The AMSAT® Journal

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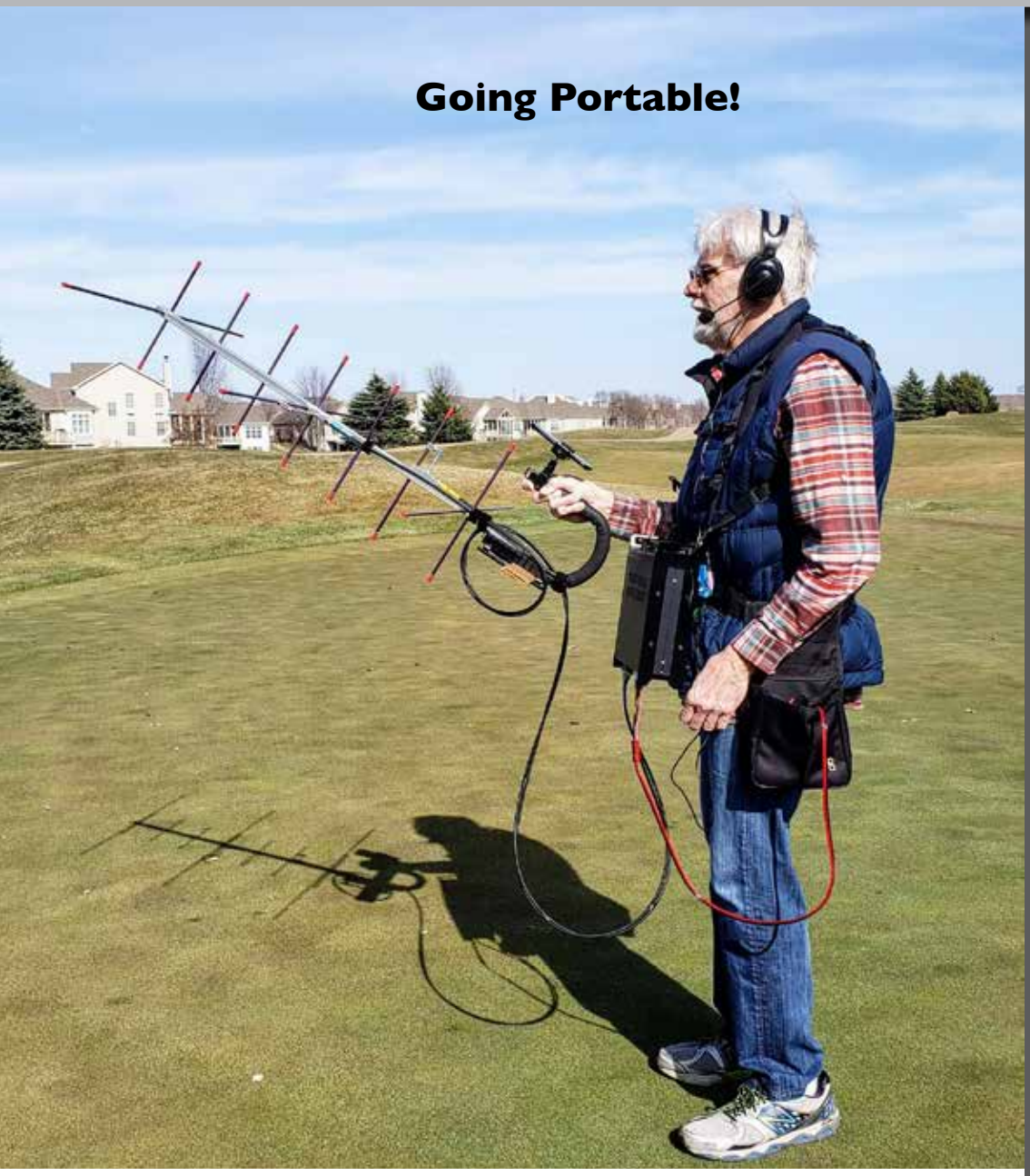
Going Portable!



In this issue —

AMSAT Announcements

2021 AMSAT Space Symposium and Annual General Meeting – Bloomington, MN – Oct. 29 – 31, 2021

The 39th AMSAT Space Symposium and Annual General Meeting will be held Friday through Sunday, October 29-31, 2021, at the Crowne Plaza AiRE in Blooming Minnesota. Crowne Paza Aire is located at 3 Appletree Square, Bloomington, MN 55245.

The Crowne Plaza AiRE is adjacent to the Minneapolis-St. Paul International Airport and only steps away from the METRO Blue Line's American Blvd. stop. Nearby shopping and tourist attractions include Mall of America, SEA LIFE at Mall of America, Nickelodeon Universe, and the Minnesota Zoo.

The Symposium includes presentations, exhibit space, and the AMSAT Annual General Meeting. The preliminary schedule is presented here and will be posted to the AMSAT Member and Event Portal website, launch.amsat.org, under the Events tab.

The AMSAT Board of Directors Meeting will be held before the Symposium, October 28-29, at the same hotel.

You can make hotel reservations by calling the hotel directly at (952) 854-9000 or (877) 424-4188 (toll free) or online by visiting crowneplazaaire.com. The group name is Amateur Satellite Group.

Symposium tickets, banquet reservations, and bus tickets for the Sunday afternoon tour may be purchased on the AMSAT Member and Event Portal website, launch.amsat.org, under the Events tab.

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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

You can feel the excitement in the air. AMSAT's Board of Directors elections are coming up. In addition, AMSAT has adopted a new Strategic Plan that affirms our commitment to higher orbits and FM operations and introduces an exciting new program. Also, we will finally get to join together in this year's symposium.

No one can deny that the introduction of political rhetoric during the last two election cycles has been a hard pill to swallow. While some felt having contentious elections was healthy for the organization, the purposefully misleading statements and personal attacks caused many of our members to tune out the noise, and in some instances, turn it off completely.

After all, the amateur radio satellite service is a hobby where people come to unwind from their daily routine and take their minds off the stresses of everyday life. They certainly did not come for the added drama.

I am happy to report, though, that this year's board of directors election should offer a return to normalcy. As AMSAT Secretary Jeff Davis, KE9V, will detail elsewhere in this issue, we have four nominations for four open positions.

While the results of the election may be a forgone conclusion, each nominee is already a volunteer who contributes to AMSAT's mission on a daily basis and has been nominated by their fellow members to lead AMSAT forward. Please read the important information about this year's elections procedures, get to know the nominees by reading their candidate statements, and support AMSAT by exercising your vote.

Another exciting announcement concerns the recently adopted Radio Amateur Satellite Corporation 2021-2035 Strategic Plan, presented to our members in this issue of *The AMSAT Journal*. The plan establishes a long-term, multi-faceted vision that includes big dreams, a continued presence in space, and a development path for the scientists, engineers, and operators of tomorrow.

Anything this ambitious will undoubtedly challenge our limited human and fiscal resources. We must parallel our new plan with new ways to manage and fund projects. AMSAT has a pool of very talented volunteers, but there will be times when we require skills beyond our current capabilities. Recruitment, partnerships, collaborative efforts, and even outsourcing are options that will help us fill in the gaps.

We must also develop the necessary skills to take advantage of external funding sources. Amateur radio satellites benefit more than just the members of AMSAT. We provide a service to the world and offer excellent educational opportunities to anyone with an interest in space science and communication technology. The path forward has been set, so let's get started!

As stated in my last "Apogee View," the 2021 AMSAT Symposium will be held in Bloomington, Minnesota. A formal announcement and open registration are forthcoming. In the meantime, I can share that the 2021 AMSAT Space Symposium and Annual General Meeting will be held at the Crown Plaza AiRE MSP Airport, 3 Appletree Square, Bloomington, Minnesota, on October 29 - 31, 2021. The Crowne Plaza AiRE is adjacent to the Minneapolis-St. Paul International Airport and only steps away from the METRO Blue Line's American Blvd. stop. Nearby shopping and tourist attractions include Mall of America, SEA LIFE at Mall of America, Nickelodeon Universe, and the Minnesota Zoo.

The 2021 AMSAT Space Symposium is open to the public, with registration available through the AMSAT Membership and Event Portal, **launch.amsat.org**. See the schedule below.

While we enjoyed last year's virtual symposium, nothing beats getting the chance to meet in person. I hope to see you there.

AMSAT 39th Space Symposium and Annual General Meeting October 28 – 31, 2021 Crowne Plaza AiRE, Bloomington, MN

Preliminary Schedule of Events (subject to change)

Thursday, October 28, 2021
0800 – 1200 AMSAT Board Meeting
1200 – 1300 AMSAT Board Lunch Break
1300 – 1700 AMSAT Board Meeting
1600 – 1900 Registration

Friday, October 29, 2021
0800 – 1900 Registration
0800 – 2100 Space Exhibit
0800 – 1200 AMSAT Board Meeting
1200 – 1300 AMSAT Board Lunch Break
1300 – 1700 AMSAT Space Symposium presentations
1700 – 1900 Dinner Break
1900 – 2130 AMSAT Reception, cash bar available

Saturday, October 30, 2021
0800 – 1600 Registration
0800 – 2100 Space Exhibit
0800 – 1200 AMSAT Space Symposium presentations
1200 – 1300 Lunch Break
1300 – 1500 AMSAT Space Symposium presentations
1300 – 1500 AMSAT Annual General Meeting
1800 – 1900 Attitude Adjustment (reception)
1800 – 2200 Cash Bar
1900 – 2200 Banquet

Sunday, October 31, 2021
0700 – 0900 AMSAT Ambassadors' Breakfast

NOTE: All times are Central Daylight Savings Time (CDST), UTC – 5 hours

AMSAT Strategic Plan: A Roadmap for Success

Robert Bankston, KE4AL
President

On June 1, 2021, our Board of Directors unanimously approved a forward-thinking, strategic plan to carry AMSAT through the year 2035. Defining who we are, what we believe in, where we want to go, and how we plan to get there is the first step on AMSAT's road to success.

Purpose

No organization can hope to succeed without having a plan, and AMSAT is no exception. Sure, wandering aimlessly from task to task may allow for singular achievements, but true organizational success comes from having a well-thought-out, long-range plan.

A strategic plan outlines a clear path, brings a sense of focus, and gives everyone within the organization something to work towards.

• A strategic plan works like a roadmap, laying out the best route for an organization to take in the years ahead.

• Because a strategic plan establishes direction, it helps the organization focus its efforts in order to get there.

• A strategic plan isn't just beneficial for an organization's management. It gives everyone in the organization a sense of purpose. With a defined mission and clear goals and objectives to work towards, volunteers will know their efforts count towards something and will be more motivated to do their job.

The Plan

AMSAT is committed to the continued development of experimental amateur radio satellites in higher orbits and beyond, while recognizing our obligation to provide continued FM amateur satellite service in low Earth orbit. AMSAT also understands its responsibility and the necessity to share what we learn and encourage technical and scientific innovation, as well as to promote the training and development of tomorrow's satellite and ground system designers, builders and operators.

The Radio Amateur Satellite Corporation (AMSAT) Strategic Plan 2021-2035, presented below, affirms that commitment and will guide AMSAT as it continues on its path – Onward and Upward!

Radio Amateur Satellite Corporation Strategic Plan 2021-2035

Organization

Our Vision

Our Vision is to deploy satellite systems with the goal of providing wide-area and continuous coverage communications, to continue active participation in human space missions, and support a stream of low Earth orbit (LEO) satellites developed in cooperation with the educational community and Amateur Radio satellite groups

Our Mission

AMSAT is a non-profit volunteer organization that 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.

Our Core Values

- We lead by example.
- We respect the individual.
- We work collaboratively towards a common purpose and shared goals.
- We embrace change and innovation to help our members, our partners and ourselves.
- We are committed to the Amateur Radio satellite community.
- We are open and honest in our communication.
- Above all, we act with integrity.

Strategic Satellite Objectives and Organization Goals

Highly Elliptical Orbit (HEO)

1. Upward to HEO. Develop and deploy a series of spacecraft capable of providing wide-area and continuous coverage from highly elliptical and geostationary transfer orbits.

Greater Orbit, Larger Footprint

2. GOLF. Develop and deploy a series of increasingly capable spacecraft through a program to learn skills and systems for which we do not yet have the necessary low-risk experience, including active attitude control, deployable/steerable solar panels, radiation tolerance for commercial off the shelf (COTS) components in higher orbits and propulsion.

Amateur Radio on the International Space Station

3. AREx-A. Partner with ARISS and ARISS-USA to advance Amateur Radio's presence aboard NASA's International Space Station, Deep Space Gateway and Artemis missions and provide opportunities to engage with astronauts in lunar and deep space operations.

Low Earth Orbit (LEO)

4. LEO. Support a stream of LEO satellites developed in cooperation with the educational community and other Amateur Radio satellite groups.
4.1 FM Operations. Develop, deploy and support a series of 1U spacecraft to support continued FM amateur satellite operations in low Earth orbit.
4.2 Partnerships. Develop a plug-and-play communications solution for educational and other Amateur Radio CubeSat programs, providing a VHF/UHF telemetry beacon, command receiver, and linear transponder or FM repeater communications module.

AMSAT STEM Initiatives

5. AMSAT Education. Support science, technology, engineering and mathematics (STEM) initiatives and training programs for satellite and ground system designers and operators.
5.1 CubeSat Simulator. Continue development of AMSAT's CubeSat Simulator Program.
5.2 High Altitude Ballooning. Develop program to support and sponsor the use of amateur radio in high-altitude balloon (HAB) launches.
5.3 Youth Initiative. Develop an educational out reach program that encourages youth to pursue STEM interests in space science and communication technology.

Educational Relations Update

Alan Johnston, Ph.D., KU2Y
V.P. Educational Relations

The first of the new CubeSatSim Loaners went to Michigan in May for an event at a public library organized by Gordon Scannell, KD8COJ, and the Livonia Amateur Radio Club. It looks great! See the photo of the display in Figure 1.

The initial CubeSatSim PCB sets sold out quickly on the AMSAT Store, but they are back in stock again now (**www.amsat.org/product/amsat-cubesatsim-pcb/**). If you got them and are starting your build, I'd love to hear from you. Send me an email (ku2y at amsat dot org) or on Twitter @alanbjohnston. It would be great to publish some photos and get your feedback on the instructions. I look forward to hearing from you.

The first release (v1.0) of the CubeSatSim software is now available on Github. At the AMSAT Store, you can also find a SD card with the Raspberry Pi software fully installed and configured (**www.amsat.org/product/amsat-cubesatsim-raspberry-pi-sd-card**). It is also available as a free download at **cubesatsim.org/download/cubesatsim-v1.0.iso.gz**. Finally, we also have the CubeSatSim Ground Station SD card image available for download. Just add an RTL-SDR dongle with an antenna, and your ground station with FoxTelem, Direwolf, and QSSTV is ready to go!

Back in May, students at Villanova University, where I teach, launched their first high altitude balloon (HAB). It was also my first HAB, and it was a great experience! The students were inspired by attending the AMSAT Space Symposium and getting a balloon from Pat Kilroy, N8PK, who encouraged them to launch a balloon.

The students also received tremendous help via Zoom from David White, WD6DRI, and Jim McLaughlin, KI6ZUM, both experienced STEM mentors from the San Diego area who have helped the Mt. Carmel High School Amateur Radio club launch many balloons and buoys.

You can track their latest floating in the Pacific at **aprs.fi/#!call=a%2FW6SUN-12.** The Villanova AIAA student chapter also launched a balloon on the same day. Our HAB launched a LoRa payload based on the AmbaSat-1 board and also an experimental CubeSatSim Lite board with a STEM payload board with GPS.

Figure 1 — The AMSAT CubeSat Simulator Loaner on display at the Livonia Public Library. [Gordon Scannell, KD8COJ, photo.]

This experience got me thinking about balloon launches and STEM outreach. It seems like they are a great stepping stone towards a space mission. I looked through past issues of The AMSAT Journal (thanks to the great online archive), but I didn't see any articles about HABs. Surely AMSAT has many STEM mentors who have experience with this aspect of our hobby with a lot to share. Perhaps it would be good to get a how-to article published in the Journal to document their experiences and help other STEM mentors. Or maybe we can link to existing good articles.

Either way, if you have experience with the educational side of HABs, I'd love to hear from you. I'm happy to help facilitate an article or symposium presentation on HABs, STEM, and satellites. HAB launches also get a mention in the new AMSAT Strategic Plan, included in this issue.

I look forward to hearing from you about your HAB experiences. For the latest CubeSat Simulator news, follow our dedicated Twitter account **@CubeSatSim**.

If you are interested in doing a demo for a group or school, I can ship you a loaner. Contact me via email (ku2y at amsat dot org) or on Twitter **@alanbjohnston.**

AMSAT Announces Candidates for 2021 Board of Directors Election

Jeff Davis, KE9V
Secretary

The nomination period for the 2021 Board of Directors Election ended on June 15, 2021. The following candidates have been duly nominated and their candidate statements appear elsewhere in this issue of The AMSAT Journal:

- Joseph Armbruster, KJ4JIO
- Robert Bankston, KE4AL
- Jerry Buxton, N0JY
- Zach Metzinger, N0ZGO

In accordance with our Bylaws, we must hold an election, even though we have four nominations for four open Director positions. As such, we will host electronic voting on our Member Portal this year, at no cost to the organization.

Ballots, along with the link to record your vote will be emailed to our Members on or before July 15, 2021. To ensure you receive your ballot/voting instructions, please make sure your current email address is up to date in AMSAT's Member Portal, launch.amsat.org. A membership account is not the same as an AMSAT Store account. In addition, a link to cast your vote will be provided on the AMSAT Member Portal home page.

Conducting an election through our Member Portal will be presented as a poll. When you click on the poll link, either within the notifying email or a page on our Member Portal, launch.amsat.org, you will be prompted to log in, if not already logged in. Once you are logged in, you will see your ballot (poll question).

After choosing from the possible options, click the Submit button to cast your vote. Unlike many online polls, the results of all votes cast, up to the point of your vote, will not be displayed.

AMSAT members can only vote once. If you click the poll link again after already voting, a vote submitted message will be displayed.

As four seats on the Board of Directors are up for election this year, all four candidates will be seated on the Board when the voting period concludes on September 15, 2021.

AMSAT Board of Directors Candidate Statements

Robert Bankston, KE4AL

I strongly believe and support AMSAT's mission to Keep Amateur Radio in space. This not only includes experimenting with new technologies/modes and pushing us farther than we have ever been before, but, also, serving the greater AMSAT community by:

- ensuring the presence of easily accessible satellites for demonstrations, casual users, and grid chasers;
- providing educational opportunities and developmental paths for tomorrow's scientists, engineers, and leaders; and
- sharing what we learn with the world to further advance amateur radio in space.

My vision for AMSAT is best outlined in our recently adopted Strategic Plan, which I authored and presented to our Board of Directors. It is not enough to rest on past accomplishments. We must set bold expectations and dare to dream.

I am also a firm believer that actions speak louder than words. As an AMSAT volunteer, past-VP of User Services, past-Treasurer, and current President, I have always sought out ways to operate more efficiently and more openly, while delivering more value to our members.

- Hosted the 2018 AMSAT Space Symposium and Annual General Meeting in Huntsville, Alabama
- Implemented AMSAT's online member management system to allow our members to take charge of their membership account and be able to more easily access their member benefits
- Improved AMSAT's accounting processes, enhanced financial transparency, and developed control measures to safeguard AMSAT's assets and ensure the accuracy of financial information
- Led AMSAT's modernization efforts and reduced AMSAT's overhead operating costs by over $150,000 per year, in the process

I have had the honor and privilege of serving as AMSAT's President this past year, leading this great organization forward and preparing it for the opportunities that lie ahead. I humbly ask for your vote to allow me to continue to serve you, our members. Rest assured, I have no hidden agendas and my only hope is to ensure AMSAT continues on its path, Onward and Upward, for the enjoyment and benefit of all.

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Zach Metzinger, N0ZGO

I am honored to be nominated as a candidate for the AMSAT Board of Directors. What follows is a little bit about my history as a radio amateur and some insight into my hopes for AMSAT.

My first ticket was Technician Plus class, granted in 1993, followed by an upgrade to Advanced class in 1995, and to Amateur Extra in 2019. I have held my original call since it was first issued in Wichita, KS. I also hold a General Radiotelephone Operator License, granted in 1994.

I'm active on HF and UHF/VHF, both terrestrial and satellite, with recent interest in the microwave bands. However, I am more of a builder and experimenter than an operator.

My first real interaction with amateur satellites was during Field Day in 1994. Hearing my own voice come back on the downlink was magical, just as it was the first time I heard inter-continental HF. I was hooked, but it took many more years before I was able to operate on satellites again.

During the last four years, I've been a volunteer for the AMSAT GOLF project, working on the Radiation Tolerant IHU (RT-IHU) board. This board is the "brains" of the satellite: sending telemetry, accepting commands, and controlling payloads such as the transponder and experiments. The first flight of the RT-IHU, on GOLF-TEE, will provide valuable reliability data on the use of common off-the-shelf (COTS) components for this critical function.

I fully believe in the path toward HEO. We'll achieve this goal through the diligent work of our volunteers on GOLF, perseverance in our leadership, and support by the membership as a whole.

It is also my hope that we'll reduce our dependency on the commercialized Internet. Rather, we should focus on creating an amateur digital network in space for bulletins, efficient digital voice, and high-speed data, while preserving low-cost-to-entry analog transponder options.

If elected, I intend to work constructively with fellow AMSAT directors to develop and deploy new technology, increase our membership through educational outreach, and "Keep Amateur Radio in Space."

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Joseph Armbruster, KJ4JIO

My name is Joseph Armbruster, KJ4JIO, and I live in Orlando, Florida. Since May 2014, I have been operating a small technology business, called 0Lat, that is primarily focused on geospatial software and hardware development. My specialty is Earth Modeling and Terrain Database Generation for commercial and defense applications. I've utilized a number of open source technologies throughout my technical career and have contributed to several, including the Python Software Foundation.

I was not exposed to amateur radio during my youth, but I did get a glimpse of it during my college years at UCF (University of Central Florida). After graduating in 2004, I got my first "real" job, got married and had the itch to get my amateur radio license. I wasn't sure what to do, so I started attending the local OARC (Orlando Amateur Radio Club) and LMARS (Lake Monroe Amateur Radio Society) meetings. I also made enough money to afford my first radio (a TH-F6A), and, with the mentoring of several club members, I was licensed! It was at the club meetings that I met Lou (W5DID), George (K4RSV) and many others from AMSAT, and I started volunteering for the group. I spent every free minute I had helping out the project in any way that I could. ARISSat-1 was amazing to me because, with just a handheld radio and antenna, I could hear the audio from space and view SSTV images. Since that time, I've

become busy with life, having kids, running my business and building up the electronics and machining complex at my house.

I hear all these grumblings in AMSAT over analog versus digital, HEO versus LEO, building state of the art versus old school hardware. Time is everything, and AMSAT should have a menu of capabilities to choose from so that, when a launch becomes available, the options can be selected and integrated for the effort. If you ask what I think the next AMSAT satellite should fly with, I would argue a camera, and we should be able to receive still images, analog and digital video.

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Jerry Buxton, N0JY

I am Jerry Buxton, N0JY. I am seeking another term on the AMSAT Board of Directors.

AMSAT is growing, and the prospects as we enter our second half-century are bright. Our membership growth sets the stage for expanded communications of the opportunities before us and the plans and execution of them.

The opportunities we see require more capital than in the recent first 50 years. Satellite projects face both the harsher space environments beyond our typically low LEO of recent missions as well as regulatory requirements in this era of multitudes of CubeSats and small satellites that will require more investment. Components and systems needed must survive in the high altitude missions as well as dispose of the satellite (de-orbit) in order to get off the ground.

The benefits and value AMSAT provides in education and member services such as helping new members to access satellites, and in presence and access that require goods and cloud services and many more, will benefit from increased capital.

We are pursuing opportunities for access to funding, grants, and so forth because we know, as you are probably just as aware, that you can't run a business or build satellites on member contributions.

I am an optimist. That does not mean that I do not consider or understand less favorable outcomes. I have an open mind in a serious discussion of the how-to or why-for in whatever activities and projects we pursue. if I disagree after any such discussion it is because of my best understanding in the way we should proceed. It is healthy for a board to have dissent in discussions or split votes on an item.

We should all be pleased to have younger candidate for the board of directors. Methods, views, and ideas are never static and in my "paying" career job I made them a part of the go-to people when designing new systems. Being a Director or any of the many volunteer positions AMSAT has is a big commitment of personal time, and shows dedication to and belief in the greatness of this organization.

Thank you for your vote.

Smile for AMSAT at Amazon.com

When making purchases from Amazon, you can select a charity and Amazon will donate .5% of a qualified purchase towards that charity. Select smile.amazon.com when making your Amazon purchases and make Radio Amateur Satellite Corporation (AMSAT) your chosen charity.

Having selected a charity, when you go to amazon.com, you will be prompted to go to smile.amazon.com. However, you can put everything you want in your cart at the original amazon.com site, then leave the site and go to smile.amazon.com and all your items will still be in your cart.

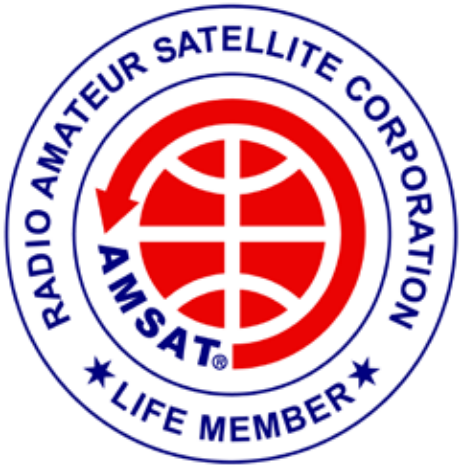
AMSAT Life Member Logo

AMSAT is proud to announce the release of its new Life Member logo – a small part of our ongoing efforts to enhance AMSAT member benefits.

Our Life Members have placed their trust in AMSAT. We thank them for their support and fully understand it is our responsibility to live up to that expectation.

- The AMSAT Life Member logo may only be used by AMSAT Life Members.
- Life Members agree NOT to use the symbol (a) in connection with any commercial enterprise or (b) in any manner which would indicate or appear to indicate AMSAT endorsement of any activity or product not expressly endorsed by AMSAT in writing.

The AMSAT Life Member logo is available for download on the AMSAT Member Portal, launch.amsat.org, under the Member Resources tab (login required).



Debugging AO-109 (RadFxSat-2, Fox-1E)

Burns Fisher, WB1FJ
Mark Hammond, N8MH

Introduction

RadFxSat-2 is also known as Fox-1E[1] and was built and launched in partnership with Vanderbilt University as the fifth of the Fox series of CubeSats. The initial plan was to construct four Fox FM repeater satellites, but some leftover parts allowed us to build Fox-1E. However, we were also short of some parts that became end-of-life; thus, some redesign was also needed.

The redesign let us make some changes from previous Foxes. In particular, Fox-1E contains a V/u linear transponder rather than a U/v FM repeater, as well as a new, more flexible command receiver. As AMSAT engineering typically does, the satellite was completed by the deadline specified by our launch integrator; it passed all of its ground tests at that time. Unfortunately, however, the launch itself was delayed for several years, and the satellite waited with only regular battery charges.

When Fox-1E was finally launched on January 17, 2021, we soon found that we were receiving no telemetry from it. Over the next several weeks, the operations and engineering teams[2]went through our commissioning and recovery checklists with no luck. As time went by, the engineering and operations volunteers could no longer work every pass of the satellite. Still, we continued to think and plan some operational tests to characterize the problem. This paper is about the debugging operations we later tried and what we have learned about the state of Fox-1E thus far.

First Signs of Life

Without any apparent response from the satellite, we were essentially limited to sending commands "in the blind" and watching for evidence of a downlink. But at the end of January, we received a report from Brad, W5SAT, who discovered that the transponder was indeed working very weakly. AMSAT command stations were able to confirm the weak operation of the transponder. Since Fox-1E now met the requirements for an Oscar number, it was assigned AO-109.

Eventually, we realized that although it was difficult, it was possible to command the satellite to turn the transponder on and off in a rather odd way. If we commanded the IHU (Internal Housekeeping Unit, the on-board computer) to be off, the transponder came on. If we commanded the IHU on, the transponder went off.

Knowing that the satellite was at least somewhat alive and responding to commands, we tried various additional commands with no luck. With no obvious changes in the satellite's behavior, we gained little information. At this point, we paused to carefully plan a series of new experiments that would give us more information about the operational state of AO-109.

Characteristics of Fox-1E/AO-109

In order to understand how to get more information from the satellite than simply "on" and "off," we needed to consider many of the characteristics of the satellite. The most important of them include:

- **Contingency mode**: Like the FM repeater satellites before it, Fox-1E can operate without the IHU. On the FM satellites, we called this mode "COR" (Carrier-operated repeater). On Fox-1E, if the IHU fails (or is turned off), the transponder is turned on but with no telemetry.[3] In addition, except for the first power-on in space, this contingency mode remains on during IHU startup until the IHU is ready to take over.
- **IHU Startup:** Each time the IHU resets or powers on, it goes through a series of startup steps before proceeding into the main part of the software to run the operating system. These steps differ depending on several factors.
  - o If the "in-orbit" flag (a bit in non-volatile memory) is NOT set, the IHU assumes we were just released from the launch vehicle and waits for about 50 minutes in a loop to satisfy launch provider requirements before doing anything else. During this time, the contingency mode transponder is off.
  - o If the in-orbit flag is not set, then after the wait, the IHU attempts to release the antennas by heating a "burn resistor" to melt the plastic lanyard that holds the antennas wrapped around the satellite.
  - o In all cases (even if "in-orbit" is set), if the antenna deploy sensors still show "stowed," the IHU will pause and then try a long burn on each antenna that is still stowed, adding about 25 seconds per antenna to the startup time.
  - o Finally, as one of the first jobs after the operating system is started, IHU sets the "in-orbit" flag in non-volatile memory.
- **Software Tasks:** The IHU software uses an open-source real-time operating system called "Free RTOS." Free RTOS provides for multiple tasks that can run simultaneously, similar to how multiple applications can appear to run simultaneously on your PC. The tasks of interest in this discussion are Audio, Command, and Downlink Control, which we will describe later. In addition, each task "reports" regularly to a watchdog implemented in hardware such that, if any task stops running, the IHU resets and reboots.
- **IHU Modes:** Again, similar to the FM Fox satellites, Fox-1E has several operating modes when the IHU is on, including safe mode and transponder mode. In safe mode, the telemetry beacon is turned on for two data frames about every two minutes but the transponder is off. In transponder mode, the telemetry beacon is on continuously, and the transponder is available. The mode that the satellite was last in is "remembered" in non-volatile memory so that if the IHU is power cycled or resets, it will return to the mode it was in after it reboots. When the satellite starts up in orbit for the first time after launch, it is in safe mode. The Downlink Control task implements the satellite mode.
- **Hardware and Software Commands:** The new command receiver provides "hardware" and "software" commands. A hardware command is decoded by hardware, while the software command is decoded by software. In other words, the IHU must be running for a software command to work. Hardware commands can cause operations that must operate without the IHU, for example, turning the IHU on and off, although the decoded command can be sent to the IHU software if it is running. Software commands are received by the Audio task and decoded by the Command task.
- **Telemetry:** Telemetry baseband modulation is generated by the Audio task and sent to a hardware modulator on the Receiver Transmitter board to be turned into BPSK modulation and then added to the uplink passband IF and mixed with a local oscillator before being given to the power amplifier for transmission.

What Can We Learn From "On" and "Off"?

At first, it seemed that we were getting only a single bit of information: On or Off. The engineering team considered some different failure modes, but with no additional information, we could determine nothing. We realized after a while that there was additional information to be had, namely the amount of time that a command took to operate. So, on March 11, Burns proposed that we command the IHU on and see how long it took before the transponder turned off. First, we assumed that having a transponder with the IHU off meant that it is using contingency mode. So what might happen when we turned the IHU on? Ground experiments with the flight spare IHU determined that this would tell us several things, as described in Table 1.

In all cases, if the transponder stays off, we can infer that all IHU tasks are running, or else the watchdog would have reset the processor and started contingency mode again.

The First New Info from Fox-1E

We needed to be very careful and methodical in our testing to wrest out subtle results, so we spent some time writing and reviewing test scripts. Mark and Burns were the first ones able to try our timing experiment on April 17. The plan was for Mark to send an uplink tone on the transponder and display the downlink on a screen that Burns could see (see Figure 1). Then, with another transmitter, Mark sent "IHU on" commands repeatedly for about 10 seconds while Burns timed the interval between when commanding started and the transponder turned off. Since we don't know when within that 10 seconds the satellite received the command, the timing would only be accurate to +0,-10 seconds.

We quickly discovered (and Mark already expected this from previous commanding) that 10 seconds was not enough commanding time for the satellite to reliably accept the command. So we repeated this experiment on several passes.[4] We did start repeating the command uplink longer and longer and eventually confirmed that we could command the transponder off. However, we had extended the command duration so long that we could not determine the time between the received command and the transponder off behavior to a sufficient accuracy to use the above table. We needed to try a different approach; when all else fails,

Approximate time from "IHU On command to transponder stopping	What code was executed to cause this time delay	Implications
Never	All or nothing	Either a total IHU failure, or the IHU is working well and is in transponder mode.
70 seconds	Attempt to re-release Rx and Tx antennas with extra-long burn	1. IHU is in safe mode 2. OS has started, and *Audio* task turned off contingency mode. 3. Sensors are showing that neither antenna was released 4. Transmitter is probably not harmed, but ability to transmit compromised 5. Receiver not damaged, but reception compromised
45 Seconds	Attempt to re-release only one of the two antennas with extra-long burn	1. IHU is in safe mode 2. OS has started, and *Audio* task turned off contingency mode. 3. Sensors are showing one antenna released, one stowed. 4. One of the two receive or transmit behaviors above
20 Seconds	Normal OS Startup	1. IHU is in safe mode 2. OS has started, and *Audio* task turned off contingency mode. 3. Sensors show both antennas deployed
Nearly Instant	50-minute post-launch timer is executing, and contingency mode is turned off	1. The in-orbit flag was never set; 2. Thus the main telemetry transmission code is not being executed 3. Possible IHU reset during the startup sequence

Table 1: Startup Time Implications

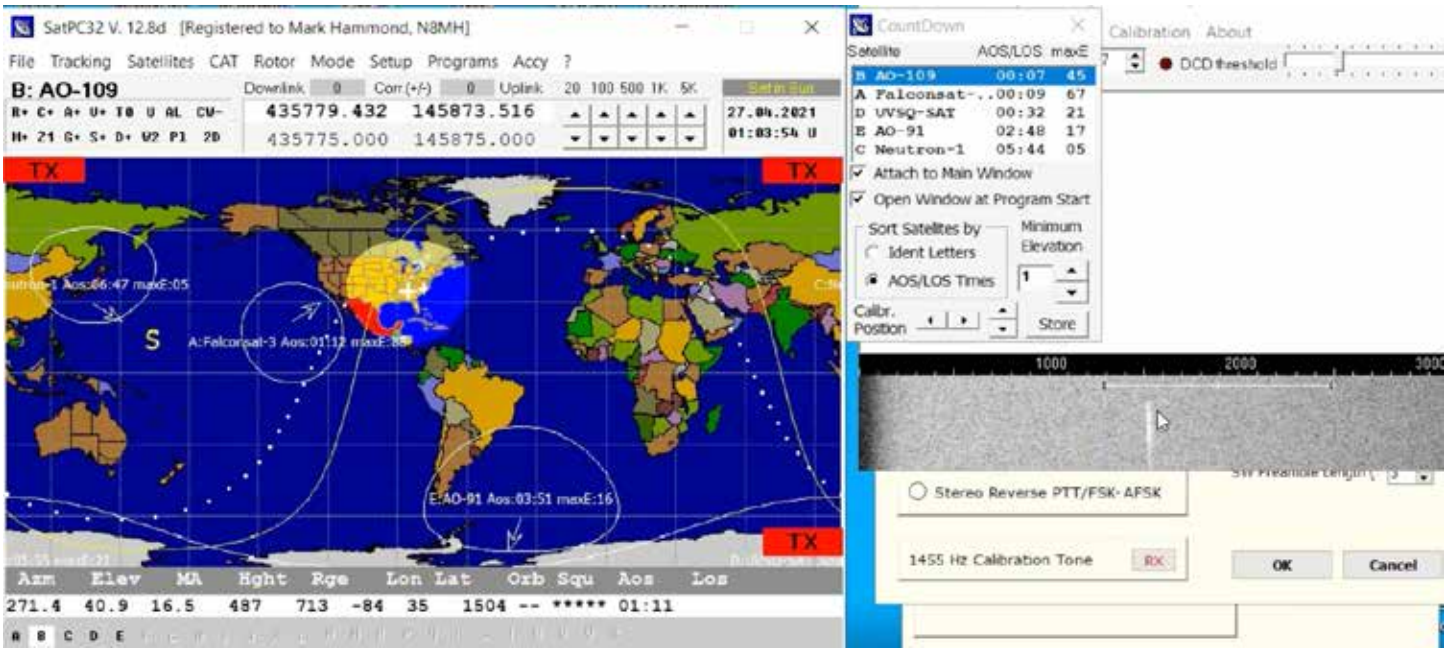


Figure 1 — Transponder off.

use more power!

On April 26, Drew, KO4MA, was available to join us using his QRO (EME-class) uplink command station. With this power, Drew's commands to turn on the IHU were accepted quickly so we could get good time measurements. In fact, we were able twice during a single pass to reproduce the experiment described above with very similar results: about 21 seconds! Looking at the table above, we see that this is very close to 20 seconds, which would indicate that the IHU is in safe mode and is reading the antenna release sensors and finding that they are showing "released"! Figure 1 shows the moment the transponder turned off when Drew commanded it. The cursor is pointing to the location in the waterfall where the downlink stopped.

Transponder Mode

Our next task was to determine whether the IHU software appeared to be running normally. We knew that the watchdog was not firing, implying that all software tasks were running but were they generally doing the right thing? We decided that the first step to determine this while making the fewest changes was to turn on the IHU, wait for the contingency mode transponder to stop (implying that the IHU has started executing the Audio task and was in safe mode), and then send a hardware command to go into transponder mode. This should start the transponder if the Command task and the Downlink Control task are running correctly. Because the timing was no longer critical, we did not require a QRO station.

On April 28, we were able to do this test. When we sent a hardware transponder mode command, the transponder came on, indicating that the IHU was running, that it was able to receive an interrupt from the hardware command decoder (which is sent to the Command task), and that the Command task was able to send a message to the Downlink Control task to switch to transponder mode. This also should have turned on the telemetry downlink, so Burns tweeted a request for ground stations to watch for telemetry. Unfortunately, no stations reported hearing any telemetry from AO-109.

Software Commands

This simple transponder mode test convinced us that the IHU was (mostly) running, but there was one more important feature that we could test and tell us something about the internal state of the hardware and software. In particular, we wanted to determine if software commands work. Software commands require more IHU features but will make more commands available to us for later tests.

Again, due to the satellite's orbital schedule (it precesses about 20 minutes each day), a desire to test while the satellite was illuminated, and our personal schedules, we had to wait several days.

Finally, on May 4, we had a chance to try the next phase of testing. First, we determined that the transponder was still running. This was important not only for the test but also to show that the IHU was still operating and that we still had power on the satellite. We also noted that the transponder downlink was fading in and out on a several-second cycle (Mark had seen that behavior before). We then sent a software command to enter safe mode. As usual, it took some repeats, but this worked! The transponder stopped, proving that software commands are operational. The implication was that the full Audio task (which is also responsible for sending baseband telemetry) was working well and giving us the ability to send additional commands.

Trying to Solve the Problem

Thanks to the results of these fairly simple tests, we knew or could infer that many things DO work on AO-109. So what can we do about the things that we know DON'T work? First, we list them by observation or symptom:

- No telemetry has ever been received on the ground.
- The transponder signal received on the ground is very weak.
- The transponder signal received is sometimes subject to regular fades.
- Commanding is difficult with modest power but works easily with high power.

And now, we try to hypothesize specific failures that cover as many of these symptoms as possible and then try to think of ways to test or mitigate them:

1. Receive (2 m) antenna is not fully open; only enough to break contact with the sensor

Expected Behavior
• Modest power uplink commands hard to receive
• Uplink transponder signals received weakly (and thus re-transmitted weakly on the downlink)
• Uplink signals might be blocked at certain satellite angles (thus, satellite spin causes regular fading)
• No effect expected on telemetry downlink

Testing and Mitigation
• Examine close-out photos of Fox-1E for possible antenna issues
  o Have been examined with no obvious problems seen
  o See Figure 2 for one example
• Attempt to predict the satellite's orientation and rotation axis to determine whether this, combined with an unopen antenna, would explain the fading
• Issue a command to fire the receive burn-wire again. (This would not help if the problem were with the burn-wire circuit itself or if there was a mechanical problem.)
  o Has been attempted

2. Transmit (70 cm) antenna not fully open

Expected Behavior
• Little effect on uplink signals, including commands
• Transmission of transponder signals weaker than expected
• Transmission of transponder signal might be blocked at some satellite angles
• Telemetry weak but likely visible

Testing and Mitigation
• Examine close-out photos of Fox-1E for possible 70 cm antenna issues
  o Have been examined with no apparent problem seen
• Attempt to predict the satellite's orientation and rotation axis to determine whether this, combined with an unopen antenna, would explain the fading
• Issue a command to fire the transmit burn-wire again. (This would not help if the problem were with the burn-wire circuit itself or if there was a mechanical problem)
  o Has been attempted
• Issue a command to increase the output of the modulator and thus increase the transmitted power of the telemetry
  o Has been attempted

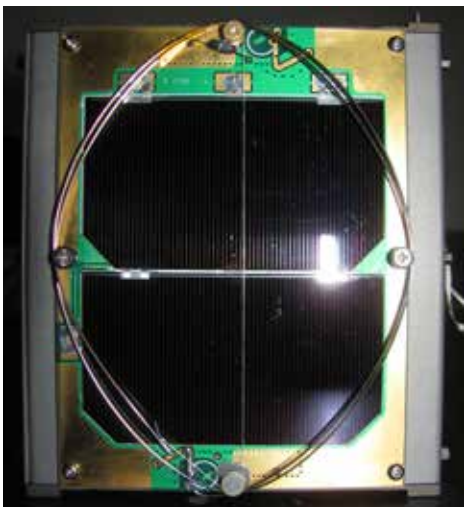


Figure 2 — 2 m antenna closeout photo.

3. **Failure of some of the logic, the signal that turns on the telemetry, or some part of the hardware that implements telemetry generation.**

Expected behavior
• In all cases, the telemetry does not come on.
Testing and mitigation
• Analysis of logic vs. behavior
  o Done with no obvious issues or new information found
• Most of the logic and RF hardware can be eliminated from suspicion since it would also affect the transponder
• Possible commanding to program the modulator differently depending on analysis results
  o Telemetry power changed with no noticeable result

Additional Tests

Between May 7 and May 19, we attempted many of these test and mitigation strategies, with Burns checking the logic and Mark sending commands. Since most of these commands would not show noticeable immediate results, Mark sent them during most of a pass, and then we observed the results later. In particular, he sent commands to release the 70 cm antenna, release the 2 m antenna, and raise the telemetry gain first by 3 dB and eventually by as much as 13 dB from its nominal amount. Finally, Burns tweeted another request for hams around the world to listen for telemetry. Still no telemetry was reported and no apparent change in transponder or command receiver behavior.

What Is Next?

As of this writing, we are approaching the end of what we can do to get more information without telemetry or to "fix" the problem. However, our analysis and experiments should help future satellites. We can hypothesize problems and then design ways to avoid them.

For Fox-1E, Occam's razor made us look for a single problem that explains all the symptoms we see, but we have not been able to find such a problem. Instead, there appears to be both a receive problem (command receiver and transponder) and a transmit problem (telemetry downlink and/or transponder). So, for example, one pair of problems that fits the symptoms is a failure of the 2 m antenna to fully open AND a failure of the modulator hardware or the SPI bus connecting it to the IHU.

We can still do additional analysis of the antenna pattern to determine if the behavior we see is consistent with still-stowed antennas. If we think of additional tests to do with commands, we can still do them.

It does appear that the transponder can still be helpful to the amateur community. We have seen CW clearly on the transponder, and a few experiments have been tried with FT4 and other weak-signal modes. By the time you read this, AO-109 may be opened for general amateur use.

As you can see, it takes a few pages to explain the detailed debugging steps we have done — a 144-character tweet is not suitable for this, nor is a quick Facebook post. Hopefully, this article will help you understand the situation better if you wish to. In any case, we hope that you will at least take away the idea that the AMSAT Engineering and Operations teams have been trying our hardest to recover AO-109.

Notes

[1.] RadFxSat-2: Vanderbilt University and NASA CSLI satellite name; Fox-1E: AMSAT's series name; AO-109: official Oscar number once in orbit with an amateur radio transmitter.
[2.] Drew, KO4MA, V.P. Operations; Jerry N0JY, V.P. Engineering; Mark, N8MH, operations command team; Burns, WB1FJ, engineering team, with help and advice from other contributors.
[3.] If the transponder is on with no uplink or telemetry, it uses relatively little power, so the "Carrier Operated" part is unnecessary.
[4.] Note that there was generally only one good pass per day, where "good" is defined as high elevation and at a time when neither of us was busy with real life, including sleeping and working.

Working Portable with the Icom IC-9700

Paul Philip, AC9O

After a 35-year hiatus from ham radio, I returned to the air in May 2019. Naturally, I didn't expect how much the technology had advanced at that time. Soon, however, I discovered digital modes (FT8) and then LEO (low Earth orbit) satellites.

My first satellite rig was a Kenwood DT-72A in full-duplex to an Arrow II antenna. Soon after, I added a Yaesu FT3-DR for the downlink because it had built-in recording ability. It also simplified changing uplink frequencies during the pass on some sats. This combination netted over 450 grids in less than a year.

During that time, the FM sats were getting more crowded, and with the lower altitude and resulting smaller footprints of the FM sats, really long-distance contacts were not possible. So, I decided to progress to the linear satellites.

I spent a lot of time on Twitter (still do) seeking advice and watching what the other sat ops were using. There were a lot of different options, but many didn't fit into my HOA-restricted environment (no outside satellite antennas on the roof).

The Icom IC-9700 looked like a good option despite being more than a little bulkier and heavier than my pair of HTs. The most important feature to me was full-duplex operation. I learned very quickly on the FM satellites that you needed to hear yourself to be effective. You have to know if you are getting into the satellite and what's happening while you transmit. Often, a stronger station will completely override your signal. Think of it like a party-line where whoever is the loudest is the only one that is heard.

Assembling the needed components into a workable ground station.

My next step was to see how hard it would be to set up a portable station using the 9700. I planned on using the same Arrow II as my antenna but needed a way to carry the IC-9700 safely and comfortably (Figure 1).

I found a DSLR camera dual shoulder carrier rig on Amazon that looked like it would work, and it does. It's plenty hefty

Figure 1.

Figure 2.

enough to handle the weight with two separate straps and shoulder pads. At the end of the adjustable straps are snap hooks for attaching a camera.

Wimo makes a great pair of angled side rails that attach securely to the IC-9700. The front handles are turned slightly outward to allow easy control access. Also, there's a slot at the front end of the rail that I use for attaching the snap hooks on the shoulder rig. Since these rails are metal, not plastic, I am confident that the straps can handle the weight.

I attached the IC-9700 to the shoulder rig securely and adjusted the straps for a comfortable fit and viewing/operating angle. However, I found that even with the front bale extended, it didn't protrude out far enough. I tried using various types of foam like pool noodles, but it just wasn't secure enough.

I came across a dense foam yoga block that looked like it might work. It's about the same width as the radio and about three and a half inches thick. I cut a slot that the radio's bale slips into and hollowed out areas for the two front feet (see Figure 2). This allows the block to press-fit to the bale but support the radio by its front feet. Now the distance is more comfortable for viewing and operating.

I purchased a Bioenno 12 VA battery to power the radio. Since this radio is capable of much higher power than the HTs, it requires a larger battery. I picked this size because it easily fits into an old shotshell belt pouch I had used for trap shooting. This also shifts the weight from the shoulder rig and makes it easier to carry. I run a DC cable from the battery, through a fuse block, and then to the radio. Thus, I can operate many passes before having to recharge. Note that I do NOT run full power; that's not a good thing on satellites. More on this later.

The last essential item is a comfortable headset with a microphone. All hands are needed for operations, so holding a mic is NOT an option. With many headsets on the market, choose one that works best for you. For full-duplex, this is an absolute necessity, even in base operations, to prevent feedback.

Last but not least, you need a couple of good-quality cables. Because the IC-9700 has separate antenna connections by band, no duplexer is necessary. Eight feet of cable works fine. A little long when walking, but if you want to put your rig on a table, then it will come in handy. Don't scrimp on the cables and connectors, and make sure they

Figure 3.

are attached securely. You wouldn't want one to come off or pull apart at the wrong time (see figures 3 and 4).

Setup of the IC-9700

As for the IC-9700's features, their number can be intimidating at first. Fortunately, Icom offers software for uploading and downloading settings and memories available at no cost on its website. All you need is a USB cable to connect to your PC. Before making a change, I download all the current settings from the radio, make the change, save it to a file and then upload it back to the radio. This capability can also be used to clone settings, or parts of the settings, to another radio.

Some of the many features that make this a great radio include:

- Full-Duplex
- Scope with Waterfall
- Reverse and Normal Tracking
- Voice Recording
- Plenty of Memory Channels
- Great Receiver Sensitivity.

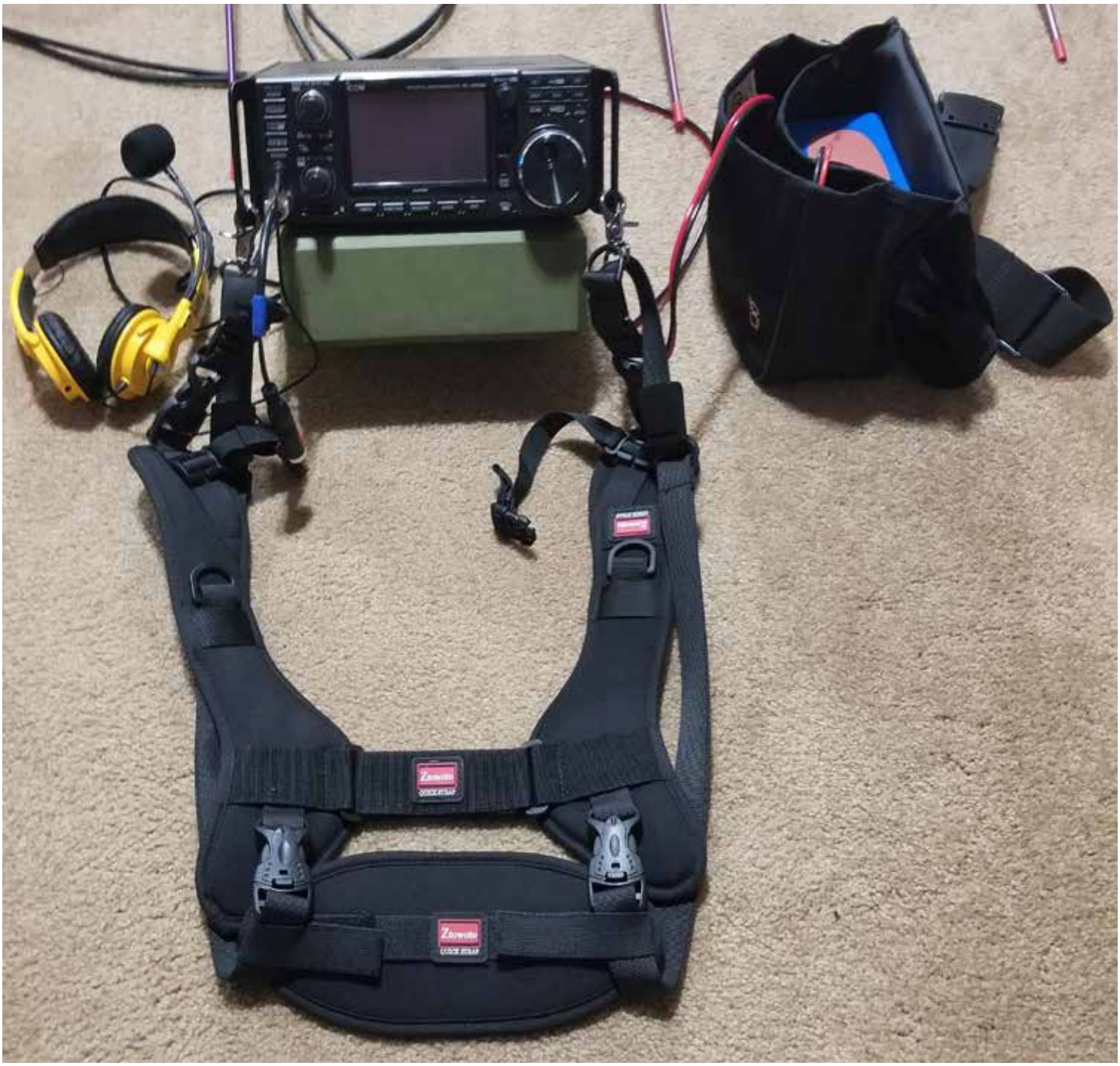


Figure 4.

I downloaded CS-9700 from Icom's website. This free utility allows you to backup and restore settings (they call it cloning) and memories with just a USB connection. I use an old USB printer cable, and it works just fine. Be sure to download the USB driver from Icom's site BEFORE connecting the USB cable. Then, use the CS-9700 utility to read all the settings from your IC-9700. You can then save the settings to your hard drive for backup. I name them by date so I can revert to earlier versions if needed. Note that you can back up the settings to the SD card if desired.

Programming memories is effortless. There are separate memories for satellite and the three ham bands. It's easy to enter the uplink (including tones for the FM birds) and downlink, name them and then organize them as you wish. I have configured the linear frequencies for the middle of the passband and tweak the uplink to be close enough to easily "find" myself at AOS (acquisition of signal — more on this later). FM frequencies are set up for AOS. I have the linear sats I use come up first, then the FM sats. You can rearrange the order quickly with the utility.

Many other settings can be preset or changed, so they default to values you desire. One setting that's nice is to limit the output power as a percentage of total output. I do this to not overtax the battery or push too much power to the satellite. Remember to use only enough power that's needed. Some birds, like AO-7, don't respond well to the "big guns" and can flip modes or cause distortion. Also, remember that the passband shares power output on the download, so be a good neighbor and keep your power to reasonable levels.

The memory banks can be exported and imported to CSV files for sharing without sending your entire configuration. For example, right-click on Satellite Memories, and you will see Export and Import options. When importing, I recommend saving your current configuration in case you don't like the result.

I keep the clock on the radio set to UTC. Bring up the Time setting and set the hour/minute to the NEXT minute of your system clock. When it rolls over, press the SET button. It keeps pretty good time on my radio, and I only need to adjust it occasionally. That way, the logs are date and time-stamped at the beginning of the pass. When I transcribe a contact, I note the elapsed time into the pass and add that to the recording time-stamp for logging.

Getting ready for a pass

I find that having a preset routine for getting ready helps to get everything together quickly. First, I put on the shoulder rig and adjust it as needed. Next, make sure the antenna and power cables are attached to the back of the rig. Also, make sure the SD card is inserted for recording. Then I strap on the battery at the waist. Next comes the headset, keeping the cable to the side and out of the way. Then I attach the clips to the side rails of the IC-9700. At this point, I can stand up and adjust the setup for comfort. Finally, my phone and Sat App are attached to the Arrow, so I pick it up and head out back for the pass.

Turn on the radio. After it comes up, be sure that it's in Satellite and Memory mode. Select the memory for the satellite pass. At AOS, start audio recording. I review and transcribe the pass later and log the QSOs. I then upload it to Logbook of the World.

The process is a little different depending on whether you are operating FM or Linear.

Operating a FM pass

Depending on U/V or V/U mode, you may need to adjust the uplink frequency. For example, when the downlink is 70 cm, I leave the 2-meter uplink at the preset frequency and allow the AFC (automatic frequency control) to adjust the downlink. However, when the downlink is 2 m, the uplink frequency will need to be manually adjusted during the pass.

For satellites like SO-50 and AO-27, I just let the AFC adjust the downlink.

For satellites like AO-91 and PO-101, it's a little more complicated. I touch the SUB option to shift the uplink frequency as needed during the pass without disturbing the uplink frequency. If you forget to do this, you may not be able to get into the satellite.

I find that VOX doesn't work well for the FM birds because of the party-line-like activity on the FM birds. During a crowded pass, I prefer to have a manual PTT switch. You can use the Transmit button on the front panel too, but you will need to press it twice per transmission, on and then off. I use a hand-held PTT switch. Others use a footswitch, but then you can't walk around during the pass.

Operating a linear pass

Operating a FM pass is kind of like having an automatic transmission. There isn't all that much to do. During a linear pass, it's more like a manual transmission. You wish you had four arms and hands and perhaps an extra brain to handle it. Don't worry. It gets easier as you get accustomed to the procedures.

As a rule of thumb, I found it easiest to adjust the uplink while transmitting and use reverse tracking (for most birds) on receive. I also use VOX to free up my hands for manual tracking of Doppler shift.

After AOS, the first item of business is to "find" yourself in the passband. I always start with the preset memory for the satellite and use short whistles. Looking at the scope, I find the blip of the carrier. Then I enable SUB to adjust the uplink frequency so I can hear my whistle. Press SUB again, so the radio is operating in Reverse Tracking mode. I can scan the passband for signals or pick a spot, enable SUB and call CQ while adjusting the uplink.

The scope comes in handy for locating yourself and finding other signals in the passband. I set the scope to +/- 25 kHz. When you whistle, you can see the pip on the scope. Other signals also clearly appear. My usual location is fairly low noise, so I have found if I can see it, I can hear it, and vice-versa.

You will need to adjust for doppler during the entire pass. If you listen too long, you may have to whistle again and adjust your frequency to where you can hear yourself. I find that I am constantly enabling and disabling SUB so I can hear myself correctly. It's not automatic control, but it gets the job done without a computer (other than your brain).

Most importantly, if you cannot hear yourself on the downlink, it's unlikely anyone else can hear and respond to you. So keep fiddling with the buttons and dial to keep yourself in place.

Completing the pass

At LOS (loss of signal), be sure to stop the recording. If you don't, it will keep running until you turn off the radio and then resume recording the next time the radio is turned on. I'm not sure why they designed it this way; I would prefer that it not restart at power-on.

I almost always transfer the audio files to my PC to begin transcribing the session. It's easier than using the controls on the 9700. And, there's a glitch in the current firmware (1.30) that does not correctly adjust the elapsed time when you use the forward and backward skip buttons. So, I turn off the radio and move the SD card to my PC and transfer the files. Be sure to put the SD card back in the radio. Otherwise, you will be unhappy at AOS when you start the recording and get the "SD Card Not Present" message. Also, I clear the audio files on the SD card. They can get quite large, and you wouldn't want to get the "SD Card Full" message in the middle of a pass!

In Conclusion

I hope these guidelines and experiences have helped to get you on the air with satellites. I split my time between HF DX chasing, VHF grid chasing on 6 meters, and satellites, both FM and linear. Until the current solar cycle improves, it helps to fill the gap when band conditions are poor. So, take a little time, even if it's only on the FM birds, and get out there and make some satellite contacts. If nothing else, you will get to know your neighbors better.

A Really Cheap Portable Satellite Antenna Mount

Keith Baker, KB1SF/VA3KSF

[Note: Portions of this article appeared in The AMSAT Journal *back in 2016. However, as we've gained many new members since then, we thought this updated version might be helpful to our newcomers.]*

The warmer weather now is upon us here in the Northern Hemisphere. And, as many of us have been in COVID-19 "lockdown" over this past year, it's only natural that our thoughts have turned to getting outside and (for us satellite enthusiasts) working the "birds" from various portable locations. So who would have thought that, just over a year ago, we'd all be eagerly looking forward to a vaccination shot in the arm?

However, operating the satellites portably with a hand-held antenna can become quite tedious, particularly throughout a long satellite pass. Fortunately, a good local ham friend of mine here in the Sarnia, Ontario, Canada area has devised a simple portable antenna mount that can remove at least some of those "aching arm" side effects of operating via our satellites in the field.

His name is Art Payne, VE3GNF, and during the past few years (when we were able to operate as a group), it has fallen on his shoulders to provide the satellite station for our Lambton County Radio Club's Field Day operation. To that extent, he has built numerous antennas and Az-El mounting systems, which have resulted in our radio club making the needed satellite contacts that gave our club those extra points for such efforts with both the ARRL and AMSAT competitions.

So, several years ago, when it came time to assemble our club's satellite station again, Art was intrigued by an article in the March / April 2013 issue of The AMSAT Journal by Rick Tejera, K7TEJ. Rick wrote about an equatorial mount for satellite antennas using one designed for a small telescope that his dad adapted for satellite tracking. Having the same interests as Rick, Art believed that he could produce a functioning system "really cheap." Thus, the birth of what Art now calls "The Gizmo." The parts to construct one should be readily available at any local hardware or "big box" store.

Building The Gizmo

To build the Gizmo, Art uses a ½ inch copper "plumbers Tee" and 4, 5/8 by 1 inch, 1/2 inch ID bushings, a piece of ½ inch aluminum rod (about 2 feet long), and a few hand tools to construct a functioning equatorial mount. First, he cut off about one inch of the rod and dressed the ends. This can be done with a file (Art used a mini lathe, but that's just because he has one). He then drilled and tapped the piece with a number 7 drill bit and a ¼ - 20 tap, keeping the rest of the rod to use as the main shaft.

Next, he threaded the short piece that has

Art poses with all the parts assembled and mounted. Just a light grip is needed to control the assembly. (Courtesy: Author.)

The "soup can" counterweight mounted on the Gizmo. (Courtesy: Author)

Here's the basic Gizmo with the counterweight, main shaft and plumbers Tee and bushings installed. Note the drill stop between the Tee and the weight. This addition is not necessary but Art finds it handy so that the shaft doesn't slide in the Tee when attached to the antenna. Also note the short stub attached to the tripod. (Courtesy: Author)

already tapped onto a standard camera tripod. He pushed three of the bushings into the orifices of the Tee and the fourth into the end of his "Arrow" satellite antenna. He then fed the remaining rod through the Tee into the bushing at the end of the Arrow antenna and passed just enough of the rod through the bushing so that he could secure the main rod with a ¼ -20 1-inch sized screw to his Arrow Antenna. He used a counterweight that he had salvaged from an old telescope mount to balance the system and positioned it on the rod so the antenna rotated easily and freely.

Art notes that if you do not have a commercial counterweight, it is easy to build a usable one by cutting a small hole in a used soup can so that a piece of ¾ inch PVC tubing can pass through it. Then, fill the can with cement. This produces a weight of about 1 1/2 pounds. Next, be sure to slit the part of the tubing that comes out of the can and tighten it onto the main shaft onto the rod by using a hose clamp. Then position it on the rod for proper balance.

Operation

Operation of the Gizmo is straightforward once you have balanced the antenna by adjusting the counterweight on the rod. First, Art suggests setting the tripod so that the front leg faces north (a compass will come in handy here). Then, set the tilt angle of the head of the tripod to the angle that the satellite will reach at its maximum altitude for the satellite pass (derived from the software you are using to predict the pass) and secure it by twisting the tripod's altitude handle so that it's tight. To assist in determining the maximum altitude setting, you can also attach a plastic digital protractor (the kind that's included in any dollar store school kit) to the tripod plate with a simple string and weight.

The short stub screwed into the tripod head set to about 45 degrees. The angle of maximum elevation of the upcoming satellite pass is set with the tripod's elevation control. (Courtesy: Author)

Next, once you've set the tripod head to the maximum altitude for the pass, rotate the azimuth part of the tripod's head to the direction of maximum elevation for that pass. Then, secure the azimuth clamp on the tripod. This should allow you to swing the antenna mounted to the Gizmo left or right so that the antenna boom is parallel to the ground and pointing in the direction at the horizon where AOS (acquisition of signal) will occur.

Now, when the satellite comes into view, all you need to do is rotate the antenna in a sweeping arc from AOS horizon to LOS (loss of signal) horizon as you track the satellite across the sky. What's more, if you need to change the polarity of your antenna during the satellite pass, the Gizmo allows you to easily rotate the antenna in the mount with just a quick twist of your hand.

I've used my own Gizmo mounting to make several solid contacts with the satellites when I've operated portably. Indeed, the system has worked so well that we plan to leave once again our fancy, wired up (not to mention expensive!) Az-El satellite antenna rotators at home and use this new, incredibly simple antenna mount for our next outdoor operating event when we can once again (hopefully soon!) gather as a group.

Building a Tiny Satellite Ground Station

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If you are looking for a great way to introduce youngsters to ham radio, you can build a satellite receiver and a tuned antenna for less than $25

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The TinyGS project is an open-source community that builds and deploys tiny LoRa receivers (ground stations) to track tiny satellites (CubeSats) collectively.

Today, there are 669 active stations worldwide — more ground trackers than the combined sum of all the big boys like Nasa, SpaceX, ESA, JAXA, etc.

The receivers are based on tiny ESP32 microcontrollers with built-in Lora receivers. Operating on 433 MHz and 868-915 MHz, the receivers listen for satellite telemetry broadcasts from space using LoRa technology. (Note: I suggest you purchase a 433 MHz board. There are more satellites on this frequency and too much noise on the 900 MHz band in the US.)

You can 3D-print a case for your receiver using projects posted on Thingiverse. If you do not have a 3D printer, contact me, and I will make sure you get a case.

The TinyGS project has an innovative tool that uploads the satellite tracking firmware to the microcontroller (Figure 1).

There are versions for Windows, MacOS, and Linux. You plug the ESP32 into a USB port on your computer, run the firmware uploader, and you are done.

The TinyGS firmware hosts a wireless access point (AP). When first booted, the ESP32 will display the AP SSID and IP address. Connect your computer or tablet to the SSID on the display. Once connected, open a browser and enter the AP IP address in the browser address bar. You will see the TinyGS dashboard (Figure 2).

Click on Configure parameters. In the System Configuration box, enter a name for your ground station and a password for the dashboard. Next, enter the SSID of your home network and the correct password.

Also, enter the lat/long of your location

Figure 1.

Figure 2.

(choose coordinates that are in your neighborhood – not your house to protect your privacy). Finally, enter your time zone. In the Board config box (Figure 3), you only need to enter the Board Type. Then, choose the correct board from the dropdown.

You can leave the 'MQTT credentials' box blank for now. You will get them later from TinyGS.

Click on the 'Apply' button at the bottom of the page. The device will reboot. If everything worked, the display will show it is connected to your home WiFi network and its IP address.

Figure 3.

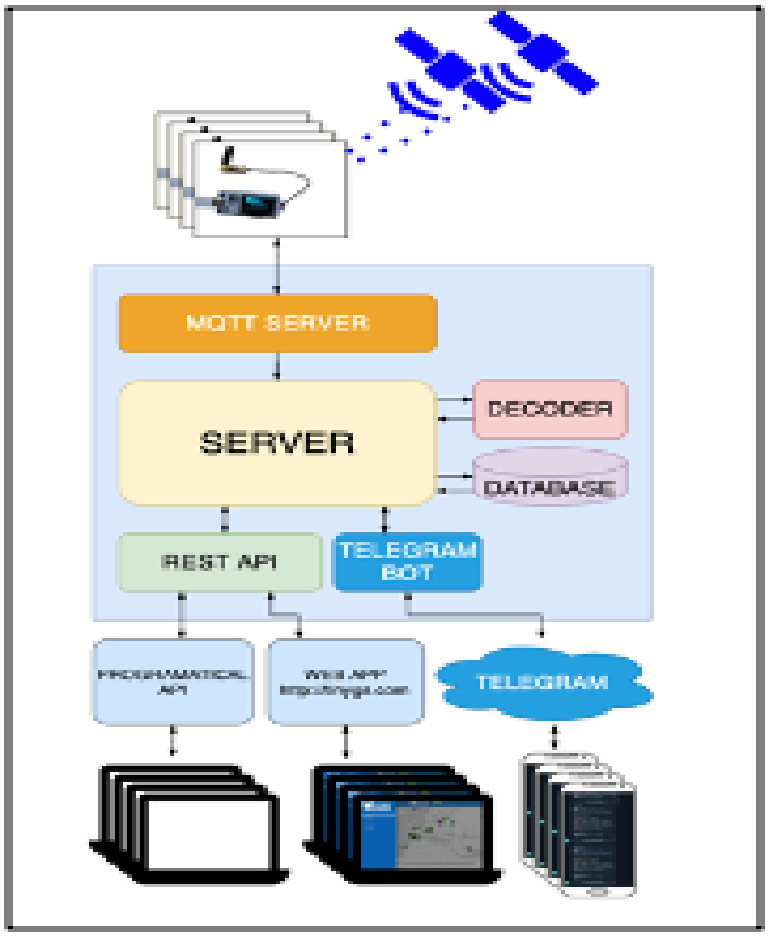

Figure 4.

If the device cannot connect to your home WiFi, it will go back into AP mode. If this happens, it is usually because you entered the wrong home WiFi credentials, or more likely, it is unable to 'see' your home WiFi network.

The ESP32 devices have really lousy WiFi antennas, so the connection range is very short.

The TinyGS system collects the data your ground station receives using MQTT transactions. The architecture of the system appears in Figure 4.

You need to create a Telegram account to receive your MQTT credentials from the project. You then enter them in your device configuration page. You can find detailed instructions on how to do this at the TinyGS website.

A note on antennas. The stub antennas that come with the receiver are useless. Most of them are tuned to the wrong frequency. Do not use them. Instead, make your own.

I purchased some copper wire from Lowe's and cut the vertical and radials based on calculations from the M0UKD website. I then used a Nano VNA to clip the vertical to a height with an acceptable SWR (1.6). This antenna has received satellite data from 2200Km (1367 miles).

If you are interested in looking at my ground station data, it is named 'N1SPW_433'. You can find it on the world map at the TinyGS website by zooming in on San Clemente, CA. (Yes – the GPS coordinates are the end of the San Clemente pier). You can also search for it on the 'Stations' page.

I have built several of these ground stations and given them away to my colleagues' kids. There is no better way to introduce them to the wonders of radios and satellites. Kids love these things!

I encourage you to build a ground station. They are inexpensive, easy to get online, and are a boatload of fun. You are also performing an excellent service to the scientists that build experimental CubeSats.

Without our commitment to the TinyGS project, they would have no way to monitor their satellites as they traverse the globe.

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.

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.

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-- Describing your AMSAT career in "Member Footprints;"
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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!

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And Help AMSAT Return to High Earth Orbit!

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 to *Keep Amateur Radio in Space*. We have set a fundraising goal of $125,000 to help keep AMSAT viable and effective in the competitive world of space communications.

GOLF-TEE (Technology Exploration Environment) is a rapid development satellite headed for LEO to fly and validate ADAC, deployable solar panel wing, radiation tolerant IHU, SDR and other technologies.

GOLF-1 is planned as a "High LEO" mission with a STEM payload in the progression of GOLF satellites.

With your membership, AMSAT is pleased to recognize your generosity. All members receive:

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Go to AMSAT.org/donate and join today!

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Journal Listing	X	X	X	X	X	X
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Coin	X	X	X	X	X	X
"RBF" Key Ring	X	X	X	X	X	X
Plaque			X	X	X	X
TAPR/AMSAT Dinner @ Dayton				X	X	X
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President's Symposium Lunch					X	X
Symposium VIP Recognition						X

Recognition items available for U.S. addresses. For contributions from elsewhere please contact Frank Karnauskas, VP-Development at N1UW@AMSAT.org. AMSAT is a 501(c)3 corporation. Donations may be tax deductible. Check with your tax advisor.

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