PROPCUBE Radio Beacons in Low Earth Orbit for Ionospheric and Radio Astronomical Applications

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ABSTRACT

Three PROPCUBE satellites were developed by TYVAK Nano-Satellite Systems with a proprietary design for the versatile beacon transmitters and a COTS single frequency GPS receiver. The PROPCUBE beacon transmits 380 to 400 MHz and 2340 to 2380 MHz from low earth orbit. Two PROPCUBE satellites were launched in October 2015 for ionospheric observations and precise satellite orbit determination with the dual frequency beacon on the satellites. The two of the PROPCUBES are placed into the same 500 km orbit with an inclination of 63 degrees. The third PROPCUBE is awaiting launch around June 2016 during the Formosat-5 mission into a 97.4 degree inclination orbit with 450 km perigee and 720 km apogee. The beacon transmissions will be either continuous wave or modulated with broadband (1 MHz) ranging codes. These signals travel from omni directional antennas on the cubesats to several receivers provided by the Naval Research Laboratory, MIT Haystack Observation, Naval Post Graduate School, Kyoto University and other collaborators around the world. These receivers will record the complex amplitude signals giving data which can be analyzed to yield (1) the total electron content (TEC) between the satellite and the ground receiver, (2) the Doppler shifted frequencies, (3) the group delay introduced by the ionosphere and by the physical propagation distance, (4) the precise (meter scale) position of the satellite in geographic (x, y, z) coordinates as a function of time, (5) the intensity of both phase and amplitude scintillations introduced by propagation though irregularities in the ionosphere, and (6) mapping of large antenna patterns such as the Arecibo 300 meter dish and other large radio telescopes. To observe the PROPCUBE signals, NRL and collaborators have constructed coherent UHF/S-Band receivers with a software defined interface. This receiver will digitize the down-converted 380 MHz and 2380 MHz beacon signals. Signal post-processing will yield the desired engineering data products. The ionospheric information will include electron density maps of the ionosphere and radio scintillation correlations with ionospheric irregularities. The satellite positions determined using Doppler ranging analysis will be

compared with the orbits determined with the GPS receiver on each cubesat. The radio telescope calibration will provide antenna gain as a function of angular position in the radio astronomical antenna beam. The PROPCUBE mission is of interest to NRL basic research to demonstrate (1) the capability of beacon cubesats for determining potentially harmful effects of the ionosphere on radio systems, (2) techniques for tracking multiple cubesats immediately after deployment from a lunch vehicle, and (3) showing the added value of radio beacons for complementing ground based soundings of the ionosphere.

Key words: Low Earth Orbit (LEO) beacons, PROBCUBE, Ionospheric TEC and Scintillations

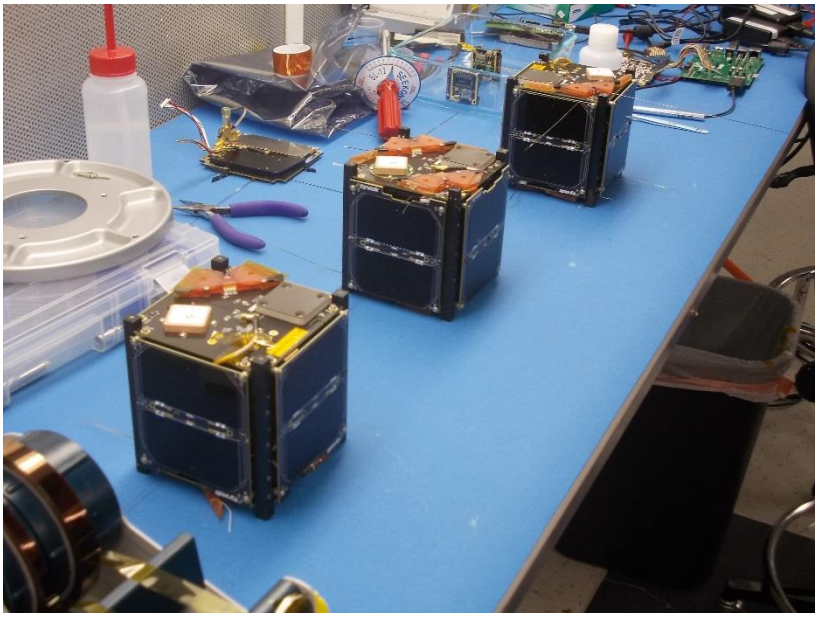

Figure 1: PROPCUBES Flora, Fauna, and Merryweather ready for flight.

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