E205-001 **Room: 201B** **Time: May 18 9:00-9:15**

VLF wave Particle precipitation Mapper (VPM)

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VLF wave ParticlePrecipitation Mapper (VPM) is a Stanford University proposed Cubesat-based mission, consisting of the two co-polar-orbiting VPM spacecraft at LEO are envisioned to provide key spatial and temporal measurements of both the ELF/VLF waves injected as well as any resultant electron precipitation induced by such waves. The primary scientific objective of the VPM mission is to determine energy spectra, temporal signatures, and spatial extent of energetic electron precipitation bursts induced by discrete whistler-mode waves, launched by ground-based sources, such as lightning discharges. It is well known that waves from ground-based sources propagate in the Earth-ionosphere waveguide and enter the radiation belts over broad regions, thus illuminating large latitudinal sectors of the radiation belts, corresponding to regions of ˜1000-km extent at ionospheric heights. The wave-induced precipitation driven by ground- and/or in-situ transmitters are thus distributed over such large regions, as predicted both theoretically and also measured indirectly with ground-based techniques. No direct confirmation of precipitation over regions of such large extent by individual wave bursts has yet been observed in situ. Quantitative determination of the relationship between wave power density entering the magnetosphere and the resultant precipitation flux is crucially important and measurement of the spatial extent is as important as measurement of flux levels. Realization of the primary science objective as articulated above requires the measurement of the waves in broadband fashion so as to identify those from different sources, with high-time and frequency resolution. Simultaneous measurement of energetic electrons is also needed with high-sensitivity (large geometric factors), high time and energy resolution, so as to assess cause and affect relationships and calibrate theoretical models (by determining the flux levels that result from given levels of wave power density) and ongoing ground-based measurements. A unique aspect of the VPM mission is the measurements of electrons simultaneously at two points separated along a polar orbital track to determine the latitudinal extent of precipitation regions illuminated by waves from different sources (e.g., lightning). Especially for waves of a transient nature, such as whistlers from lightning, precipitation bursts impinge on ionospheric altitudes (i.e., LEO), nearly simultaneously at different points along a latitudinal track, but with measurable delays with respect to the causative lightning (fractions of a second) and with differential delays (e.g., ˜100-ms over a latitude range of several degrees) between two points along a polar orbital track. GPS-based timing, providing 100-ns accuracy facilitates direct comparison of event onsets as measured on the spacecraft and ground, and between the two spacecraft. The availability of GPS-based timing, and the resultant realization of less than 100 ns absolute timing accuracy facilitates phase coherent measurement to realize interferometry between the two spacecraft and between spacecraft and ground-based VLF sites. One objective of such measurements would be to determine the structure and distribution of field aligned irregularities, the presence of which is an important factor in trans-ionospheric propagation of ELF/VLF waves, and thus for concepts of ground-based remediation.