Small Mission Accomplished by Students—Big Impact on Space Weather Research

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The Colorado Student Space Weather Experiment (CSSWE: http://lasp.colorado.edu/home/csswe/) is a three-unit (10 cm × 10 cm × 30 cm) CubeSat mission funded by the National Science Foundation, launched into a low-altitude, high-inclination orbit on 13 September 2012 as a secondary payload under NASA's Educational Launch of Nanosatellites (ELaNa) program. The ground station at the University of Colorado at Boulder (also designed and built by students) was able to find, track, and receive beacon packets during the CubeSat's first pass over Boulder. On 4 October 2012, the commissioning phase was completed and the science instrument, which measures energetic electrons and protons, was turned on.

CSSWE contains a single science payload, the Relativistic Electron and Proton Telescope integrated little experiment (REPTile). REPTile is a miniaturization of the Relativistic Electron and Proton Telescope (REPT) built at University of Colorado's Laboratory for Atmospheric and Space Physics (LASP) for the NASA/Van Allen Probes mission (http://vanallenprobes.jhuapl.edu). REPTile is designed to measure the directional differential flux of protons ranging between 10 and 40 megaelectron volts (MeV) and electrons ranging between 0.5 and >3.3 MeV. These energetic particles can affect the operations and lifetimes of Earth-orbiting spacecraft and have harmful effects on astronauts during their extravehicular activity. Solar particles incident over the polar caps also produce ionosphere disturbances that can affect radio frequency communications.

CSSWE data are stored onboard an SD card and downloaded at a rate of 9.6 kbps at 437.345 MHz (UHF) when the CubeSat passes over the Boulder ground station, with an average of seven passes each day (three to four ascending and three to four descending). All science and housekeeping data can be downloaded within 1 day. And data for any time period can be re-requested.

The science objectives of CSSWE [*Li et al*., 2011] have profound space weather implications. With its current orbit, 490 km × 790 km altitude and an inclination of 65°, CSSWE measures energetic particles coming directly from the Sun while the CubeSat traverses the polar regions where Earth's magnetic field lines are directly connected to the interplanetary magnetic field. At lower latitudes, CSSWE measures radiation belt particles trapped by Earth's magnetosphere.

The clean measurements from REPTile reveal the detailed structures and dynamic variations of MeV electrons in both outer (L = 3–8) and inner (L = 1–2) radiation belts, as shown in Figure 1. In conjunction with similar measurements (not shown here) from Van Allen Probes at low inclination, the measurements show that (1) outer belt electrons are dynamic with continuous pitch angle scattering, (2) inner belt electrons are more stable, mostly confined to the equatorial region, and (3) lower energy electrons (0.5–1.7 MeV) can penetrate deep into the radiation belt slot region (L = 2–3) and even the inner belt region during geomagnetically active times (there was a geomagnetic storm during 8–9 October). REPTile also provides clean measurements of energetic protons.

Education is a central part of the CSSWE program and small missions, such as CubeSats, provide an excellent opportunity to train the next generation of scientists and engineers on the full lifecycle of spacecraft design, test, and operation. The CSSWE program was run as a for-credit course in the Department of Aerospace Engineering Sciences at the University of Colorado at Boulder. Over 60 students, both graduate and undergraduate, from departments across campus including aerospace, mechanical, and electrical/computer engineering, astronomy, and planetary sciences participated in the project. Professional engineers and scientists from LASP provided the students with advice and mentorship throughout all stages of the project. The success of this mission shows that clean measurements of energetic electrons and protons in the near earth environment are achievable with a CubeSat that is designed, built, tested, calibrated, and operated by students. CSSWE also exemplifies the value of pico-satellite missions in providing, at low cost, important scientific measurements complimentary to larger missions such as the Van Allen Probes.

Reference

Li, X., S. Palo, and R. Kohnert (2011), Small space weather research mission designed fully by students, *Space Weather*, *9*, S04006, doi:10.1029/2011SW000668.

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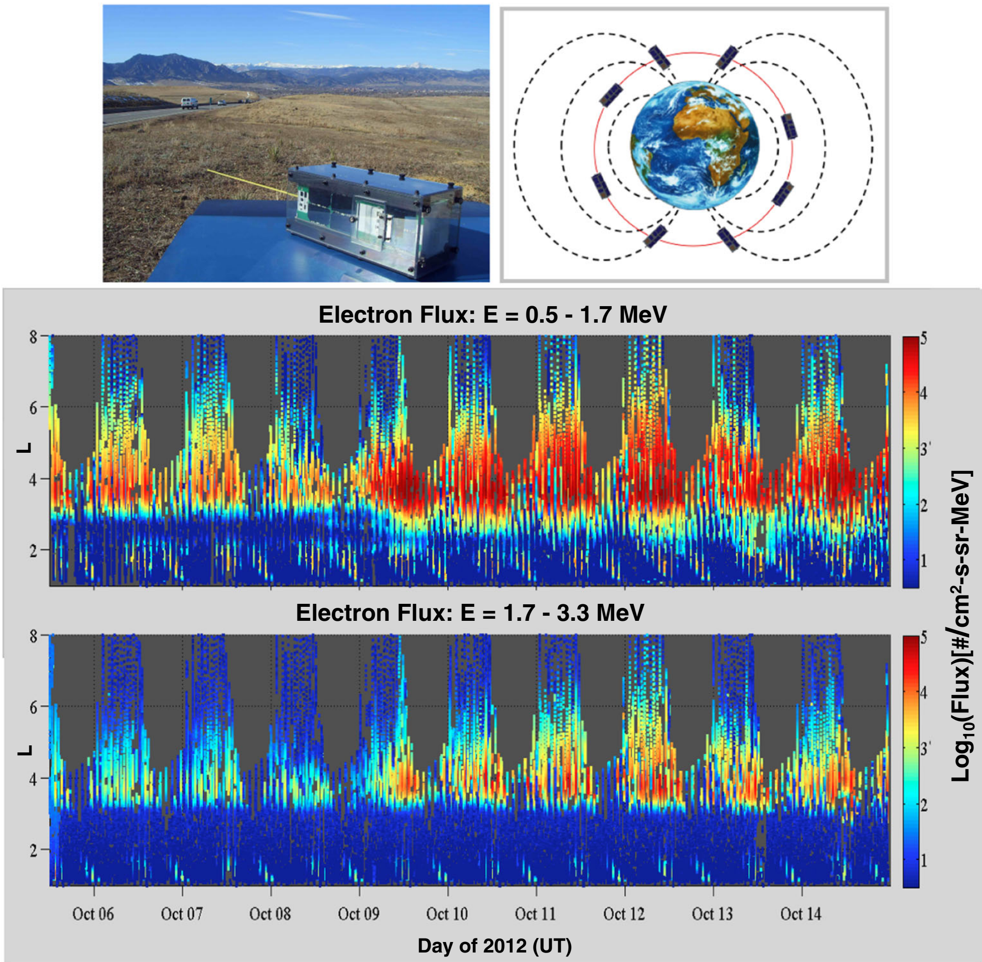

Figure 1. A picture of the CubeSat during testing (top left) and a schematic view of the CubeSat's orbit and orientation (top right)—the CubeSat has a passive magnetic attitude control system that will always try to align the long axis of the satellite with the local magnetic field. First 10 days measurement of the electron fluxes in different energy channels, color-coded in logarithm, and sorted in L-value, which can be viewed as the equatorial radial distance in units of Earth radii for the same magnetic field line if Earth's magnetic field can be approximated as a dipole (bottom).

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