Penn State G-Chaser PAWSS Payload
Analysis of the Cause of Polar Mesosphere Winter Echoes

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Abstract

Radar echoes in the VHF range are know as Polar Mesosphere Winter Echoes (PMWEs). These echoes are thought to be caused by radar reflections from the stratification of electrons into layers at around 70 km. The Polar Atmospheric Winter Student Sounding (PAWSS) payload aims to study PMWEs by analyzing polar gravity waves and their effect on neutral turbulence dynamics and their interaction with electron layering in the D region (50-90 km). PAWSS will fly on board the Grand Challenge Student Sounding Rocket (G-Chaser) in order to take the necessary measurements. G-Chaser will launch from Andøya, Norway on January 2019. The payload includes three systems- Lidar, TEC and Pulse Langmuir Probe (PLP). Measurements from these instruments will be analyzed in order to compile a atmospheric model of the rocket's trajectory. This model will consist of neutral turbulence and electron density layering. In situ rocket measurements will be supported by ground radar (EISCAT,MAARSY) and Lidar (ALOMAR), which will measure reflectivity and atmospheric dynamics during the flight.

Expected Results

- **We expect to see an increase of at least one order of magnitude in electron density as compared to the background, where the PMWE was detected.**
- **Figure 1 depicts what a VHF radar sees during a PMWE event.**
- **Electron density and neutral dynamics data will be provided by our on board instruments (TEC, PLP, Lidar).**
- **PAWSS measurements will add to the scarce record of atmospheric data below 60km.**

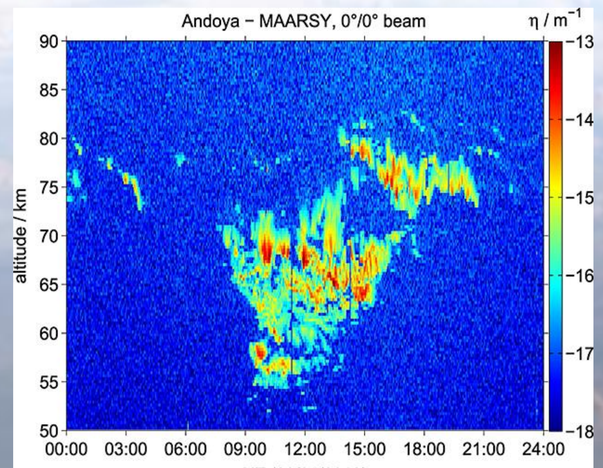


Figure 1. Data collected from MAARSY, Altitude vs. Reflectivity across a 24hr period. Provided by Latteck, R., Strelnikova, I. (2015).

Background

PMWEs can be detected using VHF radars typically operating in MHz. These echoes are caused by signals reflecting from electron layers in the atmosphere. These electron layers are formed as a result of gravity waves creating neutral air turbulence. PAWSS seeks to study this phenomenon by observing fluctuations in air and electron density as a function of altitude in order to observe electron layering and the gravity wave dynamics. PAWSS has the opportunity to provide much-needed *in situ* measurements of the atmosphere's D region. The D region of the atmosphere spans from 50 - 90 km above sea level. There are many complications when studying this region. Large changes in air temperature and density take place in this region, which makes in situ observation difficult. Therefore, very little in situ measurements of this region exist. The PAWSS team has specifically designed their instruments in order to overcome these challenges and expects to provide essential measurements to contribute to atmospheric models.

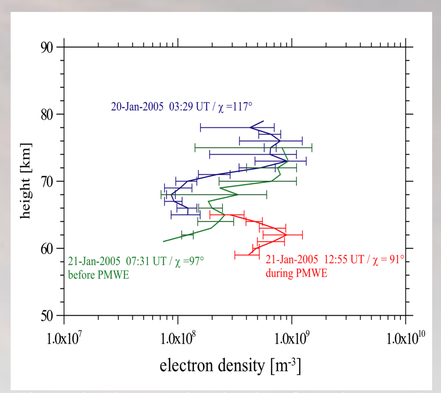
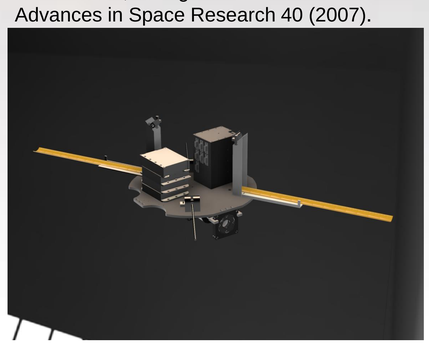


Figure 2. Electron density data from Saura MF radar before, during and . F.-J Luebken et al. Advances in Space Research 40 (2007).

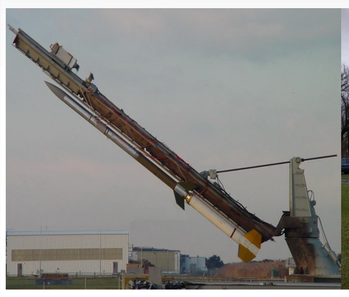


3D model of the Pawss payload. (2018)

Student Space Programs Laboratory

SSPL is a student run organization, its mission consists of giving students experience in space related fields and training them for employment in the space industry. Past and future projects include – SPIRIT I (2000), SPIRIT II (2003), ESPRIT(2006), OSIRIS-3U (2017), and G-Chaser (2019). In addition, SSPL provides student training programs to give newer students experience with the systems engineering approach to the design process. All of our past and future scientific instruments have been designed and built by students. Our current mission PAWSS will fly our very first Lidar instrument as a proof of concept along our PLPs and TECs. These missions not only serve the purpose of teaching students about engineering and science but also let them experiment and implement their designs on a spacecraft.

Missions



SPIRIT I launch, May 2000

Student training Program Rocket Launch Day (Team Kerbal), December 2016

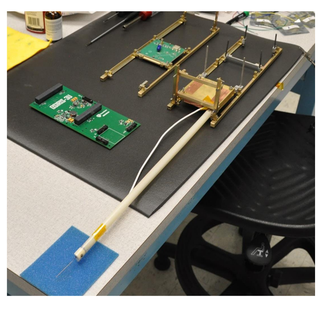
OSIRIS, June 2017

G-Chaser Team trip to NASA Wallops, May 2018

STUDENT SPACE PROGRAMS LABORATORY

Langmuir Probe

- **PAWSS will fly both a swept and a fixed probe driven by a student-built Pulsed Langmuir Probe.**
- **The PLPs should provide greater spatial resolution of electron density than TEC sensor.**

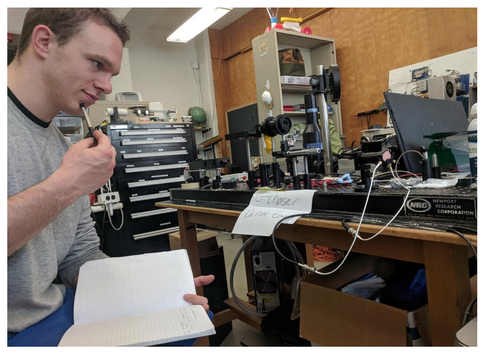


PLP testing of OSIRIS-3U (2017)

- **The probes on PAWSS will measure electron density in the range of 10^8-10^{11} e/m^3 with a resolution of approximately 3 m in order to examine the change in electron density.**

Lidar

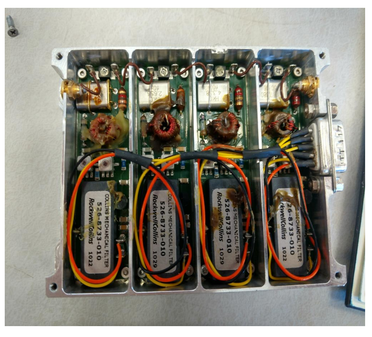
- **PAWSS Lidar will determine the density of neutral particles, mostly oxygen and nitrogen, to validate the correlation of neutral turbulence (gravity waves) to electron structure in the Ionosphere.**
- **Operating with a wavelength of 450 nm (Blue) and a vertical resolution of 3 m, will increase the volume backscatter cross section, allowing a greater number of returned photons.**
- **Built and designed by SSPL's Andrew O'neil**



Josh Davidson pictured testing the Lidar system. (2018)

TEC

- **TEC measures the Total Electron Count in order to compare data with the Langmuir Probes.**
- **Both an analog and SDR TEC will be flown.**



PAWSS analog TEC. (Designs provided by Martin Friedrich)

- **The SDR TEC was built and designed by SSPL students and will be flown as a proof of concept to one day replace the outdated analog model.**
- **Vertical resolution will be set to ~100m.**