# The AMSAT® Journal

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## AMSAT Field Day

*In this issue —*



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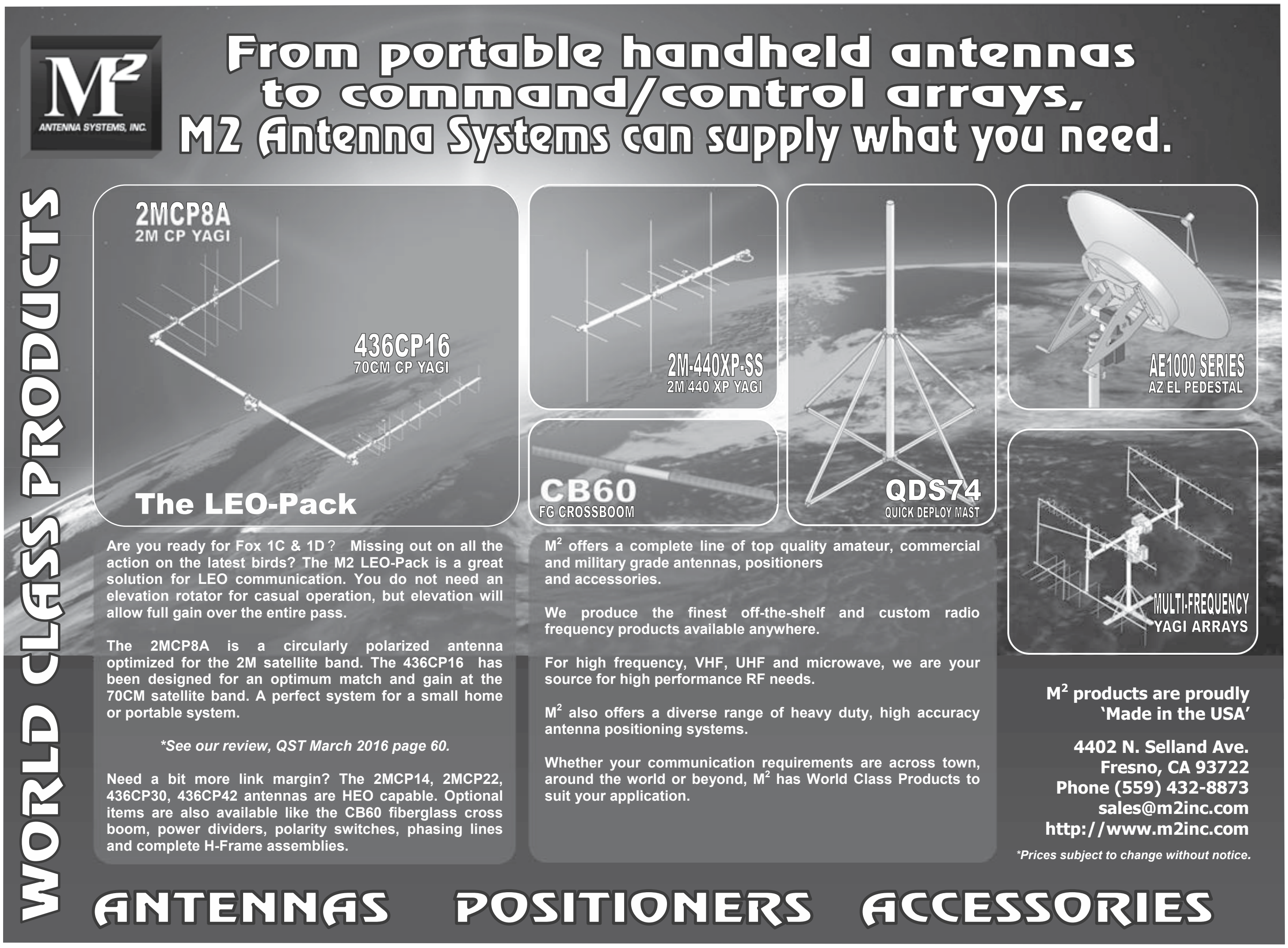


# AMSAT Announcements

## Virtual 2020 AMSAT Space Symposium and Annual General Meeting

The 2020 Virtual AMSAT Space Symposium and Annual General Meeting will be held on Saturday, October 17th from 9:00am CDT – 5:00pm CDT (UTC -5). Symposium presentations will be a combination of pre-recorded and live video segments along with question and answer sessions held via a Zoom meeting.

The Symposium will be streamed free of charge on AMSAT's YouTube account.

Registered attendees will receive a digital copy of the AMSAT Symposium Proceedings and will be entitled to join the Zoom meeting and participate in the question and answer sessions. Registered attendees will also be entered into prize drawings. Registration is free and available only for AMSAT members at launch.amsat.org/Events. Registration will close on Friday, October 16th at 5:00pm CDT.

### Call for Papers and Presentations

Proposals for papers and Symposium presentations are invited on any topic of interest to the amateur satellite community. We request a tentative title of your presentation as soon as possible.

Final papers for the Symposium Proceedings must be submitted by October 5, 2020 to Dan Schultz, N8FGV, n8fgv@usa.net. Symposium presentations should be limited to 15 minutes of pre-recorded video. Video presentations must be submitted by October 10, 2020 to Paul Stoetzer, N8HM, n8hm@arrl.net. We ask that presenters be available to take questions via Zoom following the airing of their pre-recorded video.

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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.**

# Engineering Update

**Jerry Buxton, N0JY**
**Vice President, Engineering**

## Microwaves and Nanosatellites, and Our GOLF Game

With the influx of new members (greetings everyone!) this Journal edition is a great time to recap the GOLF program and goals as well as update you on GOLF-TEE's progress.

For new members and as a general reminder to all of our members, progress on a new satellite design and construction may appear to be slow in the relative perception of time, while our engineers working on the projects may perceive the clock to be ticking down quite fast toward the completion deadline. I sort of straddle both worlds of time perception but, more often than not, my head is in the milestones of the projects. With a reminder and a bit of encouragement from a few of you, I have and will be providing regularly more visual information for the AMSAT web page, Twitter, and Facebook, as well as text information for ANS and similar outlets. The intent is to provide the common news-blurb length updates that are widely used these days.

In the AMSAT Engineering case, silence or lack of news does not mean nothing is happening. Quite the opposite is true, as silence often indicates heads-down hammering away to get a mission on orbit.

The GOLF program was approved and funds committed for the first two satellite missions at the annual board of directors meeting in Reno, NV, in 2017. Two proposals for NASA's CubeSat Launch Initiative (CSLI) program were submitted in November 2017, seeking one technological category and one educational category launch opportunity. The CSLI committee accepted both the GOLF-TEE initial "Technology Exploration Environment" mission and the GOLF-1 mission that continues development and features the typical AMSAT CubeSat program STEM education-related experiments, as well as amateur radio communications that are in all of our missions. This does not guarantee a launch but indicates a commitment by NASA to find suitable launches (and orbits) within their scope of available launches for the mission type and their launch grant budget.

The ultimate goal of the GOLF (Greater Orbit Larger Footprint) project is reaching higher orbits that provide a larger area of coverage, or footprint, within which we can make contacts with fellow hams. The larger footprint simply means that you can work someone farther away than you can with any given satellite in a lower orbit.

That leads to the endgame, which is Highly Elliptical Orbit (HEO). HEO is an orbit for amateur radio satellites that made for great fun in the '80s through early 2000. The performance and the footprint of these Phase 3 satellites put DXCC within easy reach and nearly worldwide QSOs independent of Earth's finicky magnetosphere the norm.

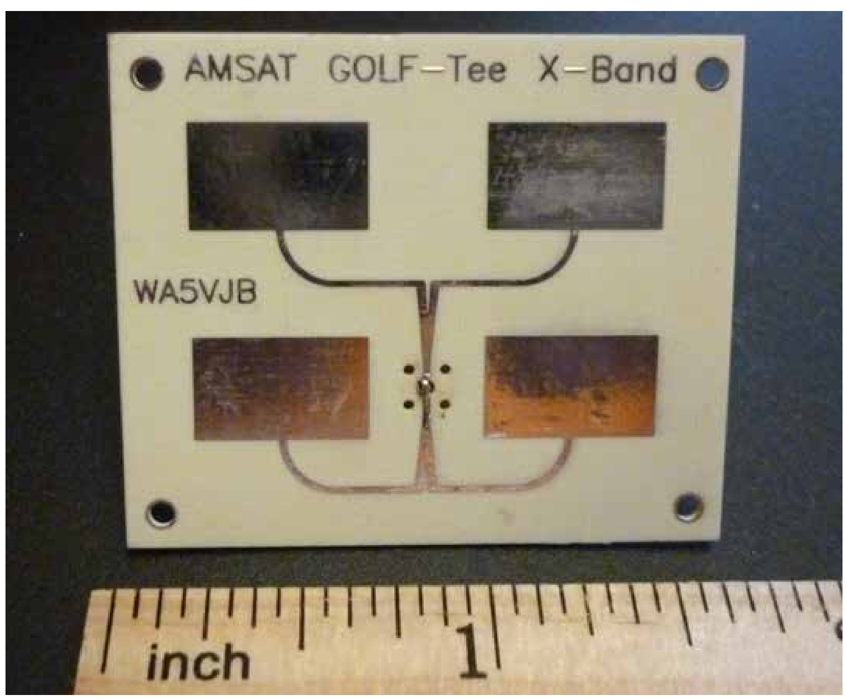


**Figure 1 — GOLF-TEE 10 GHz antenna design.**

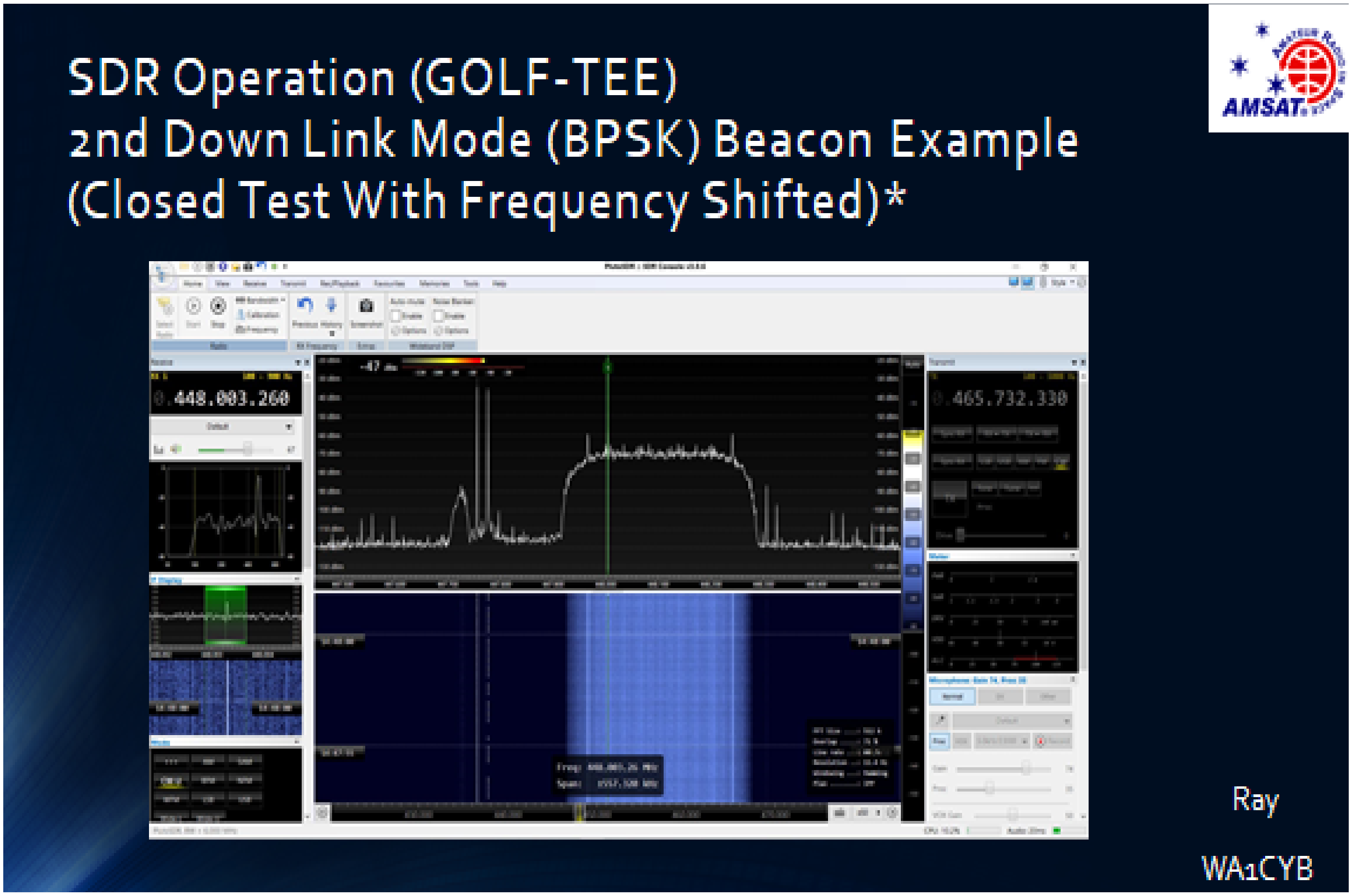


**Figure 2 — SDR operation example.**

(Phase 3 of the AMSAT phase system defines long life, capability, and highly elliptical orbits for our satellites.) The HEO era passed on if you will, largely due to the size and mass of the spacecraft in terms of launch costs and the uncertainty and caution that resulted from new International Traffic in Arms Regulations (ITAR) by the U.S. Government that squelched the international cooperation with other AMSAT organizations. Here in the U.S., plans for new AMSAT satellites turned inward to U.S. persons only and, while that meant AMSAT's new CubeSat program starting with Fox-1 could claim "proudly made in the U.S.A.," it ended the ability to produce new HEO birds, for the time being.

Fox-1 was AMSAT's return to low-cost launches by designing for the CubeSat standard that opens up our opportunities to fly. In some cases such as NASA CSLI, the launches were "free." That is a hefty savings in terms of AMSAT budgets. The Fox-1 program initiated, proved, and improved our ability to build such small yet effective satellites. In the AMSAT tradition to "keep amateur radio in space," our CubeSat programs continued to grow from our first CubeSat to the next step with bigger CubeSats, newer RF technology, and opportunities to learn the systems that are needed to build a capable, reliable, and robust HEO satellite. GOLF is the next step in returning to HEO and the coverage and opportunities of the Phase 3 orbits.

## Microwaves and Nanosatellites

One of the key elements of the GOLF program from a user perspective is the shift away from the VHF/UHF bands, to the amateur satellite microwave bands. The dimensions of the 3U CubeSat sizes used in the GOLF program make antenna size an important part of the design, and microwave frequencies are a fraction of the VHF wavelength. Satellite VHF frequencies are in the two-meter band, and even the lowest microwave band at 1.2 GHz is roughly one-tenth of the wavelength of a two-meter frequency, at just 23 cm.

On up from there, typical microwave wavelengths used on GOLF step down to 13 cm, 4 cm, and 3 cm. At 4 cm for the uplink frequency at 5 GHz, the side of a 3U CubeSat measuring about 30 cm might hold up to four C-band (5 GHz) patch antennas. The 10 GHz downlink easily fits a patch antenna array on the 10 cm square end of the CubeSat, and you might even squeeze two on there (see Figure 1).

As orbit height increases, more gain is needed on the satellite and/or your ground station to close the link. Microwave bands allow higher gain antennas in any given area and that allows the satellite to contribute some of the link gain in that area without some type of deployable gain antenna or more power from the transmitter, already on a limited power budget.

In May of 2015, early engineering work on the "CQC" project, a partnership in a lunar orbiting satellite for which AMSAT provided the communications and command links system, led to the choice of the 5 GHz band for uplink and the 10 GHz band for the downlink. At that time the Virginia Tech "Phase 4B" (P4B) project was also starting up with AMSAT providing support through a common ground station design, and the 5 and 10 GHz uplink and downlink were adopted for that mission as well. Other frequencies were being considered for P4B at the time, but I expressed the desire for our microwave band satellites to have a common mode as the baseline for all, in the way that most of the LEO satellites commonly use the VHF/UHF bands today. The ARISS AREx project is now considering the same band plan, as well.

Adoption of the common bands came to be called simply 5 and 10 in further engineering development of the two projects and, for whatever reason, I referred to it as "Five and Dime" once or twice and that became a common name that we used in presentations and other communications. Many of us knew of the phrase, while younger engineers probably just went "whatever," but that is why you hear the name commonly used to refer to the baseline 5 and 10 GHz band plan.

With GOLF becoming the next set of projects that will use microwave bands, the 5 and 10 GHz bands are also the baselines for GOLF satellites. As it turns out, the CQC project was discontinued when the team was not selected for the "free launch" manifest toward the Moon and the P4B project went the same way when the primary ride became unavailable, leaving GOLF as the premier Five and Dime project being worked on today.

The implementation of the microwave bands on GOLF is an open-ended opportunity to experiment with both analog and digital applications that will be explored and developed, with GOLF satellites pre-programmed to go with various modes for that development. Eventually, the modes can be chosen to fit the mission as we progress, such as the particular STEM experiments on a flight. The modes will also consider the development of the users in both their microwave capability (including antennas that may be restricted by covenants and such) and in their capabilities and use of both analog and digital modes. Exploration and development include our members using the satellites. As we progress, we always have the underlying consideration of the return on investment, if you will, that being the amount of usage versus the cost of the project. Launching a bird that only a small number of members will use is not good business sense when raising the funds to build the bird.

GOLF will make wide use of Software Designed Radios (SDR), and GOLF-TEE will "tee up" the program using a commercial SDR, the Ettus E-310. The choice has to do with availability, familiarity, and of course cost, and provides a good platform for the initial development of SDR in GOLF. The goal for the SDR is expressed in the GOLF-TEE CSLI proposal as a high-speed data downlink at 10 GHz. It is purposely somewhat indistinct because it allows for experimentation in achieving whatever "high-speed" downlink is possible with the given mission. The desire for this capability comes from discussions with our partners and prospective partners who are interested in more data in a downlink stream than is available on the Fox-1 satellites, which were the basis of the discussions at the time.

Ray Roberge, WA1CYB, leads the SDR development, and he has presented examples of the capability at the AMSAT space symposia the past couple of years. With the bandwidth available, operations such as the telemetry downlink as well as FM channelized and/or 100 kHz transponder capability are just the beginning of what is possible (see Figure 2).

GOLF-TEE will have SDR capability beyond just the telemetry downlink as that is the plan with the GOLF-TEE and GOLF-1 projects, to develop systems for GOLF-TEE that can be improved from what we learn building GOLF-TEE to provide expanded capability and use on GOLF-1. From the satellite user perspective, we may introduce a transponder downlink on 10 GHz providing a "parrot" of the V/u mode baseline (Fox-1E type) linear transponder that will provide users the option to explore V/x mode transponder use and the microwave bands. The use of this capability is dependent upon the successful completion of the CSLI mission goals first.

The possibility for uplinks on 1.2, 2.4, and 5 GHz are also present in a multiband antenna design on GOLF-TEE, carried as part of overall GOLF development. We see the increased popularity of the 23 cm (1.2 GHz) band uplink as seen in “L-band mode” on AO-92, and the 13 cm (2.4 GHz) band uplink on QO-100, which has also made some how-to plans and articles available. Also covering the 5 cm "Five" band of Five and Dime, the development of this antenna for use in LEO orbits plays a part in giving amateur satellite operators a path to learn and develop microwave band use for future, higher satellites including HEO. With the "trail" of GOLF satellites that are still in orbit as new and higher designs fly, steps to microwave are still available in them while the satellite operation and orbit lasts.

In a scenario for our next HEO satellite operating Five and Dime, VHF/UHF is not entirely left behind for a couple of reasons. One is having recoverability options should the satellite lose pointing capability that results in the inability to command in the microwave bands. While omnidirectional microwave band antennas would be on the satellite for telemetry transmission and command reception, VHF/UHF omni antennas and transceiver capability on the satellite would provide another backup that works in any orientation. Command station transmit power is generally cheaper and easier on those bands than with the microwave bands as well, at least at this time. The omnidirectional antennas provide another use as well when the satellite is near perigee and very rapidly moving across the sky. While the satellite possibly could keep microwave antennas pointed toward Earth, the use of omni antennas eliminates that need and provide a wider coverage than a narrow beamwidth antenna at close range. It also saves power, and wear and tear on the attitude control systems, simply letting the bird fly by until gain is needed and pointing resumes.

The path to HEO and higher orbits is exciting and inclusive bringing new bands, new techniques, and learning opportunities not just in AMSAT Engineering but to satellite users as well. Oh yes, something that kids of all ages (anyone who has fun with amateur satellites) will either recall or discover for the first time, "real DX."

Members make this happen of course, whether engineering volunteers or just goodwill ambassadors. Join the fun in AMSAT Engineering if you can play a part in the hardware and software, Elmer new satellite enthusiasts who will enjoy the fun along with you, and share the goodwill of amateur satellites and AMSAT worldwide with all of the ham satellite community. Your goodwill and sharing spreads beyond just satellite hams and can go a long way in helping AMSAT get us to HEO sooner than you might think.

# User Services Update

**Robert Bankston, KE4AL**
**Vice President, User Services**

Despite the high signal-to-noise ratio of late, AMSAT User Services continues to stay focused on its mission and committed to delivering the quality of services our members and the entire AMSAT community deserve.

Since my last report, we added member benefits on our portal, introduced a new satellite operating award, and found new ways to educate other amateur radio operators and the general public about the importance of amateur radio in space.

### AMSAT Member Portal

AMSAT's Member Portal, which launched on May 1, 2020, continues to be the greatest improvement for AMSAT in serving its members. Not only does it allow our members to renew their membership and update their contact information in real-time, it also allows us to provide exclusive content to our members that we could not have done on our main website.

On our Member Portal, you can view and down the latest issue of *The AMSAT Journal*, as well as every issue dating back to January 2014. You can also download the current *Amateur Satellite Frequency Guide*, which contains frequencies for operational voice and digital amateur radio satellites. And now, you can also view and download all of the AMSAT Symposium Proceedings, dating back to 1986. These proceedings are a treasure trove of technical papers, satellite information, and other presentations from AMSAT's annual symposia. All of this is due to the herculean efforts of Paul Stoetzer, N8HM, who donated countless hours of his personal time to put this all together. Thanks, Paul!

### AMSAT GridMaster Award

In June 2020, AMSAT accepted responsibility for administering the GridMaster Award. This award was first introduced by Star Comm Group in 2014. AMSAT thanks Damon Runion, WA4HFN, and Rick Tillman, WA4NVM, for not only sponsoring this award since its inception, but also, entrusting AMSAT with the honor of carrying on this important award for the benefit of the entire AMSAT community.

The GridMaster Award is available to all amateurs worldwide who submit proof with written confirmation of contacts with each of the 488 maidenhead grids located within the contiguous United States of America. Two-way communication must be established via amateur satellite with each grid.

Prior to June 2020, ten amateur satellite operators have been awarded a GridMaster certificate: 01 John Papay K8YSE; 02 Doug Papay KD8CAO; 03 Rick Tillman, WA4NVM; 04 Glenn Miller, AA5PK; 05 Clayton Coleman W5PFG; 06 Alvaro De Leon R., XE2AT; 07 Fernando Ramirez NP4JV; 08 Ron Oldham, N8RO; 09 Randy Kohlwey, WI7P; and 10 Frank Westphal, K6FW. AMSAT has since awarded three additional certificates: 11 Drew Glasbrenner, KO4MA; 12 Kevin Manzer, N4UFO; and 13 Hector Luis Martinez Sis, W5CBF. Congratulations to all!

If you would like to add your name to this prestigious list of awardees, visit amsat.org/gridmaster/ for more information.

### AMSAT Ambassador Program

AMSAT Ambassadors depend on hamfests and other events to educate the amateur radio community and the general public about the exciting opportunities of amateur radio in space; however, COVID-19 has stopped all public gatherings. To help fill this void, many of our Ambassadors have turned to video conferencing to reach their audiences.

On August 9th, Tom Schuessler, N5HYP, presented *Getting Started with Satellites* at the QSO Today Virtual Ham Expo. Tom's presentation, videotaped demo, and Q&A session was informative, enthusiastic, and well received, as we have come to expect from all of our AMSAT Ambassadors. He also hosted a virtual booth, where registrants could download flyers, fact sheets, and a copy of the March/April issue of *The AMSAT Journal*. Tom set the example for all future virtual AMSAT presentations. Well done, Tom!

# Treasurer's Report

**Robert Bankston, KE4AL**
**Treasurer**

I thought this would be a good time to provide our members with a mid-year financial update. Looking back through the past issues of *The AMSAT Journal*, I do not see where this has been done before; however, given the economic uncertainty brought on by COVID-19, I thought it might help to share how we are doing.

The coronavirus has touched everyone, including AMSAT. In addition to closing our office and pulling most of our physical items from our online store, the cancellation of Hamvention was financially a gut punch to our traditional business model. We have always relied on our annual products released at Hamvention, as well as in-person membership renewals. To overcome these setbacks, we had to find new ways of doing business.

Before we delve into the numbers and find out how we did, let's talk about what we will be looking at. Since our objective is to examine the effects of COVID-19, we will compare the first six month of 2020 to the first 6 months of 2019 and limit our analysis to operating activities – how much money we raised and how much we spent. In addition, to keep things simple, I have rounded all amounts to the nearest $10,000.

### Overall Performance

As of June 30, 2020, we have a net operating profit (amount we collected, less the amount we spent) of $43,000. This compares to a $10,000 operating loss for the same period in 2019. Increasing profits by $53,000 is great news, but it does not fully explain what happened. So, let's drill down into the underlying revenues and expenses to tell the rest of the story.

### Revenues

As of June 30, 2020, we collected $180,000, compared to $276,000 in the same period in 2019. This represents a $96,000 decrease in revenues, which is a HUGE drop. What happened?

Donations took the biggest hit, with a $114,000 drop. As bad as that sounds, most of this was expected due to the $71,000 CASIS grant for a specific ARISS project in 2019, as well as $15,000 in contributions for ARISS' Radio Upgrade on ISS campaign that ended in 2019. That left a $29,000 decrease in donations to AMSAT and its specific satellite projects. Most likely, this is due to the downturn in the economy related to COVID-19. In addition, AMSAT earned $5,000 in revenues from the 2019 Hamvention Dinner, which obviously was not held in 2020.

The good news is that membership dues increased $14,000 and store sales increased $8,000 over the prior year. The increase in membership dues is directly related to the May 2020 launch of AMSAT's new Member Portal, which has been a huge success in not only capturing the Hamvention in-person renewals but bringing some lapsed members back into the fold and adding some new ones. The increase in sales is due mainly to a digitally-delivered shift in our product lines, to include the 2020 *Getting Started With Amateur Satellites* and AMSAT Symposium Proceedings.

### Expenditures

As of June 30, 2020, we spent $137,000, compared to $286,000 in the same period in 2019. This represents a $149,000 decrease in expenditures.

In 2019, we spent $73,000 on ARISS' subcontractor costs related to the CASIS grant and $26,000 on Hamvention costs, both of which were not necessary in 2020. In addition, we saved $22,000 on printing costs by only providing digital copies of the March/April and May/June issues of *The AMSAT Journal*, $8,000 on postage and shipping, and a combined $20,000 in other cost-saving measures.

### Conclusion

Overall, it appears we have weathered the COVID-19 storm and have come out ahead of where we were just a year ago. Our leadership team was quick to recognize the challenges we faced and adapted our business model to succeed in these troubling times. With your continued support, we promise to ensure that your membership and contribution dollars are utilized for the greater benefit of all and to keep amateur radio in space.

# Educational Relations Update

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

As this strange summer draws to a close, I wanted to give a few updates on some educational related projects. Best wishes to all students and teachers who will be returning the classroom for the fall!

Several CubeSatSim builds underway right now are proving out the new design described in the previous two AMSAT Journal issues. Christine Mehner, M.D., Ph.D., of the Mayo Clinic is extensively covering one build on Twitter. She is using the CubeSatSim as a way to learn about CubeSat development and operation in preparation for a payload experiment. She has some very interesting research goals relating to biology and spaceflight. I'm sure we will hear more about her research in the future. You can find her Tweets with the usual #CubeSatSim hashtag or by following her on Twitter @ChrisMehnerMD. You can also follow the official CubeSatSim Twitter account @CubeSatSim for updates where we retweet all CubeSatSim postings.

The ARISS Radio Kit Project team continues to meet. The Raspberry Pi SDR software image is getting close to being finished. If you like Raspberry Pis and have an RTL-SDR dongle, you could download a beta version of the ARISS Radio Pi and try it out using this link: cubesatsim.org/ariss-radio-pi.iso.gz. It has the usual username "pi" and password "raspberry" and is pre-configured for SSH and VNC remote access. The pre-installed radio software includes:

- OpenWebRX, a web SDR that allows access to the RTL-SDR using any web browser – no software install required! It covers 500 kHz to 1.2 GHz including the amateur radio bands, short wave bands, and selected VHF and UHF bands. It supports FM, AM, and SSB demodulation, and also many digital modes including APRS, FT8, and WSPR.
- CubicSDR, a nice SDR application that runs on the Raspberry Pi. This is great for tuning in broadcast FM radio stations or tuning specific signals using the RTL-SDR.
- RTL-TCP, an application that streams the RTL-SDR signal over a network, allowing you to run any SDR application that supports RTL-TCP access.
- FoxTelem, AMSAT's satellite telemetry decoding and uploading software. This allows for tracking and analyzing telemetry from any of the AMSAT Fox-1 satellites, HuskySat-1, or even the CubeSatSim,
- Gpredict, tracking software that is pre-configured for common amateur radio satellites including AMSAT CubeSats.

In the future, the ARISS Radio Pi will also be pre-configured for receiving SSTV images from the ISS. Until then, you can participate in these excellent educational events by using these terrific videos produced by ESA, the European Space Agency, by their Radio@ISS team. Their "How to get pictures from the ISS" video is a great step-by-step introduction to SSTV and how to receive images from space, as shown in Figure 1. You can find it at https://www.esa.int/Education/Get_pictures_from_the_ISS_and_learn_about_radio_communication.

In the future, there will be more SSTV events, including ones from ESA. You can find out about when they are happening at ariss-sstv.blogspot.com/.

As a reminder, loaner CubeSatSims are available. If you plan to perhaps demo it to a group or school later in the year, I can ship you one now to learn and test. Contact me via email ku2y@amsat.org or on Twitter @alanbjohnston.


**Figure 1 — ESA Radio@ISS video on "How to get pictures from the ISS."**

# AMSAT 2020 Field Day Results

**Bruce Paige, KK5DO**
**Director, Contests and Awards**
**Board Member**

| | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|
| Satellite | 9 | 9 | 8 | 12 | 9 | 16 | 21 | 33 | 28 | 26 |
| QSOs | 335 | 263 | 443 | 305 | 316 | 424 | 728 | 945 | 746 | 1526 |
| Stations | 14 | 19 | 23 | 21 | 21 | 22 | 27 | 32 | 26 | 30 |
| Points | 455 | 329 | 613 | 357 | 386 | 448 | 778 | 995 | 848 | 1622 |

We started the year with everything being normal, and quickly things turned south. COVID-19 changed the way we do things, and Field Day was no exception. AMSAT holds Field Day on the same days as the ARRL. We simply have a slightly different rule set when it comes to satellites. We adjusted Field Day to match the ARRL rules for COVID-19. This year Home Commercial stations operating as 1D were allowed to work anyone. With this rule change, we added a separate class of winners, that of Home Stations on Commercial power.

With the change in the rules, we had a lot more participation than ever before.

As usual, the number of satellites is based upon their modes. SO-50 has one FM transponder, and I count that as one satellite whereas AO-7 has two modes, SSB and CW, and gets counted as two satellites.

We had 26 satellites in operation this year as evidenced by the chart below. Notice a couple of stations worked the packet on the ISS. That is a quick and easy three points. You might want to keep it in mind for next year.

The breakdown of satellite usage is as follows.

| | Phone | CW/Digital |
|---|---|---|
| AO-7 | 96 | 8 |
| AO-27 | 2 | |
| AO-73 | 33 | |
| AO-91 | 11 | |
| AO-92 | 12 | |
| CAS-4A | 286 | 6 |
| CAS-4B | 272 | 7 |
| CAS-3H | 1 | |
| EO-88 | 17 | |
| ISS | | 2 |
| LilacSat | 2 | |
| PO-101 | 8 | |
| RS-44 | 345 | 10 |
| SO-50 | 18 | |
| XW-2A | 104 | |
| XW-2B | 92 | 4 |
| XW-2C | 76 | 3 |
| XW-2D | 7 | |
| XW-2F | 94 | 7 |

As shown in the graph above, this year thirty stations participated in AMSAT Field Day. They reported 1526 QSOs with a total of 1622 points. There were 1479 Phone QSOs and 47 CW/Digital QSOs. Based on the numbers, it looks like RS-44 SSB was the busiest satellite. Next up were CAS-4A and CAS-4B followed by XW-2A and XW-2B. The choice for CW contacts this year was RS-44 followed by AO-7.

This year we have three groups of winners: those operating (1) Club Stations (#/A, E, F), (2) Battery/Home Emergency Power (1B/1E), and (3) Home Commercial Power (1D). All will receive their certificates in the mail as we will not be having an in-person symposium this year.

Here are the Club Station winners. In First Place, the Louisiana Radio Communications ARC, WA5LRC, with 230 points. Their operator was Hector, W5CBF. Coming in at Second Place is Huntsville ARC, K4BFT with 178 points. This year, they were not able to use the U.S. Space and Rocket Center due to COVID restrictions and went to a club member's farm. Tim, N8DEU, and Pete, N4YOT, did the setup, disassembly and operating. Laura, K4CNY, and Wesley, KM4YUB, were newcomers getting on the air with operating assistance this year. Figures 1 and 2 show their setup. In Third Place is the Johnson Space Center ARC, W5RRR, with 168 points. Figure 3 features Andy, W5ACM, taking a moment out from operating. Also operating for their station was John, AB5SS, and Tanner, W9TWJ. They were using an Icom IC-9700 and enjoyed RS-44.

For operating at Home on Emergency Power, in First Place is Scott, K5TA, with 167 points. Scott had a pretty nice setup seen in Figure 4. He was operating from his Chevy Suburban out on some unused property in his backyard. He said it was nice to be able to walk back to the house to eat and sleep a bit. In Second Place we have a tie between Greg, N4EN, and Carmen, WO3T, both scoring 48 points. Greg, N4EN, sent us Figure 5 of his antenna. Now, take a good look at Figure 6. You should see 3 guest operator inspecting the coax, B1RD, F0WL, and CR8NE. Third place goes to Patrick, WD9EWK, with 32 points. Patrick always has great photos to share from his operating locations. Field Day was no exception. Figure 7 provides a great view of his site with Figure 8 showing Patrick with his equipment.

For operating at Home with Commercial Power, First Place goes to Alexander, VA3ASE, with 161 points. Check out his antennas in Figure 9. Figure 10 shows the real satellite operators. Second Place goes to Dave, W2GDJ, with 73 points and Third Place goes to Steve, N9IP, with 57 points.

Last year, I operated using the G-5500 in manual mode along with the IC-9100 in manual mode. This year, I got SATPC32 working for Doppler correction. Thirty minutes before Field Day started, I got a FoxDelta ST2 USB interface wired and working to control the antennas — my first Field Day fully automated. The antennas were mounted on a tripod in the backyard about 20 feet from the back of the house. This meant I lost all passes that were to the North until they cleared the house. It was still fun.

Although we usually see the San Lorenzo Valley ARC, K6MMM, in the top three, this year they moved to Fourth Place. They sent in some wonderful shots. Figure 11 is a nice twilight photo and Figure 12 shows John, KJ6ZL, making some final adjustments. Figure 13 features the club's operating station. They were set up off a dirt road in the mountains above Santa Cruz, CA. Bet they had a nice view.

Dick, AH6EZ, shared a photo of his site for the Jefferson County ARC in Figure 14. In Figure 15, Glen, NK1N, is checking out the antennas before field day and in Figure 16 he is hard at work making contacts for the Boschveldt QRP Club. Stephan, KS1G, sent us his operating station and said it was his first-time running solo for Field Day and doing everything manually. Check out his modified carbon fiber boom in Figure 17.

David, W2GDJ, said that Field Day had a lot of activity and very fast-paced. He was always spinning the dial looking for another contact. Tom, N5HYP, was operating porch portable for the Irving ARC. Photo 18, he and his antennas were about 20 feet apart and he needed a sunshade in the early evening. He said mosquitos were few (in Texas they might have been few, but they weigh about a pound each ;)).

In Figure 19 we have Doug, N9DR, and helpers at the Indy United ARC, W9SU, site. I can just imagine the conversation taking place in this photo. "Remember guys, this goes over here and that one there, and the rest, I have no idea." But it should look like Figure 20 when we are done. Steve, N9IP, said he missed FO-29 this year but RS-44, CAS-4 series, and XW-2 series worked out well.

Dennis, KI4KNC, would have been operating with the Lake Monroe ARS, but this year, with COVID, he set up with his Winter Field Day equipment at the house and ran the coax in the house to enjoy the air conditioning. Gene, KJ4M, operated for the Oak Mountain QRP Daredevils. He said daytime passes were impossible. He managed to snag KI4ASK and, after that, he had a nice orderly run of four more stations.

And to close out the story, we have Ray, WA5QGD, the keeper of the AMSAT Keps. Check out his station in Figures 19 and 20. Ray was operating for the Cowtown ARC, W5COW, in Fort Worth. He said using his home station and antennas sure made a big difference this year. Really?

I hope I got everyone and was able to include a photo from your Field Day adventures. If I missed someone, it was not on purpose. We had a lot of really great submissions this year.

As I have said every year, for next year, remember, Murphy will somehow visit someone and spoil the day. Be prepared and have extra equipment, cables, and connectors. Writing this article is always the most fun for me, and I hope you enjoyed reading it.

73 and Good DX
Bruce, KK5DO

The following table shows all entries received, listed by number of contacts. In the case of a tie, call signs are listed alphabetically.

| | | | |
|---|---|---|---|
| 1 | WA5LRC | 230 | 1E |
| 2 | K4BFT | 178 | 2A |
| 3 | W5RRR | 168 | 10F |
| 4 | K5TA | 167 | 1B |
| 5 | VA3ASE | 161 | 1D |
| 6 | K6MMM | 118 | 2A |
| 7 | W2GDJ | 73 | 1D |
| 8 | N9IP | 57 | 1D |
| 9 | W9SU | 53 | 3A |
| 10 | KS1G | 48 | 1B |
| 11 | N4EN | 48 | 1E |
| 12 | WO3T | 42 | 1D |
| 13 | K4RGK | 40 | 2D |
| 14 | W3QBC | 39 | 4A |
| 15 | WD9EWK | 32 | 1B |
| 16 | WA5QGD | 29 | 1D |
| 17 | N5HYP | 22 | 1E |
| 18 | KD8RTT | 20 | 1B |
| 19 | WB0QLU | 19 | 1D |
| 20 | N8HM | 18 | 1E |
| 21 | KE8FZT | 16 | 1B |
| 22 | AH6EZ | 14 | 1D |
| 23 | KK5DO | 13 | 1D |
| 24 | KI4KNC | 10 | 1D |
| 25 | WB2JSM | 2 | 1B |
| 26 | KJ4M | 1 | 1A |
| 27 | KO6TH | 1 | 1E |
| 28 | N1AIA | 1 | 1D |
| 29 | N3CRT | 1 | 1D |
| 30 | N4QX | 1 | 1E |

**Figure 1 — K4BFT setup.**

**Figure 2 — K4BFT.**

Figure 3 — W5RRR.

Figure 4 — K5TA.

Figure 5 — N4EN.

Figure 6 — N4EN.

Figure 7 — WD9EWK.

Figure 9 — VA3ASE.

Figure 8 — WD9EWK.

Figure 10 — VA3ASE.

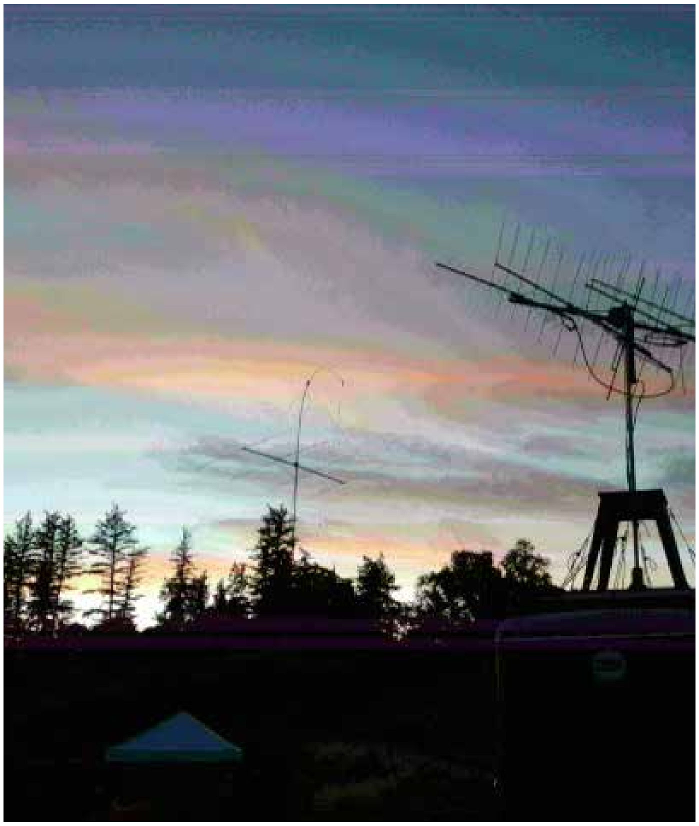

Figure 11 — K6MMM.

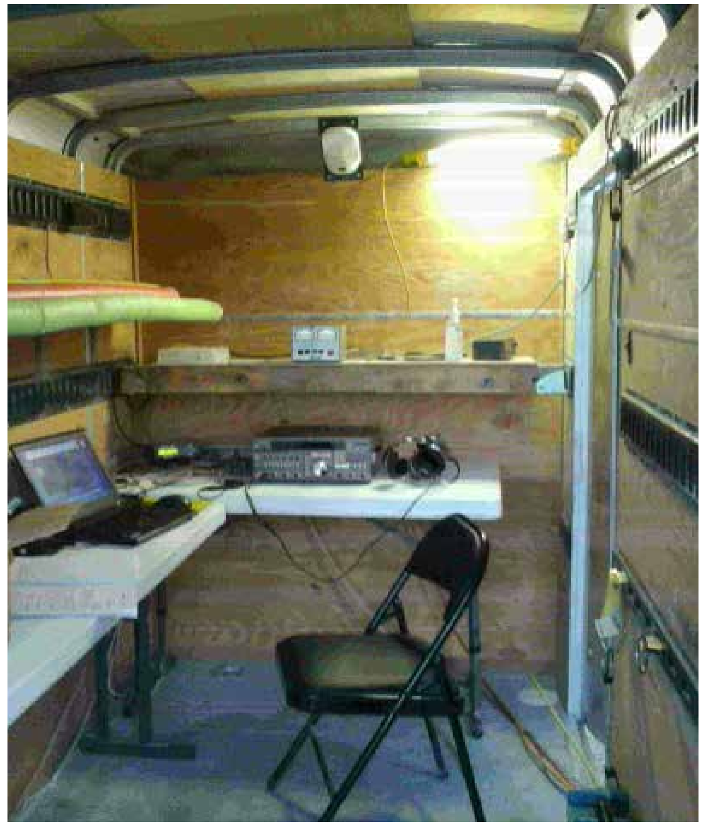

Figure 12 — K6MMM.

Figure 13 — K6MMM; John, KJ6ZL.

Figure 14 — AH6EZ.

Figure 15 — W3QBC.

Figure 16 — W3QBC.

**Figure 17 — KS1G.**

**Figure 18 — N5HYP.**

**Figure 19 — N9DR.**


**Figure 20 — N9DR.**

Figure 21 — WA5QGD.


Figure 22 — WA5QGD.

# For Beginners - Amateur Radio Satellite Primer (Part VI)

**Keith Baker, KB1SF/VA3KSF**
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*[Portions of this column previously appeared as "Amateur Radio Satellite Update" in the August 2013 edition of* Monitoring Times Magazine. *Thank you MT!]*

I trust you are all continuing to have fun listening for (or, if properly licensed, working through) our ever-expanding fleet of amateur radio satellites. In this installment, I'll once again shine the spotlight on one of AMSAT's remaining satellites from our MICROSAT series that is both still in orbit and operational. I'll also share some more helpful tips on where to look for some online data resources that may prove useful to you as you progress in your "satellite education."

## SAUDISAT 1C (SO-50)

With the demise (several years ago) of AMSAT's AO-51 satellite along with the on-again, off-again nature of AMRAD's venerable AO-27 satellite from that era, fortunately, there are several more FM "Easy Sats" now in orbit and consistently operational. One of the oldest of that original genre is SAUDISAT 1C.

SAUDISAT 1C (or Saudi-OSCAR 50) successfully launched on December 20, 2002, into a 625 X 692 Km, 64-degree inclination orbit from the Baikonur Cosmodrome in Kazakhstan. It was a project of the Space Research Institute of the King Abdulaziz City for Science and Technology in Saudi Arabia.


**The SAUDISAT 1-C (SO-50) mission patch. (Courtesy: SARS)**


**SAUDISAT 1-C (mounted in the foreground at the right) sits atop its launching structure just before launch (Courtesy:**


**The upper stage shroud that covered SAUDISAT 1-C during launch is shown here. (Courtesy: ROSCOSMOS) (Courtesy: ROSCOSMOS)**

**SAUDISAT 1-C was launched on a Dnepr rocket from the Baikonur Cosmodrome in Kazakhstan in December of 2002. The satellite remains operational to this day. (Courtesy: ROSCOSMOS)**

***SELECTED FREQUENCY AND MODE DATA:***

| *SATELLITE* | *Uplink (MHz)* | *Downlink (MHz)* | *Mode* |
|---|---|---|---|
| SAUDISAT 1C (SO-50) | 145.850 | 435.795 | FM Voice (67.0 Hz CTCSS Tone For Access) |

SO-50 carried several experiments aboard, including a Mode V/U (Mode J) FM amateur repeater experiment operating on a 145.795 MHz uplink and 436.795 MHz downlink. Miraculously, the repeater remains available to amateurs worldwide as power permits, using a 67.0 Hz CTCSS (PL) tone on the uplink for on-demand activation. SO-50 also has an on-board 10-minute timer that must be armed before use.

That is, to "turn on" the bird (if it isn't already turned on), you must first transmit an initial carrier with a PL tone of 74.4 to arm the timer, and then a 67.0 Hz tone for access. The repeater consists of a miniature VHF receiver with a sensitivity of about –124 dBm and an IF bandwidth of approximately 15 kHz. The receive antenna is a 1/4 wave vertical whip mounted in the top corner of the spacecraft. The receive audio is filtered, conditioned and then gated in the control electronics before feeding it to the 250 Milliwatt UHF transmitter. The downlink antenna is a 1/4 wave whip mounted in the bottom corner of the spacecraft and canted inward at 45 degrees.

Unfortunately, the comparatively low power transmitter carried aboard SO-50 means that some form of gain antenna (such as an Arrow hand-held cross-polarized Yagi or the Elk 2m/440 hand-held Log Periodic antenna discussed in previous columns) is all but required to successfully hear the downlink while attempting to work through the satellite.

And, for those who are unfamiliar with the satellite, Howard Long, G3LVB, has posted an excellent how-to beginner's article about working through SO-50 on the AMSAT-

UK web site at www.g6lvb.com/Articles/operatingSO50.htm.

### Satellite Data Resources

With the advent of the internet, obtaining amateur radio satellite operating mode and status information is now easier than ever. Unfortunately, because it has become so easy, obtaining the most current information from a reliable source is NOT an easy task because of what I have come to call "information overload."

So, that said, what follows are several of my recommendations on where to look that will (hopefully) make your search for the most current satellite information just a bit easier.

### The AMSAT Web Site

My go-to source for the most current satellite information continues to be our own AMSAT web page at www.amsat.org. A quick scroll down from the main page header will bring you to our "Apogee View" column where our current AMSAT president shares his views on the very latest doings of the organization. A further scroll down on that same page will bring you to the "Updates" area that contains current items of satellite status and information. Many of these items are re-posts from AMSAT News Service (ANS) bulletins.

Speaking of the AMSAT News Service, this bulletin service dates from the very earliest days of Packet Radio (that is, WELL before the rise in popularity of the Internet!) when AMSAT began to send out a weekly bulletin of satellite news and information via the (then) worldwide Packet Radio network. Those bulletins are still being sent worldwide via Internet subscription and, as the headers of the bulletins still contain Packet Radio routing information, some are actually still finding their way into what remains of the Packet Radio network!

However, you, too, can now sign up to receive these bulletins in your e-mail directly from AMSAT by clicking on "Services" and then "Mailing List Services." Scroll down to the "ANS" link and follow the directions about how to subscribe. However, if you don't want yet more e-mail filling up your (most likely) overloaded e-mail inbox, you can also browse through the ANS Archive by clicking on the "AMSAT News Service" link under the "Services" tab off the main AMSAT web page and then selecting the timing and/or threads you'd like to read.

AMSAT also offers some other mailing lists that you can subscribe to. And, what's nice is that subscribing to one or more of them is still very much free to members and non-members alike. These lists include, among others, the AMSAT-BB, an online forum for satellite discursions, as well as our weekly Keplerian Element Bulletin.

### AMSAT UK

Another excellent source of amateur satellite information from "across the pond" is contained on the AMSAT United Kingdom (AMSAT UK) web site at amsat-uk.org. Of particular note is their very extensive list of resources under the "BEGINNER" tab off the main page. Also, the AMSAT-UK folks routinely post full-motion videos of their various meetings (such as their annual colloquium) and other such gatherings.

### Gunter's Space Page

I don't know how he does it, but Gunter Krebs, via his "Gunter's Space Page" (space.skyrocket.de), has his finger on the pulse of the entire worldwide "space biz," including a wealth of amateur radio satellite information. He routinely gathers, correlates and catalogs a whole host of rocket launch and satellite information from various sources and puts it all in one place on his page. Indeed, if I'm looking for more background, construction and/or historical information regarding a particular satellite, Gunter's page is my first stop.

### The N2YO Page

Another very useful web page is Ciprian Sufitchi's N2YO Web Page (**n2yo.com**). Ciprian's site focuses mainly on satellite tracking and offers real-time pass predictions for various popular satellites by using your internet IP address to set your location. The main thrust of his page is tracking the International Space Station (ISS) showing via a map on his home page where the Station is at the moment, and when it might be visible from your location.

### Wrap Up

These are but a few of the many satellite information pages that I have found most useful out of the tens (if not hundreds) of similar pages now springing up on the web. Usually, searching for "amateur radio satellite information" will bring up related links.

In future columns, I'll again be shining the spotlight on other interesting amateur radio satellite launches of late as well as keeping you apprised of what AMSAT (and its worldwide sister organizations) are up to in space. See you then!

# Satellite Cyber Threats: Important Issues to be Considered

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**Raúl T. Aquino-Santos (SWL)**

## ABSTRACT

Satellites are important for maintaining the actual balance of the economy, society, and military activities. That is why many nations are increasingly recognizing satellites as critical infrastructure. Satellites provide a significant function in meteorology, natural disaster monitoring, communication, navigation, remote sensing, security, solar activity, among other applications, and a strong contribution to the improvement of science. Satellites use electromagnetic signals to transport information across different frequencies and modulation schemes. However, all their transmissions are susceptible to be intercepted. This increases the risk of cyber-attacks to compromise critical infrastructure functions dependent on satellite networks in sectors that include Information Technology (IT) and telecommunications (DHS, 2003). However, satellite networks employ a set of security tools and mechanisms for detecting and containing cyber incursions and, in consequence, ensuring the continuity of critical infrastructure operations. Some cyber-attacks have a political background and their aim is to affect essential services in some nations to cause damage, malfunction, or resulting in chaos in their population, which is considered as cyber terrorism. This paper presents an overview of satellite hacking, common types of attacks that can occur and some recommendations to consider for those involved in critical satellite communications systems, as well as those used for amateur radio services.

## INTRODUCTION

As Fritz (2013) indicates, a satellite system includes interrelated and interconnected parts that perform a specific task. There are three common types of satellite systems: Low Earth Orbit (LEO), Medium Earth Orbit (MEO), and High Earth Orbit (HEO). In general, a satellite system consists of the satellite itself, communications ground stations in which data is processed, such as voice and images, TT&C (Tracking, Telemetry and Control) ground station that

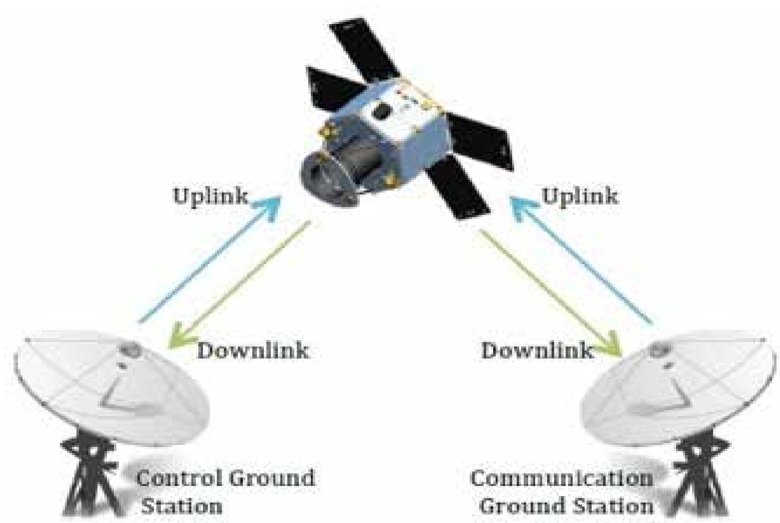


**Figure 1 — Space and Ground Satellite systems (Alshaer, 2013).**

guarantees the functionality of the satellite in the orbit by tracking it, and communicating to the satellites using the downlink and uplink frequencies that connect the satellite with these ground stations (Figure 1).

Satellite exploits differ from system to system. Some researchers have found weaknesses that allow easy hacking like the execution of malware code. These vulnerabilities may include insecure protocols, several backdoors, weak-encryption algorithms, and encrypted credentials which are the password used to login with administrative privileges. (Constantin, 2014). If we analyze it from a hacker's perspective, it is not a concern for them if they do not master all the technical details of a satellite communications system (there are satellite scripting codes for non-technical people), it is much easier to damage or disrupt hardware to affect its proper function. For example, hackers can simply purchase ready-made equipment available instead of knowing how to find an open satellite frequency, or how to build an extra-gain satellite antenna (Laurie, 2009).

In the context of this entire scenario, an important issue may have been overseen: there is an urgency to develop cybersecurity standards and regulations for commercial and amateur satellites internationally. If hackers take control of them, the consequences would be very serious. First, hackers could simply shut satellites down, denying access to their services and affecting the main infrastructure. Some of these new satellites have thrusters that allow them to speed up, slow down and change direction in space. As Akata (2020) pointed out, "if hackers took control of these steerable satellites, they could alter the satellites' orbits and crash them into other satellites or even the International Space Station".

## THREATS TO SATELLITES

In a satellite communications system, threats can be unintentional or intentional but regardless of the nature of the threat, its effects can range from loss of information, infrastructure, or significant economic damage. To simplify these two types of threats, we will try to summarize them in the following two figures: Figure 2 resumes the unintentional threats and Figure 3 specifies the intentional ones. When you have a satellite communications system, you must start by identifying the possible threats to develop a proper contingency strategy to deal with them.

Unintentional threats affect the ground system, the space segment, and its radio communication link. However, their origins are related to natural events, environmental effects inside and outside Earth and in some cases by human installations or services. This type of threat, despite having an unpredictable origin in advance, must be included in the contingency action plan for the satellite communication network.

Intentional threats have a different origin with respect to the scope and damage they intend to achieve in any element of the satellite communication system. From Figure no. 3 we are more interested in aspects related to cyber-attacks focused on causing interference and content-oriented damage. As ham radio operators, we are focused on the CubeSat LEO satellites that use off-the-self-technology to keep their development costs low. However, this represents a great advantage for hackers because their wide availability makes it easier for them to analyze their vulnerabilities. In addition, the components used for making CubeSats are open source technology which allows a hacker to implement malware and other vulnerabilities in the software or hardware of the satellite. When the satellite is in orbit, the owners of the satellites subcontract their daily management to other companies, increasing the opportunity to hack the space or ground system as simply as waiting to a specific satellite orbit to send malicious commands. Remember that satellites are controlled from ground stations and use computers. Even if those computers are not directly connected to the Internet, they can still have software vulnerabilities that can be exploited by hackers. If they infiltrate these computers, it is possible to send malicious commands to the satellites without the need for a specially manufactured satellite ground station. (Akoto, 2020).

Regardless of the type or orbit of a satellite, they will all be targets of a possible attack at any time during their life operation. For example, the following is a select timeline of intrusions into NASA's computer systems, many of which are alleged to be Chinese or Russian-state sponsored. Many of these incidents are cases of computer hacking, rather than satellite hacking, yet they can be used as a stairway to attack satellites from part of the ground-based terrestrial network. The following is a summary of NASA´s incidents related to satellite control:

2008.- "…hackers are thought to have loaded a Trojan horse in the computers at Johnson Space Center in Houston, Texas. These hackers then used the Trojan horse to access the uplink to the International Space Station (ISS) and disrupt certain operations on-board, such as email. The attack was helped by the fact that ISS onboard computers are running older software for which security fixes are no longer available…." (Steinberger, 2008).

2008.- "On June 20, 2008, Terra EOS [earth observation system] AM–1, a National Aeronautics and Space Administration-managed program for earth observation, experienced two or more minutes of interference. The responsible party achieved all steps required to command the satellite but did not issue commands" (USCC, 2011).
2008.- "On October 22, 2008, Terra EOS AM–1 experienced nine or more minutes of interference. The responsible party achieved all steps required to command the satellite but did not issue commands" (USCC, 2011).

| Type of threat | Vulnerable satellite system components |
|---|---|
| **Ground-based:** | |
| Natural occurrences (including earthquakes and floods; adverse temperature environments) | Ground stations; TT&C and data links |
| Power outages | |
| **Space-based:** | |
| Space environment (solar, cosmic radiation; temperature variations) | Satellites; TT&C and data links |
| Space objects (including debris) | |
| **Interference-oriented:** | |
| Solar activity; atmospheric and solar disturbances | Satellites; TT&C and data links |
| Unintentional human interference (caused by terrestrial and space-based wireless systems) | |

**Figure 2 — Unintentional Threats to Satellite (Malik, 2019).**

2008.- 'Landsat-7, a U.S. earth observation satellite jointly managed by NASA and the U.S. Geological Survey experienced 12 or more minutes of interference" (USCC, 2011).

2010.- "A Chinese national was detained for hacking activity targeting US government agencies. Seven NASA systems, many containing export-restricted technical data, were compromised" (Martin, 2012).

2010.- "For about 18 minutes on April 8, 2010, China Telecom advertised erroneous network traffic routes that instructed U.S. and other foreign Internet traffic to travel through Chinese servers. Other servers around the world quickly adopted these paths, routing all traffic to about 15 percent of the Internet's destinations through servers located in China. This incident affected traffic to and from U.S. government (".gov") and military (".mil") sites, including those for NASA" (USCC, 2010).

2011.- "Romanian hacker TinKode allegedly obtained sensitive information from NASA's Goddard Space Flight Center and the European Space Agency which he then made publicly available online. The information included Login credentials for admin, content management, databases, email accounts, file upload, and other key systems" (Leyden, 2011; Prime, 2012).

2011.- "NASA's Jet Propulsion Laboratory (JPL) "reported suspicious network activity involving Chinese-based IP addresses... giving the intruders access to most of JPL's networks" (Martin, 2012).

2013.- "Chinese national Bo Jiang, a former NASA contractor, was arrested as he was

| Type of threat | Vulnerable satellite system components |
|---|---|
| **Ground-based:** | |
| Physical destruction | Ground stations; communications networks |
| Sabotage | All systems |
| **Space-based (anti-satellite):** | |
| Interceptors (space mines and space-to-space missiles) | Satellites |
| Directed-energy weapons (laser energy, electromagnetic pulse) | Satellites; TT&C and data links |
| **Interference and content-oriented:** | |
| Cyber attacks (malicious software, denial of service, spoofing, data interception, and so forth) | All systems and communications networks |
| Jamming | All systems |

**Figure 3 — Intentional Threats to Satellite (Malik, 2019).**

attempting to return to China with "a large amount of information technology that he may not have been entitled to possess,"… NASA shut down access to an online database and banned new requests from Chinese nationals seeking access to its facilities amid mounting concerns about espionage and export control violations…. The security measures include a complete ban on remote computer access by Chinese contractors already working at NASA centers (Klotz, 2013). NASA employs 118 Chinese nationals in "remotely-based" information technology jobs that may enable them to penetrate the space agency's national security database servers, and 192 Chinese nationals in positions with "physical access" to NASA facilities" (Pollock, 2013).

2013.- "The US Congress passed a provision which prohibits the Commerce and Justice departments, NASA and the National Science Foundation from buying any information technology system that is "produced, manufactured or assembled" by any entity that is "owned, operated or subsidized" by the People's Republic of China. The agencies can only acquire the technology if, in consulting with the FBI, they determine that there is no risk of "cyberespionage or sabotage associated with the acquisition of the system," according to the legislation. In addition to condemnation from China, this rule could upset US allies whose businesses rely on Chinese components in some of the equipment they sell to the US" (Fritz, 2013).

## TYPES OF SATELLITE HACKING

Nowadays, getting a satellite into orbit and stating its initial basic functions is no longer a major concern. The space segment and the ground segment are vulnerable to the same types of attacks as any other computer system on the network. The perpetrator can trick the satellite into confusing it with the ground station and then start the hacking through a physical connection, or through the radio communications system. Under these conditions, satellite hacking can be analyzed into four different categories: Jamming, Spoofing, Hijacking and Controlling.

### Jamming

Jamming is a technique used to interrupt radio frequency transmissions by replacing them with different ones to avoid the receivers being able to acquire the data they were expecting and is considered as the easiest way of hacking. Jamming the uplink frequency has less impact but on the other hand, jamming radio frequency uplink control prevents the satellite from receiving control commands from earth stations with no possibility of tracking their main functionalities. Furthermore, any single cyber-attack on ground operation station equipment can produce a satellite jamming, with the consequent impact on financial transactions or data services. A DDoS attack against the computer network used by the ground station could also effectively jam a satellite without having to get involved with radio frequency issues. Even if the uplink signal is not targeted, an essential component of the satellite system would be, causing the systematic failure of the satellite communications network (Fritz, 2013).

### Spoofing

When a satellite communications system is under spoofing attack, the receiver in the space segment or ground segment accepts some type of validation or altered control information, causing false signals in the whole system This type of threat is common for several satellite systems because its developers fail to encrypt the monitoring and control of the uplink/downlink for radio communications, resulting in a high vulnerability to spoofing threats (Alshaer, 2013).

### Hijacking and Controlling

The term hijacking refers to an unauthorized, usually illegal, transmission that is generated with the purpose of being switched to a different one to be received by as many systems as possible. When this is combined with control of the system, hijacking is an illegal transmission that uses a satellite to exchange its transmission for another. In this category, Control is the most difficult part to be achieved by a hacker, but when it is done, it is possible to get complete control of the satellite, its payload and therefore the overall ground segment. By taking control of ground station links, hackers can issue commands for a satellite to misdirect it, burn it up on re-entry to the earth's atmosphere. The high security of the satellite parts at this level makes the control of a satellite significantly difficult, but hackers only need just one weakness to control and hijack all the satellite networks (Fritz, 2013).

## ACTIONS TO BE TAKEN

Hacking a satellite system is an undesired possibility that will always be present. However, it is possible to mitigate or avoid this kind of action if we start to develop regulations and cybersecurity standards in the design and construction of satellites to achieve a standardization about this security problem. The legal framework for defining who can be considered guilty of hacking and what criminal charges will be incurred for the actions taken, ensuring that the parties involved take the necessary steps to secure those systems. To minimize the damage caused by hacking a satellite system, it is necessary to make great efforts in a systemic detection of specific threats, documentation of the weaknesses encountered and having an immediate response team against cyber-attacks. (Fritz, 2013).

Threat modeling is a technique for better understanding and prioritizing the threat and risk faced by the network itself. Once the security threat or risk is detected, actions can be taken to prevent or recover from the attack as quickly as possible (Alshaer, 2013). Anti-jamming prevention includes the use of spread spectrum, empowering the signal power so it exceeds the interfering signal (jamming). Most of the information can be received with a low error rate. In a low-cost satellite infrastructure such as CubeSats, increase the embedded security processor with encryption, digital signing and identity management at their authentication and authorization access. The use of standards to improve security is important, for example, the ISO 7498-2 related to authentication, authorization, encryption, data integrity and non-repudiation. It will be important to have a response threats team to prevent, monitoring, logging and react as a part of the satellite systemic detection group (Malik, 2019).

## CONCLUSION

The security of satellite systems will be efficient when instruments, mechanisms, standards, protocols, laws, and procedures are designed and applied to prevent unauthorized persons or groups from accessing ground stations to spy confidential satellite transmissions, alter information from orbiting satellite, falsifying commands and control data. This will generally affect the infrastructure of the space and ground segment of satellite systems. These systems can be attacked through computer networks connected to the Internet, which is the most common form of hacking at present, but it is also possible to do it using radiofrequency stations that simulate the uplink and downlink of the satellite communications system. The main constraints to understanding the complexity of satellite threats are the variety of systems and the lack of standards in their development. Most satellite manufacturers keep their design information secret as a security action but restrict the development of industry standards related to construction, interoperability, and security. Despite the cost and technological difficulty of reaching space, it is relatively easy to carry out cyber-attacks to satellites. It is very important to secure ground stations that have Internet connectivity because it would be one of the primary targets for a cyber-attack, but as revealed in the NASA case study, there is still much to be done on security issues in IP networks.

SpaceX is currently the world's largest low-orbit satellite operator, with plans to have 42,000 satellites in space over the next 10 years. This number of satellites is intended to provide satellite Internet services around the world. However, SpaceX and other rival companies are under pressure to achieve this goal by accelerating the production of their satellites at low cost, which could result in a lack of security in their construction and operation. These types of actions are the ones hackers are currently looking for to infiltrate while the satellite service companies are worried to be first in space by sacrificing costs and security in their systems.

Finally, no matter what actions the satellite industry and governments take on cybersecurity in satellite systems, only one thing is sure: something must be done about it, and soon. It will be a serious mistake to continue developing satellites that do not satisfy minimum security standards, making it easy for hackers to gain control of commercial or amateur satellites to put human lives in danger or to damage space and ground segment services or infrastructure.

## REFERENCES


• Akata, W. (2020). Hackers could shut down satellites — or turn them into weapons. Astronomy Magazine. Available at astronomy.com/news/2020/02/hackers-could-shut-down-satellites--or-turn-them-into-weapons.

• Alshaer, M. K. (2013). Cyber Attacks On Satellites Review & Solutions. Available at www.academia.edu/18156391/Cyber_attacks_on_satellites_Review_and_solutions.

• Constantin, L. (2014, April 18). Satellite communication systems are rife with security flaws, vulnerable to hackers. Computer World.

• Fritz, J. (2013). Satellite Hacking: A guide for the perplexed. Culture Mandala: The Bulletin of the Center for East-West Cultural and Economic Studies. Vol 10, No.1.

• Klotz, I. (2013). NASA Steps Up Security After Arrest of Former Contractor. Available from www.reuters.com/article/us-space-espionage-idUSBRE92J1FR20130320.

• Laurie, A. (2009). Satellite Hacking for Fun and Profit. Retrieved from www.securitytube.net/video/263.

• Leyden, J. (2011). Inside the mysterious U.S. satellite hacking case. Available from www.theregister.co.uk/2011/11/21/us_sat_hack_mystery/print.html.

• Malik, W. (2019). Attack Vectors in Orbit: The Need for IoT and Satellite Security. RSA Conference, San Fco. USA.

• Martin, P. (2012). NASA Cybersecurity: An Examination of the Agency's Information Security. Available from oig.nasa.gov/congressional/FINAL_written_statement_for_%20IT_%20hearing_February_26_edit_v2.pdf.

• Pollock, R. (2013). NASA Chief Failed to Tell Congress of 118 Chinese Nationals Working in IT. Available from washingtonexaminer.com/nasa-chief-failed-to-tell-congress-of-118-chinesenationals-working-in-it/article/2525324.

• Prime: Cybersecurity Risk Management Strategies for SATCOM Networks. (2012). Available from www.milsatmagazine.com/cgi-bin/display_article.cgi?number=1142237172.

• Steinberger, J. (2008). A Survey of Satellite Communications System Vulnerabilities. Available from www.dtic.mil/dtic/tr/fulltext/u2/a487592.pdf.

• USCC. (2010). Report to Congress of the US-China Economic and Security Review Commission. Available from www.uscc.gov/sites/default/files/annual_reports/2010-Report-to-Congress.pdf.

• USCC. (2011). Report to Congress of the US-China Economic and Security Review Commission. Available from **origin.**www.uscc.gov/sites/default/files/annual_reports/annual_report_full_11.pdf.

• U.S. Department of Homeland Security (DHS). (2003). The national strategy to secure cyberspace. Washington, D.C.


# Integration of a Distributed Ground Station Network Based on Amateur Radio Infrastructure for Scientific Space Missions


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### 1. Abstract


The rapid increase of scientific and low-cost experimental satellite missions has made it necessary to develop new proposals for the integration of space platforms and ground stations for telemetry control and data downloading from sensors onboard. In recent years, the number of radio amateurs around the world with technological capabilities for downloading satellite data has grown significantly, becoming a fundamental part of international communications. In this work, a novel proposal for the integration of a network of ground stations distributed worldwide, based on Amateur Radio Infrastructure for Scientific Space Missions, is shown.


### 2. Introduction

The relationship between ham radio and space technology dates back from 1961 when the OSCAR-1 satellite (acronym of Orbiting Satellite Carrying Amateur Radio) was launched. Until January 2018, near 92 satellites of all sizes, carrying amateur radio and several related experiments, have been launched and successfully operated by hams in countries around the world according to AMSAT (2018).

In the context of the architecture of a typical space mission, and according to the general scheme shown in SMAD (1999), this is integrated by three main segments: space segment (SS), ground segment (GS) and launch segment (LS). The SS is integrated

**Figure 1 — Scheme for communication between GS and SS (Maini, Agrawal 2014).**

mainly by the spacecraft and all the hardware on-board, meanwhile, the GS is integrated by the communications equipment on-ground and all the technological and computer resources for the storage and distribution of the downloaded data from the spacecraft in-orbit.

According to Maini (2014), an Earth station (ES) is a terrestrial station mainly located on the Earth's surface. The ES is intended for communication with one or more manned or unmanned spacecraft in orbit, or with one or more terrestrial stations of the same type via one or more reflecting satellites or other objects in space, as depicted in Figure 1.

In the context of the design of GS, it is important to consider the footprint coverage and the available time for the uplink and downlink of data during each pass of the spacecraft over the GS. Undoubtedly that, having a high number of GS that allow covering the largest surface during the orbit of the spacecraft, will be the better scenario. A good idea is the implementation of a Distributed Ground Station Network (DGSN).

Some advantages of DGSN integration are the rapid installation, the ease of adaption to hard and hazardous geographical conditions, the use of fixed, semi-fixed or portable equipment for handling, storage, and the automation of the data are easy transported and distributed. The uplink/downlink to the satellite uses low transmission power, and it is the antenna systems that avoid loss of data caused by long distances between their links. Additionally, it is possible to reuse frequencies in different geographical areas of the world, allowing DGSN to be more effective compared to the performance of one o more fixed stations operating individually. Of course, we must consider the disadvantages among which we can mention spectrum congestion by disabled systems in the use of radio frequencies. Each of the stations in the network must carry out procedures and payment of fees for the use of the spectrum. There are effects due to environmental conditions and the possibility of interference by third parties and the potential risk of interception of data. All equipment requires maintenance and often needs lines of sight for links to exchange data among participating stations.

As it is established in (AMSAT, 2018), amateur radio provides access to a variety of frequencies from shortwave to microwave for amateur satellite use. Once in orbit, a satellite for amateur radio users becomes more than a simple telemetry and telecommand link for radio experimenters, students, and academics around the world, of all ages, specialties and academic levels becoming in powerful technological tools for increasing the availability and participation in the STEM education scheme. In addition, as students and academics obtain their amateur licenses, they gain valuable expertise in communication techniques that can be applied to a variety of space-related projects in spacecraft and ground station design, as well as terrestrial communications.

It is possible to take advantage of the strength of both worlds — ham radio and the scientific academic environment — with a proposed project such as the Integration of a Distributed Network based on the infrastructure of radio amateurs, which allows boosting the integration of a distributed ground station for communication with scientific satellites along with the potential as an alternative communication network in case of natural disasters or emergencies. TEPEU-1 mission is a project dating back from 2015, boosted by educational institutions in Mexico such as IPN, UNAM, University of Colima, among others. The main objectives of TEPEU-1 are the development and launch of the first experimental Mexican satellite for dual purposes: technological validation of amateur radio experiments and scientific exploration of the relationship between the ionosphere and space weather. On the side of technological validation, TEPEU-1 seeks to boost the design and integration of a space payload compatible with CubeSat standard for technological demonstration of radio communications based on amateur radio experiments and, on the other hand, the scientific studies based on the alterations of the ionosphere related with events of space weather and its impacts on the communications technologies.

The first potential client for the Distributed Ground Station Network based on Amateur Radio Infrastructure (DGSN) is the TEPEU-1 mission.

### 3. Importance of the GS in a space mission

Once you have all the requirements for the ground station such as the frequencies, types of antennas, transmission power, modulation schemes and data coding, then it is possible to evaluate the availability and performance of the GS for the mission. In addition to equipment such as antennas, radios, etc., the design of the point-to-point links is important to ensure a successful space mission.

The GS is responsible for monitoring and controlling the complete space mission, giving facilities and services including the generation and provision of raw-data acquisition and auxiliary data to the main investigation group. The complexity of the GS depends on the satellite orbit and the

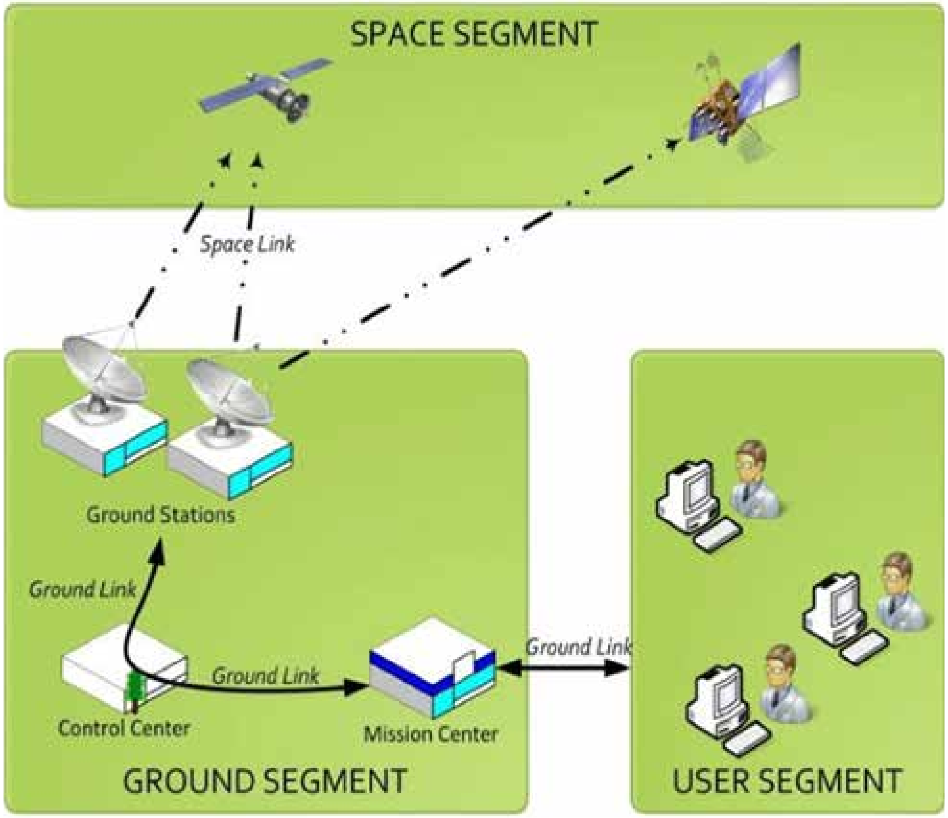


**Figure 2 — Ground segment elements (Cerqueira, Do Santos and Ambrosio, 2013).**

experiments onboard. Typically, the GS is subdivided into four elements as shown in Figure 2 (ECSS, 2008):

1. Ground Stations to handle the unidirectional or bidirectional communication link with the Space segment.
2. Control Center. Handles operation control, simulation, flight dynamics, data handling and distribution.
3. Mission Center is responsible for the mission concept, evaluation, analysis, mission exploration and payload data.
4. Network. Handles the interconnection of centers, GS, and SS, using terrestrial and space links.

When we use a LEO (Low Earth Orbit) satellite, is possible to use a low-cost ground station based on commercial off-the-shelf (COTS) products, both in terms of software and hardware components. The use of COTS integration is part of one of the technological objectives of this mission: to develop and demonstrate the coordinate interconnection among several GS for the operation of small satellite projects. Likewise, with the use of COTS elements the objective is to provide high-performance operation of the GS to ensure accurate and error-free data received from the satellite. (Gil et al, 2001).

Many LEO missions underestimate the importance of the GS and focus on the SS. However, the GS should be seriously considered from the beginning of the design of the mission, because once the satellite is in orbit it is the only link we have with the satellite, and therefore the only way to get evidence that the LEO satellite is operating properly. However, it is not only important to have an operative GS also is necessary to have trained and distributed operators who can communicate with it effectively. Typically, the LEO satellite only passes a few times a day through a specific GS location and can only establish communication with it for a few minutes, so an essential requirement to ensure the success of the mission is to have a background human team capable of establishing such communication (Duarte, 2016).

## 4. Amateur GS station model

For the DGSN, the GS is a key piece in the TEPEU-1 mission proposal; therefore, collaboration with the FMRE is established, so that satellite ham radio operators become the first receiving stations in Mexico. In addition to the invaluable cooperation of Mexican radio amateurs, a proposal for a semi-fixed GS (SFGS) is shown in Figure 3.

Considering that a GS will operate in the frequency range of 435 to 438 MHz and that the TEPEU-1 satellite will have an estimated power between 100 mW and 500 mW, the SFGS must include computer equipment to execute the software for automatic azimuth and elevation tracking as well as Doppler frequency correction (SatPC32). To have the station automated, an intermediate hardware stage is added to the SatPC32 based on Fox Delta Tracker model ST2-USB equipment, which handles the information exchange protocol for Yaesu® model G-5500 rotors, which would be the recommended rotor model for the SFGS. With this configuration in the SatPC32, the fixed earth station could receive all the information from the space segment, without need of human intervention, even in night orbits or on weekends.

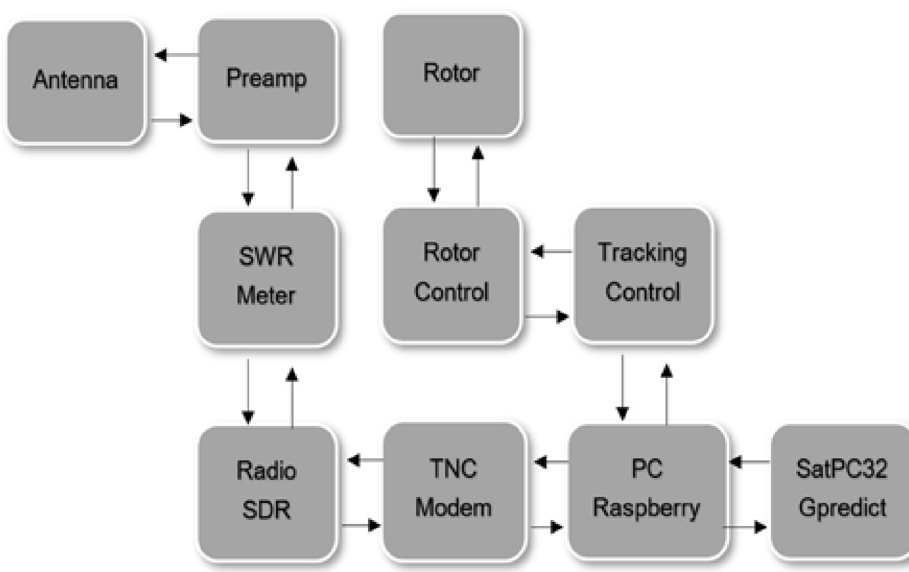


**Figure 3 — Fixed Ground Station.**

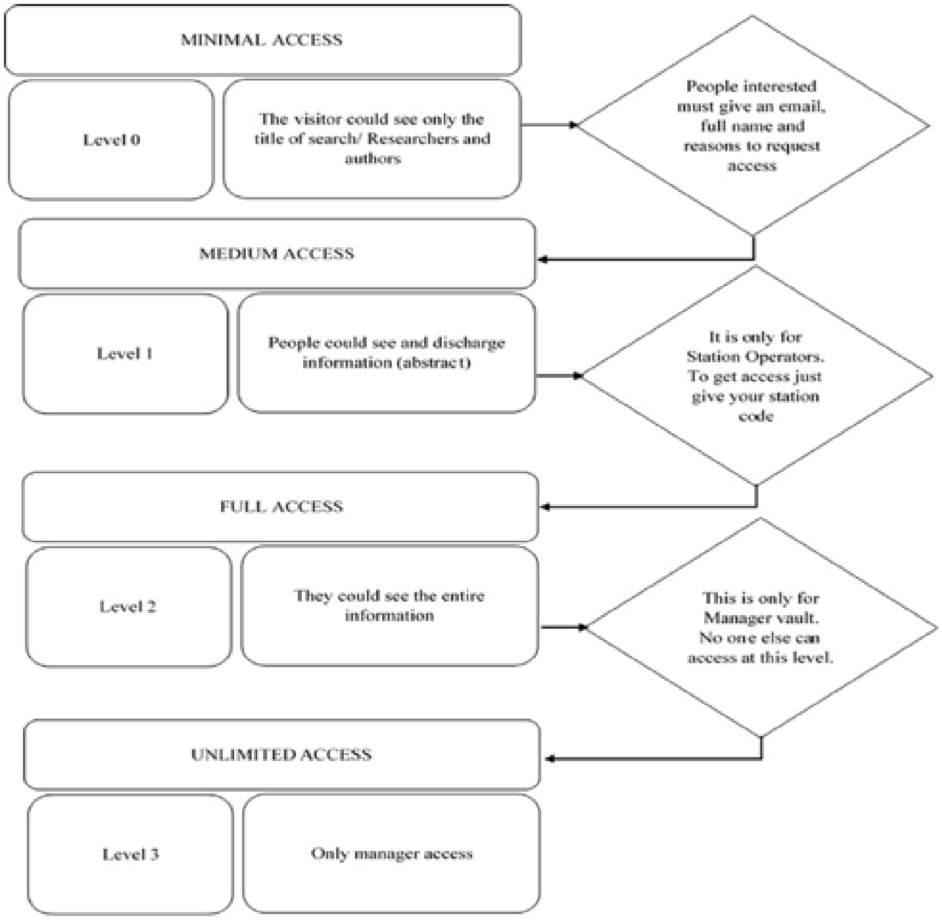


**Figure 4 — Block Diagram of a proposal for a station link.**

For the receiver system, circular polarized directional antennas with at least 15 horizontally polarized elements and 15 vertically polarized elements are recommended. One proposal is the 436CP30 model of the M2 brand which offers a gain of 15.50 dBi. It is advisable to support the antenna system with preamplifiers installed directly on the antennas; however, if coaxial cable no longer than 15 m and with low loss is recommended for use, then it would be possible to omit the preamplifiers. The coaxial line could be the LMR-400 as a minimum, or the LMR-600 to ensure low loss on the receiving line.

## Portable Ground Station

For the Portable Ground Station (PGS), some elements represented in Figure 3 are not necessary or are replaced by other elements shown in the functional blocks that make up the structure of the SFGS. In the first place, the suitable PC is replaced by a Raspberry Pi using a Linux operating system. This proposal offers adequate computing power, portability and low power consumption, essential characteristics for portability. The use of Gpredict® is proposed to calculate the orbits of the LEO satellites, which provide all the functional characteristics of the SatPC32.

For the reception system, the PGS will use an SDR (software defined radio) instead of the VHF / UHF radio used in fixed stations. The SDR is useful in places where there is no electricity supply (it can be powered by a power bank). The specifications described so far mean that the PGS does not require an interface, modem or TNC used for the fixed station. The SDR has a USB connection port that is fully compatible with the Raspberry Pi card. Another advantage of the portable station is not needing the Fox Delta Tracker model ST2-USB interface because there are no rotors for tracking the satellite orbit, instead, a circular polarization non-directional antenna will be used. This type of antenna has the characteristic of receive signals when the satellite's orbit is more than 25 degrees of elevation without the need to track the trajectory of the satellite. The only requirement is to put the antenna at a low height (no more than 3 meters) and a place free of obstacles such as trees, buildings, etc. This configuration is recommended to have a low signal loss due to having a short coaxial line, which requires a male SMA and a SO-239 female adapter to connect the SDR

## 5. Feasibility of developing a network of ground stations based on amateur radio communications

A good way for data interchange is by an internet link among all stations. Maybe, this is less attractive but more convenient to ensure data in a central vault. The vault could be the H.D. computer of one station (member); keeping its information in each computer´s station in a star configuration design for this. Figure 4 shows an arrangement for linking stations.

## Security Levels

All information is available, but not all people can access complete information. This means that members or the station operator (SO) have a free pass for the entire information. Visitors are welcome but just in the first level. The security levels and their descriptions are shown in Figure 4.

## 6. Data control and distribution scheme

The "Cloud Distributed Storage Platform" or CDSP is an essential component for the operation flow of the TEPEU project. As can be seen in Figure 4, once the data from the TEPEU sensor have been downloaded by the GS, they must be sent to the CDSP. The CDSP is composed of two main elements: the client and a set of distributed storage nodes. Each of the reception stations located throughout the planet must have an authorized CDSP client for the distribution of the captured data. Each of the reception stations located throughout the planet must have an authorized CDSP client for the distribution of the captured data. To ensure the secure flow of information among the receiving stations and the cloud storage system, each client will need to have a unique "token" for access to the CDSP. Moreover, the "core" of the CDSP, consists of a set of storage servers (elastic scaling), whose task is to store the information sent by the general coordinator. The general coordinator is responsible for validating the credentials (token) of the clients, once this is done, the processes divide and store the data together with the storage nodes (SS01, SS02, SS03), thus guaranteeing redundancy, security, and availability of information for end-users (Figure 5).

To avoid generating a bottleneck on the side of the coordinator, the use of an elastic load balancing system has been proposed, that is, the greater the number of requests from customers, the more resources from the coordinator are made available. It is important to note that the storage nodes

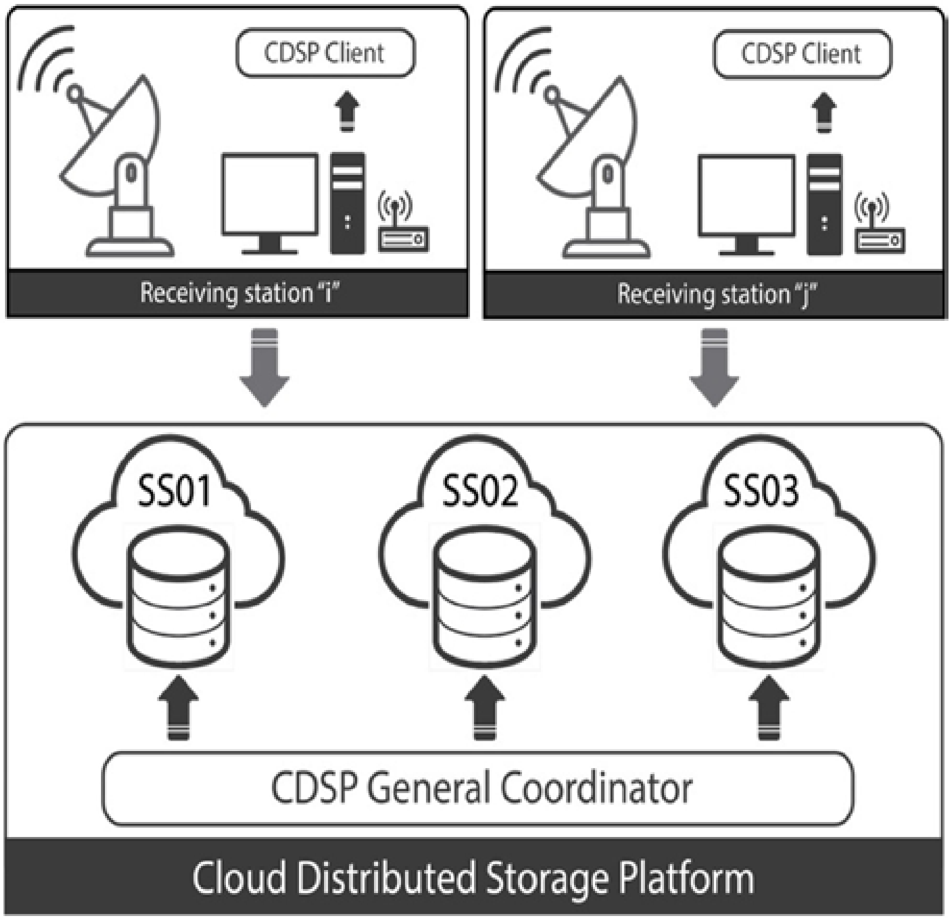


**Figure 5 — Cloud Distributed Storage Platform (CDSP).**

are not redundant, since they do not contain exact copies of each other; instead, a data partition scheme is used that allows distribution of various sections of the files (slices) throughout the storage nodes. Therefore, only a subset of these nodes is necessary to retrieve the original information thus increasing the robustness of the CDSP (Gonzalez-Compean et al., 2018).

### 7. Conclusions

In this work, a novel proposal has been presented for the integration of a network of telemetry control stations and data downloading for scientific and low-cost experimental satellite missions. The feasibility of integrating amateur radio associations around the world as part of that network has been analyzed as well. The rapid growth of technological skills and abilities by these groups positions them as a viable alternative for data download tasks. The design of a platform for distribution and storage of high availability data has also been analyzed. The partition of the information into slides will allow a high fault tolerance while optimizing the space and bandwidth required for the storage and distribution of the data, achieving a perfect interaction between the monitoring and download centers with the data centers distributed around the world.

For the mission's scientific team, the DGSN based on amateur radio is considered a major element in this study. The FMRE satellite operators are the core of the proposed DGSN. Their participation as SFGS and PGS guarantee the reception of the TEPEU-1 measurements over Mexico. However, the scientific group invites all satellite operators to join the DGSN. If anyone is interested in participating to increase this infrastructure, please contact the scientific leader:
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Email: mmendozab@ipn.mx.

### 8. References


AMSAT. (2018). FCC Part 97 "Amateur Radio Licensing for CubeSats." Available at www.amsat.org/wordpress/wp-content/uploads/2018/04/AMSAST_CubeSat_Licensing.pdf.

Cerqueira, C., Dos Santos, W. & Ambrosio, A. (2013). "Development of an Interface to a Spacecraft Simulator Empowered by Virtual Reality." *SBC Journal on 3D Interactive Systems*. 3. 37-44.

Duarte, C. (2016). Hacia el Espacio. México: "Estaciones Terrenas para CubeSats." Available haciaelespacio.aem.gob.mx/revistadigital/articul.php?interior=247.

ECSS "European Space Agency Members". (2008). *European Cooperation for Space Standardization. New Zealand: Ground systems and operations.* Available at ecss.nl/standard/ecss-e-st-70c-ground-systems-and-operations/.

Gill, E., Montenbruck, O., Kayal, H. & Briess, K. (2001). "A Concept for an Autonomous Space and Ground Segment Applied to the BIRD Satellite Mission." *19th AIAA International Communications Satellite Systems Conference*; April 17-20, Toulouse.

Gonzalez-Compean, J. L., Sosa-Sosa, V. J., Diaz-Perez, A., Carretero, J., & Marcelin-Jimenez, R. (2018). "FedIDS: a federated cloud storage architecture and satellite image delivery service for building dependable geospatial platforms." *International Journal of Digital Earth*, 11(7), 730-751.

Maini, A. & Agrawal, V. (2014). *Satellite Technology: Principles and Applications*. Third Edition. Wiley.

M.A. Mendoza-Bárcenas, et al. "Tepeu-1: Misión espacial mexicana con fines científicos y de validación tecnológica," SOMI XXXIV Congreso de Instrumentación. Año 6, no.1, Octubre, 2019. ISSN 2395-8499.

# Satellite Antenna Tracking Using Goto Telescope Mounts

**Dwayne Sinclair, NA6US**

Recently, I reviewed the video by K4WOF www.youtube.com/watch?v=kpgV8P6ocLE and was motivated to build my own satellite tracking mount. Satellite operations are considerably easier if satellite tracking is automated so that satellite passes can be focused on radio work. Somewhat comically, automated antenna tracking looks exciting and generates community interest in our amateur radio activities. I have to apologize as mistakes were made by me as I came up to speed with satellite operations. A shout out to Jason N8PDX for invaluable feedback.

As an amateur astronomer, I have been working with "goto" telescope mounts for more than a decade - "Goto" computer-controlled telescopes are designed to make night viewing easier by automatically moving the telescope to an object in the sky via computer control, and then the telescope mount can track the object for many hours. The more expensive goto telescope mounts can track objects for days with no tracking errors. With our busy lives and brief sky viewing opportunities, a "goto" telescope mount makes astronomy easy, and more complex activities such as long exposure astrophotography accessible to all. The inexpensive goto telescopes provide an easy path for new amateur astronomers as they take the guesswork out of finding objects in the night sky.

Goto telescopes are made up of four components: the Tripod/leveling base, the telescope mount (with motors) for object tracking, the optical tube, and the computer controller. The initial setup requires a simple alignment procedure but once aligned, tracking will remain accurate for many hours. All the consumer goto telescopes have a basic sky object database built into a small handheld computer controller with provision for serial connectivity to an external computer for advanced software control. The Meade ETX60 and the Celestron Astro FI are two examples of consumer-grade goto telescopes.

Telescope mounts come in two form factors: Equatorial (Eq) Mounts and Altitude/Azimuth (Alt/Az) mounts: equatorial mounts tend to be simpler and more accurate if only since once they are first orientated to your latitude, they only need to track an object in one plane. Alt/Az mounts are leveled to your location, and thus for solar system and deep space objects, they will need to move in two axes to track objects. Either mount would need to move in two axes to acquire a satellite. My personal preference is to use an Alt/Az mount for satellite tracking.

So, the important questions are "Can a goto telescope track satellites like planets, asteroids, or deep space objects?" The answer is no! "Can a goto telescope move quickly to a location in the sky?" The answer is absolutely yes! It's the ability to move quickly from one location in the sky to another that makes goto telescope mounts useful to us for satellite work. To expand on this, certainly, expensive telescope mounts are available that can track satellites, but two considerations need to be addressed: the hardware speed of the mount to track fast-moving satellites is not normally found on inexpensive consumer "goto" telescope mounts; and the telescopes mounts ability to accept satellite position data (TLE).

Briefly, the coordinate system used to track solar system and deep space objects is a different model than what is used to track satellite positions. Although many telescope mounts have the fine and fast motor control to follow a satellite, the telescope mount software would not have the ability to accept satellite TLE data. Rewriting telescope mount software for satellites is a project for another day.

When a "goto" scope is commanded to move from one location in the sky to another, the scope will move quickly to the desired location. This action is called "slew" or "slewing." For satellite tracking, we just need to slew every few seconds to accurately track satellites for amateur radio communication. Depending on the telescope mount software and hardware capabilities, the position commands for this action will either be entered as Right Ascension/Declination (Ra/Dec) coordinates followed by a slew command, or via Elevation or Altitude/Azimuth (Alt/Az) coordinates followed by a slew command.

Some goto telescope mounts will only accept Ra/Dec or Alt/Az while others will accept both formats. Equatorial telescope mounts commonly only accept Ra/Dec commands. There is a means to calculate Right Ascension and Declination from Altitude and Azimuth but to do so, you will also need your local Latitude, Longitude, and UTC Time.

The astronomy community has been satellite-tracking for some time to spot satellites at sunrise and sunset with a telescope when

Telescope mount in a foam case.

**Custom Comet Definition for a Goto Telescope Mount**

| No. | Name | Year | M | Day | | |
|---|---|---|---|---|---|---|
| C/2012 | S1 ISON | 2013 | 11 | 28.7960 | | |
| q | e | ω | Ω | I | H | G |
| 0.0125050 | 1.0000030 | 345.5088 | 295.7379 | 61.8570 | 6.0 | 4.0 |

**Satellite TLE Data**

ISS (ZARYA)
1 25544U 98067A 08264.51782528 -.00002182 00000-0 -11606-4 0 2927
2 25544 51.6416 247.4627 0006703 130.5360 325.0288 15.72125391563537

**The differences between a telescope object definition and a satellite - TLEs.**

**The author's telescope mount.**

the satellites are still illuminated by the sun. SkyTrack by www.heavenscape.com is an example of one such program and, with this program alone, you have automated satellite tracking using various goto telescope mount manufacturers. SkyTrack uses an open-source telescope mount API called ASCOM to communicate with a telescope mount which is supported by most astronomy manufacturers. What astronomy programs are missing is satellite frequencies and transceiver VFO control to compensate for Doppler.

I felt that there was a "fast path" to satellite tracking using a telescope mount. I believe the various Alt/Az one-armed and fork mounts by Meade, Celestron, and iOptron are well suited to the task. Portability is very important. I chose the iOptron Az Mount Pro as my platform with several advantages over other mounts with these features:

- An Alt/Az mount with the ability to support Altitude and Azimuth commands;
- Onboard battery so external power is optional;
- 33 lb primary dovetail interface with a secondary 11 lb dovetail interface; a secondary allows a second telescope or antenna to be attached. A dovetail is a means of quickly attaching a telescope (or antenna).
- A Wi-Fi interface so that command/control can be wireless; and
- Portability!

Amateur radio satellite tracking programs have been optimized to work with more traditional "rotators" which unfortunately have fairly "cumbersome" I/O interfaces and large power requirements. Fortunately, these programs do output altitude (elevation) and azimuth data for rotators to action.

So, are there satellite tracking programs and a way of controlling a telescope mount? Let us review the options we have available:

1. Astronomy software SkyTrack using the ASCOM API. SkyTrack will accept an amateur radio TLE database and interface with any goto telescope mount via ASCOM. This is a Windows Program. Radio VFO control would need to be performed manually or via an independent program.
2. Hamlib (the swiss army knife of radio and rotator control) includes VFO control of numerous radios together with support of rotators including telescopes. Radio software that has radio and rotator controls can take advantage of frequent updates to Hamlib that add new radio and rotators. Recently, the iOptron telescope mount was added to Hamlib joining the existing support of Meade and Celestron telescope mounts. Gpredict is one satellite tracking application that can leverage this support from Hamlib to both control VFO's for satellite frequency and doppler adjustment and rotators including Telescope mounts for satellite tracking.
3. Build Your Own. Many satellite tracking software applications will provide a basic means of outputting Altitude and Azimuth information. As an example, MacDoppler can output this information via a UDP port.

I decided to pursue a build of my own for two simple reasons: take advantage of MacOS software MacDoppler and continue to use my Mac for portable operations, and take advantage of WIFI control of my goto telescope mount via TCP/IP simplifying data cabling between mount and computer.

My software consists of MacDoppler configured for my IC-9700 connected via USB cable for VFO control. The WIFI from my Mac is connected to my iOptron goto telescope mount and a python script performs the following:

**Simple setup for phasing cables.**

**Building antenna mounts.**

• Opens the MacDoppler UDP port to receive Altitude and Azimuth information.
• Opens a TCP port to the Telescope Mount
• Formats the UDP Altitude and Azimuth information from MacDoppler into Telescope Mount commands a. Set Altitude, Set Azimuth, and Slew.
• This occurs every 1 second and this frequency is more than accurate to maintain alignment.

This Python script is available at [github.com/djsincla/goto](github.com/djsincla/goto) and can be modified relatively easily to change from TCP to serial port control of the Telescope Mount. The program also includes a module to calculate Right Ascension and Declination if the goto telescope mount does not support Altitude and Elevation.

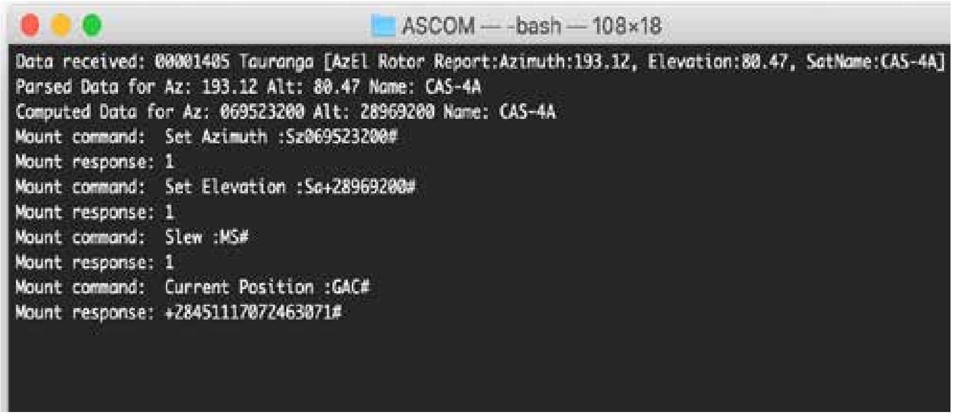
For antenna hardware, I chose the Arrow antennas phased at 90 degrees with phasing cables from Diamond for both 2M and 73 cm connected to a diplexer so that a single antenna cable runs to the radio. Antennas are mounted to the goto telescope mount using standard Telescope dovetail plates together with some PVC pipe connectors.

The iOptron Az Mount Pro I own is assembled the same as if I was going to mount a telescope. I just attach antennas instead.

Initial attempts to consolidate cabling to the mount itself were ok but I felt to simplify, it was simpler for antenna cables to hang below the antennas. PVC is inexpensive so changes to mount configuration will likely be ongoing as I continue to tweak the configuration.

I am using the Icom IC-9700 as my portable rig and both radio and the iOptron telescope mount have their own Pelican cases making deployment fast. I power everything off an accessory battery in my van that has an Anderson

**Setup for portable operations.**




**Python Script and Telescope Mount commands.**

Power Pole attached. Given the low Amp requirements of Satellite VHF/UHF operations, the van accessory battery has more than enough amp hours to cover extended sessions hunting satellites.

Price. I want to be clear that I was not building for the most inexpensive set up as I am reusing the goto telescope mount I own for astronomy. The iOptron Az Mount Pro I own is a $1200 goto mount. Everything I have done can be reproduced on a less expensive mount and I will circle back around when I have everything dialed in and demonstrate on a ~$400 goto mount.

The setup process is:

- Set up tripod and telescope mount.
- Attach antennas with phasing cables and diplexer
- Perform telescope mount alignment
- Connect diplexer to radio
- Connect radio to USB computer
- Start MacDoppler Software
- Start Python Script

Success? Yes! Several QSOs and good signal reports. Surprisingly good reception with only 10-15+ degree elevation as satellites come inbound over the ocean. I am extremely happy with progress to date as I continue to focus on operational techniques. The setup is not "clunky" and deploys quickly. I live in a dense neighborhood and will operate from a parking lot with open vistas down by my local beach.

Next steps:

- I am continuing to tweak the configuration of cabling, cable routing, phasing, and circular polarization switching.
- I continue to improve the Python script for telescope mount control.
- Look at updating the Arrows to the larger Alaskan Arrows.
- Looking at adding 23cm antennas.
- Review other program control including Hamlib together with gPredict. I don't use Windows portable, but I will confirm functionality via a VM with some of the Windows programs available.
- Adding 23 cm, as there are a few satellites that switch modes regularly.
- Review the need for preamps at the antenna.
- Building a single antenna solution on the most inexpensive goto mount I can find.

A big thank you to the following individuals/organizations:

- Don at www.dogparksoftware.com/MacDoppler.html for making some tweaks to MacDoppler. Don added a nice "advance" feature which moves the calculated position of the satellite forward in time.
- Bruce at www.heavenscape.com SkyTrack software and a simple goto mount will have you up and running in tens of minutes. Bruce has done an outstanding job fixing bugs with the ASCOM API.
- The team at directivesystems.com for phasing cables and a nice 23 cm portable antenna!
- Arrow Antennas www.arrowantennas.com/. The portability of the two-piece boom can't be beat.
- Jason for calling out my operating mistakes.
- AMSAT... More birds, please ;)

# 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.

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

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

After your article lands in members' mailboxes, and the kudos start arriving for your narrative payload, you can enjoy the satisfaction of knowing you've elevated the collective wisdom of AMSAT to a higher trajectory. Send your manuscripts and photos, or story ideas, to: journal@amsat.org.

Our editors are standing by!

# AMSAT GOLF $125,000 Development and Launch Initiative

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

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

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

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

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

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

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| **Titanium Donors** contribute at least US $400 per month | ❐ $400 / month<br>❐ $4800 one time |
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**Your help is needed to get the AMSAT GOLF-TEE and GOLF-1 Cubesats launched.**

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

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

**Build satellites** that Keep Amateur Radio in Space!

**Promote space education** through ARISS and STEM-based initiatives.

**Manage satellites in orbit** and ensure they are available for public use.

**Create and maintain vital partnerships** with government, industry, educational institutions, and amateur radio organizations to foster space research and communication.

**Learn, teach and share innovations** and best practices in space communications with other radio operators, students, government and the public.

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