The AMSAT® Journal

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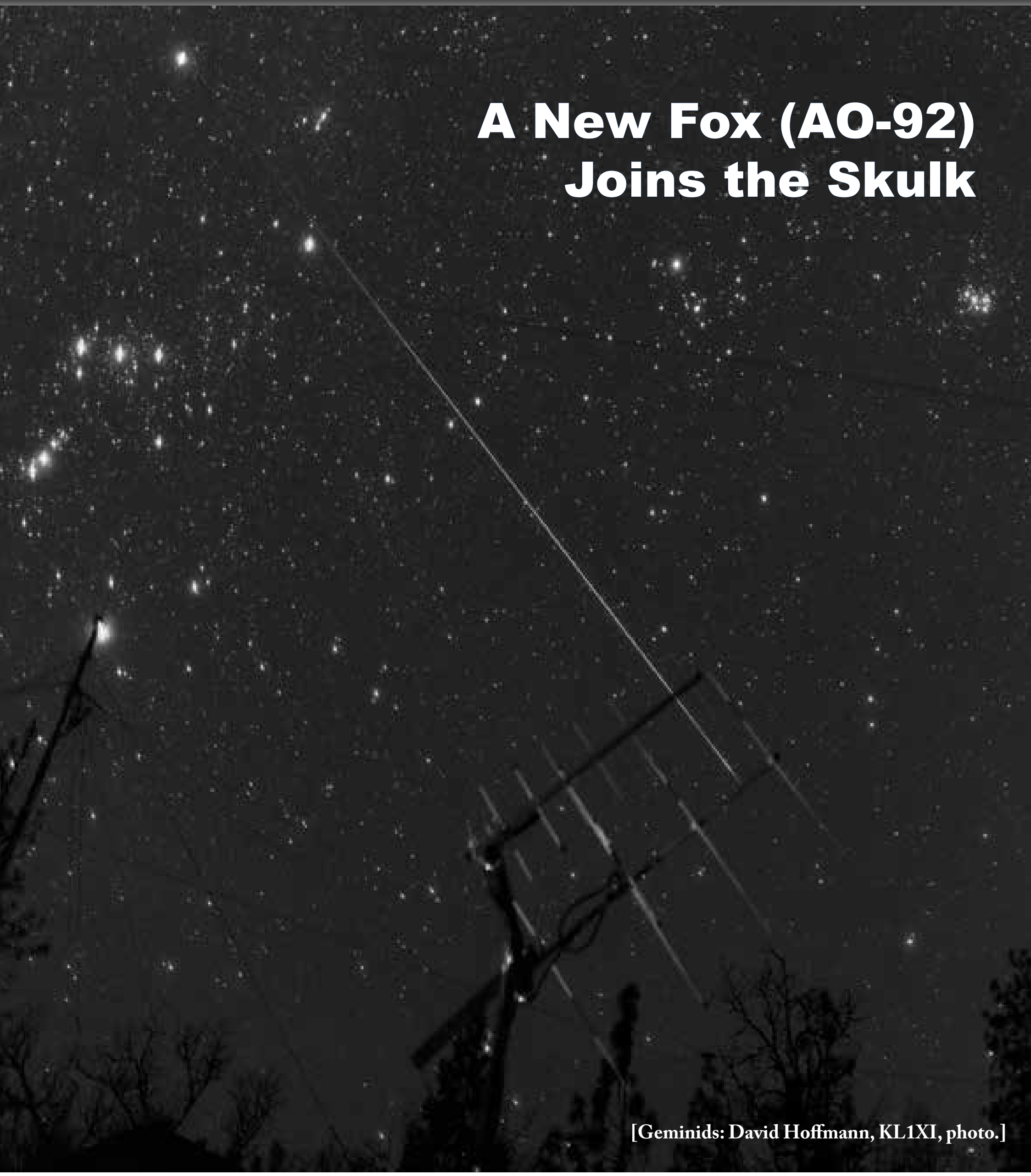
Volume 41, Number 1 | January/February 2018

A New Fox (AO-92) Joins the Skulk



[Geminids: David Hoffmann, KL1XI, photo.]

in this issue ...

Periodicals
POSTAGE PAID
At Kensington, MD
and at additional
mailing offices

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

AMSAT Announcements

The AMSAT Journal Needs Your Words and Wisdom

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

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

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

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

Our editors are standing by!

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

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

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The AMSAT Journal (ISSN: 1407-3076) is published bi-monthly (Jan/Feb, Mar/Apr, May/Jun, Jul/Aug, Sep/Oct, Nov/Dec) by AMSAT-NA, 10605 Concord St., Suite 304, Kensington, MD 20895-2526. Telephone: 301-822-4376, fax: 301-822-4371. Periodicals postage paid at Kensington, MD and additional mailing offices.

Postmaster: Send address changes to The AMSAT Journal, 10605 Concord St., Suite 304, Kensington, MD 20895-2526.

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-NA reserves the right to select material for The AMSAT Journal based on suitability of content and space considerations.

Apogee View

Joe Spier, K6WAO
President

As we all start the New Year, I hope you had a wonderful holiday season and were able to welcome in 2018 by making some satellite contacts. AO-91 was very busy as were other satellites. But the big news was the launch of Fox-1D (now AO-92). As AMSAT celebrates "keeping amateur radio in space" with RadFxSat (Fox-1B/AO-91) already launched, and the recent launch of AO-92 (Fox-1D), we look forward to the upcoming launches of Fox-1Cliff and RadFxSat-2 (Fox-1E) by this year's end. Three of the five CubeSats of the Fox series have now been launched and are operational. I cannot adequately express to the AMSAT Engineering team the gratitude I feel for their achievements. I also want to acknowledge all the AMSAT members and contributors who helped fund the effort.

Fox-1D was integrated into its Innovative Solutions in Space QuadPack for delivery to India on November 6th and was scheduled to launch on the next Indian Space Research Organisation's (ISRO) Polar Satellite Launch Vehicle (PSLV) flight, by the end of December. This date slipped into the new year. Finally, at 03:59 UTC on January 12, 2018, the solid-fueled first stage and ground-lit strap-on boosters of the PSLV in its XL configuration ignited and hurtled AMSAT's Fox-1D CubeSat along with 30 other satellites onboard the PSLV-C40 mission towards a sun-synchronous orbit.

The events along the path to orbit happened rapidly. The air lit strap-on boosters were ignited 30 seconds into the flight. The ground lit strap-on boosters separated one minute into the flight. First stage separation and second stage ignition were confirmed two minutes into the flight.

Next came a crucial moment. A previous PSLV mission (C39), on August 31, 2017, had been doomed when the payload fairing failed to separate, leaving the payload trapped inside the fairing and in a lower orbit than planned. However, two minutes and thirty seconds into the flight of PSLV-C40 on January 12, the call was heard on the ISRO launch webstream confirming "Payload fairing separation!" Webstream listeners heard mission control cheer enthusiastically as the liquid-fueled second stage continued to propel the payloads to orbit.

Four minutes into the flight, the second stage separated and the solid-fueled third stage was lit to perform its duty. Seven minutes in, the third stage burned out. After a short coast period, the third stage was discarded, and the liquid-fueled fourth stage ignited eight minutes and thirty seconds into the flight.

Sixteen minutes and thirty seconds into the flight, the fourth stage shut down, placing the vehicle into its initial orbit. A minute later, the primary payload, a Cartosat-2 series imaging satellite for the Indian government, separated followed by other satellites in the mission payload. Twenty-seven minutes into the flight, confirmation came that all of the nanosatellites had been deployed. Fox-1D achieved orbit!

Just before 05:00 UTC, Fox-1D passed over western North America, but the onboard timer that ensures the satellite is clear of the launch vehicle and other satellites on the mission before deploying antennas and transmitting had not yet expired. At about 05:17 UTC, the satellite came to life, and its antennas deployed over the North Pole. The AMSAT Engineering team and amateur radio operators worldwide watched various WebSDRs waiting for live signals. Around 05:25 UTC, multiple WebSDRs displayed the characteristic "Fox tail" of the Fox-1 FM transmitter WebSDRs. Fox-1D's transmitter was alive!

With the satellite alive and transmitting, reception of telemetry frames was crucial for AMSAT Engineering to determine whether or not the satellite was healthy. The first frame appeared on the AMSAT telemetry server at 05:28 UTC, uploaded by Anatoly Aleksandrov, UA9UIZ, of Tyazhinskyi, Kemerovo Oblast, Russia. Initial telemetry values confirmed the satellite's good health.

Satellites that achieve orbit and successfully activate are commonly renamed with an on-orbit designator. Since the launch of OSCAR I in 1961, amateur radio satellites traditionally carry the name OSCAR, for "Orbiting Satellite Carrying Amateur Radio."

Amateur radio satellites meeting certain criteria are renamed "OSCAR" with a prefix of the satellite owner's preference and issued a sequential number after they successfully achieve orbit and are activated. After confirmation of signal reception, OSCAR Number Administrator Bill Tynan, W3XO, sent an email to the AMSAT Board of Directors designating the satellite AMSAT-OSCAR 92 or "AO-92."

The commissioning process was expected to take up to two weeks. So, by the time you receive this issue of the AMSAT Journal, AO-92 should be available for amateur use. I know the Virginia Tech teams are excited about the VT imager testing. Please be aware that the L-Band downshifter is operated by the AMSAT designated ground control stations.

Fox-1Cliff is scheduled to launch before Summer 2018 from our partners at Spaceflight, and RadFxSat-2 (Fox-1E) is also scheduled to launch on a NASA sponsored CSLI mission before the end of 2018. Please remember that in the satellite launch business all dates are approximate.

The first project of the GOLF program is a technology demonstrator named GOLF-TEE (Technology Evaluation Environment). The design is a 3U CubeSat with deployable solar panels, Attitude Determination and Control (ADAC), Software Defined Radio (SDR) Transponder, and a Vanderbilt University Low Energy Proton (LEP) experiment. Now is the time to begin work on the GOLF-TEE Project.

At the end of 2017, AMSAT received generous offers from two AMSAT past presidents to match funds of up to $15,000 for contributions to the GOLF-TEE campaign between now and the end of February. Donate buttons for GOLF-TEE appear on the AMSAT website, **www.amsat.org/join-amsat/**. Make your donation twice as valuable by contributing, and help AMSAT fund the launch of the next series of satellites of the GOLF program. A launch is planned in 2019.

Donations of $100 and $1,000 or more will be eligible for a special AMSAT GOLF premium. (Both premiums are currently being designed, so please be patient awaiting delivery.) While this is the first fundraiser for GOLF-TEE, others will be announced soon.

Among my completed assignments as President over the holidays, I drafted a policy regarding the Export Administration Regulations or EAR. The policy includes a methodology to verify U.S. citizenship and provide compliance guidelines for our engineers and partners working on satellite projects. No ground-based projects should be affected at this time. A small team is reviewing the draft policy and providing recommendations and legal review. I can now focus on the creation of an AMSAT Scholarship to allow two or three students to attend Hamvention or the AMSAT Space Symposium and General Meeting. If you are interested in funding this scholarship, please contact me.

In ARISS news, I have appointed Chester (Chet) J. Latawiec, VE3CFK, of Sarnia, Ontario, Canada, as AMSAT-NA Canadian Delegate to the Amateur Radio on the International Space Station – International (ARISS-I) delegation. Chet will provide great representation for ARISS and fills a position that was vacant for far too long.

I am also heading to the East Coast to spend about a week in the AMSAT Office in Kensington, MD. While there, I expect to perform some office reorganization and streamlining to help Martha. I am also trying to get a handle on how to create an electronic repository for an AMSAT archive. I'll travel the following week to HamCation 2018 in Orlando, FL; I hope to have seen you there!

Hamvention will be at the Greene County Fairgrounds in Xenia, OH, May 18-20, 2018. Our new Hamvention Team Leader is Phil Smith, W1EME. I would like to thank our past Team Leader, Steve Belter, N9IP, for his past years of dedication to AMSAT's presence at Hamvention and for advising Phil through his first stint as Team Leader this year.

Back out west, I will be attending SeaPac in Seaside, OR, June 1-3, 2018, and hopefully Pacificon in San Ramon, CA, in the fall depending on when and where the AMSAT Space Symposium is held.

I hope you will enjoy the New Year with AMSAT. I encourage you to do your part, whether that's operating the satellites, giving AMSAT or ARISS support, or bringing AMSAT dollars or members.

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

AMSAT 2017 Symposium Committee Thanks All the Prize Donors

The 2017 AMSAT Symposium Committee would like to thank all the vendors for their incredible support of the AMSAT Symposium. Each year these great supporters of AMSAT come through by donating their products and gift certificates. Please show your support for them when you need products for your amateur radio endeavors!

2017 AMSAT Symposium Prize List:

JVC-Kenwood TH-D72A Dual Band
FM Handheld Transceiver

Elecraft — XG3 RF Signal Source
Arrow Antennas — 2 Arrow II antennas

Flex Radio — Gift Certificate ($100 Off/FLEX-6400 or $200 Off/FLEX-6600, $300 Off/FLEX-6700 or PowerGenius XL Amplifier)

Peet Bros. — Ultimeter 2000 Weather Station

M2 Antennas — PS-2M, 2 Meter Polarity Switch

DX Engineering — 2 $100 Gift Certificates

ARRL, the National
Association for Amateur Radio® — 2 $50 Gift Certificates, 2 $25 Gift Certificates

Bongo Ties — 25 packs of 10 each 5" Bongo Ties #A5-01

NCG Company CN-801VN SWR/Power Meter

MFJ Enterprises — 2 MFJ-108B 24/12 Hour LCD Clocks
MFJ-1716 BNC Dual Band 144/440 MHz HT Antenna
MFJ-1716S SMA Dual Band 144/440 MHz HT Antenna
MFJ-1739SF 2 ½" SMA-F Midget Flexible HT Duckie Antenna
MFJ-16C06 6-pack Ceramic End Insulators
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WA0H Micro-Log Micro-Log Ham Radio Logging Program

GigaParts — 3 Blue GigaParts/ICOM Hats
3 Blue GigaParts/Yaesu Hats
3 GigaParts/ICOM Antenna Tape Measures
2 Grey Yaesu System Fusion Hats
2 GigaParts/ICOM Hot/Cold Beverage Tumblers

Silver Legacy — 6 Bottles of Ferrari-Carano Fine Wine

Anonymous Donor — 6 Bottles of Assorted Fine Wine

eBay Sellers Donate to AMSAT

Are you an eBay seller? One item, ten items, or a full-time business you can donate a percentage of your winning bid to AMSAT.

To do so, do not list your item with the basic listing tool, select advanced tools. eBay will give you a warning message that it is for large volume sellers, however this is where the eBay for Charity tool is found.

You can "select another nonprofit you love" and search for either AMSAT or Radio Amateur Satellite Corporation. Choose the percentage amount of the sale you would like to donate to AMSAT, and boom!.

When your item sells and the winning bidder pays, eBay will deduct the percentage from your take and forward it to AMSAT.

Sometimes we are getting rid of our old equipment, sometimes selling something new. In any case, please consider giving a piece of the pie to a new satellite and choose AMSAT for your eBay Charity.

Engineering Update

Jerry Buxton, N0JY
Vice President, Engineering

The evolution of the Fox-1 CubeSats

In responding to the questions regarding what changed in the design of AO-91 (RadFxSat/Fox-1B) versus AO-85 (Fox-1A) that made the AO-91 receiver better, my response is that there were no design changes. That could be nit-picked, but for this column, I am talking at a higher level, so please don't pick apart any engineering related statements in their literal sense. I will be talking about processes.

I was invited to be a guest on the Ham Radio Live! show recently and the subject was "Building Satellites." I would like to thank Neil, WB9VPG, for the opportunity and the great show he has, including the show as seen from the guest point of view. It was very comfortable, and Neil is definitely a "FB Op." Please visit hamtalklive.com, and if you want to check out "my" episode, it is Episode 98. With apologies to Neil and the audience, talking about building satellites in much detail is difficult in time-limited venues, including what AMSAT does at the annual AMSAT Space Symposium and the Hamvention.

While the Fox-1 satellites are all very much alike in that the systems and bus — in fact, nearly all of the hardware — are the same design and even the same build, we have made some changes in each iteration of the Fox-1A-E. Of course, Fox-1E can be considered a different animal because of the linear transponder, but that is the only big difference, and it is fundamentally just another radio system in the same configuration and bus as the FM transponders. Yes, MPPT was different in succeeding versions from that of Fox-1A, but that is only because the MPPT design was not achieved in time to fly on Fox-1A, not because of a change in the intended design of the Fox-1 satellites.

All of the Fox-1 satellites are still AMSAT's first CubeSat platform, and the program was intended to produce more than one version. I do not believe that the popularity and launch opportunities that we now have were expected in 2009. Even as Fox-1A rolled through the assembly and final testing process, we fully intended to have time to take lessons learned and apply them to the following Foxes.

Unfortunately, or perhaps fortunately from the amateur radio in space perspective, that did not happen. In reality, the one lesson learned from Fox-1A that was able to be applied before another launch was the correction to the antenna attachment process, which is why the rest of the Foxes so far are enjoying (and exceeding) the receive capability that was intended in the design.

Fox-1C (which was later named Fox-1Cliff) came hot on the heels of the completion of Fox-1A as AMSAT purchased the launch in 2014. While we had hoped for some time in orbit for 1A before any other Foxes had to be put together, to draw from the hard lessons learned in space, the delay of the Fox-1A launch had us building Fox-1Cliff and even nearly completing it before Fox-1A launched.

The launch assignment for Fox-1D came along too when AMSAT decided to put two Fox-1s on the Spaceflight launch to expedite what was then a seemingly slow pace to orbit with launch delays. Fox-1D was built nearly in tandem with Fox-1Cliff, and they were completed together in March 2016. As a result, both only had the antenna process modification.

Building three satellites in rapid succession provided some benefit. Although the second and third were not any different from the first, more valuable lessons were gained from building those two as well. The hardware lessons are mostly applicable to future projects as the type things learned would need to be incorporated early on in the process.

What has changed most as the Fox-1 satellites evolved are our processes. From component procurement to assembly, testing to completion, the way we perform those has been refined with each iteration. Despite being mostly "carbon copies" of Fox-1A, all five of the Foxes have experienced new issues in hardware, software, and the building process that you typically would not expect. If you bought two Heathkit widgets (or Elecraft, whatever your current experience is), you would expect that assembling the second would go just like the first with the same parts, instructions, process, and the result, save any little performance difference or mistakes on your part. CubeSats do not exactly work like that, at least not your first CubeSat(s).

After Fox-1A, we knew that yanking on the antennas (gently of course) was a process that should come early on with the flight model. After Fox-1Cliff, we knew that even seemingly innocuous bus lines like the "deploy LED" that flashes after a Fox-1 powers up upon leaving the dispenser need to be inspected and tested, even though the function is, of course, worthless in orbit. After Fox-1B, we knew that doing the Day In The Life (DITL) test should come very early in the flight model testing because if the antennas do not deploy you don't want to know that after you've tested everything else and are ready for environmental testing.

With every Fox-1, we increasingly realize that even the most unlikely or even never-suspected cause of an anomaly should never be overlooked. I probably don't have that much of our editor's grace to tell the Fox-1Cliff story here (it's related to the deploy LED I mentioned), so be sure to ask if you can buy me a Mexican Coke and have me tell you about it one day.

Of course, this is just a whiff of the type of things that happen, and the effect of each on our processes may vary but is always positive. The good thing is that we learn and adjust, and Fox-1 was intended to be just that, AMSAT's step into CubeSats. What we experience and learn now will greatly help GOLF and future CubeSat programs and projects.

The task of picking up these pieces and tying them all together is something that the Systems Engineer does for us. I started working for AMSAT as Systems Engineer on the Fox-1 project in 2011. Perhaps the biggest process of all, that of coordinating the development, building, and assembly of several systems (for example Fox-1D has eight separate systems), can make or break the project. With our geographically diverse engineering and our partnerships with various universities, each of the systems is made on its own, and they only come together for the integration of the engineering model or flight model.

Ensuring the communication, understanding, and compliance with the system requirements and the cooperation of all systems when put together as a satellite is difficult enough. More difficult still is the fact that no two of the engineering team members usually see or work together with each other as one would find in an office or industrial setting. The communication, visual, interactive hands-on that often makes understanding how each other's system work together is absent in our environment.

Interface Control Documents (ICD) are the key to communicating the exact way that each system should interface with the other systems when assembled into the satellite avionics stack. Documents clearly understood to mean the same thing by all who are affected by that ICD are necessary and need to be followed to the letter to avoid costly mistakes. Costs are incurred both in money and mission success, whether it be shipping the system to be integrated into the stack for testing where a problem requires return shipping and perhaps rework of the system, or subtle anomalies that only reveal themselves on orbit where typically nothing can be done. The documentation, construction, and testing processes of the Fox-1 CubeSats have all undergone changes as a result of each build and launch.

That these things are not noticed or are perceived as small changes to each Fox-1, is a good sign that things get better with each launch. Beyond the numbers in testing and telemetry, failures or improvements are often measured by the amount of whining or accolades from the satellite users. While such data may not be the best measure, they nonetheless provide additional input for our processes.

Fox-1 update

Of course, AO-91 (RadFxSat/Fox-1B) was one of the "accolade" inputs to the processes having been successfully launched after some short delays because of low batteries (stuff happens, even to the big boys), some nautical wizards who apparently can't read a map or notices, and Mother Nature exhaling upper-level winds. Deployment from the launch vehicle, startup, and antenna deployment all happened as expected. Thanks to ham radio and satellite enthusiasts throughout the world, we were able to see the "Fox Tail" live on ZR6AIC's WebSDR over Africa. The first telemetry to appear on the "Central Scrutinizer" (AMSAT) server came soon after from IV3RYQ in Italy via FoxTelem, verifying the successful activation of AO-91. I can say that for the three of us who attended the launch party on the two aborted occasions, it was still great fun, and we got a cool Raytheon stocking cap that was useful at the launch viewing site and especially useful during the Texas winter here a few days ago. I know you are all jealous of the stocking cap, sorry.

Launch and activation of Fox-1D were also successful in early January. As I write this, AO-92 (Fox-1D) is undergoing in-orbit testing, and I expect that she will be commissioned within two weeks after launch. I mentioned earlier that AO-92 was more complex from a systems point of view than AO-85 or AO-91. That leads to a longer in-orbit test period than most of our members are probably used to from the previous launches.

AO-92 carries the University of Iowa High Energy Radiation CubeSat Instrument ("HERCI," pronounced like their school mascot's name) experiment and one of the Virginia Tech jpeg camera experiments, as well as our own "Downshifter" L band to UHF downconverter experiment to provide mode L/V FM voice capability. It packs a lot of punch with these new experiments, and each requires testing and validation by the experiment partner and AMSAT engineering, making for a longer in-orbit test period.

Fox-1Cliff will likely have a similar longer checkout before commissioning and is expected to launch in the summer of 2018. Fox-1Cliff has been ready for flight since March of 2016, as was Fox-1D. Fox-1E is coming together and, by the time you read this, we should be into final testing of the flight model for delivery and launch this year as well.

GOLF update

GOLF-TEE was submitted as a CSLI proposal, and we await the results of the selection process from NASA. Once we know our CSLI status, details will be coming out throughout the design and building process as we work toward the delivery date. The launch target we set in the CSLI is 4Q 2019, so we must be ready for flight as early as then although the actual launch schedule is unknown.

Engineering Team members from the Fox-1 program to ASCENT, which includes the AMSAT Ground Terminal team, are hard at work on ideas and designs for not only GOLF-TEE but also future GOLF, HEO, and GEO satellite opportunities. The GOLF program draws from the important lessons about the design and successful operation of AMSAT's first CubeSat and the advanced communications and technology ideas from ASCENT to provide us with a platform to learn and develop solid techniques, hardware, and experience with CubeSats that will target higher and higher orbits.

It's all good!

My Software Defined Radio Satellite Station - Version Four

Ronald G. Parsons, W5RKN

I started operating amateur satellites in the early 1990's with a variety of equipment and software cobbled together from both new and used sources and a variety of home-brew items. Very soon, I put together a list of goals for more efficient operating:

1. Automatic Doppler Correction
2. Automatic Antenna Tracking
3. Efficient Logging Procedures
4. Visual presentation of Spectrum

I accomplished the first two items using software I wrote for the Macintosh. The third bounced around different logging programs. But the fourth took a while.

This article is the third in a series describing my satellite ground station as an evolving project based on advances in software defined radio (SDR) technology.

Iteration One

I was using an Icom IC-756 on HF which had a small panadapter display. I wanted a larger display, so I purchased a FlexRadio FLEX-3000 for use on HF. The software defined radio's capabilities made possible the visual presentations I was seeking.

Some advantages of SDR:

- Ability to tune by a variety of techniques
- Ability to display a large range of frequency spectrum including a waterfall display
- Ability to decode many modes and add new modes
- Ability to define filters – width, shape
- Facilitates transponder frequency corrections
- Facilitates tuning to within a few Hertz
- Stations can be spotted easily on a sparsely populated passband
- Allows pouncing on rare DX or grid before others find it, and
- Stations not tracking Doppler shift well are more easily tracked.

In 2012, I replaced my Icom IC-910H satellite radio with 2 m and 70 cm Down East Microwave (DEMI) transverters connected to SDR radios. The local oscillators in the transverters were stabilized by an external, GPS disciplined, 10 MHz oscillator.

I used the FLEX-3000 transceiver for receiving and the FLEX-1500 for transmitting. The FLEX-1500 is a low power SDR ideally suited to driving transverters in transmit mode. This made possible full-duplex operation allowing me to listen to the satellite's downlink while transmitting. Full-duplex is extremely useful for satellite operation as it permits one to zero beat the other station's frequency and adjust transmit power so as not to present too strong a signal to the satellite.

My first two goals above were met by using Erich Eichmann's, DK1TB, Windows program, SatPC32. The fourth goal was realized using Flex Radio's PowerSDR, the software that runs the FLEX-1500 and FLEX-3000. Two FO-29 SSB satellite signals, as displayed on my computer running Power SDR, are shown in Figure 1. Other formats of this display, for example, a waterfall and a combo panafall, are also available.

This implementation worked quite well but presented complexities in setup and operation. One of the two Flex radios was controlled by Firewire, and the other was controlled by USB. Two copies of PowerSDR were required to control the two transceivers. The interconnections between the components were complex requiring two coax A-B switches and one toggle switch which had to be set differently for U/V and V/U satellites. Fortunately, I never had an accident with this switching arrangement. A block diagram of the interconnections is

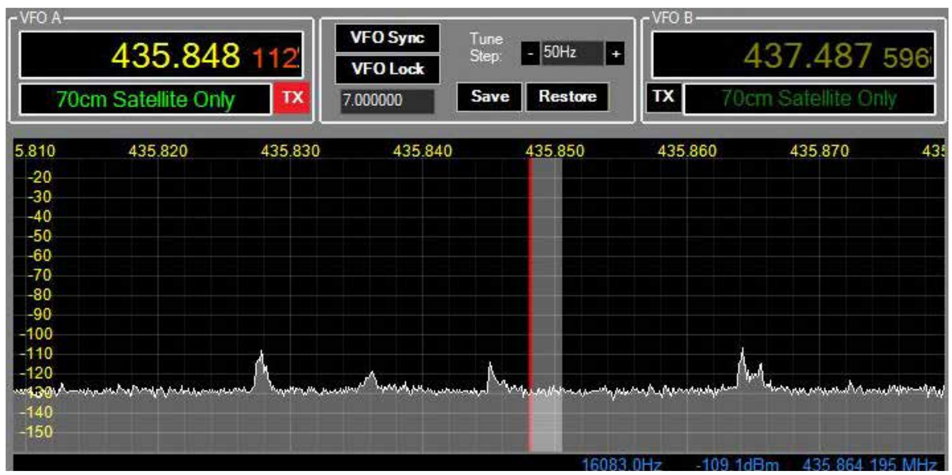

Figure 1 — Spectrum panadapter of PowerSDR showing SSB signals on satellite FO-29.

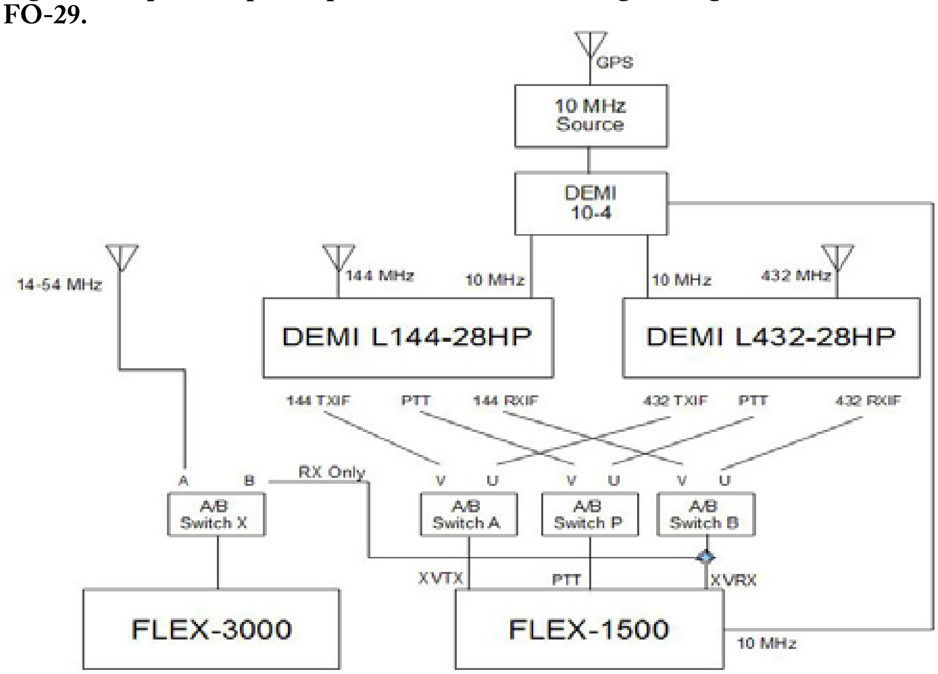

Figure 2 — Block diagram of the interconnections of the Iteration One design.

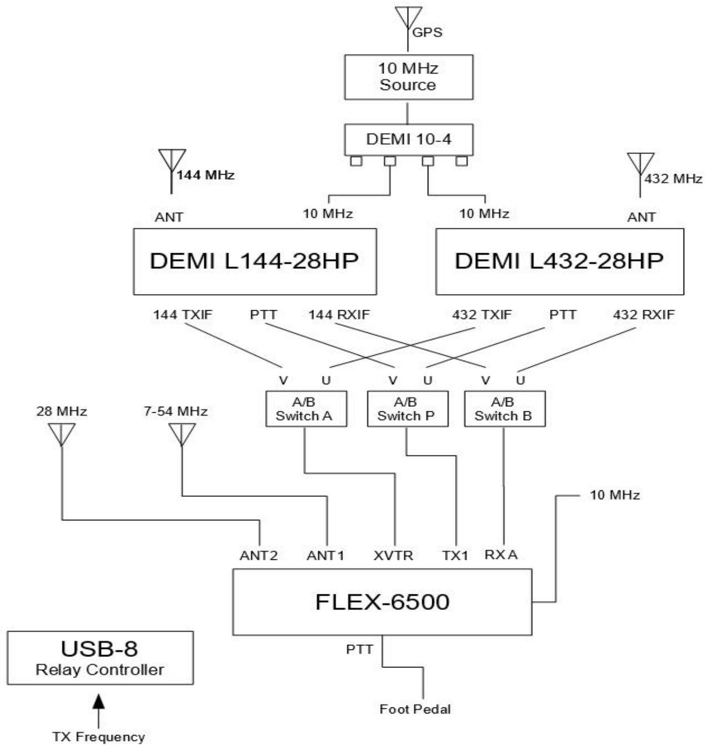

Figure 3 — Block diagram of the interconnections of the Iteration Three design.

shown in Figure 2.

The detailed design and operation of this iteration was described in *The AMSAT Journal*.[1]

Iteration Two

In 2014, a new series of software defined radios became available, the FLEX-6000 series, along with new control software, SmartSDR. This new series introduced the ability to operate multiple transceivers within a single radio, called slices, each having the ability to demodulate a selected portion of captured spectral data. I kept the DEMI transverters and obtained the two-slice model, the FLEX-6300. It had one dedicated port to drive a transverter for transmitting, but no receive-only antenna port.

A major addition was the satellite control program, FlexSATPC, by Dave Beumer, W0DHB, which became the main point of control. It interfaces between SatPC32, SmartSDR and the logging program. It also controls relays automating the switching of the coax relays which change

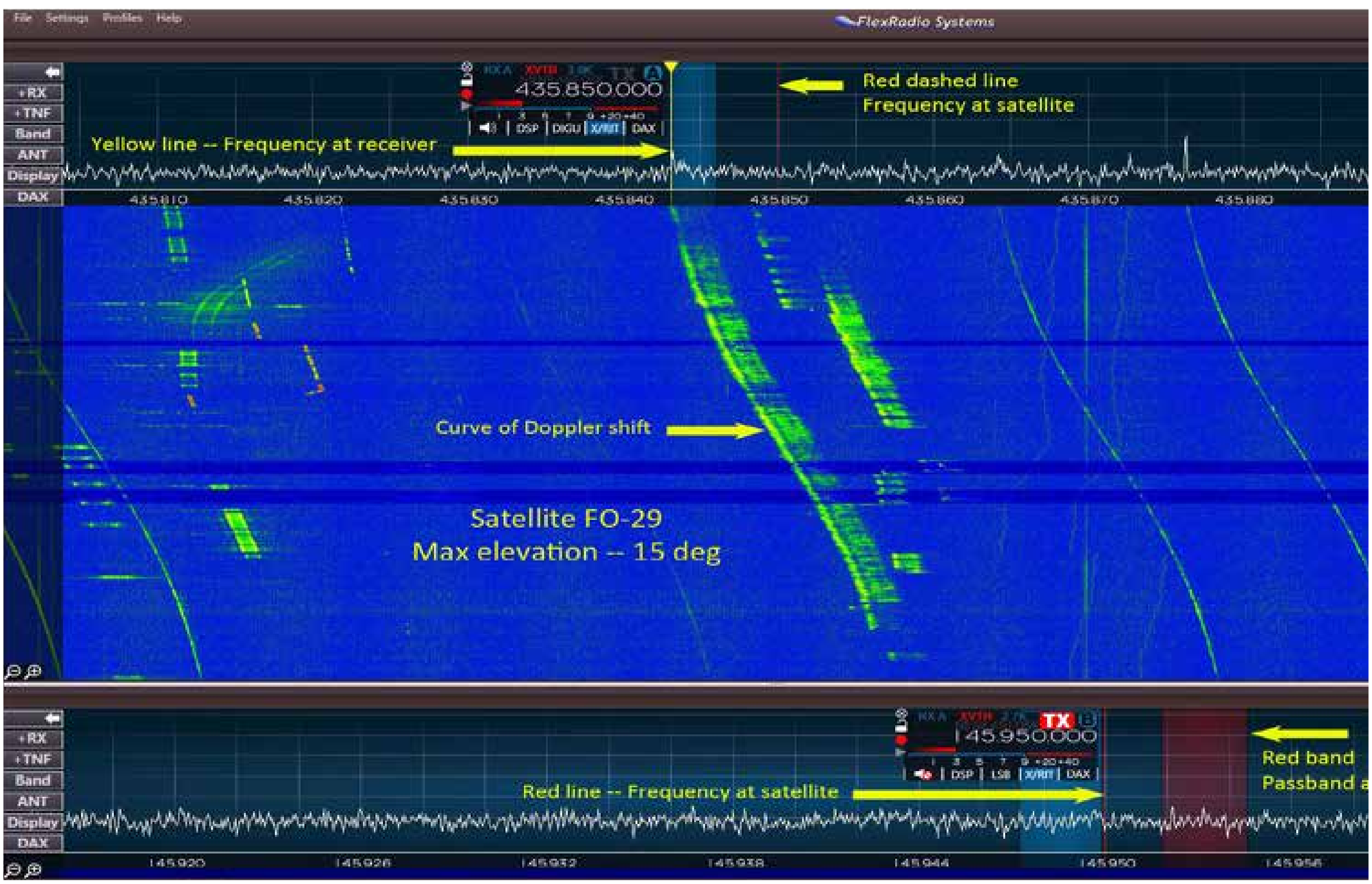

Figure 4 — Typical panadapter screen of SmartSDR showing an FO-29 pass.

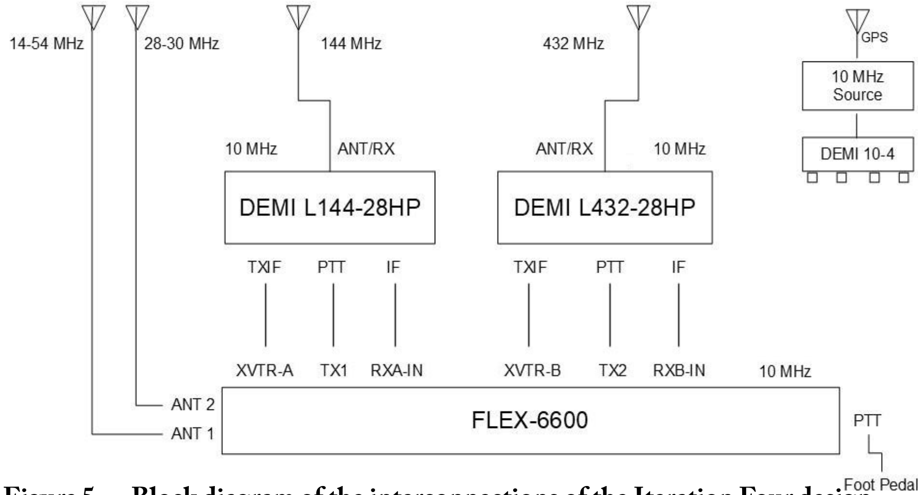

Figure 5 — Block diagram of the interconnections of the Iteration Four design.

the configuration between U/V and V/U satellites. This allows the operator to concentrate on one program to control the primary operational functions.

Iteration Three

As mentioned above, the FLEX-6300 lacked a dedicated receive-only port, leaving the main antenna port as the input/output port for the transverter. To avoid the danger of accidentally transmitting into the receive transverter, I upgraded to a FLEX-6500 which had a dedicated receive-only port. It also had four slice receivers, allowing the operator to monitor two HF bands while operating satellites. The USB-8 Relay Controller is managed by FlexSATPC and sets the relays appropriately for the particular U/V or V/U satellite. Figure 3 shows a block diagram of the interconnections.

An example of the spectrum/waterfall display showing a pass of satellite FO-29 is shown in Figure 4. The "frequency at the satellite" is highlighted because that frequency is a constant for all observers. Doppler shift causes observers to receive the downlink signal at slightly different frequencies. Using "frequency at the satellite" provides a common point of reference for every observer. There's a lot of information on that screen available to the operator.

FlexSATPC goes a long way toward fulfilling the third goal. Logging a contact is as simple as entering the callsign and pressing the tab key. The program queries QRZ.COM and populates the Grid and Name fields. The operator may fill in additional fields if desired. Pressing enter transfers the data to the local logging program.

For your uplink signal to become a downlink signal at the same frequency the operator is listening to, a spotting procedure is necessary. A common method of doing this is to transmit a series of CW dits, changing the uplink frequency back and forth until you hear your own downlink. A less "polite" method uses a constant carrier or, worse, modulating with repeating "Hellos." FlexSATPC transmits a low power constant carrier allowing the operator to observe the signal on the spectrum display. If the signal is below the listening frequency, the operator can click on one or more of the "+" buttons in the Calibration window until the observed signal coincides with the listening frequency.

The detailed design and operation of this iteration was documented in *The AMSAT Journal*,[2] as was operation of an earlier version of FlexSATPC.[3]

Iteration Four – The Great Simplification

In August 2017, I gave a presentation at the AMSAT Forum at Summerfest 2017 in Austin covering the evolution of my satellite station up through iteration three. Immediately afterward, I attended the FlexRadio presentation during which FlexRadio described their new 6400 and 6600 line of radios.

One of the new models was the FLEX-6600, an updated version of the FLEX-6500, with two transverter ports. I realized that with those two ports, all of the coax relay switching between the Flex radio and the two transverters in the prior iterations could be eliminated. It is taken care of internally to the FLEX-6600. The switching of the PTT between the transceiver and the transverters could also be handled by Transmit Profiles in the Flex SmartSDR software. The Transmit Profile in each satellite's Global Profile sets the TX Relay Output using the standard SO2R_TX1 and SO2R_TX2 Transmit Profiles.

A block diagram of the interconnections is shown in Figure 5. It could hardly be simpler — a dream come true. I could finally eliminate the array of expensive coax relays used to switch the connections between the radio and the transverters. The rat's nest of cables behind the radios also would be much reduced.

This configuration implements the two most common amateur satellite station modes:

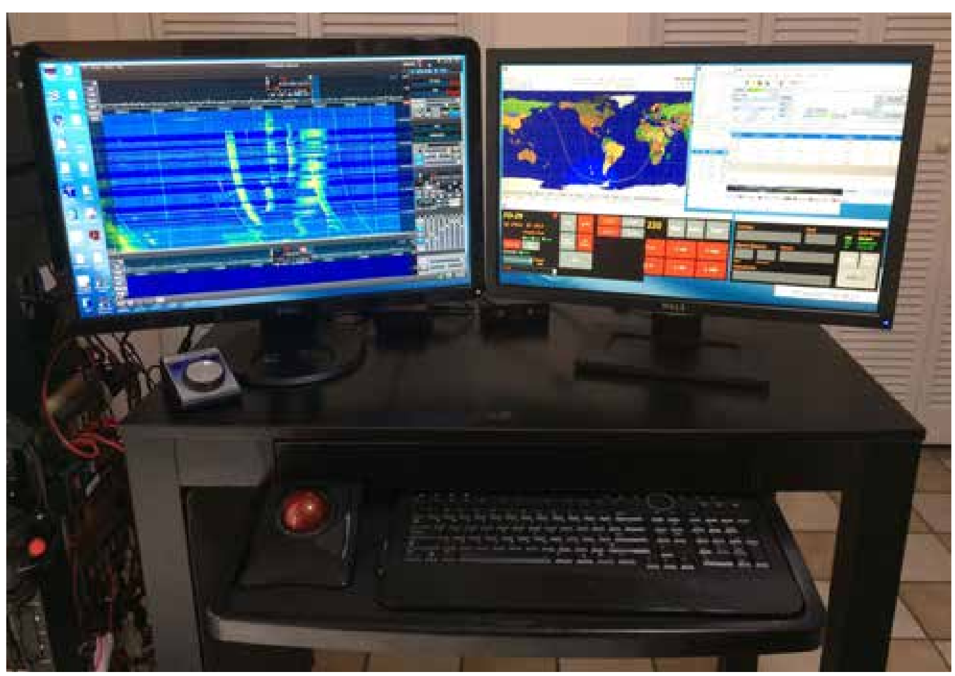

Figure 6 — The W5RKN operating position.

U/v 70 cm uplink/2 m downlink
V/u 2 m uplink/70 cm downlink

The operating position, which has been optimized for efficient use, is shown in Figure 6. I use my left hand on the FlexControl knob for manual tuning and the trackball for controlling the various software programs on the two screens. I use a trackball instead of a mouse because the large screen area would have required too much real estate on my desk for convenient operation. A foot pedal is used for PTT, and my right hand is used for the keyboard to enter logging information.

A convenient feature for grid hunting in the control program FlexSATPC displays whether a grid location entered is NEW, WORKED, or CONFIRMED. Another new feature of FlexSATPC is an interactive analog of SatPC32's WinAOS and CountDown windows which shows the upcoming passes and allows satellite switching to be controlled by clicking on this window.

The conversion to this iteration was quite simple. All the Profiles were exported before the FLEX-6500 was removed. Knowing a lot of cables would be changed, I started by removing the entire coax rat's nest behind the radio and transverters. Since coax relays would no longer be needed when switching modes, I completely removed the coax relay frame and its controller interface. The 6500 was removed and the 6600 put in its place. The cables were replaced following the new block diagram. The SmartSDR software was installed and the saved Profiles imported.

Two minor changes to the satellite Profiles were required. Since the Flex-6600 handles the selection of the uplink transverter, the TX slice antenna setting must be changed from XVTA to XVTB and the TX Profile set to SO2R_TX1 or SO2R_TX2 for each satellite and the Global Profile saved. After the usual tweaks to the configuration required anytime a radio is changed, I made my first contact. It's always a relief to hear the other station come back to you.

Although no new major capabilities are provided by this iteration, the simplification of the interconnections between the radio and the transverters made the change worthwhile. Certainly, newly constructed stations should use the new radio if possible.

Conclusion

It's been almost six years since I converted from "knob" radios to SDR designs. And I would never go back. The capabilities provided by SDR are ideally suited for the amateur satellite service. And I'm sure this is just the beginning.

References

1. Parsons, Ronald G., "A Full-Duplex VHF-UHF Satellite System Using SDR," *The AMSAT Journal*, July/August 2013, p. 12.

2. Parsons, Ronald G., "UPDATE: A Full-Duplex VHF-UHF Satellite System Using SDR," *The AMSAT Journal*, January/February 2016, p. 9.

3. Beumer, David, "FlexSATPC: Using SatPC32 with FlexRadio Systems® Radios," *The AMSAT Journal*, January/February 2016, p. 13.

Optimally Calculating and Plotting Satellite Subpoints for AO-85 (Fox-1A) CPU Resets

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keywords: bash, scripts, predict, date, bc, HTML, Google maps, AO-85, Fox-1A, telemetry, CPU, resets, South Atlantic Anomaly

AO-85, Upsets and Resets; the Early Years[1]

Before the Fox-1A satellite was even launched, during its development, Tony Monteiro, AA2TX (SK), predicted that the satellite could often reset, frequently over the South Atlantic Anomaly. He encouraged the development of an onboard recovery mechanism to survive these resets. Based on our experiences with the ARISSat-1 satellite resetting on every orbit, we knew it would be very desirable to know when each reset occurred and how many resets had occurred. ARISSat-1 had no way of counting the resets or saving the time of the reset. After several days in orbit, the ARISSat-1 battery would no longer take a charge, causing the satellite to power off every time it entered eclipse and power on/reset every time it exited eclipse.

No matter where you go, there you are[6]

For Fox-1a, we have a mechanism to determine both the number and time of the resets. Thanks to the onboard software, the non-volatile MRAM, the telemetry downlink, a worldwide network of telemetry ground stations, the FoxTelem telemetry software, and the AMSAT volunteers, the AMSAT website hosts an up-to-date master list of all the resets and reset times. Using the satellite reset time, which is the Unix time in milliseconds since 1/1/1970, and the NORAD TLEs for the AO-85 satellite, we can determine the satellite's latitude and longitude at the time it reset. It's just a set of calculations. The more accurately we know the time when the reset happened, and the younger the NORAD TLEs are, the more accurately we know the satellite's position.[2] Therefore, to create as accurate a map as possible, it is necessary to use those TLEs for the satellite that are closest to the desired prediction time. Using two-year-old TLEs will not give accurate results for the satellite subpoint location.[12]

The end result of all of the above work is a complete list of all of the CPU resets and the epoch time of the reset online at www.amsat.org/tlm/ops/FOX1T0.txt
.
The format of each line is just the reset number, a comma, and the reset time. For example,

0,1444323370000
1,1444836255000
2,1445891544000

To determine where the satellite was at the time of the reset, we need to find the set of TLEs closest to this date/time and then use "predict" to calculate the satellite subpoint. However the TLEs use a date format of YYDDD where YY is the year and DDD is the day of the year (up to 365, but sometimes up to 366).

Stand on giant's shoulders: Don't reinvent the wheel, or calendar calculations, or the date command

Assuming that we have a collection of TLEs, it is possible to convert the reset time to a date and then search through the collection of TLEs for the TLE that is closest to the reset time. The bash script "find_closest_tle.sh" does exactly this. This bash script accepts a timestamp (the reset time) and then searches through a list of TLEs to find the TLE with the time closest to the reset time. This gives the freshest TLEs for this reset. To determine the closest TLE, take the year, Julian day and fractional day for the TLE and convert this to a Unix timestamp (seconds since 1/1/1970). Performing date calculations can be non-trivial. Fortunately, we can use the Linux "date" and "bc" commands to perform most of the date calculations without all that tedious mucking about with leap years.[11] The conversion between Unix epoch and YYDDD format is done using the standard Linux "date" command with the "+%s" option.

Since the date command has already been written and debugged, and since it already knows about things like leap years, we can leverage the efforts of its author and minimize our efforts in coding and debugging which could introduce date computation errors. Once the date is converted, we can compare the TLE timestamp to the desired timestamp and save the TLEs if they are the best seen so far.

Don't reinvent satellite orbital calculations either, use something that is known to work correctly

Since we want to do this for every CPU reset, we can use another bash script (convert_T0_time_to_SSP.sh). This script gets the latest list of resets from the AMSAT website using the "wget" command and calls find_closest_tle.sh for each reset. The reset times and best TLEs are passed to the KD2BD predict program which calculates the satellite subpoint latitude and longitude for that time using those TLEs. After we perform the calculations for satellite subpoint for every reset, we then have a list of resets, latitudes, and longitudes. Now we can plot all of these points on a map using Google maps.

Map Making and the South Atlantic: Here Be Dragons (and Anomalies, and single event upsets, and plastic...lots of plastic)[8]

There's more than one way to make a webpage with a map using the Google APIs. This is just one of the ways, but it is pretty simple. There is some canned HTML "header" code that needs to be at the top of the webpage, some other HTML "trailer" that needs to be at the bottom, and the list of latitude and longitude points that are placed in between those two sections. When the three pieces are put together into an HTML file, it creates a webpage with a map. This makes it easy to generate a simple map from a bash script which will answer our question

---

This is the HTML "header" code:

```
<html><head>
  <script type="text/javascript" src="https://www.google.com/jsapi"></script>
  <script>
    google.load('visualization', '1', { 'packages': ['map'] });
    google.setOnLoadCallback(drawMap);
     function drawMap() {
       var data = google.visualization.arrayToDataTable([
         ['Lat', 'Long', 'Reset#'],
```

That's all there is! Then we add our list of latitude/longitude points within square brackets and with a comment containing the reset number and latitude and longitude. The comment will be visible when the user hovers the mouse over the point on the map.

```
 [ -56, -24, 'Reset#0 -56, -24' ],
 [ 55, 158, 'Reset#1 55, 158' ],
 [ 39, 51, 'Reset#2 39, 51' ],
```

… and so on until all of the points are listed. Lastly, this is the HTML "trailer" code:

```
]);
    var options = { showTip: true };
    var map = new
google.visualization.Map(document.getElementById('chart_div'));
    map.draw(data, options);
  };
  </script></head><body><div id="chart_div"></div></body></html>
```

These scripts were written just to "get the job done" with no attempts at optimization. After all, "premature optimization is the root of all evil (or at least most of it) in programming."[10]

Figure 1 – The map of satellite subpoints for AO-85 CPU reset numbers 0 through 713. An interactive version of this map appears online at qsl.net/ka2upw/ao85_reset_map.html, but eventually, I would like to get the map and scripts onto the AMSAT website.

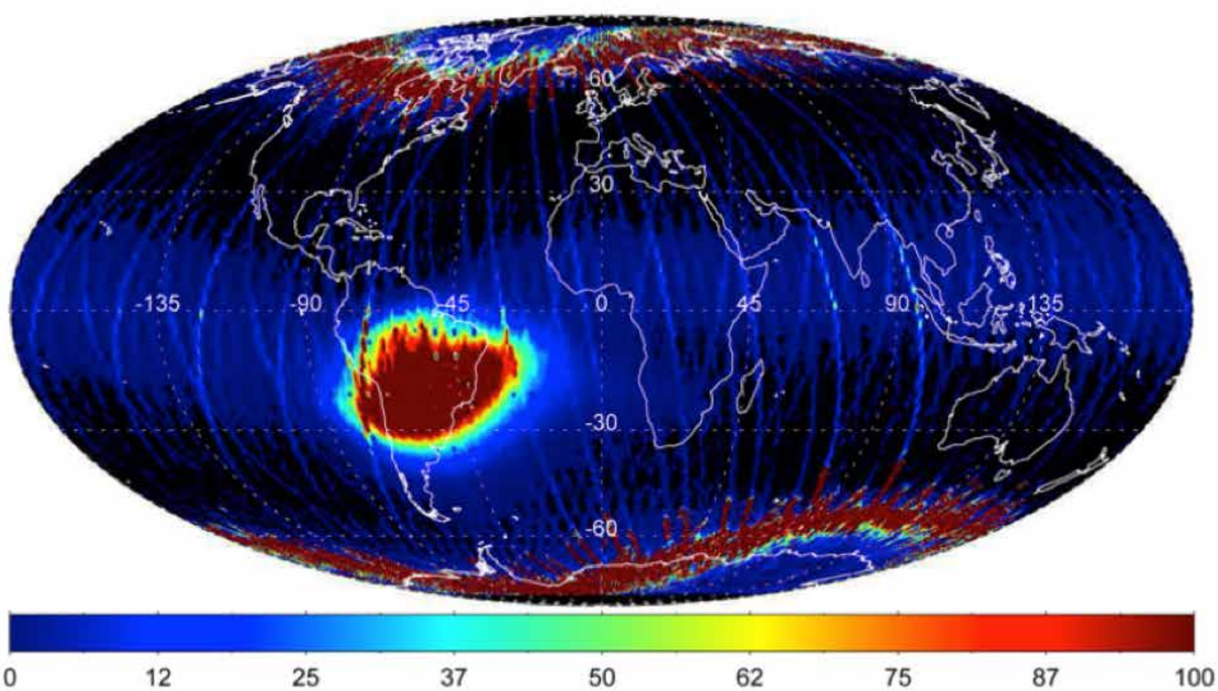

Figure 2 – The South Atlantic Anomaly[5]

"Where are the CPU resets happening?" This method has the disadvantage that it can only be used to display about four hundred points on the map. Even though there have been over seven hundred resets, many of them are duplicates and do not need to be plotted.

Sticking pins in a map – well, what's the point?

A quick look at the map of the subpoints for CPU resets shows good agreement with the South Atlantic Anomaly (SAA).[4] Many of the resets, but not all, were expected to be near or over the SAA and this is indeed what we find. Further analysis of the telemetry will let us look at the type of reset and match those up with the satellite subpoints. It will also be interesting to try and correlate the results of the radiation experiment, time of day, and solar activity with the satellite's resets. If you're interested in analyzing this, please contact the author.

Credits

"It is amazing what you can accomplish if you do not care who gets the credit."
--Harry S Truman

I would like to thank the following people who helped make this paper possible.

• Alan Biddle, WA4SCA for keeping track of CPU resets as they happen and sending emails to the FoxTLM mailing list
• Chris Thompson G0KLA/AC2CZ for FoxTelem and the AMSAT telemetry web pages
• Mark Hammond, N8MH for constructive feedback and support
• John A. Magliacane, KD2BD for writing predict and making it open source
• Philip A. Nelson for the "bc" command
• David MacKenzie, for the Linux "date" command and all its options
• Brian Fox and Chet Ramset for bash

And all of the ground stations that sent in telemetry, because without all of the collected telemetry none of this would be possible.

The author encourages and welcomes feedback and commentary, especially constructive criticisms and particularly welcomes deconstructive comments and puns, copies of your satellite recordings and telemetry, and perhaps any suggestions and remedies you might have for excessive "and" conjunctionitis.

Footnotes

[1] This subtitle was suggested by Alan Biddle, WA4SCA.

Listing 1 - convert_t0_times_to_SSPs.sh

```
#!/bin/bash

# get the latest copy of all of the T0 reset times
# assumes that we have an internet connection
rm FOX1T0.txt 2> /dev/null
wget http://www.amsat.org/tlm/ops/FOX1T0.txt

previous_reset_time=0

# use "for p in $(<filename);" notation .
# If you use the "while read p;" version then the
# last line of FOX1T0.txt will not get processed.
#
for p in $(<FOX1T0.txt); do

   # file format is reset_number, reset_time -- for example
   # 0,1444323370000

   # get just the reset number
   reset_number=`echo "$p" | cut --delimiter=, -f1`

   # get just the reset time, dropping the trailing 000 (milliseconds)
   # leaving just the seconds since 1/1/1970 (Unix epoch time)
   reset_time=`echo "$p"   | cut --delimiter=, -f2 | cut --bytes=1-10`

   if [ "$previous_reset_time" != "$reset_time" ]; then
      previous_reset_time=$reset_time
      ./find_closest_tle.sh  $reset_time > reset_$reset_number.tle
      echo -n $reset_number, > reset_$reset_number.out
      predict -q /home/pi/predict/ka2upw.qth  -t reset_$reset_number.tle  -f AO-85
$reset_time $reset_time >> reset_$reset_number.out
   fi
   echo " Done"
done
```

Listing 2 - find_closest_tle.sh

```
#!/bin/bash
# find closest TLE (to a give date).
# Given a reference date from the user (on the command line), and a file of TLEs
# (all for the same satellite) search the file containing all the TLEs of this
# satellite and find the TLE with the date closest to the reference date.
# The TLE file is assumed to be triple lines of SATNAME, TLE1, TLE2 but not
# necessarily in date order. The TLE file is assumed to contain only TLEs for
# this satellite.
# Background: orbital prediction errors get larger when older TLEs are used.
# In order to get the most accurate predictions we need to use the TLEs that
# were generated closest to the time of the desired prediction.
# Since there could be gaps in the available TLE entries, we can't just take
# the most recent before or most recent after (consider the case where you
# want a  prediction for June 1 and you have TLEs for May 30 then a gap until
# December, or you want June 1 and have TLEs for January then nothing until
# June 4).  We want the closest date.
# Note: requires the "bc" package to do some of the calculations.
#

# Reset times from AO-85 are in milliseconds, so drop the
# trailing 000 to get seconds since 1/1/1970
time_to_match=$1
closest_matching_tle_delta=999999
smallest_delta_time=99999999

# N.B. date command's "j" is day of year 1..366
julian_date_to_match=`date -d @$1 +%j`

# read lines from AO-85.TLE - a single TLE is actually three lines long.
# The first line has the satellite name.  Lines 2 and 3 have the orbital elements.
# For example:
#
# AO-85
# 1 40967U 15058D   15344.32453720  .00001845  00000-0  20662-3 0 00659
# 2 40967 064.7773 101.4283 0217658 263.0133 094.6183 14.74493538009130
#
# 1234567891111111111222222222233333333334444444444555555555566666666666
#          0123456789012345678901234567890123456789012345678901234567890123456789
# See also:
# https://en.wikipedia.org/wiki/Two-line_element_set
#

# 86400 = 60 seconds per minute times 60 minutes per hour times 24 hours per day
seconds_per_day=86400

line_number_of_element_data=0
IFS=''
while read p; do
   line_number_of_element_data=${p:0:1} # 1 or 2

   if [ "$line_number_of_element_data" != "1" ]; then
      if [ "$line_number_of_element_data" != "2" ]; then
         tle1=$p
      fi
   fi
```

[2] Werner Heinsberg would have hated this.

[3] Deleted

[4] The South Atlantic Anomaly isn't actually centered over the southern portion of the Atlantic Ocean. In fact, the anomaly moves. For more details on the movement of the SAA and a discussion of some special comments on the literature of the SAA, see footnote 5.

[5] Stassinopoulos, Epaminondas G., Xapsos, Michael A., Stauffer, Craig A., "Forty-Year 'Drift' and Change of the SAA." *NASA Goddard Space Flight Center Technical Report* NASA/TM-2015-217547, GSFC-E-DAA-TN28435. December 1, 2015. **ntrs.nasa.gov/search.jsp?R=20160003393**

[6] Weller, Peter, actor. *The Adventures of Buckaroo Banzai Across the 8th Dimension.* Sherwood Productions. 1984.

[7] I was motivated to not re-invent the wheel and use the Linux "date" command for all of the date calculation after reading some of James Miller's (G3RUH) papers including "30.6 Days Hath September" and "Sun's Up." For a collection of Miller's work see **www.amsat.org/articles/g3ruh/bibliog.txt.**

8 Actually, I'm told that there really aren't any dragons at all[9], and in fact, there are very few maps where the phrase "Here be dragons" actually appears despite there being many maps with pictures of dragons and lots of people being familiar with the phrase. I'm assured, however, that there certainly is a lot of plastic in the oceans.

[9] Except in Komodo, where there really are dragons, but they are far enough away from the south Atlantic that we can ignore them for purposes of our calculations here. But I digress…

[10] This quote is frequently attributed to Knuth, Donald, *Computer Programming as an Art. 1974.* However, it is also attributed by Knuth to Sir Tony Hoare. However, Wikiquote notes that the attribution to Hoare is doubtful, **en.wikiquote.org/wiki/C._A._R._Hoare**

[11] Apologies to the "other Doug."

[12] Calculating precisely how inaccurate the two-year-old TLEs would be is left as an exercise to the reader. Hint: use KD2BD's predict program running under Linux.

```
    # is this the first line of orbital elements?  (starts with a 1)
    if [ "$line_number_of_element_data" == "1" ]; then
       tle2=$p

       # satellite_number=`echo "$p" | cut --bytes=3-7`          #
       # classification=`echo "$p" | cut --bytes=8`
       # classification: a U here means unclassified.
       # Isn't it odd that all of the satellites are unclassified?

       epoch_year=${p:18:2}
       epoch_whole_days=${p:20:3}
       epoch_fractional_days=${p:23:9}
    fi

    # is this the second line of orbital elements?  (starts with a 2)
    if [ "$line_number_of_element_data" == "2" ]; then
       tle3=$p
       tle_epoch_as_unix_epoch=`date -d "20$epoch_year-01-01 +$epoch_whole_days days -1
 day" "+%s"`

       delta_time=$(echo "($tle_epoch_as_unix_epoch + $epoch_fractional_days *
 $seconds_per_day) - $time_to_match" | bc -l)

       # kludge to compute absolute value; sqrt(x*x) might be better?
       abs_delta_time=$(echo $delta_time | tr -d -)

       if (( $(echo "$smallest_delta_time > $abs_delta_time" |bc -l) )); then
          smallest_delta_time=$abs_delta_time
          smallest_tle1="$tle1"
          smallest_tle2="$tle2"
          smallest_tle3="$tle3"
       fi
    fi
 done < AO-85.TLE
 echo $smallest_tle1
 echo $smallest_tle2
```

Listing 3 - make_resets_map_from_out_files.sh

```
#!/bin/bash
# each of the *.out files is a single line output from "predict"
# prepended with the reset number. Each one looks like this line
# 619,1460541153 Wed 13Apr16 09:52:33  -28  158  245  -27   74   6941   1371 *
# reset,Unix epoch DOW Date Time(UTC)

# PREDICT produces an output consisting of the date/time in Unix format, the
# date and time in ASCII (UTC), the elevation of the satellite in degrees,
# the azimuth of the  satellite  in  degrees,  the orbital phase (modulo 256),
# the latitude (N) and longitude (W) of the satellite's sub-satellite point,
# the slant range to the satellite (in kilometers), the orbit number,
# and the spacecraft's  sunlight  visibility  information.

rm reset_positions.txt 2> /dev/null
# start building HTML table
echo "<table style="width:100%">"  >> reset_positions.txt
echo "<tr>"                        >> reset_positions.txt
echo "   <th>Reset #</th>"         >> reset_positions.txt
echo "   <th>Epoch</th>"           >> reset_positions.txt
echo "   <th>Date</th>"            >> reset_positions.txt
echo "</tr>"                       >> reset_positions.txt

cp map_header.html reset_map.html

for f in `ls *.out | sort -V`
do
   echo -n "Processing $f"
   SatResetNumber=`cat $f | tr -s ' ' | cut -d, -f 1`
   SatSSPLat=`cat $f | tr -s ' ' | cut -d ' ' -f 8`
   SatSSPWLon=`cat $f | tr -s ' ' | cut -d ' ' -f 9`  # west longitude

   # predict outputs west longitude values but google maps uses only
   # latitude values from -180..0..+180 so we need to convert
   SatSSPLon=`echo "define convert ( lon ) { if ( lon < 180.0 ) return ( lon * -1 
else return ( 360 - lon ) } convert( $SatSSPWLon )" | bc -l`

   echo " Lat=$SatSSPLat WLon=$SatSSPWLon Lon=$SatSSPLon"
   echo "[ $SatSSPLat, $SatSSPLon, 'Reset#$SatResetNumber $SatSSPLat, $SatSSPLon' 
>> reset_map.html
   echo "<tr>"  >> reset_positions.txt
   echo "<td>"  >> reset_positions.txt
   cat $f       >> reset_positions.txt
   echo "</td>" >> reset_positions.txt
   echo "</tr>" >> reset_positions.txt
done
echo "</table>" >> reset_positions.txt

cat map_trailer.html >> reset_map.html
cat reset_positions.txt >> reset_map.html

# Append date this map was created so we can verify auto-updates
echo -n "Last update:" >> reset_map.html
date >> reset_map.html
```

Satellite Roving — 104° Longitude

James Wilson, K5ND

Satellite roving can be a real blast. But, of course, it also has its challenges. My first activation of a grid line began with a fumbling, stumbling approach to finding a grid line. I chose the wide open spaces of Eastern New Mexico, near House, NM, and the grid line between DM74 and DM84, at 104° longitude.

The choice was reasonably simple. I was in Amarillo, DM95, visiting my daughter and son-in-law. Friday, while they were both at work, I got up at zero-dark-thirty and traveled about two and a half hours to the grid line. I allowed 45 minutes to get everything set up and then worked FO-29, XW-2A, AO-85, and another FO-29 pass.

Grid Line Found

Finding the grid line was relatively easy. In Figure 1, you can see the road and lots of shoulder for parking. Then I moved back and forth until I could be absolutely sure that I parked on the grid line. I took photos from the Maidenhead and MyGPS Coordinates apps on my phone for validation — all per the ARRL VUCC Rules.

Station Set Up

My roving set up is an Icom IC-910H, Arrow antenna, Apple MacBook Air laptop with MacDoppler, an XG Comms USB connection to the rig, as well as a 35 amp hour sealed lead acid battery. I also use the AudioNote app on my laptop to record the QSOs. It's not a lightweight setup; it's more in line with my belt and suspenders approach to most things.

I also spent some time testing my portable system before the activation because I didn't want to drive all that distance and then not get on the air. So I tested it all at home outside on the deck and then in Amarillo in my daughter's backyard, providing a few contacts from DM95.

Even with that testing, I still encountered a few problems on the grid line. The first was that the USB connector appeared to be physically broken. Fortunately, it was only the plastic case that was falling off. Electrically it worked just fine. Although, that wasn't confirmed until I booted and rebooted the radio and laptop to get the connection working. That is my normal challenge connecting to MacOS. It happens at home with my IC-9100 as well.

I discovered another problem after the first couple of passes. I was taking a few photos and realized that one of the UHF elements on the Arrow was missing. Fortunately, that didn't seem to pose much of a problem on the air. I later found the two arrow elements and the screw lying on the floor in the car. They had vibrated loose during the drive. I'm glad I found them and that their loss didn't pose an on-the-air problem.

Results

I managed to get 22 stations in the log, and many of them reported at least one new grid for their logs.

Burt, FG8OJ, was the first caller right after my initial CQ on FO-29. He reported that it was at one degree elevation for him. He was waiting for me as he needed that grid. Only Christy, KB6LTY, answered my call on XW-2A.

On AO-85, I listened to a few conversations going on until Patrick, WD9EWK, called me. He needed the grid. I had thought about skipping the FO-29 pass that was at 20 degrees and to the west. But when I got on, I worked as many stations as on the first FO-29 pass. So, that was well worth it.

I had announced my planned operation on Twitter (@k5nd), which is why Burt and Patrick and a few others were ready for the activation. I like Twitter for keeping up with grid activations. I've been on Twitter since 2008 all the while trying to determine its value. Now I've found it — connecting with other satellite operators. Try it.

Thanks to everyone who got up early to work me. It's very satisfying to provide new grids and do some small payback for the very active grid rovers that have filled up my logbook.

About the Author. Jim has been an active amateur radio operator since 1973. He started satellite operating in 2015 with his first contact with Clayton Coleman, W5PFG, who forwarded the recording. You can learn more and follow his ham radio adventures at **www.k5nd.net**.

Figure 1 – Finding the Grid Line at Zero Dark Thirty.

Figure 2 – Wide Open Spaces in Eastern New Mexico.

Techniques for Interpreting Fox-1 MEMS Gyro Readings Or Experimenting with an Experiment

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Abstract

Since the launch of Fox-1A (now AO-85), many of us have been looking at telemetry data coming from the Penn State Erie MEMS Gyro experiment and trying to understand what it means. Unfortunately, between the time of the experiment proposal and Fox-1A's actual launch, the students who proposed the experiment have graduated. Thus, we are on our own.

In this paper, I describe some trigonometric concepts and techniques which we can use to help interpret the data from the MEMS experiment, as well as a ground-based experiment I ran to confirm these techniques. Note that all Fox-1 satellites (5 total planned) contain the same MEMS gyros so there will be more data to come.

What This Paper Is and Is Not

The primary intent of this paper is to point out some analytical techniques and to describe some ground-based experiments that I used to validate them. It is NOT a detailed analysis of AO-85 behavior. I hope that readers can use these techniques better to analyze Fox-1 satellite behavior. I'm sure papers with further analysis would be welcome in *The AMSAT Journal* or future Symposia.

The Fox-1 MEMS Gyros

AMSAT's Fox-1 satellite program was designed from the start to fly science experiments proposed by students and universities. This capability would contribute not only to AMSAT's mission of STEM education, but would also provide leverage to get launch grants (for example from NASA's CubeSat Launch Initiative program). One early experiment that we picked was from a group of Penn State Erie students, who proposed to fly some MEMS (MicroElectroMechanical Systems) gyros to determine how they would operate in space. Although the original plan was to fly them on a separate experiment board, our final design put two gyro packages directly on the IHU (Internal Housekeeping Unit—computer). This means that ALL Fox-1 satellites have this experiment on board.

The gyros we are flying are ST Microelectronics LPY410AL dual-axis gyro chips, which report the rotation rate around each of their two measurement axes, X and Z. We mounted two chips on each IHU at right angles to each other. Thus, we can get two Z-axis readings as well as one each for X and Y. Their location is about 25 mm from the center Z-axis of the IHU board. (They are circled in Figure 1 near the hand-written "8").

These units provide the rotation rate as analog voltages, which are digitized by the IHU processor's built-in 12-bit Analog to Digital Converter (ADC). Readings from the X-, Y-, and one of the Z-axes are taken approximately 2 ms apart. The most recent readings from the gyros are used every four seconds to calculate the minimum and maximum value seen, and these min/max data are stored and sent to the ground every minute. Additionally, the most recent real-time reading is sent in telemetry about four times per minute. Naturally, not all readings that are sent are received.

The ADCs have a reference voltage of 3.0 V so their 12-bit range of digitized output, 0-4095, should ideally represent a measured voltage range of 0.0-3.0 V. In practice, the ADCs are not completely linear. However, in this paper and in the calculations I provide, I ignore that non-linearity.

The ADC output is measured from the gyro's "4x" pin which, according to the spec sheet, means that the minimum and maximum rotation speeds that can be measured are -30 degrees per second (DPS) to +30 DPS (-5 to +5 RPM). This rotation speed range should give an output voltage range of about .5 V to 2.5 V, with 1.5 V, meaning "at rest." However, the spec sheet also states that one should measure the at-rest value after the chip is mounted on the board (and the board is mounted in the spacecraft, we assume) to get the true at-rest value, and then calculate the spin using 33 mV change per DPS.

Figure 1 – A Fox-1 IHU On A Breakout Board With Gyros Circled.

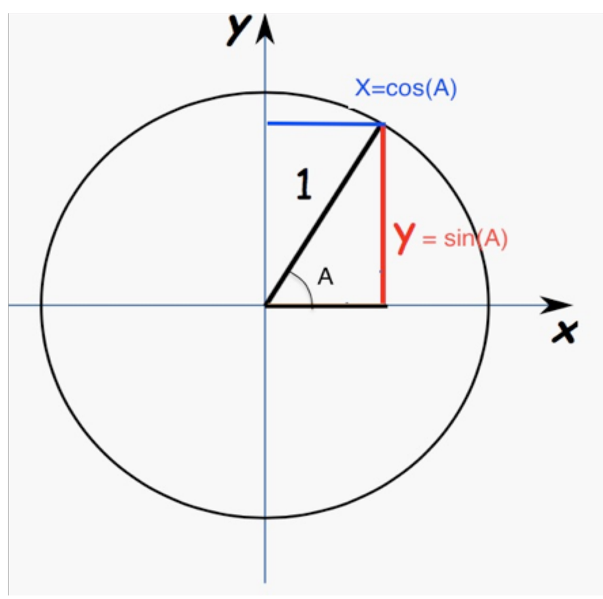

Figure 2 – A Unit Circle.

We would like to determine parameters like the satellite spin axis and rotation rate around that axis and in the process determine whether the gyro output makes sense at all. To get that information, we need some trigonometry.

Some Trigonometry

Many hams are familiar with the basic trigonometry functions and how they apply to geometry and electronics. Nonetheless, I will briefly review some concepts so that we are all thinking the same way when I talk about applying them to the MEMS gyros.

First, look at Figure 2, a simple X-Y coordinate system with a unit circle (circle of radius 1) and a vector (line with length and direction) drawn in the circle. The angle between the X-axis and the vector is labeled A. The angle between the vector and the Y-axis would be (90-A) degrees.

Now, what are the coordinates of the endpoint of the line? The diagram shows that with a vector length of 1, the X-coordinate is the cosine of the angle A and the Y-coordinate is the sine of the angle A.

Next, suppose the length of the vector was NOT actually one but some other number. You are given the x and y coordinates of the endpoint (say x and y). What is the length of the vector? The Pythagorean theorem says that the answer is $\sqrt{x^2+y^2}$. If it were in 3 dimensions, the answer would be $\sqrt{x^2+y^2+z^2}$. (You can double-check this with length 1 also!)

We need a couple more terms that can be extracted from this picture. First, suppose we don't know the angle or the sine or cosine of the angle, but we know the vector's endpoint coordinates. We can calculate the X-direction cosine by dividing the X-coordinate by the length of the vector. Similarly, the Y-direction cosine is calculated using the Y-coordinate (and in 3 dimensions, the same for Z).

And finally, we can calculate the angle A by taking the inverse cosine (also called arccosine) of the X-direction cosine. Similarly, we can calculate the angle between the vector and the Y-coordinate by using the inverse cosine of the Y-direction cosine.

Many hams are aware that these geometric concepts apply to radio waves. For example, looking again at Figure 2, suppose you have a vertical dipole antenna, which is linearly polarized along the Y-axis. A signal is transmitted through another linearly polarized antenna, but this one is aligned along the vector in the drawing (assume the signal arrives at the same polarization it left with). Then the strength of the signal you receive will be only cosine (A)*X where X is the strength you would receive if the polarization of transmitter and receiver were the same.

I was pleased when my research discovered that these concepts also apply to MEMS gyros. If a MEMS gyro is lined up on the X- and Y-axes of the picture and is spinning around an axis that matches the vector, then the gyro should read the sine and cosine of the actual rotation rate. Extend this to three dimensions, and we can calculate both the rotation rate around the spin axis and the angle of the spin axis to each of the X-, Y-, and Z-axes.

Ground-Based Experiments

Methodology

To confirm the predicted behavior described in the last paragraph for at least a couple of rotation axis angles, I used some spare hardware I had in the AMSAT NH Software Lab:

- IHU Serial Number 8 running RadFxSat flight software
- Fox-1 Receiver Board S/N 2 (prototype)
- Fox-1 Transmit Board S/N 2 (prototype)
- Fox-1 Breakout Board
- Kenwood TH-D72 HT set to transmit 67 Hz on the Rx uplink frequency
- FunCube Dongle V2
- Windows 7 Personal Computer running FoxTelem
- Leadleds Motorized Display Turntable (nominally 3 or 6 RPM)
- Alkaline D-Cells soldered together to power the satellite boards
- Assorted boxes and static-safe bubble wrap and bags.

Figure 3 shows the components of the experimental setup. I powered the Fox-1 partial stack using the batteries stored in the box below and connected via the breakout board. The box and satellite boards are on the turntable. For each experiment, after starting the turntable, I used the HT to send

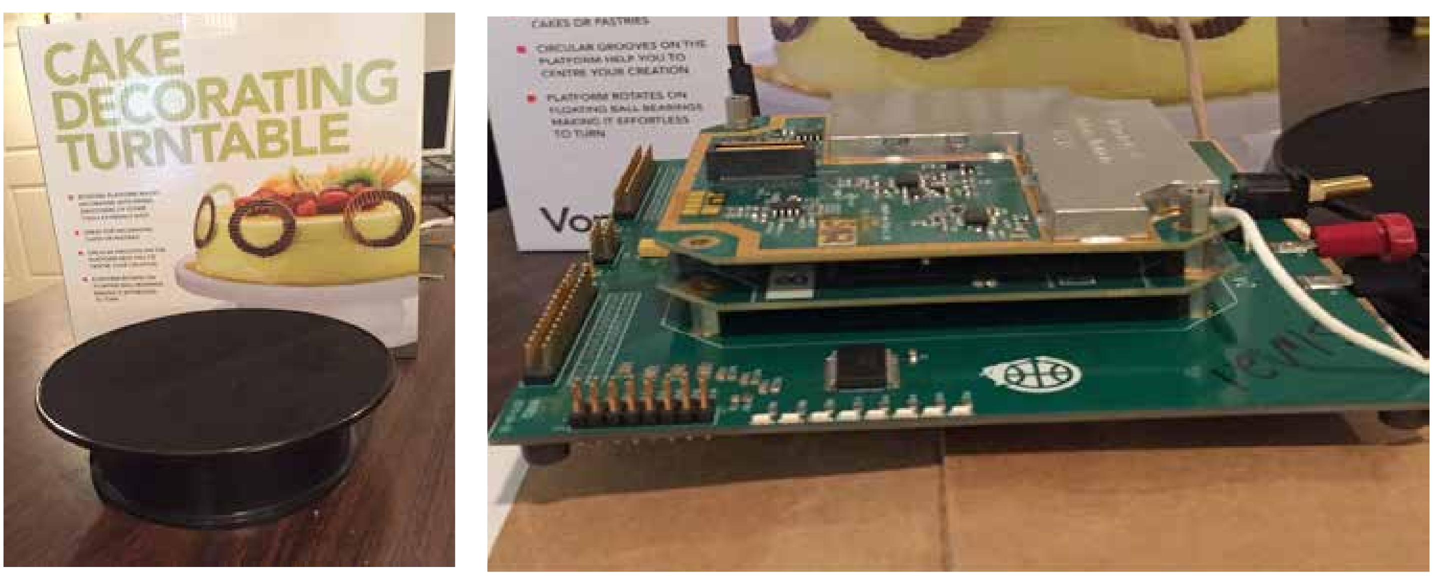

Figure 3 – Turntable and IHU/Rx/Tx Setup (Tx is below the breakout board).

Figure 4 – Rotation on a non-Orthogonal Axis**.**

an uplink signal triggering the transponder. I collected the X-, Y-, and Z-axis gyro data with FoxTelem along with the satellite time (reset/seconds since reset) and placed these values in a spreadsheet.

I ran several different experiments. Most experiments were running at the turntable's slow speed, which I measured to be about 3.75 RPM, although I did run one experiment at the turntable's high speed of about 7 RPM to understand what happens when the rotation speed exceeds the gyro's spec. I varied the direction of rotation via a switch on the turntable (both directions were about the same speed) and changed the angle of the axis of rotation by tipping the IHU on the turntable as shown in Figure 4.

For each experiment, I collected a number of data points. Fox-1 FM satellites send real-time data about every 15 seconds, so the data points are spread over the course of a minute or two. It is surprising that the variance among the readings for the same setup is so great. Without further work, I can only guess that the variance comes because the board is not perfectly level, the turntable does not move perfectly evenly, and the ADC is not perfectly consistent for each reading.

For each data sample, I calculated the voltage that the ADC was reporting and based on one of the initial 0-rotation data reports, I then calculated the rotation rate that the gyros were reporting in each axis. Using this data, I calculated the spin rate using the Pythagorean theorem, the direction cosine for each direction, and the angle of the rotation axis from each coordinate axis.

Results

The results at 3.75 RPM approximate "ground truth," although the imprecision noted above carries through to the final values. An abbreviated table of results is shown in Appendix A. For clarity, I have hidden many of the intermediate result columns, including the raw data I collected, and the direction cosine values I calculated. The complete spreadsheet will be available for the foreseeable future at **burnsfisher.net/AMSAT/Symposium2017/MEMSGyroData.xlsx.**

Notice that for experiments listed as Z Plane Flat, i.e., spin axis parallel to the Z-axis, the results show that the calculated angle between the spin axis and the Z-axis is close to 0, while the calculated angle to the X- and Y-axes are both close to 90 degrees, all as expected.

For the section where there was approximately a measured (with an iPhone) angle of 76 degrees to the X-axis, the calculated angle between the spin axis and the X-axis is indeed in the high 70s. For the section where the measured spin axis angle was about 73 degrees to the Y-axis, the calculated angle was in the mid-70s.

Another question that I tried to answer is whether the fact that the gyros are not on the center of the satellite X-, Y-, and Z- axes is important. Nothing is mentioned in the data sheet about this issue, and I would expect it made little difference (DPS is DPS no matter the center). To get a feeling for whether being off-axis made a difference, I placed the gyros approximately 10 cm away from the axis of rotation with their axis parallel to the actual rotation axis. The results show that the error is a bit higher but still relatively close to 0 degrees in Z and 90 degrees in X and Y.

What is Next?

Using Real Satellite Data

AO-85 has been sending MEMS gyro data for over two years. This data is easy to acquire using FoxTelem. You can collect your own or use FoxTelem to download all data from the central server. Then graph the X-axis gyro, add the Y- and Z-axes to the graph and push the "floppy-disk" button to store the data as comma-separated values.

Import the data as a CSV file into Excel and apply the same formulas that I used. Now you will be able to see the actual rotation rate around the current spin axis, as well as the angle of the spin axis to each coordinate plane of the satellite. One thing to remember is that all of these axes are relative to the coordinate system of the satellite, not to the ecliptic or the earth's equator or anything "absolute."

For example, we know that due to its passive magnetic stabilization, AO-85 (and the other Fox-1 satellites) should reverse their orientation twice per orbit, roughly as it crosses the equator. Suppose the satellite is spinning on the Z-axis and then flips over 180 degrees. Looking from a fixed location in space, we would see the rotation around Z going the opposite direction. However, that will not be the case for the MEMS gyro readings since the Z-axis of gyros themselves has reversed.

Questions To Answer

Starting with the basic techniques in this paper, some ideas for extending this work include:

- Whether prelaunch and launch conditions could damage MEMS devices temporarily or permanently. Is the AO-85 data nonsensical right after launch, and does it improve as time goes on?
- What does the occasional sudden gyration of gyroscope data around the time of the highest temperatures mean? Could the spin rate be exceeding the gyro's capabilities? Could something different be happening that is much more understandable when subjected even to the simple analysis here?
- Is there any way to determine some absolute satellite orientation? Combining MEMS data with solar panel data (which might tell us where the sun is).
- Is there some way of measuring nutation in the spin axis (a periodic oscillation of the spin axis orientation, such as when you poke the end of a toy gyroscope with your finger)?
- Can we see the satellite reverse its orientation? At what latitudes does this happen?

Conclusion

I have provided evidence that some simple trigonometric analysis of the MEMS gyros on Fox-1 satellites can provide useful information when a satellite is on the ground. The calculations I used are publically available. The experiments I did are only a starting point for further analysis of the more complex situation when the satellite is in orbit.

Gyro Experiments

	Raw Data				Scaler Rotation	Spin Axis Angle From Coordinate Basis Axes		
	Satellite Time	RPM			RPM	Degrees		
Z Plane Flat	Seconds	Z	Y	Z		X	Y	Z
No Rotation								
	14	0.00	0.00	0.00	0.00			
CW 3.75 RPM								
	136	-0.14	0.12	-4.32	4.32	88.17	88.38	2.44
	151	-0.12	0.30	-4.07	4.08	88.29	85.83	4.51
	165	0.06	0.24	-4.44	4.44	88.95	86.91	3.27
	180	-0.26	0.33	-4.46	4.48	86.67	85.83	5.34
	211	-0.22	0.01	-3.70	3.70	86.54	89.81	3.47
	226	-0.02	0.20	-4.79	4.79	89.81	87.66	2.34
	240	-0.02	0.39	-4.20	4.22	89.72	84.64	5.37
	255	0.20	0.01	-5.07	5.07	87.70	89.91	2.30
	284	0.24	0.60	-5.09	5.13	87.37	83.27	7.24
	299	0.02	0.18	-4.95	4.96	89.81	87.88	2.12
CCW 3.75RPM								
	331	0.37	-0.18	4.33	4.35	85.07	87.59	5.49
	345	0.13	-0.22	3.71	3.72	87.99	86.55	3.99
	360	0.24	-0.09	4.08	4.09	86.69	88.69	3.56
	374	0.03	0.02	4.15	4.15	89.55	89.72	0.53
	402	-0.30	0.00	3.37	3.38	84.89	90.00	5.11
	416	0.48	-0.48	4.20	4.25	83.46	83.52	9.22
	431	-0.27	-0.32	3.94	3.96	86.06	85.41	6.06
76 Degree Angle On X Axis								
CW 3.75 RPM								
	694	0.91	0.17	-4.31	4.41	78.13	87.78	12.08
	708	0.85	0.13	-4.10	4.19	78.35	88.16	11.80
	723	0.88	0.02	-4.75	4.83	79.52	89.71	10.48
	737	0.92	0.03	-4.37	4.47	78.09	89.64	11.92
	752	1.16	0.30	-3.84	4.03	73.21	85.77	17.35
	766	0.62	-0.04	-3.59	3.65	80.24	89.43	9.77
	781	1.03	0.25	-3.89	4.03	75.21	86.41	15.24
CCW 3.75 RPM								
	829	-0.87	0.06	3.85	3.95	77.34	89.12	12.69
	844	-0.85	-0.01	4.14	4.23	78.34	89.89	11.66
	859	-0.73	0.06	3.99	4.06	79.67	89.14	10.37
	873	-0.58	0.02	3.48	3.53	80.58	89.74	9.42
	893	-0.77	-0.15	4.33	4.40	79.95	87.99	10.25
	908	-0.89	0.00	4.08	4.18	77.64	89.94	12.36
	923	-0.70	-0.05	3.94	4.00	79.87	89.24	10.16
73 Degrees on Y Axis								
CW 3.75 RPM								
	186	-0.23	-1.50	-4.74	4.98	87.38	72.41	17.79
	201	-0.11	-1.13	-4.18	4.33	88.60	74.94	15.13
	215	-0.07	-0.82	-4.06	4.14	89.04	78.57	11.47
	230	0.02	-1.05	-4.29	4.41	89.74	76.19	13.81
	244	-0.08	-1.14	-4.54	4.68	89.01	75.88	14.15
	259	-0.09	-0.87	-3.68	3.79	88.65	76.77	13.30
	274	-0.05	-1.26	-4.99	5.15	89.46	75.88	14.13
	288	-0.19	-1.29	-4.60	4.78	87.76	74.32	15.85
	303	-0.10	-0.86	-4.38	4.46	88.70	78.87	11.21
	317	-0.10	-0.50	-3.14	3.18	88.24	80.89	9.28
CCW 3.75 RPM								
	367	0.18	1.25	4.11	4.30	87.62	73.12	17.05
	382	0.07	0.93	4.25	4.35	89.04	77.71	12.33
	396	0.27	0.70	3.72	3.80	85.89	79.33	11.45
	411	0.25	1.11	4.30	4.45	86.80	75.61	14.76
	438	0.24	1.14	4.24	4.40	86.88	74.96	15.38
	453	0.22	1.25	4.53	4.70	87.28	74.56	15.69
	467	0.13	0.80	3.21	3.31	87.82	76.08	14.10
	482	0.23	1.22	4.38	4.56	87.14	74.47	15.81
CW 3.75 RPM Gyros off center								
	71	-0.58	0.27	-4.43	4.47	82.58	86.56	8.18
	86	-0.39	0.20	-3.98	4.01	84.41	87.15	6.28
	100	0.37	0.24	-4.45	4.47	85.20	86.98	5.67
	144	-0.82	-0.01	-4.38	4.46	79.38	89.90	10.62
	158	0.20	0.05	-4.02	4.02	87.22	89.25	2.88
	173	-0.06	0.20	-4.14	4.14	89.16	87.30	2.83
	188	-0.56	0.28	-4.31	4.36	82.66	86.36	8.20

Receiving Images from the NOAA Polar Orbiting Environmental Satellites

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[An earlier version of this article was published by the Radio Society of Great Britain in *RadCom* volume 92, number 11 (November 2016), and the article appears here with their kind permission.]

Earth imaging satellites have played a key role in meteorology for over half a century. The very first images of Earth from a satellite were obtained on August 14, 1959, by the U.S. satellite Explorer 6. These images were very crude by today's standards. The first weather satellite considered to be a success was TIROS-1 (Television Infrared Observation Satellite). It was launched on April 1, 1960, and was operational for 78 days. In total, ten TIROS satellites were launched between 1960 and 1965.

The TIROS satellites were succeeded by the ESSA (Environmental Science Services Administration) series of satellites, nine of which were launched between 1966 and 1969, and finally, by the NOAA (National Oceanic and Atmospheric Administration) satellites, nineteen of which were launched between 1970 and 2009. Of these nineteen, three are still in operation, and these are the main focus of this article.

Satellite Orbit Types

Four different basic types of satellites orbit the Earth classified according to altitude. Satellites in low Earth orbit (LEO) typically have an altitude of between one hundred miles and one thousand miles. Their orbital periods range between roughly 90 minutes and 120 minutes and increase with increasing altitude. The TIROS satellites and their successors have all been LEO satellites.

Satellites in medium Earth orbit (MEO) typically have an altitude of between one thousand miles and twenty-two thousand miles. Their orbital periods range between roughly two hours and twenty-four hours.

Satellites in high Earth orbit (HEO) have an altitude greater than twenty-two thousand miles, and orbital periods greater than one day. At the boundary between MEO and

HEO at an altitude of 22,236 miles, the orbital period is precisely one day. Since the orbit of the satellite synchronises precisely with the rotation of the Earth, there is no apparent movement of the satellite. Such an orbit is called a geostationary orbit.

Each of these types of orbit has advantages and disadvantages. Geostationary orbits are useful because once the antenna, typically a dish, has been accurately aimed at the satellite then no further adjustment is required. Satellites carrying domestic television services are in geostationary orbits. Signals from geostationary orbit and HEO are relatively weak, and a high gain antenna is required to achieve reliable reception. The images from a given geostationary satellite only cover roughly one-third of the Earth's surface, and the signals from such a satellite may only be received from a similarly limited proportion of the Earth's surface.

LEO orbits are useful because the signals from these satellites are relatively strong. Even if the output power of the transmitter is only a few watts, reception is possible with a quite modest antenna and receiver. As the position of the satellite is always changing relative to the ground, it may serve most of the Earth's surface. From the point of view of Earth imaging, images from LEO satellites have a much greater resolution than those from higher altitude satellites. For this reason, many weather satellites are in LEO.

Weather Satellites

Coverage of North and South America is provided by the Geostationary Operational Environmental Satellites (GOES) program operated by NOAA's National Environmental Satellite, Data, and Information Service (NESDIS). On November 19, 2016, GOES-R was successfully launched. This new geostationary satellite has capabilities significantly beyond the previous satellites in the GOES series, including three times more spectral information, four times greater spatial resolution, and real-time mapping of lightning activity.

The satellite was renamed GOES-16 once it reached its final designated position at longitude 75 degrees west in December 2016. It is also known as GOES-East, having taken over this role from GOES-13 which is currently being moved to storage at 60 degrees west. GOES-15 (also known as GOES-West) is positioned at longitude 135 degrees west. GOES imagery may be received directly from the satellite on 1.7 GHz but, following the example set by EUMETCast, is also relayed via GEONETCast using the television satellite New Skies NSS-806 in the C-band.

In this article, we are concerned with the NOAA Polar Orbiting Environmental Satellites (POES), which are in a very specific type of LEO. These orbit at a mean altitude of around 530 miles and have an orbital period of around 102 minutes. The orbits are sun-synchronous, meaning that the plane in which each satellite orbits remains fixed relative to the position of the sun. The result of this is that each pass of the satellite takes place at roughly the same local time relative to the longitude of the pass. Currently, four Polar Orbiting Environmental Satellites in operation, having been launched from Vandenberg Air Force Base in California on the following dates:

NOAA-15 - Launched May 13, 1998
NOAA-18 - Launched May 20, 2005
NOAA-19 - Launched February 6, 2009
NOAA-20 - Launched November 18, 2017

The most recent of these, NOAA-20, is the first in the new Joint Polar Satellite System (JPSS) series of satellites. NOAA-20 is not equipped to transmit images in a format suitable for reception by amateurs, and we focus here on the three earlier POES satellites. Each of these carries an Advanced Very High Resolution Radiometer (AVHRR), which is in effect the satellite's camera. The AVHRR has sensors that measure electromagnetic radiation reflected from the Earth in six spectral bands, or channels, indicated in the chart below.

Data from two channels of the AVHRR is transmitted using a system known as automatic picture transmission (APT). The two channels that are used varies. Whilst the satellite is in sunlight, NOAA-15 and NOAA-19 usually carry channels 2 and 4, and NOAA-18 usually carries channels 1 and 4. Whilst in darkness, all three satellites carry channels 3 and 4. The data is transmitted as a horizontal line scan at a rate of two lines per second. Each line is 2080 pixels long, and hence the data rate is 4160 baud. The raw data received may be decoded using suitable software, and appears as monochrome images from the two channels side by side.

Channel	Wavelength (um)	Description	Typical Use
1	0.58 - 0.68	Visible	Daytime cloud and surface mapping
2	0.725 - 1.00	Visible	Land-water boundaries
3A	1.58 - 1.64		Snow and ice detection
3B	3.55 - 3.93		Night cloud mapping
4	10.30 - 11.30	Infrared	Night cloud mapping
5	11.50 - 12.50	Infrared	Sea surface temperature

The satellites also provide high-resolution picture transmission (HRPT) in the 1.7 GHz band. The HRPT service carries all of the channels from the AVHRR. Reception of HRPT requires a steerable antenna and is beyond the scope of this article. The frequencies currently in use (as of January 2018) for APT and HRPT from NOAA-15, 18 and 19 are as follows:

	APT	HRPT
NOAA-15:	137.6200 MHz	1702.5 MHz
NOAA-18:	137.9125 MHz	1707.0 MHz
NOAA-19:	137.1000 MHz	1698.0 MHz

Of these three, NOAA-19 consistently gives the best images. From any given location, the APT transmission from each satellite may be received for three passes each day during the daytime and a further three passes during the night.

Hardware

Reception of APT from the NOAA satellites requires a suitable receiver and antenna. A general coverage receiver or scanner covering the 137 MHz band will give fair results, but a purpose-built receiver will perform much better. Ideally, the receiver should feature automatic frequency control, enabling the receiver to compensate for the shift in frequency during the satellite pass that arises from the Doppler effect.

Also, the bandwidth of APT is around 30 kHz, which is a little too wide for most scanners, resulting in clipping of the signal. The author uses the R2ZX receiver (Figures 1), designed and built by Holger Eckardt, DF2FQ. Unfortunately, this receiver is no longer being manufactured, but the APT-06 receiver of similar specification is available from WRAASE Electronic in Germany for 188 Euros (approximately $200) including shipping.

Running software to process data from the satellites requires only a PC or laptop of modest specification with a sound card. The audio signal from the receiver is fed into the microphone input socket on the laptop. The audio volume of the receiver and the gain of the microphone preamp need to be

Figure 1 – The R2ZX receiver for APT on 137 MHz.

carefully set to maximise signal whilst avoiding distortion. The author uses a ten-year-old laptop running Windows XP as a machine dedicated to running weather satellite software and weather station software. As an alternative to the receivers mentioned above, reception of APT may be achieved using a software defined radio dongle, such as the Newsky RTL2832U/R820T2, with suitable software.

Figure 3 – MCIR ("map coloured infrared") enhancement of APT signal.

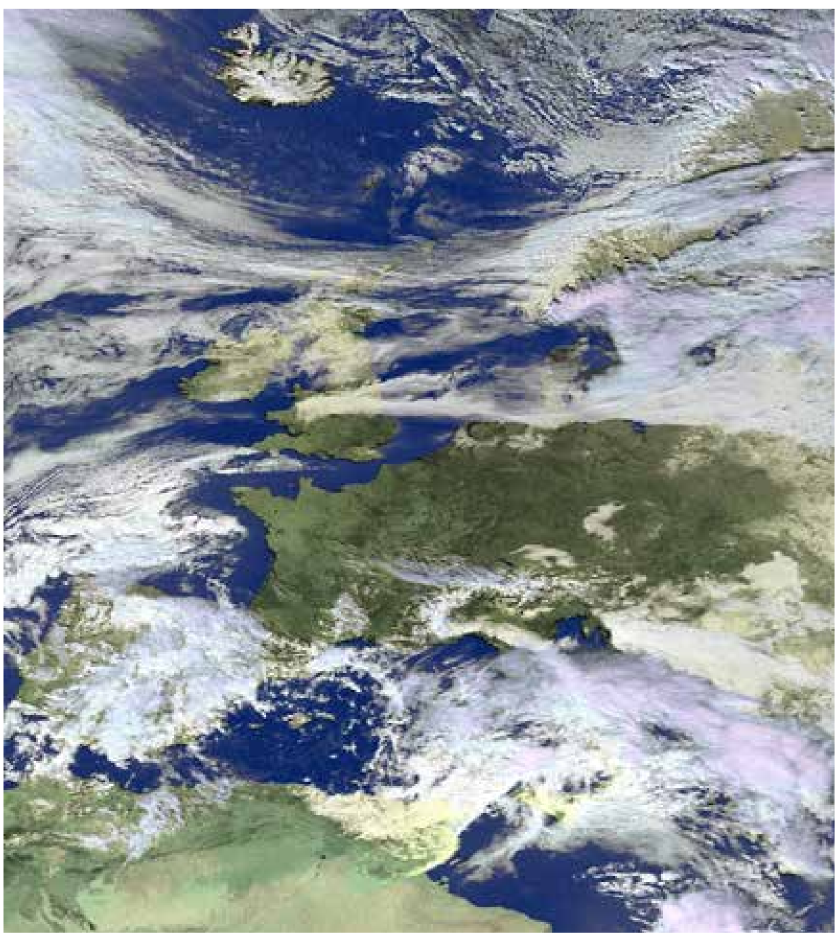

Figure 2 – HVCT enhancement of APT signal (shown here in black and white). [Courtesy of NOAA.]

The APT signals are transmitted with right-hand circular polarisation. Whilst fair reception can be obtained using a vertical antenna for the 144 MHz amateur band, the results are much improved if an antenna designed for circular polarisation at 137 MHz is used. The author uses a crossed dipole (or "turnstile") antenna mounted on a short mast on the chimney stack, and this gives excellent results. An alternative to the crossed dipole is the quadrifilar helix (QFH) antenna, but these are considerably more expensive. As with any antenna, good quality coaxial cable such as RG58 should be used to connect the antenna to the receiver.

Software

Several programs are available for decoding APT data and processing to give informative and aesthetically pleasing images. One of the most popular is WXtoImg ("Weather to Image"), which is the program used by the author. The software combines the two AVHRR images to give a single, artificially coloured image.

The basic freeware version of WXtoImg features five different enhancement options for producing an image. HVC is the most basic and gives a coloured tint to clouds which varies according to their temperature. HVCT (Figure 2) and MSA ("multi spectral analysis") both make use of a map overlay to distinguish land from sea, allowing a more naturally coloured image to be produced, with blue for sea regions and green/brown for land regions. MCIR ("map coloured infrared," Figure 3) is used to produce colour images whilst the satellite is in darkness. The "thermal" option gives an image which is artificially coloured according to temperature.

The Standard and Professional editions of WXtoImg provide several further enhancement options, including enhancements which show precipitation. There are many other additional features, including the facility to produce composite images from two or more consecutive passes of a satellite. Upgrade to the Standard or Professional editions requires an upgrade key, which used to be available for a one-off fee. However, in February 2016 the upgrade keys became available free of charge.

Satellite software uses a set of parameters known as Keplers (or, more formally, "Keplerian elements") to accurately predict the times and durations of satellite passes. These also enable accurate positioning of map overlays on the received images. The Keplers must be updated from time to time from the Internet, typically every two days or so. Updating the Keplers does not require any understanding of the numerical parameters on the part of the user, and is achieved by a single click in the file menu of WXtoImg. The software may be set automatically to record and process data from satellite passes, and so may be left unattended. The software will also drive a USB or serial interface to set a suitably equipped receiver to the correct frequency for each satellite during its pass.

The R2ZX receiver used by the author has a serial interface. Its successor, the R2FU, and the WRAASE electronic APT-06 have USB interfaces. The software may be set to only record when a specified minimum elevation above the horizon is reached, and to ignore satellite passes which fail to reach a specified threshold at maximum elevation. Careful adjustment of these parameters avoids recording and attempting to process noisy signals that will produce only grainy images.

Further Information

The analogue APT format discussed in this article is being phased out, and if future polar-orbiting satellites provide any transmission suitable for the amateur enthusiast on 137 MHz, it will be digital low rate picture transmission (LRPT). Two Russian LEO satellites already in operation provide LRPT, Meteor M N1 and Meteor M N2. Unfortunately, Meteor M N1 is now incapable of imaging the Earth due to an attitude loss on March 20, 2016, which left its sensors pointing towards the sun. However, Meteor M N2 remains operational, transmitting LRPT on a frequency of 137.9 MHz. The bandwidth used by LRPT is 150 kHz, much wider than used by APT. Because of this, reception of LRPT requires new hardware (for example, the Newsky SDR dongle mentioned above) and software. Details appear in the web links.

There are many useful web resources for the NOAA POES satellites, and some of these are given in the web links section below. In particular, the GEO (Group for Earth Observation) website features a wealth of useful information and detailed guidance on receiving APT, LRPT and HRPT from polar-orbiting satellites.

Despite there being a wealth of near real-time satellite images available on the web, there is still excitement and a sense of achievement in receiving images direct from the satellites. I hope that this article will inspire more radio amateurs to become involved in this fascinating aspect of the hobby.

Web Links

Group for Earth Observation (GEO):
geo-web.org.uk/index.php

WXtoImg ("Weather to Image") software:
www.wxtoimg.com/

National Oceanic and Atmospheric Administration (NOAA):
www.noaa.gov/

NOAA POES Operational Status:
www.ospo.noaa.gov/Operations/POES/status.html

Polar-orbiting satellite and geostationary satellite weekly status:
phqfh.co.uk/status.htm

GOES West and GOES East near real-time images:
www.goes.noaa.gov/

WRAASE electronic (hardware):
www.wraase.de/shop.html

LRPT Tutorial:
www.rtl-sdr.com/rtl-sdr-tutorial-receiving-meteor-m-n2-lrpt-weather-satellite-images-rtl-sdr/

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Spotlight on the Chinese Amateur Radio Satellites

Keith Baker, KB1SF/VA3KSF
Treasurer

[Portions of this article appeared previously in the September 2017 edition of The Spectrum Monitor magazine.]

In previous articles, I've been focusing on the many ways you can operate through the amateur radio satellites. But, without one or more satellites to operate through, even the very best ground station is little more than a money sink!

So, in this article, I'll shine the spotlight on a whole series of FM and linear satellites that our AMSAT friends in China have launched in the last few years that make up the vast majority of our current amateur satellite fleet. I'll also share some operating tips on how you can maximize your signals to and from these satellites.

Beginnings

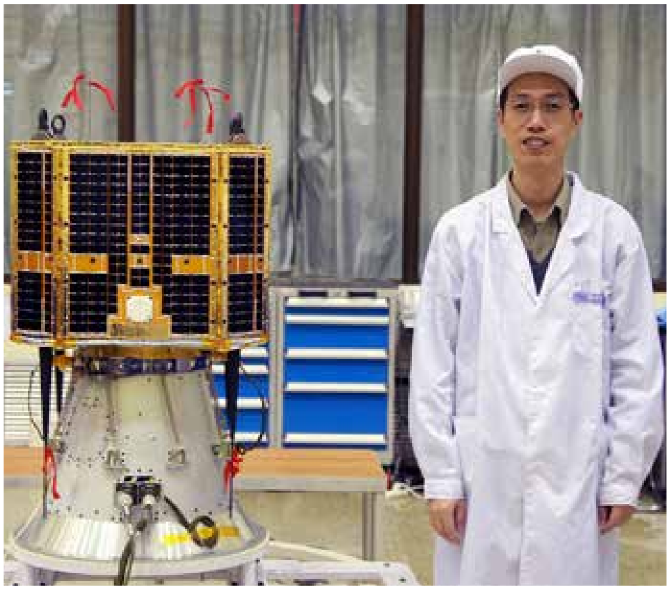
The Chinese AMSAT organization's (CAMSAT) group was largely responsible for the construction and launch of China's first-ever amateur radio satellite (CAS-1, the "CAS" most likely an acronym for "Chinese Amateur Satellite"). The satellite was also known as XW-1 (Xi Wang-1, Xiwang being the Chinese word for "hope") before launch, and, once activated on orbit, was also given the anglicized AMSAT designation "Hope OSCAR 68" (or just HO-68).

The 60 kg satellite was launched into a 1200 km by 1200 km orbit on December 15, 2009, from the Taiyuan Satellite Launch Center of China on a CZ-4C (LM-4C) rocket. Soon after launch, its linear transponder proved very popular and provided hundreds of SSB and CW contacts for satellite-equipped hams worldwide over the Christmas-New Year 2009-2010 holiday period.

However, since that time, HO-68's linear transponder has gone largely silent with only it's 435.790 MHz (CW) beacon (sometimes!) being heard. While the cause of the transponder anomaly was not widely reported, it's believed an on-orbit software crash was the ultimate culprit.

CAMSAT at Hamvention 2011

I first became fully aware of the ongoing efforts of CAMSAT to add to the constellation of amateur radio satellites



Alan Kung BA1DU poses with the fruits of his (and his team's) labor…the flight model of CAS-1 during final integration. The satellite was also known as XW-1 (Xi Wang-1…Xiwang being the Chinese word for "hope") before its successful launch. [Courtesy: CAMSAT.]

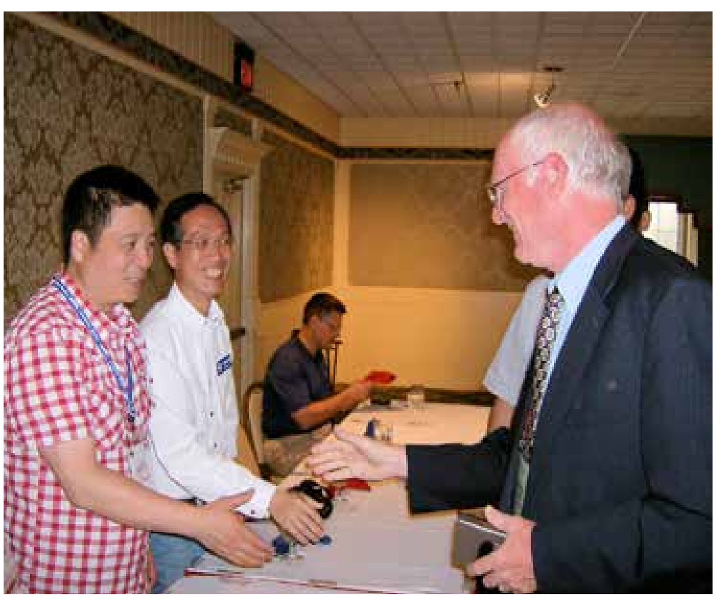
Alan Kung BA1DU (left) and his CAMSAT team pose with *QST Magazine* Editor Steve Ford WB8IMY (second from left) at the 2011 Dayton Hamvention AMSAT booth. [Author, photo.]

through a visit by some of their officers to the Dayton Hamvention in 2011. I ended up as one their "satellite hosts," squiring them around the venue and introducing them to members of various North American ham radio and satellite-related organizations. CAMSAT President Alan Kung, BA1DU, (one of the people largely responsible for the design and construction of HO-68) was also present at the event and provided AMSAT forum attendees with an overview of the Chinese AMSAT efforts. After his talk, he then presented a "plaque of friendship" to AMSAT-NA President Barry Baines, WD4ASW.

CAS-2?

In the 2011 to 2013 time frame, CAMSAT and students at the Qian Youth Space Academy in China Academy began work on the next set of satellites in the series (CAS-2) as the successors of the first CAMSAT amateur radio satellite CAS-1 (XW-1, HO-68).

The launch of the first CAS-2 was initially planned for sometime in 2014 into a 1000 km orbit with an inclination of 12 degrees via a new Chinese missile from a new Chinese launch site into a sun-synchronous



Bob Bruninga, WB4APR, the "father" of APRS (right), shares a moment with The Chinese CAMSAT delegation at the joint AMSAT/TAPR 2011 Dayton Hamvention banquet. [Author, photo.]

Alan Kung BA1DU (right) presents a friendship plaque to AMSAT-NA President Barry Baines WD4ASW at the 2011 Dayton Hamvention AMSAT forum. [Author, photo.]

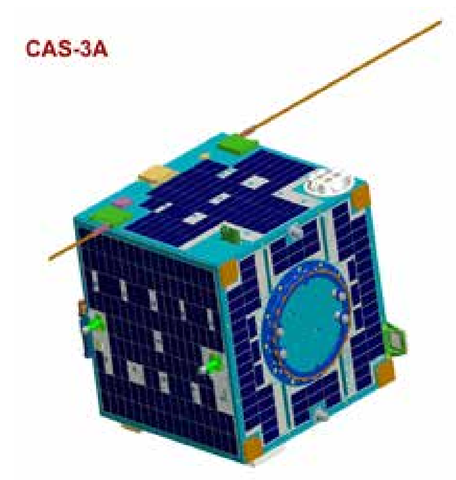
orbit to start. This orbit meant that the satellite's signals might not be receivable in those countries at high latitudes. It was also understood that most of the room in the CAS-2 satellite was to be taken up by the primary (non-amateur) payload and it was only possible to fit a single channel FM amateur transponder into the satellite. A later announcement indicated that two separate CAS-2 satellite structures were being built, A1 and A2.

Unfortunately, no further information about this particular CAS-2 imitative was ever published. Whether (or not) the satellites were ever launched (or even made it to orbit) is anyone's guess. As these satellites were all to be riding on Chinese government launch vehicles (and apparently new vehicles at that!), it's not unusual that the rest of the world would not hear about it if launch failures or other anomalies prevented such efforts from ever coming to fruition.

Enter CAS-3…and Success!

The CAMSAT orchestrated XW-2 (formerly known as CAS-3) amateur satellite system was successfully launched on Saturday, September 19, 2015, at 23:01:14 UT on

This is the Chang-Zheng-6-cz-6-rocket that carried all of the CAS-3 satellites to orbit. [Courtesy: CAMSAT.]



China's new Chang Zheng 6 (CZ-6) rocket from the Taiyuan Satellite Launch Center (TSLC) in Shanxi, China.

The XW-2 constellation initially comprised six satellites of different mass, one 20 kg, three 10 kg and two 1 kg. All six satellites are equipped with substantially the same amateur radio payloads, a 435/145 MHz linear transponder for SSB/CW communications, a CW telemetry beacon and an AX.25 19.2/9.6 kbaud GMSK telemetry downlink. Each set of amateur radio equipment has roughly the same technical characteristics, but they operate on different frequencies in the 435 MHz uplink band and 145 MHz downlink band.

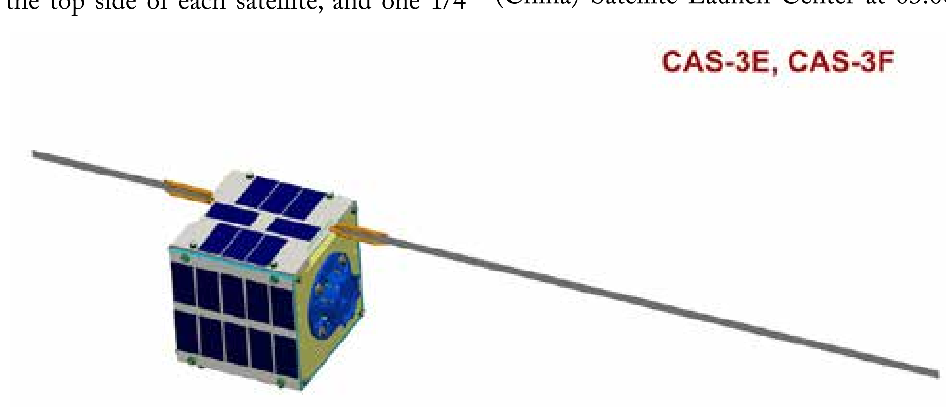
XW-2A, the largest of the fleet, is also the most powerful of the bunch, with both beacon and transponder power in the 100 mW category. XW-2B, -2C, -2D, and -2F all sport 50 mW beacons and transponder downlinks. Antennas are also all monopoles; one 1/4 wavelength monopole VHF antenna with maximum 0 dBi gain is located on the top side of each satellite, and one 1/4 wavelength monopole UHF antenna with maximum 0 dBi gain is located at opposite end of the top side, close to each edge of satellite body. All but one of the satellites (XW-2F) are three-axis stabilized on orbit with one of the satellite's surfaces continually facing the Earth.

A complete set of operating frequencies for these satellites (in .pdf format) can be found on the AMSAT-UK website at **ukamsat.files.wordpress.com/2015/05/xw-2_cas-3_-satellites-frequency-allocation.pdf**. Also, the series' CW telemetry encoding formats are also available (again from the AMSAT-UK website) at **ukamsat.files.wordpress.com/2015/05/xw-2-cw-telemetry-encoding-format.pdf**.

Along with the XW-2 satellites, three other satellites with amateur radio payloads (The LilacSats) were on the same launch. CAS-3H has an APRS digipeater, 144/437 MHz FM voice transponder, and a SSB/CW linear transponder. DCBB (CAS-3G) and NUDT PhoneSat (CAS-3I) have telemetry downlinks. More information about the LilacSat series of satellites can be found at lilacsat.hit.edu.cn/. These websites are written in Chinese, so you'll have to translate them in your browser to read the information.

But Wait, There's More!

Then, in mid-June of 2017, once again, the Chinese AMSAT organization (CAMSAT) proudly announced the launch of its CAS-4A and CAS-4B linear transponder payloads. These payloads were riding piggyback on the Chinese OVS-1A and OVS-1B optical remote sensing satellites, which were launched along with the hard X-ray modulation telescope (HXMT) satellite aboard a CZ-4B rocket from Jiuquan (China) Satellite Launch Center at 03:00



An artist's concept of the CAS-3F (XW-2F) satellite. For size comparison, the longer whip is the ¼ wave 2 m downlink antenna.[Courtesy: CAMSAT.]

UTC on June 15, 2017. Both satellites are in a 43-degree inclination orbit with an apogee of 524 km.

CAMSAT worked closely with a Chinese Government aerospace contractor to build the two satellites with amateur radio linear transponder payloads. Both payloads carry a 435/145 MHz (U/V) 20 dBm (100 mW) SSB/CW linear transponder, a 2 m CW 17 dBm (50 mW) telemetry beacon and an AX.25 4.8 kbps GMSK 20 dBm (100 mW) telemetry downlink. Each set of amateur radio packages has the same technical characteristics, but they have different frequencies for the 70 cm band uplinks and 2 m band downlinks. The two micro-satellites also carry optical remote sensing missions. With identical 494 x 499 x 630 mm dimensions, a regular square shape and approximately 50 kg mass, each satellite also contains a three-axis stabilization system.

A 43-degree inclination orbit, while not unique to amateur radio satellites, presents somewhat of a challenge to those of us located in the northern part of North America who may also wish to use them. That's because, the satellite(s) will appear to only be (briefly!) overhead in our part of the world, and no farther north than 43 degrees north latitude, once or twice a day. And that apogee point will also appear to shift steadily westward as the day progresses and as the Earth turns underneath the orbit.

At *Journal* deadline (mid January 2018) both of these satellites' amateur radio transponders have since been opened up to amateur radio use. I've found they have very sensitive uplinks and strong downlinks. My hunch is that these two new satellites will eventually become as popular as their Chinese brethren.

Operating Through The XW Series

Also, and as of the time of this writing, all but one of the XW-2 series of satellites were still on orbit and functioning well. Unfortunately, XW-2E was never heard from soon after launch, but the amateur radio transponders on XW-2A, -2B, -2C, -2D and -2F were all providing strong downlinks when last heard.

What's more, as these satellites were all deployed off the same rocket, and because they are of different sizes and therefore, slightly different orbital altitudes, they've since spread out and now tend to follow one another in their orbits. From an operational standpoint, this means that the satellites will appear to line up as they pass overhead. And, because their pass times are often separated by only a few minutes, it's quite possible to carry on a continuing conversation with the same ham via multiple XW satellites.

That is, as these satellites are all in polar orbits, as one satellite sets off to the north (or south) of your QTH, you often only have to swing your antennas 180 degrees in the opposite direction to pick up the next XW satellite coming your way. Using this technique, I've often carried on "rag-chew"-type conversations of upwards of an hour with a fellow ham while we were working through all five of the XW satellites, one by one, as they passed overhead.

In many ways, this type of operation reminds me of the times back in the 1990s when we had one or more so-called high-altitude ham radio satellites (such as AO-10 and AO-13) in very high elliptical (Molniya) orbits. We could carry on the same conversation for hours with hams in other parts of the planet.

XW Antenna Technique

Unfortunately, as these satellites (and others like them, such as the CubeSats) are so small, they do not allow for circularly polarized antennas on their space frames. Most of the time, these satellites can only sport a single, linearly polarized uplink and/or downlink antenna. So, with the satellite providing only 50 or 100 mW of downlink power to a 0 dBi single whip antenna, there will inevitably be times when your antenna(s) and the satellite's will be cross-polarized. The result is that either your uplink (or the satellite's downlink) will seem to fade out, sometimes to nothing.

Unfortunately, the natural human tendency when this happens is to crank up the power. But, because your antennas and the satellite's are momentarily cross-polarized, this rarely, if ever, helps. Usually, the best thing to do in these situations is to either flip the orientation of your antenna around (if it's of the hand-held variety) or switch to right- or left-hand polarity if you are using a switchable circularly polarized Yagi array. In my case, my fixed antennas at my home are permanently set for right-hand circular polarization. So, when I'm operating from home, I simply wait for the satellite to move to a more favorable antenna orientation and then continue my conversation.

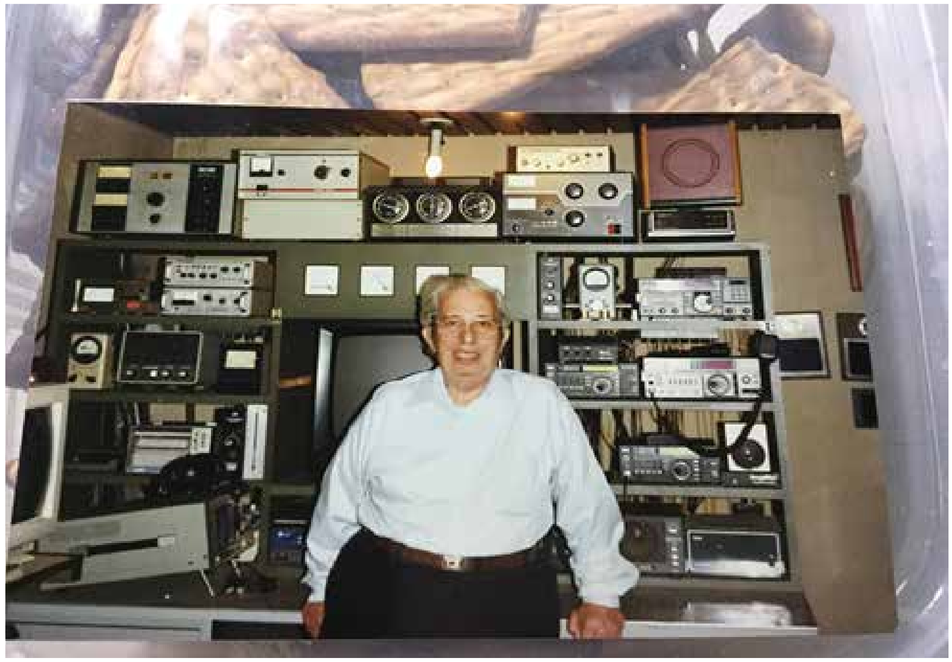
However, when operating portable (such as with a hand-held Arrow-style or Elk antenna), a flick of the wrist will sometimes bring your uplink (and the satellite's downlink) signals back into a strong (i.e., copyable) state.

I recently took my portable satellite station on the road to a city park near Sault Ste. Marie, Michigan, and had a ball working through each of these satellites from a relatively rare Maidenhead grid square (EN-76). Being somewhat of a DX station, I was a very popular camper on these wonderfully active satellites.

The author takes a break from operating on the XW satellites at Sherman Park, Sault Ste. Marie, Michigan (EN-76). [Kathryn Baker, KB1OGF, photo.]

Dr. Junior Torres de Castro, PY2BJO (SK)

Keith Baker, KB1SF/VA3KSF
Treasurer



Junior is shown here in his ham shack at his home near Sao Paulo, Brazil.

With great sadness, the Directors and Officers of AMSAT-North America have announced the passing of Dr. Junior Torres de Castro, PY2BJO. According to his son, Allan Kardec, Junior passed away on January 17, 2018, in Sao Paulo, Brazil.

A very active radio amateur, Junior was a great collaborator of LABRE (The League of Brazilian Amateur Radio Transmitters) serving for a time as its President. He was also a founder of BRAMSAT, the Brazilian AMSAT group, as well as an active member of the AMSAT-NA Board of Directors during the late 1980s and early 1990s.

But, perhaps what Junior will be best remembered for among the world's radio amateurs was his work with AMSAT-NA in helping to build and financially underwrite Brazil's very first amateur radio satellite.

Called DOVE, short for "Digital Orbiting Voice Encoder," the satellite was successfully launched on January 22, 1990, on an Ariane 4 rocket from the European Space Agency's Kourou Space Center in French Guiana. Besides the main payload, the launch also included three other AMSAT MicroSats along with two larger UoSats. Surrey Satellite Technology in England built the two larger satellites.

Junior's vision for his DOVE satellite was to provide a strong FM audio, 2 m downlink signal ("This is DOVE in Space") that easily could be received by educational institutions around the world. Downlink telemetry was via 1200 baud AFSK in AX.25 format, a digital data format that easily decoded with receivers and TNCs that were very popular among radio amateurs at the time.

When told of Junior's passing, Jan King, W3GEY, a founding AMSAT Director and AMSAT's Vice President of Engineering during the MicroSat project said, "I'm very sorry to hear about Junior. He certainly made the 4 MicroSat mission happen. He was a very important part of AMSAT and a fond memory for me."

Likewise, former AMSAT Board Member Bob McGwier noted, "This is a sad day. Junior was a great guy, full of life, and he loved AMSAT. It was a pleasure for me to help build his MicroSat for him. When I became an AMSAT employee for getting these spacecraft done, Junior paid the bills."

Another MicroSat Project team member, Jim White, WD0E, noted:

This is indeed sad news. It was a pleasure to work with him on DOVE. He was a very warm and

Junior's completed "Dove" satellite (which later became DO-17 on orbit) sits inverted prior to final integration with its launching structure.

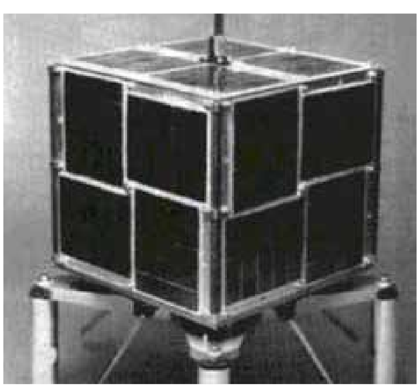
generous person and not only conceived of and funded DOVE, but also a receiver for the 60-foot radio dish that the Table Mountain Deep Space Exploration Society was refurbishing. He was always tinkering and building things at his house near Sao Paulo and dreamed of building a round swimming pool that, when drained, would double as a radio astronomy dish! During the time his DOVE satellite was sending "This is DOVE in space" we received nearly 200 SWL cards from around the world, all of which we shared with him. Needless to say, he was absolutely delighted.

At press time, funeral arrangements for Junior were incomplete, but interment was to be in Gethsemane Cemetery, Sao Paulo, Brazil.

A close-up photo of a completed MicroSat showing its solar panels.

An Ariane 4 launch vehicle successfully launched four original MicroSats and two UoSats into low earth orbit from the European Space Agency's Kourou Space Launch Center in French Guiana on January 22, 1990.

Dove satellite (far right) sits on its "Ariane Structure for Auxilliary Payloads" (ASAP) launch structure with three other MicroSats and two UoSats.



The original MicroSat series satellites were large (by today's standards!) cubes approximately 9 inches square and with a mass of some 20 pounds.

MicroSat integration and launch team wearing their clean room 'bunny suits" at the European Space Agency's Kourou Space Launch Center in French Guiana; Junior is sitting cross-legged in front.

Getting Scouts Interested in Amateur Radio via ARISS

Dave Hinkley, KA0SOG

The Scouting 500 took place September 22-24, 2017, at the Kansas Speedway, and it was quite a success. We had over 11,000 kids and another 2,000 parents, leaders and staff attend. It was the single biggest scouting event in the United States except for the National Jamboree.

Organized by Dave Hinkley, KA0SOG, Member of the Heart of America Radio Scouting Committee and Heart of America Council STEM Committee, Amateur Radio put on quite a show for area youth. How many made it through the ham radio program area is impossible to know, but it numbered in the thousands.

The biggest hit was the ARRL (American Radio Relay League), ARISS (Amateur Radio – International Space Station) contact with the International Space Station. Paolo Nespoli, IZ0JPA, was terrific. He was patient and kindly answered the scouts' questions.

Scouts participating were Dakota Lambert, Max Farrow, Grant Uher, Gabriel Decker, Ryan Clouse, Trenten Brungardt and Wesley Groff. Typical of scouts, Paolo instantly became a real regular guy with them when they asked about his favorite food on board, and he responded that it was specially prepared lasagna from his home in Italy. I'm sure Paolo could get a sample of Dutch Oven Lasagna if he gets to Kansas City.

We had seven happy young men, but the real pleasure was watching the looks on their parents' faces when their son stepped up to the mic to ask his question of the astronaut.

The ARISS contact was conducted from the spotter's room in the press box high above the Kansas Speedway and fed through the PA system to all the attendees. Nothing like 13,000 people listening in to make you a little nervous.

The scouts who got to ask questions were very impressed with their view of the track. When asked of eight-year-old Gabriel whether he wanted to be an astronaut, a ham operator or a NASCAR driver, his very polite response was that being an astronaut or Ham operator was ok but being a NASCAR driver would be really fun!

The ARISS contact was live-streamed on the Heart of America Council - BSA Facebook page and carried live on the Fox 4 TV morning news show. Local TV channel 9 also showed footage.

We had quite a spread in our display in the pit garage. We specifically wanted to contrast ham radio's link to scouting from the earliest days. The boys saw semaphore flags (and had a chance to wave them thanks to Rob Stone), wig wag flags, Morse (with a couple of sounders to try their fists), a 1929 Grebe receiver, and a 1942 Wireless 19 Set. That was contrasted against other individual stations including a 40 meter QRP kit radio with an Arduino processor (see March 2016 QST), JT65, APRS, four SSB HF stations and three FM 2-meter stations.

We also had set up a PCsat32 satellite tracking software program to track the ISS, and a logging program on display. The JT 65, APRS, logging and satellite tracker were displayed on 65" monitors to make the screens easier to see.

The only real downside was the extreme difficulty hearing SSB even with the AF turned all the way up because of the crowd noise. Thanks to Nicola Thompson, KE0MUE, and Pat McCalmon, KE0MUF, we were able to get hundred + kids talking on FM. The take away was to use amplified loud speakers so the audience could hear well enough to communicate with responding stations.

Many thanks go to our sponsors, including Nebraska Furniture Mart, who loaned us the monitors (brand new out of the box), Associated Radio and DX Engineering. I also owe big thanks to Radio Scouting, especially Venture Crew #2273, the Ararat Shrine Radio Club, the Raytown Radio Club, the MOKAN Council of Amateur Radio Clubs of the Greater Kansas City Metropolitan Area, the ARRL, AMSAT and of course ARISS.

A very special thanks to my mentor from ARISS, Dr. John Kludt, K4SQC, and Tim Bosma, W6MU, and the Santa Rosa Community College Amateur Radio Club W6SRJ.

These things aren't accomplished without plenty of horsepower, and particular recognition goes to: Keith Kaiser, WA0TJT; Gary and Frances Adams, WA0BTM and KC0TFR; Jay Smith, N0TRI; Elizabeth Stone, KE0KCT; Mike Laney, KE0GHU; Jim Craft AD0AC; Herb and Dianne Fiddick, NZ0F and KD0OBP; James Thompson, K0JGT; Pearl Thompson, K7UNA; Hyrum Thompson, KE0MFZ; Ammon Thompson, K0WAT; Andrew Christensen, KE0JKA; and Thomas Laney, KE0OCA.

Ammon and Thomas had their handhelds and ran into a handful of young scout operators. There were no better ambassadors for Radio Scouting then these scouts who walked all over the event HT in hand. The future of the Amateur Radio Service is in good hands!


OIL RECYCLING

Support AMSAT

AMSAT is the North American distributor of SatPC32, a tracking program for ham satellite applications. Version 12.8c is compatible with Windows 7, 8/8.1 & 10 and features enhanced support for tuning multiple radios.

Version 12.8c features:

- SatPC32, SatPC32ISS, Wisat32 and SuM now support rotor control of the M2 RC-2800 rotor system.
- The CAT control functions of SatPC32, SatPC32ISS and Wisat32 have been expanded. The programs now provide CAT control of the new Icom transceiver IC-9100.
- The accuracy of the rotor positions can now be adjusted for the particular rotor controller. SatPC32 therefore can output the rotor positions with 0, 1 or 2 decimals. Corrections of the antenna positions can automatically be saved. In previous versions that had to be done manually.
- The tool "DataBackup" has been added. The tool allows users to save the SatPC32 program data via mouse click and to restore them if necessary. •
- The rotor interfaces IF-100, FODTrack, RifPC and KCT require the kernel driver IOPort.SYS to be installed. Since it is a 32-bit driver it will not work on 64-bit Windows systems.
- SuM now outputs a DDE string with azimuth and elevation, that can be evaluated by client programs. Some demo files show how to program and configure the client.

Minimum Donation is $45 for AMSAT members, $50 for non-members, on CD-ROM.
A demo version may be downloaded from http://www.dk1tb.de/indexeng.htm

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

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

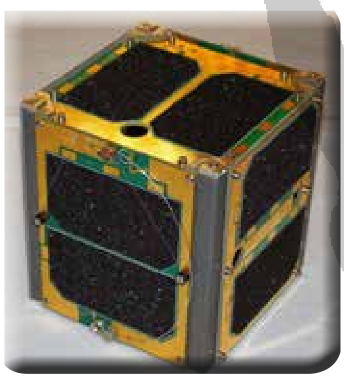
AMSAT is excited about the upcoming launch opportunities for the Fox-1Cliff and Fox-1D Cubesats. Fox-1Cliff and Fox-1D will provide selectable U/V or L/V repeater capabilities on separate frequencies once in orbit, and will be capable of downlinking Earth images from the Virginia Tech camera experiment.

AMSAT has an immediate need to raise funds to cover both the launch and related expenses for Fox-1Cliff and Fox-1D. We have set a fundraising goal of $125,000 to cover these expenses and help us to continue to keep amateur radio in space.

Fox-1Cliff will launch on Spaceflight's SSO-A dedicated rideshare mission aboard a SpaceX Falcon 9 scheduled to launch from Vandenberg Air Force Base in California in early 2018.

Fox-1D rode to orbit on an Indian PSLV vehicle launched from Satish Dhawan Space Centre in Sriharikota, India on January 12, 2018.

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



Your help is needed to get the AMSAT Fox-1Cliff and Fox-1D 1U Cubesats launched.

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

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

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

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

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

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

ARISS Development and Support

AMSAT's Human Space Flight Team is looking for volunteers to help with development and support of the ARISS program:

- Mentors for school contacts
- Support for the ARISS web
- Hardware development for spaceflight and ground stations
- Help with QSL and awards certificate mailing.

To volunteer send an e-mail describing your area of expertise to Frank Bauer at: **ka3hdo@amsat.org.**

AMSAT Internet Presence

AMSAT's information technology team has immediate needs for volunteers to help with development and on-going support of our internet presence:

- Satellite status updating and reporting.
- Add/delete satellites to ANS and the web as needed.
- Research and report satellite details including frequencies, beacons, operating modes.
- Manage AMSAT's Facebook and Twitter presence.

To volunteer, send an e-mail to Drew Glasbrenner, KO4MA at: **ko4ma@amsat.org**.

AMSAT Engineering Team

AMSAT Engineering is looking for hams with experience in the following areas:

- Attitude Determination and Control, and Thermal Engineering, to help in the design of high orbit CubeSats.
- Power systems, for CubeSats from 1U through 6U and LEO to HEO.
- Help with solar, power supply, and battery design for both LEO and HEO missions.
- Logistics, for parts procurement, inventory, and distribution.
- Documentation, for designs, tests, and public relations.

To volunteer, please describe your expertise using the form at **www.amsat.org/contact-amsat-engineering/.**

AMSAT User Services

AMSAT is looking for an on-line store co-manager to update and refresh the AMSAT Store web page when new merchandise becomes available or prices and shipping costs change.

- Add new merchandise offerings
- Delete merchandise no longer available
- Update shipping costs as needed
- Add periodic updates for event registrations
- Interface with the AMSAT Office

To volunteer, send an e-mail to Joe Kornowski, KB6IGK at: **kb6igk@amsat.org**

AMSAT Educational Relations Team

AMSAT's Educational Relations Team needs volunteers with a background in education and classroom lesson development ...

- Engage the educational community through presentations of how we can assist teaching about space in the classroom.
- Create scientific and engineering experiments packaged for the classroom.
- Create methods to display and analyze experimental data received from Fox-1.

To volunteer send an e-mail describing your area of expertise to Joe Spier, K6WAO at: **k6wao@amsat.org**.

AMSAT Field Operations

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

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

To volunteer, send an e-mail to Gould Smith, WA4SXM at: **wa4sxm@amsat.org**

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