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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 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.

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

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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 EyaSat 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



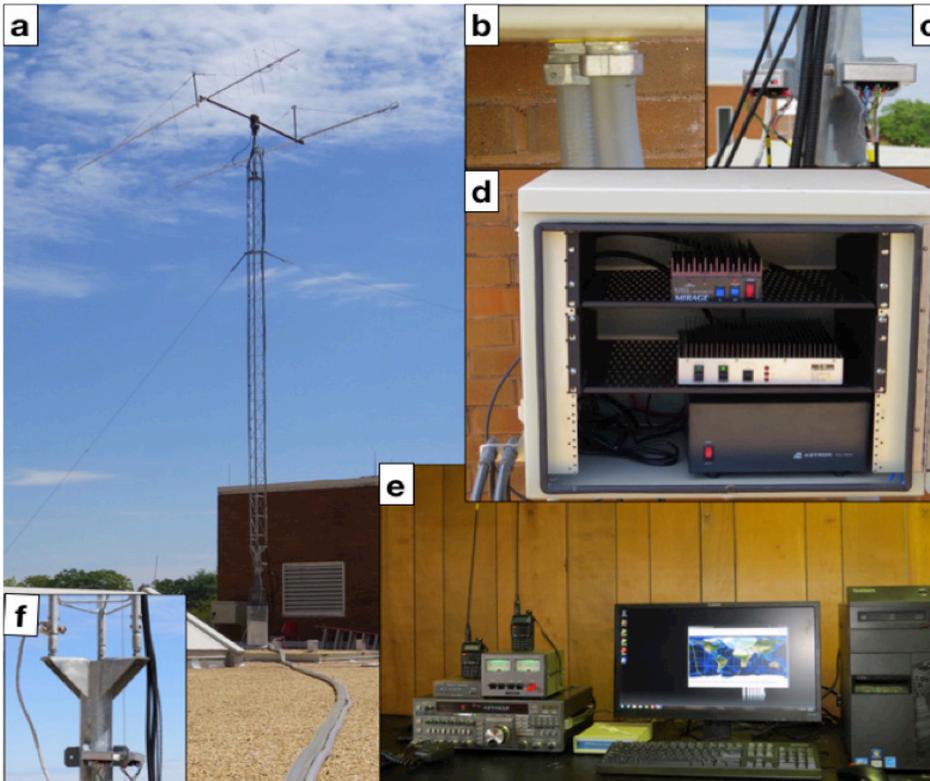


Figure 1.

(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.

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,

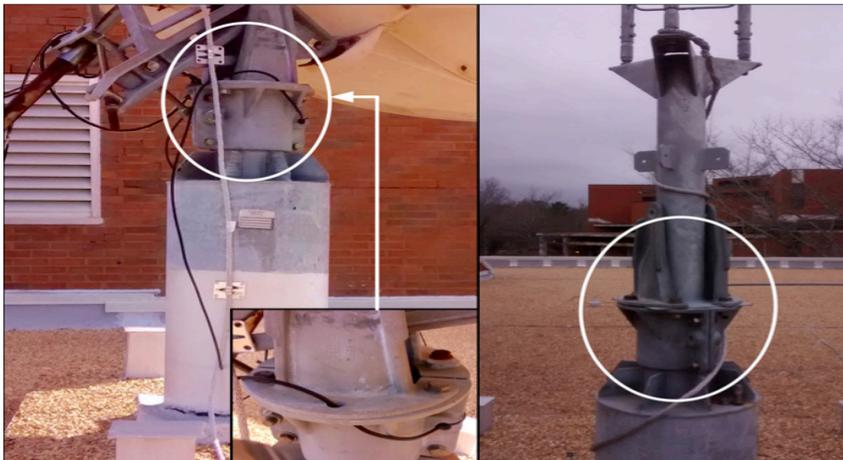


Figure 2.



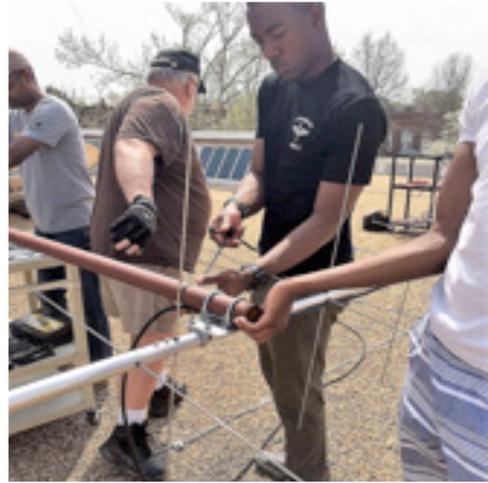


Figure 3.

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



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

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 5 shows a schematic of these connections and the actual setup.

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 6 also illustrates how each component is connected to enable a digital and analog capable system.

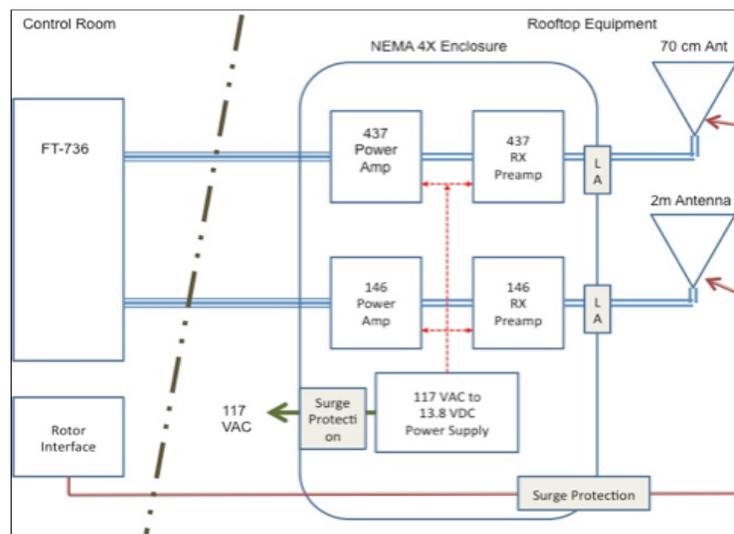


Figure 5 — Schematic of electrical connections.



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 PNM/Sats/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



Figure 7.

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.

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.

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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	

	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

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

