The AMSAT® Journal

Editor-in-Chief
Joe Kornowski, KB6IGK

Assistant Editors
Bernhard Jatzeck, VA6BMJ
Douglas Quagliana, KA2UPW/5
Paul Graveline, K1YUB

Volume 44, Number 5 September/October 2021

In this issue —

The AMSAT Journal Needs YourWords and Wisdom

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

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

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

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

Our editors are standing by!

Radio Amateur Satellite Corporation (AMSAT)
P.O. Box 27, Washington, D.C. 20044

AMSAT Club Callsign: W3ZM
AMSAT Websites: www.amsat.org, launch.amsat.org (Member Portal)

Editorial Office: Joe Kornowski KB6IGK, 3310 W. Braker Ln., Suite 300-322, Austin, TX 78758. Please e-mail *Journal* submissions to: journal@amsat.org,

The AMSAT Journal (ISSN: 1407-3076) is published bi-monthly (Jan/Feb, Mar/Apr, May/Jun, Jul/Aug, Sep/Oct, Nov/Dec) by AMSAT.

The AMSAT Journal staff is always interested in article submissions. Whenever possible, submissions should be sent via e-mail to journal@amsat.org using plain text or word processor files; photos or figures in TIF, GIF or JPG formats. Kindly do not embed graphics or photos in your manuscript. We prefer receiving those as separate files. AMSAT reserves the right to select material for *The AMSAT Journal* based on suitability of content and space considerations.

Apogee View

Robert Bankston, KE4AL
President

This issue of *The AMSAT Journal* marks my first year as AMSAT President, so I thought I would take this opportunity to update you on what we've been working on, where we are now, and what we will focus on in the coming year.

Our Engineering team has been making significant progress on our GOLF program. Under the leadership of our Vice-President of Engineering, Jerry Buxton, N0JY, our volunteer engineers have worked tirelessly to develop, prototype, and test GOLF's systems. I thank each and every one of them for donating their time and expertise.

Not to be outdone, our Educational Relations team completed its beta testing on the CubeSat Simulator and launched the CubeSat Simulator printed circuit board set on the AMSAT Store. Dr. Alan Johnston, KU2Y, and his team have done a phenomenal job. In addition, as announced at this year's symposium, they have not only developed and released the new CubeSatSim Lite version, but Dr. Johnston and his team have begun to experiment with high altitude balloon launches to take the CubeSatSim concept to the next level of educational initiatives.

Behind the scenes, we have been busy modernizing back-office tasks, finding ways to more efficiently do business, and ensuring the AMSAT machine runs smoothly. To be honest, running AMSAT without Martha has been a significant challenge.

Our modernization efforts, which really began with the May 2020 launch of our online member management system, have been the key to our overall success this year. Transforming a 52-year old organization from brick and mortar to virtual was no easy task and not without a few hiccups along the way, but we are better positioned moving forward. It was a sad day packing up the AMSAT office in Kensington, Maryland, in May and putting everything in storage. To touch all that history reaffirmed why we do what we do.

I look forward to both the challenges and opportunities that lie ahead. AMSAT is in a very solid position from both a financial and a membership perspective. We have a strong fiscal foundation, an excellent governance and management team, generous volunteers who freely donate their time and expertise, and a diverse membership base who truly care about keeping amateur radio in space.

Financially, we are on a solid footing, with over $950,000 in cash and liquid investments. Our revenues are down from last year, as is the rest of the U.S. economy; however, we are on track to exceed our profitability margin over last year because of the cost-cutting measure we implemented. In 2020, $0.82 of every dollar went to pay overhead. In 2021, that amount was reduced to $0.56 for every dollar we brought in – a 31% reduction. This means a lot more of your membership dues and revenues we develop from other sources are going towards building satellites and expanding our educational efforts.

AMSAT membership has consistently been over 4,000 the past year, with 4,045 current members as of this writing. AMSAT's membership is diverse, representing 76 countries. While each comes for varied reasons (builders and operators, scientists and educators, HEO and LEO), we all come together for a single purpose: to keep amateur radio in space.
So, what's next? With over 52 years of success, what are we going to do now?

We have an ambitious, forward-thinking plan (**www.amsat.org/strategicplan/**) that's ready to be put into action. Central to this plan are the needs to modernize how we manage projects and explore ways to collaborate with our international partners, given current ITAR/EAR restrictions.

In addition, as an all-volunteer member organization, we need help. While we have a solid core of volunteers now, expanding our programs will require additional human resources and added expertise. I will be addressing this in the next issue of *The AMSAT Journal*, but if you cannot wait, please feel free to contact me directly. We would love to have you join our team.

Our greatest threat right now is the ever-tightening regulatory environment. It is one thing to hope to return to higher orbits and even beyond, but all of this will be for naught if we can't get a satellite licensed in orbit above LEO. Proposed orbital debris mitigation regulations will require orbits above 600 kilometers to have a flight-proven, low-risk transfer orbit, long-term reentry capability, and/or improved move-away-and-stay-away storage options for orbital lifespans more than 25 years. However, proving you can get there and operate responsibly will not be enough. Every mission will be closely evaluated to ensure it serves the greater benefit of all, which, at this time, strongly favors commercial, scientific and educational interests. Thankfully, our engineers had the foresight to develop the GOLF program for this very purpose.

While we await the FCC's final ruling, we cannot sit idly by and be content with mediocrity. Instead, we must continue to push Onward and Upward. We should focus our efforts on new communication systems that more efficiently allow us to communicate in space and spacecraft which will take us towards and beyond the next space horizon. At the same time, we must establish and maintain a path of sustainability that not only introduces space communications using amateur radio to the public but also nurtures them to be the next generation of satellite builders and operators.

On a side note, I had the pleasure of attending and speaking at the 2021 AMSAT-UK Space Colloquium on October 24th. It was an incredible event, and AMSAT-UK did a phenomenal job of hosting the virtual event. In addition to the extraordinary work being done by the Surrey Space Center team on their STAR-XL project, the operators chasing QO-100, and Peter, 2M0SQL's, roving efforts in Northern Scotland, we were treated to presentations on IARU Amateur Satellite co-ordination by Hans Blondeel Timmerman, PB2T, and an AMSAT-DL update, by Peter Guelzow, DB2OS. If you missed the AMSAT-UK Colloquium, I encourage you to view it on AMSAT-UK's YouTube Channel, **www.youtube.com/user/AMSATUK/videos**.

Let me close with personally thanking all of our members, who generously donated to the AMSAT President' Club this year, and our Vice-President of Development, Frank Karnauskas, N1UW, who single-handedly resurrected this program and managed to raise over $33,000. I look forward to what Frank can do for next year.

AMSAT Recognizes 2021 President Club Donors

We would like to thank the following AMSAT members whose generosity represents over $33,000 in donations to AMSAT. Because of their contributions they have been inducted into the 2021 President's Club.

A limited number of 2021 Commemorative coins remain. We hope you will now and join these members in helping to Keep Amateur Radio in Space!

Titanium ($5000+)
John D. Botti, KC8OKB
William Brown

Platinum ($2,500+)
Alan P. Biddle, WA4SCA

Gold ($1,200+)
Barry Baines, WD4ASW
James Hain, W2IMY
Glenn Miller, AA5PK

Silver ($600+)
Douglas P. Besemer, K0VPL
Jeffrey Davis, KE9V
W. Fisher, WB1FJ
Mark Hammond, N8MH
William Hudzik, W2UDT
Mark Johns, K0JM
Allen Kenny, KK4AK
Joseph Lynch, N6CL
Ronald Parsons, W5RKN
Jason Schwarz, N4JJS
David A. Vine, WA1EAW

Bronze ($300+)
Bob Davidheiser, W5RBD
Warren Fugate, W3WE
Anton Giroux, KF3BX
Robert Grattan III, N4MRV
Stephan Greene, KS1G
Edward F. Krome, K9EK
Bruce Paige, KK5DO
Richard Ruhl, W5GLD

Core ($120+)
Gerald Buxton, N0JY
Dennis Dinga, N6DD
Joe Domaleski, KI4ASK
David Grebe, WA4LM
Sam Hancock, K4NAV
Raymond Hart, KN6DPI
Stephen Howard, AB0XE
John Kludt, K7SYS
Octavio Leyton, CE3JSX
Brian Lopeman, KI7WXP
Dave Pascoe, KM3T
Dale Peer, KF7ZBK
Robert Plant, W7NEV
Donald Pettigrew, K9ECT
Richard Polena, WW8W
David Poplewski, KC8IV
Thomas Samulenas, W1OX
Jay Schwartz, WB8SBI
Alston Simpson, WA5TJB
Carl Starnes, W4EAT
Richard Steegstra, K1LKR
Paul Stoetzer, N8HM
Thomas Talley, K0CFI
Timothy Tapio, K4SHF
Dave Taylor, W8AAS
Frank Westphal, K6FW

All members receive a full color certificate, polished gold finish commemorative coin and embroidered "Remove Before Flight" key tag. Members at the Silver Level and above also receive a handsome personalized acrylic desk plaque. Gold level and above members also receive complimentary tickets to Hamvention and Symposium events.
See the inside back cover of this issue to learn more about the 2021 President's Club!

The Life and Legacy of Tom Clark

WN0IUF, W0IUF, K0RBI, W4JBL, WA3LND, W3IWI, G4UTL, K3IO

Bob McGwier, N4HY

We Begin at The End

This article celebrates our friend and mentor, Tom Clark, K3IO, and mourns his passing. Tom died on the 28th of September this year following a thankfully brief collapse resulting from two strokes, one followed by another. The thing we should all remember about the end is Tom knew that his body was getting frail and that he was no longer able to keep up even the small rigors one might have to go through to attend AMSAT board meetings. As a result, he discontinued being an AMSAT director in 2020. He knew that things were getting tough, but Tom was not giving up. Let me assure you of that. While I write this to honor Tom, I am selfishly doing it from my perspective because I was his longtime friend, he was my mentor, and I feel I knew him best. He and Elizabeth allowed me to live in their home for half the year in many years. They had a room downstairs with a sign on the door that said "Boob's Room." For Christmas, they gave me gag gifts that I know Tom thought about for hours. I loved them both dearly, and my pain will be suppressed here to celebrate Tom Clark, the bigger-than-life person who impacted me as much as anyone outside of my parents and many of you as well.

The last month of his life began with Tom planning on taking a multi-thousand-mile car and train trip. Tom was planning to come through Alabama and spend time with Sharon and me. Sharon is N1SMM, and I'm N4HY, and Tom was very close friends with us. He was driving on his way to Texas, where many of you may know that he had a friendship with Jerry Checkon, and they became traveling companions and friends. They were going to get on a train trip and go to the West Coast, turn around, and then Tom would return through here and go back.

Tom was not sitting down and dying. He had no plans for that. He was making other plans. So, I want to try to read a couple of lines of this Dylan Thomas poem because if I try to read all of it, I promise you I will not make it through.

Tom was not rolling over and dying. He was not going "gentle into that good night." He was living. We regularly argued. We talked on the phone about technical matters. Tom was beginning to get involved in the ARDC. He was slated to join the grants advisory committee. He was going to continue, and I couldn't think of anyone better than Tom Clark to help go over the grant submissions because ARDC encourages and helps those people who apply for grants not to overlook things. And Tom was going to join the ARDC grants committee.

Then, the strokes cut him off, first from his travel and then from his life. He suffered very little after the second stroke. He was not awake. He was comatose. It was quickly determined that he had met all the conditions of his living will. Everyone involved agreed that he had. He was moved into hospice. Within 24 hours of his having moved into hospice, he passed. Tom roared into the end of his life planning lots of things but, when the time came, he roared his way out less than a day after entering hospice.

Who He Was To Many

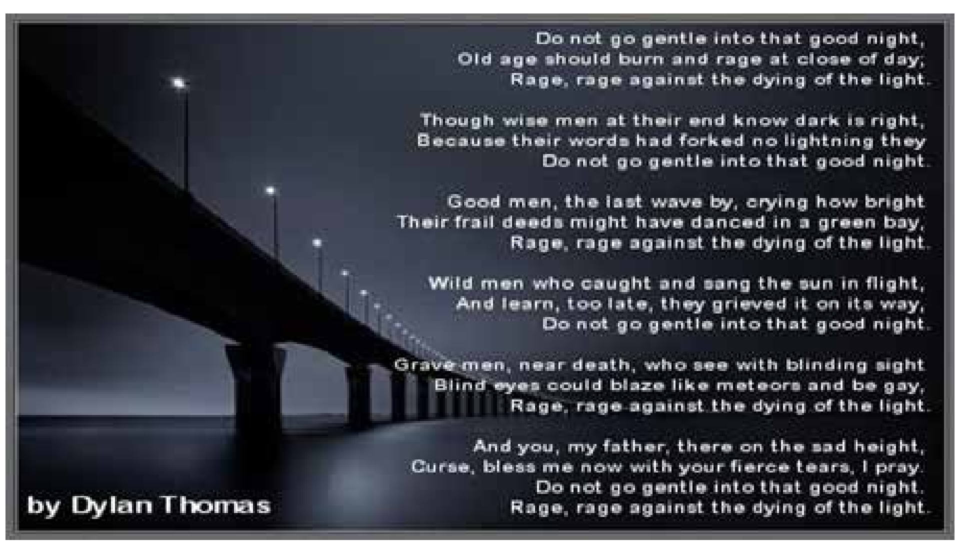
Tom was, to many of us, a friend, mentor, scientist and engineer. Being a radio amateur and part of AMSAT was in his blood. There was no way Tom's life could be defined without knowing more than half of his daily life was being a radio amateur. In addition to that, we'll cover those things that many of you may not know about Tom being a scientist and something of his early trajectory.

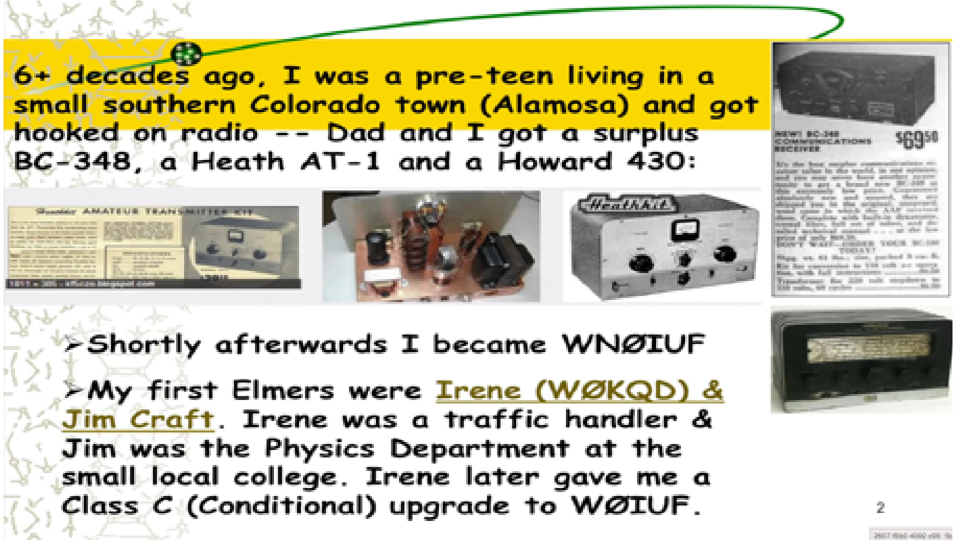
The things Tom and I had in common included we both grew up in rural areas. We both had parents that encouraged us at a very young age. Both of us became radio amateurs at approximately the same age. I was a little over 10. Tom was 11.

We each had this similar introduction to amateur radio, and both of us eventually became scientists. Beginning in 1980, when I was a first-year graduate student at Brown University, Tom and I really became close friends. That was the year he encouraged me to take the first open-source tracking program ever he had developed and do things with it. Tom could be amazingly unselfish and encouraging. I saw these acts many times. But Tom would always remind you what he did in the beginning well ahead of others. I never forgot it ever. For us, this satellite tracking program began the decades-long friendship which has not ended with his death. You will see me with the only gift I wanted and got from Tom's estate: his bolo ties, and I will wear them in his honor at all amateur radio events.

His Precocious Beginning and Move to His Life's Work

Let's move on now and see if we can't learn





some things about Tom for those of you who don't know him or need a reminder. Tom was born in Alamosa, Colorado, in the 1930s. He became a ham at age 11 and was WN0IVF. Tom and his father had the same kind of relationship I had with my father. His father helped him get his first amateur radio equipment, which was a Heathkit AT-1 and a Howard 430 communications receiver and Hammarlund HQ-150. He also had a BC-348, a little higher performance receiver.

He and his father fiddled around with the mechanics of antennas and other things. Back then, you had one year to leave the novice rank and move up. Tom was over a hundred and fifty miles away in Alamosa, Colorado, so he got his mentors, Irene (W0KQD) and Jim Kraft, to help him move up. He upgraded to Conditional General and became W0IVF. You guys should check out this equipment. Tom loved tinkering with this stuff, and the AT-1 was still in his basement when he cleared out his house and sold it.

In his teens, he moved to Pueblo, Colorado, and there became the protege of Ed Tilton, where they had Tom's first VHF QSO. Tilton had a Gonset Communicator in his car, and Tom had this little tube rig. Tom got his first QSO and then became a VHF and plus person for the remainder of his life. He loved it.

Tom went to school in Denver, where he had great Elmer physics teachers and hams. He eventually decided he would go to the University of Colorado at Boulder and, during his lifetime, held the calls WN0IUF, W0IUF, K0RBI, W4JBL, WA3LND, W3IWI, G4UTL, and finally K3IO. You might remember, of course, that you used to be unable to keep the call you were given if you moved out of the district in which that call applied. You had to apply for a new one. So, when Tom moved from the 0 district to the 4th district, he had to get W4JPL and so forth. That's why he had all these calls except for the last one. Tom loved to tell the story when the topic came up of how he got the call K3IO.

College He Loved for a Decade

When Tom went to the University of Colorado, he first got his degree in engineering physics because he wanted to be a radio guy. He was trying to continue into his professional life the fun he was having as an amateur radio operator. He did very well as an undergrad. But he really enjoyed it when he got to work on his doctoral degree, a Ph.D. in astrophysics and astro-geophysics. The photos below are from above and on the ground of the 10 MHz radio telescope Tom used for his Ph.D. degree and thesis. Tom made radio telescope observations of the sun, the planet Jupiter, and the interactions between Jupiter and Io — the emissions coming from charged particles that are flying around our galaxy as really high-speed particles and ions of the Galilean moon Io that interact with magnetic fields which give off emissions.

Tom loved this. He loved doing this so much that he stayed in graduate school for nearly a decade, but finally, they forced him to write a Ph.D. and leave because he was going to be drafted into the U.S. Army.

Io, to his mind, was the most interesting part of the work he did with a telescope he built with his own hands at the University of Colorado. So, when K3IO became available, that's when he got that callsign.

Io is a really interesting moon of Jupiter. As it goes through Jupiter's magnetic field, it has these volcanoes that spew out sulfur and other particles. These particles become ionized and interact with Jupiter's magnetosphere and turn into little transmitters because, as you accelerate electrons, they give off photons. In this case, the photons are RF photons and audible in HF on the Earth. These photons are RF emissions on frequencies that you can hear on Earth with modest antennas.

His First Job and a Lucky One

As Tom left Colorado, he had also been drafted into service. And he wasn't up for six years, so he agreed to the draft for three years. He was certain that he would go to

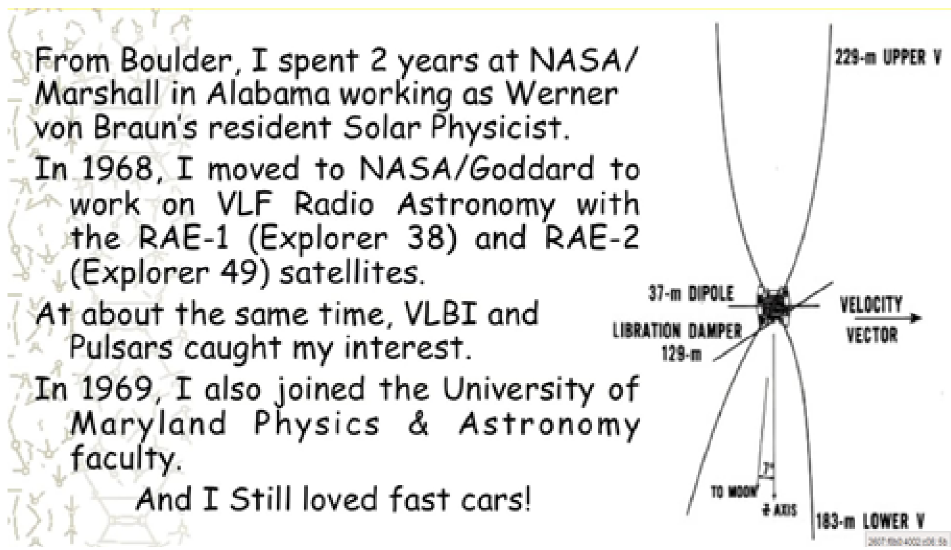
Vietnam, where he would build or blow up bridges and bomb things, etc., during the Vietnam War.

And then a remarkable thing happened. Even though he was in the active-duty service, Tom was at Marshall Space Flight Center right next to Redstone Arsenal. He was given the opportunity with his Ph.D. in physics to join Verner von Braun's staff at Marshall from 1966 to 1968. This allowed him to continue his physics and learning and be around really smart people different from the ones he knew in Colorado. So, it expanded his consciousness in terms of science, and it kept him out of the rice paddies, so we got to keep him around for a few decades.

During this time, Tom earned a decent living, so he began racing cars and doing road rallies while in Alabama. I can tell you to this day, people drive crazy over there, so it's not a big stretch of the imagination that one would do that. But Tom had an interesting way of doing road rally car racing.

He had a small house, and he regularly had to work on his engines. He would work on his engines inside his living room and regularly put the crankcase in the dishwasher. Elizabeth, his wife, was working for the government in Huntsville, where he met her. She was a South Carolina lady working in Huntsville, and she didn't seem to mind that this weird guy washed his engines in his dishwasher. When he asked her to marry him, the arc of Tom's adult life began with their marriage and his work for Verner von Braun.

Tom moved to NASA Goddard, and you can see an excerpt from a slide deck in that many of you may have seen Tom give during his talk on his sixty years as a prisoner of amateur radio, like many of us are. After Marshall Space Flight Center and working for von Braun, he went to Goddard and started working on very low frequency radio astronomy with RAE-1 & 2 Explorer 38 and 49 satellites. They were sent up on the Army rockets that came from Redstone Arsenal. I mean he was connected. Because of Werner Von Braun, he got to participate in these great experiments and build his physics reputation. At about the time this work was coming to an end or done, his most interesting work included building that spacecraft depicted on the right side of the slide, which had huge antennas. They were hundreds of meters across with dipole antennas extended. Then there was a bar that extended which was filled full of gelatinous substance (probably glycerin) that



was a libration damper. This spacecraft's long antenna appendages would be gravity locked after it stopped wobbling with the aid of the libration damper. This was interesting, and he mastered these pieces of this spacecraft.

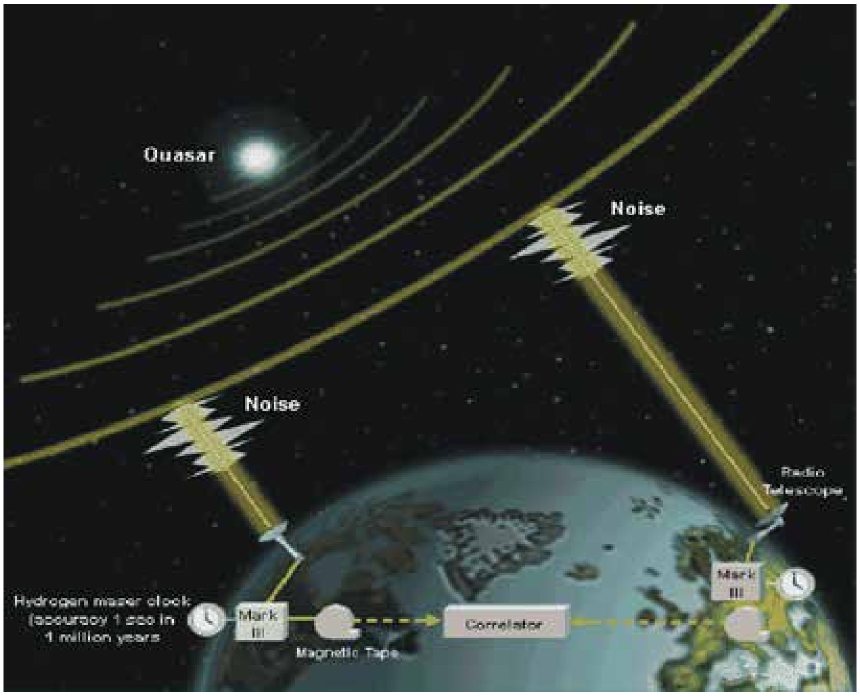
Very Long Baseline Interferometry

We arrive at the beginnings of Tom's interest in doing fun things in space. So in '69, he joined the University of Maryland physics and astronomy faculty, and he began his lifelong work in Very Long Baseline Interferometry. He continued to do road rallies and build race cars. So Very Long Baseline Interferometry (VLBI) arrived in the late '60s at Goddard, and Tom was a technical leader very quickly. As many of you know, but let me emphasize, Tom was much more than a theoretical physicist; he was an engineering and instrumentation physicist. He could build instruments and then do the theory. He was very unusual in terms of the class of person he would interact with technically. We all benefited from that because he came into AMSAT and helped us with all sorts of things.

But he wanted to use quasars and see if he could do VLBI to look at these quasars in a radiotelescope and figure out how big the antennas, the virtual antennas, had to be to get an image of the shape and the density and the emission profile, etc., of quasars. He figured out soon enough, with others, that the telescope, virtual or real, had to be the diameter of the Earth or larger, but we were limited to the diameter of the Earth then. So, Tom was critical in figuring ways to make this work.

If you consider a quasar, which is most of the way across the universe, not even close to our galaxy. They're ancient, billions of years old. But by the time the light and radio emissions from the quasar reach the Earth, it doesn't matter where on the Earth you are; the same signal arrives because all the degradations have happened along the path. So, essentially, everyone on Earth sees the same signal. What you don't have the same at all points on Earth is the angle you're pointing at the quasar, the noise sources at your local site, and the interference sources at your local site because they were observing these quasars in microwave frequencies. These microwave frequencies were line of sight unless you had some weird propagation like ducting. The noises and interferences were statistically independent. If you take this same signal and try to do constructive interference of the quasar, you get a big signal-to-noise ratio improvement on the signal from the quasar. But you had to figure out how to line up these things, so they constructively interfered rather than destructively interfered, or the signal wobbled around in phase.

At that time, and just in the nick of time, hydrogen masers were expensive, but they were available. Sitting at Goddard, you could calibrate them and move them to the place on the Earth where the antenna was. These hydrogen masers would lose less than one second of precision in a million years. Not only did they keep the time ticks coming along regularly for millions of years, but in addition, they didn't wobble a lot down in the nanosecond or picosecond range. As a result, the phase noise they introduced on the signal was minimal, and they were highly accurate. This enabled these antennas and receivers that were thousands and thousands of miles apart to constructively add their signals together even though the signals received were recorded on tape at each site.



The hydrogen maser would generate a tiny signal that was added to the incoming signal of the quasar and then recorded on magnetic tape. These magnetic tapes would be boxed up and sent back to Goddard. The magnetic tapes from all over the world for one observation period would be loaded on a big IBM mainframe, and they would be lined up because it had this hydrogen maser timing signal. Then the phase offset would be calculated. This basic phase and timing offset would be sufficient for you to image in the radio waves of the quasar.

Well, Tom became a master of this technique, and he really got it down pat. His proof-of-concept led the world in going down this path. But Tom didn't want to stop there because his mind never stopped working, not even until the last days of his life. Tom figured out that, as we look at these quasars, we could look at the change of the signal — and timing, frequency, whatever — from these different antennas, and it would tell us things about how the Earth was moving beneath the antenna. So, Tom turned VLBI into an amazing science instrument for geodesy. With his instruments, he and his team were able to measure plate tectonics and many other things.

Tom's rise over his VLBI career made him a senior scientist at Goddard Space Flight Center. He had 150 peer-reviewed publications or refereed journal papers. Tom's team became the most accurate geodesy team in the world. More than just doing radio astronomy, these VLBI measurements were now measuring the motion of the Earth underneath the instrument. They could do things like measure plate tectonics, velocity changes, and position changes every single day, not over years, averaged, but the actual daily time series. They could easily see El Nino currents in the oceans, changes in the Earth's rotation on a daily basis, and, as equipment got better, you can see the regular daily rotation of the moon wobbling the Earth in its orbit. It was just remarkable!

He could show that the Earth's surface, with all the sun and moon gravity, moved up and down inches underneath our feet every single day. Well, this work astounded the American Geophysical Union because Tom's measurements were used as the thing that scientists looked to in validating their models for all sorts of things.

Theoretical scientists typically make models that do math on paper or calculations on a computer. But, to make a theory acceptable to a wide range of people in a scientific field, there needs to be experimental data to confirm the theory's predictions. Tom's work with the VLBI and astronomy and doing this geophysical work was one of the principal data sources that helped prove and improve these theories. Every year, his measurements threw out about half of all the new theories because one thing a scientist knows is that your theory is only as good as its match to actual data. If it's a theory that doesn't work with actual data, the theory is wrong, end of story.

For this work, Tom became a fellow of the American Geophysical Union. This was one of those times when we were such good friends that my wife and I were invited to the ceremony, and we got to see Tom awarded his big plaque and be inducted as a fellow. Less than 1% of all the geophysical people get made a fellow, and Tom had six people on his team become fellows of the AGU. They were that important. I mean, imagine that there are not that many geophysical scientists working at the tip of the iceberg. So, for Tom to get six, that was probably like six out of a hundred, let's say. It was remarkable that his team did so well and was important to have the Geophysical Union honor them.

Tom was not just staying at home. He was going all around the world trying to get others involved in the VLBI to get more data and get more science. He encouraged and aided the Russians in participating in this VLBI, working all the details out of the operation, even though they were still the Soviet Union and we were enemies. It was like the current work that goes on at the International Space Station. Politics are one thing, but they weren't doing politics when they were doing science; or, if they were doing politics, they were lying to their politicians so they could do the science.

Tom went over and helped them set up VLBI instruments all over the Soviet Union and later in Russia. He was the first non-Russian to win the Russian Academy of Science gold medal for his leadership and the work he helped them do and join.

VLBI was Tom's life until it wasn't. In the late 1990s and early 2000s, NASA had shrinking budgets, and they wanted to reallocate monies. Tom was having a harder and harder time getting support for his team. It was a lot of responsibility to have to provide for all that team. He could afford to retire, and so he did. He retired in 2001 from being a 40-hour per week person which really is more than 40 when you do this kind of work. The time required can vary a lot, and it's unpredictable with these large global teams. Tom became a consultant.

He was on the board of Haystack and the advisory board of SETI. As some of you may know, Tom and I helped with the early work on the SETI stuff out in California. We were invited to the opening salvo from the Allen telescope. We watched Paul Allen push a button and get the official first signal through the Allen telescope for The SETI Institute.

Tom's Significant Other (AMSAT)

We move from his career at NASA Goddard to his passion for AMSAT. Tom was an early member of AMSAT, not a founder, but he joined shortly after its formation. Then, after everybody involved saw his worth, he became a member of the AMSAT board in 1974 and served until the fall of 2020, when he said he just couldn't go off to these meetings anymore.

Let's look at some of the things he did while he was a member of AMSAT. Tom anticipated the Phase 3. Tom wrote the first open-source general orbital tracking program. Before that, it had been relegated to government and big scientists. Tom figured out a terrific approximation that allowed these computations to put our spacecraft — that being AMSAT's, etc. —inside about a 10 km box anywhere in orbit from the two-line elements (TLEs) that were coming out of NORAD.

Tom is the father of all of that, and I can tell you from befriending Tom, and him encouraging me to do the work, and me doing Quick Track way back then when it was still writing Commodore BASIC, the work raised a huge amount of money and was a large portion of the funding of the technical work of AMSAT for years. Following that, Franklin Antonio and Paul Williams did EZ Track. That's all attributed to Tom and his inspirational leadership and his having done the prototype work.

The thing that Tom encouraged me to do, as I'm sure many of you are old enough to remember when these computers were slow as molasses, but he knew I was a somewhat capable applied mathematician. He asked me whether there was anything we could do to speed up this computation. So, I began doing exactly what all research scientists and developers do. I started studying the problem and read what others had done.

I discovered these magnificent books by Pedro Escobal where he had done all this mathematical derivation of all sorts of equations that could help you do orbital computations. I found a particular derivation by Pedro Escobal of a function that was zero when the spacecraft was on your horizon. What does that mean? That means this function was zero when you had an AOS (acquisition of signal) or LOS (loss of signal). I quickly realized that though this equation was extremely complicated looking, it was mathematically simple. Not only that, but it had the properties that allowed it to be utilized in a well-known technique called Newton's Method for finding these zeros. Finally, you could easily add a function that described your actual horizon. It was quadratic convergence and, therefore, very fast.

The way Tom's program worked, like most others, is they just step through time very slowly — chunk, chunk, tick, tock — until they saw the satellite was above the horizon or going below the horizon. Then, they announced AOS or LOS and printed out the tracking when the spacecraft was above the horizon. Applying my newly coded derivation, which I did with Tom's encouragement, would jump through time using mathematical hoops (Newton's Method). It would go from one AOS or LOS to the next AOS very quickly. It sped up the Commodore 64 from taking 20 minutes to paint the screen full of passes to under a minute. That's when Tom and I really got to know each other, and we started doing things together regularly. That was his major input there. If he had done nothing else, that would have been amazing. And remember, he did the first open-source satellite tracking program for everyone.

Tom became Executive Vice President of AMSAT in 1975 until the ocean bottom geostationary satellite in 1980 when Phase 3A did not become an OSCAR because it went under the water when the Ariane launcher failed. Shortly after that, the AMSAT board made Tom president, and he was tasked with helping save the organization. He led the organization along with our international AMSAT partners and others through the launch of Oscar 10. In the late 1980s, Tom stepped down as AMSAT president.

Tom became AMSAT President Emeritus and the official "AMSAT curmudgeon." But some of the things he did along the way included building a 10-meter antenna for Oscar 8. While no one was looking, he grabbed the spacecraft, which had significant RF instability and leakage problems, ran into a bathroom and locked the door, and soldered-in bypass capacitors all over the thing. When he came out, they fired it up, and it was still working, but all the problems were gone. Tom just had a knack and knew what needed to be done. Rather than argue about it, the typical Tom just did it. OSCAR 8 was up for years, and all of us know how well that went.

Tom worked on the design of packet radio satellites, PACSAT, with NK6K and KD2S, and Martin Sweeting of UOSAT, and Martin got the thing up. Tom designed and built the SAREX packet robot for Ron Parise, WA4SIR, to fly on the Shuttle.

He was a Microsat concept developer with Jan King, Gordon Hardman, Phil Karn and me in an old hotel room at an AMSAT annual meeting. I can assure you more than one of us was doing designs under the influence. AMSAT office administrator, Martha Saragovitz, and her husband, John Shew, were listening through the wall with a water glass in the room next door to try to figure out what we were doing.

So, Microsat was born. This is typical of a Tom interaction and development. We'd have good ideas and sit around and argue them. Tom designed all of the uplink receivers and the serial control bus for Microsats, which were incarnated and reincarnated in OSCAR 16, 17, 18, 19, 26, 27 and 31. Tom had a remarkable career with AMSAT.

Tom, Packet Radio, and AX.25

With Tom and packet radio at TAPR, he was nearly a founding member of TAPR like he was nearly a founding member of AMSAT because he was always trying to figure out how he could play and participate at the leading edge of everything. Tom always lived at the bleeding edge. He was around during TNC-1 and TNC-2 and was a member of the TAPR board from 1983 to 1988.

During the early days of packet radio, Tom wanted to be able to send packet radio digital signals through the high Earth orbit satellites and so figured out how we could point our antennas with his tracking program. But he feared chaos because the packet protocol wars were heating up.

Tom did what he usually does. He called everybody, arranged for transportation, talked the main people at Goddard into allowing a meeting on campus. He brought all the stakeholders he could — and this was almost all of them — to Goddard Space Flight Center. He locked them in a room and told them they were not leaving until amateur packet radio initial protocol was decided. We had a single standard, and AX.25 was born.

It was not perfect, as all of us know, but quickly afterward, version two came out to fix many of the problems. Phil Karn, Terry Fox and others worked on lots of these things, but this work gave us AX.25, and packet radio took off figuratively and literally and impacted a lot after.

Speaking of the impact, Phil Karn, KA9Q, built TCP-IP into a program he called NOS, and we put TCP-IP over the radio for the first time. Then he left his BELLCORE job and went to Qualcomm, where TCP-IP went over the air regularly and helped them give us smartphones.

GPS, TAC (Totally Accurate Clock AND His initials!)

It is remarkable the things that Tom touched that turned into something extraordinary. So, while he was at TAPR, of course, Tom was enamored of timing. Remember, he did these hydrogen maser clocks and tamed oscillators to use on his VLBI stations. Then GPS came along, and Tom wanted to what was available as a maser — maybe not as accurate, perhaps a little less stable. But more accuracy than we could get any other way in a much cheaper way than Hy maser, Rubidium or Cesium clocks.

Tom wanted totally accurate clocks in our laboratories and in our radio shacks for cheap. It was not cheap for someone earning minimum wage but as far as an instrument that would allow people who had the funds to go and do something in an interesting way. I'm not talking about anything ridiculous like the price of a car, but something within reason. He designed the Totally Accurate Clock, and TAPR put it out. This brought frequency and time standards to amateur radio. Former AMSAT President Rick Hambly's CNS Systems is born from the Totally Accurate Clock work that Tom did. They became sparring partners over technology and CNS Systems almost to the end of Tom's life.

Now that I've mentioned Rick, I also want a mention Martha Saragovitz and her husband, John, and Frank Bauer. Tom got in really bad shape around 2011. My wife, Sharon, and I went to Tom's house after Shirley White, his next-door neighbor, told us that Tom had been in the hospital and that he needed help. So, we went to see Tom and found that he was not taking care of himself. So, Rick, Elaine, Frank, Sharon, and I intervened. Tom was just in bad shape, but we got him to take care of himself, and he lived a good extra 10 years doing fun activities and helping AMSAT and many others. This included being an adjunct professor of engineering at Virginia Tech in the Hume Center with me.

TAPR and AMSAT, together, with lots of Tom's leadership, did many interesting things. Tom and I, and a few others, experimented with the Delanco-Spry TMS320 C10 — that's a TI DSP chip development board — that was being put together in the garage of an engineer in Washington D.C. and would sit in the ISA slot of an old original IBM PC compatible. We went along, and I wrote some modems.

I remember the first thing I did and went around the country showing it off. I took in PSK signals intended to be downlinked from FUJI and Packet spacecraft and, with a DSP program modem, turned it into a FSK signal that could be pushed into the front of a regular TNC. The regular TNC would need no modification. You would just make this external connection. That eventually got turned into a product by TAPR as Tom developed high-performance PSK modems. Then Gwynn Reedy (PACCOMM) and others turned it into a product and sold it all over.

That was the first DSP project I am aware of in amateur radio that turned into an actual product. Several digital modems were born. All sorts of experimentation were done. Learning to code DSP spread in and around amateur radio. The TAPR and DSP project just had a big impact.

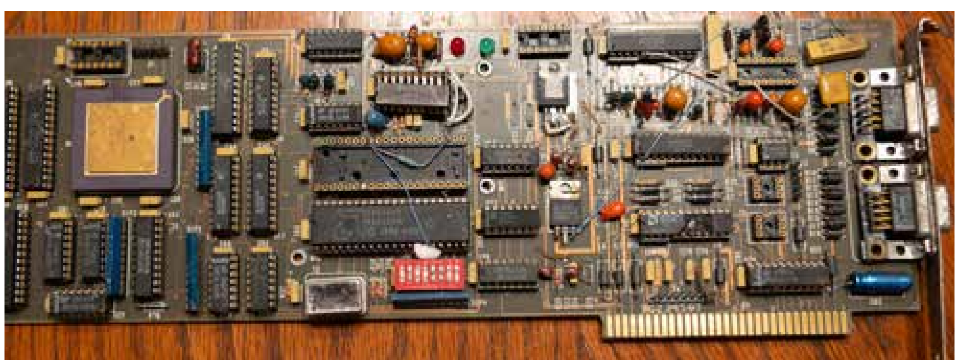
Being an applied mathematician and electrical engineer — I had a dual degree from Auburn before I got my Ph.D. from Brown; I found most of the code "circuitry" is best done in complex baseband processing. I'm not going to go into what that means here, but it's just kind of a natural math of doing radios.

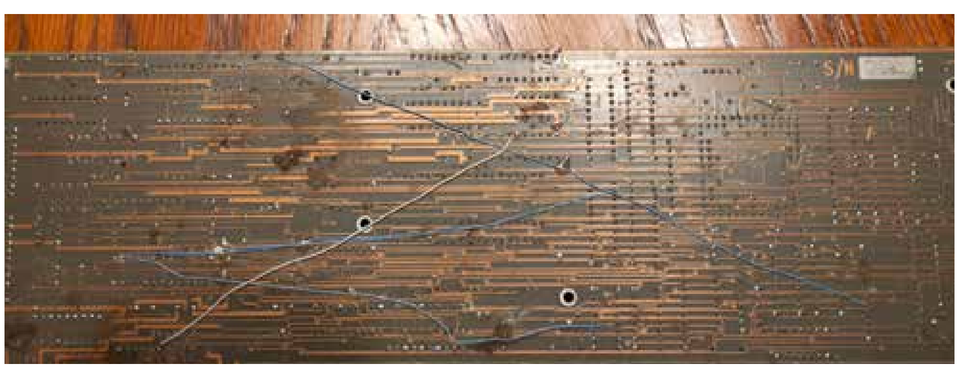
We soon realized that all analog and digital radio ideas naturally could be done and wanted to use this process that had been developed. Tom and I proposed to AEA, which did the PK 232, to build software radio. But they responded, "Well, we're not going to jump all the way there. We're going to do some other stuff first." So TAPR produced several DSP projects and then eventually high-performance Software Defined Radios.

Tom and I demonstrated that with the Delanco-Spry board and 100 W satellite-class stations —a typical KLM radio across Yagis at 100 W — we could produce detectable EME signals off the Moon. Later, Phil Karn proposed a digital scheme to do EME. It had all sorts of features to it that were lovely.

Joe Taylor quickly realized that you've got to spend a ton of power doing frequency and timing synchronization. So, the jumpy chirping signal was born. And Joe Taylor coded the signaling characteristics that Tom and Phil produced that built on the ideas that showed you had the technical signals bounce off the moon into WSJT. Joe has now changed the world. And all this stuff had its birth in TAPR and AMSAT DSP projects.

Software-defined radio was born. The board you see in the accompanying photos is my DSP56001 development board with its ISA connector, with all the blue wires that fixed all the problems on serial number one to make it work were where software defined radio was born. To AEA, Tom proposed an analog interface to hook it to the IF because, at that time, we could bring down signals at about 13 MHz samples per second in





analog-digital converters and digital-analog converters (ADC/DAC). So, we proposed complex baseband processing for all analog modes. But first, we did the digital modes on the DSPS56001. Brooks Van Pelt, Pat Spadafore, and I proposed this, and AEA turned it into the DSP2232.

The work we did here and proposed to AEA was the first, outside in the world, software defined radio proposal. Unknown to us, eSystems, a very high-level contractor doing classified work for the government, proposed software radio in an internal paper in 1984, but it didn't go anywhere. So, we proposed to AEA in 1988 the following: the DSP2232, we would do a software radio where it had this hybrid approach ADC/DAC at the IF, and all the regular processing sideband, CW, RTTY, digital modems — all of that would be done in the basement. Now we have a software radio with an analog front-end interface that made the ADC/DAC usable.

We proposed that, and AEA said yes. Within six months, George Buxton, who was the general manager of AEA, contracted Non-Hodgkin's Lymphoma, and basically, the company and this effort fell apart. This work was followed in1992 by Joe Mitola, who knew of the work because I had taken this work inside to the National Security Agency. He was allowed to write several papers. Joe became known worldwide as the father of software defined radio.

Joe and I know all this, and we're friends. We are friends enough that he and I co-founded the company Federated Wireless together. So, this is known. We've both admitted it, laugh about it, but we've gone on to do other things together. Joe is, absolutely, the father of Cognitive Radio and wrote the first book and papers.

Tom Receives ARRL President's Award

Tom received the ARRL President's Award from N3KN near the end of his AMSAT and TAPR career. Tom was happy and proud of this. He was a big-time donor, Diamond Club, etc., to ARRL. He was awarded the President's Award for all the work he did and his ongoing support of ARRL.

Tom's Favorite Pose

A favorite pose for many of us shows Tom Clark sitting in a hotel room we shared, a life member of the Central States VHF Society the year he won their Chamber's Award. Everyone that knows Tom knows this is Tom. He wouldn't bring his C-PAP machine, so he didn't sleep well without that, and he would fall asleep at the drop of a hat. So, I would shake him awake to get him to the meeting. Of course, during the meeting, if he wasn't talking, he would also snore and sleep. But when he was awake, he was a firebrand to deal with.

Tom loved, loved, loved the Central States VHF Society. They loved him and honored him for all of his technical work on VHF, UHF and microwave, which included things like Worked All Continents on 70 centimeters in 12 hours using a 140-foot dish at the Green Bank Observatory.

Tom was always marrying amateur radio escapades with his professional work because he had taken a bunch of graduate students to Green Bank with him and got them to climb all over that antenna. He even hung amplifiers and pre-amplifiers so he could make these signals. They only made one mistake and had the transmitter blanket the receiver, or they would have done 10 gigahertz work off the Moon with 140, but they did 70 centimeters, and he got Worked All Continents in half a day.

Radio Club of America Makes

Tom A Fellow

Tom was inducted into the Radio Club of America and made a fellow of RCA. That was a great honor for him because Radio Club of America is the oldest radio club in the world.

Tom and Microsat

In the Microsat Lab, Tom, as I told you, designed all of the receivers and the interface board that made the build of a satellite out of stack modules process work. The five chips are the five receiver chips that made the up-link receivers and all our Microsats. You can see the helical resonators back there for IF filtering, and you can see in Figure 12 the chips that did the FSK detection. Down along the bottom, you see that DB25 connector, that little circuit board between the edge of that module and the connector and that board, that board is the AART-based serial bus that made the spacecraft work. AO16 through AO-31 Microsats all ran this module and that board. There were probably modifications and changes in components and layouts.
In the next photo, you can see Jose Machao,

Jan King, Tom and me looking at an oscilloscope showing us the day we got bits to come out of these receivers on 2 meters. We all were in the Boulder lab working on all sorts of stuff when we assembled the Microsats and flew them in their early 1990s.

The photo shows Tom and Karl checking out AO-10, and don't they look so happy. I was really happy to see Karl write a very nice note recognizing the loss of Tom. In the end, all of the initial cantankerous natures and arguments they had, because they were two really smart people that sometimes had disagreements, there was a rapprochement and settling of all that. You can see it in Karl's very nice letter at Tom's end.

Tom, We Will Miss You

I'm going to miss Tom Clark a lot. He's a friend, a mentor, and this article doesn't do justice to all that he has done. I've left things out. I've left people out. Hopefully, I have been able to give you a taste of the impact this man has had. Farewell OM, your key is silent. Your impact is forever. 73s, SK.

Note: Several of the images are taken from a PowerPoint presentation. This was the slide deck from Tom's AMSAT symposium talk: "Sixty Years as a Prisoner of Amateur Radio."

Tom and Microsat Lab.

Tom and Karl, Technical Mentors of AMSAT in the 1980s.

Dr. Tomas A. Clark, K3IO – Remembering a Superstar

Richard M. Hambly, W2GPS

I met Tom Clark, then W3IWI, soon after moving to Maryland in 1987. Tom and I shared a lifelong passion for electronics, physics, and radio communication that we expressed both through ham radio and our professions. Tom worked for NASA as an astrophysicist and radio astronomy designer, and I worked as an electrical engineer designing radio communication equipment and systems. Thus began a three-decade journey, where we shared many experiences in ham radio and professional endeavors. Tom held quite a few amateur radio call signs, including WØIUF, W4JBL, W4JBL, WA3LND, G4UTL, W3IWI, CE3/W3IWI, SM6/W3IWI, LA/W3IWI, JW/W3IWI, JA/W3IWI, UA/W3IWI, and XE/W3IWI.

However, much to the dismay of many amateur radio hams at the time, Tom changed his long-held call sign from W3IWI to K3IO. What many did not know was that Tom's call was in honor of Jupiter's moon Io, the most volcanic object in the solar system. But why the interest in Jupiter and its moons? As Tom said in his 2005 presentation Building the Geodetic VLBI Network; Some Personal Recollections of Tom Clark, "I attended the University of Colorado in Boulder and did my Ph.D. dissertation by building a very large 10 MHz Radio Telescope". That telescope was to study Jupiter, of course.

Many years later, in February 2005, the Institute for Applied Astronomy of the Russian Academy of Sciences awarded Tom its prestigious Gold Medal for lifetime contributions to the advancement of Very Large Baseline Interferometry (VLBI), which uses radio signals from quasars to measure continental drift. This was the first time the medal was awarded to someone from outside of Russia.

Soon after settling in Maryland, I found that Tom and others had set up a ham radio packet system with bulletin boards and backbone links. I was fascinated, so with Tom's help, I set up a BBS at my work location on 2-meters and linked it to Tom's node using a 220 MHz link. Even before we really knew each other, Tom was reaching out to help and provide guidance. This was

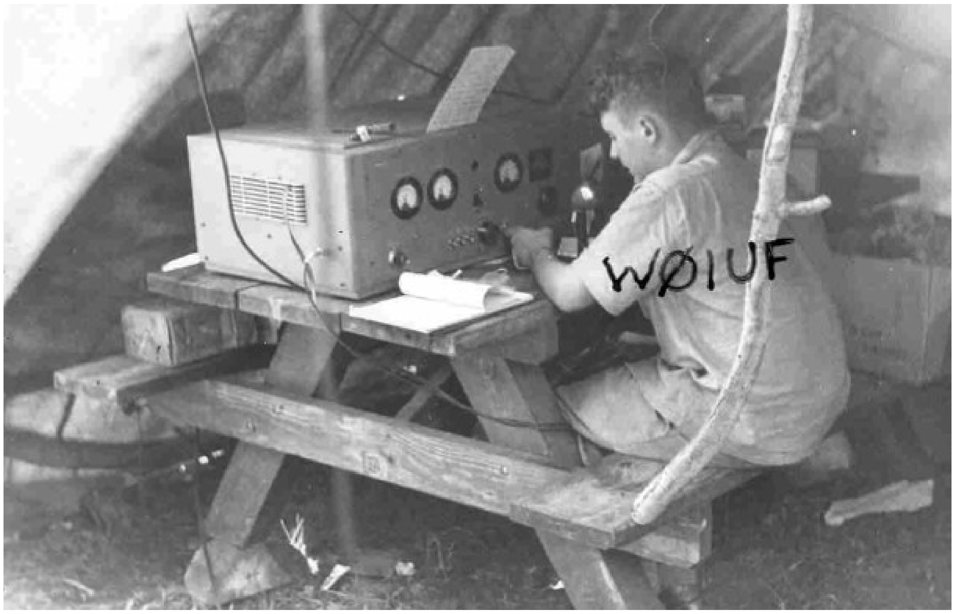


Figure 1 — High school-age Tom Clark operating a “portable” ham radio station in the field.

the beginning of over 30 years during which Tom was my mentor and friend. Tom was the smartest and most intelligent person I ever met, and he was always willing to share these gifts with others.

An area of common interest was the evolving technology surrounding what was then the new Global Positioning Satellite system, or GPS. Our professional interests in GPS were for its use as a source of precision time and frequency. Tom wanted this to augment the NASA VLBI system, and I wanted it for a U.S. Navy project. But we couldn’t avoid having fun.

On our way to the Dayton Hamvention one year, we both carried our then-new Garmin GPS III navigation units, programmed to take us to the hotel where the AMSAT group was staying. We had a great time on the nearly ten-hour ride from Maryland to Ohio, but when the Garmin's said we had arrived, all we could see for miles was cornfields. Finally, we found our way to a 7-Eleven parking lot but, instead of asking for directions, we got out our laptop computers and raced each other to find out what went wrong. The combination of stubbornness and humor that marked this trip was repeated dozens of times over the years. I will forever cherish these memories. In our quest for the best time and frequency solutions, Tom and I would often meet at NASA’s Goddard Geophysical and Astronomical Observatory (GGAO), which I learned was Tom’s local playground in Maryland. It was close to his home and had all the toys we could want, including a hydrogen maser atomic oscillator and multiple big dishes looking into outer space.

On occasion, we would travel to the United States Naval Observatory (USNO) and the MIT Haystack Observatory for advanced research or to participate in workshops. Tom would often teach at these workshops, and he drew large crowds of fascinated people. Eventually, Tom invited me to share the teaching responsibilities, which was a great honor for me. Tom knew how to take his students and make them teachers, which he did for many students over the years.

In parallel with other activities, Tom sparked my renewed interest in amateur satellites, especially AO 40. That began a long and exciting period of involvement with AMSAT. Tom showed me the history and his future vision for AMSAT, introduced me to key people from around the world and convinced me to serve in various roles in AMSAT for many years. His role throughout that period was as a mentor and a designer. For example, I saw him personally rescue the AMSAT Echo satellite mission, later known as AMSAT OSCAR 51, by making the long drive home to get a critically needed part from his huge stockpile and rushing back to save the day.

During those AMSAT years, Tom and I would make the long drive from Maryland to Dayton, Ohio, together. His wonderful wife, Elizabeth, would meet me at the door to ask me to be sure Tom ate his green vegetables, which was not his favorite food. As we headed out, I would often pick a subject for the trip to keep us engaged. One year I would ask him about Maxwell's equations, another year it would be Schrodinger's uncertainty principle, and another would be quantum mechanics. These discussions would last for hours.

Tom loved teaching, and I was a willing student. I learned more during these drives than I did from almost any other source. When teaching, Tom was animated and happy. He injected humor in these sessions and in all his presentations, whether professional or ham radio groups.

At AMSAT meetings, Tom would often give presentations on topics like antenna performance, steerable beam arrays, and Heisenberg's uncertainty principle. Regardless of the complexity of the topic, Tom was always ready to go. Most people did not know that Tom often stayed up the night before to create some of his best presentations. Tom also introduced a sense of humor in his presentations, as he did with the complex topics in his presentation," Fourier, Antennas and EAGLE," when he introduced the topic with, “Mandatory Surgeon General’s Warning: Contains some Math and Physics which may be injurious to your Little Gray Cells!!! or In other words, this presentation contains Weapons of Math Instruction."

What more can I say about Tom Clark? Well, I could fill many more pages with exploits and memories about Tom. If we add to that the memories of Tom's many students and friends, we would have a large book. Tom's life has touched many people in a positive way, and he will be remembered fondly by those people for a long time. Wherever he is now, I hope he is still teaching. Farewell, my old friend.

Remembering Tom Clark, K3IO

Barry A. Baines, WD4ASW

It isn't often we're given the opportunity to interact with a "giant" of a person whose impact on those around them, as well as their chosen endeavor, is both consequential and impactful over the course of decades.

Dr Thomas Clark, K3IO (ex-W3IWI) was such a person. This article is a brief reflection of how Tom influenced some of my AMSAT experiences.

I first became aware of Tom in 1982 when I joined AMSAT, and I later received my AMSAT life membership card stating, "This certifies that BARRY BAINES, WD4ASW is Life Member NO. 1971 of the Radio Amateur Satellite Corporation," with Dr. Thomas A. Clark, President as the signer. As was common in that day, my name and callsign neatly aligned on the name line in one font, and Tom's entry was neatly typed in a signature script representing his signature. Undoubtedly, Office Manager Martha Saragovitz used an IBM Selectric typewriter to prepare the membership card that included the AMSAT "globe" logo with AMSAT boldly printed on the card stock.

Tom served as president in the early 1980s when Phase-3A ended up in a "subterranean" orbit beneath the Atlantic Ocean following the launch failure of an Ariane-3 launch vehicle. Tom's leadership was critical in guiding AMSAT's recovery from this major failure, both in terms of fundraising and rebuilding AMSAT's commitment for future projects. The devastating loss of that satellite was transformed into an eventual success in launching Phase-3B, which became AO-10, and later Phase-3C, which became AO-13. Tom's energy kept the organization focused on creating these new satellites in collaboration with AMSAT-DL following the loss of Phase 3-A.

While Tom served as president during a critical time for AMSAT, his passion was not in managing organizations and fundraising but in the 'big ideas' or vision of what AMSAT could accomplish with new satellite designs and technologies.

Over time I maintained my interest in satellites and met others in the Jacksonville, FL area with similar interests. Each year I stopped by the AMSAT booth at Hamvention.

In 1988, Hank Fitz, WB4URU (SK), and I attended our first AMSAT Space Symposium in Atlanta, GA, which was memorable as the first U.S. Amateur-to-MIR two-way contact. This contact took place in the hotel's parking lot. I sat in the board meeting and met the directors, many of whom were "founding fathers" of AMSAT in 1969.

From this point on, I became more engaged with AMSAT, attending every AMSAT symposium from 1990 onward that I could. I also observed who were the movers and shakers of AMSAT and how the organization functioned. It became clear that a cadre of "doers" focused on satellite design/construction while others focused on supporting the operators, and still others managed the organization's administration, publications, and day-to-day management. Tom's focus was on creating the spacecraft and technologies for expanding amateur radio in space. And during these years, AMSAT continued to push the space envelope with new satellite designs such as the Microsats, the creation of SAREX, and initial planning for "Phase 3-D." Tom made his mark on all of these projects.

In 1993, I became engaged in AMSAT leadership as Director-Field Operations and was later elected to the board in 1999 by the AMSAT membership. Thirty years after AMSAT was incorporated, Tom was still making an impact as an elected board member. Indeed, Tom served on the board until September 2020 following his decision not to run for reelection after serving in AMSAT leadership for 45 years.

From my initial involvement with the AMSAT board in 1999 through my tenure as AMSAT president from 2008-2017 and my stepping down from the board in 2017, Tom's passion and keen sense of what makes AMSAT a unique organization always remained within his vision for AMSAT. As AMSAT evolved over the years, Tom's steady presence on the board evolved as well.

Over time, Tom took a more statesman-like perspective, recognizing that, when there was a disagreement, both sides of that discussion likely had salient points worthy of consideration. When Tom spoke up, the rest of us listened because Tom could summarize the outstanding discussion and then raise a different perspective worthy of consideration. He picked his battles and didn't speak unless he felt he had something to contribute.

As president, I would call Tom to discuss a particular matter and gain his perspective on how to handle a given situation. For example, when I first became AMSAT president in late 2008, the first matter I had to deal with was how best to handle AMSAT's potential violations of ITAR and the need for self-disclosure. I had shared with the board my proposal to retain an attorney to handle the self-disclosure process, but I was concerned about how our engineering team volunteers might react to the idea of self-reporting. So I called Tom to discuss my concerns and to seek his support.

Tom subsequently reached out to key members involved in collaborating with AMSAT-DL on their Phase 3-E project, explained AMSAT's "Coming to Grips with ITAR" strategy, and voiced his support for the approach we were taking. His credibility with engineering personnel helped provide the buy-in necessary for self-reporting to successfully resolve potential issues with ITAR and allow AMSAT to move forward on other projects without concerns regarding past transgressions.

I also recognized that, while Tom may have thoughts on particular issues, he didn't necessarily share them outside of board meetings with fellow board members or senior officers. Therefore, it was up to me to reach out to Tom if I wanted to gain his perspective on a particular matter. I realized that the best way to avoid potential misunderstandings at upcoming board meetings was to have a conversation with Tom and other directors to alert them to forthcoming discussions and gain their feedback before formal discussions at a board meeting. I always found Tom to be supportive and thoughtful when providing insight and feedback to particular discussion items. While serving as a board member required discussions of organizational and strategic issues, the continued focus on satellite projects motivated Tom to push for new technical solutions to take advantage of new launch opportunities to make amateur radio in space more accessible to amateurs worldwide.

AMSAT has been blessed over the years to have outstanding leaders who made a huge impact in their professional careers as well as with AMSAT's impact on amateur radio in space. The celebration of AMSAT's 50th Anniversary at the 2019 AMSAT Space Symposium in Alexandria, VA, highlighted the true impact of what AMSAT has achieved with Tom's indelible mark. AMSAT's remarkable record continues despite the evolving "environment' that

AMSAT finds itself.

One only has to look at evolving FCC regulations such as debris mitigation, changes in export regulations (both ITAR and Export Arms Regulations), the commercialization of space, evolving technologies, developing university relationships to provide the science necessary to gain governmental launch opportunities, and generational changes in membership and leadership to appreciate AMSAT's ability to adapt to changing times.

For more than 50 years, Tom was instrumental in providing guidance and vision for AMSAT to navigate through unique opportunities to keep amateur radio in space as well as sometimes turbulent seas and unexpected challenges.
Thank you, Tom.

Mourning the Passing of Dr. Thomas A. Clark, K3IO, formerly W3IWI (SK)*

ARISS-International/Frank Bauer, KA3HDO
Chair

It is with great sadness that ARISS-International recognizes the passing of a dear friend, Dr. Tom Clark, K3IO. Tom passed away on September 28, 2021 in Columbia, Maryland.

Tom Clark is recognized as a pioneer, trailblazer and a legend who led innovations and initiatives that have been transformative and significantly impactful to humanity. These include his pioneering work in radio astronomy, particularly VLBI (Very Long Baseline Interferometry), his contributions in the development of small satellite architectures that transformed the satellite industry, and his pivotal contributions in digital communications techniques and precise time measurement. These efforts span his professional career at NASA as a scientist and his parallel, avocational career as a leader, architect, and chief technologist at AMSAT-NA (President, Board Member, President Emeritus).

For ARISS, Dr. Clark co-led the startup of our human spaceflight amateur radio initiatives and helped us develop systems on the Shuttle and ISS that actively engaged students and the ham radio community. As president of AMSAT, he worked with senior leaders at the ARRL and NASA to set up agreements on Owen Garriott, W5LFL's inaugural flight of amateur radio on the Space Shuttle (STS-9). His technical and financial support to SAREX (Shuttle) and ARISS (ISS) have been vital in moving these programs to new heights. When Astronaut Ron Parise, WA4SIR, planned to fly on a March 1986 mission prior to Challenger, Tom led a team of four of us, including Bob Bruninga, WB4APR, to develop protocols and software for rapid message exchange via a packet "Robot." In the words of Bob, WB4APR, these "discussions helped firm up ideas on how APRS could be used not only as positioning tool, but also as a communication capability allowing rapid status and message reporting. Thus, allowing lots of people to rapidly make exchanges during a brief satellite pass." The packet robot was used heavily in our SAREX (Shuttle) program, starting with Ron's STS-35 flight, after the Challenger accident. APRS remains a key staple in our ARISS on-board systems. Prior to his passing, Tom was also providing technical guidance in the development of lunar radio architectures we were proposing for Gateway and other opportunities around or on the Moon.

Tom's NASA career centered upon his pioneering work to develop, deploy and evolve several generations of VLBI systems. These systems substantially improved over time due to Tom's passion of introducing leading-edge (or, in Tom's terminology, bleeding edge) technologies in radio, timing and data accumulation. VLBI is an astrophysics technique that combines observed stellar radio signals from space using several radio telescopes over a large baseline (the bigger the better). This creates a bigger effective radio telescope aperture, and thus, more spectacular results. VLBI is used to better understand the spinning motion of the Earth, the dynamics of the Earth's crust, including global plate tectonics, to provide a more accurate definition of our celestial reference frame and to more accurately measure Universal Time. Tom linked together a global network of about 30 VLBI stations to make this happen. He continued to improve the timing precision of VLBI in the mid-1990's through employment of the newly operational of GPS system. In fact, his "Totally Accurate Clock," a playful use of his initials, has been found in VLBI stations and many other networks (and ham stations) around the globe.

For AMSAT, in 1981, Tom brought computer orbit prediction to the masses by publishing a reduced set of code originally on mainframe computers that could be programmed into the nascent personal computers of the day (e.g. Sinclair, Atari, Apple, TI). This innovation proved key to tracking the Shuttle during W5LFL's flight and continues to serve hams today. He energized a demoralized international team after the spectacular loss of an Ariane-V rocket that also destroyed the Phase 3A spacecraft. His leadership propped up the team and led to the successful launch of AO-10 and 13. Clark was one of the architects of the Microsat, a set of 4 cubed microsatellites first launched in 1990 which paved the way for the CubeSat revolution. As an early founder and leader of TAPR, the Tucson Amateur Packet Radio organization, Tom helped move packet radio from an idea to a key operational capability in amateur radio. When talking publicly, Tom would frequently remind the audience that the word "amateur" in amateur radio should not be a disparaging word, because the Wright Brothers innovated as amateur aircraft builders, just like radio amateurs have innovated radio and satellite technology for the betterment of society.

Those that knew Tom personally, knows he generously provided advice, shared knowledge or helped you move a project forward that he believed in. As GPS was closing in on full operations in mid-1995, Tom and I worked on several GPS initiatives, the most notable was the use of GPS above the constellation. Tom facilitated the manifest of a GPS experiment on AO-40 that I led as a NASA Principal Investigator. This experiment was instrumental in rewriting the books on how GPS is used in space. The day before Tom's passing, NASA released a video on the benefits of these capabilities **www.youtube.com/watch?v=-1ngun6OfgQ.**

Tom's interests outside of the above, included photography, music, and cars. I leave you with a picture (below) of his final pride and joy: a Porsche Cayman which he affectionately called Ol' Yallar II.

Thank you, Tom, for all you have done for ARISS, AMSAT, NASA and humanity. We wish you Godspeed. Have a wonderful journey amongst the stars!

Tom inspects AMSAT Microsat satellite.

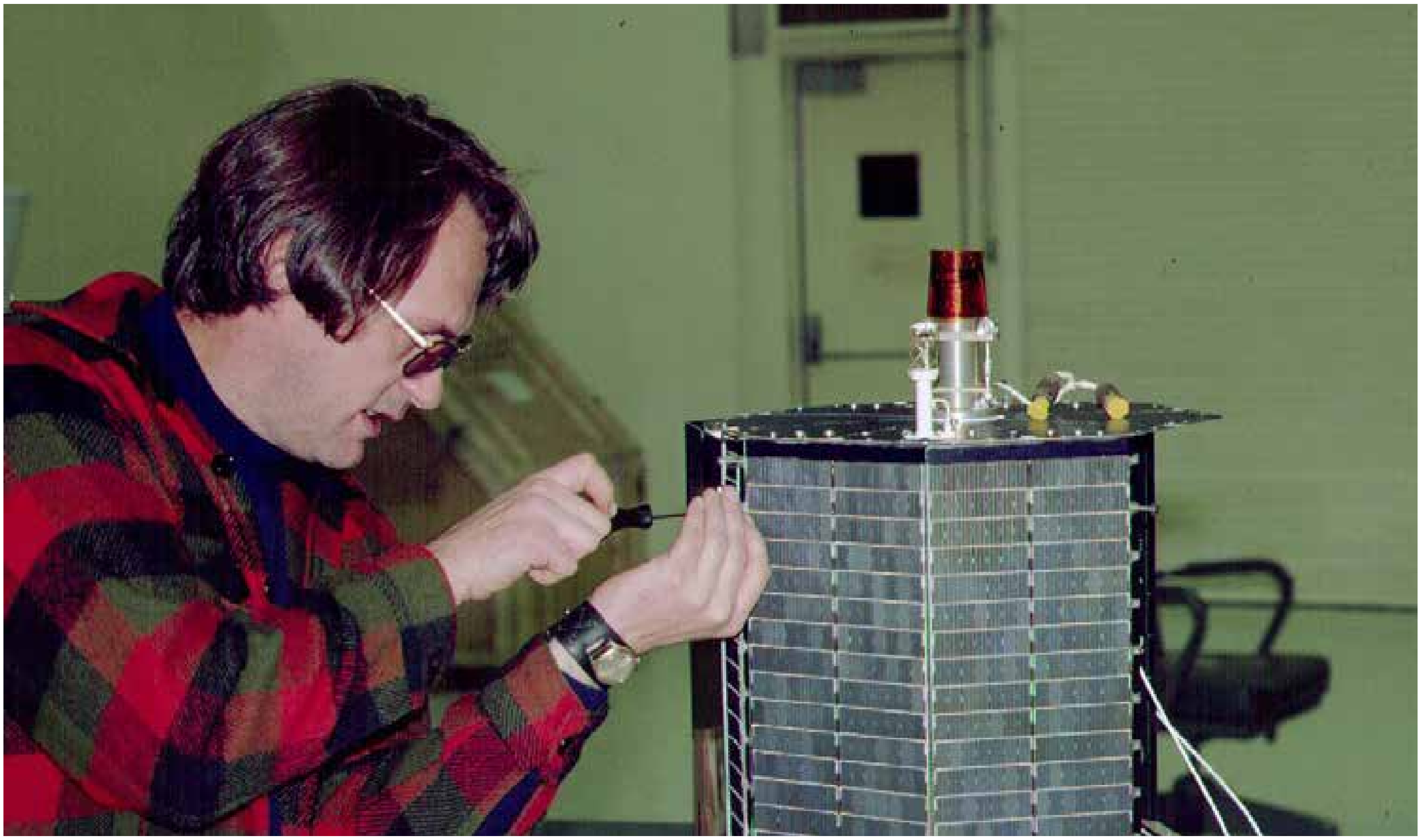
Share Your Experiences as an AMSAT Member

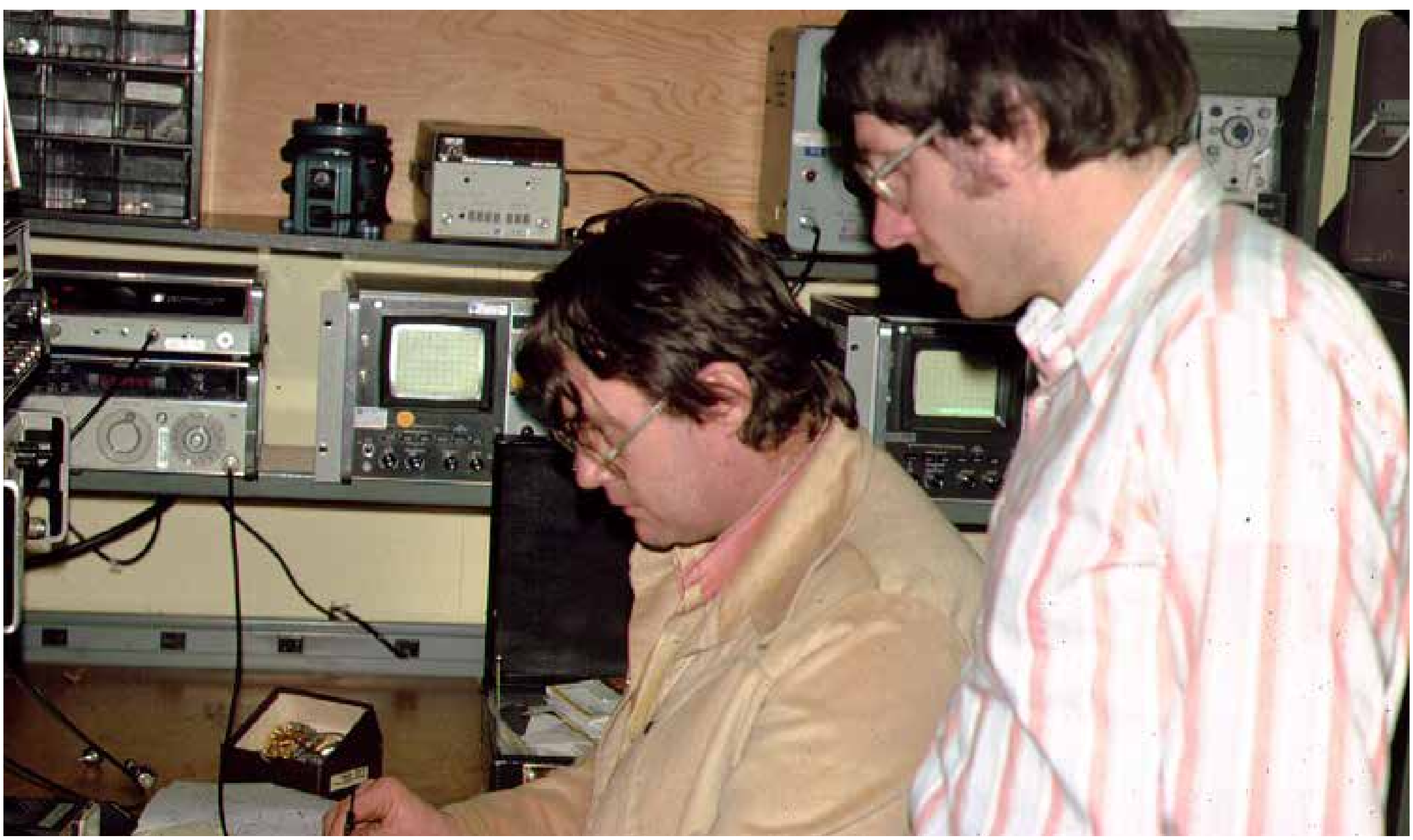
The AMSAT Journal is looking for you to share your satellite radio experiences, likes and dislikes, how you work the birds, and what you like about *The AMSAT Journal*. We'll publish a selection of responses in upcoming issues of the Journal under a column we're calling "Members Footprints." Photos are strongly encouraged! Thanks!

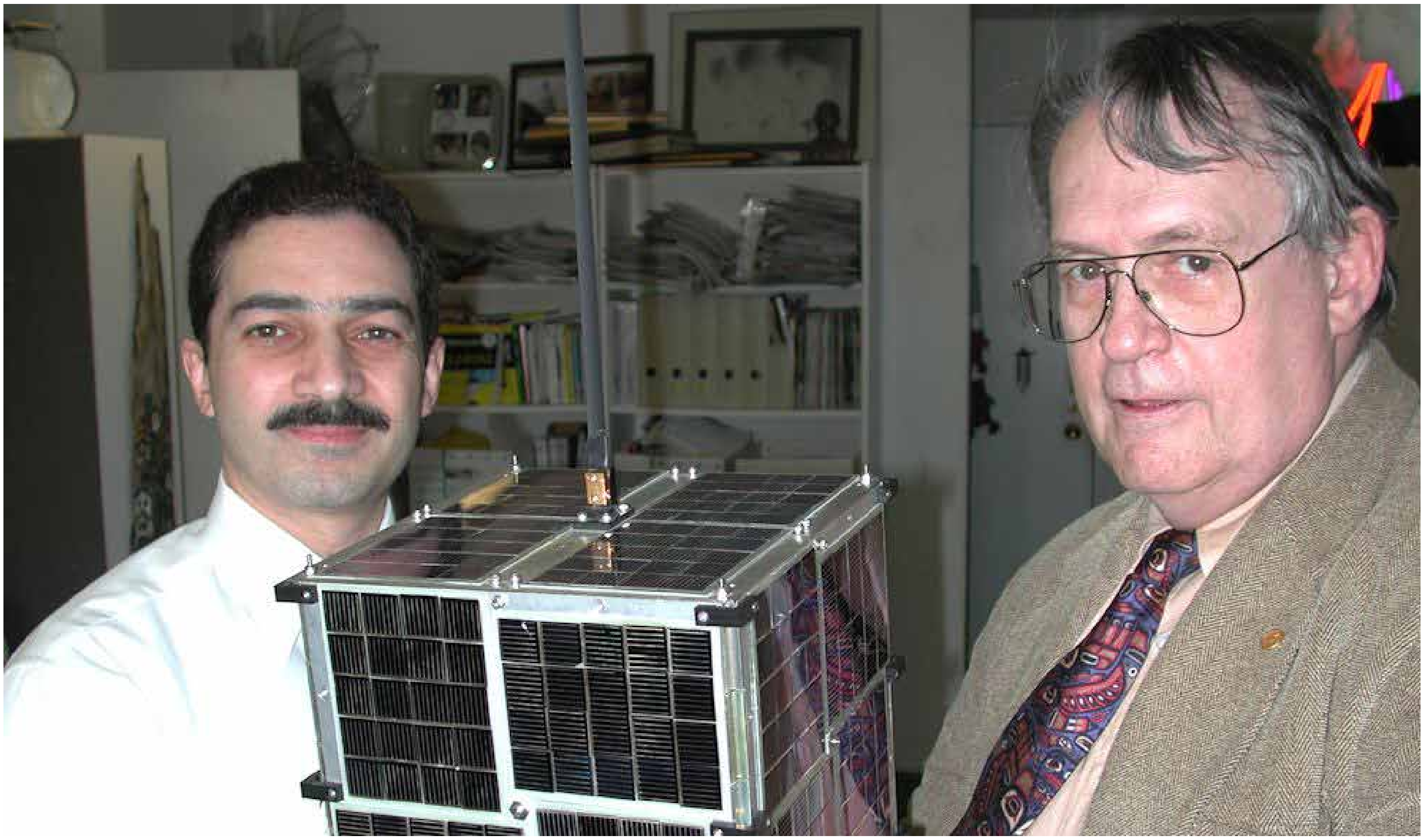
Please send the information requested below to journal@amsat.org --

- Your Name
- Call Signs Held
- Primary Grid Square
- Favorite Satellite Contact
- First Satellite Contact
- First Satellite Ground Station Description
- Current Satellite Ground Station Description
- Reasons You Are an AMSAT Member
- Favorite AMSAT Memory (a satellite contact, symposium, engineering project, event that would never have happened without AMSAT, etc.)
- Favorite Topics Appearing in The AMSAT Journal (could include things like building a homebrew antenna, assembling a ground station, using tablets and smartphones, news of upcoming launches, portable operations, ARISS, etc.

Please Provide a Hi-Resolution Photograph (see www.amsat.org/?page_








PAST
Elizabeth Clark


AMSAT

Full-Function Remote Control of a Satellite Base Station

Mark D. Johns, K0JM

Remote operation of amateur radio stations is a rapidly growing feature of the hobby in the 21st century. More and more, amateurs are finding themselves living in locations with severe antenna restrictions, and want to access a rig at a remote site with fewer limits.

As the cohort of active amateur operators is aging, many find themselves in senior housing situations where antenna installations are problematic. I'm swiftly closing in on "three score and ten" in age, and the prospect that I will have to leave my antenna farm and shuffle off to "The Home" someday becomes more real. I don't want to give up my hobby until I absolutely must.

Many remote options have become available for HF operation. The internet has opened the door to remote control possibilities that were far more complicated in the past. There are even companies that make extremely capable HF stations available for online access in return for a subscription and hourly fee.

Also, many modern radios include options for internet connections and computer control from distant locations. Most major radio manufacturers, such as Icom and Yaesu, sell software for remote control of their newer rigs. And there are a number of third-party software/hardware options for implementing remote operation on various setups.

FlexRadio, the Natural Remote

One of the primary attractions of software defined radios (SDRs), such as the FlexRadio "Signature Series" transceivers, is the ease of establishing remote control over the internet. Because the Flex is connected to a controlling computer by a network cable, the radio is essentially designed to be running remote all of the time, whether the control computer is inches away, or miles away. Flex even includes a "SmartLink" software in its radio package that allows full control of the radio from virtually anywhere that an internet connection is available.

A few years ago, I made a 20-meter SSB QSO on my home station in Minnesota from a motel room in India, using only an iPad on a rather slow wi-fi connection! The Flex is truly an amazing innovation when it comes to remote control.

But as simple as these remote control options may be, additional considerations must be addressed if one is to gain full functioning of the amateur radio station. "SmartLink," and other radio manufacturer-supplied software, usually assume that the radio is powered up, connected to a proper antenna, and waiting for the operator to establish the internet connection.

Functions such as turning power on and off, switching antennas, turning beams, and controlling amplifiers, transverters, antenna tuners, or other accessories, are all left for other solutions.

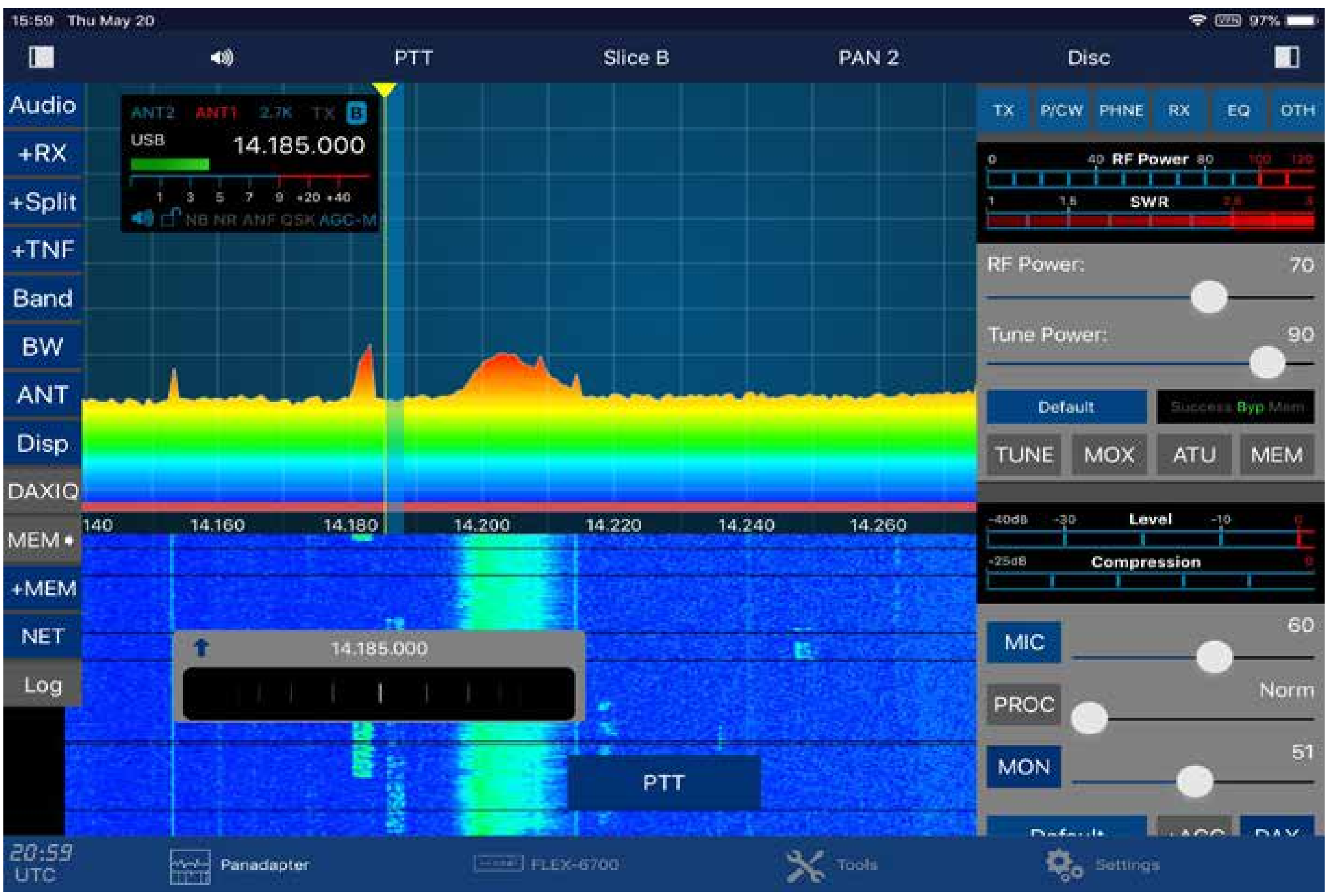


Photo 1 — SmartSDR on the iPad.

Space is Hard

As satellite operators know, making QSOs through a spacecraft involves additional challenges, whether sitting at home or operating from afar. Even if the radio is easily connected to a network, tracking the satellite, operating in full-duplex, moving antennas in both azimuth and elevation, and Doppler tuning are all functions that are required in some form.

If done manually, these add greatly to the complexity of the operation. If done via computer control, then remote operation becomes much more complicated in that these functions require connections that are outside the capabilities of the usual, manufacturer-supplied remote-control software.

Again, the FlexRadio with appropriate transverters makes a superb solution to all of this complexity of satellite operation. David Buemer, W0DHB, has written an excellent piece of software, FlexSatPC, which integrates antenna tracking, Doppler correction, and logging functions for the FlexRadio transceivers and transverters. [*AMSAT Journal*, Vol. 39, No. 1, Jan/Feb 2016, page 13] I've come to depend on this system to automate many functions of my satellite operation.

However, FlexSatPC has to run on the same computer as SmartSDR, the Flex operating software. Thus, using FlexRadio's "SmartLink" for remote operation meant foregoing the functionality of FlexSatPC. Even though "SmartLink" would run on an iPad (or even on an iPhone, if one has good eyes for the small screen), the iOS operating system did not allow the use of more than one program simultaneously. Therefore, tracking had to be done on a different device.

Going remote meant doing everything manually. While I succeeded in making some remote satellite contacts using "SmartLink" on the iPad, it wasn't a pleasant operating experience. I missed the automation and ease of operation using FlexSatPC. There had to be a better way.

John Papay, K8YSE, has been using a satellite remote system for several years. [*AMSAT Journal*, Vol. 37, No. 1, Jan/Feb 2014, page 5] After reading John's article

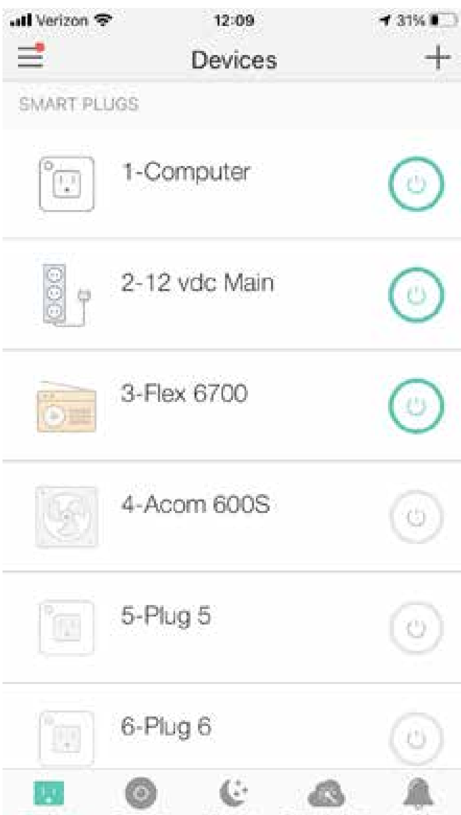


Figure 2 — The Kasa power strip control on an iPhone.

Figure 3 — The entire station hides in the radio closet. The local screen is used only for setup.

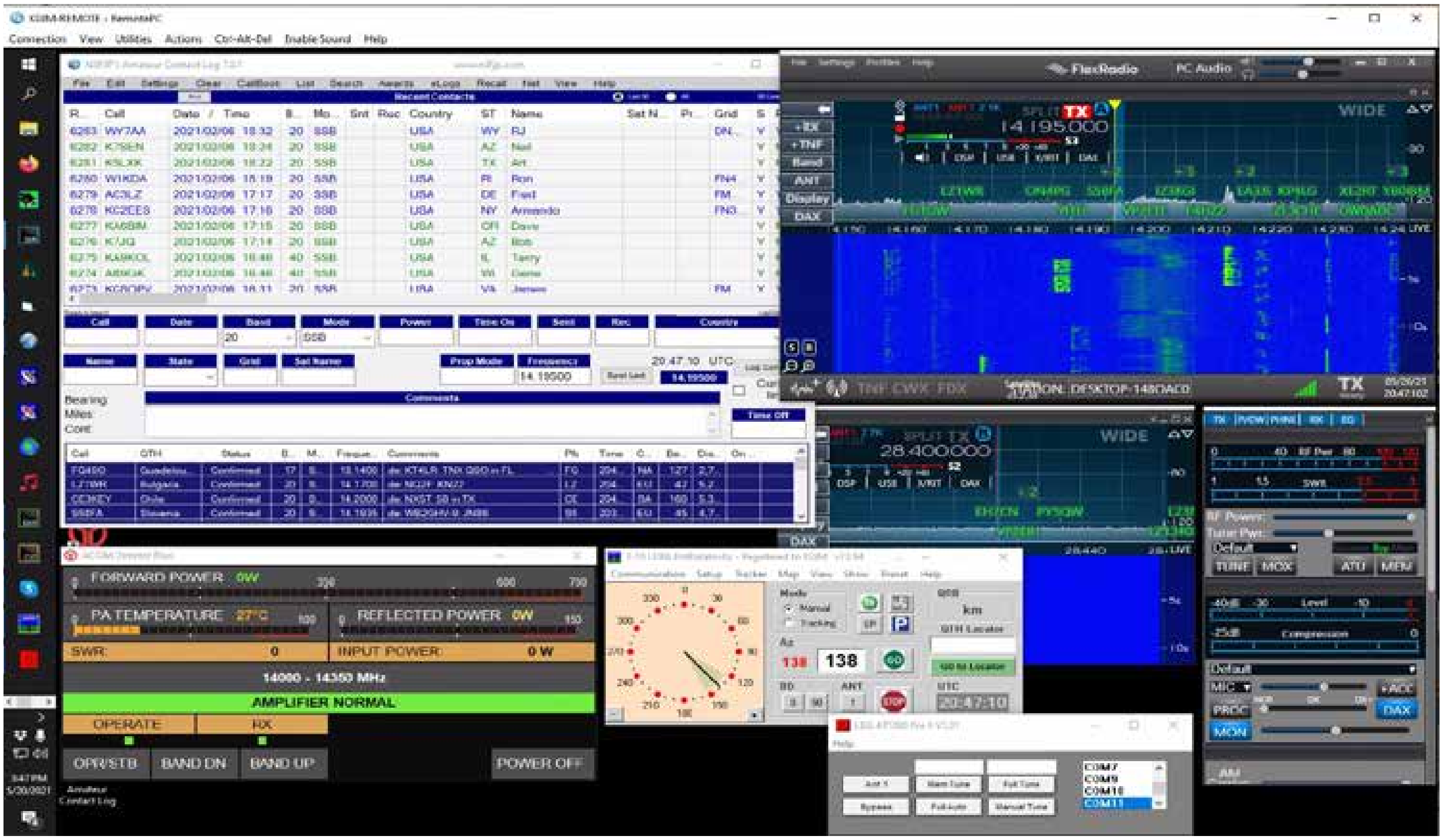


Figure 4 — I began configuring for HF operation with full control of accessories.

and asking him a few questions over the air, I decided that it would be possible to solve the remote operating puzzle, with even fewer challenges than he faced, by using the Flex. It would be almost entirely a software solution.

Positive Power Control

My first concern was positive control over the on/off functions of the remote station. This would not only be a safety and security concern but would provide the ability to reboot things in case of other difficulties. Stereotypically, tech support always advises shutting everything off and turning it all on again to fix any problem. I wanted that capability remotely, as well.

I experimented with remotely controlled AC power plugs as a means of rig control. These are sold under various brand names, Insteon, D-Link, WeMo, etc. All of them worked, however, some of them were not reliable. Some didn't seem to like having several separate units in close proximity to one another. One brand lost its mind completely in the event of a power failure and had to be manually repaired with the iPhone app on site. That might be OK when using it around the house but obviously won't do at a remote location.

The best unit I found was a 6-outlet power strip by Kasa. Each outlet can be controlled separately through a single iPhone app, and there are even a couple of power-only USB ports. Using 5 V or 12 V "wall wart" power supplies connected to small relays, I can not only control AC power to each device but can use the remote on/off functions of my FlexRadio and Acom HF amplifier. This made it possible to do a more elegant shut-down or power-up sequence, rather than simply crashing them off by remotely "pulling the plug" (which can also be done in emergencies).

The Local Computer Question

There seem to be two schools of thought regarding remote control: One school considers a remote computer to be the root of all evil and the source of every failure. The other school considers a computer – or even several computers – at the remote site to be essential.

The decision to use the FlexRadio meant a computer would have to be somewhere, either at the remote site or at the control point. If the computer were away from the radio, the Flex "SmartLink" program would be required. If not using "SmartLink," the FlexRadio would need a computer at the remote site. Newer computers with solid-state hard drives have no moving parts and seem fairly reliable. So I decided to join the computer-on-site school.

The Flex is software defined radio, but the computing power necessary is surprisingly modest. An inexpensive Intel NUC mini-computer was sufficient. Windows 10 Pro came installed, and I configured it to boot up on power-on, without passwords or PIN codes. If I had to turn it off by shutting down the outlet, it would boot back up as soon as AC power was restored.

The first step was to get the entire station working flawlessly with this new computer. So SmartSDR, SatPC32, my logging programs, and FlexSatPC all had to be moved from my usual station computer to this new box. With the Flex software, it is possible – actually preferable – to operate the station entirely from the computer screen, without a knob or switch anywhere. That was the goal.

Setup took a while. As we add features to our stations over time, we don't realize how everything builds on what we've done before. Starting a clean installation from scratch is a reminder of how complex we make these satellite stations over time. An advantage was getting all of that stuff off the computer I use for word processing, email, and web access.

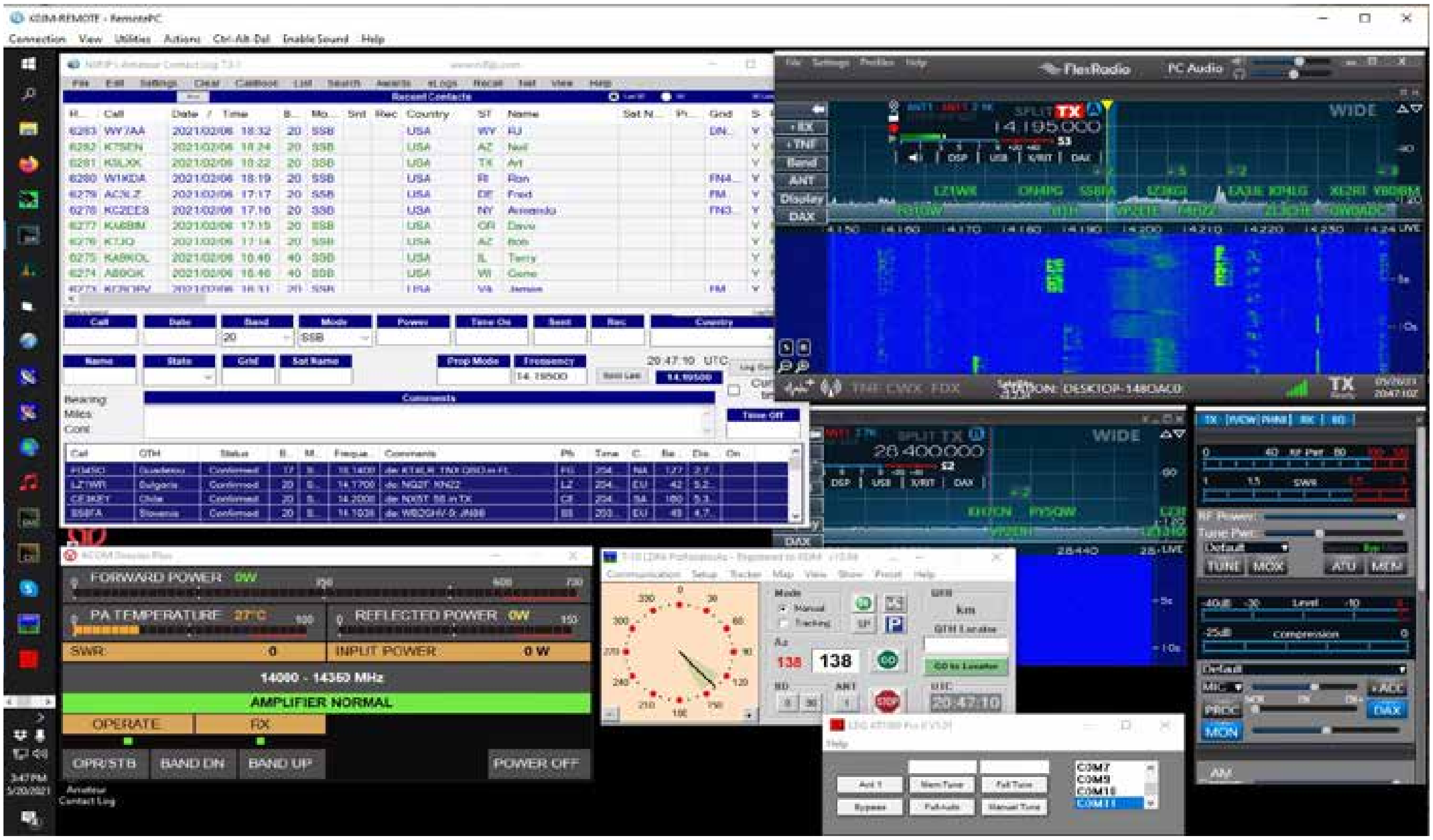


Figure 5 — Setting up Skype connections and audio levels was the most challenging part.

Figure 6 — Satellite operation on a Mac laptop. The only drawback is a lot of windows the sort through on the small screen.

It's all separate now.

Software Decisions

The next step was to be able to access this new station computer remotely, and to be able to do, from a remote screen, everything that could be done sitting in front of the local monitor. There are a number of "remote desktop" programs available for this purpose. Many of these offer free trial periods, so it's safe to experiment.

TeamViewer is a popular choice because it has a free option, and that's what I started with. But I heard many stories from amateurs who had been excluded from free access on TeamViewer because they logged too much time online. The paid version of TeamViewer is quite pricey, so I didn't want to depend on it. I was led to seek alternatives, even if they would cost a few bucks. K8YSE recommended LogMeIn. I found a slightly better price with RemotePC. Either choice was less than $40 per year.

Among the features to look for are reliability and stability, of course, and the ability to use the service on multiple platforms: PC, Mac, iOS, Android, etc. Another important feature is audio. Most of these programs allow the remote user to listen to audio from the PC being controlled, but not all do, and not all do it well. Very few allow audio from the remote user to be input into the controlled computer. The only one I found that did was inordinately expensive.

Can You Hear Me Now?

The K8YSE solution was to employ Skype for audio input to the mic of the rig at the remote site. Even now that the pandemic has given us a wide variety of conferencing tools, Skype still seems to be the best choice. Skype is reliable, configurable, and maintains high-quality audio in most connections. It can also be set to answer incoming calls automatically, which is very handy.

John's setup required extra sound cards in the computer and isolation transformers in the audio lines. This is where the FlexRadio SDR system really shines, though. All of the audio connections in the software defined radio are already inside the computer. All of the connecting cables are virtual, so the extra hardware is unnecessary. It's just a matter of correctly configuring the inputs and outputs in SmartSDR's DAX audio panel on the screen.

Once Skype's output is set to the DAX mic input, and the levels are properly adjusted (the part that took the longest time and the most experimentation), the best course of action is to turn off the Skype microphone at the remote end. This can be done at the beginning of each Skype connection, as the program won't remember to mute itself. Or the Skype remote mic audio level can be turned down sufficiently as to be effectively muted.

If rig audio is sent back through Skype, the Skype program will suppress your downlink audio while you are transmitting. You won't be able to hear yourself on the downlink because Skype is trying to avoid a feedback loop. This is why you mute Skype's audio line coming back to you, and listen, instead, to the audio being sent by RemotePC, TeamViewer, or whatever remote desktop software you have chosen. That way, you will hear your own voice in the headphones, with normal satellite delay, just as if you were listening to full-duplex audio in front of the rig.

It's also a good idea to switch off any noise-canceling features in the remote desktop software's audio processing. Otherwise, weak signals can effectively be squelched by the DSP algorithms.

An Easier Way

Because of antenna restrictions, there are all sorts of reasons to want to operate a ham radio station from a remote location. Fortunately, remote control of a ham radio station has never been easier, thanks to the internet. Radio manufacturers have created software to make such connections easy, but usually, these solutions only consider HF operation and don't have satellite ops in mind.

As satellite operators, we all know that there are additional challenges and extra devices to control if we are going to track satellites across the sky with our antennas and tune for Doppler-shifted signals. Out of the box, remote control software just doesn't take care of these extra functions.

The use of software defined radios in conjunction with remote desktop software greatly simplifies the situation and makes it not only possible but even enjoyable to operate remotely with full functional control of the remote satellite station.

Support AMSAT

AMSAT is the North American distributor of SatPC32, a tracking program for ham satellite applications. Version 12.8d features enhanced support for tuning multiple radios. Features include:

1. The CAT commands of the IC-9100 have been extended again. The program now also controls the DV mode (DV for 'Digital Voice') of the radio. With the FT-817 the program now additionally supports the CWR mode.

2. All SatPC32 programs now process significantly larger Keplerian element source files. Especially because of the numerous new Cubesats, the number of data sets contained in the source files has increased significantly. For example the file Cubesat.txt currently contains data for nearly 400 satellites.

3. In all programs (SatPC32, SatPC32ISS, Wisat32, WinAOS and WinListen), the list of satellites contained in the source file ('Available' list in menu Satellites) is now displayed in alphabetical order to facilitate locating individual satellites.

4. The program SatPC32ISS now also allows the creation of up to 12 satellite groups. The new Cubesats have also increased the number of 'in-band' satellites. Originally, in-band operation in amateur radio was only available at the ISS.

5. In order to accelerate a change between the individual satellite groups, the 'Groups' window can now be called up by clicking on vacant areas of the main window, except in the Satellite menu. Such free positions are located on the right and left of the frequency window.

6. In the Satellites menu the data sets of the satellites contained in the active source file can now be displayed. When called, the data set of the currently selected satellite is displayed. The feature helps you to immediately know the identifier of the satellite.

7. The program has improved control of the sub-audible tone required by some satellites. The program can now automatically switch the sub tone on/off when switching between PL tone satellites and others, changing between u/v and v/u satellites, changing the group, closing the program, etc.

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

Join the 2021 President's Club

And Help AMSAT Return to High Earth Orbit!

AMSAT is excited about developing and launching the next generation of Greater Orbit Larger Footprint ("GOLF") satellites. AMSAT has an immediate need to raise funds to cover development, launch and related expenses to *Keep Amateur Radio in Space*. We have set a fundraising goal of $125,000 to help keep AMSAT viable and effective in the competitive world of space communications.

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

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

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

Commemorative Coin 2" with 4-color enamel accents and polished gold finish.


President's Club 2021 – Core Level
Carl Laumann, K7ZOO

Full-color membership certificate

Embroidered "Remove Before Flight" Keychain

Higher tier members receive even more benefits! You can join with a single payment or with twelve affordable monthly payments with your credit card. For payment by check or electronic transfer, contact Frank Karnauskas, VP-Development at N1UW@AMSAT.org.

Go to AMSAT.org/donate and join today!

Tier	Core	Bronze	Silver	Gold	Platinum	Titanium
Annual Donation	**$120 +**	**$300 +**	**$600 +**	**$1,200 +**	**$2,400 +**	**$4,800 +**
Journal Listing	X	X	X	X	X	X
Certificate	X	X	X	X	X	X
Coin	X	X	X	X	X	X
"RBF" Key Ring	X	X	X	X	X	X
Plaque			X	X	X	X
TAPR/AMSAT Dinner @ Dayton				X	X	X
Symposium Admission					X	X
President's Symposium Lunch					X	X
Symposium VIP Recognition						X

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

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

Build satellites that Keep Amateur Radio in Space!

Promote space education through ARISS and STEM-based initiatives.

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

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

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

Show and share their passion for amateur radio in space everywhere they go!

Will take amateur radio to the Moon, to Mars and to deep space … with your help!

Go to https://www.amsat.org/volunteer-for-amsat/ and help create AMSAT's future legacy!