Development of a Contesting and DXing Dashboard for the HamSCI Personal Space Weather Station

Project Proposal to the Frankford Radio Club

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Introduction

The HamSCI Personal Space Weather Station (PSWS) is a modular, multi-instrument ground-based system that measures space weather impacts both locally and as part of a global, distributed network. The HamSCI PSWS system is designed to make measurements of sufficient quality to be useful in professional, peer-reviewed scientific studies while simultaneously being affordable and interesting to amateurs who wish to operate one. With support from the United States National Science Foundation (NSF), NASA, Amateur Radio Digital Communications (ARDC), and the volunteer efforts of amateur radio operator members of HamSCI and TAPR, the PSWS project has been in development since 2018 and has produced multiple peer-reviewed papers (Collins et al., 2021a,b,2023; Gibbons et al., 2022; Kim et al., 2024) and the PhD thesis of Dr. Kristina Collins, KD8OXT (Collins, 2023). Works by Frissell et al. (2014, 2018, 2019, 2022) and Perry et al. (2018) have further demonstrated the utility of observing high frequency (HF, 0.5 – 30 MHz) amateur radio communications for scientific study of space weather and ionospheric physics.

While the HamSCI PSWS network has and continues to enjoy great scientific success and support over the past few years, relatively little work has been done to make this a valuable tool for real-time amateur radio applications, such as contesting, DXing, and public service. Ideally, the PSWS network should equally benefit both the amateur radio and professional scientific communities, as this is a core objective of the HamSCI initiative (Frissell et al., 2023). In this proposal, we seek to develop a Contesting and DXing Dashboard for individual PSWS nodes that will aid amateurs in understanding HF propagation at their local station in real-time. This system will be developed as a collaborative effort between the Frankford Radio Club (FRC), the University of Scranton W3USR Amateur Radio Club and Physics/Engineering Department Faculty and Students, and members of the HamSCI community.

PSWS Equipment and Architecture

As a modular system, an individual PSWS station may include some or all the following of the following instruments: a broadband HF software defined radio (SDR) receiver, a purpose-built HF receiver for monitoring WWV, WWVH, and CHU Doppler shifts, a ground magnetometer, a very low frequency (VLF) receiver, and global navigation satellite system (GNSS) receiver, and others. In this proposal, we focus on the current version of the broadband HF SDR instrument, known as the WSPRDaemon-Grape system, show in Figure 1. This system can digitize the entire HF spectrum from ~0.3-30 MHz for both real-time and post-processing applications, simultaneously decode all WSPR activity within that spectrum, and record slice receivers with the frequency precision and accuracy afforded by a GPS disciplined oscillator. The entire system, including antennas, can be purchased and installed for ~US$1,250 or less.

The system components of the WSPRDaemon-Grape System shown in Figure 1 are as follows: (a) RX888-MkII HF SDR Receiver, operated at 30 MHz Bandwidth, (b) Leo Bodnar Mini GPS Disciplined Oscillator, (c) GPS Receive Antenna, (d) Linux x86 Server running KA9Q-radio and WSPRDaemon software. The RX-888 SDR should be connected to a wideband (500 kHz – 30 MHz) receive antenna; small active antennas such as magnetic loops (e.g., DXEngineering RF-PRO-1b) or whips can be effective. KA9Q-radio (https://github.com/ka9q/ka9q-radio), an open-source software package developed by Phil Karn KA9Q, uses fast convolution to enable multichannel reception. The KA9Q-radio output is then passed to the open source WSPRDaemon software, developed by Rob Robinett AI6VN, which handles multiband WSPR decoding and slice channel recording. In addition to being stored locally, system data is uploaded to both the WSPRDaemon database (http://wsprdaemon.org/), wsprnet.org, and the HamSCI Personal Space Weather Station Database (http://psws.hamsci.org).

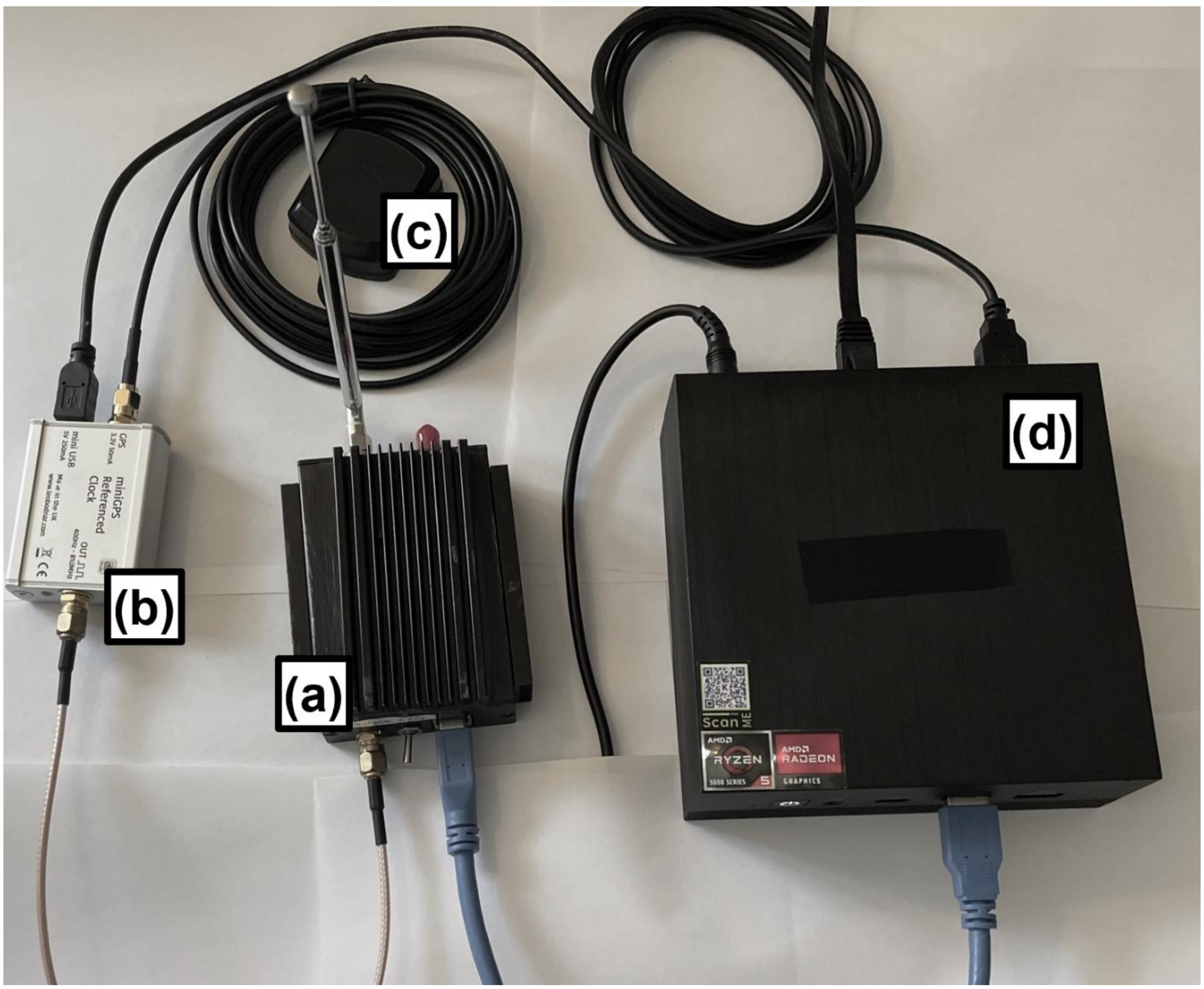

Figure 1: System components of the WSPRDaemon-Grape System used as the HF SDR receiver module of the HamSCI Personal Space Weather Station. Components include (a) RX888-MkII HF SDR Receiver, operated at 30 MHz Bandwidth, (b) Leo Bodnar Mini GPS Disciplined Oscillator, (c) GPS Receive Antenna, (d) Linux x86 Server running KA9Q-radio and WSPRDaemon software. System should be connected to a wideband (500 kHz – 30 MHz) receive antenna. Small active antennas such as magnetic loops or whips can be effective.

PSWS Network and Example Observations

As of September 2024, there are over 20 operational WSPRDaemon-Grape PSWS systems deployed throughout the world; most are located throughout North America. The WSPRDaemon-Grape system currently collects two primary types of data: WSPR/FST4W amateur radio spots and HF Doppler shifts of standards stations. Both data types are collected simultaneously on multiple bands. A typical installation will observe WSPR on all HF amateur bands from 160 or 80 m through 10 m, and nine WWV/WWVH/CHU frequencies. The WSPRDaemon software extends the standard WSPR decoding software by adding several advanced features, including direct noise and Doppler spread measurements. The WSPRDaemon noise measurements allows for the calculation of true signal strength, not just signal-to-noise ratios (SNR) as is provided by the standard WSPR decoder. Additionally, noise measurements can be used a method of diagnosing the quality and characteristics of a particular HF radio site. Doppler spread can be useful for diagnosing the propagation path of incoming amateur HF signals (*Griffiths*, 2024).

In addition to WSPR/FSTF4W decoding, the WSPRDaemon-Grape routinely monitors HF Doppler shifts of signals transmitted by standards stations WWV, WWVH, and CHU. HF Doppler are changes in the apparent received frequency of an HF signal due to changes in propagation path length as a function of time. Such Doppler shifts can be caused by changes in ionospheric refraction height caused by the lowering of the ionosphere during dawn (positive Doppler), the raising of the ionosphere at dusk (negative Doppler), traveling ionospheric disturbances (TIDs), or rapid increases in ionization due to solar flares. Solar eclipses, which can be thought of as a rapid dusk-to-dawn transition, also produce highly recognizable HF Doppler signatures.

To illustrate the sensitivity of the WSPRDaemon-Grape receiver to ionospheric effects, Figure 2 shows measurements of the WWV carrier (Ft. Collins, CO) received by the W2NAF WSPRDaemon-Grape receiver located near Scranton, PA on 8 April 2024, a day when a total solar eclipse traversed the continental United States. The white dot-dashed curve indicates solar elevation angle at the WWV-W2NAF midpoint; the white dotted curve indicates solar eclipse obscuration. Several interested ionospheric features can be observed in the data, including: (1) lack of 20 MHz reception during from ~0200-1200 UTC due to low Maximum Usable Frequency, (2) lack of 5 MHz reception during from ~1300-2300 UTC due to D-region absorption, (3) traveling ionospheric disturbances causing sinusoidal oscillations throughout the night from ~0100-1200 UTC on 5, 10, and 15 MHz, (4) Positive HF Doppler shifts with multi-path mode-splitting on all bands from ~1000-1400 UT associated with dawn, and (5) Negative-then-positive HF Doppler Shifts on all bands associated with the solar eclipse from ~1800-2100 UTC.

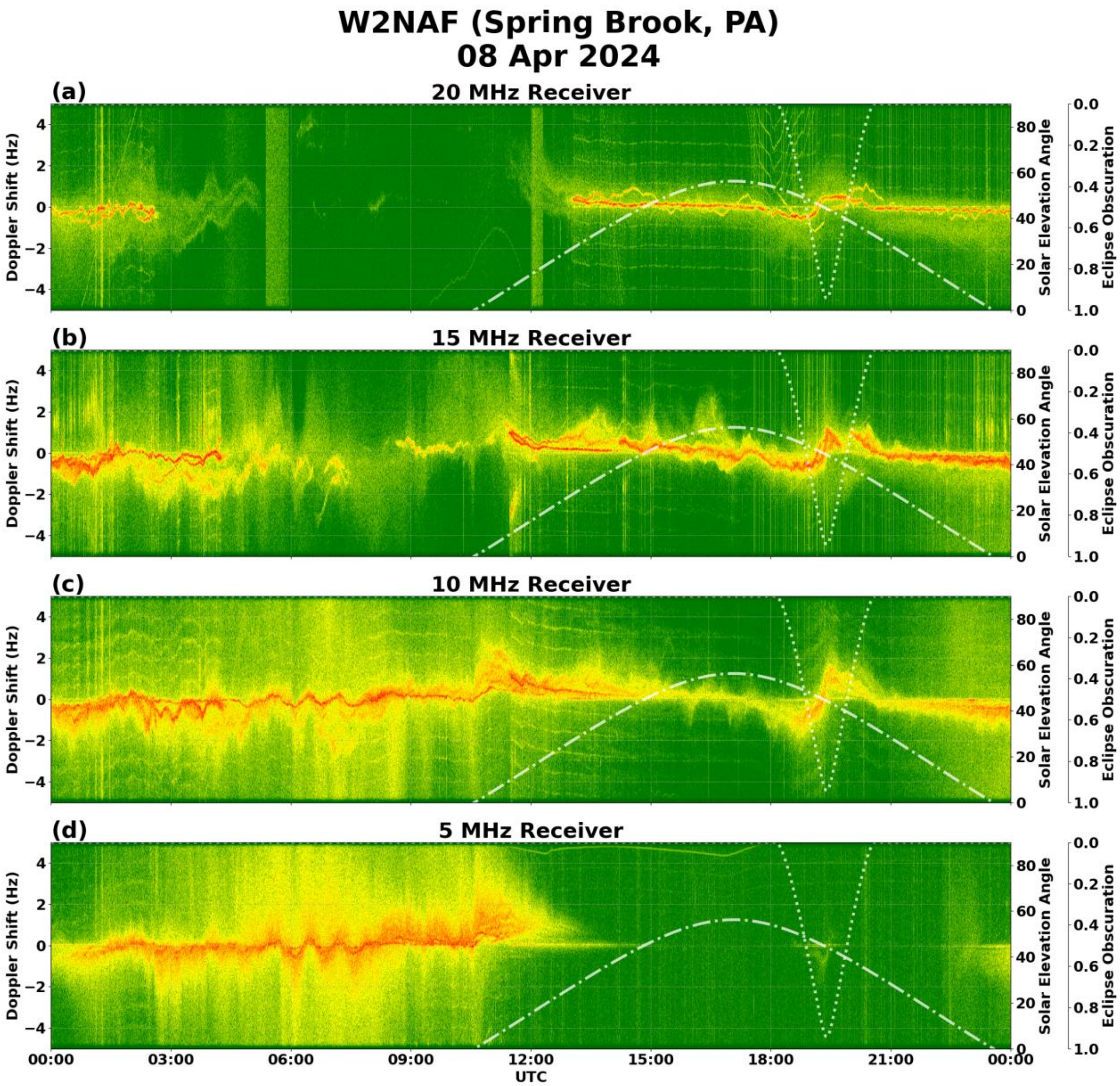

Figure 2: Example measurements of the WWV carrier (Ft. Collins, CO) on multiple HF bands received by the W2NAF WSPRDaemon-Grape receiver located near Scranton, PA on 8 April 2024, a day when a total solar eclipse traversed the continental United States. The white dot-dashed curve indicates solar elevation angle at the WWV-W2NAF midpoint; the white dotted curve indicates solar eclipse obscuration. Several interested ionospheric features can be observed in the data, including: (1) lack of 20 MHz reception during from ~0200-1200 UTC due to low Maximum Usable Frequency, (2) lack of 5 MHz reception during from ~1300-2300 UTC due to D-region absorption, (3) traveling ionospheric disturbances causing sinusoidal oscillations throughout the night from ~0100-1200 UTC on 5, 10, and 15 MHz, (4) Positive HF Doppler shifts with multi-path mode-splitting on all bands from ~1000-1400 UT associated with dawn, (5) Negative-then-positive HF Doppler Shifts on all bands associated with the solar eclipse from ~1800-2100 UTC.

Development of a Contesting/DXing Dashboard for the PSWS

The wideband 0.3 – 30 MHz SDR reception paired with the ability to record WSPR/FST4W and HF Doppler shifts on multiple simultaneous bands makes the WSPRDaemon-Grape PSWS instrument an enticing tool for real-time assessment of radio propagation in the ham shack. If the data collected by the WSPRDaemon-Grape is properly processed and displayed, and possibly combined with measurements of other PSWS nodes and external space weather environmental information, a local PSWS Node will be able to provide an amateur radio operator with effective nowcasts of propagation openings that can aid in contesting, DXing, public service, and emergency management operations. Because the data display will primarily be driven by local measurements, it will give the operator a unique real-time view of conditions at their particular station. By combining those measurements with external observations and models, a global view of space weather and propagation conditions will also be available.

We propose a collaboration of members of the Frankford Radio Club, University of Scranton W3USR students and faculty, and HamSCI community members to develop a real-time Contesting/DXing Dashboard for the PSWS. Table 1 gives a timeline of the project. Starting in Spring 2025 semester, volunteer members of the FRC will visit the University of Scranton W3USR Amateur Radio Club and Dr. Frissell's EE-451 Communications Systems class for the purpose of promoting student interest and awareness in the project, and ultimately to recruit a paid summer research student to work on the project. During this time, the FRC volunteer mentors will work with W3USR students help teach contesting and DXing and help them to understand the propagation nowcast/forecast needs operators have. Dr. Frissell will work with the FRC mentors and students to help them understand the current capabilities of the HamSCI PSWS system and develop a design/requirements document for an effective Contesting and DXing Dashboard for the system. This initial design will be presented as a poster for discussion at the March 2025 HamSCI workshop to be held at the New Jersey Institute of Technology. Towards the end of the Spring 2025 semester, one student will be recruited as a paid summer research student who will work full-time on this project for 10 weeks under the advisement of both the FRC mentors and Dr. Frissell. The initial design requirements document will be finalized at the beginning of the Summer 2025 work period, and the paid student will work on implementing the system during the summer.

Design implementation will continue throughout the Fall semester by the student as a transcript recognition or for-credit research project. An initial prototype will be installed and operational at the W3USR amateur radio station in time for the Fall Contest season. W3USR club members and volunteers will use the prototype system throughout the Fall Contest season, review system design and operation, and revise the implementation plan as appropriate. An external, volunteer non-W3USR contest station will be identified to test a prototype PSWS installation during the Spring 2026 semester and contest season, in addition to the system that will remain operational at W3USR. Feedback from the contest station volunteer and from the W3USR operation will again be used in system development. A working prototype will be presented at the March 2026 HamSCI workshop and May 2026 Dayton Hamvention. A project final report and plans for next steps will be written at the end of the Spring 2026 semester. Software and hardware developed by this project will be released to the community under open source licenses.

Funding

Funding for the summer research student and some student conference travel will be provided by the Frankford Radio Club (FRC). PSWS stations at the W3USR University of Scranton station will be provided by the University of Scranton; PSWS stations at the volunteer contest station will be provided by the contest station or FRC. See Budget and Budget Justification for details. Project funds will be administered by the University of Scranton Office of Research and Sponsored Programs (ORSP) and University of Scranton Finance Offices.

Table 1: Project Timeline for the Development of the PSWS Contesting and DXing Dashboard

Spring Semester 2025	• Promote student interest and awareness through visits to W3USR club and EE 451 Communications Systems Class • Formulate initial design requirements for DX/Contesting Dashboard • Present initial ideas at the 2025 HamSCI Workshop (New Jersey Institute of Technology, March 14-15, 2025). • Identify and recruit paid summer research student to work on the project.
Summer 2025	• Finalize initial design requirements • Have student begin working on dashboard implementation with advisement of FRC mentors as part of 10-week full-time paid summer internship
Fall Semester 2025	• Student continues working on dashboard implementation with FRC mentors. • Install prototype at W3USR station and use during Fall contesting season. • Review system design and operation; revise impelementation plan as appropriate
Spring Semester 2026	• Install and test prototype a volunteer contesting station. Use during Spring contest season at volunteer contest station and W3USR. • Get feedback from contesters and incorporate into dashboard design. • Present results at March 2026 HamSCI workshop and May 2026 Dayton Hamvention • Write project report and plan for next steps.

References

Collins, K. (2023). Development of a scalable, low-cost meta-instrument for distributed observations of ionospheric variability (Doctoral dissertation, Case Western Reserve University). Retrieved from http://rave.ohiolink.edu/etdc/view?acc_num=case1670685416402421

Collins, K., Gibbons, J., Frissell, N., Montare, A., Kazdan, D., Kalmbach, D., … Chakraborty, S. (2023). Crowdsourced doppler measurements of time standard stations demonstrating ionospheric variability. Earth System Science Data, 15(3), 1403–1418. doi: https://doi.org/10.5194/essd-15-1403-2023

Collins, K., Kazdan, D., & Frissell, N. A. (2021a). Ham Radio Forms a Planet-Sized Space Weather Sensor Network. Eos, 102. doi: https://doi.org/10.1029/2021eo154389

Collins, K., Montare, A., Frissell, N. A., & Kazdan, D. (2021b). Citizen Scientists Conduct Distributed Doppler Measurement for Ionospheric Remote Sensing. IEEE Geoscience and Remote Sensing Letters. doi: https://doi.org/10.1109/LGRS.2021.3063361

Frissell, N. A., Ackermann, J. R., Alexander, J. N., Benedict, R. L., Blackwell, W. C., Boedicker, R. K., … Yadav, N. (2023). Heliophysics and amateur radio: citizen science collaborations for atmospheric, ionospheric, and space physics research and operations. Frontiers in Astronomy and Space Sciences, 10. doi: https://doi.org/10.3389/fspas.2023.1184171

Frissell, N. A., Kaeppler, S. R., Sanchez, D. F., Perry, G. W., Engelke, W. D., Erickson, P. J., . . .West, M. L. (2022). First Observations of Large Scale Traveling Ionospheric Disturbances Using Automated Amateur Radio Receiving Networks. Geophysical Research Letters, 49(5), e2022GL097879. doi: https://doi.org/10.1029/2022GL097879

Frissell, N. A., Katz, J. D., Gunning, S. W., Vega, J. S., Gerrard, A. J., Earle, G. D., . . . Silver, H. W. (2018). Modeling Amateur Radio Soundings of the Ionospheric Response to the 2017 Great American Eclipse. Geophysical Research Letters, 45(10), 4665–4674. doi: https://doi.org/10.1029/2018GL077324

Frissell, N. A., Miller, E. S., Kaeppler, S., Ceglia, F., Pascoe, D., Sinanis, N., . . . Shovkoplyas, A. (2014). Ionospheric Sounding Using Real-Time Amateur Radio Reporting Networks. Space Weather , 12(12). doi: https://doi.org/10.1002/2014SW001132

Frissell, N. A., Vega, J. S., Markowitz, E., Gerrard, A. J., Engelke, W. D., Erickson, P. J., . . . Bortnik, J. (2019). High-Frequency Communications Response to Solar Activity in September 2017 as Observed by Amateur Radio Networks. Space Weather , 17 (1), 118–132. doi: https://doi.org/10.1029/2018SW002008

Gibbons, J., Collins, K., Kazdan, D., & Frissell, N. (2022). Grape Version 1: First prototype of the low-cost personal space weather station receiver. HardwareX, 11, e00289. doi: https://doi.org/10.1016/J.OHX.2022.E00289

Griffiths, G. “Analysis of changes to propagation and refraction height on specific paths induced by the 14 October 2023 eclipse”, HamSCI Workshop 2024. HamSCI, Cleveland, OH, 2024. https://hamsci.org/publications/analysis-changes-propagation-and-refraction-height-specific-paths-induced-14-october

Kim, H., D. Witten, J. Madey, N. Frissell, J. Gibbons, W. Engelke, A. Liddle, N. Muscoliono, J. Visone, and Z. Cao (2024). Citizen science: Development of a low-cost magnetometer system for a coordinated space weather monitoring, HardwareX, https://doi.org/10.1016/j.ohx.2024.e00580

Perry, G. W., Frissell, N. A., Miller, E. S., Moses, M., Shovkoplyas, A., Howarth, A. D., & Yau, A. W. (2018). Citizen Radio Science: An Analysis of Amateur Radio Transmissions With e-POP RRI. Radio Science, 53(8), 933–947. doi: https://doi.org/10.1029/2017RS006496