The AMSAT® Journal

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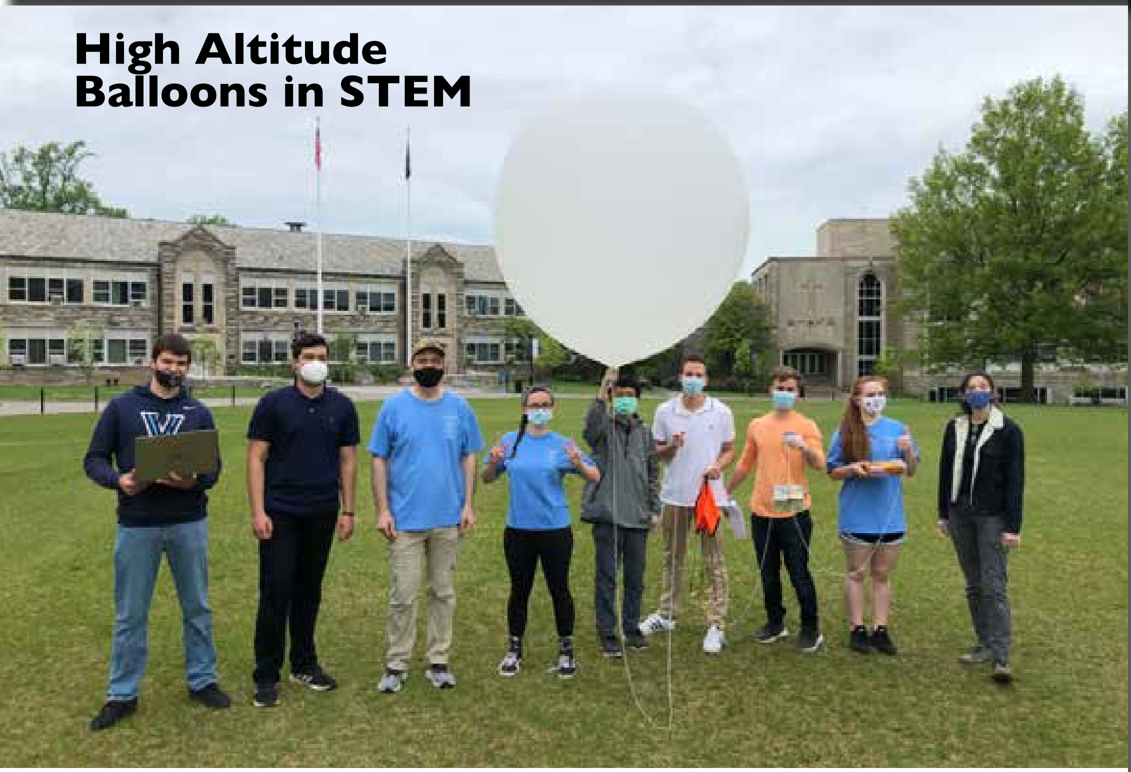
High Altitude Balloons in STEM



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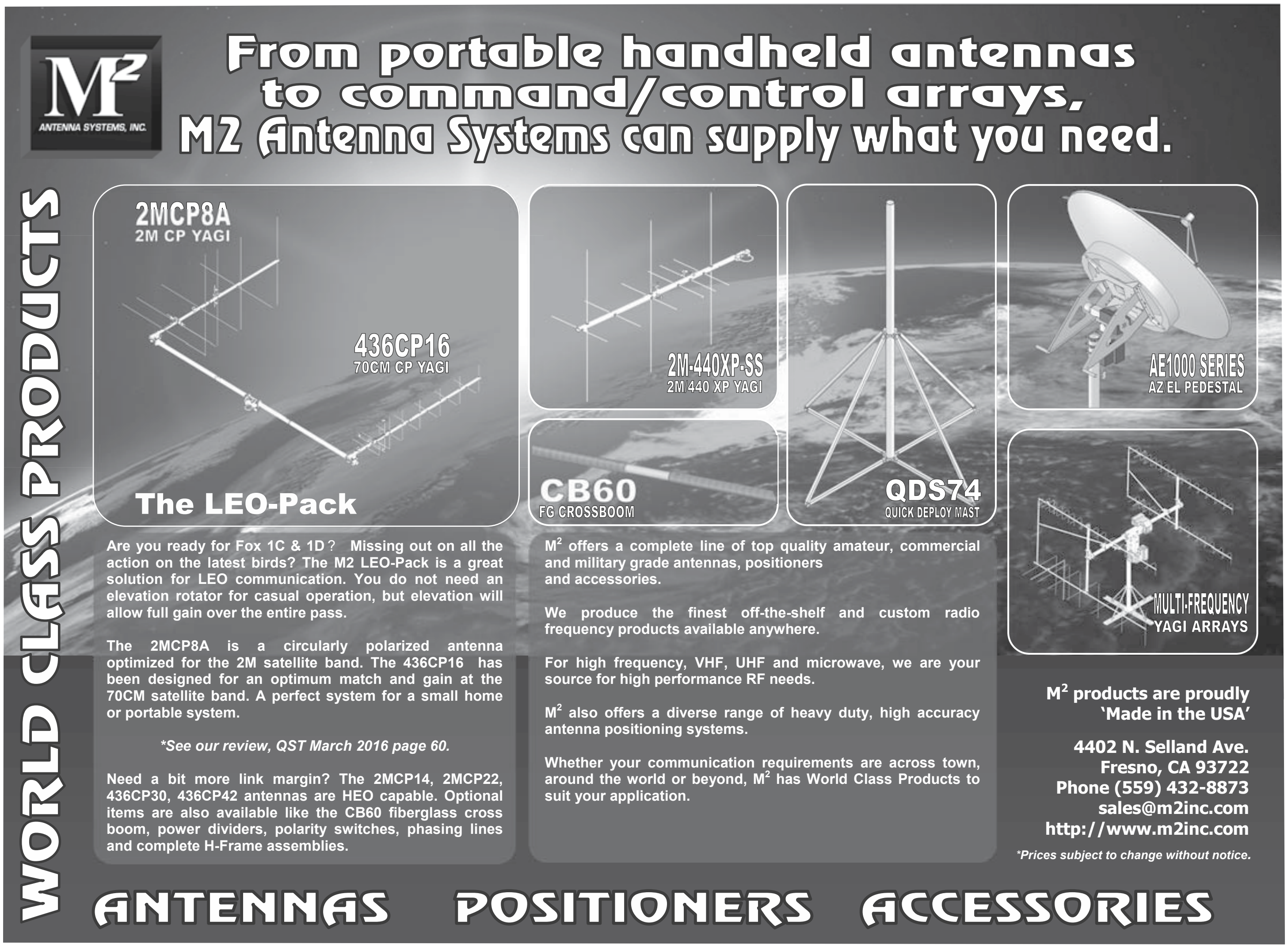

Bob Davis, KF4KSS (SK)

Bob Davis, KF4KSS, was an invaluable member of the AMSAT community, and he will be sorely missed. Bob's knowledge and attention to detail added to the success of many projects over the years.

We first met Bob in 1996 when he joined us on the Phase 3D (AO-40) project. Bob had recently graduated from the University of Central Florida with a degree in mechanical engineering. Bob was very meticulous and detailed in his work, introducing 3D drawings to the project and volunteering for various tasks that helped bring the project to fruition. He was instrumental in revising the satellite structure of the Phase 3D spacecraft, adding his expertise to the mounting system and solar panel deployment system.

Bob was involved with every AMSAT and ARISS project since 1996, including Eagle, Suitsat, ARISSAT and the FOX series of satellites. He helped design, build, test and certify the FOX and next generation and worked on the GOLF satellites. He brought a level of expertise and dedication to these projects that will be difficult to replace.

Bob came to AMSAT as a new engineer, ready and eager to make a difference in the world. I watched over the years as he matured into a fine aerospace engineer. He was a close friend and like a son to me in so many ways. I am so sad to have him gone so soon and will miss our conversations, his great laugh and all of the things the future once held for him. Rest in peace, my friend.

— Lou McFadin, W5DID

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Apogee View

Robert Bankston, KE4AL
President

As 2021 comes to a close, AMSAT's schedule for 2022 is quickly filling up. Our engineers will be busy with GOLF, launching a new program called Fox +, and beginning to formulate our return to high Earth orbits. Additionally, in-person events are kicking off again, starting with:

- Feb 11-13, Hamcation, Orlando, FL
- Apr 26-28, CubeSat Developers Workshop, San Luis Obispo, CA
- May 20-22, Hamvention, Xenia, OH
- Aug 6-11, Small Satellite Conference, Logan, UT
- Oct 21-22, 40th AMSAT Space Symposium and Annual General Meeting, Bloomington, MN.

I hope you will join us on this exciting ride if your schedule allows it.

Fox +

At the December 7, 2021, board of directors meeting, Jonathan Brandenburg, KF5IDY, presented a plan for a sustained presence of "easy sats" in low Earth orbit. As I mentioned back in the July/August 2021 Apogee View, easy sats play a critical role in introducing amateur radio in space. So, I was both excited and impressed with Jonathan's proposal. Fox + (Plus), as the new program will be called, is based on the Fox-1 bus design and will develop a new transceiver and power system in an open-hardware and open-source environment. In addition, Fox + CubeSats will host student science, technology, engineering, and mathematics (STEM) experiments and AMSAT radio experiments. Of course, the board enthusiastically and unanimously approved Jonathan's Fox + proposal.

I want to personally thank Jonathan for developing this forward-thinking program and congratulate him on being appointed Assistant Vice-President, Engineering. Well done and well deserved.

A Sad Farewell

With a heavy heart, I inform you of the passing of Robert "Bob" Davis, KF4KSS, on Friday, December 10, 2021. Bob was with every AMSAT and ARISS project since 1996, including Phase 3D (AO-40), Eagle, Suitsat, ARISSAT, the FOX series of satellites, and, most recently, the GOLF program. His expertise in mechanical engineering and willingness to share will be sorely missed. Lou McFadin, W5DID, has written a lovely tribute to Bob for this issue of *The AMSAT Journal*, and many have shared pictures of their time with Bob. Please take a few moments to read and reflect. Godspeed, Bob, and thank you for sharing your life with us.

A Welcome Surprise

Earlier this year, I learned that AMSAT had been named as one of the beneficiaries of the Robert Donnell, Sr. (KD7NM) and Joan Donnell Trust. As a result, AMSAT received an initial distribution of $250,000 in December. Unfortunately, AMSAT was unaware of the Donnell's bequest until the attorney handling the trust distribution notified us.

I am ashamed to admit that I did not have the chance to meet or even know of Robert and Joan Donnell. However, scouring the internet and our records, I did find Robert's callsign, KD7NM, see where he posted to the AMSAT-Bulletin Board and was active in ARES and packet radio in the State of Washington. Robert Donnell, Sr. KD7NM, passed away on August 24, 2011, and was followed by his wife, Joan, on February 4, 2013. Robert and Joan's daughter passed away in September 2019, which may explain the later distribution of the Donnell estate. Please let me know if you have any further information on Robert Donnell. It is important to learn as much as possible about the person who thought so much of AMSAT.

While we greatly appreciate this tremendous gift, please do not assume that AMSAT does not need more help. We have an ambitious, forward-thinking plan for the future (www.amsat.org/strategicplan/) that takes us to new heights and encourages the next generation to reach for the stars, but space is not cheap. We need your help to get us there.

Knowing that our planned initiatives cannot be funded strictly from membership dues and donations, AMSAT submitted three separate grant requests to Amateur Radio Digital Communications (ARDC) in November. One is to support a commercially purchased and launched 1U FM CubeSat to help relieve some of the strain on the remaining easy sats until AMSAT can develop the Fox + program.

Our second request is to fund the open-hardware design and construction of the GOLF program's 3U frame and deployable solar panels. And finally, our third request is for the initial kickoff of the AMSAT Youth Initiative Program, the purpose of which is to promote interest among youth in STEM topics and opportunities, particularly those related to satellite technologies, communications and electronics, and how those technologies improve life here on Earth. I will keep you apprised as soon as I hear something.

Help Wanted

Big plans and finding the money to fund them is a great start, but we cannot make it happen without volunteers. As an all-volunteer member organization, AMSAT depends on the generosity of people, donating their time and expertise to develop the next generation of amateur radio satellites, and sharing that knowledge with the rest of the world. If your expertise is in engineering, education, journalism, project management, or even office administration, we could use your help. So, join us on our journey Onward & Upward.

73,
Robert Bankston, KE4AL
AMSAT President

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When making purchases from Amazon, you can select a charity and Amazon will donate .5% of a qualified purchase towards that charity. Select smile.amazon.com when making your Amazon purchases and make Radio Amateur Satellite Corporation (AMSAT) your chosen charity.

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

AMSAT Recognizes 2021 President Club Donors

We want to thank the following AMSAT members whose generosity represents over $62,000 in donations to AMSAT. They have been inducted into the 2021 President's Club for their contributions.

Now that the year has ended, we are accepting donations for the 2022 President's Club! We hope you will join these members in helping to Keep Amateur Radio in Space!

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

Platinum ($2,500+)
Steve Belter, N9IP
Alan P. Biddle, WA4SCA

Gold ($1,200+)
Barry Baines, WD4ASW
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Douglas P. Besemer, K0VPL
John Boehme, K4PRK
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Mark Johns, K0JM
Allen Kenny, KK4AK
Joseph Lynch, N6CL
Ronald Parsons, W5RKN
Jason Schwarz, N4JJS
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Warren Fugate, W3WE
Anton Giroux, KF3BX
Robert Grattan III, N4MRV
Stephan Greene, KS1G
Edward F. Krome, K9EK
Donald Lum, WA6ICW
Bruce Paige, KK5DO
Richard Ruhl, W5GLD

Core ($120+)
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Alan Boggs, K7IIV
Max Brewer, VE9AIR
Kitchell Brown, WB6QVU
Gerald Buxton, N0JY
Sebastian Delmont, KI2D
Dennis Dinga, N6DD
Joe Domaleski, KI4ASK
James Gillanders, KG6HXN
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
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Alston Simpson, WA5TJB
Carl Starnes, W4EAT
Richard Steegstra, K1LKR
Paul Stoetzer, N8HM
Thomas Talley, K0CFI
Timothy Tapio, K4SHF
Dave Taylor, W8AAS
Wayne Wagner, AG1A
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 2022 President’s Club!

Educational Relations Update

Alan Johnston, Ph.D., KU2Y

Despite not being in person again, I really enjoyed the 2021 AMSAT Dr. Tom Clark, K3IO, Memorial Space Symposium and Annual General Meeting back in October. You can watch the recording on the AMSAT YouTube channel (www.youtube.com/user/AMSATNA). I presented an update on AMSAT's Educational Relations activities, including the latest on the CubeSat Simulator program.

We also updated attendees on High Altitude Balloons (HAB) and STEM (Science Technology Engineering, and Math) Education. The related symposium paper is republished in this month's Journal as well. In 2022, we plan to continue developing a version of the CubeSatSim suitable for a HAB payload. If you plan to launch a high altitude balloon in 2022 and would be interested in flying an experimental CubeSatSim payload, please contact me.

Personally, the big excitement was announcing the CubeSatSim Lite, the lowest cost version of the CubeSat Simulator. As shown in Figure 1, the CubeSatSim Lite is a single small board that plugs into a Raspberry Pi (Pi HAT). It only has the Low Pass Filter (LPF), control buttons, and LEDs. It does not have a battery, solar panels, sensors, or a frame that the full CubeSatSim has. It transmits simulated telemetry in all five modes currently supported by the CubeSatSim: APRS (Automatic Packet Reporting System) AFSK (Audio Frequency Shift Keying), Data Under Voice (DUV) FSK (Frequency Shift Keying), BPSK Binary Phase Shift Keying, SSTV (Slow Scan TV), and CW. All five modes can be decoded using the latest Fox-in-A-Box v3 Raspberry Pi image, available on the AMSAT Store and burnsfisher.com/AMSAT/FoxInABox/.

The CubeSatSim Lite is still in beta, but we had a small number assembled and listed on the AMSAT Store. They included a Raspberry Pi Zero W with the micro SD card, USB cable and power plug. I announced their availability live during the symposium, and before my presentation was over, they were sold out.

We are currently getting feedback on these beta units. If you got one and haven't already sent me your comments and feedback, please do so via email at **ku2y@amsat.org** or on Twitter **@CubeSatSim**. We will likely do at least one more beta production run early in 2022, so keep an eye out for announcements via AMSAT News Service (ANS) or at events where AMSAT will be presenting, such as Hamvention. There could be more live announcements!

Figure 1 — CubeSatSim Lite Beta.

You can find lots of information on the CubeSatSim Lite Wiki page: https://github.com/alanbjohnston/CubeSatSim/wiki/CubeSatSim-Lite.

Since the symposium, three new volunteers have joined the CubeSatSim Project to help write lesson plans and documentation for educators and demonstrators. I am pleased to welcome Paul Graveline, K1YUB, Fredric Raab, KK6NOW, and Mark Samis, KD2XS, to the team. Paul is also an Assistant Editor of *The AMSAT Journal*. Fredric is experienced in balloons and rocketry. Mark built a beta CubeSat Simulator in 2020. I'm looking forward to working with them in the new year!

For the latest CubeSat Simulator news, follow our dedicated Twitter account, **@CubeSatSim**.

If you are interested in doing a demo for a group or school, I can ship you a loaner. Contact me via email at **ku2y@amsat.org** or on Twitter **@alanbjohnston.**

Amateur Radio Satellite Operating — Canadian Style

Keith Baker, KB1SF/VA3KSF

[Portions of this article first appeared as: "Amateur Operating Canadian Style" in the June 2013 edition of Monitoring Times *Magazine. Thank you, M.T.!]*

The border between the U.S. and Canada forms the longest undefended one in the world. A special radio treaty also authorizes U.S. and Canadian licensed hams automatic reciprocal operation in each other's countries simply by following a few simple "rules of the road." (KB1SF, photo.)

With the spring and summer travel season now just a few months away, some U.S. amateur radio satellite operators may soon be thinking about traveling north of the U.S./Canadian border to activate the plethora of "rare" Maidenhead Grid Squares that are often going begging in the "Great White North."

As a U.S. citizen and permanent resident of Canada (I also hold both U.S. and Canadian amateur radio call signs), in this article, I'll explain what U.S. and Canadian hams have to do to freely operate in each other's country without obtaining special permission. I'll then briefly discuss how traveling back and forth from the USA to Canada under COVID has created some additional (but not insurmountable) actions that U.S. hams

The international Bluewater Bridge between Port Huron, Michigan and Point Edward, Ontario (near your author's home) forms the second busiest land border crossing between Canada and the United States. (KB1SF, photo.)

must take before they attempt to cross the land border into Canada. I'll then share some practical tips on being a "good citizen" while visiting your northern neighbor.

In the Old Days

It used to be that operation in Canada by a U.S.-licensed ham (and vice versa) required lengthy written permission from government officials in the visited country to authorize such operation. But thankfully, today, there's a U.S./Canadian treaty in place for such operation. What's more, there is no longer any need for U.S. or Canadian licensed hams to do anything other than adhere to a few simple "rules of the road" while operating in each other's country along with complying with a few recently added travel requirements as a result of the COVID pandemic.

Most U.S. hams are well familiar with the Federal Communications Commission (FCC) Part 97 that governs amateur radio operation in the U.S. However, as the various reciprocal privileges accorded to visiting U.S. hams operating in Canada are based on privileges accorded to Canadian hams, U.S. hams need to understand what those privileges are and how they are granted to Canadian hams before they travel.

U.S.-Canada Reciprocal Agreement

A treaty now allows U.S. and Canadian hams to operate freely in each other's countries. The operation of amateur radio equipment and stations in the other country's territory is covered in Treaty Series 1952 No. 7 — Operation of Certain Radio Equipment or Stations, Convention between Canada and the United States of America. In short, this treaty allows amateurs to operate in each other's territory using a license granted by their home country per the rules and regulations of the host country.

U.S. amateurs who desire to operate their radio apparatus in Canada must bring along proof of their U.S. citizenship, along with a copy of their FCC-issued license. They must also abide by the rules contained in Canada's RBR-4, a part of the Regulations by Reference (RBRs) and Radio Information Circulars (RICs) that, together makeup Canada's version of "Part 97" for the Amateur Radio Service. A complete list of RBRs and RICs governing the Amateur Radio Service in Canada can be found at: www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf05478.html.

Briefly, a U.S. amateur who is qualified to send and receive in Morse code at a speed of at least five wpm may operate an amateur station in Canada in accordance with the provisions applicable to the holder of a Canadian Amateur Operator's Certificate with Basic, Morse Code (5 wpm) and Advanced Qualifications. This grants them essentially unrestricted (i.e., "Extra Class") amateur radio operating privileges in Canada.

A U.S. amateur who is not qualified to send and receive in Morse code may operate an amateur station in Canada in accordance with provisions applicable to the holder of the Canadian Amateur Operator's Certificate with Basic Qualifications.

Unfortunately, this means that recently licensed (so-called "No Code") U.S. General and Extra Class licensees will be restricted to VHF and above during their visits to Canada. This is one of the drawbacks to the FCC's recent decision to do away with all forms of Morse testing for U.S. hams. Unfortunately, by doing so, they left U.S. hams with no option to obtain a Morse endorsement for reciprocal licensing credit with some countries that still require Morse proficiency for access to H.F. Now, this issue is usually not a problem for visiting U.S. hams who want to operate via our satellites as, at the moment, all of our satellite activity is at VHF and above frequencies.

And, as I said, there is no need for paperwork or other formalities when hams wish to operate while exchanging visits between Canada and the United States. Under the terms of the 1952 reciprocal operating treaty, visitors simply have to identify their stations using their home country call signs followed by a call area suffix (for example, VE3FRV/W9 or N9CFX/VE3). The only other requirement is that sometime during their conversation with another ham, they need to briefly state their geographical location as nearly as possible by city and state (or city and province).

Canadian Hams Visiting the U.S.

Under the terms of the 1952 treaty, Canadian amateurs operating in the U.S. have the same privileges as they do at home, but with some limitations. All operations must be in accordance with FCC Part 97 Rules, and particularly, such operation must not exceed the U.S. band (and sub-band) edges. What's more, all FCC mode restrictions must be followed.

The American Radio Relay League (ARRL) and Radio Amateurs of Canada (RAC) websites are good sources of valuable information to Canadian amateurs visiting the U.S. and vice versa. A color chart (in .pdf format) on the ARRL's website at **www.arrl.org/files/file/Regulatory/Band%20Chart/Band%20Chart%20-%2011X17%20Color.pdf** lists the U.S. band limits available to the various classes of qualification holders in the USA. Likewise, the RAC website offers information for U.S. hams visiting Canada on their website at: **www.rac.ca/operating/canada-united-states-**

reciprocal-operating-agreement/.

Legal Requirements

It is also important to remember that, according to the radio regulations in both of our countries, you must be a citizen of the country that issued your amateur license or certificate to take advantage of this special U.S./Canada reciprocal operating agreement. That is, a Canadian citizen or permanent resident who holds a U.S. call sign cannot legally use their U.S. call sign while in Canada. Under this agreement, they would have to obtain a Canadian certificate and call sign to operate in Canada legally.

Likewise, a U.S. citizen in the U.S. who holds just a Canadian certificate must also obtain a U.S. license to operate legally in the U.S. What's more, if you hold licenses from both countries (as I do) when you are in Canada, you must use the call sign shown on your Canadian certificate. When you are in the U.S., you must use the call sign on your license issued to you by the FCC. Or, to put it another way, the adage of "When in Rome do as the Romans do" applies.

The same rules apply to permanent residents of either country. For example, as a U.S. citizen, if you also become a permanent legal resident of Canada (as I have), you must obtain a Canadian certificate and Canadian call sign to operate in Canada legally. Conversely, Canadian citizens who elect to reside in the U.S. permanently must obtain a U.S. FCC-issued license and call sign.

Now, keeping track of multiple call signs (and where you are transmitting from at the moment) can sometimes get a bit confusing. For example, while riding as a passenger in the family auto the other day, I began a conversation on a local 2 m FM repeater using my U.S. call sign on the U.S. side of the border only to end that same conversation using my Canadian call sign on the Canadian side of the border while I was waiting in line to pass through Canadian Customs!

Impact of COVID

As I write this (mid-December 2021), both Canada and the U.S. have once again opened their land borders to fully vaccinated individuals for so-called "non-essential" cross-border travel. However, each country has placed some additional regulatory requirements on that ravel, with Canada (at the moment at least) placing the greater number of those requirements on that travel.

Briefly, Canada is still requiring U.S. citizens and permanent residents (and returning Canadian citizens and permanent residents who have been absent from the country for 72 hours or more) to comply with their federal regulations to minimize the spread of COVID before entry. This means that anyone wishing to enter Canada by land must be fully vaccinated with a Canadian-approved vaccine against COVID, have received a prescribed negative COVID test within 72 hours of their arrival at the border, as well as registered and completed an online registration form via an online portal expressly set up for that purpose. These requirements must all be completed before one arrives at the border.

Specific information about these Canadian Government requirements and how to complete one's COVID entry documentation are contained in a Government of Canada website at **travel.gc.ca/travel-covid/**. This website is also kept current with all the latest regulatory information and any additional requirements regarding COVID that may be needed in the future.

Currently, the only requirement the U.S. is imposing on Canadians or returning U.S. citizens and permanent residents at their land borders regarding COVID is that they be fully vaccinated with U.S.-prescribed vaccinations against COVID. They are also able to show written proof of those vaccinations if asked.

At the Border

As you prepare to cross the U.S./Canadian border into Canada with your radio equipment, make sure you have your proof of citizenship, a copy of all your required COVID documentation as well as your U.S. or Canadian Amateur Radio License readily available to show the officer at the customs booth if they ask for it.

More often than not, besides your citizenship information, you won't be asked to show anything to do with your radio equipment, as border personnel will most likely be far more interested in viewing your COVID paperwork. I also keep a copy of the U.S./Canadian reciprocal operating treaty with me just in case I'm questioned. Most customs and immigration officials on both sides of the border are well familiar with the reciprocal treaty for our service. I have yet to have any difficulty routinely going back and forth across the U.S./Canadian border with my radios.

In addition, many border agents readily recognize that we hams like to put our call signs on our vehicle's license plates. So, don't be surprised if you are asked what the letters and numbers on your license plate mean. If you are asked, remain calm and simply explain to the border official that you are an amateur radio operator and will be operating under the U.S./Canadian reciprocal operating treaty during your visit. You might also be surprised to find the border agent is also a ham (a lot of them are!) and simply want to welcome a fellow ham to their country.

In addition, and as I said, when entering Canada or (or re-entering the U.S.) U.S. residents will be asked to show some valid proof of citizenship. It's important to remember that birth certificates and simple photo I.D. state driver's licenses are no longer sufficient for U.S. residents to re-enter the USA. That's because U.S. border security has recently been tightened, and you will now have difficulty returning to the U.S. if a birth certificate or a regular driver's license (that is, one without a Radio Frequency Identification (RFID) chip) is the only proof of citizenship you have. Valid proof of your citizenship can be in the form of a passport or a so-called "enhanced" state driver's license (that is, one with an embedded RFID chip).

Participants in a U.S./Canada frequent border crossing program called NEXUS (**www.cbsa-asfc.gc.ca/prog/nexus/menu-eng.html**) can also use that card to cross as well. However, I've found that I've occasionally been asked to produce my passport or Canadian permanent resident card to officials at the border even while using my NEXUS card. The reason for this is that both Canadian and U.S. immigration officials are primarily interested in knowing your citizenship, your reason for travel and how long and where you plan to be visiting as you cross.

It's also a good idea to turn your radio off while speaking with border officials at the customs and immigration booth as you cross. The fewer questions and distractions your behavior generates while speaking with the customs and immigration officials, the better.

Will My Radio Equipment Be Taxed?

In short, your own personal radio gear should pass into and out of Canada both tariff and tax-free. However, if you are bringing either new or used amateur radio equipment of any kind into Canada from the U.S. that will be staying in Canada (such as a gift for a Canadian ham or, if you are a Canadian resident, a new purchase from the states for yourself), you'll need to declare those items to Canadian customs.

That is, while under the terms of the new Canada-United States-Mexico Trade Agreement (CUSMA) between our three countries, amateur radio equipment imported into Canada for your own use (or for someone else) is currently exempt from all tariffs.

However, those items are still subject to provincial and Canadian national sales tax if the equipment stays in Canada after you leave. So, after you have declared those items you are leaving behind to a Canadian Customs agent at the border, you will most likely then be asked to state the value of such items and, depending on what they are worth, you may be required to pay Canadian sales tax on the item.

What About Other Electronics?

While the use of unlicensed short wave receivers, Family Radio Service transceivers and "cellular blocked" scanners are legal in Canada, the use of radar detectors in most Canadian provinces is strictly prohibited.

What's more, firearms and weapons are also strictly controlled in Canada. If you have firearms or weapons with you, they absolutely must be declared as you cross. Unfortunately, it's sometimes very easy for many Americans to forget that they also keep a firearm tucked away in their vehicle's glove box or trunk. Then, when Canadian border personnel randomly select them for further inspection, they are shocked to find they face stiff fines (or even jail time!) for attempting to (albeit inadvertently) bring an undeclared firearm into Canada. So, unless you are on a Canadian hunting trip, it's best to make sure you locate, remove and then leave all such items at home.

While the use of scanning radio receivers is generally permitted, vehicle radar detectors are strictly prohibited in most Canadian provinces. Check local laws before you go, just to be sure. (KB1SF, photo.)

And while the use of mobile GPS units (if they are firmly attached to the vehicle) is allowed in Canada, adjusting one while you are driving may invite a traffic fine for "distracted driving." Therefore, it's also best to leave the "GPS navigator" duties to one of your passengers.

In addition, and as I noted earlier, some provinces in Canada have now enacted stringent motor vehicle laws that expressly prohibit "non-hands-free" electronic devices from being used while driving. While these laws aim to curb cell phone usage and texting while operating a motor vehicle, some provinces have not (yet) entirely exempted amateur radio operation from such laws. In addition, while some provinces (like Ontario) have given their own hams a limited exemption to go "hands-free," unfortunately, they have not (yet) afforded visiting U.S. hams the same courtesy.

This means that simply listening to your ham radio, scanner or cell phone while in a motor vehicle in most Canadian provinces is perfectly legal. However, in many provinces, if you are also the driver of the vehicle, it's a good idea to pull over to the side of the road and come to a complete stop if you also want to make a transmission using your ham radio or cell phone. Besides avoiding a stiff traffic fine (upwards of CDN $500), this action just makes good sense from a safety standpoint. The bottom line here is that it's best to check with the Ministry of Transport of the individual Canadian province(s) you intend to visit on your trip to ascertain the legality of amateur radio operation and cell phone use while operating a moving vehicle.

Wrap up

So, after this brief introduction, you no longer have any excuse for leaving your ham radio at home if you travel across the U.S./Canadian border. Just remember these simple "rules of the road" for COVID vaccination requirements as well as reciprocal ham radio operation in our two countries, and you'll be fine. If you're a U.S. ham, you'll also find most Canadian hams are a friendly and accommodating bunch that will welcome you with open arms on one of their many repeater systems north of the border while you are on your way to activate that "rare" Canadian grid on our satellites.

Using High Altitude Balloons in Science, Technology, Engineering and Mathematics Education

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Abstract: High Altitude Balloons (HAB) have been used by high school and college educators for many years to teach Science, Technology, Engineering, and Mathematics (STEM) topics to students by launching payloads carrying a wide variety of sensors. These payloads often use amateur radio to transmit data from the payload to the ground and, in some cases, to send control data to the payload. In addition, it is common to use Automatic Packet Reporting System (APRS) for real-time balloon tracking as one component of a payload. Other common payload sensors include temperature sensors mounted inside the payload to measure various subsystems, as well as externally, to measure temperature changes with altitude. This article will cover various aspects of designing, planning, and executing a HAB launch based on our experiences with high school and university students.

What is HAB?

In general, High Altitude Balloons (HABs) can be defined as a method used to carry scientific payloads into the Earth's upper atmosphere for research and Science, Technology, Engineering, and Mathematics (STEM) education. HABs can reach altitudes as high as 40,000 m or about 130,000 ft., considered by some as "near space." The balloons are typically latex and can range from 200 grams to 3000 grams, with the larger balloons capable of carrying larger payloads to higher altitudes.

A recent article in the July/August 2021 *AMSAT Journal* by Bill Brown, WB8ELK, entitled "Amateur Radio High Altitude Ballooning," provides a great summary of HAB and pico balloons with amateur radio payloads.

STEM Payloads

STEM payloads range from simple to very complex. An example of a simple payload may be just an APRS tracker so that students can observe the balloon's altitude and flight path in real-time. Very complex payloads carry an array of science experiments using multiple sensors or sensor packages coupled with dedicated amateur radio transmitters to return the data in real-time via custom-built ground station receivers. In addition, most payloads record data from the sensors on board to be retrieved and analyzed after the flight and when ground chase teams recover the payload.

Many payloads include still or video cameras that record images during the balloon flight. Cameras and the pictures returned from the flight, both post-flight and in real-time, excite and invigorate students and the public. Students are highly motivated to receive and view photos in real-time during the flight. It is common to use Automatic Packet Reporting System (APRS) for real-time balloon tracking as one component of a payload. Other common payload sensors include temperature sensors mounted inside the payload to measure various subsystems, as well as externally, to measure temperature changes with altitude. For example, see Figure 1 for details on how pressure and temperature vary with altitude in the atmosphere.

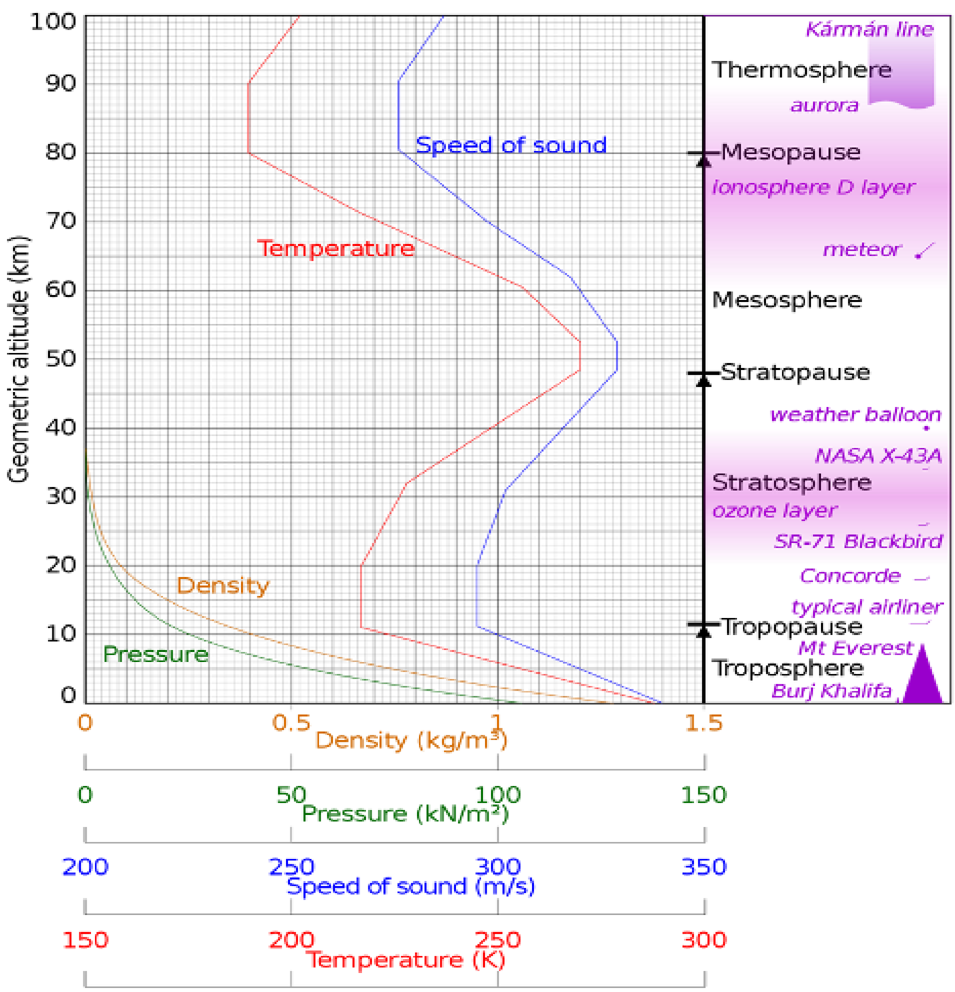

Figure 1 — Variation of Atmospheric Temperature and Pressure with Altitude. Source: Wikipedia https://en.wikipedia.org/wiki/File:Comparison_US_standard_atmosphere_1962.svg.

Today there is a large selection of commercial off-the-shelf (COTS) sensors that can be flown on HABs. These include inertial measurement units (IMU), pressure, humidity and temperature combination sensors, radiation sensors, visible light, UV, and IR imaging sensors (including video and still image cameras), voltage and current sensors to monitor the health of payload batteries and power systems, and magnetometers. A Peltier cell can be used to evaluate the differential temperature between the outside and inside of the payload enclosure. Vacuum and various gas sensors can be included to determine how the atmospheric composition changes with altitude. Some student payloads have included Geiger counters to evaluate radiation changes with altitude.

Amateur Radio and HAB STEM Education

How can ham radio be used in STEM education? From its inception, ham radio has been about experimentation, learning, and advances in electronics and the radio arts. This makes the goals of STEM education and amateur radio a perfect fit. Many articles and information about the synergies between amateur radio and STEM education are available. A few links are included here for readers wanting more information, and the reader is encouraged to use these as a starting point for additional research:

- amsat-uk.org/tag/stem/
- ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=7423878
- www.omagdigital.com/publication/?i=294969&article_id=2431546&view=articleBrowser&ver=html5
- blog.discoveryeducation.com/blog/2017/01/01/worldintoyourclassroom/
- www.nasa.gov/mission_pages/station/research/news/b4h-3rd/ge-inspiring-youth-with-space-science.

Some fundamental ham radio teaching opportunities include lessons around RF transmitters used in balloon payloads, ranging from simple APRS trackers that can be a student construction project, such as a Trackuino (https://github.com/trackuino/trackuino), to COTS ready-made items like the WiMo PicoAPRS-Lite APRS Transceiver Module. An advantage of flying an APRS equipped payload is that an existing network of APRS i-gates form a ready-made ground station network in many parts of the world.

More complex payloads may include LoRa

(Long Range) RF modules that transmit data from multiple sensor packages. These types of flight-specific payloads likely will require their own custom receivers (ground stations) to receive and decode the payload data. Some of us have begun experimenting with using LoRa boards such as AmbaSat-1 **ambasat.com** and using a network of LoRa stations such as The Things Network (TTN) www.thethingsnetwork.org and TinyGS tinygs.com.

Flying balloon payloads with multiple RF transmitters using a variety of modulation types and data encoding and decoding is an opportunity to give hands-on learning about how RF signals are encoded and decoded. This can also include lesson plans around error correction techniques.

A discussion around transmitters would not be complete without a lesson that provides some fundamental antenna basics. This topic can be wide-ranging but might include a discussion on antenna types appropriate for balloon flights such as wire and J-poles. Building directional antennas for tracking and payload recovery can also be a great STEM activity. Many plans are available on the internet, including this step-by-step set www.instructables.com/The-Tape-Measure-Antenna/.

HAB and CubeSats

HAB flights can be a completely stand-alone activity, but they can also be a way of introducing students to building and launching spacecraft, specifically educational-focused CubeSats. CubeSats are nanosatellites built to a standard to keep construction and launch costs to a minimum. See cubesat.org for the latest CubeSat Design Specification document. With the similarities in designing, planning, and executing a HAB flight and a CubeSat flight, a HAB flight can be a great early activity for a team planning a space mission.

The AMSAT CubeSatSim helps bridge the gap between HABs and CubeSats, shown in Figure 2. The CubeSatSim is a low-cost, functional educational model of a CubeSat that can be built with a few hundred dollars in a few weeks. Students can learn soldering, 3D printing, Raspberry Pi, and testing skills. In addition, receiving and decoding telemetry in the classroom can be useful training for either a HAB or CubeSat mission. Full details are available at CubeSatSim.org and open-source instructions and code at CubeSatSim.org/wiki.

The CubeSatSim also has a STEM Payload board with several sensors, which could be useful for a HAB or CubeSat mission, shown in Figure 3. The board uses a Sparkfun Pro Micro or the STM32 "blue pill" microcontroller, which can be programmed with the Arduino IDE for simplicity. While it is not optimized for a HAB flight, the CubeSatSim STEM Payload board has been flown on a HAB mission.

Figure 2 — AMSAT CubeSatSim, the CubeSat Simulator.

Examples of HAB Flights

The following YouTube video link shows the highlights of one of Mt. Carmel High School's HAB balloon flights (www.youtube.com/watch?v=FidFKb4bj1Y). It details some of the data collected by the payload and some post-flight data processing done by the students.

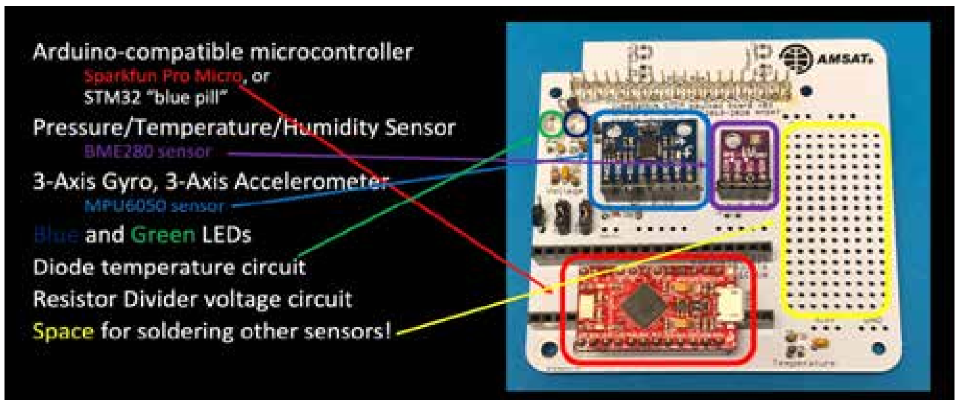

Figure 3 — AMSAT CubeSatSim STEM Payload Board showing microcontroller and sensors.

Figure 4 — Almost ready to launch Mt. Carmel High School HAB, June 2021.

Figure 5 — Photo taken from the Mt. Carmel High School balloon payload looking southwest towards the Pacific Ocean, June 2021.

Figure 6 — Recovered payload in a remote area of Anza Borrego Desert State Park, June 2021.

Photos 7 & 8 from a HAB flight by the Villanova University CubeSat Club:

Figure 7 — Villanova University CubeSat Club 200 gram size HAB just before launch showing the parachute, radar reflector, and foam board payload holder. Photo from www1.villanova.edu/villanova/engineering/newsevents/newsarchives/2021/community/CubeSAT-Balloons.html.

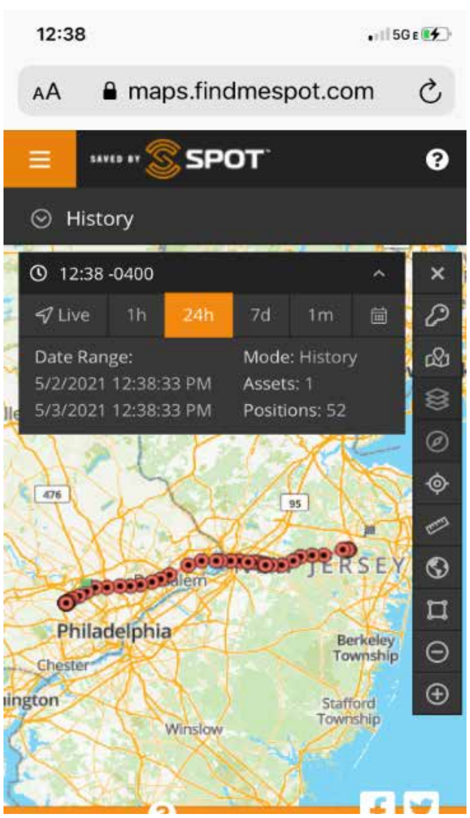

Figure 8 — A GPS track for a HAB flight by the Villanova University CubeSat Club.

Figure 9 — Balloon launch setup in Cambridge, England.

Figures 9-11 are examples of flights conducted in England using the Raspberry Pi and Microbit boards:

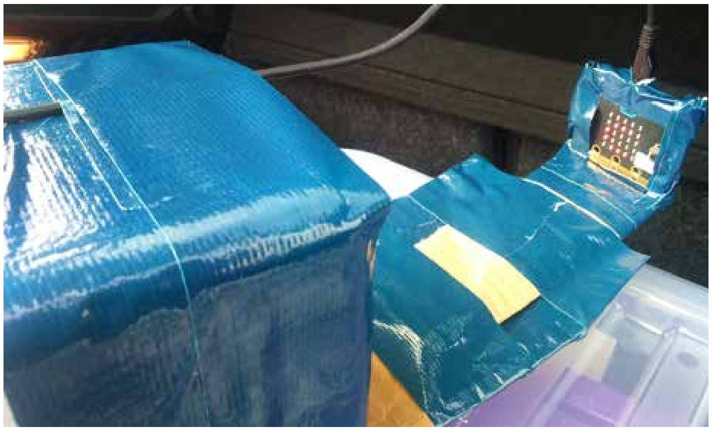

Figure 10 — Microbit board mounted on an extension of the payload box used to gather data on acceleration and saved to the Raspberry Pi inside the payload box.

Figure 11 — Students from St. John Henry Newman School in Stevenage mounted sensors on the outside of the box to gather data on UV, temperature, pressure, and a camera took photos with data saved to the Raspberry Pi.

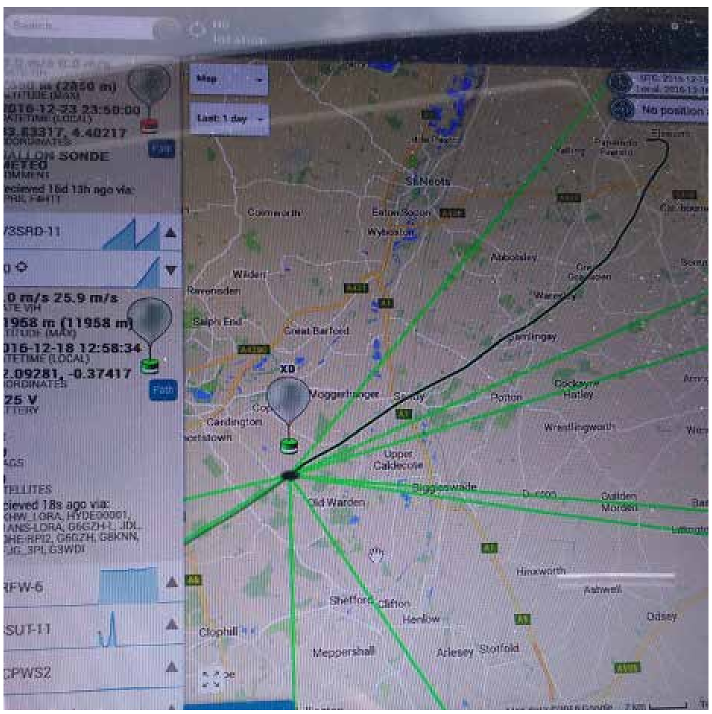

Figure 12 — Live tracking on HABhub.org to follow balloon launching and landing.

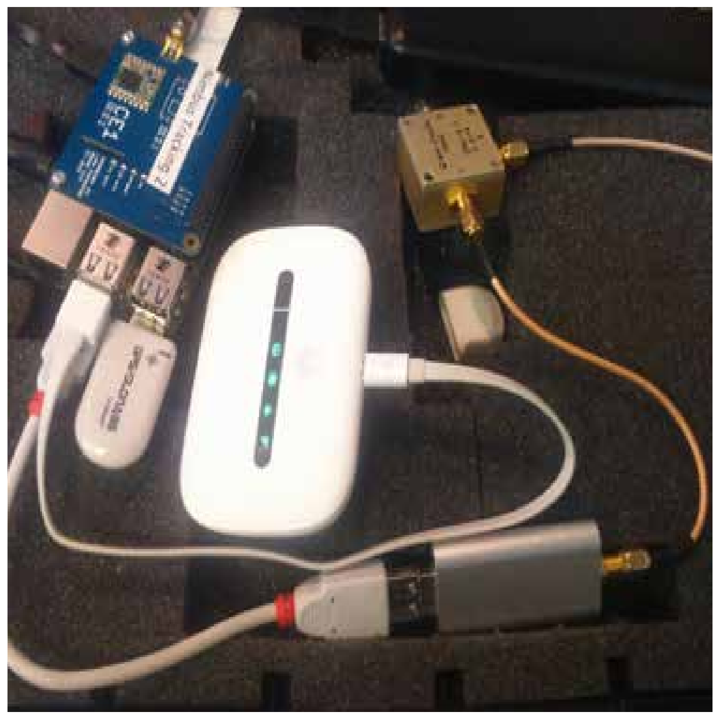

Figure 13 — Raspberry Pi kit used for receiving the signal using a LoRa board. Data and photos were streamed back through the internet.

STEM Learning Opportunities

Educators' STEM teaching opportunities are limited only by the imagination of students, teachers and mentors. Some common STEM topics include:

- Introduction to weather balloons and near space
- Ideal gas law
- Basic electronics, including circuits, circuit design
- Basic electronic hardware components such as sensors, microprocessors, transistors, resistors, and capacitors
- Learning how to solder and use essential hand tools
- Learning how to use basic test equipment
- Atmospheric composition and changes with altitude, general atmosphere and weather concepts
- Experiments on the impact of Near Space atmosphere on various foods and plant life.
- Using various sensors to gather data on temperature, pressure, UV levels, etc.
- Near space vacuum
- Microprocessor programming and elements of software design. Introduction to software code
- Working in teams
- Working with data sets and post-processing of the data collected from the payload. Graphing and data interpretation
- The electromagnetic spectrum, which can include lessons in visible, IR, and UV light as well as components of the

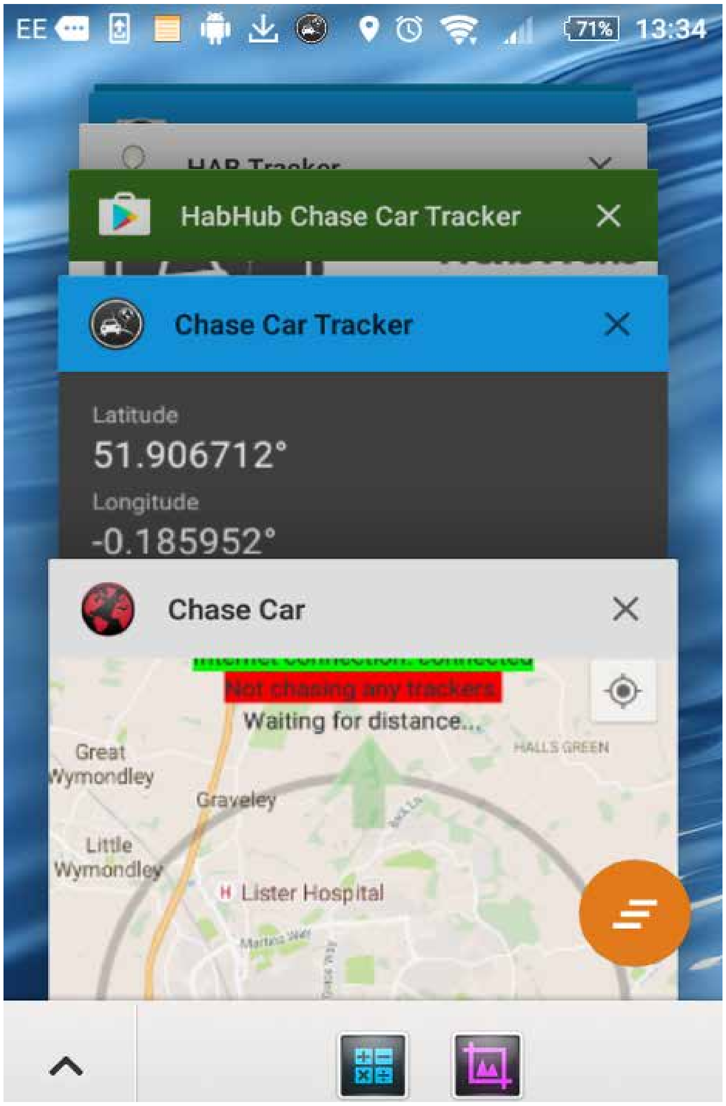

Figure 14 — Various "chase car tracker" mobile apps are available.

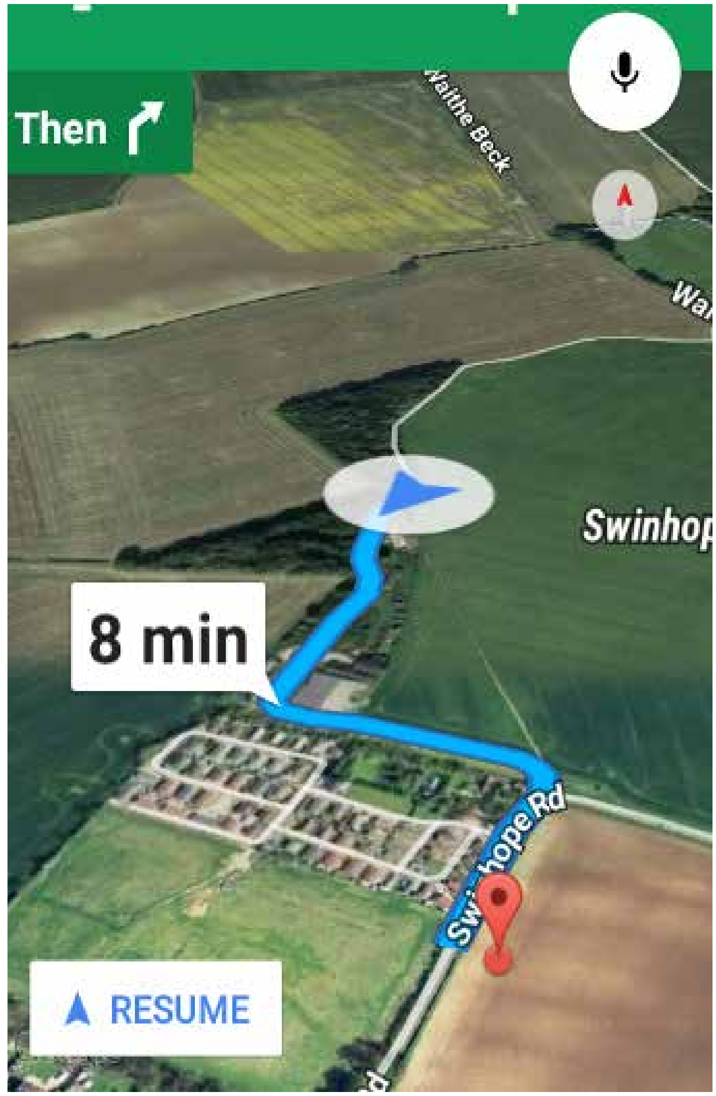

Figure 15 — Payload retrieval using GPS tracker coordinates of the location of the landing. Google Maps was then used to travel to the landing site to pick up the payload.

Figure 16 — A payload using Raspberry Pi boards, micro:bit sensors, cameras and powered by mobile charging batteries and AAA lithium batteries.

Figure 17 — Image from NearSpace from a Raspberry Pi NoIR (No InfraRed filter) Camera.

radio frequency spectrum
- Introduction to amateur radio, including possible amateur license classes
- Antenna design and selection for the payload and ground stations
- Basics of radio transmitters, data encoding and decoding, antennas and radio receivers (elements of ground stations)
- GPS receivers and received APRS position reports. How does GPS work? APRS can be used to discuss the use of maps, tracking, and location.
- Photos taken at altitude can be used to discuss aerial photography and how to determine the actual size of objects seen in the photos.
- FAA flight rules and NOTAM
- Engineering principles including preplanning, what sensors will be included in the payload, what is practical to fly and what is not, basic design and trade-offs, documentation (project notebook), presentations, and post-flight lessons learned (likely failure analysis).
- Opportunities to discuss electrical engineering concepts are plentiful. Some electrical engineering concepts include batteries, battery selection, and power system requirements for the payload. Payload sensors and circuit design concepts.
- Mechanical engineering concepts around payload enclosures, thermal properties of various components, thermal requirements and design concepts
- 3D printing
- Safety in the lab and the field during launch and recovery operations.

Lessons Learned

We have learned some practical lessons in performing HAB flights with students, which might be helpful for your own STEM outreach activities.

Use chemical hand warmers instead of oxygen-activated hand warmers in thermal production designs. Discuss why oxygen-activated hand warmers don't work well at altitude.

Confirm that payload and ground stations antenna(s) have the same polarity (for example, don't have payload antenna horizontally polarized and all of the ground station antennas vertically polarized).

Conduct at least one preflight dry run, so students know what to expect on flight day and make sure the flight day go box contains all of the tools and supplies needed on flight day. What spare tools and parts should be included in the go box? How are the experiments powered up? Is there a power-up sequence that must be followed for the entire payload to function correctly? How does the team confirm the experiments are working properly? Are the ground stations receiving and posting the correct data from the experiments? What issues were encountered during the dry run, and how will the procedures and checklists be updated before launch day?

Review launch and recovery safety requirements and confirm the entire team has a solid understanding of the safety expectations. For example, are all team members' contact information correct in the event of an emergency? Does the team know and understand the notification tree in the event of an emergency and for the night before launch go/no go communication? Do the recovery team members know and understand the expected weather conditions in the landing zone?

Calculate and double-check the amount of gas required for the flight and confirm the proper volume of gas with some margin for error is on hand for the day of flight.

For preflight, confirm that students have reviewed FAA requirements, know and understand the NOTAM notification process. Do they have the proper FAA phone numbers and email addresses and all information required by the FAA to file the NOTAM? Every location has distinct notification requirements, so interpret any blog or article as one example, not the definitive process you will need to go through. Reach out to your local officials weeks rather than days ahead of your launch. Do designated chase teams know how to communicate with other chase teams? If using amateur radio, what repeater and simplex frequencies will be used? Do chase teams have portable ground station equipment to decode the payload downlinked data and utilize the decoded data to recover the payload?

Will students use social media to alert the school and public of the upcoming flight? How will real-time flight data be communicated to the student body and general public? Does the communication team have all of the relevant information, such as payload APRS call signs, expected launch date and times, expected flight path, and radio frequencies, so that they can publish the information before and during the flight?

Who has been assigned to document the balloon launch and possibly the payload recovery? Make sure there are plenty of still and video pictures of the launch. If possible, photograph the payload landing site as the first step in payload recovery (before disturbing the payload).

Flight day checklist is critical to a successful balloon launch and flight. Preplanning by making a flight day checklist and following it on the day of the flight increases the chance that the payload experiments will operate. Which payload experiments require calibration just before flight, and has the calibration checklist been prepared, practiced, and then followed on launch day? Have the flight path and landing predictions changed just before the fight? Have these changes been communicated with the chase teams?

We had flights where an experiment was not turned on properly and confirmed it was functioning before the release of the balloon, which caused no data to be collected from that experiment. Checklists will ensure all rechargeable batteries have been charged adequately before flight and all data logging devices that use an SD card have preflight test data erased. Knowing the mass of the entire balloon flight stack is critical to knowing how much counterweight should be used to confirm proper balloon inflation. Ground stations are properly activated and connected to the internet when required. GPS tracking redundancy can be key to payload recovery. Typically, the High School ARC's payload includes an APRS transmitter and a commercial SPOT Trace GPS tracker. This tracker requires a service fee, but there are options to activate and deactivate service, helpful in saving expenses during the off-season.

Conclusions

In this paper, we have discussed the use of High Altitude Balloons for STEM education. We believe they are a great tool to generate interest and excitement with students. We have discussed the use of sensors and cameras to gather data for analysis, as well as amateur radio trackers and transmitters for relaying that data. Finally, we have shared lessons learned over many flights and projects with students. We would love to hear about your own HAB flights and experiences, so feel free to reach out to us via email or social media.

Cajun Advanced Picosatellite Experiment

Nick Pugh, K5QXJ
k5qxj@amsat.org

Abstract: This paper will give a brief history of the satellite team at the University of Louisiana and its future plans. The series of satellites launched at UL is called Cajun Advanced Satellite Experiment ("CAPE"). The first satellite was launched in 2007 in Russia, followed by CAPE II, launched in 2013, and CAPE III, launched in 2020. Cape I is still in orbit but brain dead, Cape II deorbited in 2014, and CAPE III is still partially functioning. This paper will focus on our next mission, CAPE IV. The mission of the CAPE team is to provide students the opportunity to design, build, and operate devices in very harsh environments. CAPE IV will be a 3U and launch six smaller satellites, called T Sats, built by middle and high school students.

The Mother Ship

This is a 3U space frame to be equipped with a UHF and a VHF LoRa radio. (See Figure 1.) The mother ship will eject six smaller satellites built by middle and high schools. Also included on the mother ship will be an experimental 40% efficient solar cell, a radiation experiment, and a magnetic material experiment. The frame will have a backplane arrangement to allow easy access to replacing the PCB without disassembling the whole satellite. The antennas will be constrained with burn wires attached on the outside of the frame enabling resetting with our disassembly.

Mother Ship 3-D Prototype

The Radios:

The satellite will have two radios. The first radio is a tech demonstrator designed to have a system gain to allow omni antennas of the spacecraft to close the link to lunar orbit. This will enable spacecraft communications to a tumbling satellite in lunar orbit a back door low-speed channel to rescue missions that lose attitude lock.

Specifications:

1. Frequency: 145 MHz
2. Sensitivity: – 148 dBm
3. Rf power: 37 dBm
4. DC power input: 16 watts @ 8 volts DC
5. Modulation: chirped spread spectrum
6. Data rate: 18 bps to 100 kbps adaptive

The second radio is the rescue radio. This radio is designed to remain operational if all systems fail on the satellite. It is designed with a small separate microcontroller with a small battery backup. The microcontroller employs a GPIO to reset the main microcontroller and independent UART and I2C busses. The radio and microcontroller are put in sleep mode over 90% of the time to lower power consumption.

Specifications:

1. Frequency: 437 MHz
2. Sensitivity: - 148 dBm
3. RF power: 17 dBm
4. Power consumption: <2 microwatts sleeping, 33 milliwatts receiving, 330 milliwatts transmitting
5. Modulation: chirped spread spectrum
6. Data rate: 18 bps to 100 kbps adaptive

The Radiation Experiment

A Secondary Payload (Scientific Experiment), i.e., the E-ARMOR – Enhanced, Astronaut-Wearable Radiation Meter for Operation in Potential Radiation Environments – will mature and demonstrate a credit-card sized, astronaut-wearable radiation dosimeter intended to automatically apprise astronauts as to their radiation exposure so that they may protect themselves in a timely manner. Detection of gamma-rays is vital to deep space habitation and deep space CubeSat experimentation as it is an indicator of dangerous and damaging secondary radiation exposure. The E-ARMOR experiment seeks to: (a) Measure the orbital time/position dependent proton fluence, (b) Estimate the energy dependence of the proton fluence, (c) Estimate the effect of orbital electron fluence on the degradation of luminescence, (d) Measure the surface temperature of the europium tetrakis (EuD4TEA) and polymethyl methacrylate (PMMA) sample using phosphor thermometry, and (e) Modify simple cell phone cameras to measure gamma-rays. Complementary Metal Oxide Semiconductor (CMOS) image sensors on common cell phones are known for their sensitivity to gamma-rays. Extending this concept by forming a constellation of modified cell phone radiation detectors could provide information on the gamma-ray fluence over a larger area than just the original CAPE-4 spacecraft. Developing multiple detectors for the CAPE-4 mission will be a challenge, requiring collaboration between engineering, computer science, and physics students.

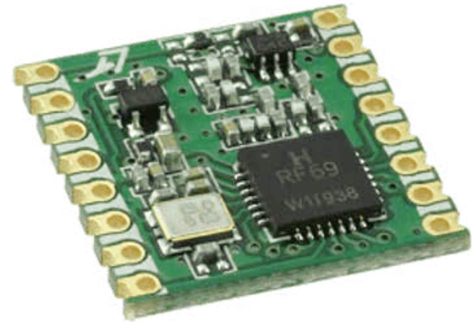

Figure 2 — LoRa Radio.

T-SAT

This mission will eject six small satellites designed and built by middle and high schools in our area. The CAPE team will provide the bus, including the antenna, LoRa radio, the main microcontroller, solar panels, battery, and peak power tracker. The high schools will design and build experimental payloads. The schools will construct their own ground station. This ground station will allow almost horizon to horizon communication to their satellite. There will be seven satellites with inline of sight for several months; they will be able to use mesh techniques to extend the time they will communicate to their satellite. To gain the knowledge to design and build satellites, they will start by flying high altitude balloons, ~ 2 balloons a year until launch. They will be

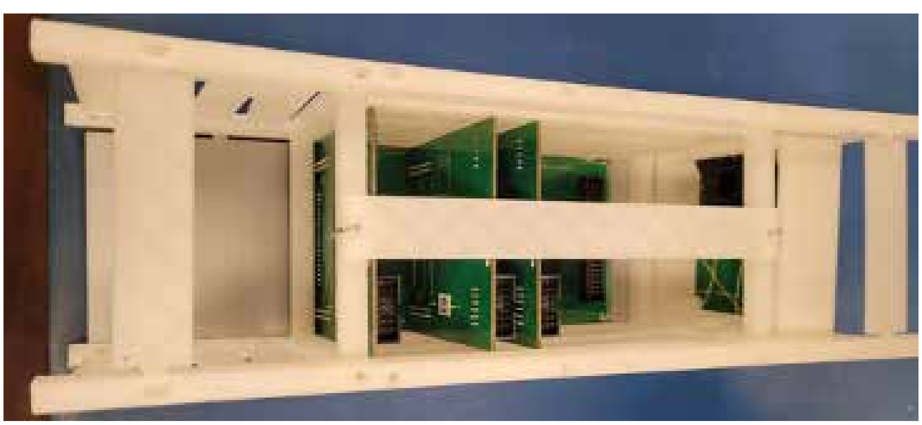

Figure 1.

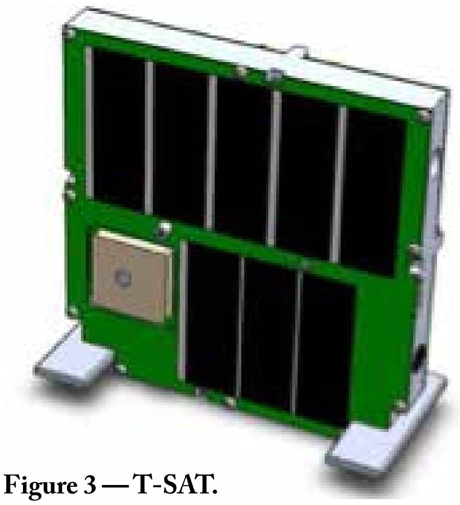

Figure 3 — T-SAT.

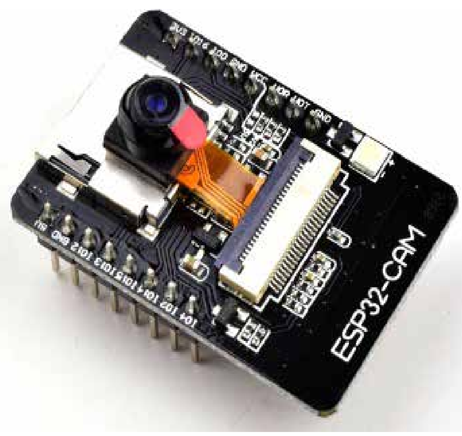

Figure 4 — $10 camera.

Figure 5 — 9-Axis IMU.

Figure 6 — Temperature & Humidity sensor.

increasing the complexity of their design on their balloon missions. Below are images of possible sensors the high schoolers may use in designing their satellites.

The Balloon Training for Middle and High School Students

In this program to train young students to learn the skills needed, the UL team will mentor six schools in the area to fly high altitude balloons. It is anticipated they will fly at least one balloon a year until we get a launch to LEO. The UL team will produce a starter kit including a Seeedunio, LoRa radio and a ground station. The schools will have two-way communication to the balloon for most of the flight. In addition, these teams will be responsible for tracking and recovering their balloon.

Antenna Range

The CAPE team is progressing on the construction of an antenna test range. This will be able to measure antenna patterns and receiver sensitivities. The antenna range will allow the team to perform day-in-the-life tests required by NASA under a simulated on-orbit environment. One of the suspected failures on previous missions was to measure EMI radiation coming from the electronics in the satellite. The university will make this range available for other universities to come and test their satellites. The devices under test will be placed in a weather resistance enclosure to test the solar panels and their associated sensors exposed to the sun.

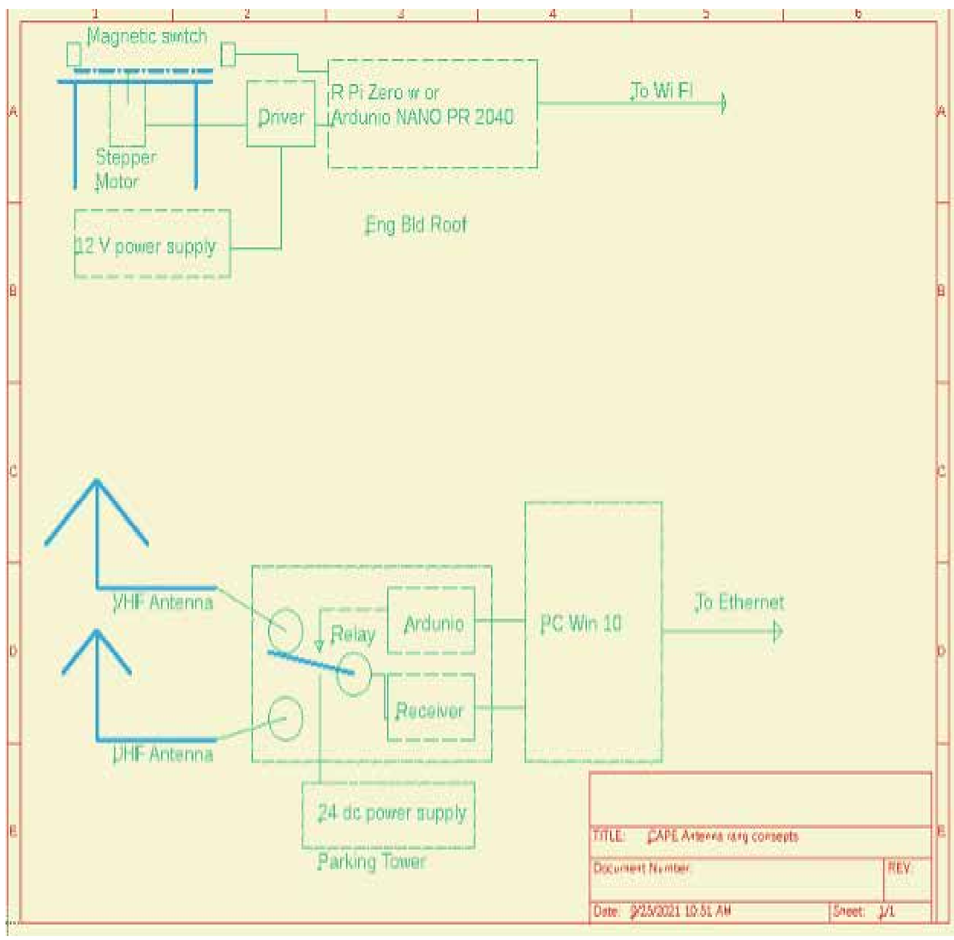

Figure 7 — Block diagram of the instruments on the antenna test range.

Cheap Antennas for the AMSAT LEO's

Kent Britain, WA5VJB

Hand-held dual-band antennas are popular for QSOs through many of the low Earth orbit (LEO) satellites. This article covers several 145 MHz antennas, a greater number of 435 MHz antennas, and how to combine them into one antenna.

If you've got a STRONG arm or plan to use it with a tripod, then by all means, the 4-element 145 MHz and the 8-element 435 MHz can be used together. Or there are the 2-element 145 and 5-element 435 MHz used in the AMSAT demonstrations. It's only 32 inches long. Something much lighter for backpacking? How about using a 20-inch long 2-element on 145 MHz and a 3-element on 435 MHz. For the Arrow antenna enthusiasts, this smaller 2-element on 145 MHz and 3-element on 435 MHz will perform about the same as the Arrow antenna if you are using the SMT band splitter.

One popular commercial antenna mounts the elements 90 degrees to each other. This is a mechanical, not really an electrical, decision. On this antenna, the elements can be mounted crossways, but mounting them flat makes the antenna much easier to lay down in the back of the truck or store in the garage.

Construction:
For the boom, 5/8" x 5/8" or ¾" x ¾" wood works well. However, if you plan to mount the antenna outside for the long term, a coat of spar varnish, spray enamel, or some of that waterproofing stuff you use on wood decks will add years to the life of the antenna.

For the elements, I used 1/8" material. The 435 MHz reflector and directors were from a roll of Radio Shack aluminum ground rod wire (RS stock number 15-035). Forty feet will run you about five bucks and make a lot of antenna elements. But #10 bare copper wire, bronze welding rod, and hobby tubing have all been used. If you want to use 3/16" diameter elements, cut them 0.2" shorter than the dimensions in the tables to compensate for the thicker material. The 2-meter elements were all made from bronze or brass welding rods. I like to use something I can solder the coax to and the welding rod solders well.

Figure 1 — Cheap LEO antenna.

Figure 2 — Drew, KO4MA, using the Cheap LEO antenna during a Dayton AMSAT LEO demonstration.

Figure 3 — Element splice.

Figure 4 — The 145/435 MHz band splitter.

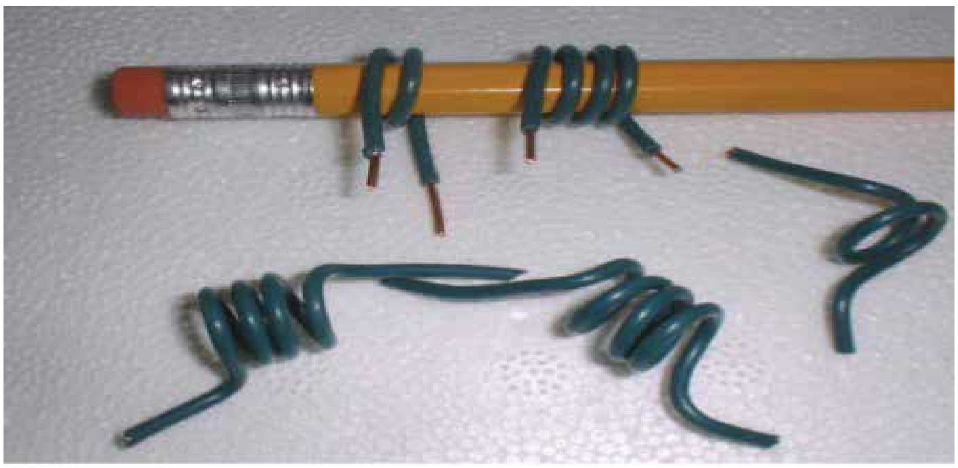

Figure 5 — Winding the band splitter coils.

The welding rod is only 36" long. A section of 1/8" i.d. copper or nrass hobby tubing makes a good splice. Just slip it on and solder them together. Save some of that hobby tubing. If you have a habit of "I trimmed the antenna twice, and it's still too short!" then you can solder a piece on the end of the driven element and start over.

I usually hold the elements in place on the boom with a drop of super glue. But Silicon glue and even paint have been used.

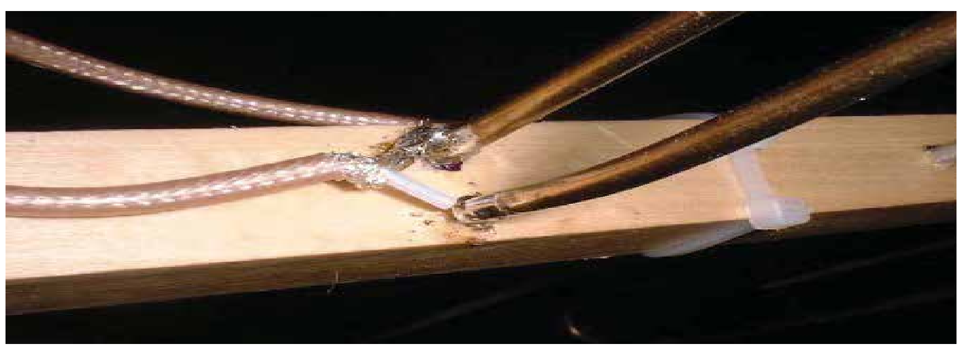

Figure 6 — Close-up of driven element.

Splitter:
The band splitter is just a 250 MHz high pass filter and a 250 MHz low pass filter connected. This doesn't have to be very complex or even very accurate. As long as the filters cut off somewhere between 200 and 400 MHz, they will work fine. So if the coils get squished, bend them kind of back in shape, and go for it. This one is built cheap, just out in the air on a piece of PC board. You can build the splitter into a box if you like, with connectors and all, but it's not going to change their performance. And this band splitter even makes a good project if you want to use two other 145/435 MHz antennas.

Remember, we are not trying to filter off harmonics, just make the 2-meter energy go to the 2-meter antenna, and the 435 MHz signals go to the 435 MHz antenna.

You're too late; I have already been asked if it needs to be a #2 or a #3 pencil. For the record, I wound my coils on a red grading pencil. For those of you with a more mature sense of humor, just about all wood pencils make a 0.3" coil form.

We are frequency spitting the signals, not power dividing, so the length of the coax between the splitter and the antenna is not critical. You want to keep the coax as short a practical, but its exact length is not important. Got a box of 4.7 pF's? You can use 2 of them instead of the 10 pF. Be sure to keep those leads very short. I used Teflon coax on my splitter; it solders so much easier than foam RG-58. You're free to build it in a box and use connectors if you like, but it's not really necessary.

Power Handling
Power handling of this band splitter depends almost entirely on your caps. With 50 V, 20 W is about your limit. Dig up some 1 kV caps, and the coax will probably melt first as you warm up that 4CX250.

One of my first prototypes tried to use the last 2-meter director as the 435 MHz reflector. While an interesting idea to save weight and make the antenna shorter, performance suffered too much. So all versions now have a reflector on the 435 MHz portion. The

Parts list.

Antenna Version	Capacitors	Coils	Wire & Turns
435 MHz High Pass	2 x 4.7 pF Caps	1 Coil	1-1/2 turns #18 or #20 wire on a Pencil
145 MHz Low Pass	1 x 10 pF Cap	2 Coils	3 turns #18 or #20 wire on a Pencil

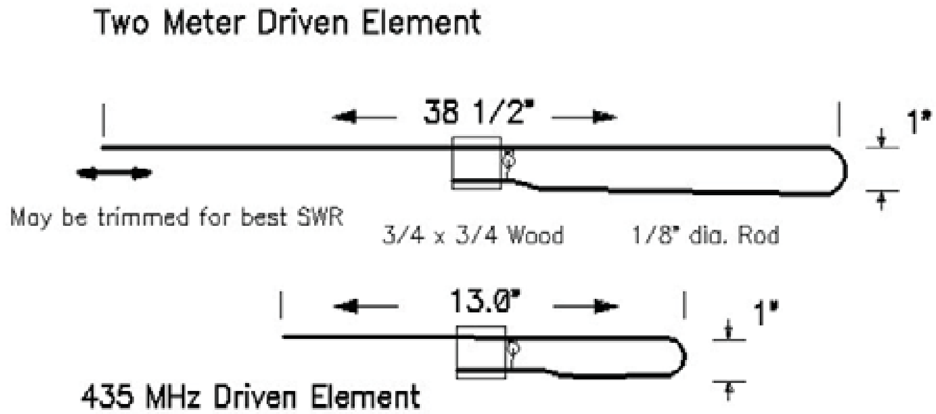

Figure 7 — Dimensions of the driven element.

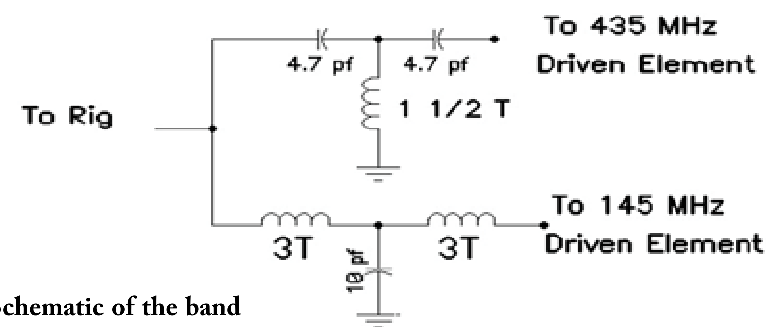

Figure 8 — Schematic of the band splitter.

	Ref	DE	D1	D2
2 element				
Length	40.5	**		
Spacing	0.0	7.0		
3 element				
Length	40.5	**	36.5	
Spacing	0.0	8.5	19.75	
4 element				
Length	40.5	**	37.0	32.5
Spacing	0.0	8.5	19.0	40.0

	Ref	DE	D1	D2	D3	D4	D5	D6
3 element								
Length	13.5	**	12.2					
Spacing	0.0	2.5	5.5					
4 element								
Length	13.5	**	12.4	11.5				
Spacing	0.0	2.5	5.5	11.5				
5 element								
Length	13.5	**	12.5	12.25	11.75			
Spacing	0.0	2.5	5.25	12.0	18.5			
6 element								
Length	13.4	**	12.4	12.0	12.0	11.0		
Spacing	0.0	2.5	5.5	11.25	17.5	24.0		
8 element								
Length	13.4	**	12.4	12.0	12.0	12.0	12.0	11.1
Spacing	0.0	2.5	5.5	11.25	17.5	24.0	30.5	37.75

** Driven element Dimensions from Figure 7.
Ref is the reflector, DE is the driven element, and all spacings are measured from the reflector element. All dimensions are in inches.

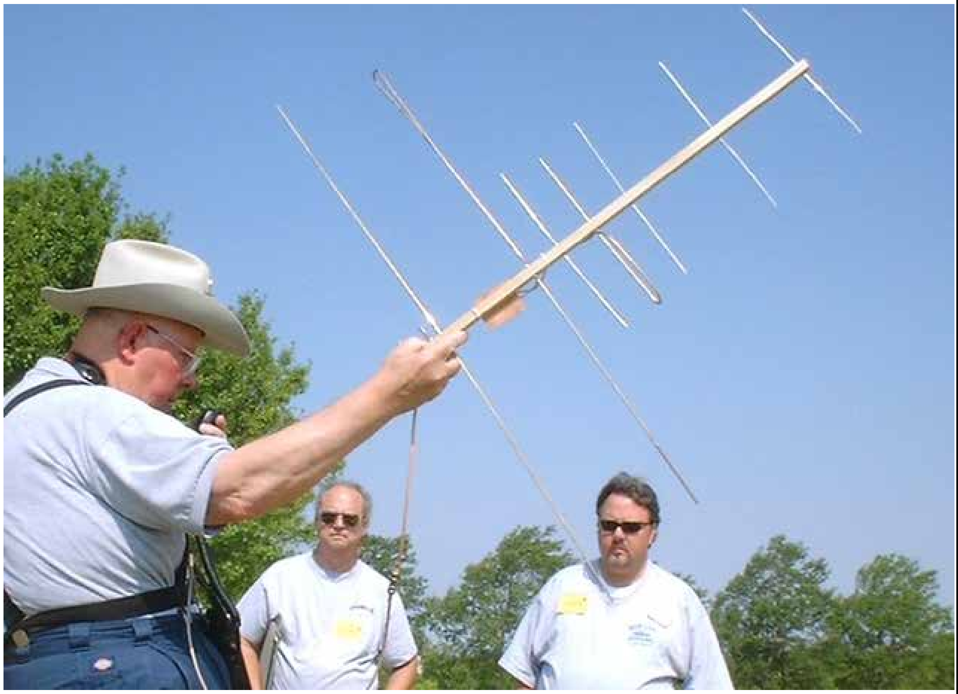

Figure 9 — Keith, W5IU testing the cheap antenna.

last 145 MHz director and the 435 MHz reflector will interact. If you plan to mount them in the same plane, I find it's easiest to space them three inches apart. These J driven elements usually bring several comments from people new to "Cheap Yagi's."

The coax shield goes near the center of the top of the element. This is a voltage null, and directly soldering the coax to the driven element has a lot of advantages.

The tip of the coax goes to the tip of the J. So you can think of this driven element as 3/4 of a folded dipole or a gamma-match with no capacitor. In free space, the J driven element has about a 150 Ohm impedance. As other elements are added, they load down the impedance of the driven element. If the antenna has relatively wide element spacing, a direct match to 75 Ohms is possible. Bring in the reflector and directors a little closer, and then you have a direct match to 50 Ohms. So the impedance matching is the length and spacing of the other elements. Just build the antenna to the dimensions, solder on the coax, and start talking. No tuning is required.

Tuning it up:
For the ultimate in performance, connect a coax to just the 2-meter portion and trim the free end of the J for the best SWR for your favorite LEO uplink frequency. Then connect the coax to just the 435 MHz portion and again trim the free end of the element for best SWR. Now install the band splitter and, this time, tweak the coil spacing for best SWR at your spot frequencies. You have now gotten the last 0.1 dB out of the antenna.

For everyone else, just build the antenna to the dimensions, and the SWR will be under 2 to 1 on both frequencies. Just build it and talk. The design is pretty idiot-resistant.

This antenna can be built in 30 combinations of elements and polarizations. One should fit your need. The 2 elements on 145 MHz and 5 elements on the 435 MHz version have done great in the field tests. Now you can have fun with the LEOs for less than $10.

For even longer versions of AMSAT Cheap Yagis and even L-band versions, visit **wa5vjb.com/references.html**.

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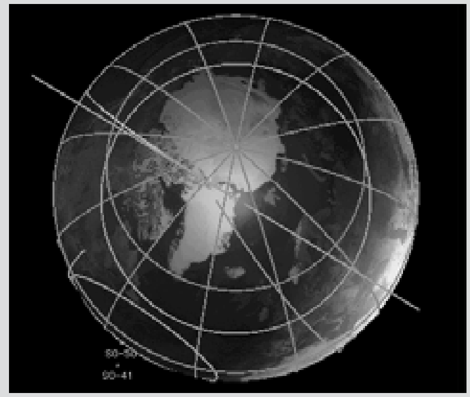

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Support AMSAT

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.

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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.

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