AMSAT Phase 4 Ground Project Update

Michelle Thompson • W5NYV

I hate space. It's cold. Very cold. Deathly cold! It's hot. Hotter than hot. Deadly heat! The unrelenting radiation and unforgiving isolation result in an engineering tradition that demands onerous redundancy and cloistered conservatism. What's not to hate about something unsurvivable, untenable, intractable, uninhabitable, horrifically expensive to invade, and accessible only by a sparse few citizens that survive the training that only a few countries can afford?

I hate space because space is the enemy. The only rational choice is to hate the enemy, and enemies are to be fought. The trouble is that you can't really fight space. Eventually, space will destroy your work. You cannot do anything except design your best, test everything, cross your fingers, toss it up there, hope it succeeds, and celebrate when your mission exceeds its planned lifetime.

Launching things into space is what AMSAT has done, and done very well, for a long time. The organization has seen significant changes in technology, access to launches, types of launches, and types of communications over the past 46 years.

For the vast majority of these endeavors, the communication equipment required on the ground has been easy to build, purchase or adapt. The new generation of sophisticated projects, like Phase 4B, Phase 3E, and the Cube Quest, however, present digital communications challenges that we must overcome with a new generation of microwave radios.

Digital Communications Complexity

Phase 4 Ground supports payloads that include highly capable digital communications, such as Phase 4B, Phase 3E, and the Cube Quest Challenge, representing a significant step forward for AMSAT.

Digital communications services require a much more complex receiver than traditional analog services. This is not telemetry crammed under voice or an experimental image mode that gets turned on once a quarter. These missions offer entire banks of fully-realized channels, allowing text, voice, voice memo, images, data, and possibly video to be exchanged between a wide variety of station types on the ground. If we do not provide real technical support, quality tutorials, working equipment recipes for build-it-yourself, and excellent off-the-shelf purchase options to operators, then the satellite's capabilities will go unused.

We have a moral obligation to make good on the opportunities that we have been given. We are required to do all that can be done to provide accessible, relevant, fun, and rewarding communications access. This means that for all the amazing efforts by the payload team, all the stress of a high profile launch, and the mystery of regulatory hush, the real action is on the ground and should be done in the open.

We should invite commentary, critique and feedback. We should welcome the widest possible variety of volunteers and make it easy for them to participate. We should publish and share what we learn, design, and recommend, so that many others can build upon and improve the radio designs.

Radios for AMSAT's "Five and Dime" Microwave Strategy

Phase 4 Ground will produce an ensemble of open source solutions for the digital radio problem that the AMSAT microwave strategy poses.

The amateur radio service has a space allocation in both 5 GHz and 10 GHz ("five and dime"), and that's where AMSAT's microwave satellite strategy is directed. AMSAT considered all the microwave bands, from 1.2 GHz through 24 GHz, and chose "five and dime" for a combination of technical and regulatory reasons. Choosing the right band for the job involves a lot of moving parts, with each alternative presenting various difficulties and challenges. The selection of "five and dime" resulted from substantial discussion and consideration.

Phase 4 Ground is pursuing both a manufactured solution and developing a set of documents that fully enable motivated operators to build their own gear or assemble a station from commonly available parts and products.

Prospective users really must have the option to buy a complete radio for the proposed digital satellite strategy to work. Our goal is nothing less than the creation of a world-class radio.

Those do-it-yourself operators who want an adventure in digital communications also must be provided access to the documentation required to build a complete station. Operators wanting to build a station from existing radio components, such as SDRs or commonly available surplus gear, should be able to find the information on how to do that.

Why Microwave?

One big reason for choosing microwave is the small size of high gain antennas, which are needed to overcome path losses to distant spacecraft. Perhaps even more important, it's the only way to get higher bandwidth transmissions. Microwave is the only place where digital modes with decent data rates can happen in amateur radio.

From a regulatory perspective, we either start using the microwave bands or we continue to lose them. Sustained and well-funded commercial interests seek to consume everything from 1 GHz to 6 GHz, and in some cases, beyond. There are no current satellite projects on 5 GHz or 10 GHz. We need to get up there and get active, or else.

We have an additional motive for pursuing digital microwave. This new radio also will work terrestrially, and will provide expanded choices and resources to the terrestrial amateur microwave community. Instead of a satellite, operators would use a "Groundsat" on a mountaintop or tower. Operators would get all of the services that the satellite code provides, but on the ground instead of in the air.

Terrestrial amateur activity on the microwave bands primarily consists of beacons and contests. Gear is often homebrew or purchased and then integrated into rigs from a few manufacturers. This means that there really isn't a lot of readily available amateur gear for 5 GHz and 10 GHz. Our goal is to change that. We aim to provide an ensemble of solutions, ranging from "u-build-it" to "u-buy it," and as many points in between as we can knock together and test.

The goal of developing a radio that is reconfigurable (and therefore reusable) for multiple payloads, as well as performing a modern terrestrial microwave role, is an ambitious one. Doing it with a geographically diverse volunteer team that must successfully interface and collaborate with multiple organizations, corporations, government, and a wide array of individuals, while maintaining focus and discipline, is a very tall order.

This project is risky, messy, multithreaded, and involves significant integration challenges. It is also well worth doing, incredibly rewarding, and will provide plenty of good designs as a side effect of the research and development required to make a quality radio. While the risks are substantial, the benefits exceed the risks.

Progress to Date

We decided to separate the development of the radio from the development of the payload by creating a separate team for each. The two teams communicate through a common air interface document. This collaboratively developed document specifies the waveforms that are recognized by the radio on the ground and the payload in the sky.

In some aspects, the payload team calls the shots. That team is heavily restricted by the facts of life in space compared to the radio team, so we on the radio team must be able to accommodate them on things they cannot change or modify, like instructions they get or restrictions they are given from the primary payload. I
n other aspects, we on the radio team define other parts of the interface in order to increase overall system capability or avoid an expensive problem on the ground. This is an ongoing process that requires excellent communication and skill to pull off.

Splitting the teams this way means that the payload team can continue to comply with strict ITAR controls without unnecessarily restricting discussions of the ground team. A separate ground team can then pursue a non-ITAR open source process that relaxes otherwise unnecessary restrictions.

For example, Phase 4 Ground can welcome volunteers that otherwise would not be able to participate, and we can publish documents that we otherwise would not be able to share. This allows us to take advantage of the widest possible range of engineering comment and critique. Being able to actively seek feedback and guidance improves our ability to produce quality work. It may not be any easier to do the work, because things worth doing are rarely easy, but we are better able to take advantage of the widest possible reading of our work. Being able to get quality advice saves enormously valuable time.

We have begun to define our system, and we have identified a framework. Phase 4 Ground uses Digital Video Broadcasting (DVB) standards from www.dvb.org. These standards are widely adopted. The ones most relevant to us are the second-generation terrestrial television (DVB-T2) and second-generation satellite communications standards (DVB-S2 and the recent extension to DVB-S2 called DVB-S2X). Instead of simply using these standards to transmit television, we're using these standards to ship our data.

An additional standard that we're using is called Generic Stream Encapsulation (GSE). GSE provides a way to turn IP packets into data streams that are easily handled by the way DVB transmits data.

For Phase 4B, we are developing an adaptation of DVB-S2 that will allow stations with a wide variety of capabilities to efficiently use the satellite links to the best of each of their abilities. Our goal is to implement DVB-S2 in a way that allows the satellite to tailor transmissions to stations in a way that complements their individual capability and current link quality. This requires a variety of codes and modulations, along with the ability to sense when more or less coding or a different modulation type is required. This method is called Adaptive Coding and Modulation.

The idea here is for the satellite to recognize when a station needs a more durable signal, or can get by with less coding "armor." When a signal needs more help, the satellite adds more of the right type of redundancy, so that the information transmitted to the station is received with a low probability of error. When there is a strong enough signal that some redundancy can be skipped, the coding requirements can be relaxed. The benefit of all this work is that the amount of data that can get through the system, or system throughput, is optimized.

Using a high-quality and widely adopted standard like DVB-S2 provides a huge learning opportunity for all the volunteers involved. For Virginia Tech students directly involved with the payload development, the opportunity to learn current industry techniques and get real-world experience in implementing them provides a significant post-graduation advantage. For many of us on Phase 4 Ground, a similar opportunity exists to work with a state-of-the-art communications protocol that we might not otherwise get.

The DVB standards provide very well thought out solutions to the most common problems of digital transmission. However, the decision to adopt them does not mean we're anywhere near the finish line. Implementing the standard in a ham-centric way requires figuring out what parts of the standard are necessary, what are unnecessary, what needs to be modified, and what additional mechanisms need to be designed.

For Phase 3E, DVB-S2 will be proposed. For Cube Quest Challenge, DVB-S2X is being pursued. DVB-S2X is an extension to DVB-S2. The reason for selecting it is that it contains very low signal to noise codes and modulations that will work for the very large path losses expected during the lunar mission.

Selecting, understanding and properly implementing a standard like DVB presents a substantial challenge. However, that's just the tip of the iceberg. The RF chain has many challenges. Remember the choice of frequencies? That 5 GHz uplink has a second harmonic that just happens to be within the range of the sorts of low noise block down converters that we'd really like to use on 10 GHz.

Even with a two-dish solution, with a separate 5 GHz uplink antenna and 10 GHz downlink antenna, the isolation between the two dishes is not perfect. This is a full duplex system. The side lobes for a typical parabolic dish are only down 20 dB or so. If an operator selects a booming 5+ watt power amplifier for the uplink, and doesn't manage to point the receive dish as well as he could, then what happens to the downlink? This is an area of active research.

Multiple solutions are being designed, built, and tested. Our expectation is to be able to provide a variety of designs. Some may work better in some ways than others. Some advantages will not be compelling to all operators. For example, for emergency communications or portable use, two dishes are not desirable. We're working on a single antenna solution for this. The challenge is isolation and filtering. In contrast to portable requirements, for fixed installations at home, two large dishes would seem to work perfectly. Our job is to document and explain as many different types of solutions as possible. Operators then will have the option of which one they want to experiment with.

Access Control

Access control is another challenge presented by digital communication. Digital systems provide a means for identifying, authenticating, and authorizing access to a communications resource. Decisions on whether to do this, how to do this, how much of this to do, and what sorts of burdens are reasonable to inflict upon "the good users" in order to filter out "the bad users" are all part of the design process for Phase 4 Ground. Getting this right means that the satellite is easy to use but hard to abuse. Getting it wrong means people give up trying to use it.

We are incredibly fortunate to have very high-quality teams at Virginia Tech and Rincon dedicated to the creation of the 4B payload. This project is the culmination of over a decade of groundwork by people like Bob McGwier, N4HY, and will require two or three years of work by Virginia Tech, all the companies involved, and AMSAT Phase 4 Ground.

The Phase 4 Ground team currently consists of nearly 60 volunteers who have signed up to work on the project. "Work" includes building equipment, calculating things that need calculating, path-finding the best existing solution to adapt to our project, reviewing documents for dumb mistakes, making communications happen, blank paper engineering, cheerleading, designing beautiful graphical user interfaces, evangelizing, fundraising, documenting, providing adult supervision, programming, meeting people that might provide services we need, updating the documentation, more programming, coming up with algorithms, and many other roles and responsibilities.

All our documents and software are and will be at our github account at **github.com/phase4ground.**

Sign up to be an AMSAT technical volunteer at **www.amsat.org/?page_id=1096**. You don't have to be an expert. You just have to want to become one.

AO-85 Hooks a Father and Son in Uruguay

Carlos Pechiar • CX6BT

It was early January, a sunny summer morning here in Uruguay. I was sitting under a red umbrella on the eastern-most beach, next to the border with Brazil. While keeping an eye on my two sons playing in the ocean, I periodically restarted the scanner on my Baofeng handheld transceiver (HT), which kept sweeping from one end of the band to the other with the characteristic radio silence of a remote and sparsely populated place. Suddenly, to my surprise, the scanner stopped on a very clear and strong signal. The callsign indicated an Argentine station. First, I thought he was a nearby tourist working mobile, but then the male voice said he was operating from La Plata, Argentina, about 300 miles away. I heard him say "Alfa Oscar 85", and that rang a bell. A quick online search on my smartphone confirmed that I was listening to AMSAT's Fox-1 satellite.

I couldn't believe I was listening to a QSO between a "Lima Uniform" and a "Papa Yankee" on my cheap HT with no additional antenna. I stood up, ran to the waterline and gathered my kids to briefly explain what was happening. But I was the one most excited. During the following days, I listened to many QSOs over AO-85 during different times and conditions. Without an adequate antenna, however, I knew I wouldn't be able to participate in any of them. By that time, I already was hooked on getting into working the satellites.

Once back home in Montevideo, I downloaded pass prediction software and built a very crude dual band handheld yagi out of wood and measuring tape. I wanted to get on the air as soon as possible, and, as someone once said, any antenna is better than no antenna at all. It became a matter of perfecting my orientation technique and fighting against the wind until I finally managed to make my first QSO over a satellite.

The day of my first AO-85 QSO, my older son, Felipe, helped me. Since then, when I get back from work, I take a look at the pass prediction software and, if the satellite is available, I go outside with him to try to make a new contact. Since the first time I listened to this satellite on the beach in January until now, my interest in satellite QSOs has continued evolving. On Twitter, I follow some fellow hams who are passionate about satellites,

I know that my setup, and especially my antenna, needs improvement and that, once this is done and my technique mastered, I will start working other satellites, too. In terms of my amateur radio knowledge and experience, I consider myself a relatively inexperienced ham radio operator. In the past, I was attracted only to the HF bands in phone mode. Most importantly, I have been aware of CubeSats for some years now since my brother was chief engineer of a state university project, the goal of which was to use only student development to put a satellite into orbit. The now-defunct Antelsat successfully completed that mission.

What struck me most from my encounter with AO-85 in January, and all that I have been learning so far on this subject, is how much easier operating through satellites is than it seems. Moreover, I recently started listening to a couple of ham radio oriented podcasts during my commuting time, and each one I hear reinforces my belief that this hobby is incredibly broad and extremely satisfying.

The only barrier is finding the right motivation. For me, the motivation is in the air. Just a couple of days ago, I had the opportunity to show some of my sons' friends how I could receive signals from a satellite. When I told them what was going to happen, they put aside all their connected mobile devices with their popular apps and came outside to look up to the sky and listen to the radio.

Today, I found my study material for the ham radio license exam and gave it to my son, Felipe. I told him that we would take a look at it together. Maybe he will become a ham, too. This will be a good year for my hobby. Sharing it with my son is the best part.

Felipe Pechiar helping his father, Carlos, CX6BT, with his first AO-85 QSO. [Carlos Pechiar, CX6BT, photo.]