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Space Weather Effects on the Orbit of the CUAVA-1 Satellite and a Possible Future Australia-led Space Weather Satellite Project

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This presentation is two parts. The first being space weather effects on the orbits of the CUAVA-1, CUAVA-2, and Waratah Seed-1 CubeSats developed by the ARC Training Centre for CubeSats, UAVs, and Their Applications (CUAVA). The second describes the plan for an Australia-led but international satellite constellation focused on terrestrial space weather research and space situational awareness.

First, we investigate the effects of space weather on the orbit of the CUAVA-1 CubeSat between October 2021 and November 2022. Two orbital parameters, the time derivative da/dt of the semi-major axis and the B^* drag coefficient, derived from Two-Line Element data, are compared with 1-day averages of the Dst and Kp geomagnetic indices, F10.7 cm solar radio flux, EUV MgII index, and X-ray flux. Time series of the orbital parameters show events superposed on slowly varying secular changes with some noise; these events are correlated with changes in the F10.7 and MgII time series, but not the others. Spectral analyses reveal periods close to 25 ± 2 days. The cross-correlation functions for most time series have a well-defined, classic, shape with quasi-periodic ≈ 25−29 day oscillations and maximum correlations at lags close to 0 days: da/dt and B^* are well correlated with each other, MgII, F10.7, and the X-ray flux, but less significantly with Kp and Dst which have a much narrower central peak. As 25 ± 2 days is close to the Sun's synodic equatorial rotational period, the interpretation adopted is that EUV and other radiation from persistent solar active regions cause enhanced ionisation and heating of the sub-solar atmosphere, while geomagnetically-driven particle precipitation and joule heating do likewise at auroral and polar latitudes, resulting in expansion and so enhanced spacecraft drag. This confirms via different techniques and orbital data earlier analyses and models focused directly on drag measurements and neutral densities. Atmospheric expansion should be rapid (≪ 1 day). The foregoing approach is extendable to any tracked satellite, potentially offering extension to thousands of orbiting satellites and thus simultaneous three-dimensional data on neutral atmosphere changes, satellite drag, and orbits around the globe.

Second, a group of Australian and international colleagues is developing an Australia-led but internationally linked satellite constellation to address space weather and space situational awareness. Currently titled MESSENGER (for Monitor Earth's Space Situational Environment, Navigation, Geosensing, and Electromagnetic Radiation), the project involves two 6U or 12U CubeSats in Sun synchronous orbits with a common bus design based on the successful CUAVA-2 and Waratah Seed-1 CubeSats (launched 16 August 2024). Intended to be research infrastructure that provides data for Australian and international researchers and industry groups, the goals include (1) exploring Earth's "ignorosphere" and measuring Earth's neutral, plasma, radio, and space debris environments in time and three-dimensional position, (2) performing GNSS remote sensing of the ionosphere, sea-ice boundaries, atmospheric and ionospheric disturbances, soil moisture levels, and natural hazards, and (3) measuring satellite drag and performing Precise orbit Determinations (PODs). We will describe the current status of the project, for which we are still seeking collaborations, instruments, and funding to implement.