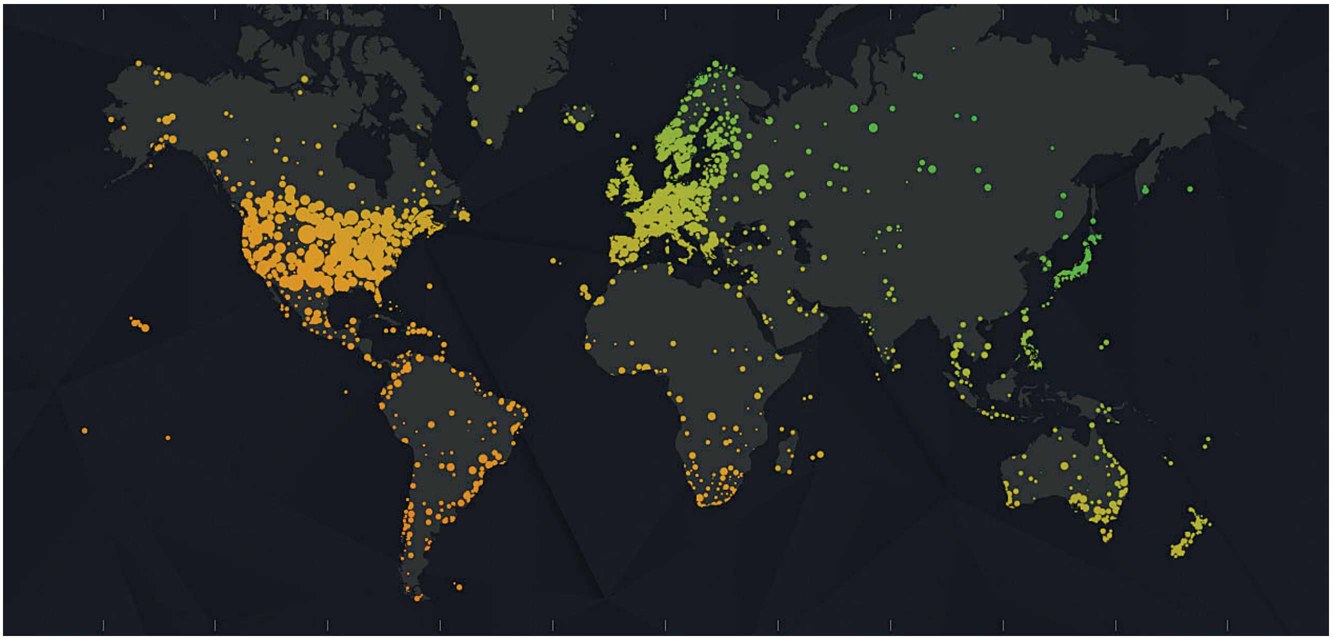
The Personal Space Weather Station



Collect measurements on noise level, meteor scatter, geomagnetic variations, and more, and contribute the data to scientific explorations worldwide.

Ward Silver, NØAX

During the Solar Eclipse QSO Party (SEQP) last August, hams made a massive number of observations of propagation before, during, and after the eclipse. With the SEQP in the rear-view mirror and the dataset being analyzed by scientists around the world, the question becomes, "Now what?"

There will be another total solar eclipse in 2024,[1] but in the meantime, there are a lot of interesting events and phenomena to keep an ear on every single day. Hams can take a cue from the Citizen Weather Observer Program (**wxqa.com**)[2] and how it demonstrates that individuals can support research with their own observations. The "Personal Weather Station" initiative is another example. Organized by Weather Underground (**www.wunderground.com/weatherstation/overview.asp**), measurements of parameters like temperature, wind speed, humidity, and rainfall are collected on servers for online display and as a permanent record of the weather at more than 250,000 locations around the world (see Figure 1, above).

Hams have their own weather to monitor — space weather, such as that displayed at **spaceweather.com**. Instead of temperature, we might measure noise level. Instead of rainfall or humidity, we can watch for meteor scatter or variations in the geomagnetic field. All of these are monitored by professional weather stations, of course, but there are a lot more hams in a lot more locations. Furthermore, with hams recording data day in and day out, if a "that looks funny…" moment happens, the data will be available before, during, and after, just like it is for our eclipse experiment. This is helpful to scientists trying to understand an event.

Figure 1 (above) — A map showing locations of Personal Weather Stations reporting on the Weather Underground website.

The Personal Space Weather Station (PSWStn)

Like a weather station, the purpose of a PSWStn is to collect measurements of common parameters on a long-term basis to develop a historical record. Stations submit their data in a standard format to a central storage server. The resulting database is a long-term record for research. Most stations will measure the same parameters. Stations might change their measurement routines or support one-time events or experiments with special instrumentation.

Unlike a weather station, the PSWStn will be measuring electromagnetic phenomena that usually change much faster than the weather. In addition, we may be able to capture transient events like meteors or radio bursts. For our measurements of fast-changing things to have value, we'll have to time-stamp each one using an accurate, precise clock, or *time base*, which we'll discuss later.

The data we collect will have to be readable by a collection service and then later (perhaps much later) by researchers. Hams have confronted and solved that problem before. Developers of logging software support the Amateur Data Interchange Format (ADIF, **www.adif.org**), so that log data can be shared between programs and new programs created. Contesters use the Cabrillo format (**wwrof.org/cabrillo**) to submit logs from one program to many different sponsors.

Space weather data will consist of many different types of measurements, ranging from one-bit ON/OFF digital inputs to analog values like signal strength to recordings of the audio or radio spectrum. In particular, RF spectrum recordings can be very large — in the range of terabytes. The HamSCI Amateur Radio Communications (HARC) database is a MySQL database schema for submitting and storing the very large data sets that will be generated by a PSWStn network. The current database is storing the many “spot” observations generated by the Reverse Beacon Network (**reversebeacon.net**), PSK Reporter (**www.pskreporter.info**), and WSPRnet (**wsprnet.org**) during the SEQP. Analog values and waveforms can be added in the future.[3]

The basic architecture of the PSWStn is shown in Figure 2. The various instruments generate digital status data, analog values, and waveforms or spectrum recordings. A controller reads all the data, converting it from analog to digital if necessary, combines it with a timestamp from the time base, and stores the combination as a record. At regular intervals, the controller uploads a package of information to the HARC database. The controller might also need to control the individual instruments in some way, such as turning them on and off, initiating a calibration, or switching them from one mode to another.

You can keep tabs on the PSWStn development process and status on the HamSCI website at **hamsci.org/swstation**.

The controller can be any suitable computer or microcontroller if it acquires, stores, and uploads usable data in the necessary formats. Raspberry Pi single-board computer modules might be a good choice for a standalone and portable package, or a PC could be used in a home-based, fixed station. The controller should also include a user control interface to allow the station and its instruments to be calibrated and configured.

The controller may not have to access the internet directly or continuously. Data could be packaged as a file and transferred via text messaging, commercial e-mail, or the amateur Winlink system. Individual measurements could be transferred via the APRS network. For truly remote locations, low-bandwidth satellite connections via Iridium or Inmarsat are a possibility.

The PSWStn Time Base

One of the most important elements of the PSWStn is the time base. When evaluating fast-changing or transient events, it is critically important to align data from different sources. This allows researchers to work backward and find out where a signal originated or to associate signals with a known

Who’s Interested in Space Weather Data

The SEQP observations are being processed into a usable dataset by geophysics researchers at Virginia Tech, the New Jersey Institute of Technology (NJIT), and elsewhere. Scientific papers are already being generated from this data, both in peer-reviewed refereed professional journals and in conference presentations. The latter include those presented at the recent American Geophysical Union (AGU, **www.fallmeeting.agu.org/2017**) conference held in December 2017 and the HamSCI Workshop held at NJIT in February 2018. The figure below is from a presentation by Nathaniel Frissell, W2NAF, at the AGU meeting (**www.hamsci.org/2017-agu-frissell**).

Quite a few professional research organizations are likely to take an interest in amateur-generated data sets. Along with day-to-day measurements, special events and experiments are of interest, too. Here’s a list of some of the organizations interested parties might belong to:

- International Association of Geomagnetism and Aeronomy (IAGA, **www.iaga-aiga.org**)
- International Union of Radio Science (URSI, **www.ursi.org**)
- Institute of Electrical and Electronic Engineers (IEEE, **www.ieee.org**)
- Committee on Space Research (COSPAR, **www.icsu.org/what-we-do/research-programmes/thematic-organizations/committee-on-space-research-cospar**)
- International Reference Ionosphere (**irimodel.org**), a working group maintaining a standard model of the ionosphere used for propagation prediction, for example.

There are also groups that fund geophysical research, such as NASA (**nasa.gov**), NOAA (**noaa.gov**), the National Science Foundation (NSF, **nsf.gov**), the Air Force Office of Scientific Research (**afrl.dodlive.mil/tag/afosr**), and the Office of Naval Research (ONR, **www.onr.navy.mil**).

event. For example, could a specific signal or event be associated with a particular meteor or a solar flare? The data's time stamp would have to be accurate to within a few milliseconds (or better!) to tell for sure.

The most common source of such accurate time is a *GPS-disciplined time base*. Each GPS satellite contains an atomic frequency standard and sends time codes in its downlink signal. GPS receivers use the time information from multiple satellites to locate the receiver precisely. Synchronizing to this signal creates a time base with the same accuracy as the frequency standard. GPS-disciplined modules are available new, as surplus, or can be constructed as a home project.

Internet time servers are also an option. Your home PC can keep its time synchronized to time services via the internet. (For *Windows* users, the "Internet Time" function within the "Set the Date and Time" control allows you to select a time-sync service and control when the time-sync operation is performed.) Synchronization is not as good as having a GPS-disciplined time base, but is still accurate enough to time-stamp measurements of slowly changing data.

What Happens to the Data

Data collected and donated by hams for the common good should remain publicly available for historical and scientific research. The best successful example we have for similar efforts is the open-source model for software development, which makes the software's source code available to all and usable by anyone who agrees to certain licensing requirements.

Similarly, those who use the data for analysis and to support their own work will need to have some assurances about their legal rights and obligations. Again there are successful examples to follow, such as the Backyard Bird Count, which is led by the Audubon Society and the Cornell Laboratory of Ornithology. The data policy of this citizen-scientist collaboration, provides a template for the PSWStn effort.[4]

The PSWStn and You

Now it's time to build a PSWStn of your own. This being a brand-new effort, you can't log into your favorite ham radio distributor and order one. You or your club will have to build one, which is part of the fun. Measurements can be made at any frequency from LF and MF, where our new allocations are located, through the microwave spectrum.

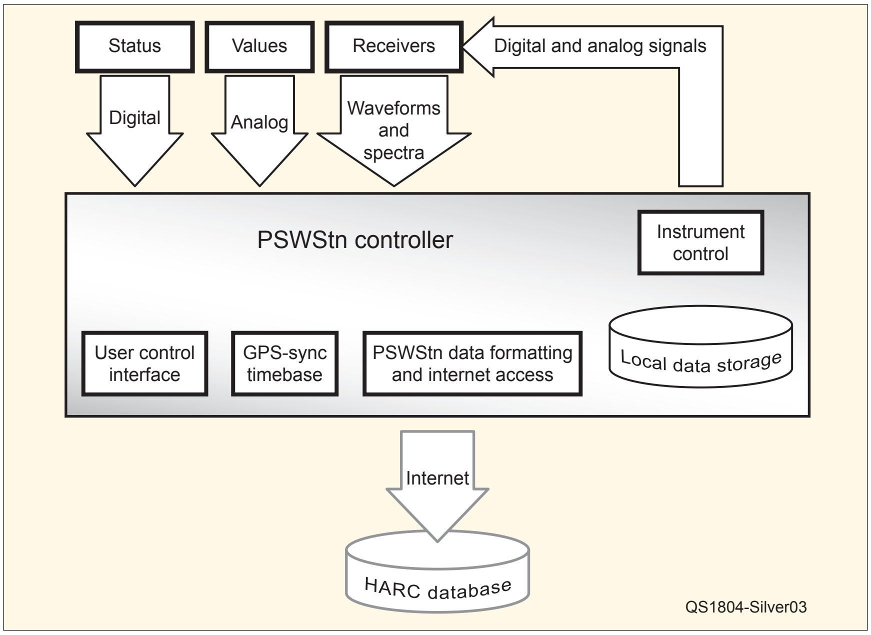


Figure 2 — Architecture for Personal Space Weather Station, including data collection by the HARC database.

Satellite Telemetry

Logging satellite telemetry is another way to have fun while supporting the scientific research community. Experimental CubeSats have telemetry channels for both satellite management and data from whatever research is being conducted. You can help by receiving, decoding, and recording the telemetry.

The SatNOGS antenna and az-el rotator system installed by Corey Shields, KB9JHU. [Corey Shields, KB9JHU, photo]

The process of tracking and tuning in satellites can be automated. A good example is the winner of the 2014 Hackaday Prize, the SatNOGS automated telemetry receiving system (**satnogs.org**). By operating a SatNOGS (or similar) system, you can support numerous university research programs, both amateur and non-amateur.

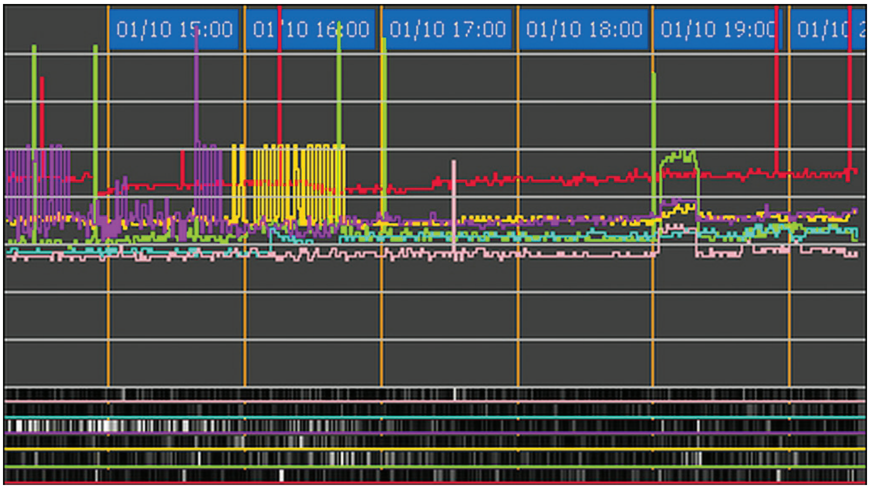


Figure 3 — The RF Seismograph by VE7DXW measures wideband noise on six HF bands as a propagation indicator.

Useful Types of Amateur Space Weather Data

Digital Status Parameters

- Calibration and control signal status
- Thresholds such as sunrise/sunset, noise level (squelch)
- Counts and detection — gamma-ray, lightning detection

Analog Value Parameters

- Received power level, either wideband or narrowband
- Signal strength as an RMS ac voltage or dc AGC level
- Received signal phase and direction
- Magnetic field strength and direction (flux gate)

Waveforms and Spectra

- Narrowband (audio) — beacons and broadcast stations, Doppler spectrograms (example at **www.k5cm.com/wwv-doppler-corr.htm**), scatter monitoring
- Medium band (IF) — see RF Seismograph
- Wideband (RF) — broadband recording
- Ionosonde recordings

You can even start with the instruments and data that were successfully collected for the SEQP. An automated receiver (a *node*) for the Reverse Beacon Network, PSK Reporter, or WSPRnet (see the previous website references) is a great way to get going with a mature design and help available. Very little is required beyond a suitable receiver, a dedicated antenna, and enough computer power to do the processing and connect to the internet. The software is free and you can start generating data right away.

The RF Seismograph instrument developed by Alex Schwarz, VE7DXW, digitizes the IF of a transceiver such as the FT-817. By monitoring a set of frequencies, an assessment of background noise floor and changes indicating variations in propagation can be recorded.[5]

You can also build your own receivers and other instruments. The book *Radio Science for the Radio Amateur* and *Propagation and Radio Science* by Eric Nichols, KL7AJ, provides a lot of background on the basic elements of making your own measurements and what they might mean.[6] The new digital modes, such as MSK144, can monitor calling frequencies for pings and bursts, too.

Ongoing PSWStn Development

You'll be able to keep tabs on the PSWStn development process and status on the HamSCI website at **hamsci.org/swstation**. As various developments make progress, such as the HARC database definition and interface, they'll be publicized on the HamSCI website, along with articles describing different types of instruments, controllers, and software. If an organization creates an experiment or program to use amateur-collected data, links will be provided.

If you are interested in the citizen science of Amateur Radio — and you don't even have to be licensed to participate — the PSWStn is an opportunity to contribute. The program will need observers, developers, designers, and scientists. Propagation data is of increasing importance to the study of solar behavior, of terrestrial climate, and to our favorite hobby. Join the fun!

Notes

[1]**eclipse.gsfc.nasa.gov/SEgoogle/SEgoogle2001/SE2024Apr08Tgoogle.html**

[2]*HamRadioNow* programs 372 and 373 are available at **www.youtube.com/user/HamRadioNow**.

[3]A paper describing the HARC details is available at **hamsci.org/sites/default/files/publications/2017_TAPR_DCC/2017_Katz_TAPR_DCC.pdf**.

[4]**http://www.birds.cornell.edu/citscitoolkit/toolkit/policy/Bowser%20et%20al%202013%20Data%20Policy%20Guide.pdf**

[5]**www.arrl.org/news/scanning-rf-seismograph-monitors-hf-propagation-in-real-time**

[6]Available at the ARRL Store — **www.arrl.org/shop**

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