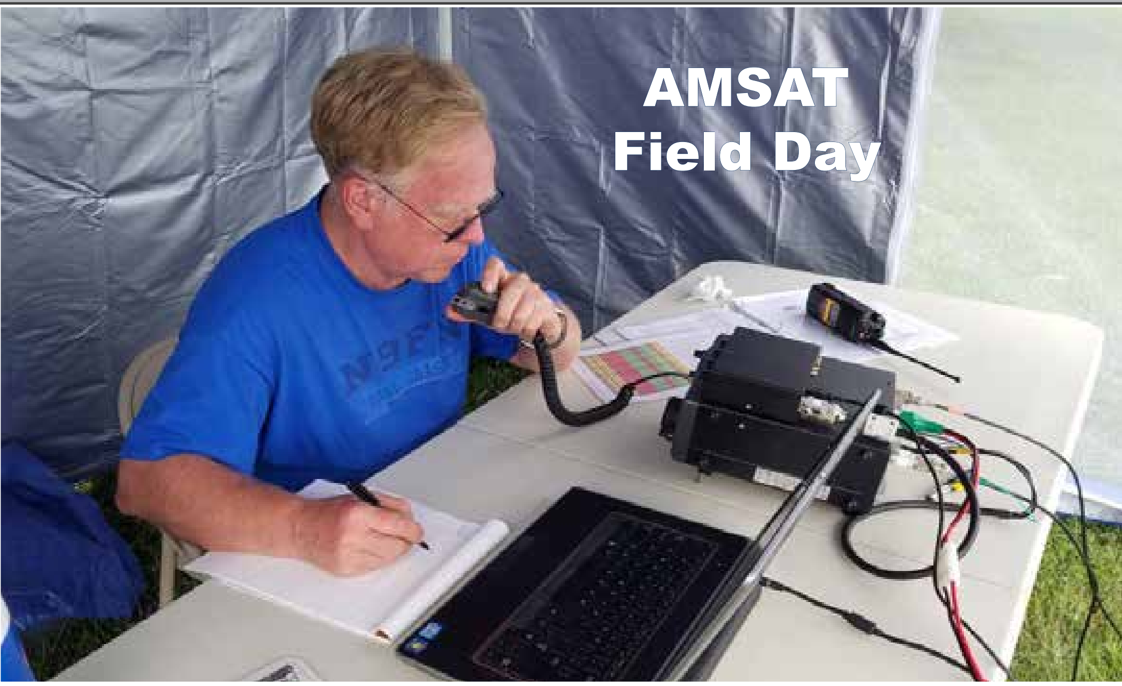
The AMSAT® Journal

Editor-in-Chief
Joe Kornowski, KB6IGK

Assistant Editors
Bernhard Jatzeck, VA6BMJ
Douglas Quagliana, KA2UPW/5
W.M. Red Willoughby, KC4LE
Paul Graveline, K1YUB

Volume 41, Number 4 July/August 2018



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

2018 AMSAT Space Symposium, November 2-4

AMSAT announces that the 2018 36th Annual AMSAT Space Symposium and General Meeting will be held on **Friday through Sunday, Nov. 2-4, 2018, in Huntsville, Alabama**. Location will be at the U.S. Space and Rocket Center, One Tranquility Base, Huntsville, Alabama (www.rocketcenter.com). Hotel accommodations will be next door at the Marriott at the Space & Rocket Center, 5 Tranquility Base, Huntsville, Alabama. Feature include:

- Space Symposium with Presentations
- Operating Techniques, News, & Plans from the Amateur Satellite World
- Board of Directors Meeting open to AMSAT members, to be held at the Marriott at the US Space and Rocket Center.
- Opportunities to Meet Board Members and Officers
- AMSAT Annual General Membership Meeting
- Auction, Annual Banquet, Keynote Speaker and Door Prizes !!

Our keynote speaker this year will be announced at a later date.

- Multiple activities/attractions in the Huntsville area.
- Huntsville Botanical Garden, Monte Sano State Park
- U.S. Veterans Memorial Museum, Von Braun Center
- Tours of Redstone Arsenal and Marshall Spaceflight Center (TBD).

The Marriott is located at 5 Tranquility Base, Huntsville, AL. Amenities include: Free parking for attendees, complimentary WiFi.

Hotel reservations may be made by attendees directly with Marriott reservations at 1-(800) 228-9290 or (256) 830-2222. Please mention the Radio Amateur Satellite Corporation (AMSAT), Reference Number M-BIHHXTA.

Attendees may also make their reservations online at **amsat.org**.

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.

Radio Amateur Satellite Corporation (AMSAT-NA)
10605 Concord St., Suite 304, Kensington, MD 20895-2526
Telephone: 301-822-4376 – Toll Free: 888-322-6728
Facsimile: 301-822-4371
AMSAT-NA Club Callsign: W3ZM
AMSAT-NA Web site: http://www.amsat.org

The AMSAT Journal Staff
Editor-in-Chief: Joe Kornowski, KB6IGK, kb6igk@amsat.org
Assistant Editors:
Douglas Quagliana, KA2UPW/5
Bernhard Jatzeck, VA6BMJ
W. M. Red Willoughby, KC4LE
Paul Graveline, K1YUB
Circulation: Martha Saragovitz, martha@amsat.org

AMSAT-NA Board of Directors
Jerry Buxton, N0JY, n0jy@amsat.org
Tom Clark, K3IO, k3io@amsat.org
Drew Glasbrenner, KO4MA, ko4ma@amsat.org
Mark Hammond, N8MH, n8mh@amsat.org
Bruce Paige, KK5DO, kk5do@amsat.org
Paul Stoetzer, N8HM, n8hm@amsat.org
Clayton Coleman, W5PFG, w5pfg@amsat.org
Alternate: Peter Portanova, W2JV, w2jv@amsat.org

AMSAT-NA Senior Officers
President: Joe Spier, K6WAO
Executive Vice-President: Paul Stoetzer, N8HM
Treasurer: Keith Baker, KB1SF/VA3KSF
Secretary: Clayton Coleman, W5PFG
Manager: Martha Saragovitz
Vice President, Engineering: Jerry Buxton, N0JY
Vice President, Operations: Drew Glasbrenner, KO4MA
Vice President, User Services: Open
Vice President, Human Spaceflight: Frank Bauer, KA3HDO
Vice President, Educational Relations: Alan B. Johnston, KU2Y

Honorary Positions
Immediate Past President: Barry Baines, WD4ASW
President Emeritus: Tom Clark, K3IO
Founding President: Perry Klein, W3PK

Editorial Office: Joe Kornowski KB6IGK, 5317 Musket Ridge, Austin, TX 78759. Please e-mail Journal submissions to: journal@amsat.org, Editor's telephone: 512-574-1233 (cell). Advertising Office: AMSAT-NA Headquarters, 10605 Concord St., Suite 304, Kensington, MD 20895-2526, Telephone: 301-822-4376.

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

The main news for AMSAT that came out of Hamvention this year was the announcement of this year's 36th Annual AMSAT Space Symposium and General Meeting to be held Friday through Sunday, November 2-4, 2018, in Huntsville, Alabama. The location will be at the U.S. Space and Rocket Center, One Tranquility Base, Huntsville, Alabama (**www.rocketcenter.com**). Hotel accommodations will be next door at the Marriott at the Space & Rocket Center, 5 Tranquility Base, Huntsville.

Hotel reservations for the Symposium may be made by individual attendees directly with Marriott reservations at 1-(800) 228-9290 or (256) 830-2222 (be sure to mention Radio Amateur Satellite Corp.) or use the weblink on the AMSAT Symposium page. This year the Symposium Proceedings will be provided on a USB stick. If you would like a printed copy, the cost will be an additional $20. The price for the Symposium is $60 each, and the banquet tickets are $50 per person, available through the AMSAT Store. Student admission to the Symposium will be $30 and must be coordinated through me. Student admission will only be to the paper presentations.

The second major announcement at Hamvention was the ARISS FundRazr kickoff to enable the ARISS radio upgrade on ISS for student outreach. ARISS is in critical need of an infrastructure update to ensure that programs like students talking to astronauts in space via amateur radio can continue. Through your donations, ARISS seeks the following upgrades:

- Next Generation radio system to support easier radio mode transition, enabling new, exciting capabilities for hams, students and the general public including:
    - New amateur radio communication and experimentation capabilities, including an enhanced voice repeater and updated digital packet radio (APRS) capabilities;
    - Slow-Scan TV (picture up and downlinks) in both the U.S. and Russian segments of ISS;
- New multi-voltage power supply will support present and future radio capabilities and allow wireless experiments to be conducted.

ARISS needs to build 10 Next Generation radio systems to support our development, on-orbit operations, training and long-term maintenance. This includes units on-orbit (2 units--1 unit each in U.S. and Russian segment), flight spares (2 units), training (3 units), testing (1 unit) and ground-based maintenance & troubleshooting (2 units).

Donations are fully tax deductible within the U.S. under AMSAT's status as a 501(c)(3) organization. Go to **fundrazr.com/find**, enter ARISS in the search box, and select the "ARISS Radio Upgrade..." campaign.

At Hamvention, AMSAT also received a generous donation of $5000 from the Dayton Amateur Radio Association (DARA). DARA is the leading group that hosts Hamvention and is a longtime supporter of AMSAT and all things amateur radio. Paul Stoetzer, N8HM, AMSAT Executive Vice President, and Keith Baker, KB1SF/VA3KSF, AMSAT Treasurer, and I were invited to the DARA Banquet honoring the 2018 Hamvention Award winners. These included:

- Club of the Year: The Portage County Amateur Radio Service
- Amateur of the Year: Valerie Hotzfeld, NV9L
- Technical Achievement Award: Chip Cohen, W1YW
- Special Achievement Award: Heriberto Perez, KK4DCX; Victor Torres, WP4SD and Emilio Ortiz JR, WP4KEY.

It was especially poignant to hear the accounts from our fellow hams in Puerto Rico who were on the ground initially and passing message traffic after Hurricane Maria. Other attendees included officials from DARA, the ARRL, and the Sheriff of Greene County, who is also an amateur radio operator.

I have to thank Phil Smith, W1EME for his exceptional job in championing the setup of the AMSAT booths at Hamvention. This was Phil's first year as AMSAT's Hamvention Coordinator after working with Steve Belter, N9IP, for many years. Phil and I had a chance to discuss plans for next year's Hamvention since that will be AMSAT's 50th Anniversary, and you don't want to miss that one!

I also had a booth set up at the SEA-PAC Pacific Northwest event, met with many AMSAT members and signed up a few new ones. I was back in Reno, NV, for NVCON at the Boomtown Casino Hotel July 20 through 22. The AMSAT table was busy, and I gave a presentation on "Satellite Operating 101." I also delivered the keynote address at the Saturday evening banquet on AMSAT Youth Outreach. I focused my remarks on ARISS, my proclivity to "Throw a CubeSat" at younger attendees at ham events, and family amateur radio activity.

Further out towards September 21-23, I'll be one of the hosts for the AMSAT Academy at the 2018 Duke City Hamfest/ARRL Rocky Mountain Division Convention in Albuquerque, New Mexico, along with Skyler Fennell, KD0WHB, and Bill Ripley, KY5Q. In October, I'll attend the AMSAT-UK Colloquium, ARISS-I, followed by the Symposium in Huntsville, AL.

The final comment period for the Federal Communications Commission Notice of Proposed Rulemaking In the Matter of Streamlining Licensing Procedures for Small Satellites (International Bureau Docket #18-86) ended August 7th. AMSAT's comments were submitted to remind the Commission that Part 97 Amateur spectrum is a key issue for all users of the Amateur Satellite Service. The ARRL submitted similar comments.

The AMSAT Board of Directors recently voted that all social media needed to be unified under the direct control of the corporation. The Official AMSAT Facebook Group is now located at:
www.facebook.com/groups/AMSATNA/.

AMSAT Vice-President, Educational Relations, Alan Johnston, KU2Y, has been working with Pat Kilroy, N8PK, on the CubeSat Simulator Project proposed at last fall's Symposium in Reno. Pat has secured assistance from NASA Goddard in the form of student intern help this summer. The team has already reviewed the Mark Spencer, WA8SME, CubeSat simulator design and programming and has begun the next steps for the design of a version 2.0. Through donations and funding, they have acquired the digital transceiver for the Raspberry Pi provided by Jonathan Brandenburg, KF5IDY, as the base for the simulator. They expect to have three prototypes developed by the time of the Symposium in Huntsville.

Lee McLamb, KT4TZ, Senior Editor, AMSAT News Service has resigned after many years producing and shepherding the weekly ANS. As I came from being an ANS weekly rotating editor, I know what dedication it takes to produce the ANS. I want to thank Lee for his over 15 of service to AMSAT, including his roles as AMSAT Executive Vice President, and board of directors alternates. Lee will continue to serve the amateur satellite community as an advisor to Region 2 of the Amateur Radio Satellite Frequency Coordination panel of the IARU.

William "Bill" Tynan, W3XO, has stepped down as the AMSAT OSCAR Number Administrator citing poor health. Bill has been granting applicants who qualify OSCAR numbers for over two decades since the late-1990's. Even Bill cannot remember the first number he issued but believes it was either TO-31 or SO-35. In any case, he has issued at least 57 OSCAR numbers. This is over 60%, or very close to two-thirds, of all the OSCAR numbers issued. I have named Drew Glasbrenner, KO4MA, AMSAT Vice-President of Operations from New Port Richey, FL, as the new AMSAT OSCAR Number Administrator.

AMSAT has two more Fox series CubeSats ready for launch by the end of the year (if schedules hold), and development on GOLF is proceeding. But it takes funding, including donations and contributions, to build and launch our satellites, so please give what you can. 73-Joe, K6WAO

From the Editor — Digital Developments

Joe Kornowski, KB6IGK
Editor

The use of digital modes in amateur radio has grown dramatically in recent years. One of the newest modes, FT8, developed by Joe Taylor, K1JT, and Steven Franke, K9AN, and incorporated in WSJT-X, has gained phenomenally rapid adoption within the amateur radio community. As of March 2018, Taylor reported that FT8 usage globally hovered around 15,000 users per week. Club Log reported that, by the end of 2017, FT8 represented more than half of the QSOs uploaded to Club Log. For the full year, of the 32 million QSOs uploaded, 5 million were FT8.

According to the ARRL, "For newcomers, data emissions are far more popular than telegraphy" (Petition to FCC for Rule Making, February 2018). Inevitably, computer generated data "bits" have now overtaken "dahs" and "dits."

This trend may be reflected in anecdotal data from the 2017 *AMSAT Journal* readers' survey in which a couple of young aerospace engineers characterized the notion of real-time, two-way voice communication as passé, explaining that young engineers expect current technology to be digital and delay-tolerant. For them, working satellites in real-time simply requires too much planning and time commitment for their busy schedules. Having a digital station setup to remotely and automatically exchange data via satellites makes more sense to them.

Creating innovative ways to develop and operate digital satellite communications might help inspire the next generation amateur radio satellite enthusiasts. In this of issue of *The AMSAT Journal*, we begin to take a look at the state of digital modes on amateur radio satellites.

For some time, several satellites have enabled QSOs via digital/packet modes. The more commonly used International Space Station, NO-84 (PSAT) and FalconSAT-3 carry digipeaters for APRS/packet messaging support; 2 meters on ISS and NO-84, and 2 m/70 cm on FalconSAT-3. Operators easily can access these low earth orbit digipeaters with a handy talkie (HT) and a handheld Elk or Arrow antenna, or sometimes even a whip antenna. Additionally, NO-84 enables

PSK31 communications, while FalconSAT-3 offers a BBS that requires decoding with the WiSP software suite.

In the "BIRDS-2" report, we learn that a new constellation of three APRS CubeSats will be deployed in early August. On June 28, 2018, the Joint Global Multi-Nation Birds Satellite project ("Birds project") — a cross-border interdisciplinary satellite project for non-space faring countries that includes Japan, Ghana, Mongolia, Nigeria and Bangladesh — launched three CubeSats to the International Space Station for August deployment. The mission of the BIRDS-2 constellation of MAYA-1, BHUTAN-1 and UiTMSAT-1 is to (1) provide digital message relay service to the amateur radio community using an APRS digipeater and (2) demonstrate a store-and-forward (S&F) system.

Bob Bruninga, WB4APR, in his article, "Unique Features of PSAT2 and QIKCOM2," provides an update to his previous report from the March/April 2016 issue of the *Journal*, which focused on the new modes for APRS satellites PSAT2 and QIKCOM2, including a new VHF DTMF grid/message uplink on PSAT2 with a voice/APRS downlink. Such enhancements hopefully will make it easier for operators using PSK31 and those using simple DTMF HT radios to communicate position and text from anywhere.

Finally, in "Tuskegee University Amateur Radio Station — VHF/UHF Digital Communication with Legacy Systems," the Department of Aerospace Science Engineering describes how they built a ground station primarily intended for tracking amateur radio satellites and downlinking data from Pico/Nano/Micro satellites and CubeSats. The team's creative use of inexpensive equipment and components provides a cost-effective approach that other schools might consider following.

Engineering Update

Jerry Buxton, N0JY
Vice President, Engineering

2018 – The Year of the Fox

On July 11, 2018, I presented the Mission Readiness Review (MRR) for RadFxSat-2/Fox-1E in Chantilly, VA. Review panel members from the integrator, TriSept, and our ELaNa launch provider, NASA LSP, gave the thumbs up to the steps and artifacts that I presented to demonstrate that we are ready for integration and launch.

As such, the last of the Fox-1 series of five CubeSats is officially completed and, given the current launch schedules for Fox-1C and RadFxSat-2/Fox-1E, this should be "The Year of the Fox" with "3 in 2018!" (a tongue in cheek nod to the Hamvention 2015 t-shirt design).

If 2018 actually does see the launch of three Foxes, with Fox-1D (AO-92) in January and the other two before the end of the year, it would be a fitting closing to the eight years since the inception of the Fox program in 2010 through the launch of the final bird. The accomplishment is tremendous, even more so given our all-volunteer "workforce" with over 100 hams involved over the course of the program.

And it is the tireless dedication of a core group of those volunteers that has brought the program to a successful conclusion, at least in the sense that we have three operating Fox-1 satellites and two that are operationally ready to go. While I have shared some of the activity that goes on in the process of building a satellite through this column, presentations, and my YouTube channel, what I've shared is the tip of the iceberg of what it takes to put a working and robust satellite designed to last a decade or more into orbit and operating (mostly) "nominally." The efforts of the entire Fox-1 team should be applauded by all AMSAT members and non-members alike, with special thanks given to those who have seen it through to the end.

Fox-1 was AMSAT's first CubeSat. In the words of former VP of Engineering, Tony Monteiro AA2TX (SK), from an article he wrote in 2010, "While AMSAT has pioneered the development of small, low-cost satellites, the CubeSat concept takes this idea even farther (and smaller!). Our AO-51 satellite is a relatively tiny 10-inch cube that weighs less than 25 pounds. A basic CubeSat, on the other hand, is an even smaller 4-inch cube and weighs less than 3 pounds. AMSAT has adopted the CubeSat idea for our next satellite project to take advantage of the low launch costs. The small size, however, does pose some interesting design challenges."

For those of you who have seen the Fox-1 "life-size model" at Hamvention or a local hamfest, the size of a 1U CubeSat is amazing, and the amount of functionality and space-hardiness that AMSAT crammed into a Fox-1 is a marvel. No less than 9 printed circuit board (PCB) systems are "carefully crammed" onto their own 4-inch PCB stacked with just 8 mm between the systems. For those of you who are metrically challenged like I am, that's less than 3/8 inch between boards!

Entire systems reside on a single board. From the –Z ("bottom") to +Z ("top") ends, the stack consists of the FM transmitter (1A-D) or the full transponder (1E), the FM receiver (1A-D) or the Improved Command Receiver (1E), Integrated Housekeeping Unit (IHU), PSU (MPPT), battery (taking two PCB levels), and four experiment slots hosting a variety of experiments from university partners and AMSAT (e.g., our own L-band downshifter).

Although you might think that the PCB in a modern HT, for example, is much smaller than the 4-inch transmitter board in Fox, when you consider the thermal requirements, radiation effects and shielding, and outgassing properties of components the HT would very likely not last the decade in space intended by AMSAT's designs. While the cost of a Fox-1 spacecraft is negligible in the real world of satellites, we all want our satellites to be orbiting and operating as long as possible, right up to re-entry.

Figure 1 — Map of AO-85 resets [Courtesy of www.qsl.net, KA2UPW, NASA and Google Maps].

With the miniaturization readily available and required in CubeSats comes the increased risk of failure due to the environment mentioned above. That requires that we proceed with caution and risk mitigation through the careful consideration of components that will both fit the footprint and provide a margin of risk mitigation to achieve the desired operational lifetime of the satellite. Hence, we avoid creating a radio on a chip which includes all of the systems and is subject to catastrophic failure as one unit, rather than the distributed architecture of the Fox-1.

For example, Fox-1 is designed to work without the IHU. Of course, the IHU is highly desired and provides a lot of the satellite's functionality, from telemetry to the various operating modes to the operation and telemetry of the science experiments. But in the design of our first CubeSat, we anticipated and later actually observed that the IHU would suffer "upsets" from radiation while passing through the South Atlantic Anomaly (SAA). Discussion of options ranging from designing the IHU to reset every orbit that passed through the SAA to only an annual reset was part of the overall IHU software design process, and more so the IHU hardware and its effect on and control over the rest of the satellite.

As anyone keeping score may have noticed, AO-85 is up to reset number 776 as of this writing. That number is hugely inflated by a series of several hundred resets shortly after launch, but it is extremely regular and actually provides a job and fun for one of our dedicated AMSAT retirees. You can see on a map of the AO-85 resets (Figure 1) how the majority undoubtedly occur in the SAA (**www.qsl.net/ka2upw/ao85_reset_map.html**).

To that end, Fox-1 software is designed merely to store critical variables in static MRAM (magnetoresistive random access memory) and, when a stray particle or other system event causes a reset, the IHU simply reboots, reads the latest states from the MRAM, and continues where it left off. Additionally, the hardware is designed such that the radio (FM or transponder) will operate as long as there is power in an autonomous state, much like a terrestrial repeater, when the IHU is not working. There is evidence of reset events where stations may have been in QSO at the time of the reset but quite likely never noticed the event because the radio kept working while the IHU rebooted.

Vanderbilt University, our partner with experiments on Fox-1A, Fox-1B, Fox-1C, and Fox-1E, provides a wealth of information on commercial off-the-shelf (COTS) components in our current low Earth orbits. This improves everyone's knowledge of what the environment is like and how components are affected, helping us understand the choices in components based on risk and cost.

Such basic but important steps are a vital part of the Fox-1 program in that, as AMSAT has always done, we are learning from the designs and the function of our first CubeSats. Failures are undesirable of course, but certainly not unexpected, because space is a totally nasty environment even for million dollar satellites. Every event, whether a success or failure or total head-scratcher event, is part of our process of building satellites and "keeping amateur radio in space."

Eight years is a long time to all of the ham satellite enthusiasts wanting and waiting to work with new satellites, but that is a remarkably short time in the overall process of conceiving, funding, building, and securing launches for satellites by a group of those same hams. Looking back, the seven years that I have been with AMSAT Engineering is a long time, but in the cycle of each Fox-1 satellite that we build during that period, it was always barely enough!

AMSAT members should celebrate the accomplishment of the Fox-1 program upon the launch of our last two Fox-1 birds, whether you have been here for the duration or are a new member just getting into this exciting part of the hobby.

This effort will continue, with some of the same and many new volunteers, into the GOLF program. What we have learned from Fox-1 will make GOLF better. Also, the new opportunities of higher orbits open the door to further experimentation with systems and in new and nastier environments. We build upon our experience and look forward to bringing in new adventures as we proceed on our course of growing our CubeSat capability and continuing the successful deployment of amateur radio satellites. AMSAT has been building satellites to fit whatever space/size is (affordably) available on a launch vehicle for 44 years going back to OSCAR 1. CubeSats are that new affordable size and shape, and so we continue our heritage.

While I don't believe I can fully impart or explain the activity or amount of work (and fun!) that goes into building amateur radio satellites, I hope that you will seriously consider your ability to help out with the next one. Circuit design, PCB layout, software, and soldering are just part of the process; additional needs include documenting, inventory, scheduling, and a host of others.

More volunteers also means less time required of any particular system volunteer. While we all dearly like to deliver new satellites for everyone, we reach our limits sometimes, and also put at risk our mission success when only a handful of volunteers carry the load and responsibility. Since the projects are long-term, spanning several years, we must keep the work fresh and fun for everyone.

I hope you enjoy all of the Fox-1 birds and the accomplishments of this excellent amateur radio organization to which you belong, and support!

Educational Relations Update

Alan B. Johnston, KU2Y
Vice President, Educational Relations

I am honored to be writing my first *AMSAT Journal* column as Vice President of Educational Relations. I look forward to helping inspire the next generation of students to become enthusiasts of amateur radio satellites, just as I was as a teenager many years ago.

My father, Frank, KA2ORW (SK), introduced me to amateur radio when I was in my early teens. We studied together and got our ticket at the same time. After some HF contacts, I was excited to discover amateur radio satellites and actively worked AO-8 during an early 1980's summer in New Jersey, using homebuilt turnstile reflector and full-wave loop antennas. My amateur radio and satellite hobby led me to become an electrical engineer. Recently, through my teaching at Rowan University, I have become active again, and it has been fascinating to see what has changed and what has stayed the same.

Certainly, the number of amateur radio satellites has increased substantially. At least one satellite always seems to be overhead these days instead of having to wait hours for the next pass. The AMSAT Communication Satellites website page, **www.amsat.org/two-way-satellites** (Figure 1) shows 6 FM, 13 linear, and 5 digital satellites in operation. The FM birds are quite different to work than the linear ones in earlier days. Doppler shift is less of a problem, but congestion is definitely an issue. With regards to overcrowding, I'd say we have become victims of our own success with so many currently active and enthusiastic satellite operators! So far, I have enjoyed making contacts on AO-85 and AO-91, including one during Field Day.

All of my satellite QSOs years ago were CW, so I now enjoy hearing voice. Instead of using an OSCARLOCATOR (I still have mine, see Figure 2) and looking up EQX (equatorial crossing) data printed in a magazine, we now use online tools or tracking software such as SATPC32 or MacDoppler (don't forget to update your TLE!) and see the footprint on the digital map.

Thanks to the magic of SDR and waterfall visualization, instead of scanning the band listening for downlink activity, I can see the band light up on my computer screen. I am amazed that a twenty-dollar USB SDR device performs so well in combination with excellent open source software.

I came across some of my hand-copied CW telemetry notes from AO-8 and RS3 through RS8 from that summer. I find copying and decoding satellite telemetry still exciting. Instead of hand decoding, today many tools are available. Great software such as FoxTelem decodes and automatically uploads the telemetry data for the Fox series satellites to AMSAT servers for analysis. The Fox Telemetry Leaderboard (**www.amsat.org/tlm/**; see Figure 3) shows over 500 stations that have successfully uploaded telemetry data. This is pretty amazing! I really like the feature that shows the latest uploaders so you can see your own callsign after uploading.

FM Repeater Satellites

- SO-50 (SaudiSat-1C)
- AO-85 (Fox-1A)
- AO-91 (RadFxSat / Fox-1B)
- AO-92 (Fox-1D)
- LilacSat-2 (CAS-3H) Transponder activations sporadic
- IO-86 (LAPAN-A2) In equatorial orbit, activations by schedule

Transponder Satellites

- AO-7
- FO-29 (JAS-2)
- AO-73 (FUNcube-1)Transponder active in eclipse on weekdays, full-time on weekends
- XW-2A (CAS-3A)
- XW-2B (CAS-3B)
- XW-2C (CAS-3C)
- XW-2D (CAS-3D)
- XW-2F (CAS-3F)
- EO-79 (QB50p1 and FUNcube-3) Transponder is currently offline
- UKube-1 (FUNcube-2)
- LO-87 (LUSEX / ÑuSat-1) Transponder active sporadically over Europe and Latin America
- EO-88 (Nayif-1 / FUNcube on Nayif-1) Transponder active in eclipse only
- CAS-4A
- CAS-4B
- UBAKUSAT Transponder not yet active

Digital Satellites

- FalconSAT-3
- NO-44 (PCsat) Sporadically active
- NO-84 (PSAT) PSK31 active continuously / Digipeater when power permits
- LilacSat-1 FM up / Codec2 digital voice down
- IO-86 (LAPAN-A2) In equatorial orbit, activations by schedule
- ISS Frequency Summary
- ISS HamTV

Re-entered or Inoperative Satellites

- LO-75 (Cape-2) Now re-entered
- VO-52 (Hamsat) Now end of mission
- FO-82 (Shin'en-2) Now in solar orbit
- LO-78 (LituanicaSat-1) Now re-entered
- XW-2E (CAS-3E) Non-operational

Figure 1 — Communication Satellites, www.amsat.org/two-way-satellites.

Figure 2 — 1981 OSCARLOCATOR setup for an AO-8 pass over New Jersey.

AMSAT

Fox-1D Telemetry Leaderboard

Num	Ground station	DUV Frames	9k6 Frames	Total	Last 7 days
1	SP8CGR	80,365	0	80,365	2,709
2	WA4SCA	59,010	1,310	60,320	2,355
3	WA7FWF	52,166	169	52,335	2,499
4	G7WIQ	51,759	0	51,759	1,017
5	SQ5WAF	47,388	0	47,388	1,850
6	N7DJX-DN13	47,199	107	47,306	1,394
7	K4OZS	45,999	942	46,941	1,576
8	N8MH	35,133	893	36,026	1,240
9	OM3BC	34,495	0	34,495	0
10	wc7v-dn46	33,105	69	33,174	2,123
165	KU2Y	91	180	271	190

Fox-1D | latest spacecraft health | Camera Images
Frames: 54,007 - last 24 hours: 6,633 - last 90 mins: 477
From ground stations:
KB5SQG WA4SCA NF0T KB6LTY KU2Y K4OZS WA7FWF KO4MA wc7v-dn46 NA5SS AK7WS W7YD W7QL W1EME AC2CZ R2ANF VTGS K1ECU@ARRLHQ KM6LYV

Show all ground stations | Show all spacecraft | Include Ground station: Clear

Figure 3 — FOX Telemetry Leaderboard for Fox-1D AO-92 after a camera image pass (www.amsat.org/tlm/).

Figure 3 shows the telemetry status for Fox-1D AO-92 after a camera image activation pass in mid-July that showed 477 frames of telemetry data uploaded in the previous ninety minutes. The educational uses for this spacecraft data are seemingly endless (look for a future article on this topic).

Making contact on Twitter after a satellite QSO is new to me and great fun. Social media can really add to the enjoyment of our hobby and help build the amateur radio community. Search for #amsat and #hamradio on Twitter to find us! It is just another way to exchange 73's with fellow amateurs.

As for the rest, I'm still learning. So much is new, including grid chasing, roving and gridline and square activations. I have even heard some Walmart associates on the air, likely part of the WMPLOTA event.

Much has changed, and for the better, I'd say. One thing that has not changed, unexpectedly, is AO-7, which, as I was amazed to learn, came alive again a few years ago. I was very excited to pick up the weak "hi hi" of the telemetry signal a few weeks ago. I have sent some CQs on this venerable old bird and look forward to a future AO-7 QSO.

Another aspect that has not changed, and never will, is the excitement of hearing the bird when it comes over the horizon, right on schedule! AMSAT is a fantastic community that has designed, launched, and operated these satellites, and I am very proud to be able to make a contribution to the effort on the educational front.

I am in the process coming up to speed on so many of the AMSAT educational projects and plan to provide updates on their progress in the coming months. I am pleased to report right now that work is underway on the next generation of the CubeSat Simulator, thanks to Pat Kilroy, N8PK, and his interns Quest, Onyeo and Nico, at NASA Goddard in Greenbelt, Maryland. We hope to do some demos at the AMSAT Space Symposium in November.

I look forward to meeting and interacting with many of you, especially if you are a teacher or an educator or are interested in reaching out to schools to share your hobby. If you have experience or interest in integrating amateur radio satellites into STEM education at any level, I would love to talk to you. Feel free to contact me at **ku2y@amsat.org** or on Twitter @alanbjohnston. See you on the birds!

Birds-2 Project: APRS CubeSats Deploy in August

The Joint Global Multi-Nation Birds Satellite project ("Birds project") is a cross-border interdisciplinary satellite project for non-space faring countries supported by Japan, along with Ghana, Mongolia, Nigeria and Bangladesh. During this two-year project, students shall design, develop and operate five units of identical 1U CubeSats (1 kg, 10 cubic cm) belonging to the five participating countries and operated from seven ground stations (one ground station in each of the five participating countries as well as Thailand and Taiwan), form for the first time a constellation of five CubeSats operated by seven networked ground stations. The project is being executed by fifteen students from six of the seven participating countries. The students are enrolled as Master or Doctoral degree students in Space Engineering International Course at the Graduate School of Engineering of the Kyushu Institute of Technology, supported by four faculty members. This project, which won the 2017 GEDC Airbus Diversity Award, is intended to provide students from developing nations an opportunity to engage in a hands-on satellite project.

The June 29, 2018, SpaceX Falcon 9 launch of the Dragon cargo capsule included CubeSats of the BIRDS-2 satellite constellation. All CubeSats in the BIRDS-2 constellation MAYA-1, BHUTAN-1 and UiTMSAT-1 have identical designs and utilize the same radio frequencies. While independently made, the operation and control of the three CubeSats will be shared by the three teams after they are released from the ISS early in August. The satellites will be operational for six months.

"The three will form a constellation, orbiting the Earth from different places. This will provide the countries with more opportunities to make measurements and run experiments than just with using one CubeSat," explained Joel Joseph Marciano Jr., manager of the PHL-Microsat program in the Philippines.

The primary mission of BIRDS-2 CubeSat constellation is to provide digital message relay service to the amateur radio community using an APRS digipeater onboard. The APRS digipeater onboard BIRDS-2 CubeSats will use 145.825 MHz for both receive and transmit, which is a standard configuration used by other satellites such as ARISS and LAPAN-A2.

Another mission of the BIRDS-2 CubeSat constellation is to demonstrate a store-and-forward (S & F) system. The goal of this mission is to investigate technical challenges through experiments on appropriate data format, multiple access schemes, and file-handling protocol while complying with limited operational time and power constraints.

The BIRDS-2 CubeSat S&F system will collect data from remote ground sensors, store them onboard and download them to the different ground stations in the BIRDS-2 network.

Additional experiments will use the BIRDS-2 CubeSat constellation to enhance research and conduct experiments in the fields of single latch-up event detection, magnetic field measurements using a commercial off-the-shelf (COTS) anisotropic magnetometer, and flight testing of a COTS GPS chip which can be used for future CubeSat missions if proven effective. Students also will explore a passive attitude stabilization mechanism consisting of magnets and hysteresis dampers for proper orientation of a camera on a CubeSat. All measurements and image data will be shared with the public on the BIRDS-2 project website.

The BIRDS-2 CubeSat constellation will expand amateur radio communication experiments on the operation of CubeSat constellations via a network of UHF/VHF amateur radio ground stations (started in the BIRDS-1 CubeSat constellation project). BIRDS-2 hopes to promote awareness of amateur radio communication and amateur satellites among the general public and students, especially in the participating nations of the BIRDS-2 Project: Bhutan, Malaysia, Philippines, and Japan.

The IARU has coordinated 437.375 MHz CW beacon for downlink and 145.825 MHz for the APRS experiment.

Philippine news coverage of MAYA-1 can be accessed at **tinyurl.com/ANS-BIRDS2-cubesats.**

Visit the BIRDS-2 website at **birds2.birds-project.com/.**

Unique Features of PSAT2 and QIKCOM2

Bob Bruninga, WB4APR
US Naval Academy
WB4APR@amsat.org

Abstract

This article updates the *AMSAT Journal* article of Mar/April 2016, "APRS Satellites, PSK31 and DTMF/Voice." That article focused on the new modes for APRS satellites which include ten-meter PSK31 uplink with UHF FM downlink built by Tomas Urbanec, OK2PNQ, and Ales Povalac, OK2ALP, from Brno University in the Czech Republic, which is now flying on PSAT (NO84) and will fly on the upcoming PSAT2 which is manifested on the SpaceX Heavy launch scheduled for October. For PSAT2, they added an SSTV camera that can fit into the same UHF FM audio downlink at the same time. Exciting additions include the new VHF DTMF Grid/message uplink with Voice/APRS downlink on PSAT2, as well as the QIKCOM2 module also scheduled for a host this fall. Finally, we will cover a few tricks we use to keep these student project satellites easy to build and flexible in design.

Late Update: As of July, the power cord to QIKCOM2 (finished in 2016 and fully integrated with its host spacecraft) will been cut and the host will fly it as a dead mass because the FCC refused to process our license filing for two years, maintaining that students at the Naval Academy cannot build an amateur payload without processing via the federal NTIA. This added requirement on the host spacecraft to have to re-do its NTIA filing to accommodate this minor payload was too-little-too-late and an unacceptable (but understandable) risk to the host. [note: we do have a 2nd flight model still looking for another host].

APRS Single Card Command and Control and User Transponder

The main transponder on both PSAT/PSAT2[1] and QIKCOM-2[2] is the traditional 1200 baud AX.25 packet radio relay similar to what has been flying on PCSAT[3] since 2001 and the ARISS experiment on the ISS[4]. Both of these missions deliver packets to users worldwide via the global network of volunteer ground stations available live on, **pcsat.findu.com** for PSATs and **ariss.net** for the ISS. These pages display live maps of the most recent user position data and capture all message traffic between users. These latest APRS transponder and satellite command and control systems rely on a Byonics.com MTT4B micro tracker condensed down onto single CubeSat sized 3.5" square card shown in Figure 1.

We want to maintain as many space digipeaters as possible on the space packet frequency of 145.825 MHz in support of

Figure 1 — The re-configured TinyTrack-4 reconfigured for CubeSats and called the SATT4.

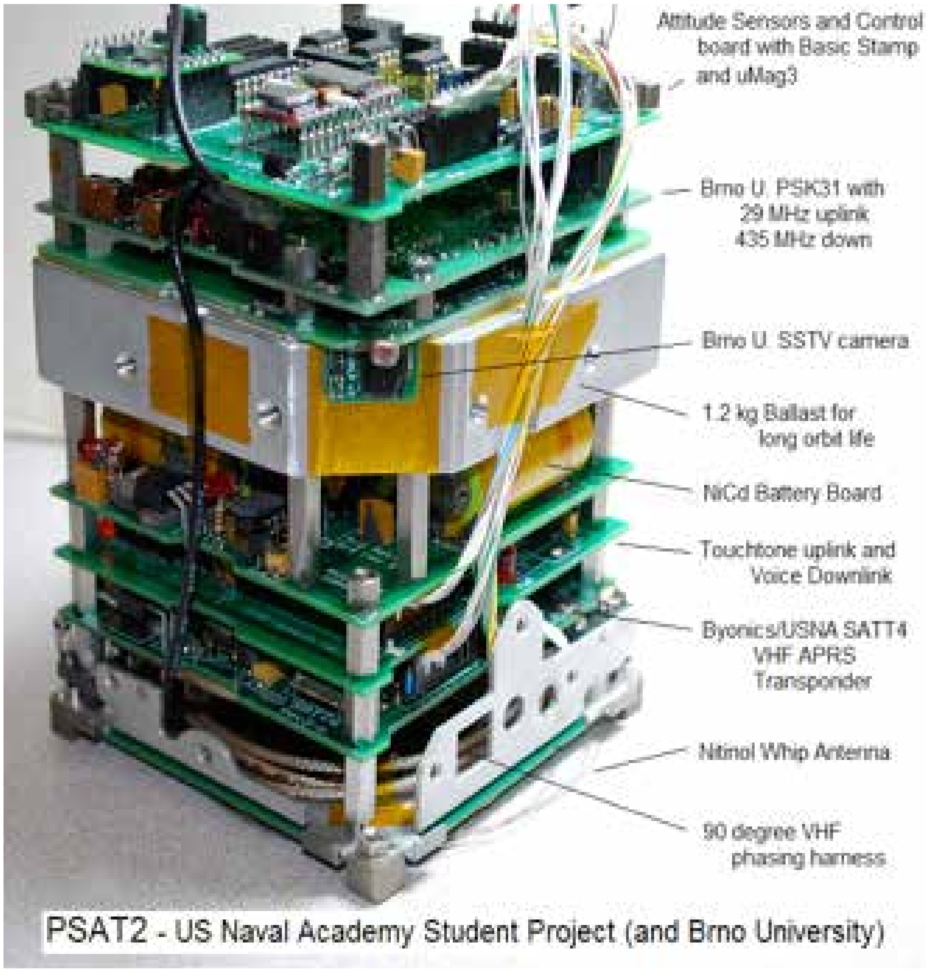


Figure 2 — The PSAT stack and central ballast fits easily in a 1.5U CubeSat frame.

this experimental data channel to provide greater connectivity between users. Others are welcome to build their simple CubeSats around this comm card. See **aprs.org/satt4.html.**

Structure

The complete 1.5 Unit CubeSat stack for PSAT2 is shown in Figure 2. It contains not only the SATT4 APRS transponder and the Brno University PSK31 HF transponder, but also a new DTMF uplink and voice APRS transponder, as well as an SSTV camera added to the PSK31 transponder downlink. It is topped with an attitude and control board with a magnetometer and Basic Stamp processor for attitude experiments with the sun sensors and torque coils on each solar panel.

Notice also the 1.2 kg ballast mass. We always add ballast to our APRS satellites to the maximum allowable mass to extend the orbit life. A late change was necessary when we performed the de-orbit analysis now required by the FCC. We discovered that stainless steel ballast would easily survive re-entry and be a hazard on Earth, so we rebuilt it from an aluminum block filled with lead which will burn up before it makes it to the ground. The life is expected to be under five years still due to low orbit opportunity.

The VHF and UHF antennas are orthogonal whips fed 90 degrees out of phase with a 90-degree hybrid chip for UHF and two ¼ wavelengths of coax for the VHF. The whip antennas are made from extremely flexible Nitinol wire wrapped around the spaceframe that will extend perpendicularly to the space frame when released. The release mechanism is a simple ¼ W resistor that burns a knot of fishing line that holds all the antennas. Hitting the resistor with a few seconds at 3 W assures a very hot but reusable resistor. Reusability is essential for testing and then flying what-you-tested. We have demonstrated dozens of cycles without failure.

HF/UHF PSK31 Transponder

The PSK31 multi-user FDMA transponder[5] experiment built at Brno University is similar to what we flew on RAFT[6], PSAT and PCSAT2[7]. The users on the ground see the usual full PSK31 waterfall, but the center of the spectrum on PSAT2 will contain a simultaneous SSTV downlink. This camera experiment will downlink shots from the camera when power battery permits and it sees Earth, or otherwise, some pre-loaded images.

The beauty of the HF PSK31 SSB uplink and UHF downlink as FM audio is that the usual 18 kHz UHF Doppler shift does not affect the individual PSK31 signals but only the FM receiver passband tuning. The users will merely retune their FM receivers 5 times during the pass in 5 kHz steps to stay in the passband.

There is still +/- 1 KHz of Doppler on the HF uplink and, for most of the pass, standard PSK31 decoding software can keep up with the Doppler. However, to simplify operations, Andy Flowers, K0SM, has written an uplink PSK31 application[8] that not only uses the satellite tracking elements to pre-adjust the uplink for Doppler but, as a separate program, also allows the user to operate full duplex using the existing PSK31 software for downlink. Signals from stations using this application will appear fixed in the downlink waterfall, while others using conventional software will drift.

This PSK31 text messaging transponder allows messaging between up to 30 modest ground stations simultaneously in full duplex. HF uplink stations do not need gain antennas but can use a vertical omni antenna and a SSB transmitter with an output of about 100 W because of the range-gain match of the LEO orbit geometry. That means more gain near the horizon where the satellite is farther away and less gain at higher elevations where the satellite is almost 10 dB closer.[9] Full duplex allows each operator to type text to any other operators while viewing all other stations at the same time.

PSAT2 continues to use NiCd cells for their robustness to abuse and because they can be directly charged from the solar panels without a complex charge regulator. We match the I-V curve of the solar cells to the charge/discharge curve of the NiCd cells. Also, we have plenty of pass budget, so there is no need for the lighter weight of Lithium cells and their inherent dangers of over/under charging.

DTMF/Voice – APRS for Everyone

This DTMF uplink feature extends satellite APRS capability not only for those with APRS radios but also to anyone with a radio and a DTMF touchtone keypad. The

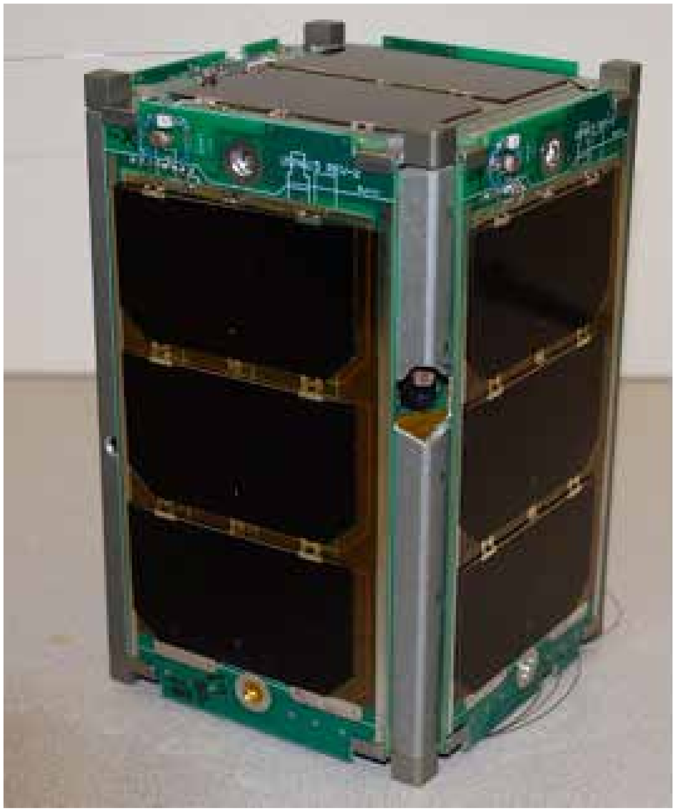


Figure 3 — PSAT2 uses $8000 of modern triple-junction solar cells for double the power of the cheap silicon ones on PSAT ($80). See also the SSTV camera port in the corner rail.

Figure 4 — On this panel, you can see 5 wraps of the various antenna wires as well as two convenient viewports in the corner rail for observing status LEDs for troubleshooting.

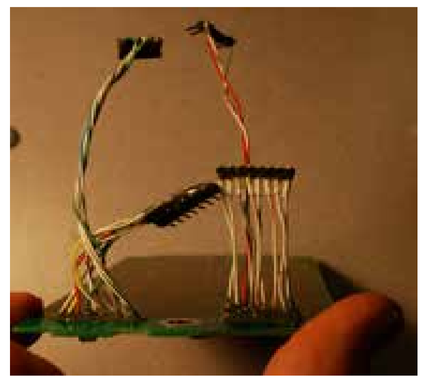


Figure 5 — This solar panel has four pigtails. One for the actual panel functions and the other three are the various connections to the boards for the external ground service signals.

DTMF user stores his or her callsign and grid in a DTMF memory and can send it at the press of a button when the satellite is in view. The spacecraft not only converts this DTMF grid report into an APRS position packet on the downlink for capture by the global APRS ground station network, but the spacecraft also repeats the message in voice so that all of the DTMF-only users can hear the contact as well.

A Byonics DTMF micro-receiver and DTMF decoder chip receive the DTMF and then convert it to APRS and speech by a basic stamp processor and text-to-voice synthesizer. What makes all of this possible is the 16-digit key DTMF memories in most handheld radios. In 16 digits, we can store not only the full callsign but also 4 digits for the grid which is adequate for an APRS position report.

For messages, we take advantage of the fact that hams always say the same thing. Most of what anybody says has already been said before. Thus, instead of spelling out every message to be sent, we merely store the top 99 on the spacecraft and then call them up by number. Ham radio has always used this shortcut for frequent messages in the 47 standardized ARRL Numbered Radiograms[10] plus a few dozen more we have added. We can communicate quite well, therefore, with just a 2-digit message number and a 2-digit modifier. These modifiers can be injected into any standard message with a blank number field. For example, “1140” means message number 11 and puts in “40” to signify "Establish amateur radio operations on 40 meters.”

Just like the grid report, the entire message is converted to APRS packet format on the downlink and also spoken for the benefit of all the other DTMF-only users.

CubeSat Flexible Design Approach

My student project satellites take many shortcuts to save time and money. One of the most unusual techniques we use to reduce risk and to simplify final integration of the student project CubeSats is to design the antenna release mechanism and all spaceframe penetrations *last*. This sounds impossible, but it works. We do this for the simple reason that you don't know the length of the 5 antennas (2 VHF, 2 UHF and a 6 foot one for HF) until the spacecraft is built and final tuning completed for lowest SWR. Not knowing the length makes it impossible to design the release mechanism in advance.

Similarly, the stack of cards seems always to be changing throughout the design and integration, and only at the end do you know where the various penetrations and camera view-port end up. We also like to have some holes to be able to see the status of some LEDs during testing.

Saving the penetrations until last allows us to design all the solar panels the same and early in the process. For antenna release, we include on each solar panel multiple solder pads for literally dozens of possible locations for the antenna release burn resistor. At the end, when all the antennas are tuned and pruned, we solve the problem of where to wrap all the antenna wires so that their ends all arrive at the same point. That is where we put the burn resistor. Tie the nylon string knot and call it done — simple, sweet and never requires any redesign.

We have the same flexibility for spaceframe penetrations because we design those to go towards the corner of any board that needs them. Once the stacking plan is finalized, we can drill holes through the rails where needed with no impact on the solar panels. We think this is pretty clever, though it does it does add internal complexity to work around or offset the location of the corner stacking spacers between boards.

Another simple technique we use to avoid complexity and the need for special connectors is the use of regular 0.1" pin headers for all connections including RF. They can be cut to any length, soldered and then epoxied over the solder to provide strain relief to survive vibration. Every solar panel has one pigtail connection except for the panel with the external ground-support connection. As shown in Figure 5, that panel has a total of four pin header pigtails for the final connections to the top card in the stack.

At VHF and UHF there is no need for proper impedance coax connectors for the antennas on these small boards. We use a 2 or 3 pin header and make sure that alignment pressure, epoxy, or Kapton tape holds them in place through vibration. The other end of any coax is soldered to the board or antenna connection and becomes a one-ended pigtail for easy assembly.

Conclusion

We hope PSAT-2 will not only contribute to better connectivity of the APRS space constellation of relay satellites, but will also excite many more hams who may only have access to PSK31 and/or their old reliable DTMF walkie-talkie. Now they, too, can communicate position and transmit text from anywhere on Earth. We welcome other APRS transponders on the common 145.825 MHz frequency supporting generic digipeating.

References

1. **aprs.org/psat.html**
2. **aprs.org/qikcom-2.html**
3. **aprs.org/pcsat.html**
4. **ariss.net**
5. **aprs.org/psk31uplink2.html**
6. **aprs.org/craft/save-raft.html**
7. **aprs.org/pcsat2.html**
8. **www.frontiernet.net/~aflowers/dopplerpsk/dopplerpsk.html**
9. **aprs.org/PSK31/PSK31 Link Budgets for Psat-b.doc**
10. **nts.ema.arrl.org/node/30**

Tuskegee University Amateur Radio Station – VHF/UHF Digital Communication with Legacy Systems

Sharanabasaweshwara A. Asundi, KJ4UYW
Assistant Professor,
Department of Aerospace Science Engineering
Tuskegee University,
Tuskegee, AL 36088
sasundi@tuskegee.edu

Sharath S. Byakod, KN4LZL
Junior Student,
Thomas Jefferson High School for Science and Technology
Alexandria, VA 22312
sharath.byakod@gmail.com

Background and Introduction

As the only accredited aerospace program by the Accreditation Board for Engineering and Technology (ABET) at a Historically Black College and University (HBCU), the Department of Aerospace Science Engineering at Tuskegee University (TU) impacts a significant number of African American aspirants. However, many more hopeful and deserving candidates need to be accommodated into the program, with more representation for HBCU graduates in the space industry to positively affect workforce diversity.

The Department of Aerospace Science Engineering at TU in making an earnest attempt to strengthen the astronautics stream of the aerospace engineering program at TU. As part of this effort, the department has sought and received support for a high-altitude balloon project and has participated in NASA's University Student Launch Initiative competition [1]. The department has acquired the EyasSat classroom satellite kit [2, 3] to give students hands-on training in the functioning, assembling, and testing of satellite subsystems. Additionally, the department has received grants from the United States Air Force Office of Scientific Research and the National Science Foundation to pursue research in magnetic mapping of pico/nano/micro-satellites (PNMSats). To follow through with the vision of initiating a Pico/Nano/Micro Satellites (PNMSat) and CubeSat [4-7] program at TU, equipping the university with an amateur/ham radio station seemed appropriate.

More than two decades ago, the Department of Aerospace Science Engineering initiated the task of setting up an amateur ground station at TU. However, after procuring some of the equipment, the initiative was abandoned. To rekindle the project, the department conducted an inventory of the existing equipment and submitted a proposal to Rockwell Collins to procure the remainder of the equipment and complete the development of Tuskegee University Amateur Radio Station (TUARS). With support from Rockwell Collins, the department set up a well-equipped amateur radio station capable of analog and digital communication on TU's campus. This article describes the development of this unique station.

Goals and Objectives

The goal of setting up TUARS is to lay the foundation for a PNMSat/CubeSat program at TU. The radio station is also envisioned to supplement coursework, train and license students in radio communication and, overall, instill the spirit of ham radio community into the hearts of TU students, faculty and staff. In particular, the following objectives defined the scope of TUARS:

- Enable ground tracking of low Earth orbit (LEO) satellites
- Facilitate interaction with the International Space Station (ISS) astronauts
- Communicate with fellow ham radio enthusiasts in the region
- Develop an insight into the design and development of LEO satellites
- Gain practical insight into orbit design and understand orbital elements
- Enable U.S. Armed Forces ROTC and Marine cadets to experience radio communication, and
- Enable engineering fraternity on campus to experience hands-on radio communication.

TUARS Description

The Tuskegee University Amateur Radio Station is located in Luther Foster Hall (LFH), which is also known as the Engineering Building, on the campus of Tuskegee University. The various constituents of TUARS are shown in Figure 1. The antenna tower is installed on the roof of LFH

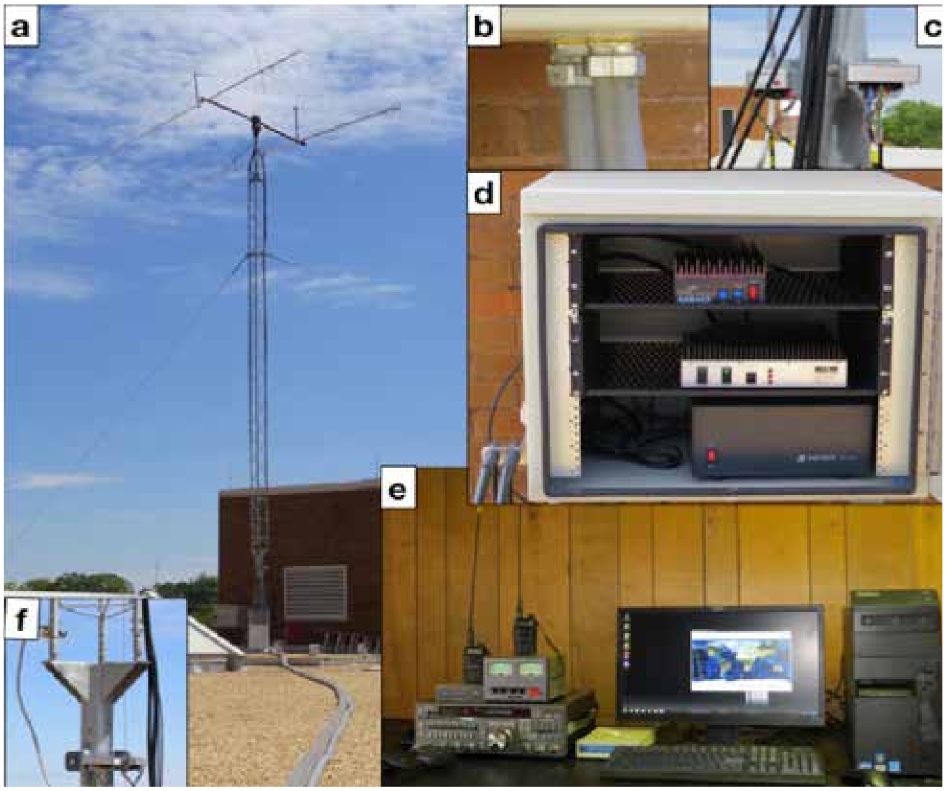


Figure 1.

(Figure 1a), and the control room is located on the 5th floor in room #522-D (Figure 1e). The feed lines run through a shielded conduit (Figure 1a & 1b), which burrows into an electrical box (Figure 1d) [8] on one end and the window of the control room on the other end. The following sub-sections will describe in detail the constituents of TUARS.

Antenna Tower

The initial idea for the installation of the antenna tower was to utilize the Rohn 25G Ballast Roof Mount (25GBRM) for non-penetrating roof installation and the installation itself was planned on top of "Chappie" James Center due to it being the tallest building in the vicinity. Accordingly, we procured the various parts required for this installation. However, we faced many challenges in the installation on top of this building, such as cable routing and the length of the cable required to route to the control room, which would potentially result in high signal losses. After much deliberation, the installation was moved to the roof of LFH.

After surveying the roof of LFH, we identified an existing installation hosting a decommissioned dish antenna as the pedestal base for the installation of the TUARS antenna tower. Figure 2 shows the pedestal base and the mounting provision before installation and post-installation of the base section (25GBRM, Part No. KY2699) of the Rohn 25GRM tower.

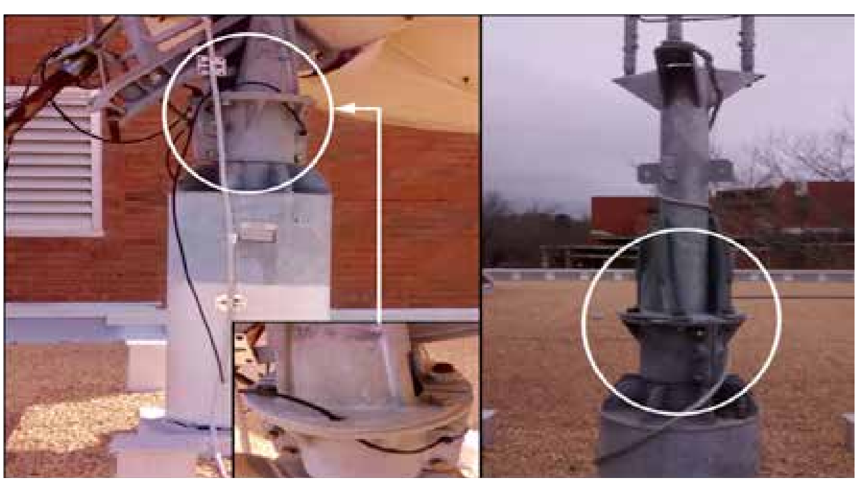


Figure 2.

The pedestal base is firmly secured to the roof of LFH, which serves two purposes: (1) eliminating the need for an elaborate, wide area Rohn 25GBRM, and (2) increasing the height of the tower by about four feet. On top of the base section of the Rohn 25GBRM, two standard 25G 10' guyed tower sections and a 9'9" standard top section are installed [9, 10]. A hoisting pole with a pulley arrangement was used to hoist one section at a time.

Rotators, Antenna and Cross-boom Assembly

Upon completion of the tower installation, the rotators, antenna and cross-boom assembly (RAC-assembly) was prepared on the ground before it was hoisted on the tower. The RAC-assembly included the following components before it could be raised:

- Fiberglass cross boom (M2 Antennas FBC60)
- 2 m VHF antenna (M2 Antennas 2MCP22)
- 70 cm UHF antenna (M2 Antennas 436CP42UG)
- Yaesu 5400B azimuth and elevation rotators
- 2 coaxial cables of length up to ~50'
- 2 6-channel rotor cables of length up to ~50', and
- power and grounding cables of adequate length.

Both the 2 m VHF and the 70 cm UHF antennas arrived disassembled. Students went through the process of identifying and measuring the elements of the two Yagi antennas and carefully assembled them. Although instructions and schematics of the two antennas are well documented [11,12], the assembly process can benefit significantly with inputs from a ham radio operator. Specifically, the process of centering the antenna elements and the method of putting on the keepers needed attention. The antennas thus assembled were mounted on either side of a cross boom [13]. However, before completing the RAC-assembly, the cross boom was treated with Rustoleum to increase its longevity. Figure 3 shows an untreated and treated cross boom affixed to the azimuth rotor.

Most UHF/VHF antennas are configured for azimuth and elevation rotation. To simplify installation and maintenance,

Figure 3.

Figure 4 — Guy bracket [Courtesy www.w3yy.com/Phillystran.htm.]

however, TUARS uses azimuth motion only. In such a configuration, a rotor base plate is installed inside the tower section for mounting the azimuth rotator. One such base plate was installed inside the tower section to support a metal mast/pole passing through the top section of the tower. The part of the mast that projects out of the top section is used for mounting the azimuth rotor. Essentially, this mast is the base on which the entire antenna, cross boom and rotor assembly are mounted.

Although the top section has its own mast, an independently mounted mast provided a nice edge for resting the azimuth rotor. The elevation rotator is mounted on top of the azimuth rotator, and the cross-boom is installed as the elevation rotator shaft. The coaxial cables connect the two antennas and are firmly secured to the cross-boom with electrical tape.

The cables were secured to the cross-boom to ensure sufficient slack for angular motion of the RAC-assembly. The azimuth rotator torques the elevation rotator to affect 3600 angular motion of the RAC-assembly while the elevation rotator provides 1800 (-900 to +900) angular motion. The carefully assembled rotators, antenna, and cross-boom structure were hoisted on top of the tower using the pole-pulley rig that was used for raising the tower sections (see Figure 8). The tower sections are secured against any extreme lateral motion utilizing a guy bracket and a guy connection assembly (GBGC-assembly). The tower is secured by one set of shackle-thimble-grip rigging at the base and another at the mid-section. The GBGC-assembly is very similar to that shown in Figure 4 [14].

The GBGC-assembly was completely installed before hoisting the RAC-assembly. However, during the raising of the RAC-assembly through the set of 3 guy wires, we noticed that the wires obstructed the path of transporting the RAC-assembly on top of the tower. To correct this, two of the three guy wires were partially disassembled by loosening the shackle-thimble-grip rigging at the base. To ensure an optimum amount of tension, which was achieved during the initial installation of GBGC-assembly, the shackle-thimble-grip was marked with spray paint and uninstalled. The partial disassembly of the GBGC-assembly enabled the RAC-assembly to be transported easily on top of the tower.

Amplifier Cabinet Electrical Interfaces

To facilitate amplification of outgoing and incoming signals, an electrical cabinet was installed at the base of the antenna tower. The electrical cabinet hosts an Astron 35-A (13.8 V 25 A continuous 35 A peak rated) power supply [15], the Mirage B-1016G power amplifier with a pre-amplifier (10 W in and 160 W out amplifier on 2 m) [16], and a custom built TE Systems Model 44349GS RF-switching UHF RF power amplifier with preamp. To facilitate internal connections, the cabinet is equipped with a power strip connected to an external power source and a cooling fan. Two shielded conduits burrow into the cabinet from the bottom to allow the cables from the control room to interface with the power amplifiers. A built-in provision for external connections routes the antenna and rotor cables flowing from the top of the antenna tower. Figure 7 shows a schematic of these connections and the actual setup Figure 5.

Command and Control Center Setup

The command and control center (CCC) is housed in room #522-D on the 5th floor of the LFH on the TU campus. Figure 6 depicts a functional block diagram and the physical setup of the CCC in Figure 6. The CCC enables radio enthusiasts to track satellites and establish a communication link through the antenna system mounted on the rooftop. It consists of two display screens, computers, Baofeng UV-5R [17] handheld transceivers, EASY DIGI UV-5R interfaces [18], a Yaesu FT-736R ground station transceiver with 2 m and 70 cm bands [19], a Yaesu G-5400B rotor controller [20], and the Tigertronics SignaLink USB radio interface [21] with the accompanying cables and connectors. Figure 8 also illustrates how each component is connected to enable a digital and analog capable system.

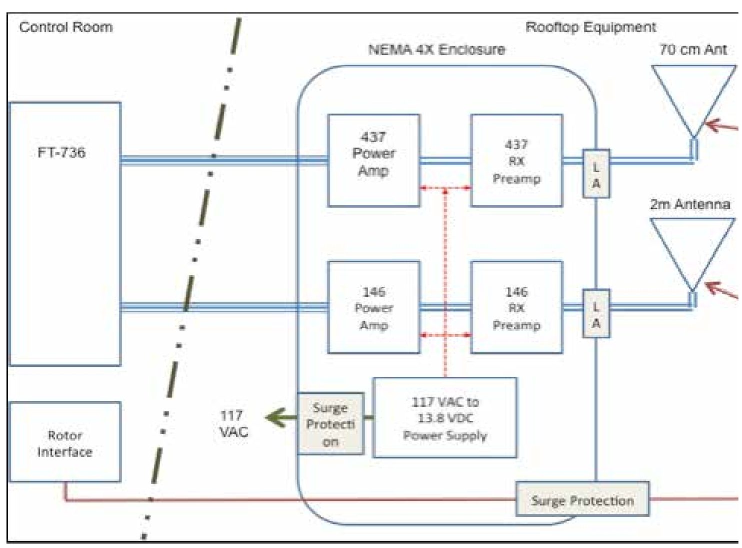


Figure 5 — Schematic of electrical connections.

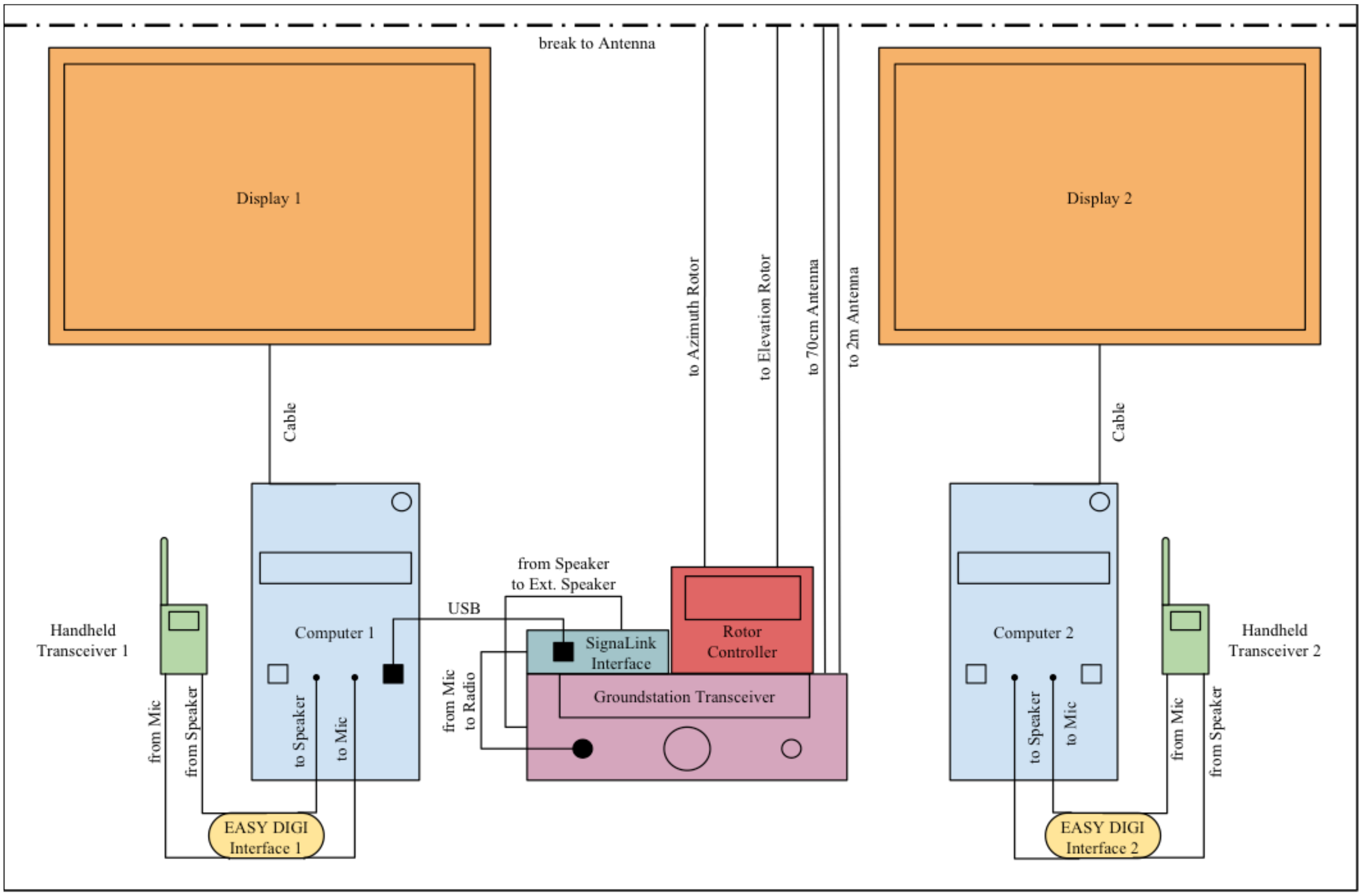


Figure 6 — Command and control center schematic (top) and physical setup (bottom).

The computers facilitate the visualization of ground trace for tracking a satellite/spacecraft. The ground station transceiver is connected to the antennas located on the rooftop, while the rotor controller is installed with the intent to manipulate the azimuth and elevation of the antennas. Finally, the handheld transceivers, EASY DIGI interfaces, and SignaLink enable digital communication and, more critically, a system for emulating satellite communication. The Yaesu GS-232 computer controller is available as an option to allow for digital rotation (azimuth and elevation) of the rooftop antenna system.

Tests and Results of Digital Communication

TUARS is primarily intended for tracking amateur radio satellites and downlinking data from PNMSats/CubeSats. However, a basic test of analog/voice communication was conducted with the Baofeng handheld transceiver (HT) communicating with the ground station (GS) transceiver. With the HT transceiver, one could contact the ground-station with practically anywhere on TU campus. It was more critical to test the TUARS setup for its ability to downlink data from satellites passing over TU campus. A high school student (one of the authors of this article) at Thomas Jefferson High School visited TU and contributed significantly to this exercise, along with others. When digital communication testing was undertaken, the computers were void of any internet connection to ensure the data transmission would only happen through the transceivers.

HT to HT Digital Communication Tests

TUARS was developed in a limited budget. The Baofeng UV-5Rs are simple radios without a built-in data interface to communicate with a computer. The EASY DIGI interface [18], which is designed and built in the U.S., is a highly excellent product for facilitating digital communication on these radios. The EASY DIGI interface uses the VOX circuit on the transceiver to do PTT by selecting the VOX option in the settings to be '1,' and the volume control to be 1/4th to 1/3rd of the maximum. Two sets of cables interface the microphone and speaker of the HT transceiver to the speaker and microphone of the computer, respectively, through the adapter. Modulation software interprets the incoming signals through the built-in soundcard of the computer. Two such HTs are set up and tested for their utility as emulated satellite transceivers. DigiPan 2.0 [22], a free modulation software application specially designed for PSK31 and PSK63, was selected to send and receive digital data between two HTs connected to their respective computers.

To evaluate the functioning of HTs as emulated satellite transceivers, five tests are conducted for each modulation mode: BPSK31, QPSK31, FSK31, BPSk63, and PACTOR RX [23-26]. These modulation schemes encompass a majority of those used by amateur radio satellites, particularly CubeSats. Since the HT transceivers are identical, the connection needed to be verified in only one direction while they both operated in the same modulation mode. To change a transceiver from one mode to another, the DigiPan software connected to that transceiver is set to operate in "RX" mode. When DigiPan is set to "Dual channel mode" - "Transmit A," the transmitting and receiving computers will both display the messages in the uppermost box. On the transmitting computer, the message will be typed and sent through the lowermost box. To ensure the connection is properly established, the diamond cursor must align with the orange data stream displayed in the frequency window on the receiving computer.

Here, the transmitting computer is denoted by the callsign "KJ4UYW," and the receiving computer is denoted by the callsign "KN4LZL." In the DigiPan software, under the "Options" drop-down menu, set "KJ4UYW" to "TX" and "KN4LZL" to "RX" to satisfy these requirements. On the Baofeng UV-5R handheld transceiver connected to KJ4UYW, the receiving and transmitting frequencies are set to 444.768 MHz and 446.768 MHz, respectively. Logically, these frequencies are reversed on the Baofeng UV-5R handheld transceiver connected to "KN4LZL." Below are some of the basic tests, which were executed to verify the functioning:

When the "Call" button in DigiPan on "KJ4UYW" is pressed, the message "DE KJ4UYW" is displayed on both computers. The message, "This is Test_1." and "1, 2, 3. ABC. !@#." when entered in DigiPan on "KJ4UYW", gets displayed simultaneously on both computers. The transmission of this message is verified for the various modulation modes built into DigiPan.

After testing all the modulation modes using the described method, the results are as follows:

- When set to "BPSK31", "QPSK31", "FSK31", and "PSK63" modulation modes, the test message was both transmitted and received correctly.
- When set to "PACTOR RX," this modulation mode is locked to "receive only" in the DigiPan software [22]. While it was not possible to use the test message on this mode, data was consistently received and displayed on "KN4LZL," and thus was considered to be "passing."

HT to GS Digital Communication Tests

Similar to the setup of Baofeng UV5Rs as digital communication systems, a workaround is sought to set up the GS transceiver, the Yaesu FT-736R [19], as a digital communication system. The Yaesu FT-736R is without a doubt a well-built radio, and hams across the world recognize it. The initial plan to make it capable of digital communication was to use a terminal node controller (TNC) connected to the data port on the back of the transceiver. Although the team was able to source an old TNC, it was almost impossible to find the right connector. Moreover, the TNC would limit the data rate to 9600 baud. After much deliberation, the team found an excellent product in Tigertronics' SignaLink USB interface [21], which facilitated soundcard-based digital modulation and would interface with the computer through a USB. Although the SignaLink USB interface is not indeed a plug-n-play system, detailed instructions are provided on its website to get it working with a host of legacy radios. The DigiPan software was selected because it offers the PSK31 digital radio modulation mode, which is recommended for setting up the SignaLink USB. Additionally, the software itself is recommended by Tigertronics for use with their SignaLink USB interface.

A total of 10 communication tests are conducted, two for each modulation mode from the "Mode" drop-down menu of DigiPan. Unlike the HT to HT digital communication testing, since the transceivers on either end are different (HT-GS), the testing for all modes is done in both directions, meaning that the transmitting and receiving computers switch midway. One HT transceiver is connected to a computer through the EASY DIGI interface, and the GS transceiver is connected to another computer through the SignaLink USB interface. Once the physical connections are made, the GS transceiver and the SignaLink USB interface settings are calibrated. While the GS transceiver is set to operate in "FM," the "Mic Gain" and "RF Power" are set to 50%, and all "VOX" features are turned OFF. On the SignaLink USB interface, the "TX" knob is set to be just above minimum, the "RX" knob to 50%, and the "DLY" knob to minimum. In the DigiPan software, the soundcard selected for both "Transmit" and "Receive" is "USB Audio Codec," which is the SignaLink USB interface's internal sound-card.

In the first set of tests, the transmitting computer is connected to the HT transceiver through the EASY DIGI interface, and the receiving computer is connected to the GS transceiver through the SignaLink USB interface. The "TX" is denoted by callsign "KN4LZL" and the "RX" is denoted by callsign "KJ4UYW." On the Baofeng UV-5R handheld transceiver, the RX and TX frequencies are set to 145.600 MHz and 146.200 MHz, respectively, and vice-versa on the GS transceiver. The testing method is the same as described earlier, except that "DE KJ4UYW" will now say "DE KN4LZL" because "Call" is now pressed on "KN4LZL." The results for the first 5 tests are the same as those achieved and described earlier.

In the second set of tests, the receiving computer is connected to the HT transceiver through the EASY DIGI interface, and the transmitting computer is connected to the GS transceiver through the SignaLink USB interface. Again, the testing method and the results for this set are the same as those achieved earlier.

Digital Communication Test Results

From the two set of tests conducted, we concluded that the TUARS is well equipped and ready for its envisioned purpose. The HT to GS test results, in particular, were very positive and demonstrated that, in the event of a relevant amateur radio satellite, CubeSat in particular, passing over Tuskegee, TUARS with its tracking and telemetry infrastructure is capable of downlinking data from the satellite for use in teaching and/or research purposes.

Lessons Learned, Conclusion and Future Work

Before the installation of the 40' tower and successful operation of TUARS, the TU faculty and students took several small steps towards being successful. The Tuskegee University Amateur Radio Club (TUARC) was formed and, with the guidance of a faculty mentor, the TUARC set up portable handheld stations to listen to communications in and around Tuskegee, AL. Figure 7 shows a couple of such activities. Tuskegee University and the city of Tuskegee have a long-standing history in air and space. Considering the significance of TTU's aerospace program, this is an effort to establish a PNMSat/CubeSat program. Setting up the Rockwell Collins Earth Station @ Tuskegee University, created a firm foundation on which to build a CubeSat program.

Figure 7.

The proposed project will greatly encourage students from TU, particularly women, to experience the joy of being a radio enthusiast. Additionally, this effort will seek collaboration with the Booker T. Washington High School to encourage younger kids to take up this hobby. Also, we are working to showcase this as a significant capability to start a small satellite program at Tuskegee University.

References

1. **NASA Student Launch | NASA, Retrieved July 4th, 2018, from www.nasa.gov/audience/forstudents/studentlaunch/home/index.html**
2. **Barnhart, D. J., Sellers, J. J., Bishop, C. A., Gossner, J. R., White, J. J., & Clark, J. B. (2005, November). Eyassat: A revolution in teaching and learning space systems engineering. In Proceedings of the AIAA Space Systems Engineering Conference, Atlanta, GA.**
3. **Burditt, G. (2016). EyasSat, LLC | Classroom Satellite Training Modules. Retrieved July 4th, 2018 from http://www.eyassat.com/**
4. **Heidt, H., Puig-Suari, J., Moore, A., Nakasuka, S., and Twiggs, R., "CubeSat: A new generation of picosatellite for education and industry low-cost space experimentation," Proceedings of the Utah State University Small Satellite Conference, Logan, UT, 2001.**
5. **Schaffner, J. and Puig-Suari, J., "The Electronic System Design, Analysis, Integration, and Construction of the Cal Poly State University CP1 CubeSat," 16th AIAA/USU on Small Satellites Conference, Logan, UT, Citeseer, 2002.**
6. **Munkata, R., "CubeSat Design Specification Rev. 12," August 2009.**
7. **Mehrparvar, A., Pignatelli, D., Carnahan, J., Munakat, R., Lan, W., Toorian, A., Hutputanasin, A., and Lee, S., "CubeSat Design Specification Rev. 13," The CubeSat Program, Cal Poly San Luis Obispo, US, 2014.**
8. **OPSOD-192420-FT - Utility | DDB Unlimited, Retrieved July 4th, 2018, from store.ddbunlimited.com/utility/opsod-192420-ft.html.**
9. **ROHN 25G Tower Series Specifications, Retrieved July 4th, 2018, from www.rohnnet.com/files/2015_Rohn_Full_Catalog.pdf#page=28**
10. **Rohn 25G Ballast Roof Mount, Retrieved July 4th, 2018, from www.rohnnet.com/rohn-25g-ballast-roof-mount.**
11. **M2 Antenna Systems Inc. 436CP30, 432-440 MHz, Retrieved July 4th, 2018, from www.m2inc.com/FG436CP30.**
12. **M2 Antenna Systems Inc. 2MCP22, 144-148 MHz, Retrieved July 4th, 2018, from www.m2inc.com/FG2MCP22.**
13. **M2 Antenna Systems Inc. CROSSBOOM, HD FG 11', Retrieved July 4th, 2018, from www.m2inc.com/FGCB60.**
14. **Rohn Products LLC GA25GD 25G guy bracket assembly |**

TESSCO, Retrieved July 4th, 2018, from www.tessco.com/products/displayProductInfo.do?sku=94734.
15. Astron RS-35A Product Reviews, Retrieved July 4th, 2018, from www.eham.net/reviews/detail/3018.
16. Mirage B-1016G Product Reviews, Retrieved July 4th, 2018, from www.eham.net/reviews/detail/1983.
17. Baofeng UV-5R | BaoFeng's First Dual Band Handheld radio, Retrieved July 4th, 2018, from baofengtech.com/uv-5r.
18. "EASY DIGI™" UV-5R INTERFACE for laptops and desktops | eBay, Retrieved July 4th, 2018, from www.ebay.com/itm/EASY-DIGI-UV-5R-INTERFACE-for-laptops-and-desktops-/323006664493.
19. Yaesu FT-736R, Yaesu FT736R Transceiver E736 FVS1 FTS8 FEX-736-220 TV-736, Retrieved July 4th, 2018, from www.universal-radio.com/catalog/hammulti/ft736r.html.
20. Yaesu G-5400B Product Reviews, Retrieved July 4th, 2018, from www.eham.net/reviews/detail/5187.
21. Tigertronics SignaLinkTM USB Radio Interface, Retrieved July 4th, 2018, from www.tigertronics.com.
22. DigiPan 2.0., Retrieved July 4th, 2018, from www.digipan.net/.
23. Steve Ford, WB8IMY (2001). "Chapter 4 - PSK31". ARRL's HF digital handbook. Newington, CT: The American Radio Relay League. ISBN 0-87259-823-3.
24. Steven L Karty, N5SK. "PSK31 Spec". ARRL Website. Retrieved June 21, 2018, from www.arrl.org/psk31-spec.
25. Eduardo Jacob, EA2BAJ. "PSK31 'Official' Homepage". Retrieved June 21, 2018, from aintel.bi.ehu.es/psk31.html.
26. Kennedy, G.; Davis, B. (1992). Electronic Communication Systems (4th ed.). McGraw-Hill International. ISBN 0-07-112672-4., p 509.
27. Frenzel, L. (2012, April 27). "What's The Difference Between Bit Rate And Baud Rate?" Electronic Design. Retrieved June 21, 2018, from www.electronicdesign.com/communications/what-s-difference-between-bit-rate-and-baud-rate.
28. Steve Ford, WB8IMY (2001). "Chapter 5 - PACTOR". ARRL's HF digital handbook. Newington, CT: The American Radio Relay League. ISBN 0-87259-82.

AMSAT Field Day Results 2018

Bruce Paige, KK5DO
Director of Awards and Contests

This was one heck of a Field Day, and the numbers prove it. Last year, I reported that in 2002 we had 1905 QSOs and 38 participants. In 2003, we had 2117 QSOs with 37 participants and 2802 points. Then we lost our HEO satellite. As a result, the number of satellites dramatically fell, as did the number of participants.

Including all the LEO satellites in operation, the 33 total operating satellites this year almost equaled the number of stations operating. We had 32 stations submitting entries. We also had nearly as many participants as we did back in 2002 and 2003. They reported 945 QSOs for a total of 995 points. This is more than any other year (since the loss of HEOs) and more than double that of many years. Of the total QSOs, 916 were Phone QSOs and 29 were CW/Digital QSOs.

As in the past, satellites were counted based upon the number of modes. As an example, SO-50 has one FM transponder, which counts as one satellite whereas AO-7 has two modes, SSB and CW, and was counted as two satellites. The reason is that you can work the same station on the same satellite in each mode available for that satellite.

The International Space Station (ISS) had no voice contacts again this year. However, three groups made contacts through the ISS digipeater. One of those said that it was the easiest Field Day contact they had ever made. I would have to agree when you are the only two stations on the bird.

The breakdown of satellite usage is as follows:

	Phone	CW/Digital
AO-7	29	3
AO-73	16	1
AO-85	9	
AO-91	16	
AO-92	10	
CAS-4A	185	1
CAS-4B	181	1
EO-88	2	
FalconSAT		2
FO-29	89	1
ISS	3	
NO-84		11
SO-50	11	
UKUBE-1		10
XW-2A	67	1
XW-2B	76	1
XW-2C	75	2
XW-2D	55	2
XW-2E	4	
XW-2F	82	

We had several stations operating from home with both emergency power and commercial power. They were (by call area and alphabetically) CU2ZG, N1AIA, K6FW, KB6A, KB6LTY, WB6SC, N7NEV, N8HM, WD9EWK. Some were on commercial power, some emergency and some on battery.

Here are this year's winners. All will receive certificates at the AMSAT Symposium in Huntsville, Alabama, later this year. In First Place, no stranger to Field Day is Huntsville Amateur Radio Club, K4BFT, racking up 138 points.

Right behind in Second Place is the Loudoun Amateur Radio Group, K4LRG, missing first place by a mere four points and reporting in at 134 points. They moved up from third place last year (see Figures 1-3).

San Lorenzo Valley Amateur Radio Club, operating as K6MMM, fell from third place last year to 11th place this year with 34 points. The group spent more time explaining satellites to the visitors and new hams — for which they should be congratulated — than concentrating on working every pass.

Johnson Space Center Amateur Radio Club Achieving came in Third Place, operating as W5RRR, with 116 points. It has been quite a while since they participated in AMSAT Field Day.

Finally, the top home station operating on emergency power with 24 points is Paul, N8HM, a title that he held in 2015 and 2017. This was 6 points less than he earned last year

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Satellite	12	12	9	9	8	12	9	16	21	33
QSOs	328	387	335	263	443	305	316	424	728	945
Stations	20	18	14	19	23	21	21	22	27	32
Points	486	505	455	329	613	357	386	448	778	995

Figure 1 — K4LRG.

Figure 2 — K4LRG.

Figure 3 — K4LRG.

yet still a strong showing to take the top spot from home on emergency or battery power.

I was a player again this year with the Texas Emergency Amateur Communicators, operating as W5SI. With only a clear shot to the North, South and West, we were able to work some very rare DX on two satellites, SO-50 and FO-29. We contacted my good friend Andy, W5ACM, some 30 miles away operating W5RRR for both of our contacts. Go figure.

The Seattle Auxiliary Communication Service, W7ACS, as well as the York Region ARC, VE3YRA, jumped in for their first attempt at satellite QSO's this Field Day. We were sorry to hear that Brad, VE3HII, became a silent key the Thursday before Field Day. He was the mentor for Alex, VA3ASE, who operated the station alone this year.

As we have said in past years, watch for "Murphy." Here is what happened with the Sierra Foothills ARC, W6EK (Figure 4). This was our first "serious" attempt to get a satellite contact during Field Day. As Doug, KO6TH, reports as follows:

"I, the 'satellite guy,' arrived at our Field Day site armed with my trusty FT-736R and its 1.2 GHz module, 17-turn helix antenna, Elk (plus an Arrow from another club member), and sufficient pass-prediction IT infrastructure to start my own data center, fully expecting to Ka-Ching! 100 points into the coffer within 10 minutes of Field Day starting. Got all set up, double-checked where North was (hind-sight, we were still wrong, but it didn't matter). Then I looked at the S-meter. The meter was indicating 20-over-9 noise over the entire 2-meter band. And, I'm going to hear a sub-one-watt signal from a thousand miles away in space? Yeah, right."

We included them in the score for this year as they did participate and were busted by Murphy. They were never able to hear anything for more than a few seconds and thus show as a zero in the listing.

We had one DX station operating from home on battery power this year, Pedro, CU2ZG.

Tom, N5HYP, commented for the Irving ARC, N5BB, that they loved the way CAS-4A and CAS-4B birds came around during the afternoon on Saturday (Figures 5-6).

Stephan, KS1G, pretty much summed it up for the K4LRG group when he said:

Figure 4 — W6EK.

Figure 5 — N5BB.

Figure 6 — N5BB.

Figure 7 — W6PA.

"The ops at W5RRR (JSC club). QSOs on 7 birds, CAS-4A @ 1539 6/24 UTC was VERY SPECIAL. A young man who is very interested in ham radio at the mic. You were his first satellite QSO, and he was double excited when I told him where you were. You made this kid's day! Thank you, sirs."

Over at the Hospital Disaster Support Communications System (W6PA) site, like many other sites, they are still using manual antenna pointing. They said, "that gives us a chance to show visitors how satellites rise and set. We gave them the opportunity to point the antennas, using an app that provides AZ and EL." In the photo is future ham Gracelee Dowler aiming at CAS-4B (Figure 7).

Patrick, WD9EWK, mentioned that he was surprised at the very little activity on NO-84 with one QSO on a cross-country pass Saturday afternoon. Where were you when NO-84 made its pass across the sky? (See Figures 8 and 9.)

My friends, Andy (W5ACM) and John (AB5SS), operating at the Johnson Space Center as W5RRR, had this to say about Field Day this year:

"We worked every pass we could, even the middle of the night AO-7 pass, and were happy to see the station performed very well. With all the satellites available to work, we rarely got a break to work any HF! We were expecting to make most of our contacts on AO-7 & FO-29, but the CAS-4A/4B pair gave us a third of our contacts and stood up to the heavy load of Field Day quite well. The XW-2x satellites are usually easy to make contacts on but with all the strong signals hitting them, their AGC appeared to kick in, and it was much harder to make a contact. The FM satellites were as expected. We were set up to make an L/v contact through AO-92, and made several on a pass just before Field Day started; unfortunately, it switched back to U/v mode before we could work it during the event. We don't have a 1.2GHz antenna up on our rotor yet, so I, AB5SS, stood outside with the antenna and played rotor while Andy, W5ACM, made the contacts."

Over at the Antietam Radio Association, W3CWC, site, they had problems with SatPC32 and Doppler correction. Personally, I have always used manual tuning.

We had some good photos from the Lafayette DX Association, W9LDX, where Dave, N9FN (Figure 10) and David, N9KT

Figure 8 — WD9EWK.

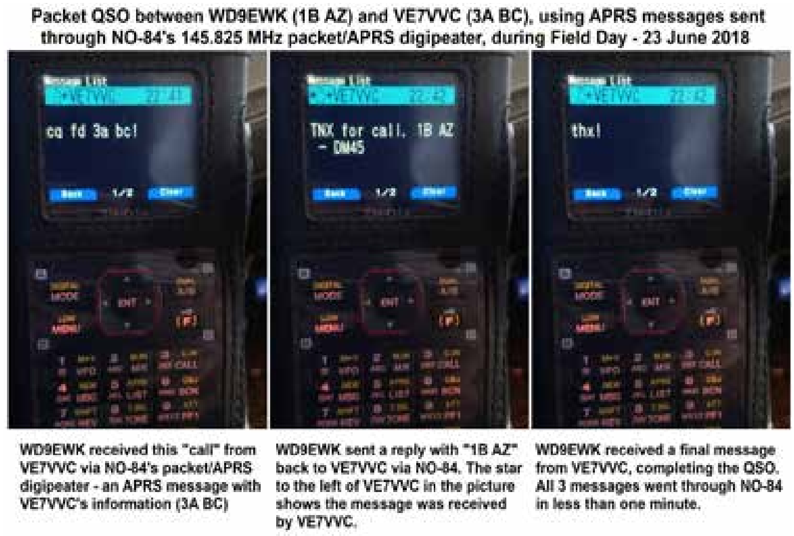


Figure 9 — WD9EWK.

Figure 10 — W9LDX.

Figure 11 — W9LDX.

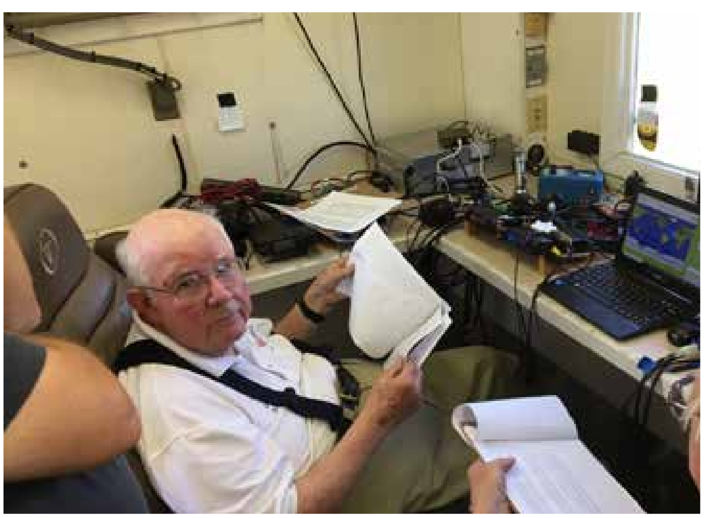


Figure 12 — K5COW.

Figure 13 — K5COW.

Figure 14 — W3BQC.

Figure 15 — W3BQC.

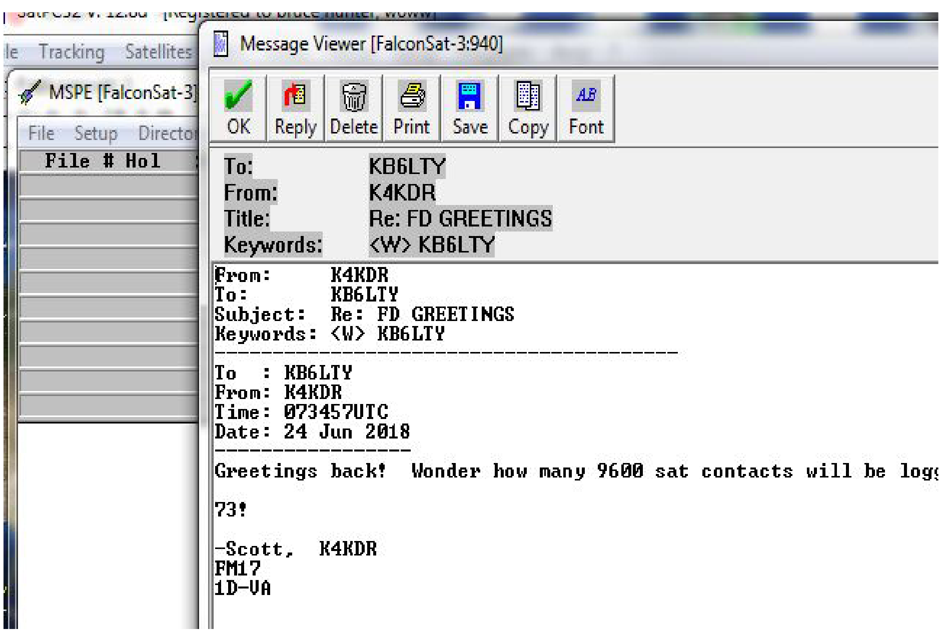


Figure 16 — KB6LTY.

(Figure 11) operated without their past satellite Gurus Steve, N9IP, and Steve, W9TN. A few photos from Cowtown ARC, K5COW, where it was "Hotter than Hades," and that is in the Texas shade (Figures 12 and 13). Lastly, Figures 14 and 15 show operations from the Boschveldt QRP Club, W3BQC.

KB6LTY worked FalconSAT-3 and provided Figure 16 of the contact.

For next year, remember, Murphy will somehow visit someone and spoil the day. Be prepared and have extra equipment, as well as cables and connectors.

Here is a table of all entries received. In the case of a tie, call signs are listed alphabetically.

1	K4BFT	4A	138
2	K4LRG	4A	134
3	W5RRR	12F	116
4	VE3YRA	5A	80
5	W9LDX	1A	57
6	W4MLB	2F	55
7	K4LKL	4A	47
8	K6FW	1D	44
9	W6PA	2A	43
10	K4JJ	3A	41
11	K6MMM	3A	34
12	N5BB	2A	25
13	N8HM	1B	24
14	WD9EWK	1B	23
15	N4EH	5A	22
16	AI6DO	2B	19
17	KB6LTY	1D	16
18	W1BIM	6A	15
19	W3BQC	2A	15
20	KB6A	1D	12
21	N7NEV	1E	8
22	WB6SCA	1B	6
23	CU2ZG	1B DX	4
24	K5COW	4A	4
25	W3CWC	7A	3
26	VE7NA	2A	2
27	W3NAN	3F	2
28	W5SI	5F	2
29	W7ACS	2A	2
30	K8UNS	4A	1
31	N1AIA	1B	1
32	W6EK	4A	0

Calculating the Orbital Period of Satellites

Michael K Butler, G4OCR
email: m.k.butler@bolton.ac.uk

It is well known that the square of the orbital period of a satellite is directly proportional to the cube of the satellite's distance from the centre of gravity of the Earth. This is one of the laws of planetary motion discovered by Johannes Kepler through empirical observation in the early seventeenth century. In this note, we show why this is true as a consequence of Newton's universal law of gravitation and Newton's second law of motion. In order to understand the derivation of Kepler's law that follows, only an elementary background in mathematics required.

We shall write **r** for the position vector of the satellite relative to the centre of gravity of the Earth, and r for the magnitude of position (distance). We shall write **v** for the velocity vector of a satellite, and v for the magnitude of velocity (speed).

Derivation of Kepler's Law

Newton's law of universal gravitation states that the magnitude of the force of gravity F exerted between two objects of masses M and m is directly proportional to each of the masses, and inversely proportional to the square of the distance r between the centres of gravity of the two objects:

$$F = \frac{GMm}{r^2} \quad \textbf{(Equation I)}$$

G is known as the gravitational constant. In our examples that follow, M is the mass of the Earth and m is the mass of the satellite. For simplicity, we shall assume that our orbits are circular with the Earth at the centre, so that r remains fixed throughout the orbit, and that the speed v is constant. In practice, orbits are usually elliptical with the Earth at one focus of the ellipse.

Newton's second law of motion states that when a force of magnitude F acts on a body of mass m to produce an acceleration of magnitude a, then these are related by:

$$F=ma.$$

Consider Figure 1. Suppose that the satellite is at point P, and has position vector **r** relative to the centre of gravity of the Earth and velocity vector **v**. After a small interval of time δt has elapsed the position vector of the satellite has moved through an angle θ so that it is now at point Q with position vector **r'** and velocity vector **v'**. The change in position is:

$$\delta \mathbf{r} = \mathbf{r}' - \mathbf{r}$$

By trigonometry, the magnitude of the change in position is:

$$|\delta \mathbf{r}| = 2r \sin\frac{\theta}{2}$$

as shown in Figure 2(a). The change in velocity is:

$$\delta \mathbf{v} = \mathbf{v}' - \mathbf{v}$$

Again by trigonometry, the magnitude of the change in velocity is:

$$|\delta \mathbf{v}| = 2v \sin\frac{\theta}{2}$$

as shown in Figure 2(b).

The magnitude of the mean acceleration over the interval δt is given by:

$$\frac{|\delta \mathbf{v}|}{\delta t} = \frac{|\delta \mathbf{v}|}{|\delta \mathbf{r}|} \times \frac{|\delta \mathbf{r}|}{\delta t} = \frac{2v \sin\frac{\theta}{2}}{2r \sin\frac{\theta}{2}} \times \frac{|\delta \mathbf{r}|}{\delta t} = \frac{v}{r} \times \frac{|\delta \mathbf{r}|}{\delta t}$$

If we let the interval δt become vanishingly small, then: $\frac{|\delta \mathbf{r}|}{\delta t}$ approaches the speed v. Hence the magnitude of the instantaneous acceleration is

$$\frac{v^2}{r}$$

and Newton's second law of motion becomes:

$$F = m\frac{v^2}{r} \quad \text{(Equation II)}$$

By equating expressions for force in equations (I) and (II) we get:

$$m\frac{v^2}{r} = \frac{GMm}{r^2}$$

By canceling m's and r's on both sides, we get:

$$v^2 = \frac{GM}{r}$$

Note that the m's canceling leads to the intuitively somewhat surprising result that the orbit of the satellite is independent of its mass.

Suppose that the orbital period of the satellite is T. Since the circumference of the orbit is $2\pi r$, we have:

$$v = \frac{2\pi r}{T}$$

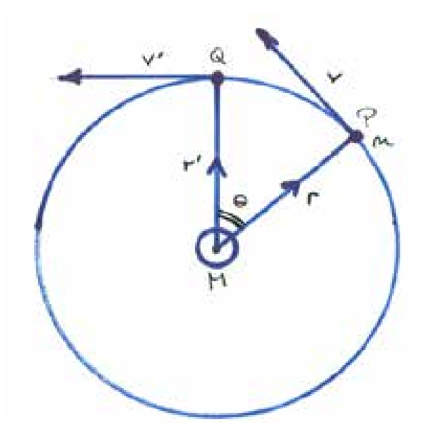


Figure 1 — The circular orbit of a satellite of mass m around the Earth of mass M. Initially the satellite is at point P with position and velocity vectors r and v. After a small time increment has elapsed the satellite has moved through an angle θ and is at point Q with position and velocity vectors r' and v'.

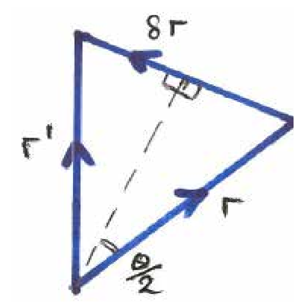


Figure 2a — The angle θ is bisected to give a pair of right-angled triangles. By trigonometry, the magnitude of δr is 2r sin $\frac{\theta}{2}$

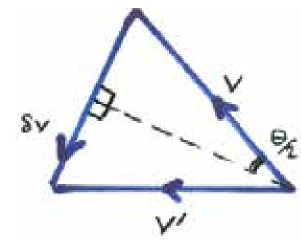


Figure 2b — The angle θ is bisected to give a pair of right-angled triangles. By trigonometry, the magnitude of δv is 2v sin $\frac{\theta}{2}$

Hence:

$$\left(\frac{2\pi r}{T}\right)^2 = \frac{4\pi^2 r^2}{T^2} = \frac{GM}{r}.$$

Cross multiplying, we get:

$$r^3 = \frac{GM}{4\pi^2}T^2.$$

Since both G and M are constants, we may rewrite this equation as:

$$r^3 = kT^2$$

where k is a constant. Hence we have shown that the cube of the distance r is directly proportional to the square of the orbital period T, as claimed.

Practical Calculations

For the purposes of our calculations, we shall measure the orbital period T in minutes and the distance r in miles. The radius of the earth is approximately 3960 miles, and so we have:

$$r = 3960 + h$$

where h is the altitude (or height) of the satellite above the ground in miles.

Geostationary satellites have an altitude of 22236 miles and an orbital period of exactly one day, which is 24×60=1440 minutes. From this, we can calculate the constant k to be:

$$k = \frac{r^3}{T^2} = \frac{(3960+22236)^3}{1440^2} = 8.67\times10^6.$$

Having obtained a value for k, we can now calculate the orbital period for a satellite of any given altitude. For example, the International Space Station orbits at an altitude of approximately 250 miles. We may calculate the orbital period as:

$$T = \sqrt{\frac{r^3}{k}} = \sqrt{\frac{(3960+250)^3}{8.67\times10^6}} = 93 \text{ minutes}$$

For a satellite at an altitude of 500 miles, the orbital period is:

$$T = \sqrt{\frac{r^3}{k}} = \sqrt{\frac{(3960+500)^3}{8.67\times10^6}} = 101 \text{ minutes.}$$

For a satellite at an altitude of 750 miles, the orbital period is

$$T = \sqrt{\frac{r^3}{k}} = \sqrt{\frac{(3960+750)^3}{8.67\times10^6}} = 110 \text{ minutes.}$$

Conversely, if we wish to discover the altitude at which the orbital period will be exactly two hours, or 120 minutes, then we may calculate this as:

$$h = r - 3960 = \sqrt[3]{kt^2} - 3960 = \sqrt[3]{8.67\times10^6\times120^2} - 3960$$

$$= 1038 \text{ miles.}$$

If we wish to discover the altitude at which the orbital period will be exactly five hours, or 300 minutes, then we may calculate this as:

$$h = r - 3960 = \sqrt[3]{kt^2} - 3960 = \sqrt[3]{8.67\times10^6\times300^2} - 3960$$

$$= 5246 \text{ miles.}$$

As a final example, the Moon has an orbital period of approximately 27 1/2 days, which is 39600 minutes. From this, we may calculate the Earth-Moon distance as:

$$r = \sqrt[3]{kt^2} = \sqrt[3]{8.67\times10^6\times39600^2} \approx 239000 \text{ miles.}$$

The author is a Senior Lecturer in Mathematics in the School of Engineering, University of Bolton.

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.

SpaceVNX: A Path Towards Reliable High-Performance Computing in Small Satellites

Jorge Piovesan,
Alonzo Vera, KG5RGV
Jeff Love
James Lyke
Patrick Collier
Bill Ripley, KY5Q

[Note: The work of Jorge Piovesan, Alonzo Vera, and Jeff Love was supported by the United States Air Force under Contract No. FA9453-17-P-0430. Any opinions, findings and conclusions or recommendations expressed here are those of the authors and do not recessarily reflect the views of the United States Air Force.]

Introduction

The small satellite/nanosatellite industry has been successful in using commercial off-the-shelf (COTS) parts to enable low-cost, high-performance space missions. The drawback of this approach is that it sacrifices the reliability of the spacecraft, which limits the applicability of these methods in more critical missions. To address this limitation, this abstract explores an approach to use the VITA 74 standard (VNX) to implement a reliable high-performance computing architecture for small satellites using COTS parts.

The goal of the proposed architecture is to enable more capable, more reliable small spacecraft solutions while giving integrators the flexibility and scalability to implement a wide range of requirements. A backplane architecture like VNX is an optimal approach to achieve this goal because of its modularity, standard interfaces, system management methods, and interconnection topologies.

As a first step towards implementing a reliable high-performance architecture for small spacecraft, this abstract documents an approach to use highly capable COTS parts in conjunction with lower cost Radiation Hardened/Tolerant supervision circuits/ICs to protect the system from Latch-up events and use the VNX architecture to provide redundancy to allow the system to continue operating even after one of these events.

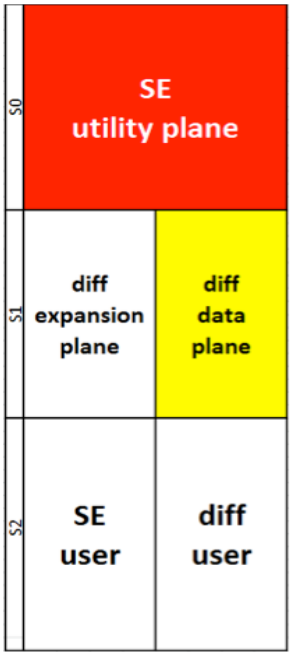


Figure 1 — VNX interconnection planes.

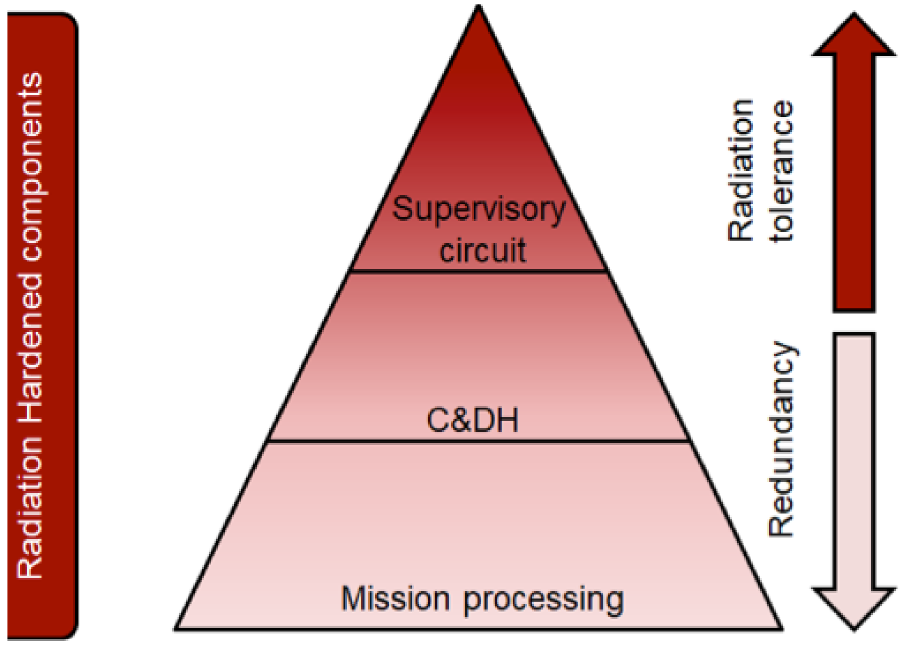


Figure 2 — Approach to improve reliability in nanosatellite missions without substantially increased costs.

Background

VNX is a variation of the VPX standard that reduces the complexity and size of VPX towards applications of limited SWAP. The VNX interconnect backplane consists of five planes (Figure 1): 1) The utility plane, 2) The Differential data plane, 3) the Differential expansion plane, 4) the Differential User defined plane, and the 5) Single-ended user-defined plane. Two types of modules exist. A 19 mm module, and a 12.5 mm module. Each of these modules is connected via an FMC-type connector to the backplane with a different number of pins (400 for the 19 mm and 200 for the 12.5 mm), distributed among this connection planes.

The utility plane is used mostly for power distribution and system supervision. Signals include 4 different power rails, I2C communication, systems reset signals, PCIe clock distribution, and some pins for user-defined signals.

The differential data plane and the differential expansion plane are used for high-speed data transfer between modules. The data plane uses PCIe as interconnection fabric, while the expansion plane can be defined by the user for but can also be used for additional PCIe interconnection.

The differential and the single-ended user defined planes are used for other types of data transfer between modules and are wholly reserved for the user to define the protocols.

Implementation Approach

We propose to address space reliability (especially radiation tolerance) through a combination of radiation hardened (or tolerant) semiconductors, redundancy, and circumvention and recovery approaches. A critical parameter to be considered when designing the proposed architecture is cost-effectiveness. The small satellite and nanosatellite markets require cost-effective solutions; therefore, complex radiation hardened components are not attractive alternatives to implementing this architecture. However, radiation tolerance is important to provide guarantees of mission success. Therefore, we propose to design an architecture that uses radiation hardened/tolerant components in the simpler but more critical subsystems of the spacecraft (e.g., Housekeeping), while implementing redundancy and circumvention and recovery (when desired) in the most complex subsystems of the spacecraft (Mission processing). This is represented in Figure 2. Note that criticality is understood as tolerance to downtime, where more critical systems are allowed minimal downtime (if any), and less critical system can have sporadic periods of downtime.

The preliminary architecture we studied included a System Controller module in charge housekeeping and supervising reliability features, two redundant Computing modules (that include storage), and two redundant I/O modules as shown in Figure 3. The focus of this study is to address possible Latch-up conditions by including overcurrent protection devices where commercial off-the-shelf (COTS) components are used.

The System Controller module (19 mm) includes the radiation tolerant supervisory IC, and COTS PCIe switch and clock references, with overcurrent protection to prevent damage in the PCIe ICs in case of Latch-up. The Computing module (19 mm) consists of a Latch-up overcurrent protection circuit and a single board computer (SBC) as a mezzanine card. Finally, the I/O module (12.5 mm) consists of a latch-up overcurrent protection circuit and the circuitry required to convert PCIe (or any other protocol) to the desired I/O protocol(s).

The approach to interconnect the modules in this preliminary architecture and provide some level of redundancy in the interconnection fabric has the following characteristics:

- The system controller supervises the other modules via I2C, and ON/OFF, and STATUS signals that are routed in the utility plane.
- The modules exchange data via high-speed PCIe lanes. Some of the lanes are connected through the PCIe switch in the system controller module, while other lanes connect a pair of modules without the PCIe switch to provide connectivity redundancy.

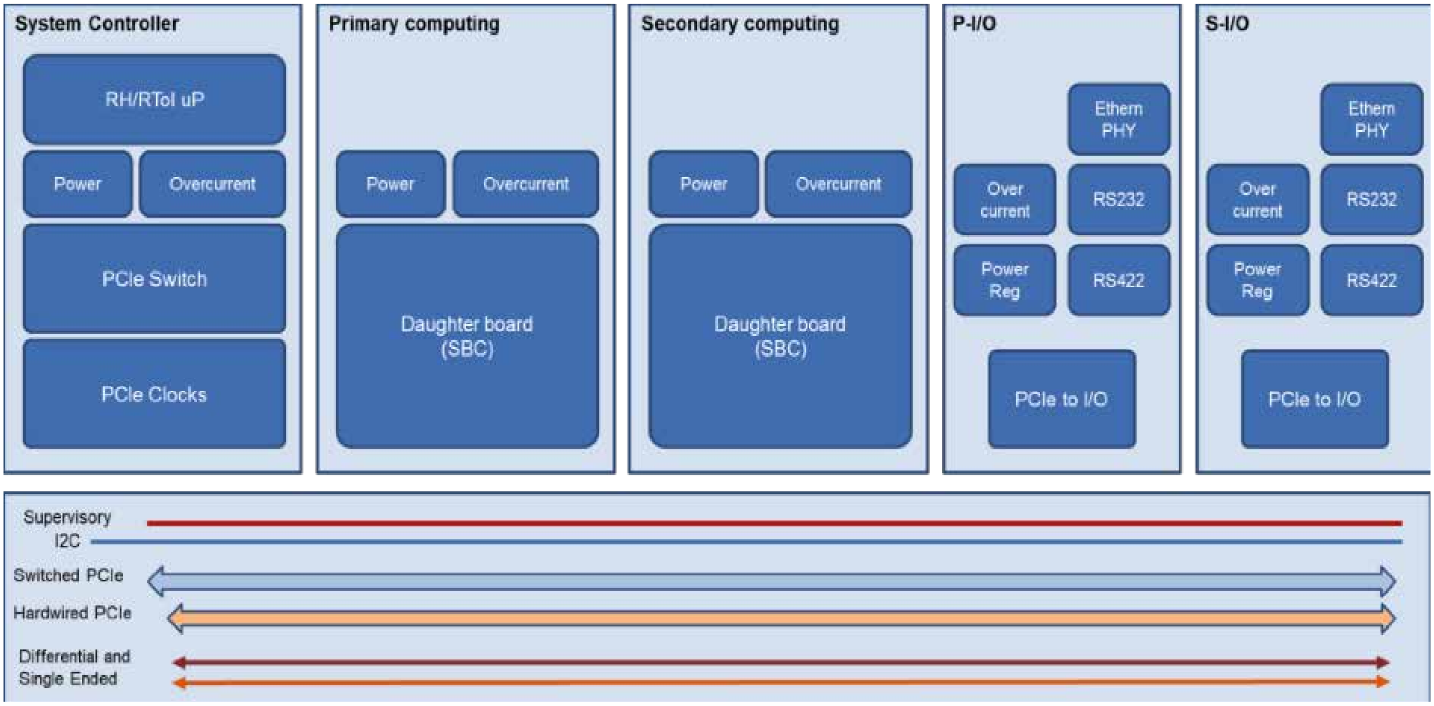


Figure 3 — Preliminary architecture with a System Controller, two Compute modules, and two I/O modules.

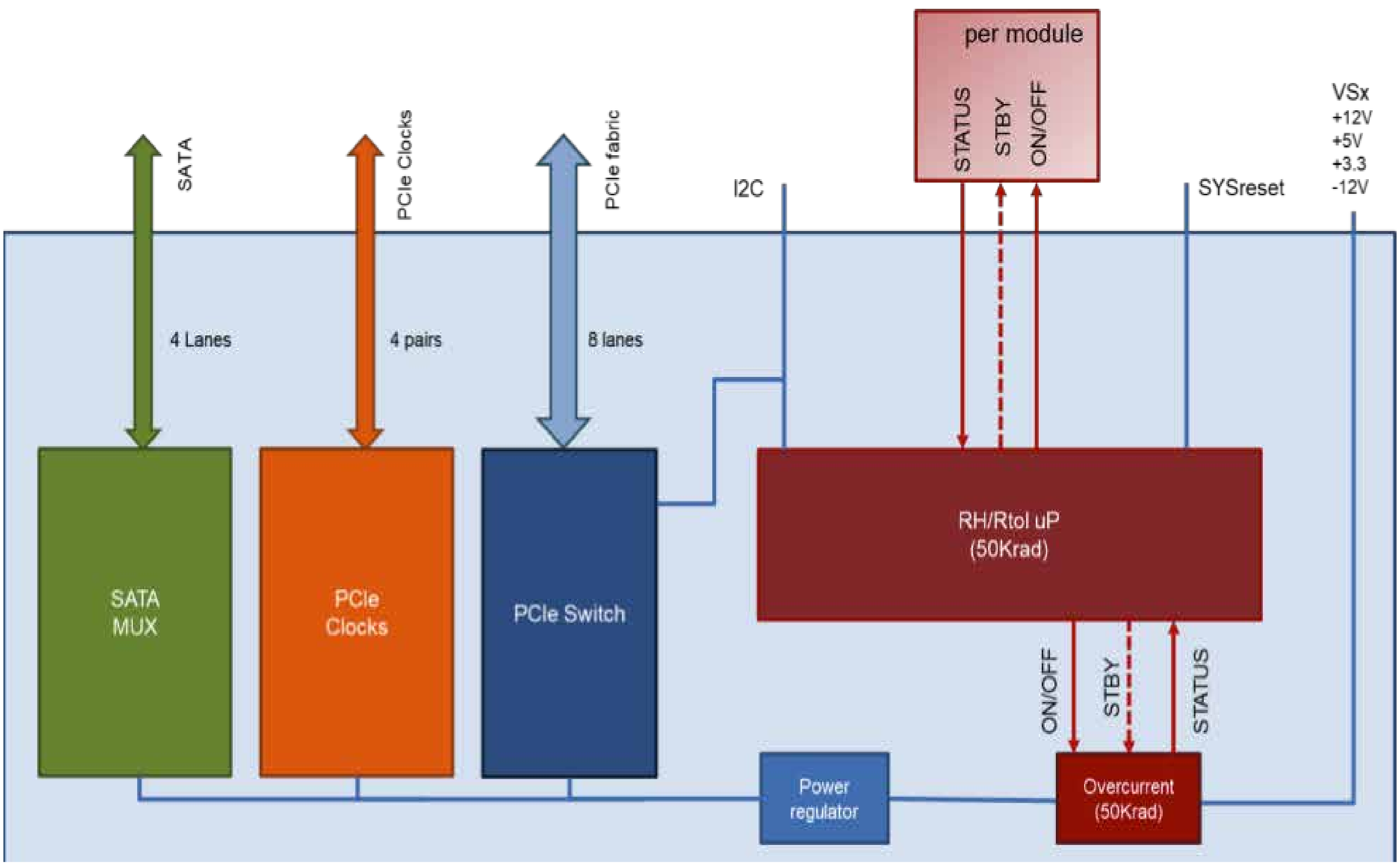


Figure 4 — Block diagram of System Controller Module.

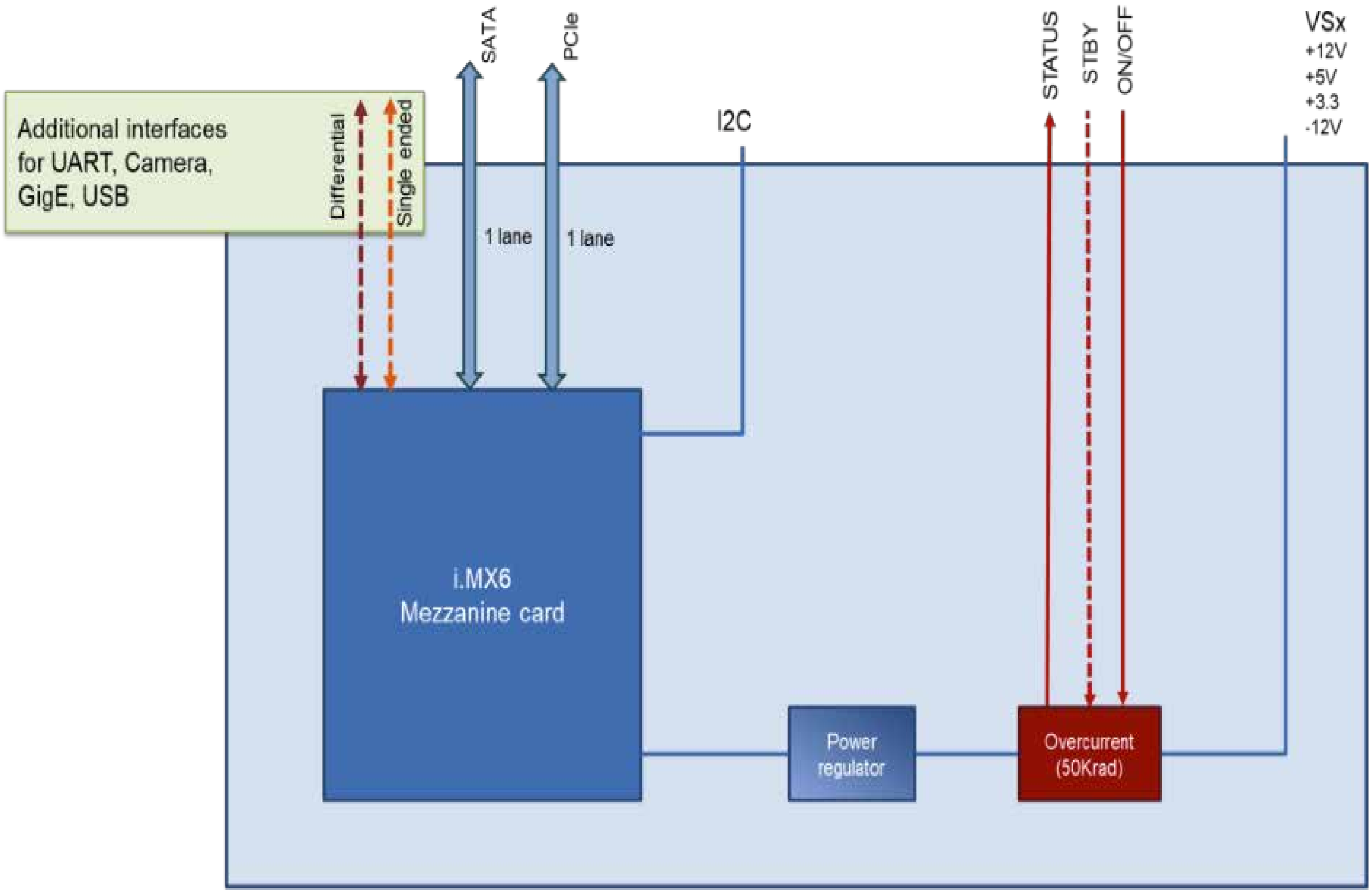


Figure 5 — Example of a compute module based on an i.MX6 SBC mezzanine card.

- Similarly, the differential and single-ended user-defined signals are connected in pairs between all modules to provide different signal paths.

A more detailed view of the system controller module is seen in Figure 4. In this case, the system controller module consists of a Rad-tolerant (e.g., 50KRad) microprocessor, the Rad-tolerant Latch-up Overcurrent Protection IC, a PCIe switch, a PCIe clock source, and a SATA Multiplexer to enable redundant storage modules. The microprocessor has I2C signals and enough GPIO signals to supervise the STATUS and ON/OFF signals of each module in the backplane.

An example of a computing module using an i.MX6 based SBC and a Latch-up overcurrent protection IC that is controlled by the system controller is seen in Figure 5. The SBC mezzanine card uses one PCIe and one SATA connection to interface to an I/O and a Storage module respectively. The interface is done through the PCIe switch and SATA multiplexer in the system controller. Other modules can be implemented using a similar approach.

Conclusions and Future Work

The most essential components of the resulting architecture are:

- A System Controller module capable of supervising all other modules in the system, monitoring for radiation-related failures, and providing high-speed interconnection among modules speed serial fabric (e.g., PCIe).
- Dual redundant Computing, Storage, and I/O modules that implement the mission of the system.
- A backplane interconnect board, where all modules are interconnected.

The main enhancements to the existing VNX architecture are the Radiation Tolerant system controller supervision circuitry, the Latch-Up overcurrent protection methods integrated into the System controller and all other modules, and the inclusion of dual redundancy methods to allow the system to continue operating even after a module suffers a Latch-Up Event.

The next steps towards the implementation of the of a proof-of-concept Radiation Tolerant architecture based on the VNX standard include:

- Implementing and testing the reliability management system using the System Controller module
- Implementing and testing the backplane interconnect fabric that enables the reliability enhancements that were studied during Phase 1.
- Extending the reliability management system to address other radiation-related failure modes (e.g. Single-Event Upsets).
- Involving industry partners such that multiple vendors can demonstrate computing, storage, and I/O capabilities.

Satellite Operation for WMPLOTA

Patrick Stoddard, WD9EWK
wd9ewk@amsat.org

A Twitter discussion began in April, after Chris, K7TAB, worked satellites from a Walmart parking lot in West Virginia, about having an activity focused on operating from Walmart stores. Walmart stores are everywhere and generally allow vehicles to park in their lots for extended periods, including overnight camping. This may have started out as a joke, but in the span of a couple of weeks, the activity was given a name, Walmart Parking Lots on the Air, or "WMPLOTA." A web page appeared with information about the planned event (wmplota.org), and the event date was set for the weekend April 28-29, 2018. Rules were relatively simple: operate from a Walmart store's parking lot, in sight of the Walmart sign or a Walmart shopping cart if the sign isn't visible from where you are in the parking lot, and make contacts. Scoring was more complicated, given the number of bonuses and multipliers that were created, but a spreadsheet helped to make that an easier task. As satellite operators talked about WMPLOTA, other hams heard about it, including some who don't normally work satellites. For me, I wanted to see how many Walmart stores I could visit during part of the WMPLOTA weekend.

On Saturday, April 28, I noted 10 passes on the 4 FM satellites (AO-85, AO-91, AO-92, SO-50) between approximately 9 am and 2:30pm or 1600-2130 UTC. One was a 2-degree AO-85 pass, which I took out of consideration, leaving 9 passes in that timeframe. I wanted to see if I could work the 9 passes from 9 different stores. Around the Phoenix area, there are almost 30 different Walmart stores, including Supercenters, Neighborhood Market grocery stores, and even one location that only has a pharmacy. One of these stores straddles the DM33/DM43 grid boundary in central Phoenix, and a couple of other stores were near that grid boundary (within 3 km, or just under 2 miles, of the line). Using the pass predictions showing the gaps between passes, I came up with a plan to visit Walmart stores in Phoenix, Scottsdale, Mesa, and one store on the Salt River Indian Reservation east of Scottsdale for each of those passes. All of these stores were near freeways, which helped with travel between locations. I used my Icom IC-2730A 2 m/70 cm FM mobile radio and Elk dual-band log periodic antenna for my station at each site.

I started the event operating from Walmart store 2515, at 38th Street and Thomas Road in central Phoenix. The east end of the store and its parking lot straddle the DM33/DM43 grid boundary (112 degrees West). I decided to start here because I had only one row of parking spaces I could operate from, and I wanted to have more time to document my location on the grid boundary. This store is only a few miles west of my house, and the drive on a Saturday morning to get there was uneventful. After parking and documenting my location - see photos of my station with the store in the background, and of my location on the grid boundary - I waited for AO-85 to come up. When it did, I worked seven stations from this store. Four of these QSOs were with stations at other Walmart stores. This was an excellent start to my day of operating from different Walmart stores.

After that pass, I took the AZ-51 freeway to northeast Phoenix. There are two Walmart stores along Tatum Boulevard in this part of Phoenix, and I planned on working from both of them. The next pass at 1650 UTC was an AO-92 pass covering most of the continental U.S., and I worked 8 stations from store 4232; some at other stores. After the AO-92 pass, I drove 3 miles north to store 1598 for a western AO-85 pass and logged 4 QSOs. One of the 4 was with another store.

For the 1800-1900 UTC hour, I drove the AZ-101 freeway to Scottsdale for two more stores. The first of these stores, 2766, was in north Scottsdale. I worked a SO-50 pass a few minutes after 1800 UTC, logging 5 QSOs including one with another Walmart store. Now things got interesting. As SO-50 disappeared, I had 10 minutes to travel over 7 miles south on the AZ-101 freeway to store 2112 on the Salt River reservation near Scottsdale. I stopped working SO-50 a couple of minutes before LOS, packed my car, and arrived just in time for the start of the western AO-92 pass at 1826 UTC. Although I missed the first two minutes of it, I worked six stations, one of those at a Walmart store.

At this point, I had successfully made contacts from five different Walmart stores, and the gaps between passes were longer for the remaining four passes. I planned to visit a group of Walmart stores along the US-60 freeway in Mesa, where these stores were separated by two miles. This made travel between stores easier for the remaining four passes.

A few minutes after 1900 UTC, I targeted an eastern AO-91 pass that covered from coast to coast. I worked this pass from store 3799, at Country Club Drive (AZ-87) on the south side of the US-60 freeway. Even with

the normally crowded conditions on AO-91, I worked eight stations from this location, including three other Walmart stores.

A half-hour later, I had an overhead SO-50 pass I worked from store 2768 at Stapley Drive and the US-60 freeway, two miles east of store 3799. From this store, I logged eight contacts, including three from other Walmart stores. In addition to the WMPLOTA activity, AD0DX was operating from the DM68/DM69/DM78/DM79 4-grid intersection in Colorado. Everyone was able to make QSOs, without the congestion heard from the earlier AO-91 pass.

About 45 minutes after SO-50 LOS, I had another AO-91 pass at 2045 UTC. I drove another two miles east to Lindsay Drive and Walmart store 5304, a Neighborhood Market grocery store. I worked six stations from there, including another Walmart store and two stations who told me I was their first satellite QSO. By early afternoon, the temperature had reached 100 degrees.

After the AO-91 pass, I drove another two miles to Walmart store 5428 for a low western SO-50 pass, the last of the nine passes I planned to work. Unfortunately, I heard nobody else on this pass.

For the eight stores I visited, I logged a total of 52 contacts. One of the eight stores sat on a grid boundary, and two others were near a grid boundary. I took pictures of my station, including a picture with a Walmart store and U.S. flag in the background, along with claiming other bonuses, multipliers, and awards for my 6.5 hours playing radio from Walmart stores. I was able to work at least one other Walmart store at each of the eight stores I visited. Justin, K5EM, created a spreadsheet which captured the scoring for this event, including all of the multipliers and bonuses. With this scoring, I claimed a score of 9313 points for my 52 QSOs from 8 different Walmart stores. Had I operated from more stores, or spent more time at the stores I visited, I could have easily pushed the score into five digits.

WMPLOTA may have started out as a bit of a joke, but many satellite operators showed up and worked stations throughout the weekend. If there are other WMPLOTA activities in the future, I will try this again. I'd like to visit different stores, and maybe add in non-FM satellites. Lots of options to consider...

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 2018.

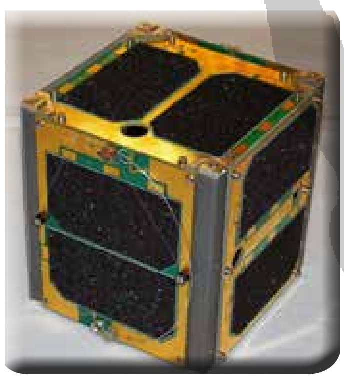
Fox-1D rode to orbit on an Indian PSLV vehicle launched from Satish Dhawan Space Centre in Sriharikota, India on January 12, 2018.

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.

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



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

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

AMSAT Ambassadors - NEW

AMSAT Ambassadors program is looking for satellite operators to share enthusiasm for Amateur Radio in Space with others by:

- Promoting AMSAT at in-person events, practical demonstrations, online, or in written communications
- Offering personal mentoring and coaching to new enthusiasts either in-person or via online means
- Connecting members and potential enthusiasts with proper resources at AMSAT.

To volunteer, send an e-mail to Clayton Coleman, W5PFG at: **w5pfg@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**.

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.**

Find more information at amsat.org. Click AMSAT – then click Volunteer.