HamSCI: Ham Radio Science Citizen Investigation

New opportunities for scientific partnership and experimentation, and the August 2017 Solar Eclipse QSO Party.

Ward Silver, NØAX

You can be part of the historic solar eclipse coming in August 2017, putting your skills and station to work in the service of science. Of course, you'll certainly have the chance during the Solar Eclipse QSO Party, but you don't have to wait that long. You can contribute right now, operating in support of HamSCI — Ham Radio Science Citizen Investigation.

History of Amateur-Science Collaborations

In assembling and editing the book *A History of* QST*, Volume One: Amateur Radio Technology*,[1] I was struck by the breadth and depth of amateurs supporting research efforts. Sometimes discoverers and sometimes reporters, hams have a long involvement with scientific research. No doubt that is the reason why our Basis and Purpose (§97.1) contains, "(b) Continuation and extension of the amateur's proven ability to contribute to the advancement of the radio art."

The earliest example of formal collaboration was the Short Wave Fading Tests conducted by the Bureau of Standards, the Naval Research Laboratory, and ARRL in 1920.[2] Hams were already familiar with daily and seasonal variations in propagation. What better group to perform a widespread set of reception reports than the amateurs? From these early experiments came an improved understanding of propagation at radio frequencies and the first theories of what the ionosphere was (then known as the Heaviside layer), explaining how it behaved.

In the years following World War II, ama-

Figure 1 — Students participating in a summer camp at Embry-Riddle Aeronautical University steady a high-altitude balloon before launch. The balloon reached 85,000 feet while carrying an APRS tracker and sensor package.

teurs discovered transequatorial propagation, or TEP, of VHF signals. When the International Geophysical Year came along in 1957 – 58, hams were asked to help make measurements of propagation at 50 and 144 Mc (MHz), followed by the Propagation Research Project on 50, 144, and 220 Mc. Hams generated more than 300,000 individual reports, supporting the International Geophysical Cooperation effort of 1959 and helping to create the first numeric models of the ionosphere.

Amateur Science Today

Ham contributions to science are by no means a thing of the distant past. More recently, receiving tests in 1997 and 2008 generated huge numbers of reception reports, surprising researchers with their quality and volume.[3] CubeSats (aka nanosatellites) carrying short-term experiments are being launched by the dozen, transmitting data to ground stations over telemetry links in the 70 centimeter amateur band. Amateurs are involved in teams exploring the upper atmosphere through balloons and rocketry, as well (see Figure 1).[4, 5] In 2015, the Radio Society of Great Britain (RSGB) conducted the first-ever Eclipse QSO Party to collect propagation data during a partial solar eclipse.[6]

During the past 7 years, individual software defined radios (SDRs) combined with *CW Skimmer* software developed by Alex Shovkoplyas, VE3NEA, have been assembled into the Reverse Beacon Network (RBN — **www.reversebeacon.net**). It is an all-volunteer, donation-supported group with hundreds of "reverse beacons" operating on every continent but Antarctica (so far!). The RBN continuously monitors portions of all HF amateur bands for CW signals, logs the sending call sign, sending speed, and, most importantly, the signal-to-noise ratio of the signal.

Because RBN measurements are archived, they are available for study — and this is exactly what Nathaniel Frissell, W2NAF, then a doctoral student at Virginia Tech, described in his 2014 scientific paper, "Ionospheric Sounding Using Real-Time Amateur Radio Reporting Networks."[7] There are a number of interesting articles and discussions on the RBN blog at **www.reversebeacon.blogspot.com**.

The Initiative

As you can see, amateurs have been supporting "real science" all along, but you may not have heard about it! Enter HamSCI. At the 2015 Dayton Hamvention, a group led by Nathaniel Frissell, W2NAF; Magda Moses, KM4EGE, and Bob McGwier, N4HY, got together to discuss data collection during the upcoming total solar eclipse in August 2017. From this initial meeting, HamSCI was created.

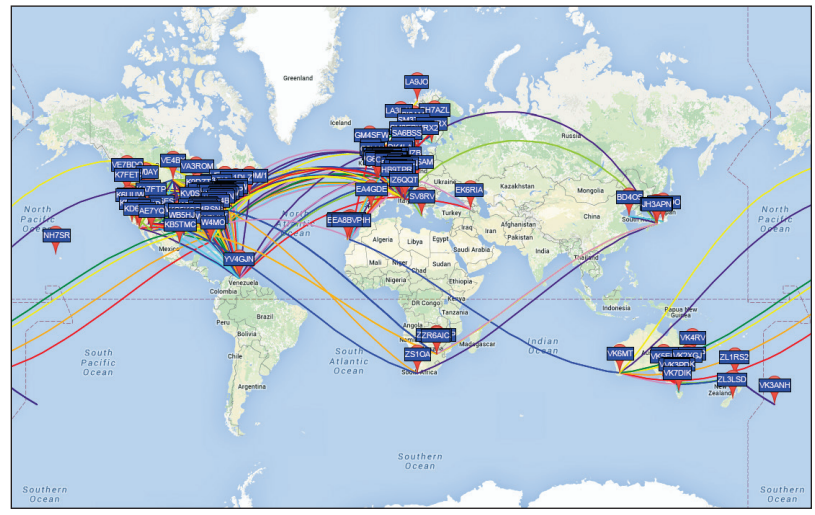

Figure 2 — The map shows WSPR signals being received around the world with the color of the path indicating frequency. Current WSPR reception reports are available on a map at **wsprnet.org/drupal/wsprnet/map**.

Before presenting its overall mission, it is important to explain that HamSCI:

- Is not an operations or funding program
- Is not a supervisory or management organization
- Is not a non-profit corporation or foundation
- Will not perform or direct research

Becoming a Reverse Beacon

If generating reports for the RBN sounds interesting, it is simple to participate. All that is needed is an SDR receiver and a PC running the *CW Skimmer* and "aggregator" software as explained on the RBN website (**www.reversebeacon.net**). Receivers in underserved and "interesting" locations are especially needed. Or perhaps you have IT skills to contribute — the expanding network needs support and service. There is lots of data to analyze, as well!

HamSCI (**www.hamsci.org**) is an effort to publicize and promote various scientific efforts and projects involving amateurs and Amateur Radio. This "big picture" effort will help foster collaboration between amateurs and the research community that may be unaware of the resources Amateur Radio provides. It also provides hams with an opportunity to learn about and participate in radio science. As groups begin to work together, sharing data and methods, having a common forum assists in developing and maintaining standards and agreements.

Who is HamSCI? The role of students in research is by definition very fluid as they join, participate, and graduate. This requires a long-term host sponsor, a role that will be filled by faculty and research staff at both Virginia Tech and the New Jersey Institute of Technology (NJIT), including NJIT postdoctorate Nathaniel Frissell, W2NAF, and VT professors Bob McGwier, N4HY, and Greg Earle, W4GDE. VT is providing the web server to host the HamSCI website, which will be maintained by VT faculty and students as research programs and team members come and go. Researchers from numerous other institutions, including Johns Hopkins Applied Physics Laboratory, SRI International, Montclair State University, the University of Calgary, and others are also involved with HamSCI's activities.

Amateur Tools and Programs

You don't have to wait for programs to be created in order to participate. You

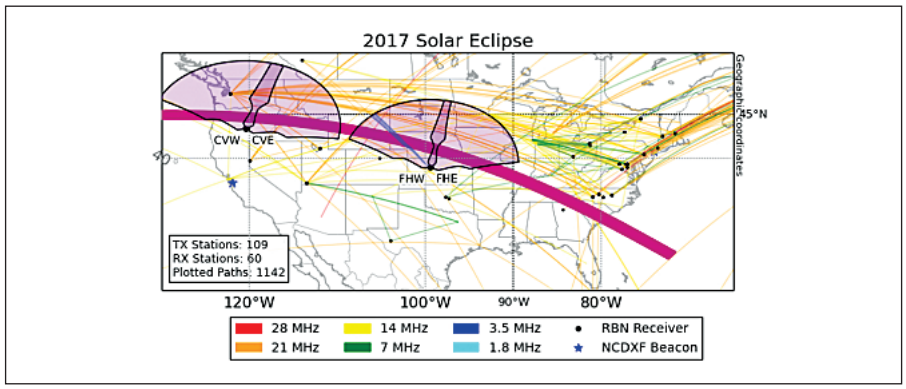

Figure 3 — The path of the total eclipse (dark blue line) begins in the northern Pacific and crosses the US from west to east. The partial eclipse will be visible from a much larger region covering most of North America. [Graphic courtesy of the Virginia Tech Eclipse Team]

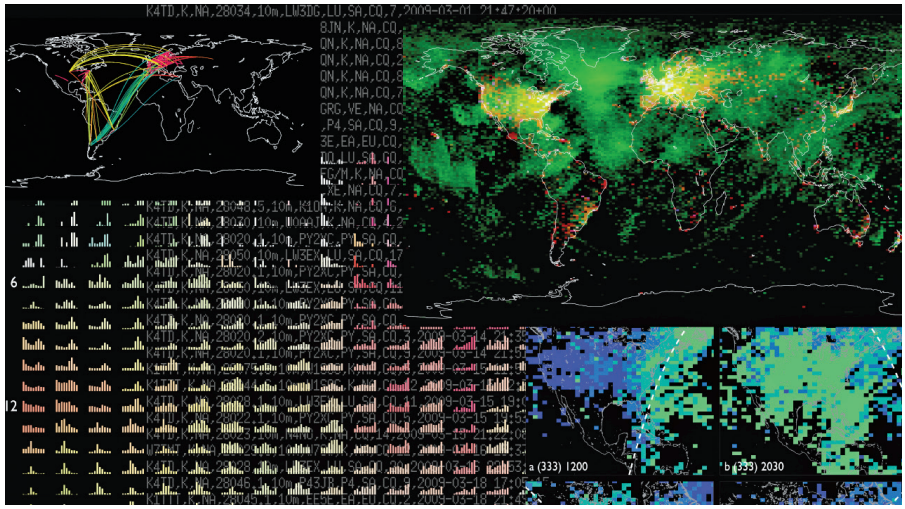

Figure 4 — The figure shows high-level results of several scientific analyses performed on the Reverse Beacon Network data to extract maximum usable frequency maps and details about the occurrence of sporadic E. This work was presented at the American Geophysical Union Fall Meeting in San Francisco in December 2015 and will be published in a scientific journal at a later date.[13] [Ethan Miller, K8GU, graphic]

can begin with the Northern California DX Foundation's (NCDXF) international beacon system (**www.ncdxf.org/beacon**). Started in the early 1970s, it has expanded to 18 beacons on six continents. Nothing more than an HF receiver is needed to listen as the automated beacons transmit their signals one after the other on 20 through 10 meters. Hams have used these beacons for years to assess propagation in real time, often finding readable signals when modeling and prediction programs say such propagation is unlikely.

The RBN mentioned earlier was named as a play on the NCDXF beacon system, because it receives signals instead of transmitting them. It was only a matter of time before the two systems linked up, and today you can get reception reports for the beacons from RBN "nodes" worldwide. (Click DX SPOTS > BEACONS > NCDXF BEACONS on the RBN home page.) Because the NCDXF beacon stations all use the same transceiver and antennas, their reception reports are particularly valuable, acting as "standard candles" of known strength for comparison to other signals.

Fans of the *WSJT* software by Joe Taylor, K1JT, know about WSPR (pronounced "whisper"), a mode using *MEPT_JT* software optimized for extremely weak-signal propagation assessment on HF. Sub-QRP signals regularly span the globe with milliwatt signals that could not be received on CW by even the most sensitive ears: Successful reception of WSPR signals with signal-to-noise ratios (SNRs) of –30 dB are regularly reported. Reports are shared on the WSPRnet website (**www.wsprnet.org**) with paths displayed on a colorful map and the data archived for analysis (see Figure 2). The PSKReporter website (**www.pskreporter.info**) also collects and displays contact information for HF PSK communications.

NASA and NOAA have long sponsored citizen science activities. These extend into the radio world with programs such as RadioJOVE (a radio astronomy experiment to receive emissions from Jupiter — **radiojove.gsfc.nasa.gov**) and ARISS, the presence of Amateur Radio on the International Space Station. University programs have been busy building and launching CubeSats (**www.cubesat.org**), originally conceived and developed by AMSAT (**www.amsat.org**). These "nano-satellites" carry a single scientific experiment into space and transmit their data back to Earth to be received by amateurs.

Individual hams have their very own databases of contact information, too — their logbooks! ARRL's Logbook of The World service (**www.arrl.org/lotw**) has grown to nearly three-quarters of a billion QSOs dating back to 1945. This is an enormous database of validated point-to-point propagation information. Imagine the value of that data to ionospheric researchers looking for unusual propagation, the effects of daily and seasonal variations, and even weather-related changes.

How to Participate

There are lots of opportunities for hams to make contributions, ranging from performing and reporting on your own experiments, to joining a research program as a field data collector, or making your computer available to analyze data (see the sidebar, "Becoming a Reverse Beacon").

Hams are using WSPR to bounce VHF signals off of airplanes (this is known as aircraft scatter, or ACS), and have discovered that long-lasting wing tip vortices also reflect signals — propagation from clear air! They're just getting started. The ability to synchronize station time with the high-precision GPS time base is leading to speculation about whether it might be possible to determine signal paths on HF through microwave in real time.

Interest in geophysics of the ionosphere and solar phenomena is higher than it has been in the decades since satellite-based communication supplanted many of the

worldwide HF networks. Understanding interactions between the Sun and Earth's geomagnetic field is a top priority for maintaining our power grid. Characterizing the geophysics of our upper atmosphere is also crucial to assessing the extent, causes, and effects of changing climate. All of these fields make use of observations and experiments performed at radio frequencies used by hams. With research resources limited, the volunteer nature of Amateur Radio multiplies its value to science.

Research programs also use HF radio communications from amateurs. For example, ePOP CASSIOPE listens to our signals with a satellite in order to assess the short-term structure of the ionosphere.[8] Coupled with ongoing programs such as the National Science Foundation's SuperDARN system of HF radar stations, amateur signals and measurements improve the data set's size and quality.[9] There is a growing realization that the worldwide community of Amateur Radio stations is a valuable source of both data and observations.[10] The HamSCI website's "Projects" page presents a growing list of papers and programs involving Amateur Radio. New papers, projects, and programs are being created all the time.

You'll get off to a fast start by studying the basics of propagation and RF measurements. *The ARRL Handbook* and *The ARRL Antenna Book* are good references. The recent ARRL publications by Eric Nichols, KL7AJ, *Propagation and Radio Science* and *Radio Science for the Radio Amateur*, will help you dive deeper into the science of radio.[11] Set up your station to use one of these new digital modes, or join an observing network like the RBN. Make sure your reception reports are made available for collection. You can make and calibrate your own measuring instruments, as well. Keep an eye on the HamSCI website and the ARRL News to learn about additional opportunities for you to contribute.

The 2017 Solar Eclipse QSO Party

Make sure you put August 21, 2017 on your calendars, because there will be an eclipse of the Sun visible across all of the United States and Canada that day.[12] With a track of totality stretching coast-to-coast from Portland, Oregon to Charleston, South Carolina, this event provides an unprecedented opportunity to assess effects of the eclipse on the ionosphere using radio signals (see Figure 3).

To encourage hams to participate as much as possible, an on-the-air multi-mode QSO party will be held throughout the day. The RBN and possibly other networks will be configured to collect propagation reports across our MF, HF, VHF, and UHF bands. There will be projects for hams to tackle such as special antenna designs, observation methods, test instruments, and more. Information about the QSO party and how hams can most effectively participate will be published by ARRL and on the HamSCI website.

Data will be collected during the QSO party by the RBN and other propagation reporting networks (see Figure 4). A complete data set will be assembled by a team at Virginia Tech. Then the research community will go to work integrating the data with that of other programs and platforms, analyzing the results, and publishing their reports. The goal is for hams to illuminate the ionosphere across the radio spectrum in order to generate a detailed picture of what happens as the eclipse creates a region of darkness moving across the continent.

This is a real opportunity for hams to experience a once-in-a-lifetime event in a way that only Amateur Radio provides. It's also a golden opportunity to introduce members of our community, students, and other interested people to Amateur Radio's unique ability to experience the natural world through radio.

Going Forward

The point of HamSCI is, of course, that there are plenty of science-worthy activities taking place on the ham bands all the time. It's just that these activities aren't widely known to hams or to researchers. That's the prime reason for creating HamSCI — bringing them all together so we can start using our abilities to advance the goals of science and benefit in return through improving our skills and our stations.

HamSCI will help amateurs take advantage of technology's remarkable advances in order to strengthen and publicize ham radio's scientific facets. Science, service, skill — three attributes that will keep Amateur Radio strong and vigorous as we go forward into our second century.

Notes

[1]*A History of* QST*, Volume 1: Amateur Radio Technology*, Item no. 0003, available through the ARRL Store at **www.arrl.org/shop**.

[2]S. Kruse, "The Bureau of Standards — ARRL Tests of Short Wave Radio Signal Fading, Part I," *QST*, Nov 1920, pp 5 – 12, and "The Bureau of Standards — ARRL Tests of Short Wave Radio Signal Fading, Part II," *QST*, Dec 1920, pp 13 – 19.

[3]**www.arrl.org/w1aw-bulletins-archive/ARLX005/1997** and **www.arrl.org/w1aw-bulletins-archive/ARLX002/2008**

[4]Amateur Radio High-Altitude Ballooning (ARHAB) — **www.arhab.org**

[5]Puerto Rico Space Grant Consortium — **www.prsgc.upr.edu**

[6]**www.rsgbcc.org/hf/rules/2015/Eclipse-QSO-Party.shtml**

[7]**onlinelibrary.wiley.com/doi/10.1002/2014SW001132/full** and **www.arrl.org/news/undergrad-radio-amateur-uses-reverse-beacon-network-in-research-project**

[8]**epop.phys.ucalgary.ca**

[9]**vt.superdarn.org**

[10]**www.earthmagazine.org/article/amateur-radio-users-help-scientists-study-space-weather**

[11]Available through the ARRL Store, Item no. 0277, at **www.arrl.org/shop**.

[12]**eclipse.gsfc.nasa.gov/SEmono/TSE2017/TSE2017.html**

[13]Miller, et al, SA43C-05: *The Ionosphere's Pocket Litter: Exploiting Crowd-Sourced Observations* (Invited), AGU Fall Meeting 2015, San Francisco, CA. This research is based upon work supported in part by the Office of the Director of National Intelligence (ODNI), Intelligence Advanced Research Projects Activity (IARPA), via ODNI Contract 2012-12050800010. The views and conclusions contained herein are those of the authors and should not be interpreted as necessarily representing the official policies or endorsements, either expressed or implied, of ODNI, IARPA, or the US Government. The US Government is authorized to reproduce and distribute reprints for Governmental purposes notwithstanding any copyright annotation thereon.

Ward Silver, NØAX, is a Contributing Editor to the ARRL, working with *The ARRL Handbook, Antenna Book*, license manuals, and *QST*. He is an Amateur Extra class licensee and primarily active on HF and with his local ARES group. He has an active interest in scientific research by amateurs and is working with the HamSCI team as an ARRL liaison.