HamSCI and the 2017 Total Solar Eclipse

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Introduction

Since the beginning of the United States amateur radio service in 1912, amateur radio operators have made significant contributions to radio technology and the understanding of radio science. This work must be continued today, as Part 97 of the FCC rules states that a primary purpose of the amateur radio service is the "Continuation and extension of the amateur's proven ability to contribute to the advancement of the radio art." Recent advances in the fields of computing, software defined radio, and signal processing provide unprecedented opportunities to meet this mandate, specifically in the field of radio science. These opportunities are already beginning to be realized with the advent of systems such as the Reverse Beacon Network (RBN), the Weak Signal Propagation Reporting Network (WSPRNet), and PSKReporter [Frissell et al., 2014]. In addition, enabling amateurs to make and contribute legitimate observations will expose amateur radio to a wider community of people interested in science around the world.

To more fully realize these efforts, we propose a new initiative known as HamSCI, the Ham Science Citizen Investigation. HamSCI will be an umbrella initiative to promote the use of amateur radio in all types scientific investigations. This is particularly timely, as the term "Citizen Science" is becoming common vernacular in many scientific fields and has recently received formal recognition in the field of Space Weather [Knipp, 2015]. While HamSCI potentially constitutes a very broad program, in this document we will focus on activities surrounding one particular event, the upcoming 2017 total solar eclipse as an example of activities within the domain of HamSCI.

The path of this total eclipse will traverse a path from Oregon southeastward to South Carolina over a two-hour period on 21 August 2017. It is anticipated that this eclipse will generate unusual HF and VHF propagation conditions and interesting ionospheric physics. In this document, we will outline possible ways in which the amateur radio community could support the generation of data that would be useful for scientific studies of this eclipse. This includes an eclipse "QSO party" (an on-the-air event to maximize contacts or "QSOs"), augmentation of the Reverse Beacon Network and other signal reporting networks, in coordination with university-level researchers.

Organizational Structure

HamSCI has the potential to be a larger, umbrella initiative to assist in organizing and coordinating amateur radio activity contributing to science. Initial leadership of this project will be comprised of leaders from Virginia Tech, the ARRL, and the Reverse Beacon Network. This initial team includes:

Virginia Tech:

- Nathaniel Frissell, W2NAF
- Magda Moses, KM4EGE
- Dr. Gregory Earle, W4GDE
- Dr. Robert McGwier, N4HY
- Dr. Tom Clark, K3IO

ARRL:

- Ward Silver, N0AX (Contributing Editor)
- Sean Kutzko, KX9X (Public Relations and Media Manager)
- Katie Allen, WY7YL (Public Relations Committee Chair)
- Ed Hare, W1RFI (ARRL Lab Manager)
- Joel Harrison, W5ZN (Former ARRL President)

Reverse Beacon Network:

- Felipe Ceglia, PY1NB
- Pete Smith, N4ZR
- David Pascoe, KM3T
- Nick Sinanis, F5VIH/SV3SJ
- Dick Williams, W3OA
- Alex Shovkoplyas, VE3NEA (Afreet Software, author of the CW and RTTY Skimmer and Skimmer Server used by RBN nodes.)

HamSCI will be initiated by activities focused on the 2017 total eclipse experiment. Figure 1 shows the initial organizational structure of HamSCI and the eclipse experiment.

“QST” is defined as comprising the entire set of ARRL publications and media.

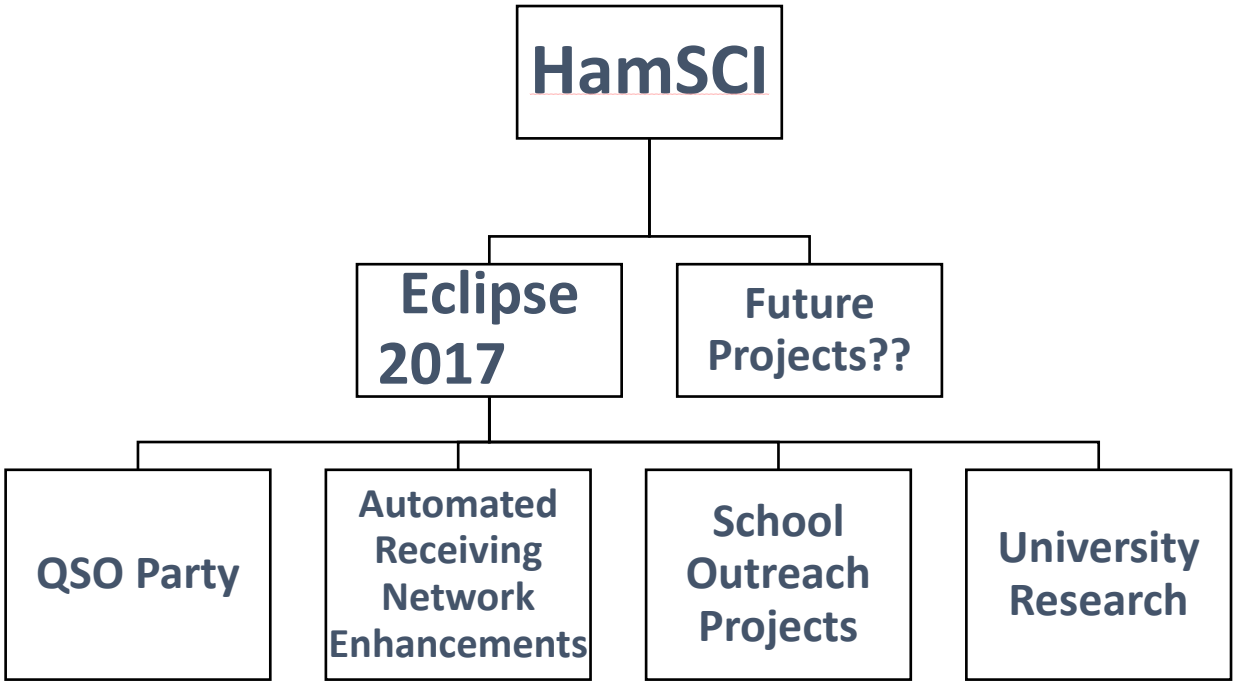

Figure 1. HamSCI Structure

The Eclipse 2017 experiment is divided into four major subcategories. These are:

1. Eclipse QSO Party
    - A ham radio operating event with the primary purpose of creating HF and VHF activity during the eclipse that can be easily monitored by automated reporting networks (such as the RBN).
    - This event should feel similar to a contest or other fun operating event in which amateur radio operators might participate.
    - Observations by automated reporting networks and QSO party logs will be made publicly available and become the data used for event analysis.
    - The QSO party will be publicized by the ARRL as a major operating event.
    - The University Research branch of this experiment will work with the ARRL in designing operating event rules that will best target science questions of interest.
    - Amateurs will be encouraged to use well-characterized antennas and calibrated power levels as "standard candles" to enhance data quality.

2. Automated Reporting Network Enhancements
    - Networks such as the RBN, WSPRNet, and PSKReporter already provide excellent observations, but are not necessarily optimized for a science experiment. RBN's primary mission is to serve as a tool for contesters.

- The University Research branch of this experiment will work with the administrators of these networks to better equip them for scientific observations during the eclipse. Target areas of improvement are increasing the number of receivers, providing better calibrated measurements from each receiver, and creating a "science" operating mode that will tailor the behavior of the reporting network to target specific science questions.
- It is likely that most effort will be concentrated on the Reverse Beacon Network at this point, as a result of previous work and discussions that have already been conducted with the operators of that network.
- A set of requirements for data collection and reporting will be published to encourage other networks and individuals to collect and report data. Examples of other networks and data collection opportunities include APRS, JT-65 and JT-9, and the American Meteor Society's radio meteor observation program.

3. School Outreach Projects
    - This is an opportunity to create an education/public outreach activity for K-12 schools.
    - The Radio Society of Great Britain (RSGB) included this type of program in their March 2015 eclipse experiment.
    - Developing a standard observing kit or project suitable for primary and secondary student teams would lower the barrier to participation. The NASA Radio JOVE Project is an example of this type of program.

4. University Research
    - This branch of the experiment will provide the scientific motivation, guidance, and analysis resources for the Eclipse Project.
    - Currently, this team consists of personnel from the Virginia Tech Space@VT Center and the Virginia Tech Hume Center.

Project Timeline and Goals

	HamSCI Team	University Research
2015	• Brainstorm at Hamvention • Develop HamSCI Project Document • Finalize Project Outline and Goals • Write QSO Party Rules • Publish rules for QSO Party Support (N1MM, WinTest, N3FJP, WriteLog, etc.) • Develop school outreach project • Garner official ARRL support and approval • Discuss additional support from organizations such as Yasme Foundation, NCDXF, etc. • Develop project website/social networking tools • Develop overall management structure of HamSCI and Solar Eclipse 2017 project	• Submit CEDAR Science NSF Proposal (Due July 17) • Work with RBN team members to identify ways to enhance RBN Network • Develop data analysis/usage techniques • Development of WSPRNet Experiment • Develop package of recommended antenna designs • Develop receiving network upgrade specifications • Develop and publish data collection specifications • Promote HamSCI within university/college education community • VT will seek funding from and cooperation from IARPA under its HFGEO project and return data collected on utility of WSPRNet and RBN distributed nodes for characterization of the ionosphere. • Promote HamSCI within the US Government community of stakeholders in HF Communication.
2016	• ARRL Publication and Testing of recommended antenna, power calibration tools, receiver • Promote HamSCI within primary and secondary education community • HamSCI QST Articles • Return results as required, on development and characterization work to IARPA HFGeo if we are successful in gaining their support.	
2017	• QST Article: QSO Party Participation and Rules • August 21, 2017: Eclipse & QSO Party • QST Event Summary • What's next for HamSCI?	• August 21, 2017: Total Solar Eclipse! • Data Analysis
2018-2019	• Publish final findings in scientific journals, QST	

Eclipse QSO Party

In order to generate data to study the ionospheric effects of the 2017 total solar eclipse, we propose a well-publicized Eclipse QSO Party to take place for a number of hours before, during, and after the solar eclipse event. QSO Party logs and observations from systems such as the Reverse Beacon Network will serve as the data generated for this event.

The eclipse QSO party will not be a contest, but rather a nationwide operating event publicized by the ARRL. Similar to ARRL Field Day, points may be earned in this event, but awards will not be given and contest-style log checking will not occur. However, participating stations should be recognized, at the very least with something such as printable PDF certificate. It is important that this event be fun and have a low barrier to entry in order to ensure the greatest amount of participation. An emphasis in the rules should be placed on making sure contacts are spread across all HF/VHF/UHF contest bands (1.8 MHz through 432 MHz) and are observable by networks such as the RBN, PSKReporter, and others. Log submission could be handled in a similar manner to state QSO parties, through a website such as Bruce Horn's http://www.3830scores.com/. At the end of the event, all logs and data generated will be made publicly available for study.

We propose using the rules of the Radio Society of Great Britain's (RSGB) 20 March 2015 Eclipse QSO Party as a model for the 2017 Eclipse QSO party (see appendix for RSGB rules). In order to better answer certain science objectives, we propose some modifications to the RSGB rules.

Similarly to the RSGB rules:

- Primary modes for this event should be digital and CW to facilitate use of automated receiving networks.
- Establish calling practices/exchanges that are easily recognized by automated receiving networks.
- Avoid WSPRNet and other known reporting network frequencies
- Promote the use of recommended antennas and power levels to improve data quality
- Ask stations to provide real signal reports with guidelines
- Ask stations to provide additional details about operating conditions in logs, including actual latitude/longitude, antenna design and orientation, radio hardware type, etc.

In contrast to RSGB rules:

- Use all contest HF bands, possibly also VHF (6 and 2 m and 70 cm) bands.
- Evaluate RSBG 20 minute rule to encourage higher rate of QSOs.

Overall, the rules should generate the required data without discouraging potential participants or greatly hindering operators during the event.

One additional method for generating good log data for this contest would be to create a special "Eclipse QSO Party" mode for major contest software such as N1MM. In this mode, logging software used with computer aided tuning (CAT) system could automatically provide important radio configuration information in the log without operator intervention. This information could potentially include actual signal to noise ratio measurements made by the radio during the QSO as well as settings such whether or not automatic gain control (AGC) settings were enabled.

We propose that the University Research team work with the ARRL Contest and Publicity branches in finalizing the rules of this QSO party and publicizing it to the amateur radio community.

Reverse Beacon Network

The Reverse Beacon Network (RBN) is an amateur radio reporting system comprising a network of automated receiving stations designed to facilitate the needs of amateur radio contesters and DXers. These stations scan and decode portions of the radio frequency (RF) spectrum for CW and some digital modes. RBN stations typically focus on monitoring HF activity, and many receiving stations are capable of monitoring multiple HF bands simultaneously. These stations report the call sign received, the time the call was heard, the mode, the frequency, the band, and the signal-to-noise ratio (SNR) back to a central server. All of the data generated is archived and is made publicly available on the RBN website (http://www.reversebeacon.net/raw_data/). This network has enormous potential for ionospheric research [*Frissell et al.*, 2014]. In this proposed study, the RBN will be used to collect a large quantity of data that can be used to evaluate ionospheric conditions along and across the eclipse path as a function of time during the eclipse event. The large spatial and frequency sampling range of the RBN, along with its automated nature, makes it an ideal system for this task.

The RBN's large geographic coverage is due to the work of volunteer amateur radio operators who set up and maintain receiving stations. However, this has also resulted is a wide variation both between different stations' systems and in the RBN's spatial density coverage. Based on previous work with RBN data, as well as discussions with RBN personnel we anticipate that enhancements to the RBN will be necessary in order to meet the scientific objectives of the 2017 eclipse experiment. Beginning in the summer of 2015, personnel at Virginia Tech will work with members of the Reverse Beacon Network team to identify ways to enhance the RBN for studying the eclipse. These enhancements will likely include the establishment of new RBN receiving stations, development of best-practice recommendations for calibrated, multi-band antenna design and installation, and development of an RBN receiving mode for the eclipse campaign. The University Research group will work with the Reverse Beacon

Network team to encourage the implementation of any recommended enhancements or changes in a manner that is consistent with the Reverse Beacon Network mission.

K-12 School Outreach Projects

HamSCI and the 2017 eclipse provide an excellent opportunity for K-12 outreach. During the March 2015 eclipse in Europe, the RSGB provided schools with instructions for a simple listening experiment that required minimal equipment. The ARRL may wish to develop a similar program, possibly through the ARRL Education and Technology program.

University Research

Collaboration with university-level research programs is an integral part of the HamSCI program. This relationship will allow the results of HamSCI activities, such as the ones described in this document, to be more rigorously analyzed and placed into the scientific literature. This type of collaboration will provide HamSCI with key scientific guidance, as well as the opportunity to dedicate additional funding and resources for projects. Currently, a team of researchers at Virginia Tech is fulfilling this role.

Current project leaders include:

- Dr. Gregory Earle, W4GDE, Professor in Electrical Engineering
- Dr. Robert McGwier, N4HY, Professor and Hume Center Director of Research
- Nathaniel Frissell, W2NAF, Ph.D. Candidate in Space@VT SuperDARN Laboratory
- Magda Moses, KM4EGE, Undergraduate in Electrical Engineering/Space@VT

Virginia Tech is actively preparing to support the 2017 eclipse project. Student time has already been allocated to do preliminary studies during the 2015 summer. This includes additional evaluation of RBN data currently available, as well as testing of a Virginia Tech-sponsored RBN receiver.

A proposal is currently in preparation to obtain funding for equipment such as additional RBN receivers, as well as for funding event data analysis by student and professional investigators. The Virginia Tech Amateur Radio Association would also play a role in these studies. It should be noted that this funding is only in the proposal stage, and is not guaranteed.

The Hume Center at Virginia Tech is planning to submit a proposal to the IARPA HF Geolocation (HFGEO) program to fund a network of QRP WSPRNet transceivers to be used as an active monitoring program during the 2017 eclipse. More information regarding IARPA may be found at http://www.iarpa.gov/index.php/research-programs/hfgeo. Additionally, the Hume center has computing resources that could be utilized by both the eclipse project and the HamSCI initiative.

Finally, a university relationship provides the additional advantage of allowing amateur-radio generated data to be used in conjunction with already established scientific-grade data sets. These data sets include measurements from ionospheric radars, ionosondes, riometers, magnetometers, spacecraft, GPC-TEC receivers, and more. Due to the size and complexity of the solar-terrestrial system, it is crucial that work be done to integrate all of the data sources together when conducting ionospheric and space science research. Each of these data sets complements the others, and the amateur radio contribution has the potential to be vitally important.

ARRL Support

We believe the American Radio Relay League could provide critical support for the HamSCI initiative. As the largest amateur radio organization in the United States, it is uniquely positioned to help implement and guide the HamSCI program. The primary role of the ARRL will be to promote operating activities such as the Eclipse QSO party, as well as to encourage membership participation in scientific and educational activities. We also see the ARRL playing a role in helping the HamSCI team understand what activities will be best suited for and needed by the amateur radio community. These roles can be accomplished through the publication of supporting QST articles and promotion through the ARRL website and other communication channels, as well as through discussion with appropriate members of ARRL leadership and staff.

We also believe this program will be beneficial to the ARRL membership, as it provides a substantive program for furthering the advancement of the radio art. This program will allow amateur radio operators to more directly and purposefully participate in science, while still enjoying the hobby of amateur radio.

Potential Topics for QST Articles

Below is a list of possible relevant topics for future QST articles:

- Overview of Eclipses and Radio Science
- Introduction to the HamSCI Initiative
- Eclipse QSO Party: Rules/How to Participate
- Calibration of radio receivers and antennas for scientific studies
- Results of the Eclipse 2017 QSO Party

Additional ARRL Support

Ed Hare, W1RFI, has an interest in supporting the 2017 Eclipse Project by having the ARRL labs better characterize receivers in popular amateur radios in order to calibrate receiver data that will be recorded by participants in the 2017 Eclipse QSO party. The ARRL Lab staff can apply additional expertise in order to characterize antennas, power measurements, and data reporting.

Other Relevant Eclipse Efforts

Other citizen science groups are already taking an interest in the 2017 eclipse. Some of these efforts are briefly described below.

GRAPE
http://www.sweoc.org/GRAPE.html

GRAPE, the Great Radio Atmospheric Propagation Experiment, is a project to study the effects of the 2017 total solar eclipse on radio propagation and employs a number of experiments to collect data via amateur radio operation. This project appears to be spearheaded by a single radio amateur, Elwin Morin, Jr., KG7QCK. The objectives on the website appear related to those described in this document, although not as large scale. This effort has been noted by QRZ.com and AMRAD.

Citizen CATE
https://sites.google.com/site/citizencateexperiment/

Citizen CATE, Citizen Continental-America Telescopic Eclipse Experiment, is a project that calls for volunteer amateur astronomers across the US to photograph the corona of the sun over the course of the eclipse.

Conclusions

This document proposes a new program entitled HamSCI, the Ham Science Citizen Investigation. This program would be an umbrella initiative to cover a number of projects in which amateur radio operators can directly contribute to scientific investigations. This is accomplished through a unique collaboration of university researchers, automated amateur radio monitoring networks (e.g., Reverse Beacon Network, PSK Reporter, and WSPRNet), and the American Radio Relay League. Such a program will be beneficial to all parties involved.

The HamSCI initiative will begin by focusing on studying the effects of the 2017 total solar eclipse, which will be observed in the continental United States on 21 August 2017. An eclipse QSO party, similar to the one conducted by the Radio Society of Great Britain in March of 2015, will serve as a primary operating activity and data generation tool for the 2017 total solar eclipse.

Appendix: RSGB Eclipse QSO Party Rules

Source: http://www.rsgbcc.org/hf/rules/2015/rEclipseQSOparty.shtml

RSGB Eclipse QSO Party 2015 -- How to participate

The RSGB Contest Committee announces an "**Eclipse QSO Party**" in cooperation with the Propagation Studies Committee during the partial eclipse on the 20th March. Information about the experiments being carried out and links to other relevant sites are here

This is not a contest, but some of the RSGB Contest Committee software and web facilities will be used to collect and display activity reports.

The **D layer of the ionosphere may not be as strong** due to the eclipse, and stations on the lower bands – 1.8 MHz, 3.5 MHz and perhaps 7 MHz may be heard that would otherwise be inaudible during the day.

All available radio amateurs are invited to participate -- this is an opportunity to contribute to our knowledge of propagation and the ionosphere.

Those who wish to participate but **cannot operate on the day of the eclipse** may contribute if they have automatic skimmer / wideband RX (e.g. SDR) facilities. Please record the QSO Party and contact the Contest Committee to submit your recording.

1. GENERAL INFORMATION				
(a) Participation	This is not a contest, rather **it is an experiment** to see and report on the effects of a partial eclipse on daytime propagation in the 160m, 80m and 40m bands.[1] Everyone is invited to take part, whether RSGB members or not, and within the UK or outside.			
(b) When?	Date:	20 March 2015	Time:	08:00 - 11:30 UTC
	Duplicate QSOs and skeds may be made in this QSO Party. It is suggested that a gap of 20 minutes or more is left between duplicate QSOs on the same band and mode, but this could be reduced if conditions appear to be changing rapidly.			
(c) Modes	CW and PSK-63.			
(d) Frequencies	Participants with **antennas for 1.8MHz** are requested to use that band as first choice. Otherwise please use 3.5MHz if possible, or 7MHz if			

[1] In 2017 QSO Party, use as many bands as possible.

	not. It would also be helpful for participants with appropriate antennas to make QSOs on all three bands in succession to compare signals.			
	Please do not operate within **1kHz of these WSPR frequencies**, which will be used and monitored during the experiment: 1.8366MHz, 3.5926MHz and 7.0386MHz			
	1.8MHz:	CW: 1810 - 1835 kHz	PSK-63: 1838 - 1840 kHz	
	3.5MHz:	CW: 3525 - 3550 kHz	PSK-63: 3580 - 3583 kHz	
	7MHz:	CW: 7010-7035 kHz	PSK-63: 7040 - 7043 kHz	
(e) QSO format	Call CQ using the procedure, "**CQ CQ CQ de G9XYX G9XYZ G9XYZ**" when beginning on a new frequency, and from time to time. This will trigger the CW/PSK skimmers/reporters which are monitoring in various locations. Do not call TEST or CONTEST.			
	Exchange **real report** and 4-character locator. For example, "459 IO83". Sending 599 to everyone is not useful for analysis purposes!			
	Additional information about each QSO should be recorded on paper or using the "Note" facility available with contesting software. For example, "0905 GM9ABC stronger on vertical". Then please copy or transcribe into Soapbox comments in your log.			
	Those using PSK-63 with **software showing a signal-to-noise level** are requested to note the average level received for each QSO, and transcribe this data into the Soapbox of the log.			
(f) More information:	Email the Contest Committee	Email the Propagation Studies Committee		
	Description of experiment and other web links			
2. DURING THE QSO PARTY				
(a) Logging:	**Computer logging** is recommended, using the Stew Perry Topband Distance Challenge format for			

	Cabrillo logs.
	Record the frequency (not just the band) in logs if possible.
	Use the **Soapbox section** to note information on conditions, activity and to compare changes in band, antenna and power levels used.
	Note **details on your equipment** in the Soapbox. When using more than one antenna per band, report which one is used for each QSO.
	Logs should be submitted to the Contest Committee Robot before the 6th April 2015.
	The Contest Committee Logfile Generator is available for entry of logs using the web input system.
	Logs will be circulated within the RSGB Contest Committee and the Propagation Studies Committee, and to others who wish to investigate the effects of this experiment.
(b) Recording:	Participants who have **recorded their operations in the QSO Party** (in an MP3 file, for example) are asked to note this in their Soapbox comments, in case the recording could be used for analysis.
(c) Using N1MM Logger:	Les, G4OGB, has suggested a way to use N1MM logger for this QSO Party -- many thanks.
3. RESULTS	
(a) Display of results	**This is not a contest**, but a table of participants with QSO data will be shown in the Contest Committee web pages
(b) Certificates	**A Certificate of Participation in the Experiment** will be awarded to all stations who make 5 QSOs or more in the Eclipse QSO Party

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