The AMSAT® Journal

Editor-in-Chief
Joe Kornowski, KB6IGK

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

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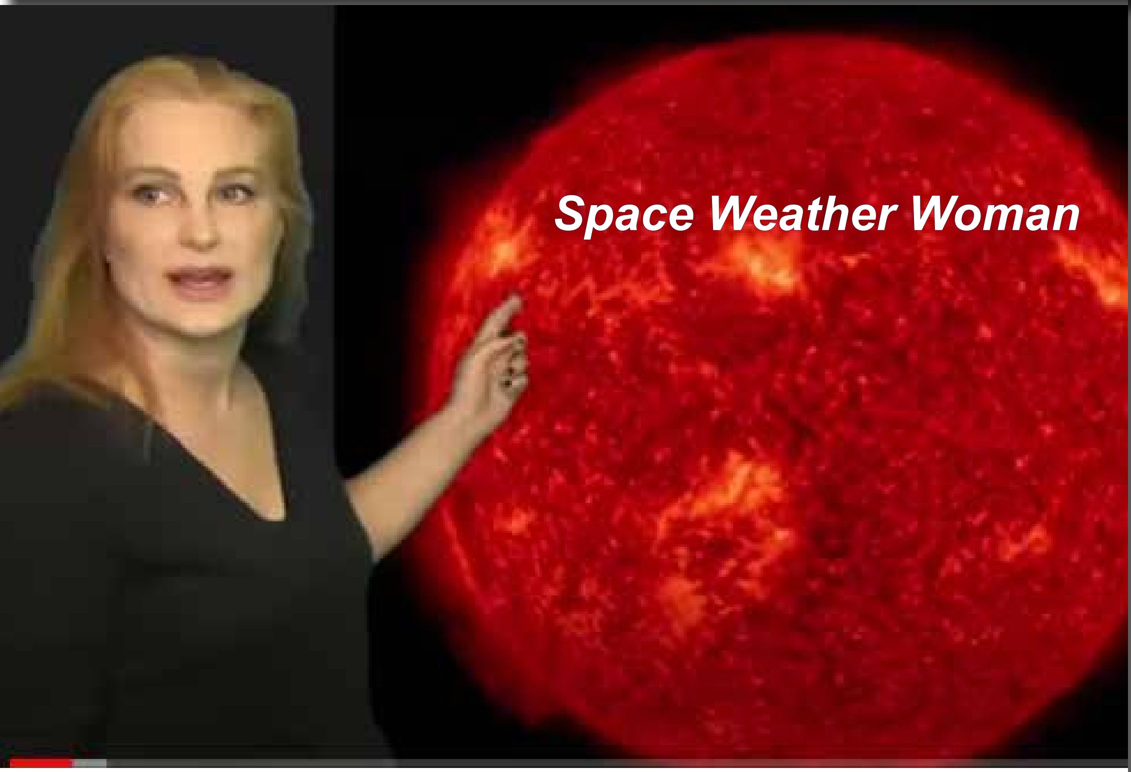

In this issue —

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!

Radio Amateur Satellite Corporation (AMSAT)
P.O. Box 27, Washington, D.C. 20044

AMSAT Club Callsign: W3ZM
AMSAT Websites: www.amsat.org, launch.amsat.org (Member Portal)

The AMSAT Journal Staff
Editor-in-Chief: Joe Kornowski, KB6IGK, kb6igk@amsat.org
Assistant Editors:
Douglas Quagliana, KA2UPW/5
Bernhard Jatzeck, VA6BMJ
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Editorial Office: Joe Kornowski KB6IGK, 3310 W. Braker Ln., Suite 300-322, Austin, TX 78758. Please e-mail *Journal* submissions to: journal@amsat.org,

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

Apogee View

Robert Bankston, KE4AL
President

This year's Orlando Hamcation (February 11-13) was an excellent opportunity to meet with AMSAT members, past and present, amateur radio operators interested in getting started with amateur radio satellites, other amateur radio organizations and commercial vendors. The past two years have left many of us feeling isolated, with forced locked-downs and canceled events, so meeting in person and being able to share AMSAT's vision and mission was truly a welcome and encouraging relief.

I want to thank all volunteers who donated their time over the long weekend to serve as AMSAT Ambassadors at our booth and everyone who stopped by to say "Hi," if nothing more. Our volunteers did a phenomenal job of answering questions and serving our members. Questions and comments appeared to focus on three categories – HEO/GEO, education, and getting started on amateur radio satellites, which was reassuring, as these are the main areas where AMSAT is currently focusing its efforts. In addition, many members expressed gratitude for the changes and new direction AMSAT is taking to advance the art, science, and enjoyment of amateur radio in space.

ARISS occupied the booth right next to us. It was nice to meet up with all of them again. I am happy to see them doing well and excited about our continued partnership.

We held a forum at Hamcation, entitled "AMSAT – Onward and Upward," at which I talked about where we have been, where we are now, and where we are going. In addition, we had the pleasure to hear from one of our youngest AMSAT members, Willem Glassbrenner, KO4UYE, who shared his school science project, an experiment on the importance of having the correct antenna polarization when communicating through amateur satellites in space. Willem did an excellent job. We are all proud of him and encouraged by the presence of youth participating in amateur radio in space and the insight and enthusiasm they bring.

Although M2 Antennas could not attend Hamcation this year, they generously donated a LEO Pack antenna system to serve as our door prize at the AMSAT forum. Thank you, M2 Antennas!

While at Hamcation, I met with Steve Goodgame, K5ATA, ARRL's new manager for education, and TAPR President, Scotty Cowling, WA2DFI. AMSAT has a long history of working with both organizations to promote amateur radio generally and in space. I enjoyed meeting with both ARRL and TAPR to discuss how we can reestablish and advance those relationships as we move forward.

Speaking of getting together again, all indications are that the 2022 Hamvention is a go to occur May 20-22, 2022, in Xenia, Ohio. AMSAT will be in full force and co-host the AMSAT/TAPR Dinner held in memory of Bob Bruninga, WB4APR (SK). Bob has done much for amateur radio, terrestrial and in space. TAPR and AMSAT thought it was only fitting that we use this time to honor Bob's life and his contributions. More information about AMSAT at Hamvention and the AMSAT/TAPR Dinner will be provided in the coming weeks. We hope you can join us.

Looking Up

The proliferation of commercial and governmental satellites at or above 550 kilometers has certainly raised the bar for admission to higher orbits. Unless you have the necessary reasons for being in this "protected" space AND have a well-demonstrated flight heritage that will reduce the risk of interfering with the other satellites to zero, in my humble opinion, you are not going to be given access.

Despite what appears to be an impenetrable FCC-licensing firewall for orbits above 550 kilometers, AMSAT is not giving up on our return to higher orbits. Instead, we are exploring multiple ways to get us there, including developing rideshare opportunities and partnering with governmental agencies.

GEO Rideshare

By all appearances, an amateur radio-only satellite will not earn us a ticket into a geostationary orbit. We only see getting there as a payload aboard a commercial communications satellite. QO-100 (Es'hail 2) proved it was possible. We will be forming a task force to search out rideshare opportunities over North America. Cold calling and begging for a ride have not worked. We need a team of "insiders" to not only open the door for us but get us in front of the decision-makers. If you work in the industry or know the right person, we could certainly use your help.

GTO/HEO Partnerships

Partnering with a governmental agency should carry the necessary clout to get us over the 550-kilometer fence. The trick is to find the right partner and a way we can help them achieve their goal(s).

One such opportunity lies with NASA, which is actively working on using CubeSats to replace the now failed Van Allen Probes.

Radiation has undoubtedly played a role in degrading each of our launched satellites in the past. Therefore, gaining a better understanding of how radiation affects our mission success and experimenting with how we can mitigate that exposure should be an AMSAT priority.

We partnered with Vanderbilt University to study the radiation effects on electronic components in our Fox-1 series of satellites. AMSAT should take a similar approach by partnering with NASA in developing GTO and HEO targeted satellites to measure and report radiation exposure, study the effects of radiation on COTS components, and, in the process, include a radio transponder for amateur radio use.

In addition, each NASA 6U CubeSat mission often costs more than $4.5 million because almost everything is outsourced. So, I propose that we demonstrate or provide them with a cheaper, more innovative solution.

Implementing a supportive and/or parallel program, whether with NASA or a similar agency, may provide us with access to assistance, technologies, and/or launch opportunities that would normally not be available to us. It is something definitely worth pursuing.

Until next time, Onward & Upward!

Educational Relations Update

Alan Johnston, Ph.D., KU2Y

For the first time in a couple of years, all the AMSAT CubeSatSim Loaners are out! Here are some places they have appeared lately:

- In October, Steve Driver, N9BWT, Scoutmaster - Troop 1, Jeffersonville, IN, showed off a loaner during Jamboree-on-the-Air (**www.scouting.org/international/jota-joti/jota/**) and had about 50-60 scouts of all ages participate.

- In December, Melissa Pore, KM4CZN, engineering teacher at Bishop O'Connell High School in Arlington, VA, used a CubeSatSim Loaner in her classroom with her students.

- In January, a loaner was displayed to the Southern Pennsylvania Communications Group/K3AE club in Shrewsbury, PA, by Jack Spitznagel, KD4IZ, an Associate Editor at AMSAT News Service.

- In February, another loaner appeared at Hamcation at the ARISS booth thanks to Randy Berger, WA0D, ARISS Director of Engineering. Also, the CubeSatSim Lite was displayed at the AMSAT booth by Robert Bankston, KE4AL, AMSAT President.

- Students of Dr. Lynnane George, Senior Instructor, Mechanical and Aerospace Engineering Department at the University of Colorado, Colorado Springs, are using a loaner unit to test and evaluate the CubeSatSim.

With the improving weather, my students are busy readying the of launch their next high altitude balloon (HAB). I'm looking forward to it! Perhaps your group is also getting ready to do some launches? It would be great to hear about your HAB launches and the

Figure 1 — Recovered NOAA National Weather Service RS41 Radiosonde, reflashed for amateur radio HAB use.

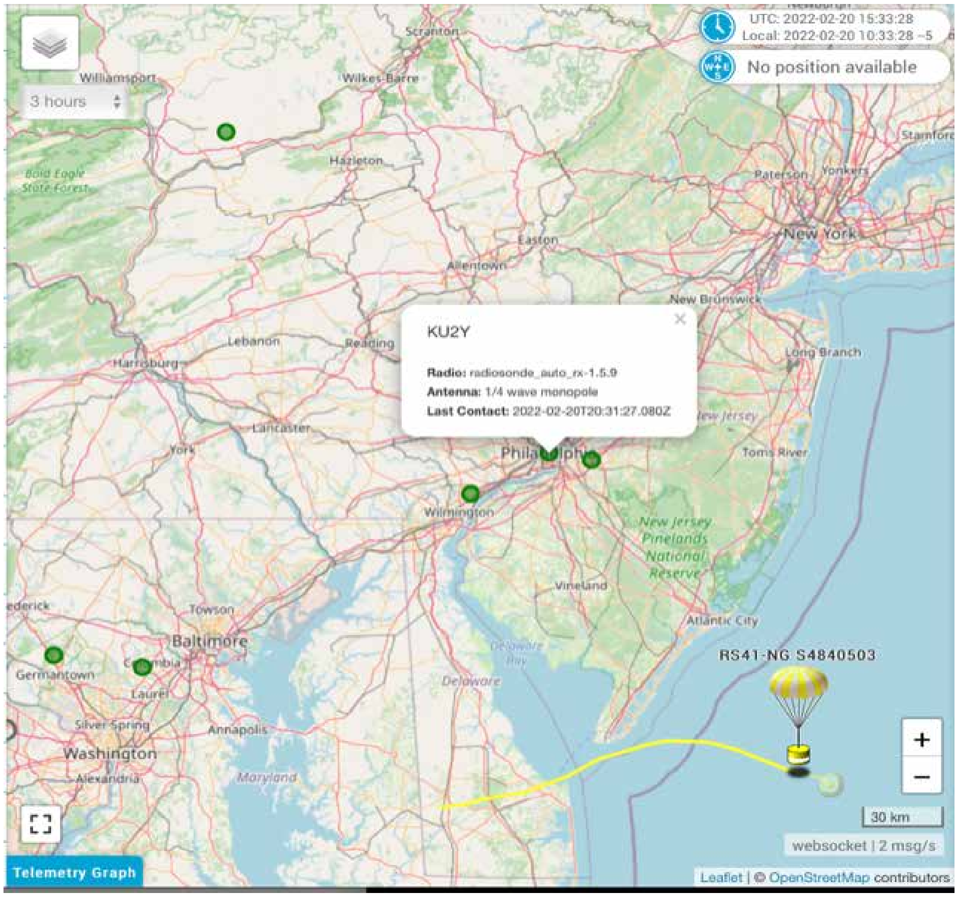


Figure 2 — sondehub.org shows my KU2Y ground station.

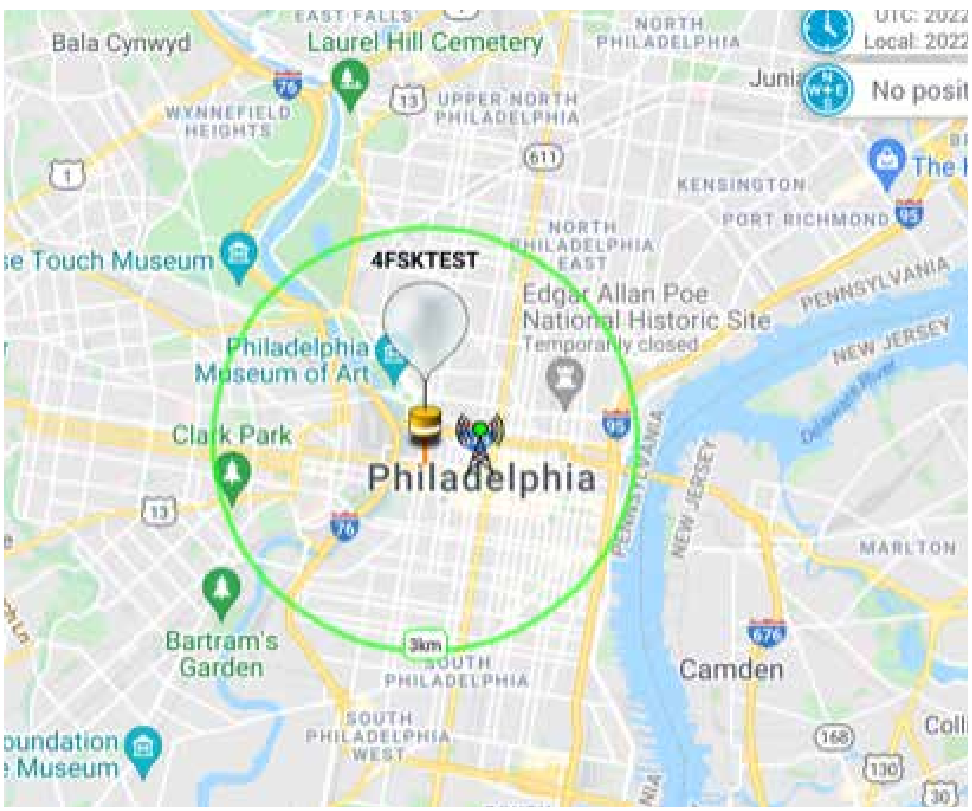


Figure 3 — tracker.habhub.org shows my KU2Y ground station and my 4FSKTEST payload.

STEM outreach associated with them.

Lately, I've been learning about radiosondes (**en.wikipedia.org/wiki/Radiosonde**), the weather balloon payloads launched by weather services. In the U.S., radiosondes are launched regularly from many places by NOAA National Weather Service (**www.weather.gov/upperair/factsheet**). The weather service launches several models of radiosondes. At least for the RS41 type sondes, NOAA no longer wants them returned after they land, and enterprising hams have taken to tracking and recovering them, then reflashing the STM32 firmware to transmit on amateur radio bands. Jim McLaughlin, KI6ZUM, David White, WD6DRI (team members of the CubeSatSim project), and other mentors at the Mt. Carmel High School Amateur Radio Club in San Diego have a lot of experience with these repurposed balloon payloads. Jim and Dave recently shared two that they recovered with me. One is flashed with the Project Horus firmware (**github.com/projecthorus**) so that it transmits 4 FSK telemetry on the 70 cm amateur radio band.

Thanks to David and Jim, I've also succeeded in getting my Raspberry Pi and RTL-SDR ground station going. My station now shows up as a green dot on sondehub.org, which displays live tracking for weather service sondes. When the ground station is running in Horus decoding mode, the reprogrammed RS41 sondes will plot tracking data on **tracker.habhub.org**. I also got my 4FSK flashed sonde to connect and show up on the website.

Unfortunately, it doesn't seem that many NWS radiosondes fly near my location, but maybe a field trip is needed to try to track and recover some in nearby states.

An article on radiosondes and amateur radio should appear in an upcoming *AMSAT Journal*. If you would like to contribute, please get in touch with me.

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

If you are interested in doing a demo to a group or school, such as one of the events I mentioned earlier, I can ship you a loaner. Contact me via email **ku2y@amsat.org** or on Twitter **@alanbjohnston**.

Engineering Update

Jerry Buxton, NØJY
Vice President, Engineering

Demanifested/De-manifested

Is that even a word? "Manifested" is commonly used in our CSLI (NASA's CubeSat Launch Initiative) launch lingo. NASA and launch providers/integrators consider your space vehicle (SV) to be manifested on a given launch mission once we accept a launch opportunity and are accepted by the integration team. Acceptance is based on an orbit suitable to our intentions and a SV suitable to the capability, intentions, and requirements of the launch provider.

"Manifest" per my big, fat Webster's Third New International Dictionary is defined as a list of cargo on a flight (paraphrasing), hence the use in who/what is being carried on a rocket launch.

"Demanifest" is the term put forth by NASA as an option, such as in our discussions of the situation with GOLF-TEE regarding the ELaNa 46/STP-S28B launch. "De-" is a prefix of Latin origin meaning to remove, reduce or reverse. Demanifested, then, is what happened when we chose to reverse or remove the manifest of our GOLF-TEE on the ELaNa 46/STP-S28B launch. (I go with de-manifested just because the spell check doesn't object and highlight the word when I type it.)

De-manifested in the News

ANS-030 January 30, 2022, puts out the official word of the de-manifesting. I am credited for describing some of the reasons for the decision to de-manifest GOLF-TEE:

• AMSAT finds itself in a similar situation to what other payloads and space-industry providers are experiencing. The worldwide pandemic and supply chain shortages threaten everyone's ability to properly and successfully deliver for launches.

• Out of respect for NASA, the launch provider, and other payloads, it is important to withdraw now, rather than later or, even worse, missing a launch integration deadline, which has possible financial penalty implications.

• GOLF-TEE and GOLF-1 have both been selected to participate in the CSLI program, and NASA will continue to look for another launch for GOLF-TEE.

Those are the bullet points for what/why, and don't worry it's not as bad as it sounds.

When NASA provided demanifest as an option in our discussions, I had a bit of a recoil upon reading the word. It's the opposite of what you are used to hearing and has always been something that you obviously want to avoid once you are manifested. However, it was a valid and "plus side" option in this case.

Reading Between the (ANS) Lines – Bullet One

The pandemic followed by the supply chain issues were the major contributors leading to the decision to demanifest.

In 2017, AMSAT entered into an agreement with Ragnarok Industries to acquire its developing attitude determination and control system (ADCS) for test and use in GOLF missions. Our relationship with Ragnarok dates back to about 2015, when the newly formed ASCENT team began work to provide communications and control systems for the Heimdallr CubeSat. Ultimately, the Heimdallr design did not make the top three, and, while the "runners up" were given the option to continue and compete if they found their own launch, the Heimdallr team did not have the resources to buy such a launch, and the project terminated.

The development work that ASCENT had done contributed quite a bit of design and thought to our own work, including the 5 GHz uplink and 10 GHz downlink communications chosen by ASCENT for the Heimdallr design. Once the ASCENT team had decided that, I chose to propagate "Five and Dime" to the Phase-4B project at the time, as well as making it the standard for future P-3, P-4, and P-5 satellites we would produce moving forward, and so GOLF-TEE and GOLF-1 as well, for starters.

In mid-2017, Ragnarok again offered to partner with us, specifically to carry the (still new) design of the Ragnarok ADCS. This would also bring the opportunity to learn the system rather than a black box situation, and offer "competitive pricing" for the Ragnarok systems. This sparked the move to GOLF-TEE, as it fit with our progression plans for the new GOLF program. So, I brought it before the AMSAT Board of Directors at the 2017 annual meeting in Reno.

With the board's approval, I submitted two CSLI proposals, GOLF-TEE and GOLF-1, both of which were accepted by NASA. This led to GOLF-TEE being manifested on the launch mission.

Ragnarok has their HQ in New York City, and the variety and impact of the COVID-19 "shutdown" activities that varied by state and city wound up forcing them out of their office. They began to work from home to the extent possible. However, equipment and the logistical challenges could not be overcome in a meaningful way. They also lost employees (contractors). The duration and impact of the pandemic-related situation had a dire effect on Ragnarok's ability to produce the ADCS. Fortunately, our geographically diverse Engineering Team was not impacted to any meaningful degree by COVID-19, itself, or local restrictions due to the pandemic. So, we carried on.

In early 2021, we accepted the GOLF-TEE launch with the understanding that Ragnarok was headed back to the office. That was also when we saw the first indications of "long lead times" for some components, though we were unaware of how much that situation would worsen. And upon re-starting, Ragnarok quickly became stymied by the same developing supply chain issues. We all continued, but, by the end of summer, it was obvious that Ragnarok was in trouble as far as meeting their deliverables driven by our mission timeline. By then, AMSAT, too, was experiencing the growing "automotive chips" lack of supply for some of its own systems. Last push efforts to have some of the Ragnarok systems delivered were unsuccessful, and that was the time for a go/no-go decision.

Reading Between the (ANS) Lines – Bullet Two

The Engineering Team discussed options and actions to proceed with the mission and make the timelines. The ADCS options were the primary issue, of course, with essentially three choices that we identified:

- Fly a commercial ADCS;
- Fly with no ADCS; or
- Hope that the launch got postponed, and we could stick with Plan A.

A commercial ADCS option is very expensive relative to our expectations and the budget. Moreover, the whole point of GOLF-TEE, and a stated CSLI goal, was to fly and learn ADCS as part of our GOLF Program strategy to build the capability and expertise to maneuver.

No ADCS could be accomplished at that point, except in a very degraded state of operation. ADCS is needed to point the solar panel array design that is also part of the GOLF-TEE mission and CSLI goal, and with respect to the microwave antennas. The latter could work "pretty well" only because of the low-LEO orbit (≈550 km) and the broad beamwidth of the microwave antennas that were designed to provide some level of effectiveness if the ADCS failed on orbit. In the end, we believed that there would be no real point or benefit to flying while being unable to fully understand the capability of the solar panel array with respect to power/sun angles and explore and allow user experimentation with the microwave capability.

A launch postponement was a somewhat valid option, being that we have all seen very well how often and how much launches can "move to the right." In gratuitous consideration of this possibility, we noted that the launch date ("ILC" or Initial Launch Capability) had not wavered and, coupled with the fact that I'm extremely stubborn about putting any stock into a launch delay being a "more time freebie," the option was properly dismissed.

Next, I reached out to NASA to let them know of our situation. I had kept them updated on our developing challenges, and were seeing that in other payloads, as well as some of the launch providers, especially those developing the newer launch systems. I explained our considerations and determinations and asked about the suitability of the first two options for NASA, as they provide for our cost of the launch, and these would alter the CSLI proposal that they had accepted.

This was when I learned about the "demanifest" option. It turned out that, for this particular mission, no penalty would result if we chose to demanifest at that time. Typically, once you are manifested on a launch, if you do not deliver, or choose to be removed from the launch, you can be held financially liable for costs that NASA and/or the integrator incurred in the work done to accommodate you up to that point. Additionally, you may be held responsible to provide a "mass simulator" which is effectively a your-CubeSat's substitute — a size and mass of inert material — flown in your deployer to maintain the mass and center of gravity of the launch vehicle. Of course, the mass simulator is not released from the deployer.

Eagle eyes might recall some previous AMSAT budgets that had a conditional $35,000.00, which started with Fox-1A, apparently a number given before my time that would be our liability if we did not deliver Fox-1A. That was carried to a few of the subsequent Fox-1 missions in the annual budget as well, including those launched by Spaceflight. The mass simulator has become sort of a thing of the past with the proliferation of CubeSats that often exceed the number of launch opportunities who are willing to "fly stand-by," hence be manifested where you de-manifested. However, he other costs still apply.

Further discussion with NASA and the Engineering Team led to the final decision to demanifest. As mentioned in the ANS, there were other considerations that go beyond our financial comfort and bail-out expediency. NASA spends a lot of good-faith time in finding CSLI launches and ensuring the proper delivery and integration of the selected payloads. They have always done a wonderful job in helping us, and with mutual respect, I would expect us (AMSAT) to consider NASA's situation in whatever we do. There may be another stand-by payload that they could fly, giving as much time as possible to NASA and that payload to make that happen is simply being good people.

The launch provider, a term I often use interchangeably and generally in referring to the integration contractor and the launch vehicle provider, closely and constantly interacts with every payload. They need to keep everyone on a strict timeline, make sure that many "deliverables" including the mass and center of gravity (among lots of other mechanical things) are proper and within limits, and ultimately ensure the safety of all SV payloads, the primary, and the launch range. We were at a point in the launch timeline where it was proper to give immediate notice to them in order to cause the least disruption and allow them to adjust to the new circumstances and possible replacement payload.

Reading Between the (ANS) Lines – Bullet 3

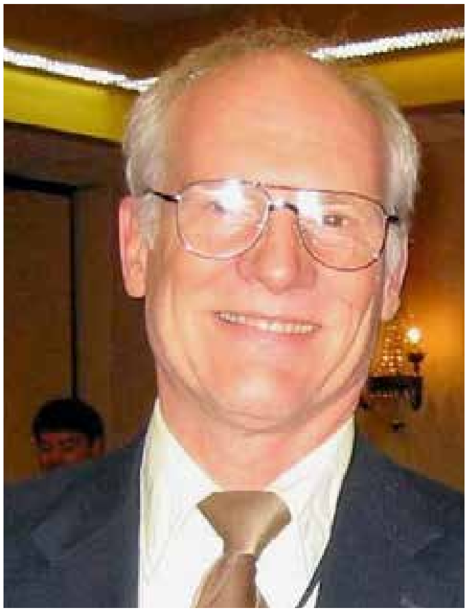
The last bullet is the bottom line for our members. That is simply that GOLF-TEE still stands to be manifested on another launch. There is no detrimental effect on GOLF-1 or GOLF-TEE in the eyes of NASA or the USSF (the provider of the STP-S28B/ELaNa launch) in fact, USSF welcomed us to come back for a later go. Rather than making the best of the situation by flying degraded with no ADCS or spending money on an ADCS that was a temporary patch but not in line with our goals and the goals NASA selected us for, we simply step back and use the time to get things back on track. We have been in situations where we had to adjust and make things work as best we could for other missions, which were actually much, much further down the timeline, but none that had such an effect on those missions as with GOLF-TEE.

NASA expressed their desire to have GOLF-TEE lead the way, to be the next/first to be manifested again upon the next opportunity. I believe this demonstrates their confidence in and respect for AMSAT. We are back where we were a year ago just before that launch offer.

The unfortunate loss of Bob Davis soon after this without a doubt has slowed GOLF progress. We now need to find new talent in mechanical engineering, which is paramount to the development and flight of our "in-house" solar panel array design. It is ironically fortunate that the decision came when it did. The timing with the introduction of Fox Plus, though, allows us to engage new volunteers with more projects and the opportunity to pick up the development of solar panel wings for GOLF. The solar wings are a critical part in a low cost, in-house, scalable solution for GOLF and Fox Plus, as we continue having fun and keeping amateur radio in space.

Bob Bruninga, WB4APR, SK

Joe Kornowski, KB6IGK
Editor



[Keith Baker, KB1SF/VA3KSF, photo.]

AMSAT joins the entire amateur radio community in mourning the loss of a luminary, Bob Bruninga, WB4APR, who passed on February 7, from the effects of COVID-19 and cancer. He was 73.

The father of the Automatic Packet Reporting System (APRS), Bob blazed the trail for amateur radio digipeating in space. As former AMSAT President Keith Baker, KB1SF/VA3KSF, reflected::

Back when I was part of the AMSAT leadership, I recall Bob and I having a conversation at that year's Dayton Hamvention. Bob wanted our permission to try running APRS through one of our satellites.

At the time, our AO-16 PACSAT (one of the four original packet satellites launched back in 1990 and which was "owned" by AMSAT-NA) was, by that time orbiting virtually unused as most store-and-forward packet satellite work had already moved to the higher throughput PACSATs UO-22 and KO-23.

I also vividly remember taking his request back to our AMSAT board of directors for discussion. A long-held tradition from the earliest days of the AMSAT OSCARS was to designate Wednesdays as "Experimenter Days." Clearly, what Bob and his crew wanted to try with APRS on AO-16 fit that definition perfectly. And, no doubt, the results of those initial (and highly successful) experiments running APRS data through AO-16 laid a firm foundation for Bob's later work at putting APRS transceivers on the MIR and ISS. It also led to a whole series of APRS satellites developed, launched and controlled by Bob and his crew at the U.S. Naval Academy.

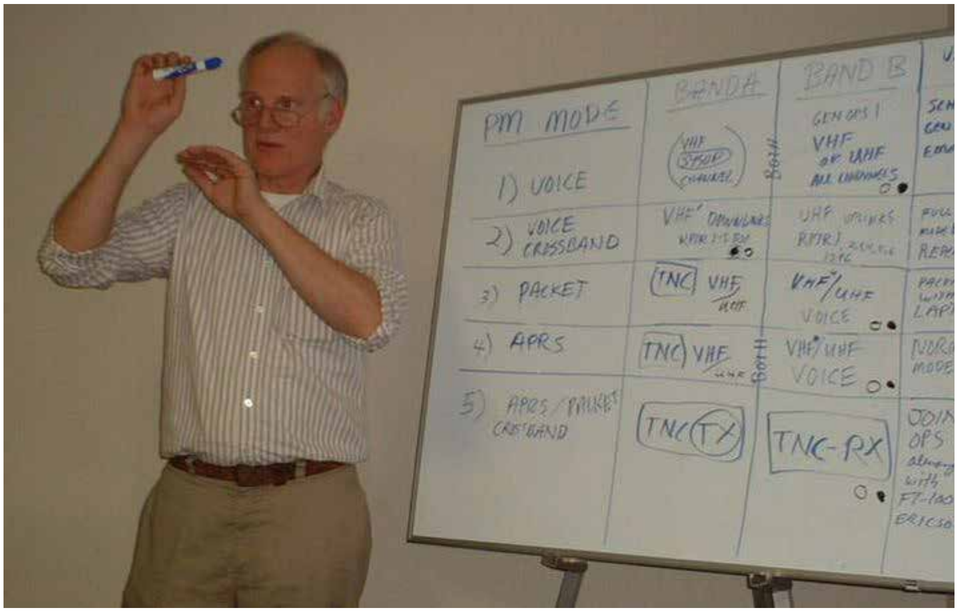
A selection of his many contributions and innovations as an engineer, educator, mentor, Navy veteran, public speaker, author, and solar power advocate, among other things, appears below from some of the other organizations who benefited most from his time and talents.

ARRL

[Courtesy of ARRL Letter, 02/09/2022]:

While best known for APRS, Bruninga was also a retired US Naval Academy (USNA) senior research engineer who had an abiding interest in alternative power sources, such as solar power. In 2018, he authored Energy Choices for the Radio Amateur, published by ARRL, which explores developing

L-R, Bob Bruninga, Tom Clark, W3IO (SK) and Mark Kanawati, N4TPY. [AMSAT, photo.]



Bob at 2003 ARISS creative architecture meeting for the new radio configuration now on ISS. [ARISS, photo.]

changes in the area of power and energy, and examines the choices radio amateurs and others can make regarding home solar power, heat pumps, and hybrid and electric vehicles. Bruninga drove an all-electric car and had experimented with a variety of electric-powered vehicles over the years.

APRS originated in 1982, when Bruninga wrote his first data map program that plotted the positions of U.S. Navy ships for the Apple II platform. A couple of years later, he developed what he called the Connectionless Emergency Traffic System (CETS) on the VIC-20 and C64 platforms for digital packet communications to support an endurance race. The program was ported to the IBM PC platform in 1988, and was renamed APRS in 1992. The recognized North American APRS frequency is 144.39 MHz, and APRS is globally linked via the internet. Bruninga founded the Appalachian Trail Golden Packet (ATPG) event, which fields APRS nodes from Stone Mountain in Georgia to Mount Katahdin in Maine each July.

ARRL Contributing Editor Ward Silver, N0AX, remembered Bruninga this way: "Bob kept pushing APRS beyond its origins as a position reporting system. He developed and helped implement numerous other uses of APRS in support of what has become the 'Ham Radio of Things,' with great potential for future amateur radio applications. Bob's far-reaching vision and imagination were as good as it gets."

Bruninga mentored USNA midshipmen in building and launching amateur radio satellites and CubeSats, beginning with PCsat in 2001. PCsat was the first satellite to directly report its precise position to users via its onboard GPS module. Subsequent USNA spacecraft included PSK31 capability (HF to UHF) and other innovations.

Amateur Radio on the International Space Station (ARISS) ARRL liaison Rosalie White, K1STO, recalled that Bruninga attended many ARISS-International meetings and contributed "enormously" to ARISS APRS activities, leading a team in developing protocols and software for rapid message exchange via a packet "robot."

White said APRS remains a key staple in the new ARISS InterOperable Radio System (IORS) that's now on board the ISS. She added that Bruninga offered input for future NASA Lunar and Gateway opportunities in which ARISS hopes to take part.

Last year, ARRL CEO David Minster,

L-R, Tom Clark, W3IO (SK), John Glenn, Perry Klein, Art Feller, W4RT and Bob Bruninga. [AMSAT, photo.]

Bob and former senator and astronaut John Glenn. [AMSAT, photo.]

NA2AA, on behalf of ARRL, honored Bruninga with a brick in the ARRL Diamond Club Terrace at ARRL Headquarters. ARRL sent him a letter of appreciation along with a replica of the brick.

Bruninga held a bachelor's degree in electrical engineering from Georgia Tech (Georgia Institute of Technology) and a master's degree in electrical engineering from the Naval Postgraduate School. Bruninga was a 20-year U.S. Navy veteran. Dayton Hamvention® honored him in 1998 with its Technical Excellence Award.

Bruninga authored and co-authored numerous academic papers over the years, and was frequently in demand as a speaker and presenter at amateur radio gatherings. Survivors include his wife, Elise Albert; daughter, Bethanne Bruninga-Socolar, WE4APR, and son A.J. Bruninga, WA4APR. Arrangements are pending, although his daughter said that a celebratory memorial service will be held this summer in Annapolis, Maryland.

ARISS

[Frank H. Bauer, KA3HDO
ARISS International Chair
ARISS-USA Executive Director]

The ARISS international team mourns the loss of Bob Bruninga, WB4APR, a genius who pioneered digital amateur radio techniques, invented the APRS digital signal protocol and designed the innovative ARISS Kenwood Radio Crew Interface. Bob passed away on February 7, 2022, after a fearless 2-year battle with cancer and, in the end, succumbing to COVID-19.

Bob's brilliance permeated all through the amateur radio community, primarily via his invention of APRS, the Automatic Packet Reporting System. In Bob's words, APRS is a "two-way tactical real-time digital communications system between all assets in a network sharing information about everything going on in the local area." In

Midshipman with Bob in the USNA Sat Lab. [USNA, photo.]

Midshipmen with Bob in the USNA Sat Lab. [USNA, photos.]

APRS' nascent days, Bob joyfully shared, in real-time through APRS, the annual midshipmen 230 mile "running of the football" from the U.S. Naval Academy to the Army-Navy game football stadium. With the help of his Naval Academy students, Bob developed several innovative, low-cost amateur radio satellites that continue to be employed by hams worldwide. He promoted the development of a network of APRS satellites in low Earth orbit on a shared frequency—145.825 MHz—and he was proud that the ARISS radio station was part of that network. A replica of his first student satellite development, PCSAT/NO-44, is displayed at the Udvar-Hazy National Air and Space Museum in Northern Virginia. Bob's contributions and creativity in Human Spaceflight Amateur Radio are many — spanning nearly forty years. In early 1985, prior to Astronaut Ron Parise, WA4SIR's, planned flight on STS-51E in March 1986 (which was delayed after the Challenger accident), Bob worked with an AMSAT team to develop protocols and software for rapid message exchange via a packet "Robot." In Bob, WB4APR's own words, these "discussions helped firm up ideas on how APRS could be used not only as positioning tool, but also as a communication capability allowing rapid status and message reporting. Thus, allowing lots of people to rapidly make exchanges during a brief satellite pass." The packet robot was used heavily in our SAREX (Shuttle) program, starting with Ron's STS-35 flight in December 1990. APRS remains a key staple in our ARISS on-board systems.

In the early 2000s, when ARISS was developing its second-generation radio system, Bob became the chief architect of the ARISS Kenwood D-700 radio program modes. Our chief requirement was to make the crew interface simple and easy to switch between operations modes. Bob distilled our requirements into an elegant crew interface with four program modes, to support school contacts, voice repeater, APRS, and experimental operations. Bob's program mode crew interface is also embedded in our Next Generation InterOperable Radio System that employs the Kenwood D-710 GA radio system. Each time you use the ARISS radio system in any of its operations modes, you can thank Bob's brilliance for making it happen.

On behalf of the ARISS International Team, I would like to convey our heartfelt thoughts and prayers to Bob's wife, family and his many friends. Bob, we thank you for your unquenching drive to innovate radio communications and your pioneering spirit that transformed your brilliant ideas from a dream to reality. Because of you, your APRS signals continually serve as an amateur radio beacon of inspiration, hope and peace throughout the infinite universe.

U.S. Naval Academy

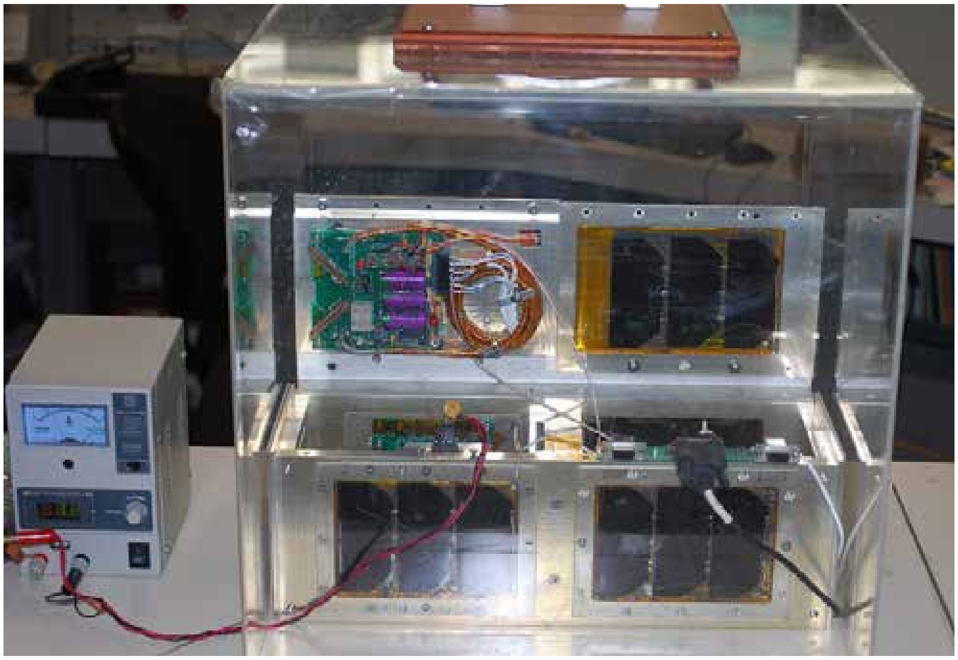
The AMSAT Journal interviewed Jin Kang, Ph.D., KB3UKS, Director, Naval Academy Small Satellite Program:

Journal: Dr. Kang, can you tell me a little bit about when and how you first came to know Commander Robert Bruninga, known to us at AMSAT as "Bob," and his history with the Naval Academy?

Dr. Kang: "Bob" for us, as well. He was around for many years. I joined the Naval Academy team in 2012, and I was basically hired on to do the same thing Bob was doing, small satellites, assigned to Bob's lab and basically supporting and providing more opportunities for the students for the small satellite program.

Journal: So, tell me about the lab and where it fits. As I understand it, you run sort of the overall small satellite program at the academy.

Dr. Kang: Yes. So, we call it the Naval Academy Small Satellite Program. I'm



PSAT-3 on display at U.S. Naval Academy.

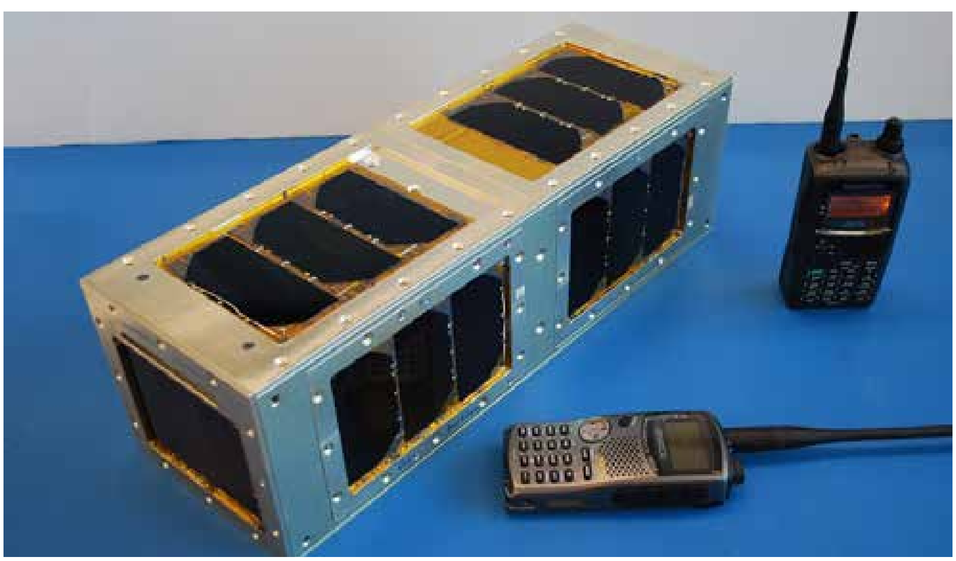
leading that effort and Bob in the lab was in direct support of that piece. So, I'm sort of the vision portion of it with Bob doing the execution. He helped students put together satellites and ground station management, which, as you know, Bob worked magic in that — the lab supporting all of the student activities that go on.

Journal: Would you describe the mission of the lab as mainly sort of a tactical or the hands-on part of the program?

Dr. Kang: That's pretty much exactly it. The lab provides hands-on education and training to our midshipmen in the art of satellite technology. After graduation, they can be directly plugged into other satellite programs.

Journal: And was Bob the only instructor or operator of the lab since its inception?

Dr. Kang: Bob was managing the lab, and there have been faculty directors who were basically serving in my role. They all were involved. Of course, Bob was in the weeds getting things done. And there have been a few faculty members before me who were working with Bob to build up the satellite program. Once I joined, it was pretty much Bob and me.



PSAT-3.

Journal: How was Bob with his students? Can you describe his teaching style and his interactions with his students?

Dr. Kang: Great! I mean he's sort of a legend. When I first came in, for example, on the satellite hardware I wasn't an expert by any stretch of the imagination on the communication side. Me and my students would sit there trying to troubleshoot bringing the VSWR down on their antenna. Bob would pass by, kind of look at it, and put a paper clip on the tip of it and then everything worked perfectly, right? So, he goes around working his magic, and students liked him. Everyone knew him. He pretty much lived in the lab. I never got there before Bob got there, and he never left before I left.

He was just always willing to help and would always be available. And what I truly appreciated about him was his patience with students. Students would come and ask him questions, and, of course you can just give them a short answer, like "do it this way." But Bob would sit down with them, and make sure that the students did the process, and have them come to their own solution on their own. And that really turned it into a good learning, lasting experience for the student. That's one of the things I very much liked about him.

Journal: So, what's going on with the lab now since Bob left?

Dr. Kang: It's still going strong. Bob retired in 2020, I believe, so he left a legacy of satellite communications and a lot of hardware that he built in-house — things like that. We're leveraging off of the stuff that he's done between bringing in all of the amateur radio side of things and then a little bit of government frequency side of technology. We're continuing pretty much exactly as when Bob was here but with a vacuum in technical expertise. But program-wise, we're continuing where Bob left off.

Journal: What about the projects that were in the pipeline when Bob left? Are they continuing? I was looking at the website to see what was on the boards for upcoming projects that haven't launched yet or maybe are not even in development yet. What's happening with those?

Dr. Kang: Once I joined, we switched over to CubeSats from small satellites or micro satellites. So, we're now pretty much exclusively CubeSats. We've launched seven so far, with Bob and me working together. As Bob was retiring, the latest of the CubeSat satellites was called PSAT-3. We launched PSAT-1 and PSAT-2 with great success. PSAT-3 was the last satellite he worked on. PSAT-3 was flight-ready, but the ride got cancelled. The rocket didn't make it through the program, so all the satellites got pulled off the manifest. It's completed, but right now it's on display sitting here. Unfortunately, since only Bob had intimate knowledge of everything that was going on, we don't think we could refurbish it and get it launched.

That's unfortunate, but one of the things that we don't get to do is display our work because everything we build goes into space, and we never see it again. So, this is great because we get to see a fully finished satellite sitting there in the display case. Also, we have two more satellites getting ready to launch manifested later this year on a 3U CubeSat that Bob also helped develop, as well as another one manifested the year after.

Journal: I saw in your current projects page on the website "HFSAT (USNA-16)."

Dr. Kang: Yes. That was Bob's idea of having an HF antenna wrapped around a CubeSat. That one has gone away with the loss of Bob's expertise. We plan to turn it into an S-band experiment. We haven't done an S-band in the past, so we're going to try that, manifested for the end of next year.

RSAT (USNA-19) on the website was dead on arrival, unfortunately. We have a follow-on mission to that — RSAT-2, but that is going to be a payload sitting inside the International Space Station, not a free-flyer, but still a 3U CubeSat. So that's the one that's been manifested for later this year.

Journal: Is there anything else you want our readers to know about Bob that we haven't covered?

Dr. Kang: If you're looking for an anecdote, a funny one that I tell all my colleagues is you know, obviously, Bob was somewhat famous, and we would go to conferences together, like a small satellite conference. And I would write my name and a huge "USNA" my on my name tag. And the first thing Bob would write on his name tag was "WB4APR" in bold letters, so that people would see his callsign first and then recognize him in that world. I thought that was a very interesting thing. I was privileged to have worked with someone who had so much knowledge and experience, and I learned so much from it.

Space Weather for the Satellite Operator with Dr. Tamitha Skov, WX6SWW

Paul Graveline, K1YUB
Assistant Editor

The field of space weather has been somewhat neglected over the years but not anymore. The recent Space X loss of about 40 newly launched LEO satellites garnered major headlines and attention. As we earthlings increasingly depend on space for direction finding and worldwide internet connections, what happens in space, especially the interaction between the sun and Earth, becomes more significant to our daily routine.

The early stages of the new sun cycle 25 have already heightened attention to the importance of being educated about it.

One of the emerging highly knowledgeable and respected sources of information about space weather is Dr. Tamitha Skov, whose distinctive call sign is WX6SWW. Through her weekly space weather forecasts and frequent mini-courses videos on YouTube, she is rapidly becoming one of the best-known space weather experts sought by the major cable and tv networks, especially as space weather becomes more mainstream.

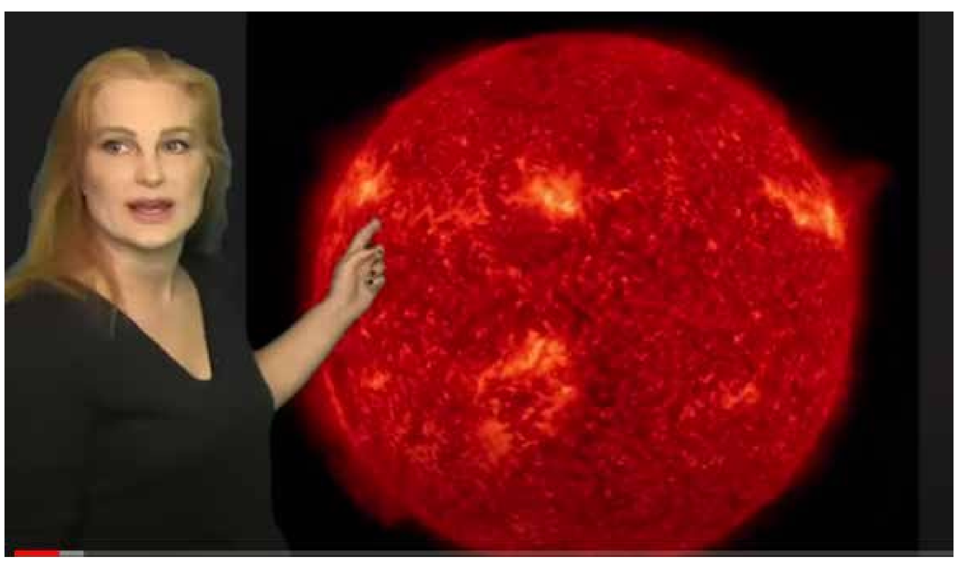
Although relatively new to amateur radio, she is already receiving accolades in the ham world. She captured the 2021 Hamvention award for technical excellence — quite an achievement in such a short time.

She has an interesting background with a doctorate in plasma physics from USC and many years working in the aerospace industry. More recently, she has been concentrating on promoting space weather by teaching college courses, producing her weekly forecasts and participating in cooperative research with well-known space weather scientific researchers such as Nathaniel Frizzel, W2NAF.

Her weekly space weather forecasts are similar to the terrestrial weather forecast presently given on your local 6 o'clock news. In fact, one of Dr. Skov's prime objectives is to train aspiring and present weather forecasters to incorporate space weather into their daily terrestrial forecasts and to be able to intelligently explain space weather to their listeners, especially regarding any concerns (like dislocation of GPS services) which might be relevant to their daily lives.

Since many of the *Journal's* Technician Class readers may not follow HF developments where space weather is closely followed, *The AMSAT Journal* invited WX6SWW to discuss issues focusing on the space weather significance for satellite users.

You can follow Dr.Skov regularly by logging on to her website, **SpaceweatherWoman.com,** and searching YouTube for her weekly updates and mini-courses. The mini-courses will be considered classics as space weather becomes more significant in the coming years.



Dr. Skov discussing a developing solar storm. [Paul Graveline, K1YUB, photo.]

he Journal thanks her for taking time from her hectic schedule to answer our inquiries.

The Hamvention write-up about Dr.Skov seems to sum it all up: "She is a real space pioneer."

Journal: Many AMSAT members use satellites but don't operate on the HF bands. Hence, they might not be familiar with how storms on the sun can affect satellite radio conditions. Could you briefly go over the types of threats like flares, coronal mass ejections, etc., the sun generates for ham operations?

Dr. Skov: When we talk about satellite communications and just satellites in general, two issues come up. The first one, of course, is the health and safety of the satellites themselves. That's a big issue, and certain types of space weather in the space environment affect the satellite's health and safety. There's also the radio communication point of view, which is a second component.

There are essentially four different types of space weather events that affect Earth. And the two that are most well-known and are often conflated are solar flares and coronal mass ejections.

Solar flares have no particles, but it's all electromagnetic waves, so you can imagine immediately when you think of this, you're going to be thinking radio communications.

So, solar flares cause radio bursts, and these can give you a radio blackout that can last hours or more. If you get a short duration flare, often we call it an impulsive flare, or it's just barely above the threat level then disappears, you know, goes back down. That's more like a radio brown-out causing radio communications issues on the dayside but doesn't totally trash the bands. And it may not trash all of the bands, just the lower frequencies.

The second phenomena are coronal mass ejections (CME). Now, these give off the material — all the junk. These are the ones that give us all the eye candy in terms of the sun belching. They move much more slowly than flares because these things don't move at the speed of light, and they often are launched simultaneously. We have solar flares, but CMEs and solar flares are two different things. We need to keep that in mind because they cause totally different problems for satellites and radio communication.

Flares happen at the speed of light, and CMEs are often launched at the same time. This phenomenon travels much more slowly. But if its magnetic structure is configured the right way, it can actually boost radio propagation, and it ends up enhancing radio propagation because it helps feed the ionization of the upper atmosphere.

Ham radio operators have to deal with everything on HF, VHF and UHF. I mean, there are issues depending, even if you're talking using a repeater. For example, technicians have told me they have to adjust repeaters during significant solar activity.

A third threat is solar radiation storms, which are the bugger that really scares you with low orbiting satellites.

So, when you talk about solar flares, you're talking more about non-destructive jamming of radio communications. But, when you talk about CMEs and radio radiation storms, they can do destructive damage to satellites because you can get spacecraft charging.

Solar radiation storms can potentially cause destructive impacts to the health and safety of the satellite because of the energy that they provide in the particles.

Besides flares, CMEs, and radiation storms, coronal holes and fast solar wind are some of the biggest problems for satellites because they give us what we call recurrent streams. So, in a sense, solar wind rings Earth's magnetic system like a bell every 27 days, and it causes the radiation belts to get really energized. Satellite operators in GEO hate times when we have solar wind, for it is a terrible problem for satellite operators.

To sum up, I think it's ironic that most people who report on space weather always talk about solar flares, and the funny thing is that the solar flares themselves are actually the least dangerous. The most damaging are the solar storms.

Journal: Most ham satellites are in LEO. Is the height of the orbit important?

Dr. Skov: Absolutely. The classic example is the most recent launch of Starlink. You don't launch your LEO satellites at 210 km. That's like a sounding rocket area. There's a reason why people are using sounding rockets for probing the ionosphere. It is because of the danger posed to the satellites. The most viable orbit doesn't even begin until about 400 km and above, and even that is dangerous. Even the ISS does orbit boosting because of its low altitude.

On the other side of the coin is the South Atlantic Anomaly. Many people don't realize that the cell that causes the South Atlantic Anomaly causes a particle storm. You have to kind of fly through it, and people don't realize that what they're actually passing through in that region is the hairy inner edge of being in a radiation zone. People don't realize that, but it's the Earth's magnetic field. Even astronauts shelter in place when they go through the SAA.

But that is in LEO. In GEO, the biggest issue is spacecraft charging, not single event effects — a totally different space environment. Two-thirds of all anomalies are due to spacecraft charging, and then you get like an arc discharge, and you can get an EMP from that which takes out your satellite, so you know it's getting shocked. You have seen a computer when you accidentally shock it was too strong as shock can fry electronics. That happens primarily in GEO.

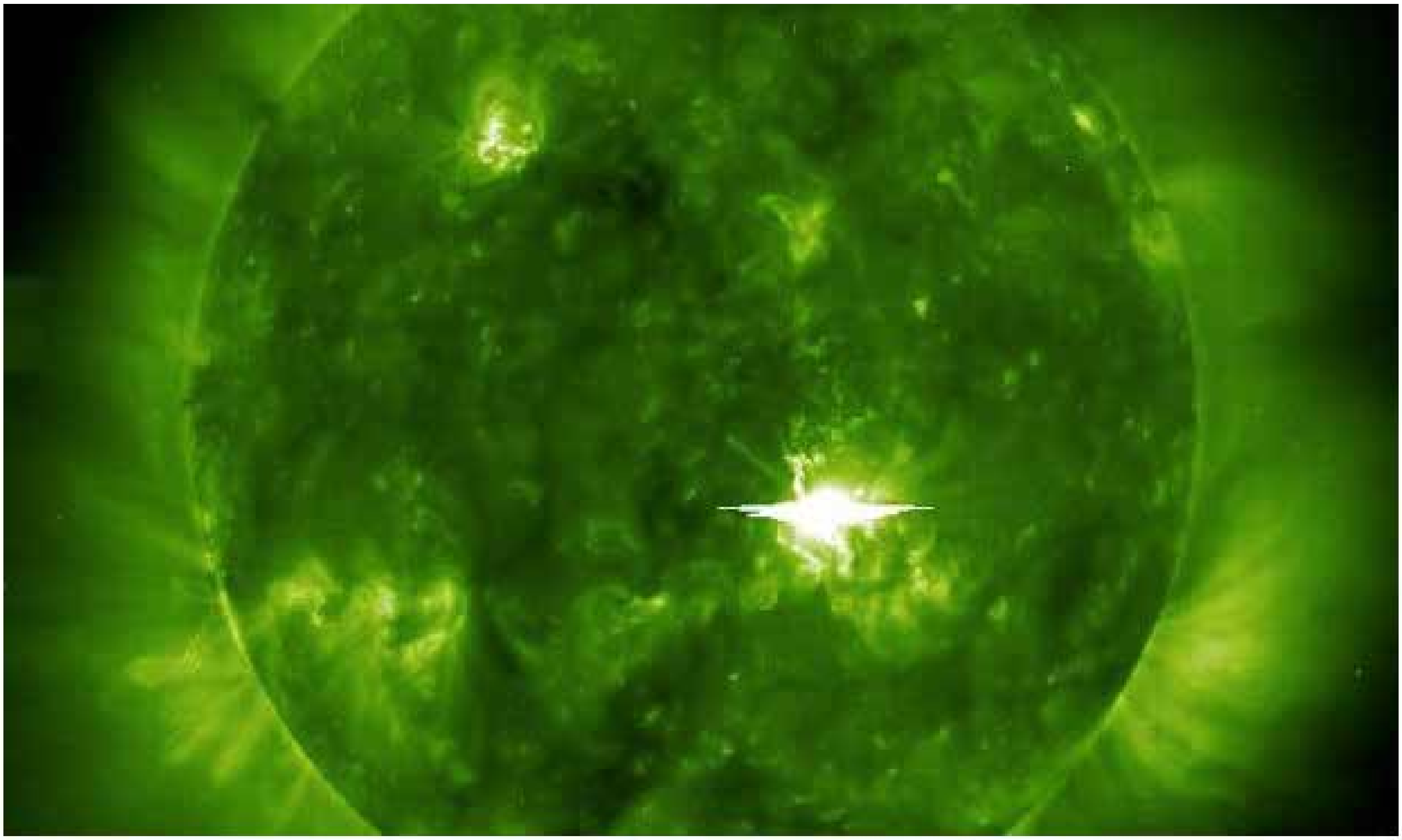
I think that's the biggest thing that satellite operators have to realize is that space is not, you know, that space isn't space. Not all space is the same space. You have microclimates around the Earth. And depending upon what altitude you are in, that dictates everything about how you design your satellite.

Journal: Why do we have so much trouble getting the predictions correct? Don't we have monitoring devices to tell what's coming?

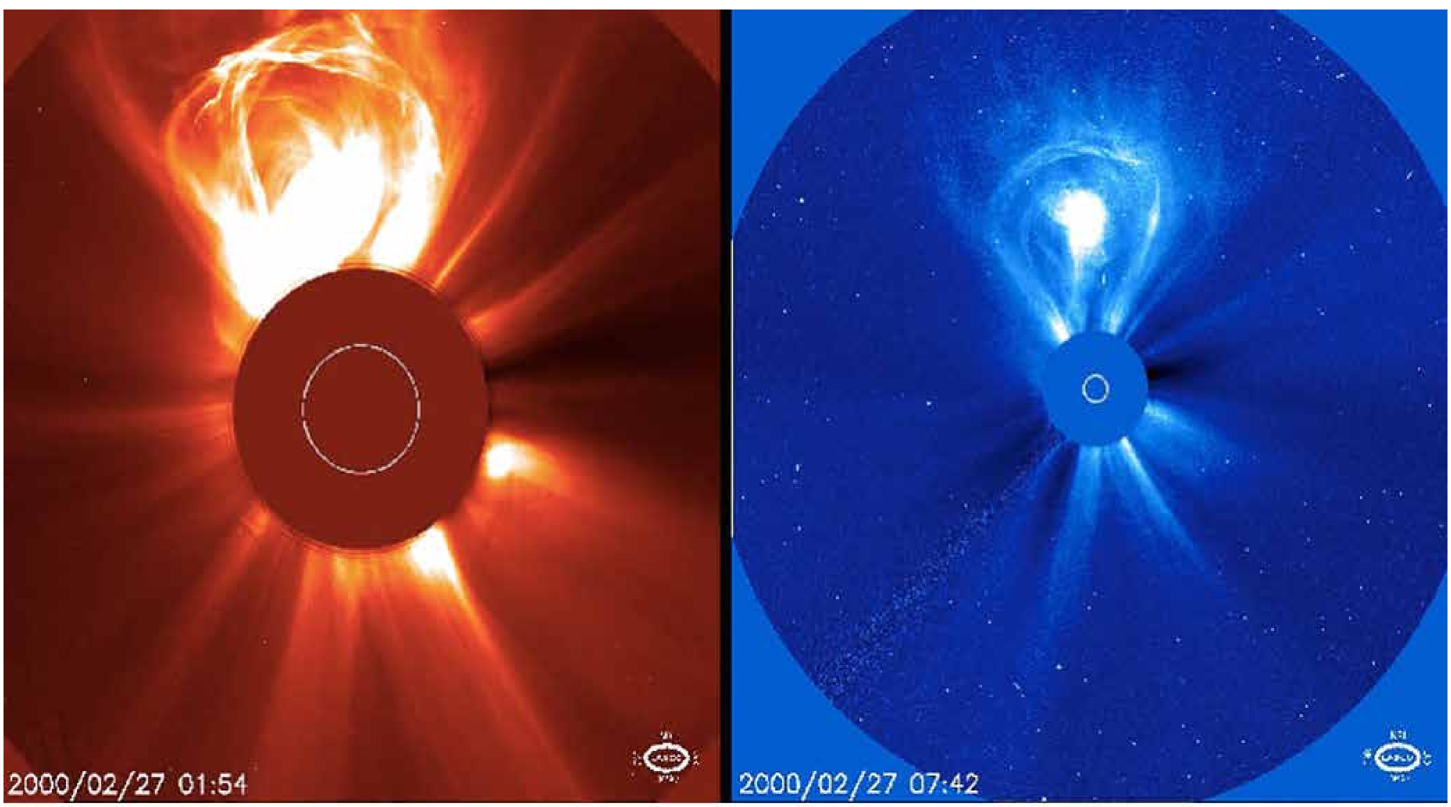
Dr. Skov: Yes and no. Space weather is a very young science. It didn't even exist until about 1957. Until 1950, we didn't even know there was the solar wind. So space weather is very much where terrestrial weather was back in the 1950s and 60s, when we had very little more than a warning or tornado warning like a tornado siren.

Right now, we have measuring devices up in space, but they are extremely expensive, mainly because there is so much space to cover. Most of those instruments are imagers or some kind of remote sensing. What we're doing is that we're looking at something very far away, and then we are trying to judge it as it comes towards us.

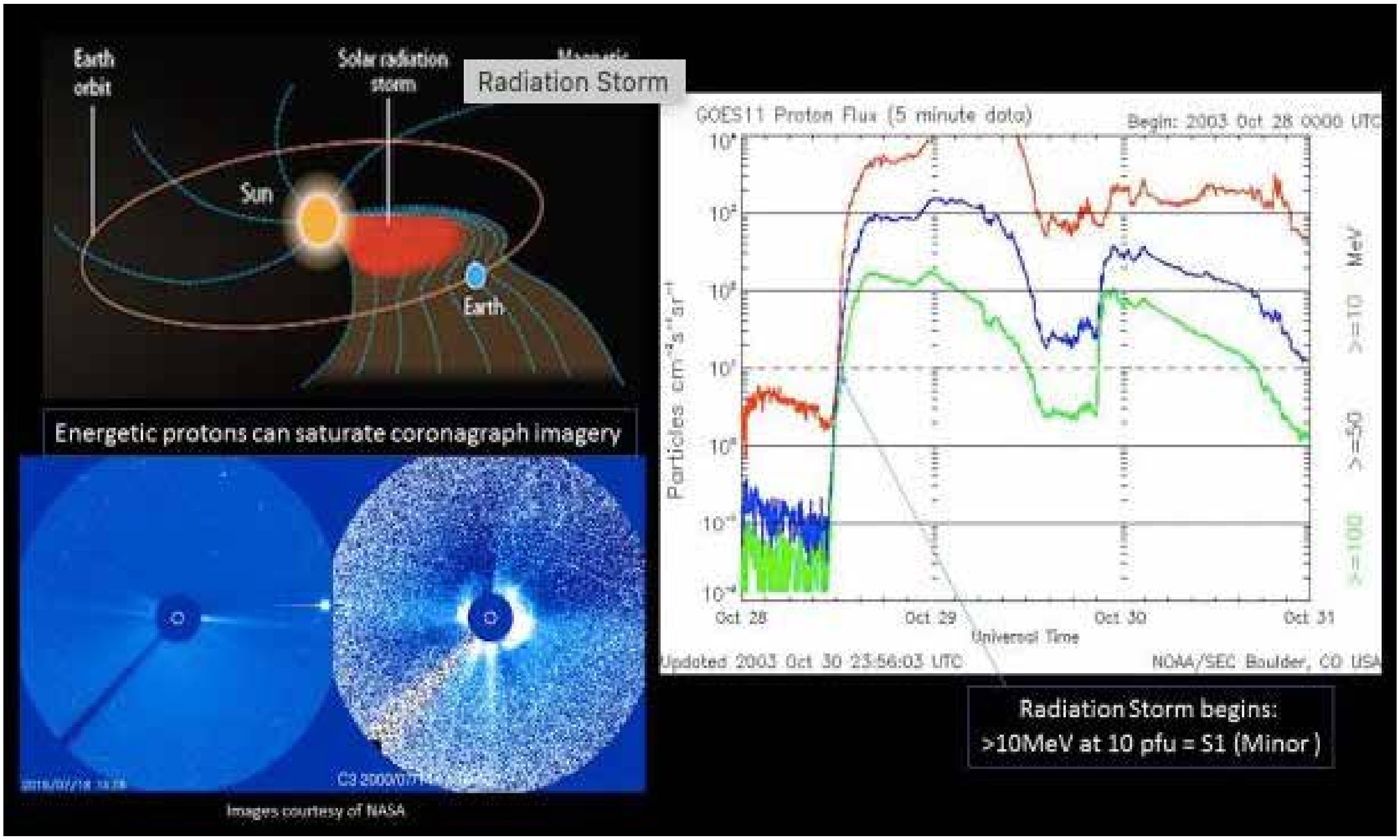
I can give you an idea by imagining trying to judge the arrival time of a car that is going to drive cross-country from New York to Los Angeles, and all you have to go on is the speed of the car that backed out of the driveway in New York. That's it, so you know it's almost impossible. I mean, you've got traffic along the way. You have no idea of the



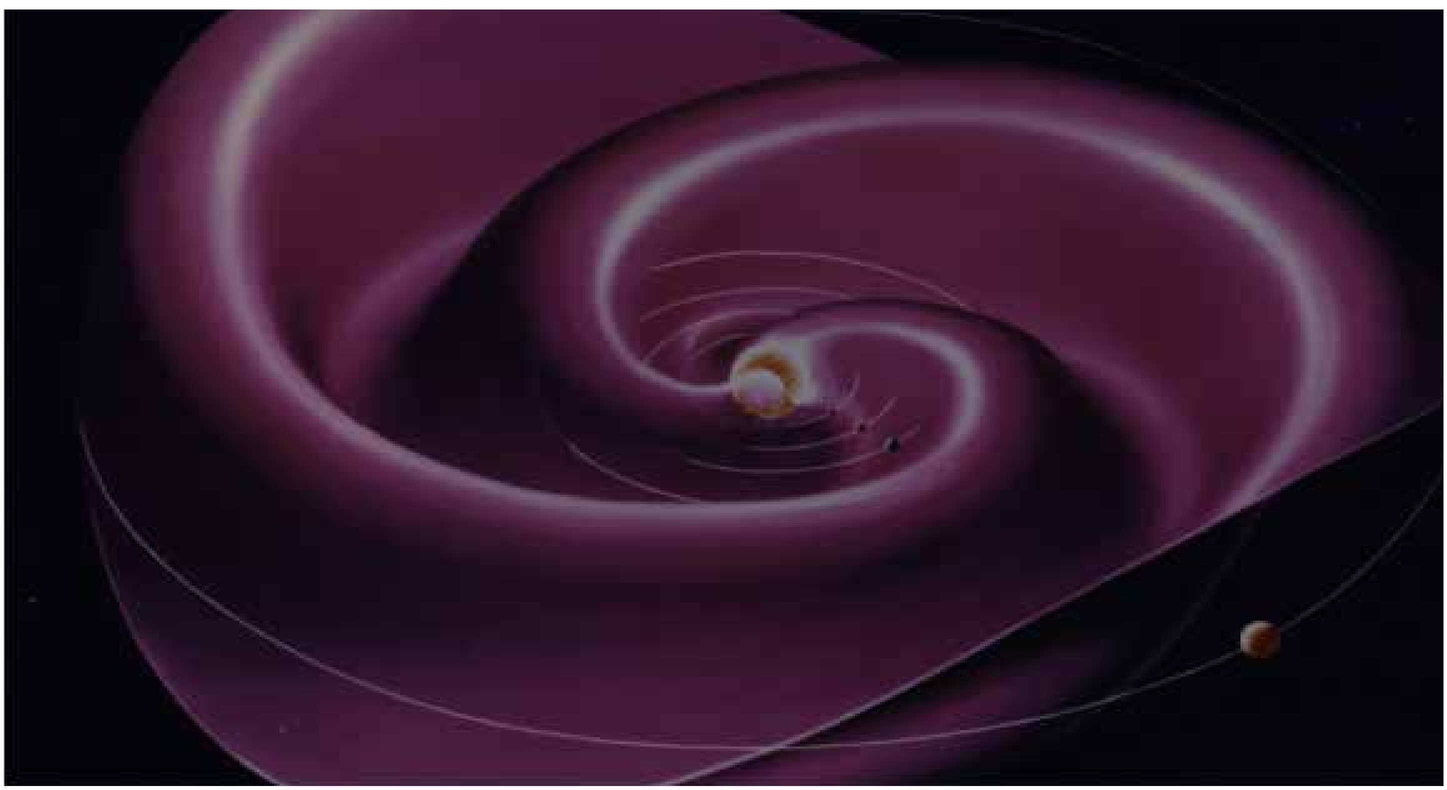
Solar flare. [NOAA, photo.]



A coronal mass ejection on Feb. 27, 2000 taken by SOHO LASCO C2 and C3. A CME blasts into space a billion tons of particles traveling millions of miles an hour. **Credit:** SOHO ESA & NASA



Solar radiation storm. [NOAA/NASA, photo.]



Solar wind. [NOAA, photo.]

bathroom breaks you need to take. It's the same kind of idea with a solar storm as you see it leaving. Well, that's like a car backing out of the driveway, and outside of that, it gets off the grid, it becomes invisible, and you have no idea how long it's going to take for it to get there. You can only estimate. And you estimate using the speed that you saw it back out of the driveway — backing out of the sun's driveway.

But that's really where we are. It doesn't matter how expensive or the quality of the camera. That's not what the problem is. That's not the limiting factor. Once it's out of view of the camera, we have no idea of everything else that happens along the way.

Journal: If we had another Carrington type of event, considered the granddaddy of storms, what problems would that pose for satellite operations?

Dr. Skov: If I went down a timeline of what would happen, first, of course, because we have a solar flare likely because usually when you have a granddaddy, you have all of this stuff. You get everything.

Of course, the first thing you deal with would be the fastest stuff to arrive, which would be the stuff at the solar flare that affects satellites.

I mentioned earlier that it's radio burst. So, first of all, you would get radio transmissions completely jammed right away, and the sun would be screaming so loudly that radio communications would be affected.

My biggest fear lies not so much in getting a Carrington class event with a big storm that jams radio transmissions but instead having this happen when an intense natural disaster occurs. What I call a perfect storm would be where you have a terrestrial weather event like the hurricane that decimated Puerto Rico. We had something very close to that back in 2017 with Irma and Marie. Then we had region 2693 giving us outrageously intense radio bursts that we're jamming even satellite phones so they could not do search and rescue or get out on the satellite phones. The Red Cross blamed the hurricane for that, but we knew better.

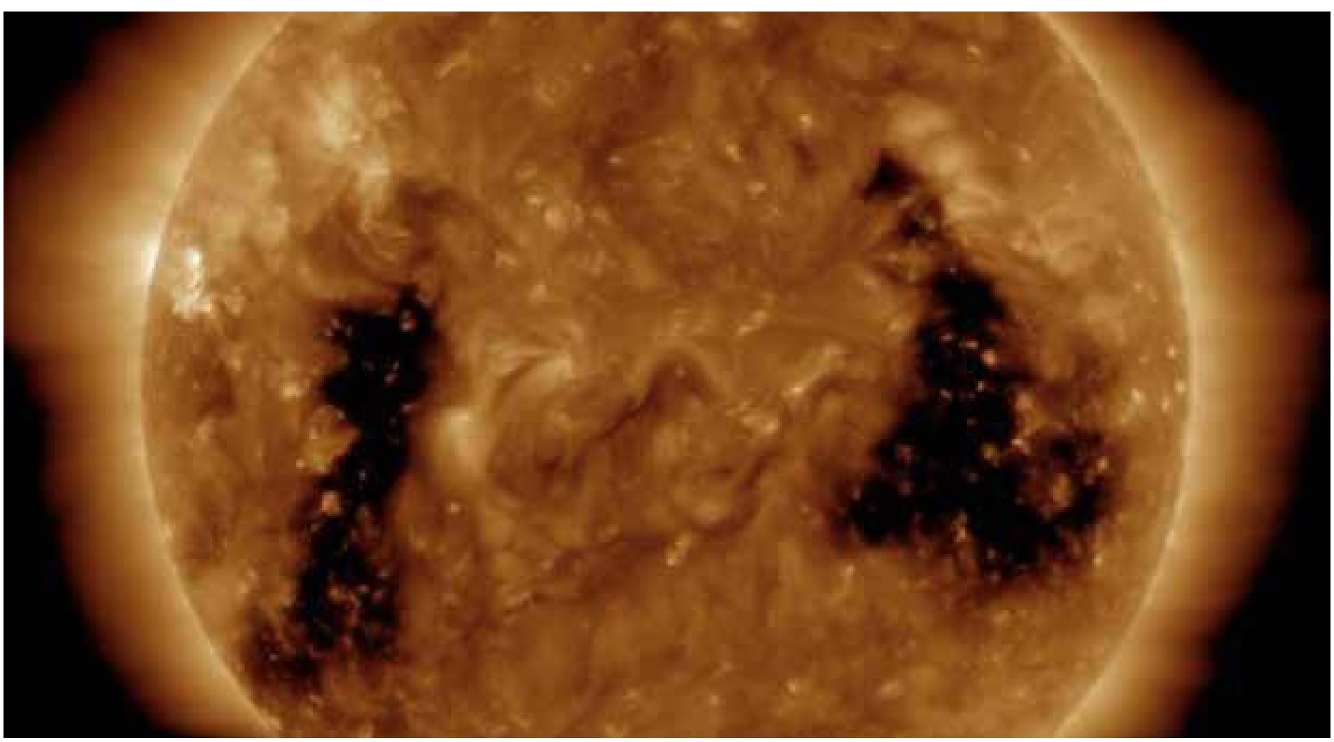
So, the first thing that would happen would be the radio bursts jamming the transmissions for potentially hours, which causes you all sorts of havoc. And then, when we got through that, in about 17 hours (between 14 and 17 hours later), you would get a solar storm as well hitting Earth. You'd get an EMP (electromagnetic pulse) because anytime you get something that massive and that fast slamming into the Earth's magnetic system, it crushes the system down and causes a huge change in the magnetic field. That again causes more issues on the ground than for satellites, but that would be the first thing.

We once almost went to war because we had the Americans getting jammed and satellites having issues, and there were all sorts of problems. And it was the scientists that they called to calm down the military. So many events have raised eyebrows in one fashion or another.

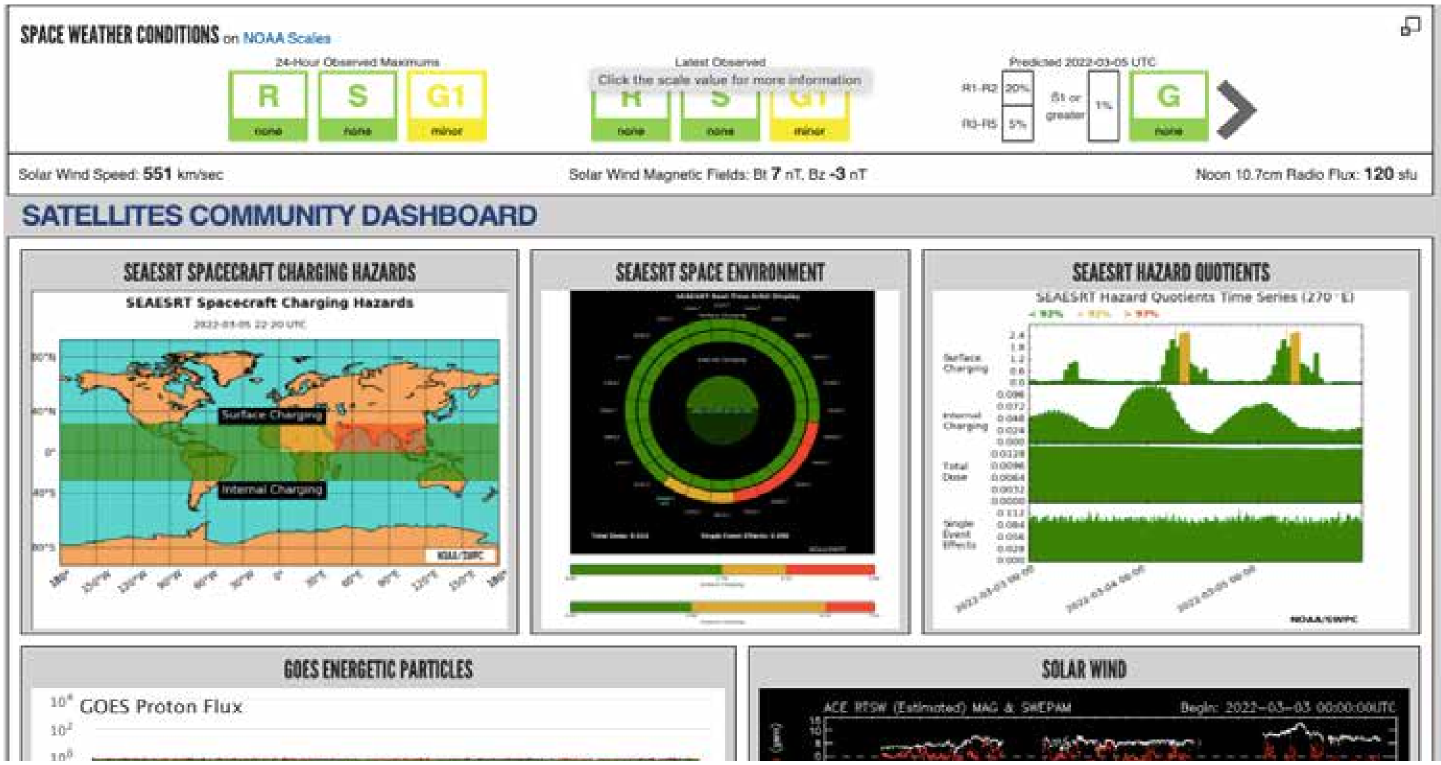
As regards satellite communications, the first thing that would happen would be that radio bursts would jam transmissions of the satellites. Then, once the solar storm hit, the satellites would notice the energetic particle environment getting bigger.

The second most significant thing that would arrive is the particle storm, which would end up causing single event effects, especially out in GEO and MEO, maybe a little bit down in the LEO area. Usually, LEOs are pretty protected from radiation storms from the sun. Nonetheless, they would be bathed in this radiation storm, which would start damaging satellites, causing spurious commands and all sorts of things. We might get some spacecraft to go into safe mode, for example, and telemetry memories would flip, and there'd be all sorts of destructive and some non-destructive anomalies.

We could have satellites getting yellow, with many charging anomalies occurring. We would start getting real birds falling out



Coronal holes. [NOAA, photo.]



noaa.gov Satellites Community Dashboard. [NOAA, photo.]

of orbit, which would actually be a more significant issue over the next few days, even after the solar storm passed.

We could continue to see a degradation of orbits in LEO because the upper atmosphere continues to inflate for a little bit before it comes back down. So, it is kind of a multi-faceted type of attack just from what seems to be one single event on the sun.

Journal: I've been asked by some hams what you would recommend for amateur radio satellite operators to help protect their stations against damage in the event of a CME or other serious event.

Dr. Skov: I think if you protect yourself from lightning, you're going to be okay and in terms of doing the same kind of protection for any type of solar storm. You'll be way overprotected for anything a solar storm could bring you.

But here's the thing: what it comes down to is operator error. What happens when you have a big solar storm or radio bursts or anything like that is that the operator suddenly thinks there's something wrong with my station because I'm not able to communicate to the satellite, so then they begin to tear apart their rig, climb their tower or keep trying to troubleshoot these nonexistent Gremlins. The problem is they're not paying attention to space weather, and that's when damage occurs.

I talk to maritime mobile service people, even in the Navy. They have spent hours having their technicians tearing apart their whole console on Navy ships, trying to chase down what is wrong with their rig because it's not they can't communicate. It turns out if they had just waited six hours, then it usually would have gone away. But they weren't being aware of the space weather people. So, it's a self-inflicted injury that they need to be aware of.

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References

Most ham operators probably are aware of the WWV geophysical report published every 3 hours (**www.swpc.noaa.gov/products/geophysical-alert-wwv-text**). At the top of that is a navigation bar with is a list of topics, one being a "DASHBOARDS." Click on that, and you will find some specialized dashboards suited to various audiences. Ones of most interest to hams would be RADIO and SATELLITES.

Clicking on the SATELLITES dashboard presents you with a number of diagrams and charts:

The SEAESRT REAL TIME ORBIT DISPLAY is helpful to see when the satellite is in danger from a solar storm. An explanation of the reading of this chart may be the subject of a follow-up article.

The SOLAR WIND Chart is helpful to know the present state of solar activity. The first, third and fourth lines would be the most relevant to the ham community.

Choosing the RADIO dashboard provides a level of D-region absorption map which, during solar storms, shows the affected frequencies. It is only active during short-term solar activities like flares. During solar minimum, it is usually black for weeks, even months, in a row! The Ovation Auroral Forecast, which shows the current auroral activity — especially significant for GPS users and HF hams.

See, J. Kornowski, "Protecting Satellites and Ground Stations from EMP and CME," *AMSAT Journal*, July/August 2016, pp. 21-24.

Once again, thanks to Tamitha for her interest and time in sharing information about space weather with the amateur radio satellite operators in mind.

An EZNEC Model of the Lindenblad Antenna

Grant Zehr, AA9LC

The Lindenblad gets little attention in the world of amateur radio antennas, even though recognized as one of the best options for an omnidirectional satellite antenna. Checking the ARRL QST Archive turns up only two entries. In comparison, search for quad or Yagi, and you will find around 400 entries. Even "helix" returns 20 entries. The ARRL Antenna Book gives the Lindenblad about half a column. John Kraus gives the Lindenblad array half a paragraph in his well-known Antennas. The RSGB VHF UHF Manual (4th ed.) does not mention it. Nor does my copy of William Orr's Radio Handbook (19th edition) or his Radio Amateur Antenna Handbook. You get the idea. Where can you go to learn more about this antenna?

I found a couple of good discussions of the Lindenblad online (1,2), but many questions remained. Perhaps a computer model would be helpful. After all, I had EZNEC installed on my computer and had worked through some basic designs. So all I needed was a good Lindenblad model to work with. But I never could find a helpful model. Fortunately, I had the opportunity to speak with Roy Lewallen, W7EL, who developed EZNEC, at the Dayton Hamvention. He provided a couple of tips that pointed me in the right direction and helped me develop useful EZNEC models for VHF and UHF Lindenblad antennas.

EZNEC

EZNEC is one of the most popular and powerful antenna modeling programs available to radio amateurs. While it may seem overwhelming to the beginner, with patience, anyone who has basic computer skills can become adept at creating computer models of typical antennas used by radio amateurs. EZNEC is certainly no more challenging to use than a modern word processor or spreadsheet program. I use EZNEC Pro/2 version 6.0, available free of charge at **www.EZNEC.com**.

If you are just getting started with EZNEC, it is a good idea to work through a basic introduction to the subject, such as Ward Silver's book, Antenna Modeling for Beginners. Another good introduction is "How to Start Modeling Antennas using EZNEC" by Greg Ordy, W8WWV, which is available online. Alternatively, you can simply work through the "Test Drive" documentation that accompanies EZNEC. That's where I found the information I needed for this Lindenblad model.

Disclaimer

I am NOT a trained professional in the field of antenna modeling. The antenna model I include here has multiple known limitations and will NOT allow you to build a perfectly functioning antenna in one try. But if you build this model, you will learn how to construct and arrange the four needed dipoles, match them to a 50-ohm source, and see what happens if you make changes to the antenna design.

Building a Lindenblad antenna (model)

As an exercise, we will build an EZNEC model of the AA2TX "EZ Lindenblad for 2 meters" (3). If you have already installed EZNEC Pro/2 version 6.0 and built a dipole or loop antenna model, you should be able to follow along and duplicate the Lindenblad model shown here. Reading the AA2TX article before you begin will help you understand how that antenna was designed and built.

Setup

Curiously, one of the most confusing things about starting a model with EZNEC is opening a new antenna file. There is no "new" command, so you must begin by opening one of the existing examples. In the Control Center window, click on Open and find the file "Dipole1.ez." After opening the file, immediately save the file using the "Save As" option. Next, give the new model a name you select, perhaps "Lindenblad 01." Now you have a new file with a different name.

As you make changes to your model, you will want to save your work periodically with a new name/number so that you can retrace your steps if needed. In the Control Center window, click on the title bar and change the title to "AA2TX Lindenblad." Next, change the frequency to 145.9 MHz. Be sure the ground type is "Free Space." Next, change the units to inches to make data entry easier. In the Control Center window, click on the 'Units' button. You will see a window titled "Select Units." Click the Inches button to change dimensions to inches. Your Control Center should now look like Figure 1.

Getting started

Now you will need to modify the dipole to

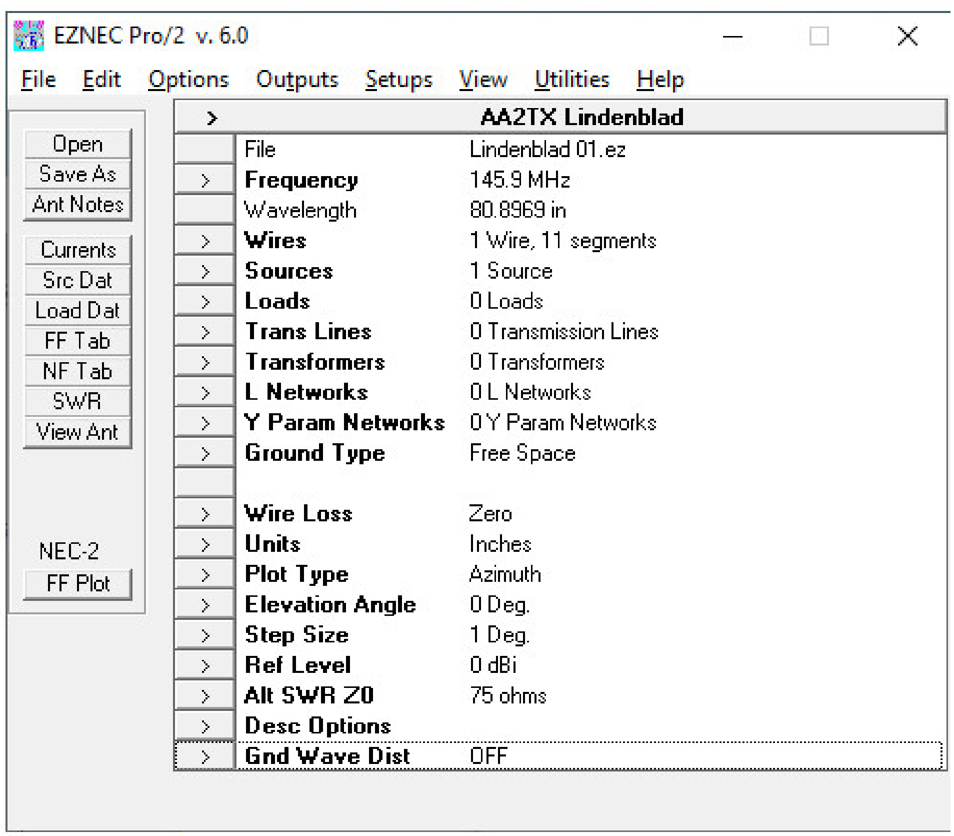


Figure 1.

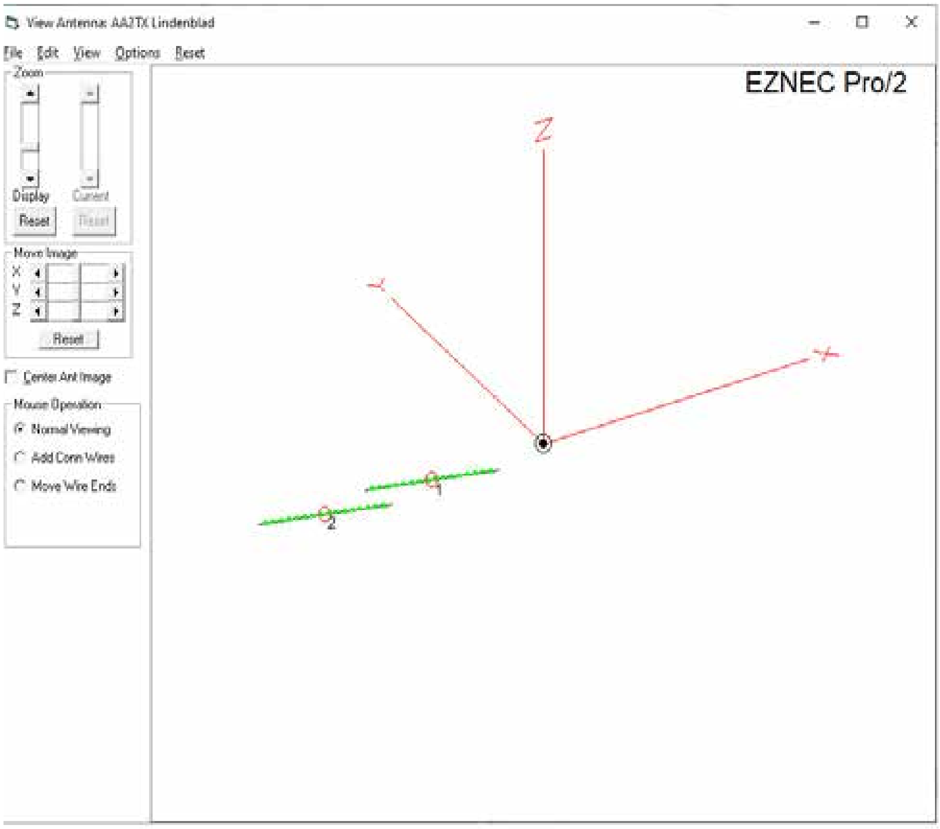


Figure 2.

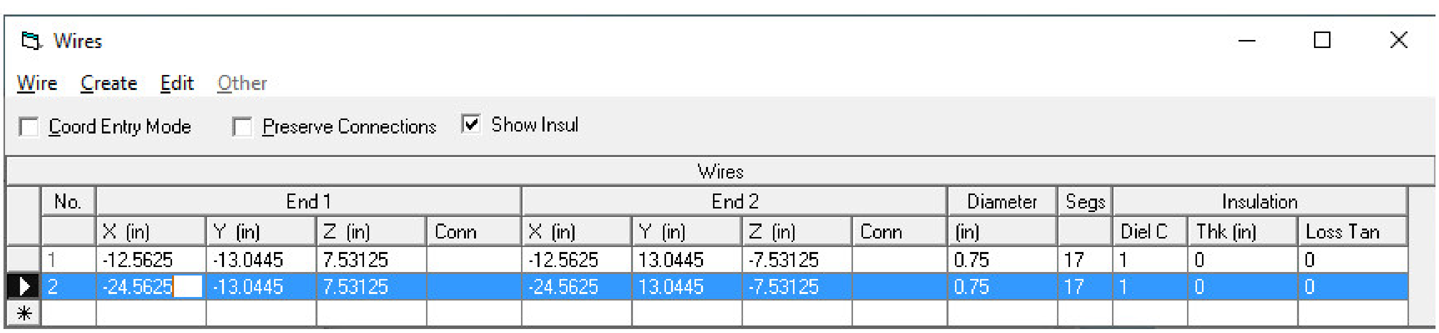
match the AA2TX design. Click on the Wires selection button in the Control Center to open the Wires window. Then edit the Y values to obtain a dipole 30.125 inches long (from the AA2TX article) while keeping the center of the dipole on the X-axis. Simply enter -15.0625 inches for the Y value at End 1 and +15.0625 inches for the Y value at End 2. The X and Z values should all be zero. In the Diameter column, change the diameter to 0.75 inches. Change the number of segments (in the "Segs" column) to 17. Click on the View Antenna button in the Control Center, and hover the cursor over your dipole (Wire) to check the length of the wire. A small window will appear with wire data. The length should read 30.125 inches, and the diameter should read 0.75 inches. Now you can check the SWR (from 140-200 MHz, 1 MHz steps) to see where this dipole is resonant. There should be a low SWR point at around 180 MHz. Remember to set the Z0 box to 75 ohms when checking the SWR since our single free space dipole impedance is approximately 75 ohms. Click or drag your mouse along the SWR curve to read each frequency's SWR and other data.

Next, we need to rotate our dipole thirty degrees around the X-axis. Open the View Antenna display. In EZNEC, the red lines on the X, Y, and Z axes extend from zero in the positive direction. Clockwise (CW) and counterclockwise (CCW) are defined as viewed from the positive end of the specified axis. To rotate our dipole, go to the Wires window, select the "Wire" pull-down menu, then "Rotate Wires." Rotate Wire 1 thirty degrees CW around the X-axis. If your dipole moves to the wrong coordinates, select the Edit pull-down menu, "Undo" the change and re-enter the parameters.

It is time to move our dipole into its correct position in the four-dipole array. Let's move it along the X-axis in the negative direction (toward the left in the View Antenna display). Since the dipoles in the AA2TX antenna are 25 1/8 inches apart, we will move our dipole half of that distance (12.5625 inches). To move the dipole, we have two options. We can edit the X parameter on each end of Wire 1 or save a step and use the "Move wires XYZ" function. That is found in the Wires window, under the Wire pull-down menu. Click "Move Wires XYZ," select "Move X by" and type in -12.5625 inches. Check the View Antenna display. Your tilted dipole should have moved off to the left.

We could go through those steps again for the next three dipoles, but it is much easier to use EZNEC's Copy and Rotate functions. First, let's make a copy of our wire, Wire 1. In the Wires window, use the Wire pull-down menu again and select "Copy wires." With the Copy Wires window open, select "offset Copy X by" and make that value -12 inches. That creates a copy of Wire 1 and places it on the X-axis 12 inches further away from the center point. In the View Antenna window, it will show up as an identical dipole with the number "2" and a circle near the center. The circle represents another source (Figure 2). We will want only one source when we are done, but we'll deal with that later.

If you look in the Wires Window now, you will see that EZNEC took care of all the details of creating our second wire. We will use the Rotate function again to move the



No.	End 1 X (in)	End 1 Y (in)	End 1 Z (in)	End 1 Conn	End 2 X (in)	End 2 Y (in)	End 2 Z (in)	End 2 Conn	Diameter (in)	Segs	Insulation Diel C	Insulation Thk (in)	Insulation Loss Tan
1	-12.5625	-13.0445	7.53125		-12.5625	13.0445	-7.53125		0.75	17	1	0	0
2	-24.5625	-13.0445	7.53125		-24.5625	13.0445	-7.53125		0.75	17	1	0	0

Figure 3.

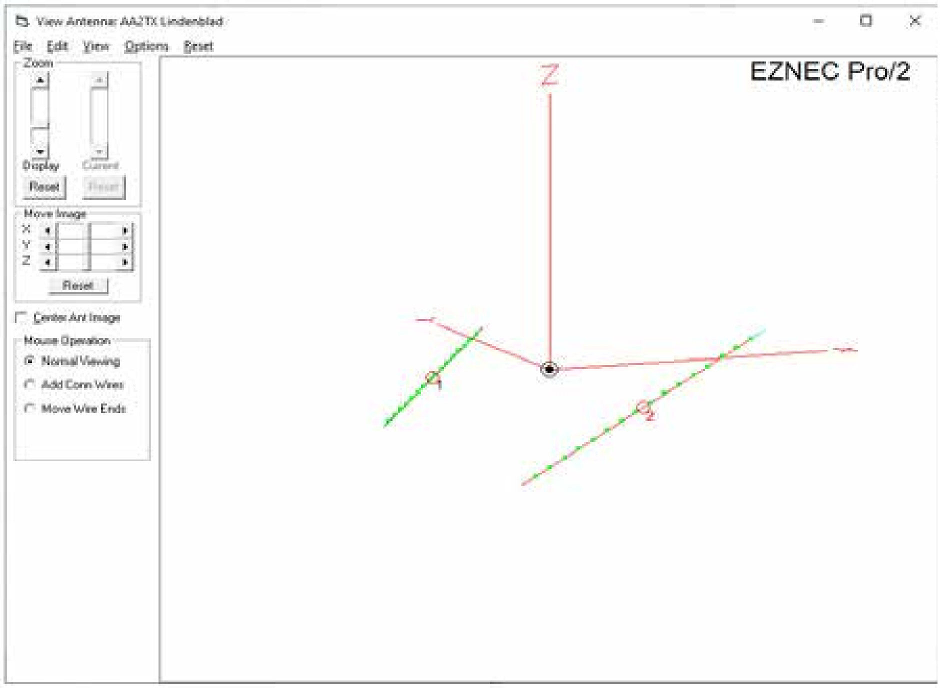


Figure 4.

second dipole onto the Y-axis. This time we need to specify that we want to rotate only Wire 2. Working in the Wires Window, identify the row of data for Wire 2 and click on the far-left box. The row of data for Wire 2 should turn blue. (Figure 3)

Next, with Wire 2 highlighted, select the "Wire" menu and then the "Rotate Wires" option as we did above. We want to rotate 90 degrees this time, but we are rotating around the Z-axis, this time CCW. Enter those values and click "Ok" and dipole number 2 should move to the Y-axis (Figure 4).

We have the second dipole on the Y-axis, but it's out of position by 12 inches. No problem. Go back to the "Wire" menu, then "Move Wires XYZ," and move Wire 2 (only) toward the center point by 12 inches. Since we're on the Y-axis, select "Move Y by" and enter 12 inches. It's plus inches this time (remember, the red lines on the X, Y, and Z axes extend from zero in the positive direction in EZNEC). Check the position of the second dipole by opening the View Antenna display and looking at the antenna from the top.

To get a top view, position your cursor near the top of the View Antenna display (putting your cursor on the large capital "Z" works well). Next, grab and drag the letter Z straight down. This will rotate the antenna drawing on the screen and give you a view of the antenna from the top. Or, simply press the letter Z key on the keyboard. You will see a top view of your Lindenblad (looking down along the Z-axis). The two dipoles should be the same length and arranged at right angles, as shown in Figure 5.

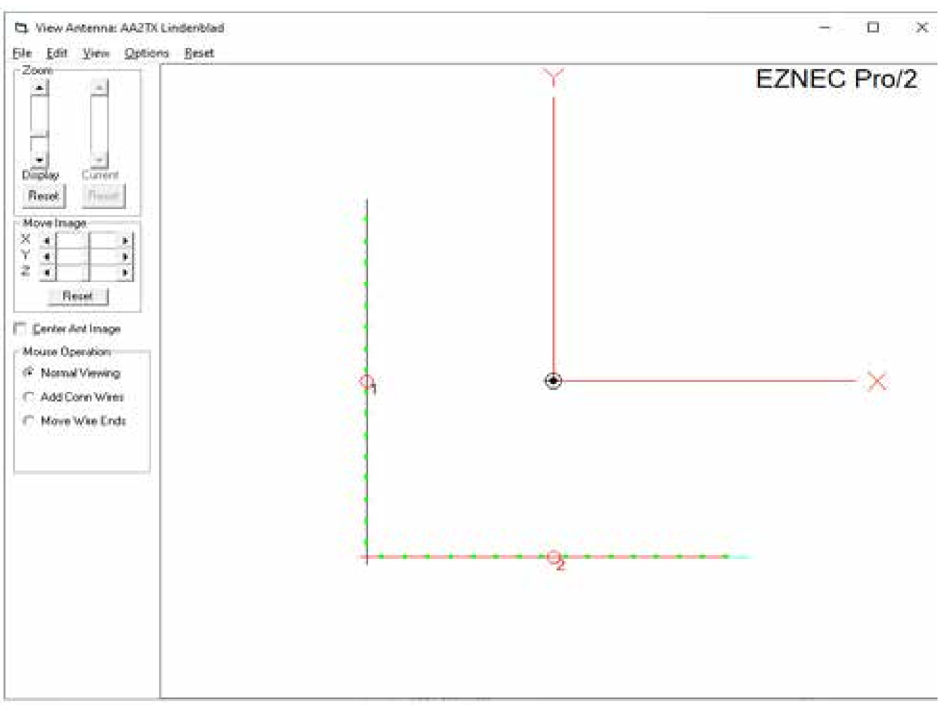


Figure 5.

In the View Antenna display, use the "Reset" pull-down menu and the "Reset Position" option to reset the position of your antenna. You now need to create wires 3 and 4 in the same way. Copy Wire 1 two more times (creating Wires 3 and 4). Rotate them around the Z-axis to 180 and 270 degrees. Don't forget to move the wires back to the correct spacing after rotating them. I guarantee that you will select the wrong wire(s), angles, or axis at least once. Check the 'View Antenna' display after each step to make sure your creation makes sense and starts to look like a Lindenblad. Remember where the "Undo" button is! This would be an excellent time to save your work.

The tricky part

So far, our antenna has used the basic EZNEC functions, which are covered in the introductory tutorials. But the EZ Lindenblad design does something interesting. It uses a length of transmission line to change the impedance of each dipole from 75 ohms to about 200 ohms. The four transmission lines are then connected to provide a 50-ohm feed point where you can connect your station transmission line (the EZNEC 'Source'). So, in our model, we need to attach a specified length of transmission line from the source to the center of each dipole.

We have already created the dipoles (Wires 1-4), and it is easy to connect a transmission line to the center of each dipole (Wire). But where does the source go? A source is normally connected to a wire segment, but we have no segment to use. The EZNEC solution is to create a Virtual Segment.

Virtual Segments are explained in the Test

Transmission Lines

Trans Line Edit

Transmission Lines												
No.	End 1 Specified Pos.		End 1 Act	End 2 Specified Pos.		End 2 Act	Length	Z0	VF	Rev/Norm	Loss	Loss Freq
	Wire #	% From E1	% From E1	Wire #	% From E1	% From E1	(in)	(ohms)			(dB/100 ft)	(MHz)
1	V1			1	50	50	23.6	75	0.78	N	0	0
2	V1			2	50	50	23.6	75	0.78	N	0	0
3	V1			3	50	50	23.6	75	0.78	N	0	0
4	V1			4	50	50	23.6	75	0.78	N	0	0

Figure 6.

Drive section of the EZNEC help files. Our Virtual Segment is a mathematically identified point where the four transmission lines and the source come together. In real life, that is where we would put a connector to attach the 50-ohm coaxial transmission line leading to our station. However, it does not appear on the "View Antenna" display, so you must keep track of your transmission lines and virtual segments via the tables that appear in the appropriate windows.

It's time to delete all the sources. Open the "Sources" window, and highlight and delete each source. We will create a new Source after we have a transmission line to attach it to.

Let's create a transmission line for dipole 1 (Wire 1). Go to the Control Center and find the line labeled Trans Lines. It should read "0 Transmission Lines." Click on the "Trans Lines" selection button to open the Transmission Lines window. Select the Trans Line pull-down menu in the Transmission Lines window and select "Add." We will add just one for now. Doing this creates another line of data in the Transmission Lines window, numbered "1."

In the box labeled "End 1 Specified Pos." under "Wire #," simply enter "V1." That creates a virtual segment at the source end (end 1) of the first transmission line. Tab over to "End 2 Specified Pos." In the two boxes below that heading, set Wire # = 1 and % From E1 = 50. That is end 2 of the first transmission line, and we just attached it to Wire 1, 50% of the distance from End 1, which is in the center of Wire 1. That is all that is needed to place the transmission line. EZNEC needs some more information, however. Move right to the column labeled "length" and enter 23.6 inches (from the AA2TX article). Move to the Z0 column, and enter the transmission line's characteristic impedance, 75 ohms in this case. The next column is for the velocity factor, 0.78 for this design. The other boxes can be left unchanged.

Next, put a source back into the model. From the Control Center, open the Sources window, select the Source pull-down menu and add a source (just one). We must define its connections, but it only has one. Go to Source 1, Specified Position, Wire #, and enter "V1". That connects our source to virtual segment 1, located at end 1 of the transmission line.

Three more identical transmission lines are needed to connect the Source to Wires 2, 3, and 4 at the center of each wire (50% from E1). The easy way to do that is to open the Transmission Lines window, and add three more transmission lines. In the Transmission Lines window, select "Trans Line," "Add," and specify 3 lines. Then copy the data from Line 1 to Lines 2, 3, and 4. You can use the Windows Copy and Paste functions to speed things up. End 1 of each transmission line should go to V1. End 2 of each transmission line (End 2 Specified Pos.) should go to the center of its respective dipole (wire). E2 of Trans Line 2 goes to Wire 2 at 50%, E2 of Line 3 goes to Wire 3 at 50%, etc. (You may see error messages, which should clear when all the data are entered.) Then enter the correct values for each transmission line's length, impedance, and velocity factor. Your transmission line table should now look like Figure 6.

In summary, End 1 of each transmission line is connected to V1, and this point becomes the new source for the Lindenblad antenna model. Confirm this by going to the View Ant display, pulling down the "View" menu, and selecting "Show Virtual Seg Conn." That opens a small window listing all the connections to V1 (SRC1 and TL1-4).

We have now completed our EZ Lindenblad antenna (Figure 7). You can drag your mouse over the View Antenna display to see your antenna from various directions and confirm that you have assembled your

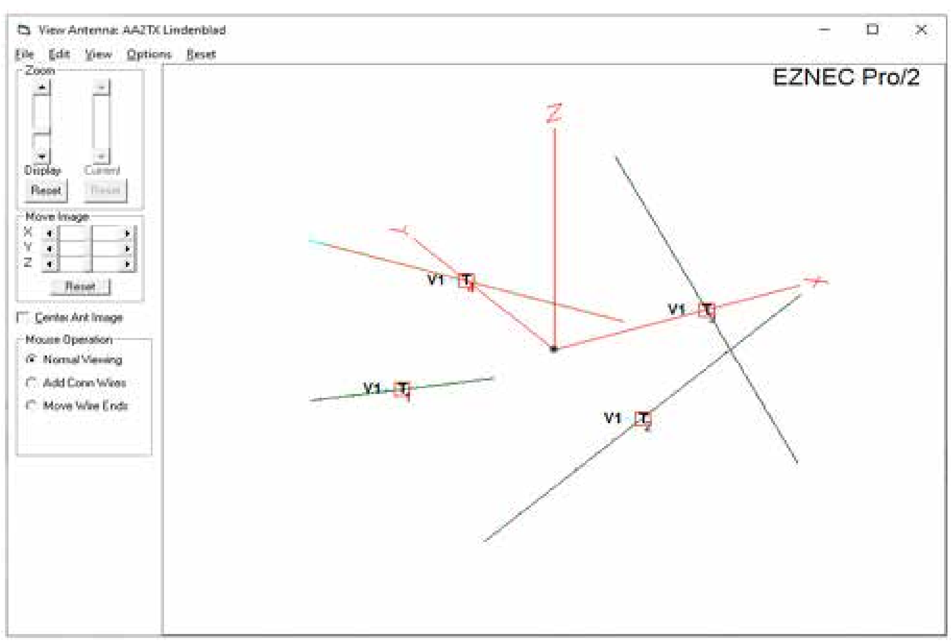


Figure 7.

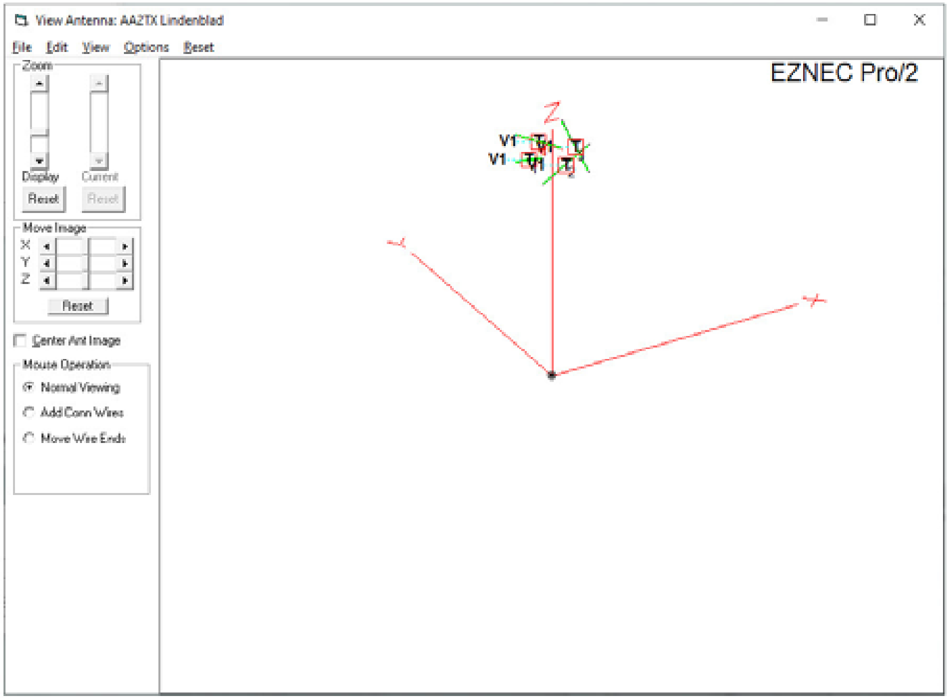
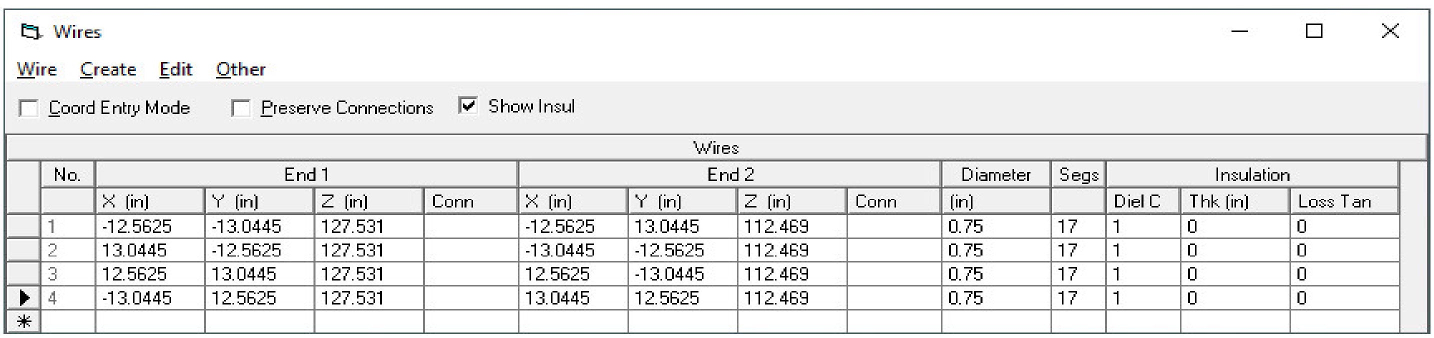


Figure 8.



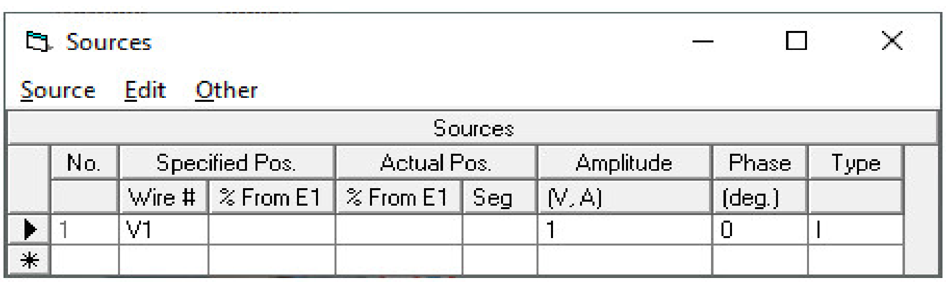
Wires

Wire Create Edit Other

Coord Entry Mode Preserve Connections Show Insul

No.	End 1 X (in)	End 1 Y (in)	End 1 Z (in)	End 1 Conn	End 2 X (in)	End 2 Y (in)	End 2 Z (in)	End 2 Conn	Diameter (in)	Segs	Insulation Diel C	Insulation Thk (in)	Insulation Loss Tan
1	-12.5625	-13.0445	127.531		-12.5625	13.0445	112.469		0.75	17	1	0	0
2	13.0445	-12.5625	127.531		-13.0445	-12.5625	112.469		0.75	17	1	0	0
3	12.5625	13.0445	127.531		12.5625	-13.0445	112.469		0.75	17	1	0	0
4	-13.0445	12.5625	127.531		13.0445	12.5625	112.469		0.75	17	1	0	0

Figure 9.



Sources

Source Edit Other

No.	Specified Pos. Wire #	Specified Pos. % From E1	Actual Pos. % From E1	Actual Pos. Seg	Amplitude (V, A)	Phase (deg.)	Type
1	V1				1	0	I

Figure 10.

Lindenblad correctly. The small square with the letter "T" at the center of each dipole indicates that a transmission line attaches at that point. Remember that the transmission lines connected to the squares are antenna components, functioning as RF transformers. Each of the short transmission lines you created and attached to the center of an EZNEC "wire" (at end 2) connects to the "source" (at end 1). The transmission line leading back to your station is also connected to the source, which is not visible in the "View Antenna" display. However, the location of the source is described in the "Sources" window.

Finally, remember that our antenna is still operating in free space. The free space option makes building the antenna easier but does not represent the real world. To simulate a real-world situation, go to the Control Center, select Ground Type and change it from Free Space to Real Ground. In the Ground Type window, choose Real Ground/ Mininec. You will get error messages because half of your antenna is below ground. That is easily remedied. From the Wires window, select the Wire pull-down menu and then choose "Change Height by." Enter +120 inches, which will place your antenna 10 feet above ground. When you check the View Antenna window, you will see your antenna 10 feet above ground (Figure 8). If your model doesn't look quite right, you can compare your Wires window with Figure 9, your Transmission Line window with Figure 6, and your Sources window with Figure 10, making any changes needed.

For fun, go back to the Control Center, change the Plot Type to 3D and click on the FF (Far Field) Plot button. You will see a nice 3-D image of the Lindenblad antenna pattern (Figure 11). You can turn and tilt the display by dragging your cursor across the 3-D Plot Screen. If your display gets too confusing, you can use the View Antenna "Reset" tab. Your antenna now consists of four dipoles and matching transmission line transformers, with a single feed point (source) located 10 feet above ground where you can connect your hypothetical transmission line. The dipoles are all tilted to 30 degrees. It is a good representation of the AA2TX design.

Does it work?

If you now check the SWR curve for your antenna (over the range 145-155 MHz, 1 MHz steps, Z0 = 50 ohms), you will see something like Figure 12. The antenna is nicely resonant but at a higher frequency than the operating frequency AA2TX described in his article. What is wrong? Does this mean the model is useless?

British statistician George E.P. Box is credited with saying, "All models are wrong, but some models are useful." Because our model fails to account for every factor that affects the design's performance, it is

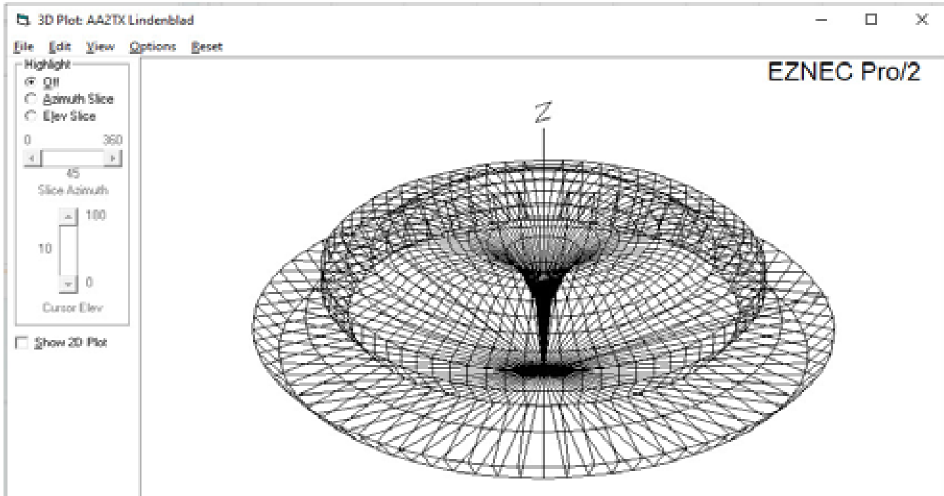


Figure 11.

"wrong." We haven't accounted for the short leads between the coaxial connector and the transmission line transformers, the dielectric effect of the PVC fittings, the effects of the support structure, etc. For this reason, our model does not show precisely the same performance as the real-world antenna AA2TX built. (4)

The model is still useful. It demonstrates that the transmission line matching system works nicely. It produces an accurate radiation pattern for the antenna. We can make changes in our model and get a good idea of how a real antenna would respond to the same changes. What if the diameter of the dipoles is changed? What if we change the spacing between the dipoles? What if we make the transmission lines a bit longer? Our Lindenblad model can quickly answer these "what if" questions.

Conclusion

EZNEC is a powerful tool for amateur antenna builders. While it will rarely design a working antenna for you on the first try, it can almost always help you better understand how your antenna works and how to solve problems you may encounter as you work on your project. If you cannot find an EZNEC model for the antenna you want to build, make your own!

End notes

1. "Circularly-Polarized Omnidirectional Antenna," George H. Brown and Q.M. Woodward Jr., *RCA Review*, Vol. VIII, June 1947, No. 2, pp. 259-269.
2. "Antenna Options, Horizontally Polarized Omni-Directional Antennas: Some Larger Choices," L.B. Cebik, W4RNL, *QEX*, January/February 2008, pp. 40-44. Includes discussion of "A Practical Lindenblad Array."
3. "An EZ-Lindenblad Antenna for 2 Meters", Anthony Monteiro, AA2TX, *QST*, August 2007.
4. We can incorporate more of these factors into our model if we choose. The stray capacitance at the point the four transmission lines connect is one of these factors. As an exercise, the reader is encouraged to add a second virtual segment and insert an EZNEC L-network (RLC type) with a shunt capacitance of about 10 pF, and series inductance = zero. Move the source to V2 and insert the network between V2 and V1. Note the change in SWR from 144-148 MHz.

The next issue of the Journal will include Grant's and Tom Planer's (KJ9P) article, "An EZ Lindenblad for UHF." — ed.

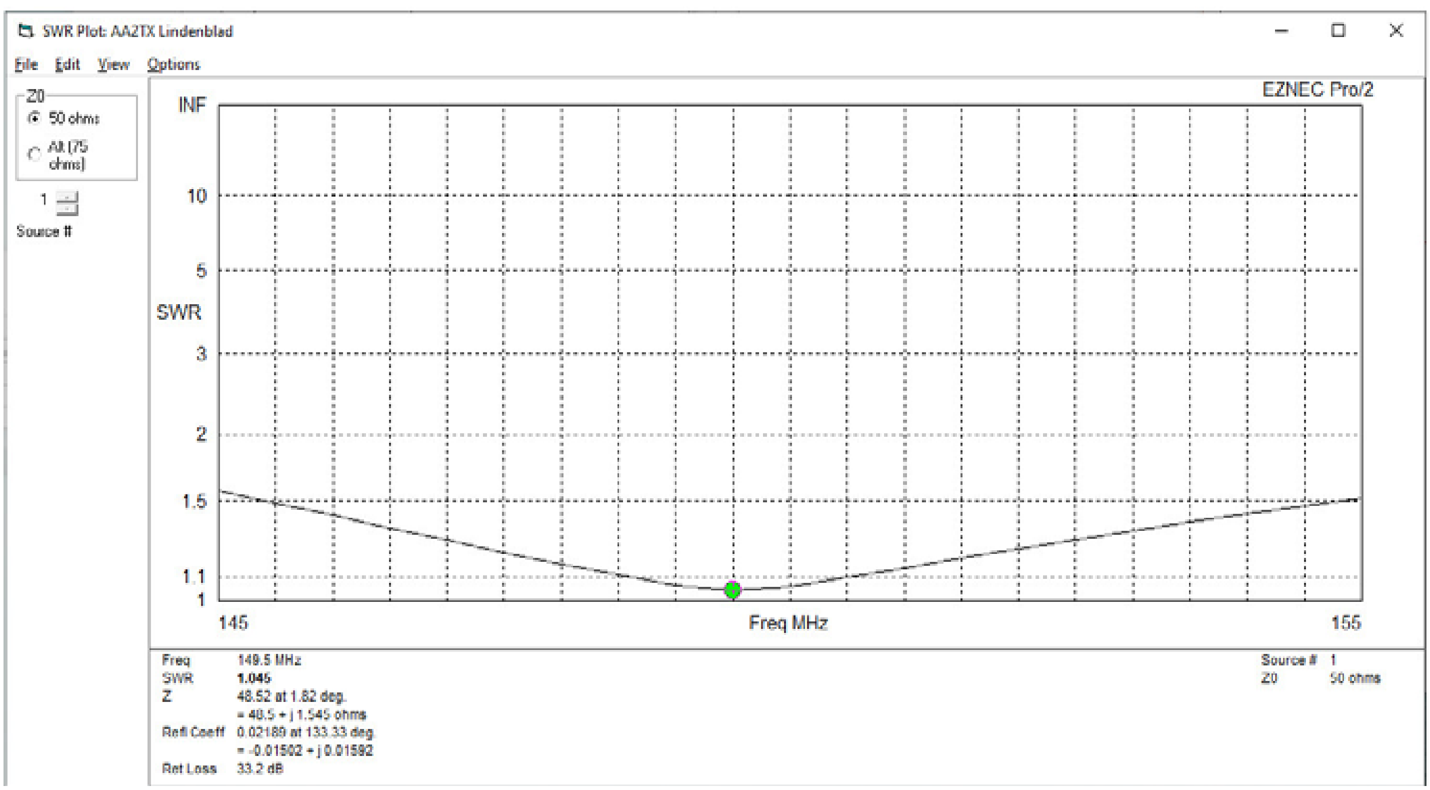


Figure 12.

Member Footprints: Share Your Experiences as an AMSAT Member

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

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

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- First Satellite Ground Station Description
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- Reasons You Are an AMSAT Member
- Favorite AMSAT Memory (a satellite contact, symposium, engineering project,

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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.
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