeater antenna looks a lot like its namesake, an ordinary kitchen eggbeater.

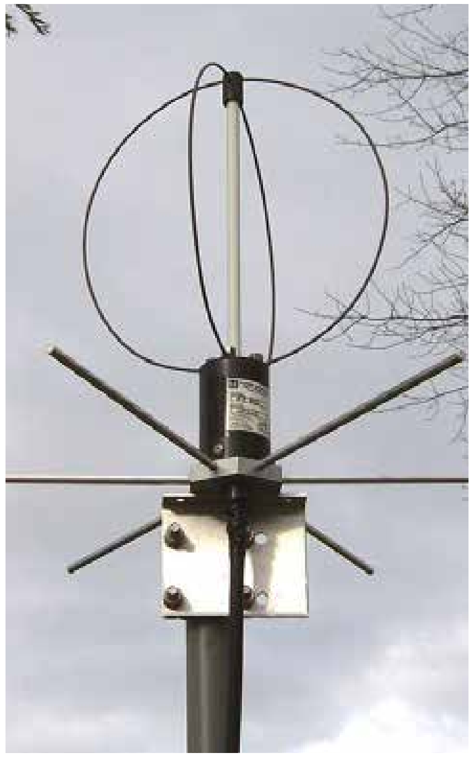
This antenna is composed of two full-wave loops of wire (or some other rigid metal material) fed 90 degrees out of phase with each other. Some designs even sport parasitic reflector elements underneath the array to give the antenna higher gain. At the horizon, the eggbeater displays a horizontally polarized linear pattern, which also makes it useful for weak signal VHF or UHF terrestrial work. However, at higher elevations, the antenna exhibits an increasingly right-hand circular radiation pattern, which makes it ideal for satellite work.



The "Eggbeater" is a good omnidirectional base station antenna useful for working the LEO birds. (Courtesy: M2 Antennas)



Adding ground plane elements under the "Eggbeater" increases the overall upward gain of the antenna. (Courtesy: M2 Antennas)



This photo shows a view of the author's 70 cm, M2 "Eggbeater" antenna. Note the ground radials mounted underneath the phasing coil. (Courtesy: KB1SF)

Gerald Brown, K5OE, has published an excellent online article on how to homebrew satellite-optimized eggbeater antennas at wb5rmg.somenet.net/k5oe/Eggbeater_2.html. Eggbeaters are also available from commercial antenna manufacturers such as M2 Antennas of Fresno, California (www.m2inc.com). I'm currently using a pair of commercially made M2 eggbeater antennas at my home QTH and find they work reasonably well for the LEO birds, especially if the antenna's reflector elements are installed.

Now, granted, eggbeaters won't give you horizon-to-horizon, S9 signals either into or out of the birds like a long-boom Yagi will. But, as I've noted previously, satellite work is, by default, weak signal work. Using a reasonable amount of uplink power (usually 25 watts or less) and a pre-amplifier for the downlink mounted either on the antenna mast or, if your high-quality feedline is short enough, in the shack produces good results with these antennas on most overhead (or near overhead) passes. As a general rule, I don't bother trying to work a satellite pass with my eggbeaters unless the satellite will be at least 45 to 50 degrees above my horizon at its highest point and closest approach.

Here's a partial view of the phasing coil and ground plane of the author's 2m, M2 "Eggbeater" antenna. Note that the ground plane radials are offset by about 1/2 wavelength (10.5 inches) from the top of the phasing coil and driven elements. (Courtesy: KB1SF)

A Quadrifilar WHAT?

Another omnidirectional antenna design suitable for satellite work is a Quadrifilar Helix (or Quadrafilar Helicoidal) antenna. This antenna consists of four quarter-wavelength or half-wavelength elements fed with a 90-degree phase difference. The polarization is circular, and the beam widths are often greater than 90 degrees, which means this antenna will cover a HUGE chunk of the sky.

These antennas are also relatively small and relatively easy to build out of common materials such as copper tubing and PVC pipe. However, element lengths and spacing have to be very precise to achieve a truly circularly polarized pattern.

Some ham operators (and others who are also interested in other such pursuits as weather satellite reception) offer design tips and construction details for these antennas via various web sites. One appears at **web.archive.org/web/20190629211229/perso.wanadoo.es/dimoni/ant_qha.htm**. Another web site on the subject (**www.jcoppens.com/ant/qfh/calc.en.php**), actually sports a helpful online calculator where element lengths and spacing for these antennas can be calculated simply by entering the desired resonant frequency.

The Quadrafilar Helix antenna is a relatively easy to build omnidirectional antenna that can be optimized for both amateur radio and weather satellite work. (Courtesy: Bob Cash, N8IMO)

The Lindenblad

Yet another omnidirectional antenna design that can be useful for satellite work is the Lindenblad. This antenna is named for Nils Lindenblad of the Radio Corporation of America (RCA) who, back in the early 1940s, began experimenting with antenna designs that might be useful for the (then emerging) television broadcast industry. The antenna uses four dipoles spaced equally around a 1/3-wavelength circle, with each element canted at a 30-degree angle from horizontal.

Like the Quadrafilar Helix, construction articles on how to "roll your own" Lindenblad abound on the Internet. Howard Sodja, W6SHP, optimized the Lindenblad design for satellite work in a series of articles for the AMSAT Journal back in the early 1990s. His articles can still be found in the AMSAT web archives at **www.amsat.org/amsat/articles/w6shp/lindy.html**.

In addition, AMSAT's past Vice President of Engineering and board member, Tony Monteiro, AA2TX (now, sadly, a Silent Key), wrote extensively on the Lindenblad design. Construction details of his 70 cm version of the Lindenblad appeared in the Proceedings for the 2006 AMSAT Annual Meeting and Space Symposium at **www.qsl.net/nwlarn/sat/70ParaLindy.pdf.**

Directional Antennas

As the name implies, directional antennas focus RF energy in one direction. Not only do these antennas allow you to transmit your signal to satellites that are farther away from you, but they also help your ground station pick up weaker signals, provided that the antennas point in the right direction. As all satellite work is weak signal work, anything that boosts an already weak satellite downlink signal is a good thing.

Many satellite operators use some form of Yagi antenna in their Earth stations. The design, Yagi-Uda, is named for its Japanese inventors, and consists of one or more dipoles that are fed with RF and act as driven elements. Parasitic (that is, non-fed) elements (called reflectors) are then mounted behind the driven element with one or more parasitic elements (called directors) mounted in front. The whole array is then mounted on a cross boom of some sort.

Yagi antennas can be either linear or circularly polarized. Yagi antennas with only one row of elements are linearly polarized (either horizontal or vertical, depending on which way you mount them). For example, the Arrow Antenna I've highlighted in a previous column is simply two linearly polarized Yagi antennas (one for 2m and one for 70 cm) mounted at 90 degrees to

The Lindenblad antenna is yet another, relatively easy to build omnidirectional antenna suitable for satellite work. (Courtesy: AMSAT)

Satellite antennas don't need to be fancy to be effective. Here, a pair of vertically polarized, homebrew Yagi antennas made from bits of wire and wood are mounted on a wooden cross boom. (Courtesy: AMSAT)

each other on the same handheld boom. However, Yagis with two rows of the same sized elements offset by a 90-degree phase difference are circularly polarized (either right-hand or left-hand, looking down the antenna from the rear).

As I've also discussed, for satellite communication, circular polarization is desirable because the difference in loss between right-hand (RHCP) and left-hand (LHCP) circular polarization is only about 3 dB. And while this loss represents about half of your uplink or downlink signal, remember that the difference between horizontal and vertical polarization is theoretically infinite. In the real world, however, the difference between horizontal and vertical polarization is around 30 to 40 dB. But that's still over a thousand times more loss than the difference between RHCP and LHCP!

Also, the number of elements on a Yagi is directly proportional to its gain. More elements mean more gain. However, as in most other things in life, there's a tradeoff between gain and beamwidth. That is, the higher the gain, the narrower the beamwidth. So, while a 40-element Yagi may provide excellent gain, it becomes quite another matter to keep it continually pointed directly at a satellite that's rapidly moving across the sky.

The bottom line here is that, while circularly polarized Yagi beam antennas are wonderful for full coverage satellite work (and I've used my share of them over the years), they are not essential. I've still achieved consistently good results — particularly on the LEO birds —using any number of simple, linearly polarized (handheld or mounted) Yagi beams or eggbeater designs.

You can find any number of "cheap and easy" Yagi antenna designs and construction details on the Internet. A collection of three such articles by Richard Crow, N2SPI, ran in the *AMSAT Journal* in 2006 and have since been re-published on the AMSAT web site at **www.amsat.org/cheap-and-easy-yagi-satellite-antennas**.

Dish Antennas

Dish antennas are the next step up from Yagi antennas for satellite work. However, the benefits of a dish are often not worth the cost at the VHF and UHF frequencies used by our current amateur satellite fleet. A dish starts to become feasible in the 1.2 GHz range. However, here again, the high gains (and narrow beamwidth) achieved by a dish antenna are usually offset by the fact that an LEO satellite is often (and rapidly) moving across the sky. What's more, complexity and costs increase dramatically when using dishes because there are not that many amateur radio dish suppliers around. Usually, you'll have to adapt dish feeds and reflectors manufactured for other purposes.

Looking Ahead

In future articles, I'll continue our discussion of innovative ways to optimize your satellite base station, including how to select the proper feed line and connectors for your antenna as well as what to look for when choosing a base station radio. I'll also pass along some more tips on how to find and track our amateur radio satellites. In the meantime, you can always get the very latest information about current satellites in orbit (or those still on the drawing boards or awaiting launch) at our AMSAT web site, **www.amsat.org**.

Three College Students' Perspectives on Ham Radio and Amateur Radio Satellites

Dawson Duckworth, KC3NNB
Lauren Hurley, KD2RHC
Kaixuan Ji, AC3EN

I. Introduction

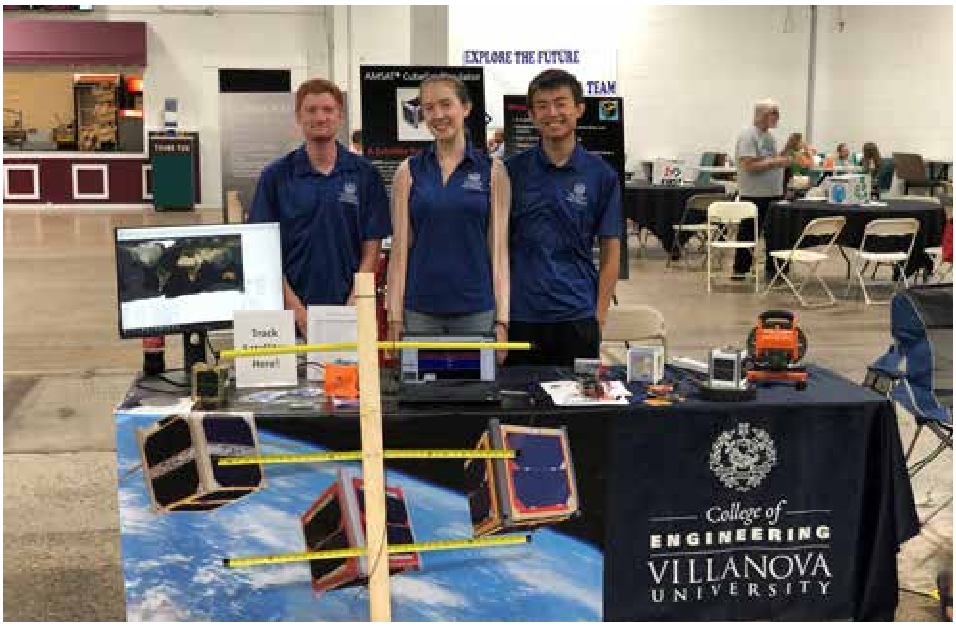
We are three college students attending Villanova University in Villanova, PA, who recently got our ham radio licenses and are involved with amateur radio satellites. In this article, we explain how we learned about amateur radio, what motivated us to get our licenses and become involved in amateur radio satellites, and what we like about the hobby. Finally, we give our opinions on what the amateur radio community and AMSAT should do to attract more people our age to ensure the future of the hobby. Each of our perspectives appears in a separate section.

II. Dawson Duckworth

I am currently a junior at Villanova University, studying Electrical Engineering with a minor in Computer Science. I have been interested and fascinated by science and particularly space my entire life watching shows such as Neil deGrasse Tyson's "Cosmos: A Spacetime Odyssey" and Carl Sagan's "Cosmos: A Personal Voyage." I am not sure what it was that always kept drawing me back to studying space. Still, every time I look up into the sky at night, I like knowing that we are only a small speck in a possibly infinite universe that is billions of years old and will still be active for billions of years after we are all gone.

On the first day of my Fundamentals of Electrical Engineering Lab, Dr. Alan Johnston, KU2Y, who had just started teaching at Villanova, asked the class if anyone was interested in starting an amateur satellite/ radio club because the school did not have any space-related engineering clubs. I knew this was my chance to do something other than just watching documentaries on TV, so I talked to him after class. Later that year, we formed the Villanova CubeSat Club. Since then, we have improved designs on

(L to R) Dawson Duckworth, KC3NNB, Lauren Hurley, KD2RHC, Kaixuan Ji, AC3EN, Alan Johnston, Ph.D., KU2Y.



the prototype CubeSat Simulator that Dr. Johnston had made, and we attended events such as Hamvention in Dayton, OH, and RobotStock in Oaks, PA. We have grown as a group so much since the beginning of the club last year. With support from the school, we intend to accomplish some impressive goals this year.

One of the first activities we worked on as a club was to contribute to Satellite Network Operators Ground Station (SatNOGS) with Raspberry Pis. This was the first time I had ever heard of amateur radio, and I did not understand how it could be used. I did not know before starting the CubeSat club that you could communicate with people all around the world by bouncing signals off satellites or that everyday people could pick up telemetry from a satellite with only an antenna and software-defined radio.
After some club meetings, we even went outside to try picking up signals from some of the AMSAT satellites as well as weather satellites and the International Space Station. By attending these "listening parties," club members generated a lot of interest in amateur radio, and some members began getting their Technician Class licenses, including me. I passed my technician's license exam, along with two other club members, at Hamvention last May. Since then, I have enthusiastically attended amateur radio and satellite events and talked to people who have so much more experience than me. I look forward to learning more in the future.

The amateur radio community has a long tradition. Over the past year, I have met college students who got their licenses for many different reasons. Having said that, the community needs to promote and publicize to younger people in colleges and even high schools because most people know nothing about amateur radio. If AMSAT were to fund radio clubs in colleges, for example, I am confident that more people would join the amateur radio community. However, that support needs to happen sooner rather than later. I see the amateur radio community growing in the future, but AMSAT and other organizations need to promote and publicize the hobby across the country for that to happen.

III. Lauren Hurley

I first learned about amateur radio in my Introduction to Electronics course last year at Villanova. I loved this course because it was offered through the physics department, so we learned how electronic components work on a fundamental level, not just how to use electrical equipment. Later in the

semester, our professor, Dr. Jeremy Carlo, N2ZLQ, devoted an entire class period to discussing amateur radio. We learned about the history of how radio developed, how radio signals carry information, and how receivers work. At the end of the year, we all had to do a research project on a subject of our choice. I chose amateur radio because I wanted a more comprehensive understanding of radio technology, as well as the history and culture of ham radio. By the time I had finished this project, I realized that I knew most of the material covered on the Technician License exam. I had four weeks off for winter break, so I borrowed an ARRL license manual from the library, reviewed it, and passed my license exam in January of 2019.

While researching my project, I checked out several old books from the Villanova library. I learned how amateur radio used to work before satellite communication and before repeaters. One of the books mentioned the AMSAT satellite OSCAR 7 as a new development. I'm interested in satellites because they offer future possibilities for amateur radio.

The CubeSat Club spent some time in the spring tracking satellites and trying to make contacts, and it was more exciting than I expected. Using a handheld radio to talk through repeaters almost seems too easy. Satellite communication adds a new thrill to making contacts: one only has a limited time for making contacts while the satellite is passing overhead, so time is of the essence. On a linear satellite, if one hears another operator talking on a different frequency, one has to decide whether to "chase" him and switch frequencies or keep calling CQ on the same frequency. Moreover, satellite communication is accessible even to people without FCC licenses. With a little equipment, anyone can track satellites and listen to hams or receive telemetry. Thus, satellites expand the scope of the CubeSat Club, because even non-hams can participate and learn how satellite signals work.

With the proliferation of communication technology in the past half-century, radio contact may have lost its appeal. Young people growing up with cell phones won't marvel at making a QSO the way their grandparents did. In my opinion, the way to attract new members would not be to hand them a brand-new handheld and stress how easy it is but rather to do the opposite.

This new generation loves do-it-yourself projects. Many public libraries have introduced "maker spaces" where patrons can come to build or sew things. Indeed, crafts like sewing and knitting have seen a massive resurgence in recent years. In fact, I was drawn to knitting because I liked the idea of understanding how to make clothes exactly how I preferred.

To attract new members, AMSAT should stress that ham radio offers enormous potential for people to build things themselves and customize what they make to suit their wants and needs. Then, amateur radio would stand out from other communication methods, like texting or phone calls, and seem less like "magic" and more like an art. For instance, our club built Yagi antennas with some wood and tape measures. Everyone seemed shocked at how simple it was. In this era of online shopping, we expect things to come packaged and complete without understanding how they function. So when we do it ourselves, it is a moment of wonder and deeper comprehension.

IV. Kaixuan Ji

I am a junior at Villanova University, currently pursuing my Bachelor of Science degree with a double major in Electrical Engineering and Physics.

I bought a book on amateur radio communication back when I was in middle school. However, I spent all my free time running around on the playground rather than sitting down and reading. Last year, my Electronics professor, Dr. Jeremy Carlo, N2ZLQ, was the president of the Mid-Atlantic Radio Club (MARC). He brought his ham radio equipment to class when we were on the topic of telecommunication and reignited my interest in amateur radio.

Later that semester, I found out that my Fundamentals of Electrical Engineering professor, Dr. Alan Johnston, KU2Y, the faculty advisor of the Villanova CubeSat Club, is also a ham. Last summer, three CubeSat Club members, including myself, went on a field trip to Hamvention to represent the AMSAT CubeSat Simulator of the club at the AMSAT Education table. Before the trip, I spent a week reading the *ARRL License Manual* to get prepared. As a result, I passed my Extra Class license exam at Hamvention on the first day!

Amateur radio technology is a great educational tool for Electrical Engineering classes. For example, performing signal processing on a blackboard or in MATLAB (matrix laboratory) is relatively abstract while it is relatively figurative on a transceiver; the audio can make the process come alive. For a suitable transceiver, the transmitted or received audio can even be displayed as an FFT (Fast Fourier Transform) on the oscilloscope. Students can learn about multiple digital communication protocols, which will be helpful in some of their upper-level classes.

Amateur radio also can provide emergency communication when internet, phone service, and other conventional communication methods fail during times of crisis. Even absent a disaster, amateur radio can serve as an emergency communication tool during popular events. Also, after getting his/her license, one can join organizations such as the Amateur Radio Emergency Service (ARES) and Radio Amateur Civil Emergency Service (RACES), which contribute to communications in public service for an even broader community.

Satellites play essential roles in many science and engineering disciplines. However, it is hard for people to experience the existence of satellites since the satellites are far away from us, operating silently and invisibly. With the help of an organization such as SatNOGS, one can easily set up a satellite ground station by using a Raspberry Pi. It is always fun to play with the ground station! In the meantime, the CubeSat Simulator is a great educational tool for people, especially high school students, to learn about satellites and related technologies. More importantly, it is portable and affordable, so it has the potential to enter classrooms all around the world.

Getting people's attention about ham radio and satellite technology and encouraging them to join clubs and organizations are important. However, even more essential is ensuring people decide to stay involved so that they can grow and give back to the community. Though many resources can be found online about satellites, it is not easy to get started: tracking satellites and making satellite contacts can be tricky and time-consuming. Thus, it is essential to have volunteers serve in the role of a mentor ("Elmer") to help the newcomers to AMSAT utilize all the resources that the organization has to offer. If the community continues to grow, building a geostationary amateur radio satellite will no longer be a dream but a reality. I wish AMSAT luck on launching a GEO satellite as soon as possible.

V. Conclusion

In conclusion, we all got involved in amateur radio at the start of our college careers and shared a passion for learning about the hobby. We were lucky to be exposed to this craft, but unfortunately, not enough students like us get that exposure. AMSAT should devote more efforts to community outreach to let more people know about ham radio. Moreover, AMSAT should stress the do-it-yourself aspect of the hobby to attract new members. AMSAT has a lot to offer but needs to make additional efforts to keep the tradition going. We're excited to see what the future of amateur radio in space will bring.

ARISS Upate

Frank H. Bauer, KA3HDO and Dave Taylor, W8AAS

The ARISS (Amateur Radio on the International Space Station) program began operations from the ISS in December 2000 as the first payload activated by the first crew. To date, ARISS has made over 1270 contacts in 62 countries, providing over 500,000 students with direct exposure to ham radio and related lessons. Along the way, ARISS equipment has given thousands of hams access to astronauts and a space-based platform for communications.

Overview of the Preceding Year

ARISS was involved in many educational, outreach, and technical activities throughout the year, as well as providing opportunities for ham radio communications. Although ham radio volunteers support ARISS activities around the world, this paper concentrates on activities by the U.S. team.

Educational Activities

ARISS strives to inspire, educate, and engage youth and communities in science, technology, engineering, arts, and mathematics (STEAM).

In the U.S., ARISS provides two proposal windows each year in the spring and fall. During these windows, we accept proposals from U.S. groups looking to host a contact and select those with the best education plans to move ahead for a contact. Each window includes webinars to provide information to prospective host groups.

U.S. Education Team

Last year, ARISS formed an Education team to complement the Operations team. The 22 educators — all alumni of ARISS contacts — meet monthly with the mission of expanding ARISS educational outcomes and communicating the ARISS STEAM experience to other educators.
Last year saw the introduction of Education Ambassadors, who provide schools with educational guidance much as Technical Mentors assist schools on the operational side of a contact.

Other Education team accomplishments include:

- plans for an electronic space for sharing STEAM lesson ideas and resources among educators hosting a contact
- leading the proposal process for U.S. contacts
- supporting development of a radio kit that can be distributed to ARISS schools.

U.S. Operations Team

The Operations team oversees contacts with ISS. The main activities of this team are guiding a school's technical preparation and operating telebridge ground station. In the past year, the Ops team has continued this work, holding weekly telecons to coordinate scheduling.

Astronaut Contacts

From October 1, 2018, to September 8, 2019, ARISS conducted 66 successful contacts in

U.S. contact sites since 2000.

20 countries. As usual, about 2/3 of these contacts used an on-site amateur radio station.

Nineteen U.S. contacts were conducted in 17 states. Since 2000, we have had contacts in 48 states, 1 territory (Puerto Rico), the District of Columbia, and Guantanamo Bay Naval Base.

South Dakota and Wyoming, we're looking for you!

Educational Outcomes

Talking to an astronaut is only part of what students gain when their school hosts an ARISS contact. The schools (or library, or summer camp, etc.) execute a multi-faceted education plan leading up to the contact. Most include introductions to the hobby by hams from local clubs. In some cases, the equipment used for a contact becomes the foundation of a school ham radio club.

In addition, many schools add exciting extras to the lesson plans, such as:

- a visit from a local ex-astronaut (or maybe a current one);
- building hand-held antennas and tracking satellites with them;
- building and programming robots;
- building and launching model rockets;
- building and tracking balloons with telemetry;
- attending U.S. Space Camp or a rocket launch; and
- visits to/from local space industries, such as spacesuit manufacturers and NASA engineers.

Conferences

Members of the U.S. Education and Operations teams presented papers, staffed exhibits, and sometimes both at numerous conferences, including:

- Space Exploration Educators Conference (Houston, Texas)
- Space Port Area Conference for Educators (Kennedy Space Center, Florida)
- ISS Research & Development Conference (Atlanta, Georgia)
- 3-D Printed Hab Challenge (Edwards, Illinois), and
- Satellite Educators Conference (Los Angeles, California).

Recognition

MarconISSta, a Ph.D. research project that shared the ARISS antennas for on-orbit spectrum analysis of amateur radio satellite bands, concluded in February 2019. Martin Buscher (the Ph.D. student responsible for the project) presented two papers reporting results at the IAA Symposium on Small Satellites for Earth Observation. The MarconISSta was transferred to ARISS for future research.

NASA's annual report ISS Benefits for Humanity (April 2019) featured ARISS as one of the groups providing education from ISS. Also included in the report were links to a NASA web page article about ARISS and an article on the MAI-75 experiments that use ham radio and SSTV.

SSTV Events

ARISS continues to hold special SSTV sessions from the Russian Zvezda module. These events use a Kenwood TM-D710E and a laptop running MMSSTV software. The ARISS events generally run continuously for two to four days over all parts of the world. The three events in the past year, with their themes, were:

- Feb 2019 – NASA on the Air
- Apr 2019 – Human Spaceflight, and
- Aug 2019 – Memorial to Owen Garriott.

In addition, Moscow Aviation Institute conducted four MAI-75 propagation tests using SSTV in January, April, June, and July. These typically occur over Russia and are not audible in the U.S.

A team in Poland creates special diplomas (certificates) for each ARISS SSTV event. These are available to anyone who receives one or more images. You can request a diploma at **ariss.pzk.org.pl/sstv/**.

You can submit your received images and view many of the ones received by others at **spaceflightsoftware.com/ARISS_SSTV/index.php**.

Hardware Status

In the past, ARISS has operated one or two radio stations aboard ISS. Under our flight rules, our equipment is activated 24/7, except during EVAs and docking/undocking of visiting spacecraft. However, because most of our equipment was built before 2000, it is showing its age, and we have had unpredictable downtimes in recent years. The digipeater has been particularly troublesome.

At this time, the digipeater (using an Ericsson HT and the original ARISS TNC) is frequently off, possibly due to an intermittent cable. A new TNC module flown in November 2018 failed to fix the problem. Because of limited engineering resources and the long lead times for replacing hardware, ARISS has since concentrated on getting the new radio system (Inter-Operable Radio System) ready to fly as soon as possible. As described later in this report, we are nearly there.

SSTV operations use an unmodified Kenwood TM-D710E that belongs to the Moscow Aviation Institute (MAI), which flew it for experimental use. Because of problems with the Ericsson system, current voice operations also use this Kenwood radio.

International Meeting

As an international working group, ARISS is managed by delegates from five world regions, corresponding to the five space agencies that contribute to ISS. In June, ARISS-International Delegates and other members of the ARISS team (37 people in all, from 11 countries) met at the Canadian Space Agency (CSA) headquarters outside Montreal.

Highlights of the meeting included:

- a talk on CSA Gateway planning by CSA's Program Manager of the Lunar Gateway Program, Ken Podwalski
- discussions by the ARISS team on ideas for participating in NASA's Deep Space Gateway program, such as ham radio modes and bands, equipment development, education, and public outreach, and
- approaches for improving ARISS operations.

Dave Honess, M6DNT, ESA International Education Operations Coordinator, talked about ideas for enhanced ARISS education. Future SSTV sessions were discussed, including one to honor the late Owen Garriott, the first astronaut to use ham radio in space.

During the meeting, JVC Kenwood engineer Shin Aota, JL1IBD, presented two ARISS IORS D-710GA transceivers to ARISS-Russia. One radio will become the ham station in the ISS Zvezda module, and the other will be used for training cosmonauts.

Progress Toward the Future

The ARISS hardware and management team has been kept incredibly busy this past year dealing with multiple projects.

Attendees at the ARISS-I meeting.

Interoperable Radio System (IORS)

The past four years have seen ARISS developing a new radio system for ISS to replace the aging equipment currently on board. This system has two components:

- a modified Kenwood TM-D710G transceiver, and
- an ARISS-built low-voltage power supply that can provide correct voltages for the D710G, Ham Video transmitter, VC-H1 SSTV unit, and future additional equipment

Both components will be certified for use anywhere aboard ISS. Two systems will be flown, one for the U.S. operating segment and one for the Russian segment.

IORS Flight-Identical Test System

Last year, a flight-identical unit was built and tested at NASA JSC. Minor problems that were uncovered have been fixed and the changes incorporated into the first flight unit. Some final issues from the safety and engineering reviews are being resolved, but meanwhile the first flight system, destined for Columbus module, is with NASA for an anticipated launch aboard SpaceX CRS-20 in March.

HamTV

Earlier this year, ARISS completed the negotiations and paperwork necessary to return the failed Ham Video transmitter to Earth for troubleshooting. It returned by the Dragon spacecraft in January 2019 and in May reached Italy for evaluation by Kayser Italia, the company that built it. Because there is no funding for this effort, their engineers work on this between other projects. Tests indicate that the modulator (MiniMod board) failed. A flight spare for this board is available; negotiations are underway regarding the repair and retesting.

Dealing with Bartolomeo

About three years ago, ARISS learned of a plan to attach an external payload platform to the Columbus module. This platform, called Bartolomeo, would require the ARISS VHF/UHF antenna to be moved. ARISS managers and technical staff have had many meetings over the years to make plans, change them as the platform evolved, negotiate with ESA and Airbus, build a replacement antenna, and finally end up with a new agreement that keeps the existing antenna but with a new coax feedline. Still to be determined is whether ARISS will experience any interference from other antennas on the new platform (when it is finally installed).

Moving Out from Earth

NASA is looking outward to lunar orbit and the moon — and ham radio should go along. NASA and ESA both have asked ARISS to submit proposals for ham radio on the Lunar Gateway. Plans are underway.

Making It All Happen

ARISS has all the needs and expenses of a for-profit business: people to make things happen, regular meetings (electronic and face-to-face) to keep a world-wide team in sync, hardware design and manufacture, and more. But this is ham radio, and we are non-profit. The labor we've got, in the thousands of hours donated by our ham volunteers. But everything else costs money, and ARISS must raise it from donations.

Sponsors

ARISS is grateful to its continuing sponsors. Funds to provide full-time scheduling support at Johnson Spaceflight Center are provided by NASA's Space Communications and Navigation (SCaN) office and by the ISS U.S. National Laboratory (formerly known as CASIS). Support for day-to-day operations comes from AMSAT-NA and ARRL.

Fundraising

To raise funds to keep ARISS's work going, we are continually looking for donations. We have created a challenge coin to encourage donors. We plan to solicit donations at contact venues when we find a delicate way to do so.

In addition to these on-going efforts, ARISS

IORS flight-identical test system.

conducted several special activities.

FundRazr

In October 2018, ARISS established a FundRazr.com page to raise funds for completion of the Interoperable Radio System. Included are many premiums, growing more desirable as donation levels increase.

Our FundRazr has been extended. If you have been putting off donating, there is still time to support ARISS and earn a premium. You can donate at fundrazr.com (search for ARISS).

Auction

In April, ARISS conducted an online auction for two major items: a TS-890S radio signed by NASA astronauts (donated by JVC Kenwood) and a limited edition, multi-volume box set of the 2019 ARRL Handbook (donated by ARRL).

ARDC Grant

While preparing for the 2019 AMSAT Space Symposium, ARISS learned of a substantial (and unexpected) grant from the philanthropic arm of Amateur Radio Digital Communications (ARDC). This grant moves ARISS considerably closer to having the funds needed to complete all ten of the systems necessary for training, engineering, and deployment.

Following ARISS

For up-to-date information about ARISS, including future contacts, follow us at any (or all) of these media sites:

- ARISS website: **www.ariss.org/**
- Facebook: Amateur Radio on the International Space Station (ARISS)
- Twitter: @ARISS_status, and
- amsat-bb.

To share information about ARISS with a teacher or other person interested in hosting an ARISS contact, direct them to this page on our website: **www.ariss.org/submit-a-contact-proposal.html**. Details about submitting a U.S. proposal are at **www.ariss.org/hosting-an-ariss-contact-in-the-us.html**.

CatSat: Pathfinder for New Ham Satellite Opportunities

Michael Parker, KT7D, Rincon Research Corp.;
Christopher Walker, K7CKW, Univ. of Arizona/FreeFall Aerospace, Inc.;
Douglas Stetson, FreeFall Aerospace, Inc.

1. Opportunities

Recently two exciting opportunities arose for amateur radio through cooperation with the University of Arizona (UofA) and two local Tucson companies, FreeFall Aerospace, Inc., and Rincon Research Corporation.

a. Antennas

The first opportunity (described here only briefly) involves six, 6.1-meter diameter radio telescopes recently acquired by the UofA's Steward Observatory with support from Rincon Research Corp. Until recently, the antennas were part of the Berkeley Illinois Maryland Array (BIMA) for millimeter radio astronomy and used at frequencies as high as ~250 GHz. Figure 1 shows the antennas before shipment from Owens Valley, CA. Five of the antennas are now located in the Tucson area. The sixth is located at the Rincon Research facility in Centennial, Colorado. Both organizations are interested in public outreach. This means that significant time will likely be available for amateur radio activities on at least two of the antennas.

Figure 1—Arizona Array Antennas. Each antenna is a fully steerable, 6.1 meter parabolic reflector that can operate up to ~300 GHz.

These antennas are particularly sensitive and suited for operation above 10 GHz. Current thinking is that the antennas will be configured to support 10.5 GHz Moon bounce, as well as to serve as ground stations for the CatSat satellite described below. Some, perhaps all, of the antennas will have cooled, low-noise, mmwave receivers suited for radio astronomy.

Suggestions about the use of these antennas for experiments, cis-lunar communications, etc., are invited. The first of these antennas should have been completed by now, followed quickly by two more.

b. Satellite

The second opportunity involves the launch of a 6U CubeSat, targeted for late 2020. The project named CatSat, after the UofA mascot, began in 2018 as a student-faculty design study in cooperation with FreeFall, Inc. The objectives of CatSat are twofold; (1) to serve as a technology demonstrator of a high bandwidth communications link from a smallsat and (2) to study high frequency (HF) propagation between the Earth's surface and low Earth orbit (LEO). To achieve a high bandwidth telecom link with the limited transmitter power available on a CubeSat, CatSat will utilize a new, deployable antenna invented at the UofA and further developed by FreeFall, Inc.

The antenna consists of an inflated Mylar sphere, where one hemisphere is metalized and the other remains clear. The metalized hemisphere serves as a spherical reflector that focuses the incoming radio waves passing through the clear side of the sphere to a focal line located ~1/4 of the sphere's radius in front of the metalized surface. A linefeed situated at the focus collects the radiation coming from different parts of the reflector and delivers it to a radio via a transmission line. A 3D CAD rendering of CatSat is shown in Figure 2.

The Arecibo Radio Observatory utilizes a very similar approach. There a linefeed collects radiation from a ~1000 ft spherical reflector. The Arecibo reflector is too large to physically move. However, the broad field of view of the spherical reflector allows the telescope to be pointed by moving the linefeed. For CatSat, a new phased array linefeed (PAL) was invented that enables the reflector's beam to be steered $+15^0$ electronically, thereby preventing the need to precisely control the orientation of the

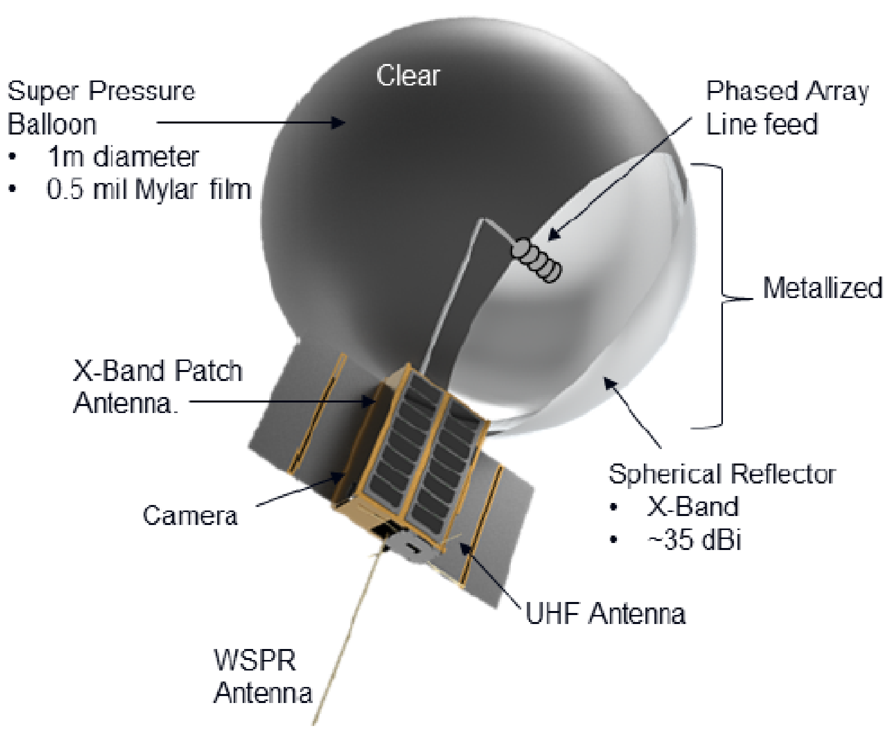


Figure 2 — CatSat Schematic. CatSat is a 6U CubeSat that will demonstrate a high bandwidth X-band telecom link using an inflatable spherical reflector. It will also probe the Earth's ionosphere by simultaneously monitoring WSPR signals from Earth from 5 to 30 MHz.

spacecraft to maintain a lock on a ground station. The inflatable antenna for CatSat is being developed and donated by FreeFall, Inc. An early version of the antenna that was tested from a NASA stratospheric balloon is shown in Figure 3.

As a demonstration of the power of such an antenna system, CatSat will downlink high definition images from space to the ground. For probing the Earth's ionosphere, CatSat will also carry a broadband receiving system that will be able to receive thousands of WSPR beacons or FT8 signals worldwide. The detections will provide a unique dataset that can be used to constrain models of the Earth's ionosphere and the effects of space weather.

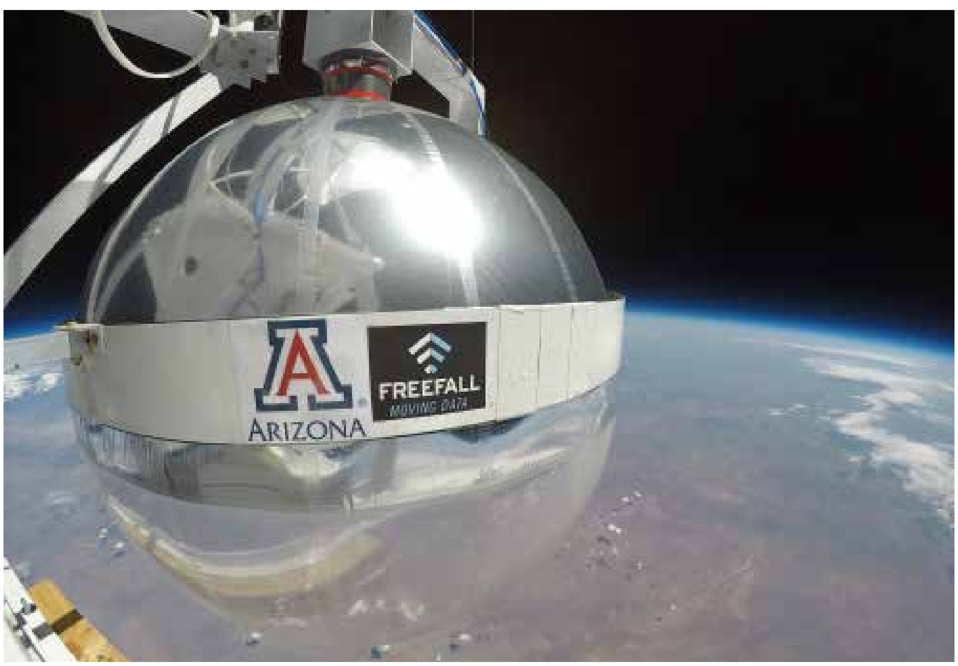


Figure 3 — Stratospheric Test Flight. The technology behind CatSat's inflatable spherical reflector was tested 30 miles up on a NASA high altitude balloon flight in August 2018. the Earth's ionosphere by simultaneously monitoring WSPR signals from Earth from 5 to 30 MHz.

By late 2018 several key design decisions had been made. Based on an inflated antenna diameter of about a meter and an operating frequency of ~10 GHz, a 3 dB beamwidth of ~2^0 is expected. This requires pointing accuracy of about 1^0. To observe antenna inflation, a still camera and low-gain downlink will be included. To add functional redundancy and demonstrate the benefits of a high-gain, inflatable antenna, CatSat will also have the ability to switch its microwave downlink signal between a low-gain patch antenna and the high gain, inflatable antenna. A UHF up/downlink will be used for command and control of the satellite.

In November 2018, a proposal to fly CatSat as part of NASA's CubeSat Launch Initiative program was submitted and approved. CatSat is now a candidate for a piggy-back launch opportunity to a ~500 km, sun-synchronous orbit in December 2020.

2. Time Passes

In late 2018 Rincon Research heard about the satellite project and offered to donate an AstroSDR, a powerful, single-board CubeSat radio. The AstroSDR is similar to the satellite radio planned for the original Phase 4B rideshare (see Figure 4). This board has now flown in space several times. Its high-performance FPGA must be programmed to utilize the unit's performance fully. However, the FPGA solves some problems and offers unique opportunities.

To meet the challenge of a December 2020 launch, the CatSat team is currently

Figure 4 — AstroSDR from Rincon Research Corporation. The board contains a software-defined radio (SDR), FPGA signal processor, ARM processor, and data storage.

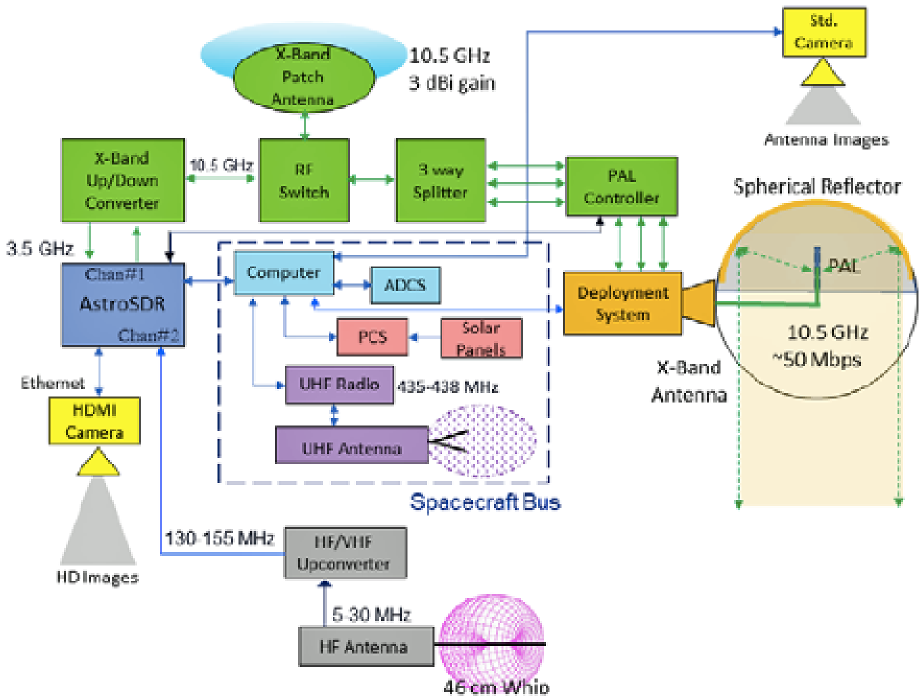


Figure 5 — CatSat Block Diagram. CatSat will be the first CubeSat utilizing a deployable, spherical reflector to establish a high bandwidth telecom link to relay high definition images to Earth. It will also utilize a state-of-the-art SDR to receive and relay WSPR signals recorded in orbit to X-band ground stations.

exploring the possibility of purchasing a 6U spacecraft bus. Several smallsat vendors can provide a 6U bus that meets mission requirements, thereby allowing the CatSat team to focus its efforts on developing the X-band and WSPR experimental payloads.

3. X-Band System

Since the AstroSDR can output any frequency up to 6 GHz, a 10.5 GHz transmitter can be implemented by using its output as a 1st IF frequency followed by up-conversion utilizing an oscillator driving a mixer with one or more amplifier stages. For example, an AstroSDR output at 3.5 GHz might be mixed with a 7 GHz local oscillator and the sum frequency of 10.5 GHz selected for power amplification. A block diagram of the satellite electronics as of early Sept 2019 is shown in Figure 5.

A computer-controlled switch provides the capability of routing the X-band output to either a low-gain antenna or the high-gain inflatable antenna. The low-gain antenna will be the primary communication path to most ham stations since the narrow beam of the inflatable antenna will only illuminate one city at a time.

Also, note that the diagram shows a 10.5 GHz receive capability in addition to transmitting. Exactly how this would be used, if implemented, is open for discussion. With the addition of the AstroSDR, the possibility of implementing a linear transponder 5.9 GHz up and 10.5 GHz down can be considered. This would be straightforward to implement using a 5.9 GHz LNA feeding the AstroSDR.

However, several factors should be considered. First, the narrow beamwidth of the 10.5 GHz high gain antenna in LEO would only cover one city at a time. To maximize spatial coverage, the low-gain spacecraft antenna would be used. This would, in turn, require precise pointing of narrow-beam ground antennas at the LEO to close the link. Second, Doppler compensation would be quite a project for the ground stations, since the frequency shift would be more than plus-minus 300 kHz. Third, the life-time of the satellite is projected to be ~1 year due to atmospheric drag. Given all the above, we believe that few hams would want to make the necessary investment of time and effort to utilize the transponder.

Finally, discussions with individuals who continued working on digital ground stations similar to the five and dime concepts associated with the defunct phase 4B rideshare revealed there is a desire for a system capable of onboard multiple access channelization of the uplink and onboard processing resulting in a single DVB-S2x downlink. This appears too complicated for CatSat to handle in the short time available before launch. Instead, the CatSat team proposes transmitting a DVB-S2x signal at 10.5 GHz for test and calibration purposes. At a minimum, CatSat could plan to transmit some stored DVB-S2x test patterns and, probably, also transmit still images or video from onboard cameras.

4. HF Ionospheric Experiment

Due to orbital motion, the transmitted signal from a WSPR transmitter on CatSat will be Doppler shifted. There could also be dispersive and refractive effects due to the ever-changing structure of the ionosphere.

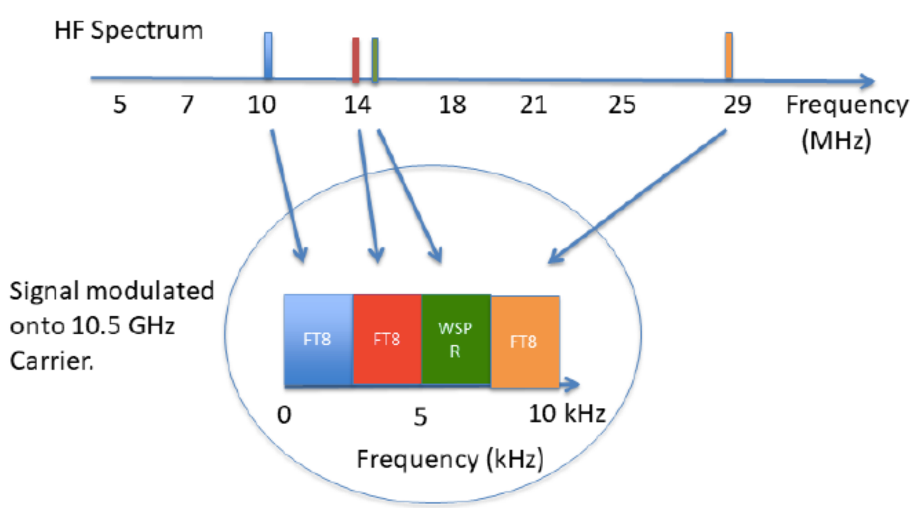


Figure 6 — Example of four 2.5 kHz channels spaced across the HF band being tuned by the AstroSDR and packed into a 10 kHz wide FDM signal for transmission to ground. Multiple simultaneous stations are typically seen in each 2.5 kHz channel.

Configuration	SNR		
	10 kHz BW Real-time HF or Frame Grab image	10 MHz BW Real-time TV or 50 KHz HF Sped up 200X to dump 33hr of HF in 10 min pass	500 kHz BW HF 50 kHz Sped up 10x Dump orbit In 10 minutes
Satellite omni to Ground 6.1m dish	39 dB	9 dB	22 dB
Satellite Hi Gain to Ground 6.1m dish	71 dB	41 dB	54 dB
Satellite omni to Ground 0.6m dish	18 dB	-	1 dB
Satellite Hi Gain to Ground 0.6m dish	50 dB	20 dB	33 dB
Satellite Hi gain to Ground 3 dB gain	16 dB	-	-

Table 1 — SNR performance of different satellite antenna and ground station combinations at 2,000 km range.

Therefore, the reception of a WSPR transmission from CatSat would require the receiving software to be modified to compensate for these effects. An alternative approach would be to receive WSPR signals on-orbit and relay them to ground using the 10.5 GHz downlink. Utilizing the wide bandwidth of the AstroSDR, it then becomes possible to receive all WSPR signals occurring in multiple HF bands. For example, a 125 MHz local oscillator can be used to upconvert the entire HF band from 5 - 30 MHz to 130 - 155 MHz. An AstroSDR tuned to 142.5 MHz would then have the whole HF band in its digitized passband. The FPGA programming in the AstroSDR can then select multiple narrowband segments, say 2.5 kHz wide containing signals of interest. For example, one might tune to WSPR activity on 20 meters with one 2.5 kHz passband while simultaneously listening to FT8 on 30, 20, and 10 meters. After all, "it's just software." The four digital receivers could then be combined into a four-channel frequency division multiplex signal with a total bandwidth of 10 kHz for transmission to ground over 10.5 GHz. The basic concept is diagrammed in Figure 6.

Alternatively, the four channels which are already digital could be combined into a time-division multiplex signal and digitally modulated onto the downlink and received at 10.5 GHz. The ground station could record the entire 10 kHz bandwidth and play it back, de-Doppler processing and demodulating one station at a time. Depending upon band conditions, each 10.5 GHz receiving station could copy dozens of HF ham stations on each satellite pass. Since the stations broadcast their location, propagation conditions from many sites to the satellite could be determined on many simultaneous frequencies. Serious experimenters spaced around the world could share recorded data to form a picture of propagation over the entire orbit of the satellite.

An alternative plan would be to store the 10 kHz wide FDM signal, or its TDM equivalent, in the AstroSDR's digital memory. Then, when in view of a high-performance ground station, it could be played back over the low-gain transmit antenna at 10 times the original rate (100 kHz bandwidth). In such a case, 10 minutes of transmitting would play back 100 minutes of the previous pass, an entire orbit around the Earth! With the high gain satellite antenna, this data compression approach can be used to significant effect. When the high gain satellite antenna is pointed at a high gain ground station, such as the 6.1-meter dish, one might play back at 1,000x (10 MHz bandwidth) the original collection rate.

Table 1 shows the performance of some possible combinations of satellite and ground antennas together vs. downlink bandwidth. One watt of X-band RF power was assumed. A 0.6-meter ground station antenna pointed at the satellite omni-directional antenna can easily support 10 kHz bandwidth of real-time HF or transmission of a frame-grabbed picture. If the satellite's hi-gain antenna were aimed at the 0.6-meter ground station, real-time TV could be supported.

A 10 kHz downlink could be established to a non-pointed antenna with hemispherical coverage. Downlink calculations include 3 dB polarization loss and 3 dB pointing error for each dish antenna. A gain of 35 dB is assumed for the satellite high gain antenna. A goal could be to record 50 kHz of bandwidth, equivalent to 20 simultaneous SSB receivers tuned across the HF ham bands for 24 hours. All the data could then be dumped in one 10 minute pass over Tucson. These data would cover the entire world and could be made available over the internet. So, a ham might log into a server and listen for her or his signal and other signals as heard by a satellite over the south pole and later in orbit over the equator.

This has the potential of being a powerful research tool. A researcher able to decode the transmitter info could know the location and strength of all signals being heard by the satellite as it orbits the Earth. And since multiple ham bands are being covered simultaneously, the info would be available as a function of frequency. To include multiple ham bands simultaneously will require a significant FPGA programming effort, but this is now our goal.

5. Summary

CatSat and the Arizona Array offer hams the opportunity to push the frontiers of technology in classic ham fashion. The inflatable antenna experiment and the Arizona Array of dishes are both on the leading edge of technologies that will be developed as spacecraft shrink and more space vehicles fly to greater distances. On the other hand, the HF experiment addresses questions about HF space-to-Earth propagation that have existed since some of us listened to Sputnik I with our ham radio receivers. The existence of a worldwide network of HF ham stations broadcasting their positions, combined with CatSat and the clever use of digital signal processing, will likely reveal unexpected phenomena. Given the creativity of hams, we expect CatSat will be just the beginning of another chapter in space exploration enabled by amateur radio.

ARISS Inter-Operable Radio System: Progress Toward Flight

Frank Bauer, Lou McFadin, Kerry Banke, Bob Bruninga, Bob Davis, Ken Ernandes, Ed Krome, Kenneth Ransom, Gordon Scannell, Mark Steiner, Dave Taylor

Introduction

The Amateur Radio on the International Space Station (ARISS) team hopes to fly the Inter-Operable Radio System (IORS) as a vital segment of the ARISS payload with elements flown on the ISS beginning in the year 2020. This equipment will be interfaced with other ARISS payload hardware and used on the International Space Station (ISS) to support the National Aeronautics and Space Administration (NASA) and other space agencies in space agency outreach, educational outreach, backup communication and experimentation. The ARISS IORS consists of a suite of amateur radio equipment designed to be employed in both the US Operating Segment and the Russian Operating Segment using either the 28 VDC or 120 VDC ISS power system. The IORS consists of a Kenwood D710GA amateur radio transceiver mounted to the Multi-Voltage Power Supply (MVPS), and the associated interconnecting cabling.

Objectives of upcoming changes to the ARISS equipment on the ISS will:

- Improve the Columbus Module downlink signal reception through a higher power transmitter.
- Enhance ARISS capabilities for educational contacts, every-day amateur use, and ISS backup communications
- Develop a standardized VHF/UHF radio and power supply system that will be inter-operable across all ISS Segments and modules, including both the U.S. and Russian segments.
- Certify, launch, install and operate a JVC Kenwood system with an ARISS/AMSAT-built inter-operable power supply and supporting cabling.

Mission Overview

ARISS is a long-running program using amateur radio equipment onboard the ISS to involve students exchanging questions with astronauts on orbit. More than 1000 organizations have participated since the payload was first turned on in November 2000. Organizations include schools, museums, scouting events, and special events. It is also used to perform communications experiments with amateur radio operators on the ground. NASA's intent in having astronauts take part in ARISS is to involve the largest possible number of people, particularly youth, in Science, Technology, Engineering, Arts, and Math (STEAM) education in conjunction with the U.S., Russian, European, Canadian and Japanese space programs and through the help of amateur radio operators around the world. ARISS also serves an essential function as a tertiary backup in the event of communications outages on the U.S. and Russian sides.

Through ARISS, astronauts make scheduled and unscheduled amateur radio contacts with schools, random contacts with amateur radio operators, and contacts with astronauts' families. A few schools are selected from around the world for scheduled contacts with the ISS crew, after completing a comprehensive proposal that indicates a plan most consistent with ARISS educational goals. Scheduled contacts give the schools a 95% chance of achieving success. Ten or more students at each school ask the astronaut questions. The nature of these contacts embodies the primary ARISS goal of inspiring and educating students to pursue STEAM careers.

Progress Toward Flight Readiness

The IORS, under the leadership of Principal Investigator Frank Bauer, has made significant progress toward flight readiness:

- Final testing (i.e., power quality and acoustic) of the IORS flight identical hardware was completed July 15, 2019.
- The Russian segment JVC Kenwood flight and training transceivers were delivered to Russian team member Sergey Samburov on July 27, 2019.
- The first flight MVPS was constructed and underwent testing at JSC in November 2019. This testing included abbreviated power quality and acoustic tests, including bonding and grounding tests and relevant safety assessment testing. These tests verified that the flight unit matched the flight identical hardware and was ready for flight.
- Throughout 2019 and continuing in 2020, ARISS has worked on system and safety verifications designed to show that our equipment is safe for use aboard ISS. The Phase 1 and Phase 2 Safety reviews were held last year; the Phase 3 (and final) Safety Review is scheduled in mid-February.
- The remaining MVPS hardware (including Russian flight, flight backup, and training units) is under construction and integration. This will be a continuing process for many months.

The first IORS system has been approved for launch on the SpaceX CRS-20 resupply launch (currently scheduled for March 2). This system is destined for the Columbus module, replacing the existing Ericsson HT and packet system. Because some safety and engineering verifications remain to be closed, the system initially may be put in storage aboard ISS, but certification and installation is anticipated soon after.

MVPS Power Certification at Both 28/120 Volts

Electromagnetic Interference/Electromagnetic (EMI/EMC) tests were performed at Johnson Space Center (JSC) in July 2019. The Kenwood D710GA and

Figure 1 — EMI Test Configuration.

TABLE 4.1: SSP 57000					
EMI TEST	**DESCRIPTION**	**Input Power**	**Configur ation**	**COMPLY? Y/N**	**NOTE**
CS01	30 Hz - 50 kHz, Power Leads	28Vdc	A	Y	Test
			B	Y	Test
CS02	50 kHz - 50 MHz, Power Leads	28Vdc	A	Y	Test
			B	Y	Test
CS01	30 Hz - 50 kHz, Power Leads	120Vdc	A	Y	Test
			B	Y	Test
CS02	50 kHz - 50 MHz, Power Leads	120Vdc	A	Y	Test
			B	Y	Test
CS06	Spike, Power Leads	28Vdc	A	Y	Test
			B	Y	Test
CS06	Spike, Power Leads	120Vdc	A	Y	Test
			B	Y	Test

Figure 2 — Excerpt of IORS EMI Test Results.

MVPS were found to be compliant with the NASA JSC standards, specifically those found in SSP 57000 EMI requirements for CS01, CS01, and CS06.

The EMI test configuration is shown in figure 1. Figure 2 is an excerpt from the EMI test results.

MVPS Acoustic Testing

The acoustic testing performed at JSC was done with the MVPS configured for maximum fan speed, which showed that the fan noise exceeded the permissible level for continuous operation and would be allowed for 8 hours/24 hours operation. NASA sent on-loan an acoustic measurement setup to our ARISS team in San Diego for additional acoustic testing under simulated realistic operating conditions rather than the worst-case tested at JSC. These results have been forwarded to JSC, and we are waiting for analysis by NASA. After NASA's evaluation is complete, we may need to work out an operating schedule based on their analysis and the needs of ARISS.

Figure 3 is the IORS test configuration at JSC. Figure 4 is the acoustic measurement

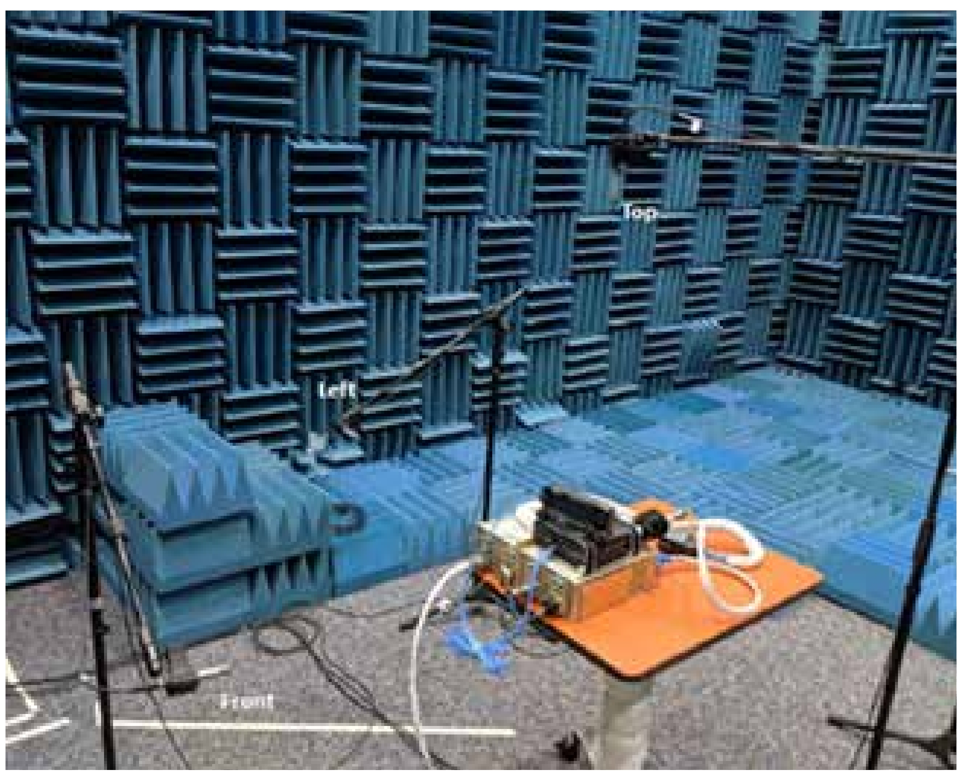
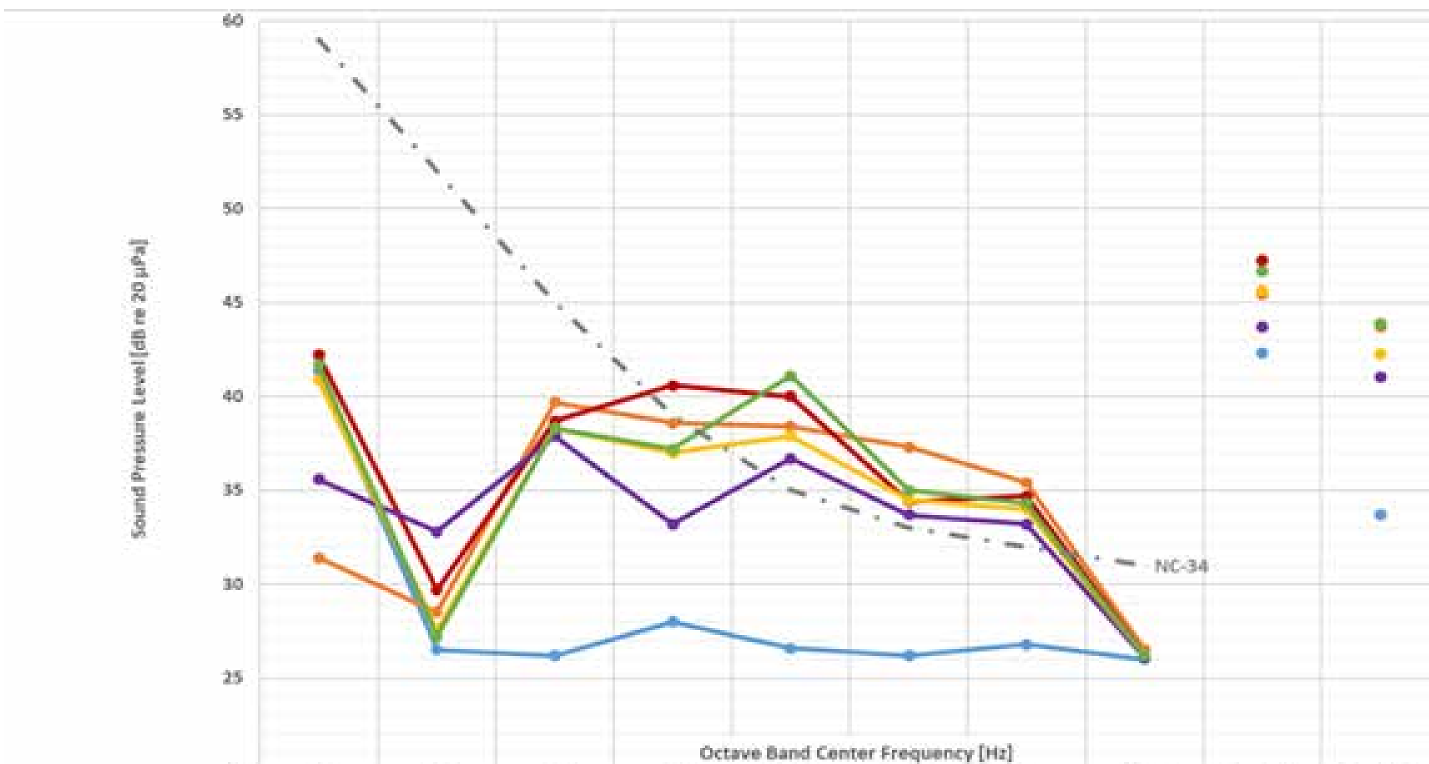


Figure 3 — IORS Acoustic Test Configuration at JSC.

Figure 4 — NASA Acoustic Test Equipment.



	63	125	250	500	1000	2000	4000	8000	Overall L	Overall LA
Background	41.4	26.5	26.2	28	26.6	26.2	26.8	26	42.3	33.7
Full Speed	31.4	28.5	39.7	38.6	38.4	37.3	35.4	26.5	45.4	43.7
Digital Mode	42.2	29.7	38.7	40.6	40	34.4	34.7	26.2	47.2	43.8
Repeater Mode	35.6	32.8	37.9	33.2	36.7	33.7	33.2	26.1	43.7	41.0
Voice Mode (10 min)	40.9	27.5	38.3	37	37.9	34.5	34	26.2	45.6	42.2
Voice Mode (2 hours)	41.7	27.2	38.3	37.2	41.1	35	34.3	26.2	46.7	43.8
NC-34	59	52	45	39	35	33	32	31		

Figure 5 — IORS Tested Worst-Case Sound Pressure Levels.

equipment loaned by NASA JSC for follow-on acoustic tests in San Diego.

The data is taken at octave frequency intervals over a 20 second period. The San Diego tests were performed using voice, digital mode and repeater mode operation. Table 1 is an example of the San Diego data:

An Arduino was used to control the radio transmit function as follows:

#1 Voice mode - 60 seconds on/90 seconds off tested after 10 minutes and 2 hours
#2 Digital mode – 2 seconds on/2 seconds off tested after 2 hours
#3 Repeater mode – 20 second on/1 second off/20 seconds on/50 seconds off tested after 2 hours

Figure 5 shows the ISS-HAM IORS sound pressure levels during its loudest operation as tested at NASA JSC.

MVPS Touch Temperature Test

Early in the MVPS project, a series of tests were performed to ensure the selected cooling fans were adequate to meet the NASA temperature and acoustic noise requirements.
The touch temperature test ensures no externally-exposed MVPS surfaces can reach a temperature that could cause a burn or other injury to a crew member. The temperatures are measured after operating at the most extreme end of the normal operating conditions, including the Kenwood D710GA transmitting in a high duty cycle digital mode being the most severe. All transceiver operating modes are tested. The transceiver is mounted in the flight configuration on top of the MVPS, as shown in figure 6, which also indicates the location of the temperature measurement sensors.

The NASA temperature standard for continuous human contact is a maximum of 45°C (or 113°F). However, since the MVPS has no external controls other than switches, a separate Hot Permissible Material Temperature (TPM) was computed for incidental and intentional contact of one second or less. The computed TPM for the MVPS was 72°C (or 161.6°F). The ARISS team nevertheless opted for the IORS hardware to be tested to the more stringent (i.e., cooler) 45°C standard.

The sensor locations and descriptions are as follows:

- "T1 SS fin" is a TMP36 solid-state sensor clamped to the top center fin of the heatsink on the side opposite the fan air inlet. This is a human-accessible touch temperature. It is always the second curve down from the top of the graph.- "T1 TC int" is a type K thermocouple epoxied into a drilled recess near the above-referenced heatsink internal to the MVPS and not human-accessible. Signal is conditioned by an Adafruit AD8495 amplifier.
- "T4 SS fin" is TMP36 as above but in the fins of the heatsink on the same side as the fan inlet. This sensor is also human accessible.
- "T4 TC int" is a thermocouple internally mounted to the same heatsink as "T4 SS fin."

The touch temperature tests were performed both with loads cycled according to Kenwood D710GA published operating profiles and at a continuous load (i.e., "brick on key") conditions. There are three Kenwood-defined loading profiles. These include the 25-watt voice, 10-watt digipeater, and 5-watt repeater operation. The MVPS temperatures remained well within acceptable levels for these tests.

Figures 7 through 9 are the plots of the temperature results. Specifically, figure 7 provides the temperature results for the 25-watt voice mode, figure 8 provides the temperature results for the 10-watt

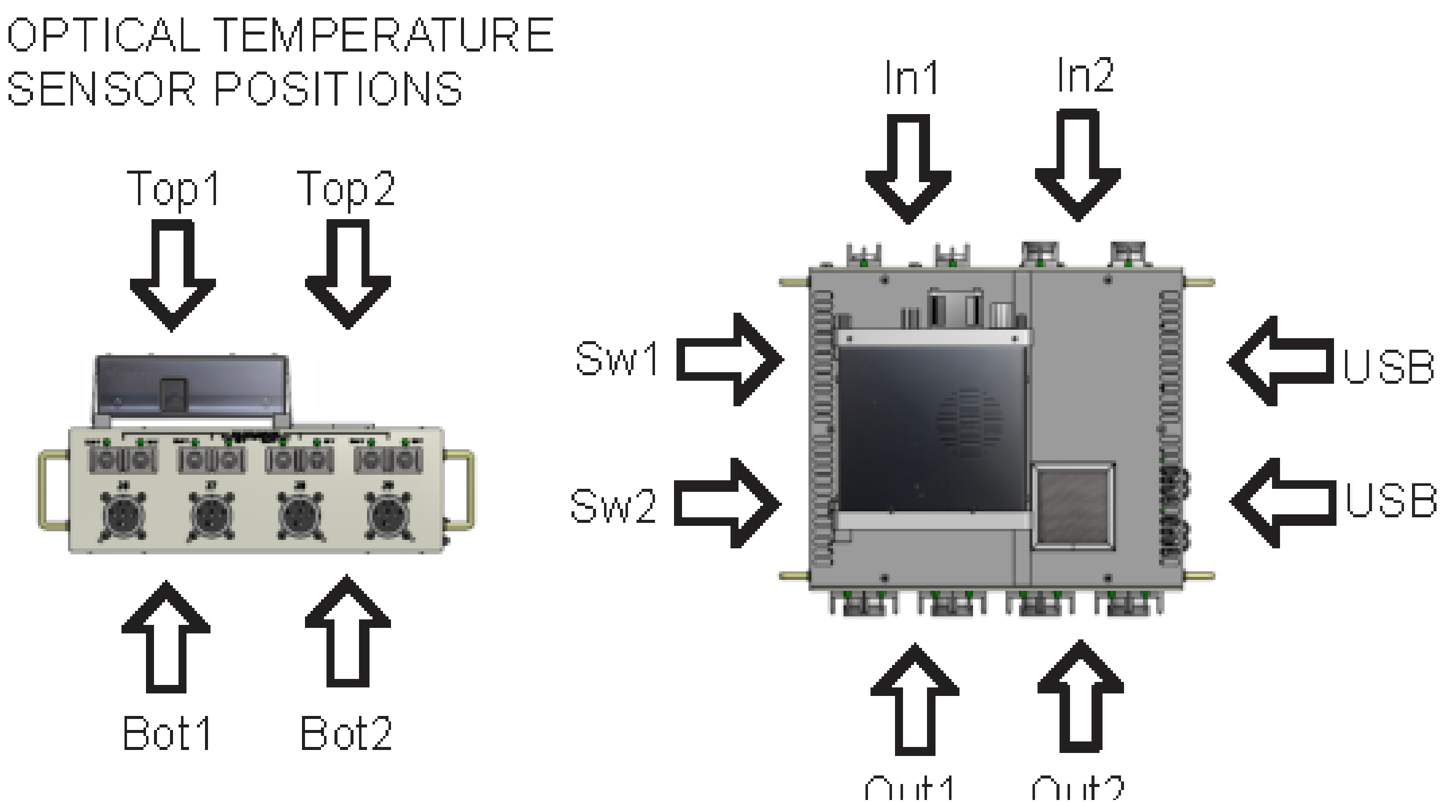


Figure 6 — MVPS Touch Temperature Sensor Locations.

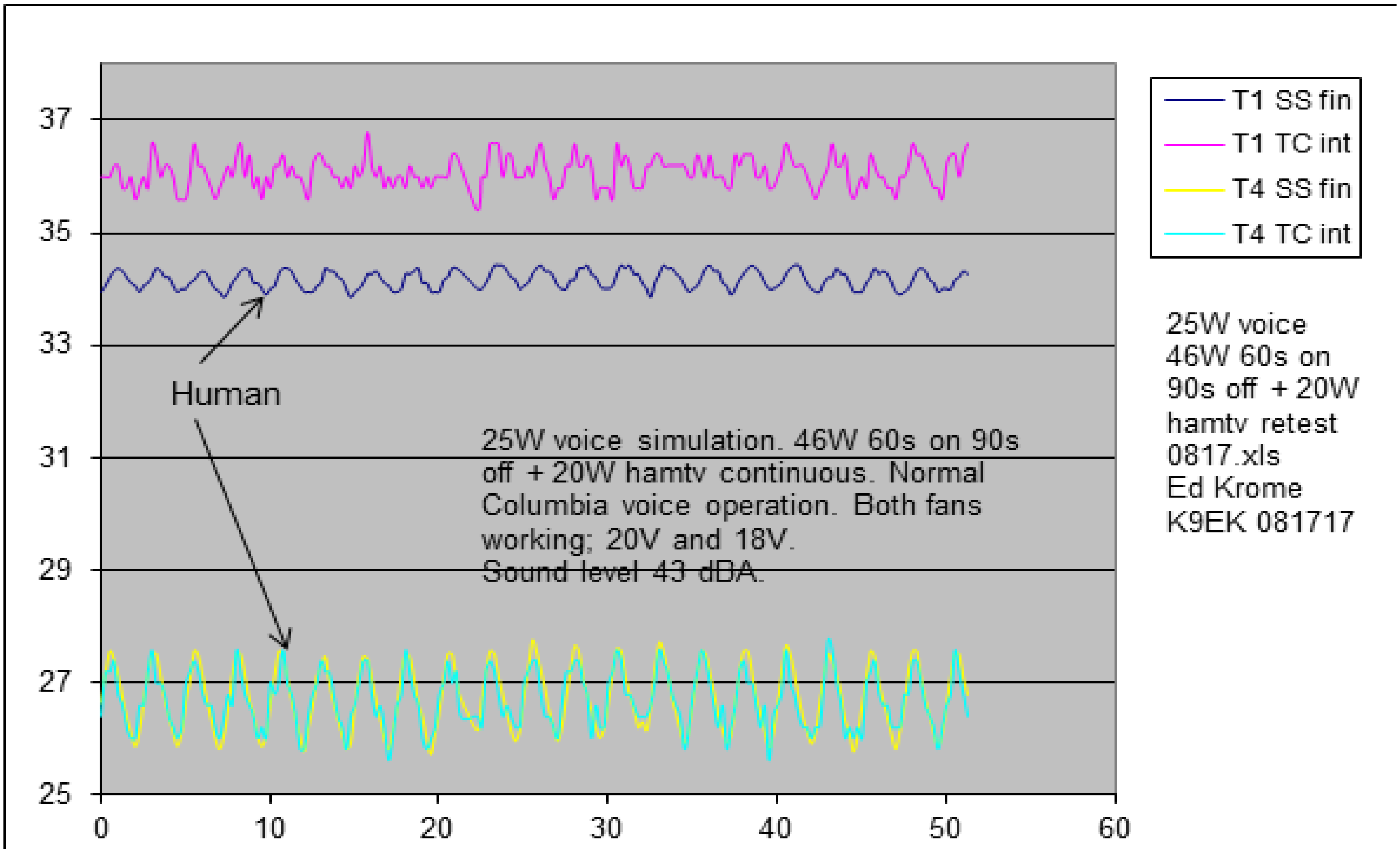


Figure 7 — Temperature Results for the 25-Watt Voice Mode.

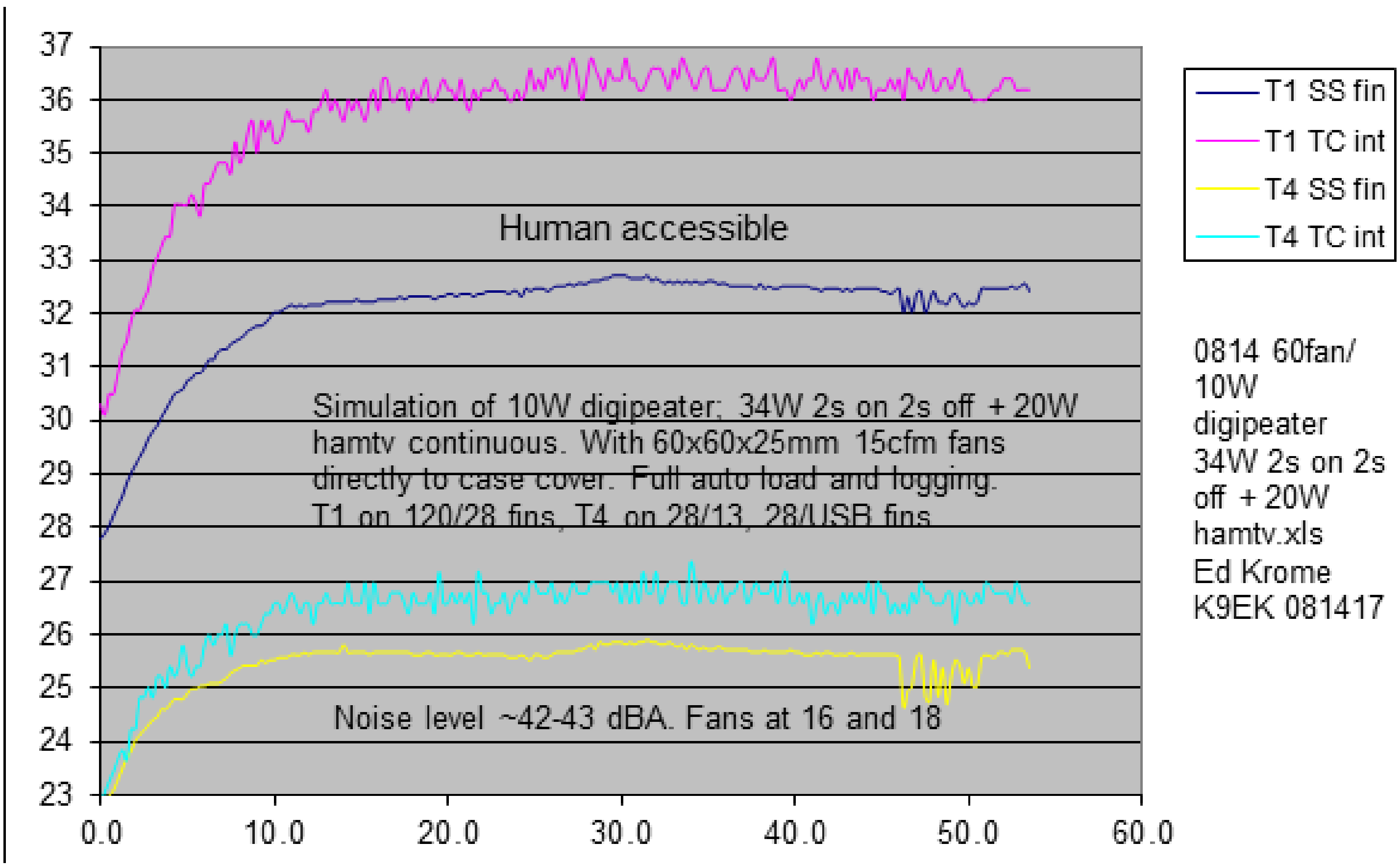


Figure 8 — Temperature Results for the 10-Watt Digipeater Operation.

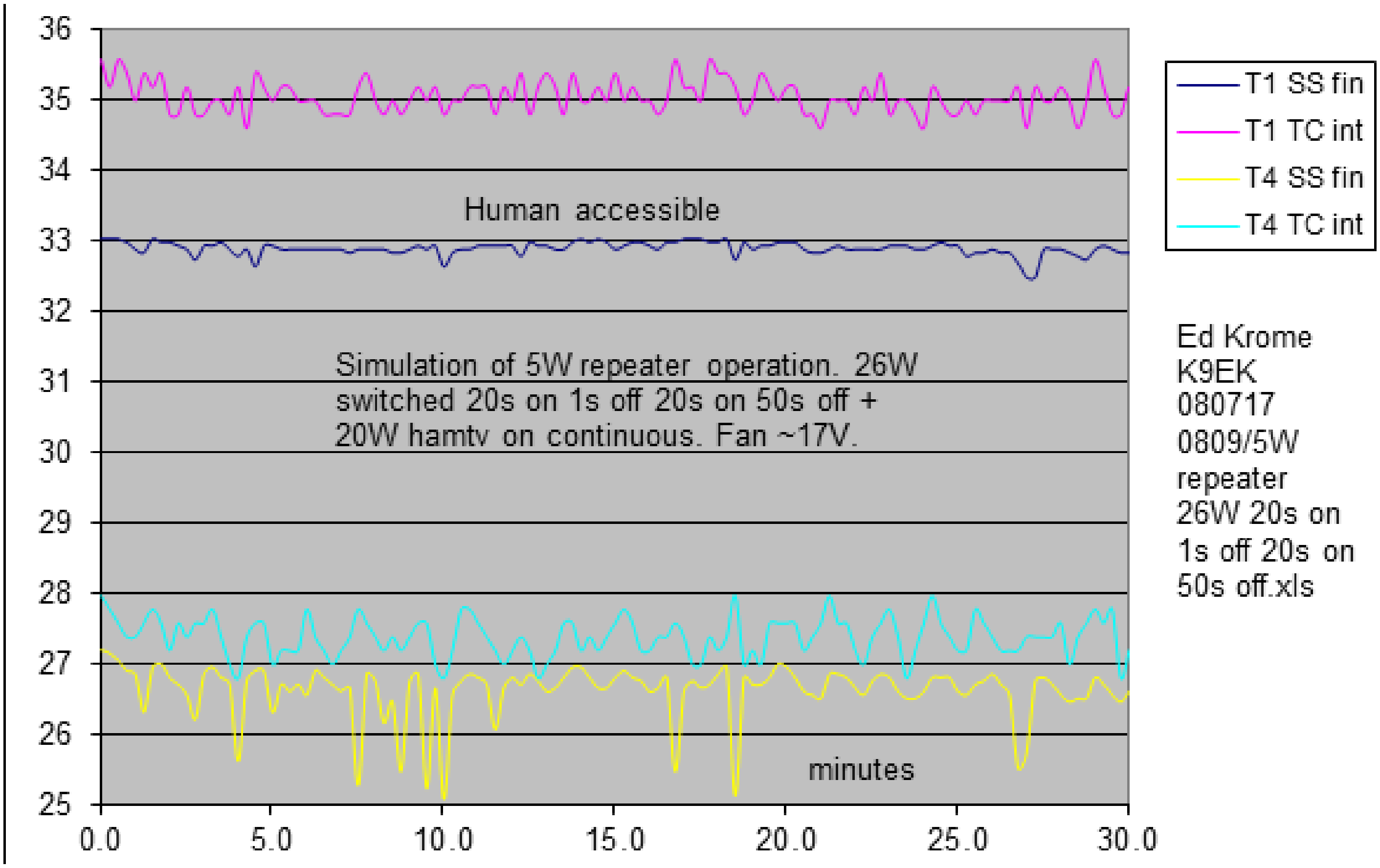


Figure 9 — Temperature Results for the 5-Watt Repeater Operation.

digipeater mode, and figure 9 provides the temperature results for the 5-watt repeater operation.

Kenwood D710G Transceiver Firmware Programming

The transceivers were updated to the latest custom ARISS firmware from JVC Kenwood in April 2019, in preparation for testing at Johnson Space Center. Three units (S/N 1005, 1006, and 1008) were programmed by Dave Taylor, Kenneth Ransom, and Bob Bruninga during firmware development. Ken Ernandes programmed the remaining seven units in possession of ARISS Chief Engineer Lou McFadin. These included the two U.S. flight units (S/N 1001 and 1002) and the two Russian flight units (S/N 1003 and 1004). This is a relatively automatic process, though there is a manual selection to distinguish between the U.S. and Russian software configuration. Figure 10 shows the U.S Flight Unit #1 in the process of being programmed to the latest firmware version.

NEW INTER-OPERABLE RADIO SYSTEM (IORS) HARDWARE

The new IORS system enhancements include:

- Higher power downlink improves school contacts, SSTV downlink and APRS operations
- Improved audio during voice contacts
- Reduced system downtime through a dedicated power supply
- More robust soft/firmware in the radio system to prevent accidental programming and reduce repeater mode command steps
- Upgraded JVC Kenwood D710 fan supports continuous repeater mode operations
- Sharing of hardware resources across modules when failures occur
- Common operations and training across US and Russian segments
- Supports future system developments
- Support for additional radios and accessories.

The new IORS equipment consists of a JVC Kenwood D710GA transceiver, a Multi-Voltage Power Supply (MVPS), and interconnecting cables. This hardware will be interfaced with some of the legacy ARISS equipment to transmit and receive through the legacy antenna systems. The intent is to have an inter-operable system with components that will be certified and can be operated anywhere on ISS, but specifically will be used in the two areas with ARISS legacy antennas: the US Columbus Module and the Russian Service Module. Interoperability provides the following advantages: it leverages existing ISS power cables, it can be moved between modules in the event of on-orbit failures, and it allows for common training and operations.

IORS Transceiver

The JVC Kenwood D710GA transceiver, shown in figure 10, is a spaceflight modified version of this commercially-available product. The key safety modifications to this transceiver are the reduction of the maximum radiated power from 50 W to 25 W (through a hardware design modification by JVC Kenwood) and installation of a more robust (higher volume) cooling fan to reduce thermal load.

IORS Power Supply

The MVPS is custom designed for the ARISS system, with Kerry Banke performing the electrical design and Bob Davis performing the mechanical design. Figure 11 is an MVPS block diagram. The MVPS is equipped with two (2) voltage inputs, supporting 28 VDC and 120 VDC

Figure 10 — U.S. Flight Unit 1 Being Programmed.

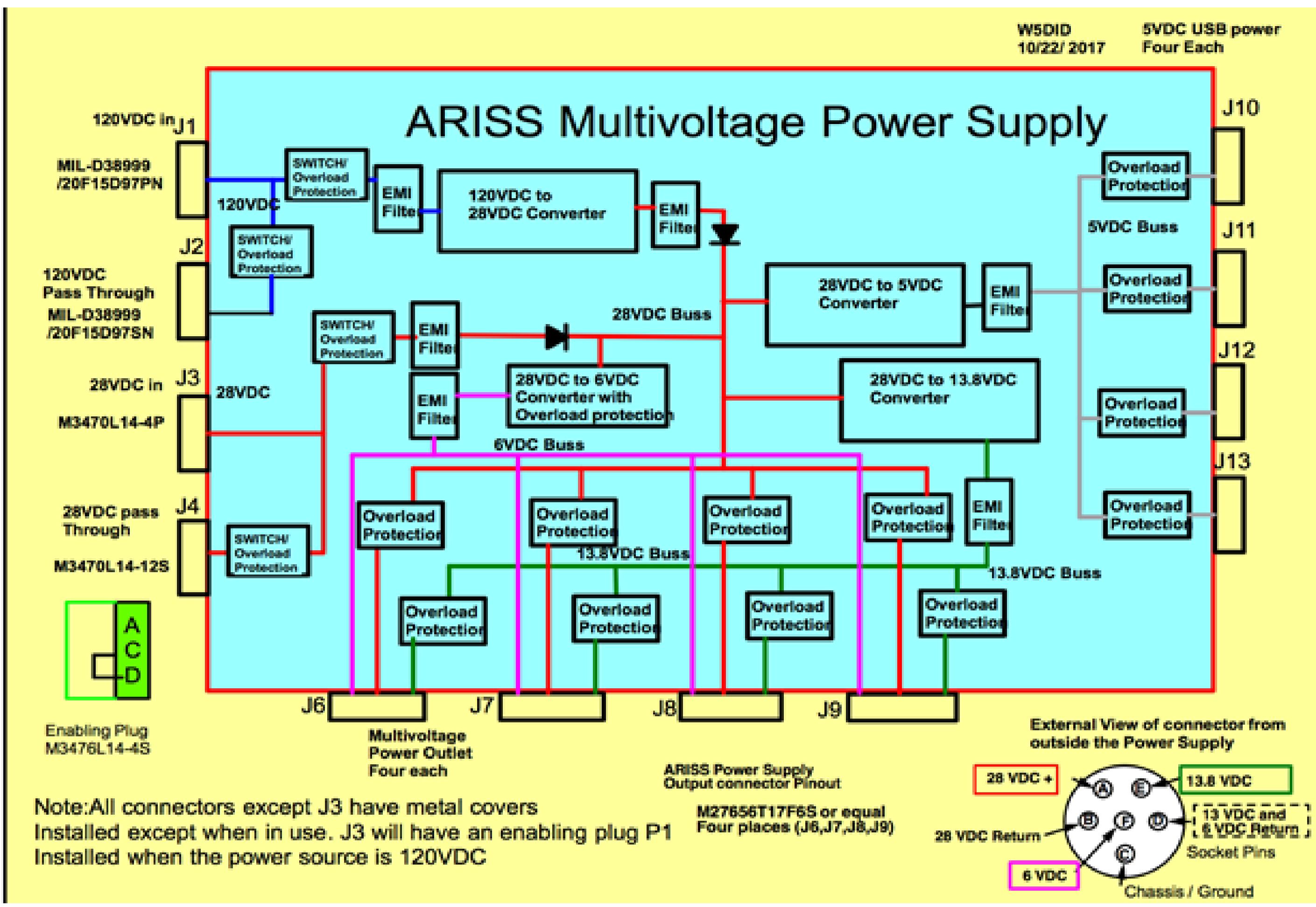


Figure 11 — IORS Multi-Voltage Power Supply (MVPS).

Figure 12 — MVPS with JVC Kenwood D710G Transceiver Mounted.

ISS power systems. The MVPS includes four (4) multi-voltage outputs, plus four (4) Universal Serial Bus (USB) power ports. Figure 12 is a photograph of the flight identical MVPS with a Kenwood D710GA mounted in place. The transceiver is mounted via Velcro straps. There is one 120 VDC input that supports USOS module use and one 28 VDC input that supports RSOS module or USOS use. Each of the two inputs is equipped with a pass-through output to allow further equipment to be powered from ISS power via the MVPS, without having to remove power connections to the MVPS. The MVPS includes an integrated mounting bracket that allows the Kenwood D710GA radio to be mounted directly to the power supply via Velcro straps.

IORS OPERATING MODES

This section provides a brief description of the ARISS operating modes with the new IORS equipment installed. This is generally presented from the perspective of the ground operator. Details and updated information will be provided on the ARISS web site, www.ariss.org.

Voice Contacts

The ARISS system will continue to support two-way FM voice contacts pre-scheduled for schools as well as random amateur contacts (25 Watts). The voice downlink frequency for random contacts is 145.80 MHz (worldwide). The voice uplink frequency is 144.49 MHz for ITU regions 2 and 3 (the Americas, Pacific, and Southern Asia) and 145.20 MHz for ITU region 1 (Europe, Russia, and Africa). Amateurs are cautioned not to transmit on the ISS downlink frequency. The voice contacts are split mode, so the crew listens on the uplink frequency and transmits on the downlink frequency. Thus, the crew will not hear operators transmitting on the downlink frequency. The most this will accomplish is making such an operator unpopular with others monitoring the downlink and/or attempting contact.

Cross-Band Repeater Operations

The JVC Kenwood D710G transceiver is also capable of operating as a cross-band repeater (5 W). This operating mode will make the ISS an FM "easy sat" with an added bonus. The ISS crew will be able to join conversations occurring between ground stations in this repeater mode. The cross-band repeater capability was one of the drivers in the more robust thermal design in the D710GA.

The uplink frequency will be in the 145.990 MHz (67 Hz PL), and the downlink frequency will be in the 437.800 MHz.

Digital Communications

The IORS will have a packet digipeater. This will continue operations on the 145.825 simplex frequency, but will no longer support a BBS.

Summary

The ARISS IORS has made significant progress toward flight-readiness. The flight-identical hardware has been through a rigorous set of testing to ensure compliance with NASA safety and operational suitability standards for human-occupied spacecraft. The flight hardware is currently being fabricated and will undergo an abbreviated set of tests to ensure it functions consistently with the flight-identical hardware. Following a successful system and safety verification closeout and final safety review, the ARISS IORS is expected to be declared flight-ready by the end of 2019 or in early 2020. The ARISS IORS team is pleased to be providing a new and highly-capable amateur radio station onboard the ISS that will offer enhanced and exciting contact opportunities for both scheduled school contacts and general amateur use.

Introducing HuskySat-1

Drew Glassbrenner, KO4MA, Vice President Operations

Let's get acquainted with HuskySat-1, the University of Washington's first satellite! The 3U CubeSat was launched on a Cygnus cargo spacecraft to the International Space Station on November 2, 2019. Designed, built, and tested by the Husky Satellite Lab, the satellite will test two experimental payloads, a pulsed plasma thruster using sulfur propellant, and a 24 GHz downlink system. It also carries a low-resolution camera system built in collaboration with Raisbeck Aviation High School in Tukwila, Washington. By the time you read this, HuskySat-1 should have deployed from the Cygnus cargo spacecraft after departing from the International Space Station in late January and raising its 51.6-degree inclination orbit to 500 km altitude. This orbit-raising maneuver before the deployment will ensure a longer lifetime for the mission, before disposal by atmospheric reentry.

HuskySat-1 carries an AMSAT built and designed radio based on the Fox-1E linear transponder, referred to as COM1. Comprised of 90mm by 92mm boards, the three board radio stack also includes a version of the Fox-1 IHU to convert signals to the host system, including CAN, I2C, SPI, Serial, or discrete GPIOs. This radio provides the primary command uplink and telemetry downlink for the satellite, as well as a 30 kHz wide linear transponder for use after the primary mission is completed. The AMSAT telemetry beacon onboard HuskySat-1 is a 100 mW, 1200 baud BPSK signal at 435.800MHz. This beacon carries all of the spacecraft telemetry and is compatible with the latest release of the FoxTelem software. This compatibility means amateur stations around the world can collect and submit telemetry along with that obtained from the Fox-1 satellites. The 24 GHz beacon on Huskysat-1 (COM2) sends a test file at 1 Mbps at 24029.00 and is active only when commanded from the ground.

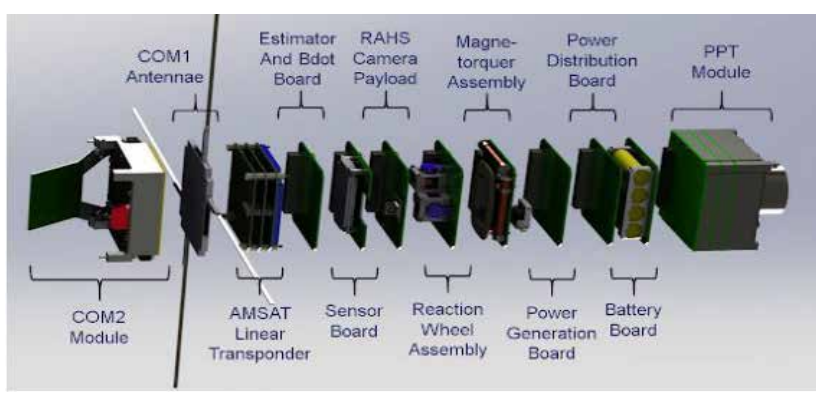
Licensed to the Husky Satellite Lab under a Part 5 Experimental license from the FCC, the satellite will be turned over to AMSAT to be operated under Part 97 Amateur rules after the primary mission is completed. After the transfer, AMSAT will activate the linear transponder for use by amateurs worldwide. The transponder is based on the Fox-1E transponder design and is a 30 kHz wide, inverting linear transponder designed for SSB and CW usage. However, some time for digital mode experimentation is envisioned after commissioning is complete. The transponder output power is approximately 450 mW maximum. The uplink for the transponder is 145.910 to 145.940 MHz, and the downlink is 435.810 to 435.840 MHz. These frequencies are shared with the aging FO-29 satellite. Operation should be very similar to FO-29, although the Doppler shift will be somewhat faster due to the lower orbit of HuskySat-1. Portable stations should find this an easy satellite to work, with non-computer controlled stations tuning the 70 cm downlink for Doppler shift by ear.

Based on initial discussions dating back to 2014, the AMSAT-UW collaboration is the first of a series of projects where AMSAT provides the radio system for a university mission, and the university agrees to operate the transponder in return. John Klingelhoeffer, WB4LNM, led the RF design, with Marc Franco, N2UO, responsible for the amplifier, Dan Habecker, W9EQ, for the RF assembly and tuning, Eric Skoog, K1TVV, for the command receiver, and Chris Thompson, G0KLA/AC2CZ, for the telemetry modulator. Bdale Garbee, KB0G, modified his previous IHU design to serve as the interface, and Burns Fisher, WB1FJ, and Carl Wick, N3MIM, were responsible for the software.

UW team members include Robert Winglee, Nathan Wacker, Paige Northway, Paul Sturmer, Anika Hidayat, John Correy, and Eli Reed.

HuskySat-1 flight model.

HuskySat-1 AMSAT radio, above, with exploded view below.



The Kylee Chronicles: A Youngster's Odyssey into the World of Amateur Radio Satellites

Randy Shirbroun, ND0C

The Early Years

My daughter, Kylee, has demonstrated a fascination with amateur radio since she was old enough to sit at the operating desk with me. At the young age of 18 months, she enjoyed sitting beside me as I worked DX or contested. Typically, I wear a headset with a boom microphone, so I put in a splitter to allow her to have her own little pink headset. This eventually progressed to occasionally abandoning the headsets and using a handheld microphone to facilitate Kylee saying "hi" to the other operators during casual operating.

When Kylee was about five years old, we got on the air in the School Club Round-Up, and she made several contacts herself, start to finish. She learned very quickly to run the "push-to-talk" button on the mic by herself. (We had done some practicing off-air.) Of course, I coached her on the proper exchange and the correct phonetics to use. She seemed to enjoy making contacts and was thrilled when stations would reply to her call and ask her age. Interestingly, she never exhibited the least bit of "mic fright." I sent QSL cards out for her contacts, and she enjoyed getting cards back in response.

Over the last several years, I have become very active in Summits on the Air (SOTA), initially as a "chaser" working operators perched on summits across the U.S. and in Europe while running QRP power levels typically. The rare opportunity to "activate" some summits myself allowed me to combine our family love of hiking in the mountains with QRP portable operating.

Amy, my wife, and Kylee would typically check out the views or rock-hunt a little while I spent about 45-60 minutes operating from a summit. Kylee also served as a very exuberant ambassador of amateur radio to the other hikers on the summits. The antenna attracted attention and generated questions such as "what is this?" or "what is he doing?" while I was engrossed in working stations contest-style. Kylee would answer for me, saying, "this is ham radio." Soon she was announcing that fact to all hikers arriving on the summits, whether they wanted to know or not!

Kylee, KE0WPA, and her dad, Randy Shirbroun, ND0C in their shack.

In the summer of 2014, after I had purchased a new Yaesu FTdx3000 for my station, I set up my old FT897D transceiver in Kylee's "toy room" and rigged up a dedicated dipole antenna and tuner. She was able to do some listening, learning how to handle a rig and practice tuning in SSB signals whenever she wanted, whether I was around or not. She didn't get a microphone!

In the days leading up to the 2014 ARRL 10 Meter Contest, I decided I'd let Kylee do the operating with my assistance in tuning and logging. We only operated a couple of hours, but she had a blast — and so did I! We operated in the ARRL's Kid's Day Activity, and she enjoyed talking to other young people, but none were as young as she was.

The following year she operated in the Minnesota QSO Party (MNQP) while I served as the control operator, of course. She was able to generate some nice "runs" and was so relaxed and comfortable that at times I noticed she was slumped way down in her chair, nonchalantly petting the cat lying beside her while she was working stations.

Several operators, recognizing Kylee's youthful voice, would ask her age and took the time to give her compliments like: "you're doing a great job." That was very sweet, and she would beam when she heard those comments. It seemed that the voice of a young girl added a few dB to the five-watt signal!

Getting a License and Discovering Satellites

With Kylee's enjoyment of operating, it was apparent what the next step should be. In the summer of 2018, she used some conventional books and flashcards to study for her Technician license. She has difficulty maintaining focus and avoiding distractions, and this study protocol proved to be less than ideal for her learning style. But she battled through and took the exam in August 2018. Unfortunately, she missed a passing grade by only one question. She was heartbroken, but with the school year just starting, that took priority, and life moved on.

As she had been working towards the Technician exam that summer, I had some concerns regarding the limitations she would face with the Technician privileges. I've enjoyed operating on six meters during the summer Es season, but that would only give her limited, and by its very nature, sporadic, opportunities to operate. And of

Kylee, KE0WPA, on Whistler Peak.

course, ten-meter propagation has practically not existent as we are bogged down in the doldrums of the sunspot minimum.

My ham radio experience of 50 years has been limited to HF and six meters, focused on QRP DXing, contesting, and SOTA. I have always been intrigued by satellite operations and even EME but had never seriously explored either. But in one of those "duh!" moments, it occurred to me that satellites offered Kylee an excellent opportunity for a lot of on-the-air activity with the privileges of a Technician license.

About six weeks after Kylee failed to pass her exam, I thought I would explore this world of LEO FM satellites more seriously for myself. I ordered a very inexpensive Yaesu handheld transceiver and an Arrow II antenna. I did my homework by reading the AMSAT book and watching a couple of YouTube videos. Then, I walked out onto my driveway one evening in early October 2018, aimed the antenna to where AO-92 was supposed to be, and amazingly I heard the satellite! And even more incredulously, I made a couple contacts on that first pass!

My intent in playing with the birds was to find out if this was something that would make sense for Kylee. If so, I would use it as an incentive to convince her to "get back on the horse" and make another effort to get her license. It didn't take long for me to realize that this would be perfect for her. A notable side-effect was that I got hooked on the FM satellites! This was pretty cool stuff!
In 2018 I had organized a school ham radio club (W0WCS) at Kylee's school. I set up an HF station in the school to operate primarily during School Club Roundup, but also during some other contests as well as just casual operating. Once I started playing with the birds, we also put W0WCS on the air to get satellite contacts, both to demonstrate that new aspect of the hobby to the kids and allow Kylee specifically to get the hang of operating on the sats.

In the spring of 2019, I bought Kylee an online Technician study course. We thought the style of learning and the use of an iPad would appeal to her – mostly a generational thing, I think. So that summer, she worked on it, with a lot of help from her mom, to remind her to do it daily and to help minimize distractions. Well before the exam date, she was demonstrating an excellent knowledge of the material, so we were all confident in the outcome – but also aware of the role that test anxiety might play.

In August 2019, I had several business meetings requiring out of state travel. As a result, I was not able to go with Kylee and her mom on the 60 mile trip to Sioux Falls to

take her exam this time. But she sure didn't need me; she had the material down cold. She blew through the test in ten minutes and missed only one question, passing with flying colors.

Two days after Kylee passed the exam, we left for an 18-day camping expedition, traveling west through South Dakota, Wyoming, and up through Montana to Alberta. After several days in Glacier, Banff, and Jasper National Parks, we headed back home through Saskatchewan and North Dakota. With the prospect of roving through many rare and semi-rare grids, I took the radio and the Arrow – it was too good an opportunity to pass up!

About a week into our trip, we started to check the FCC website each evening, looking for official confirmation of Kylee receiving her license and, of course, to find out what her call sign was. Then one night in a campground in Alberta, there it was. She was the proud holder of call sign KE0WPA! And of course, she got on the very next FM LEO satellite pass, operating portable VE6.

An exciting phenomenon followed: all of a sudden, it was KE0WPA that did virtually all the operating and roving the Canadian grids we traveled, making well over 100 contacts in just a few days She even did a SOTA activation from the summit of Whistler's Peak by satellite!

Although school and related activities limit her on-the-air activity, she has maintained her high level of enthusiasm for working the birds. Her chief complaint is holding that Arrow when standing out in the cold Minnesota winter wind. I'm not too fond of that either. I drilled a series of holes in the boom to make it slightly less cumbersome for her.

By mid-December 2019, Kylee had 85 confirmed grid squares in her quest for VUCC, but due to school, she had not been active for several weeks. But with the onset of Christmas vacation, I decided to give her an incentive to complete the required 100 confirmed grids before we left on a family vacation after Christmas. I had around 285 grids confirmed, so I challenged her to a little contest to see if she could hit 100 before I hit 300. Thanks to some awesome roving efforts by several operators, Kylee beat me to the respective goal and attained VUCC just before the end of the year, about four months after first getting her license. (I was glad she won our little competition!)

Kylee loves roving and already has over 20 grids activated. She is anxiously awaiting summer when the weather will be more conducive to road trips and roving!

The support Kylee has received from so many AMSAT members has been incredible. It has gone well beyond verbal compliments and expressions of support. She has also received generous gifts of AMSAT t-shirts, books, informational brochures, souvenirs — even equipment! She loves hearing and contacting her friends on the birds, and she knows dozens by name when she hears their call signs. It is very much like a family. And she loves picking up new grids too, as she is working towards getting Satellite VUCC endorsement stickers

The next order of business, as time allows (and when the weather gets warmer!), is to get on the linear satellites. There is no doubt that summer family vacations will again include roving from a variety of grids that we travel across. And of course, Kylee is gunning for her General class license this summer.

Support AMSAT

AMSAT is the North American distributor of SatPC32, a tracking program for ham satellite applications. Version 12.8d features enhanced support for tuning multiple radios. Features include:

1. The CAT commands of the IC-9100 have been extended again. The program now also controls the DV mode (DV for 'Digital Voice') of the radio. With the FT-817 the program now additionally supports the CWR mode.

2. All SatPC32 programs now process significantly larger Keplerian element source files. Especially because of the numerous new Cubesats, the number of data sets contained in the source files has increased significantly. For example the file Cubesat.txt currently contains data for nearly 400 satellites.

3. In all programs (SatPC32, SatPC32ISS, Wisat32, WinAOS and WinListen), the list of satellites contained in the source file ('Available' list in menu Satellites) is now displayed in alphabetical order to facilitate locating individual satellites.

4. The program SatPC32ISS now also allows the creation of up to 12 satellite groups. The new Cubesats have also increased the number of 'in-band' satellites. Originally, in-band operation in amateur radio was only available at the ISS.

5. In order to accelerate a change between the individual satellite groups, the 'Groups' window can now be called up by clicking on vacant areas of the main window, except in the Satellite menu. Such free positions are located on the right and left of the frequency window.

6. In the Satellites menu the data sets of the satellites contained in the active source file can now be displayed. When called, the data set of the currently selected satellite is displayed. The feature helps you to immediately know the identifier of the satellite.

7. The program has improved control of the sub-audible tone required by some satellites. The program can now automatically switch the sub tone on/off when switching between PL tone satellites and others, changing between u/v and v/u satellites, changing the group, closing the program, etc.

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

AMSAT GOLF $125,000 Development and Launch Initiative

AMSAT is excited about developing and launching the next generation of Greater Orbit Larger Footprint ("GOLF") satellites. AMSAT has an immediate need to raise funds to cover development, launch and related expenses for GOLF-TEE and GOLF 1. We have set a fundraising goal of $125,000 to cover these expenses and help us to continue to keep amateur radio in space.

GOLF-TEE (Technology Exploration Environment) will be a rapid deployment to LEO to establish/verify/learn ADAC, Deployable Solar Panel Wings, Radiation Tolerant IHU, SDR.

GOLF-1 is planned as an approx. 1300 km LEO, progression of GOLF-TEE technology, first STEM mission with VU and APS, AO-7/FO-29 supplement, and our first "High LEO" CubeSat.

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

AMSAT President's Club
Support GOLF-TEE and GOLF-1

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

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

Your help is needed to get the AMSAT GOLF-TEE and GOLF-1 Cubesats launched.

For the latest news on GOLF 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.

With a 50-year Legacy of Success, AMSAT Volunteers …

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