Van Allen Probes On-Orbit Dynamics Performance

Uday J. Shankar[(1)], **Madeline N. Kirk**[(2)], **and Gabe D. Rogers**[(3)]
[(1)(2)(3)] *JHU/APL, 11100 Johns Hopkins Road, Laurel, MD 20723*
[(1)] *240-228-8037, uday.shankar@jhuapl.edu*

ABSTRACT

The Van Allen Probes were launched into Earth orbit on August 30, 2012 for a nominal two-year mission to study the Earth's radiation belts and their interaction with the Sun as part of NASA's Living With a Star Geospace Program. The two nearly identical spacecraft are spin-stabilized at approximately 5.5 RPM, flying in highly elliptic orbits to pass within and immediately exterior to the Van Allen Radiation Belts. An instrument used for electric field measurement dominates the dynamics of the probes. This paper examines the dynamics performance of the Van Allen Probes and compares the on-orbit performance to pre-flight predictions. This also serves to validate the models used for the predictions.

The Electric Fields and Waves (EFW) instrument uses two sets of long thin wires for electric field measurements. Each set forms an electric dipole a hundred meters long, held in tension by the centripetal force of the spinning spacecraft. While these wires weigh less than one percent of the mass of each spacecraft, they account for about four-fifths of the inertia. They dominate the dynamics of the spacecraft—a classic case of the "tail wagging the dog." This complex dynamics is evident during spacecraft maneuvers (re-orientation, collision avoidance, spin-up/down, and during the deployment of the wires). In addition, the spacecraft dynamics gets perturbed during perigee passes (due to expansion of the wires from heating from earth albedo) and during eclipses (due to the contraction of the wires due to cooling). To quell the disturbances arising from these effects, each spacecraft carries passive fluid-filled nutation dampers.

Extensive analysis was conducted prior to launch. Detailed simulations ensured the spacecraft would satisfy all attitude control and estimation requirements. Linearized models were used to predict dynamics modes (frequencies, mode shapes, and damping times). At that time, the two dipoles were designed to be at different lengths: one at hundred meters and one at eighty meters. Just prior to launch, the concept of operations for the EFW changed and it was decided to extend both dipoles to a hundred meters each. A quick study revealed that this resulted in no major changes to the dynamics (stability, etc.). This paper updates the predictions based on the new lengths and on the as-flown mass properties of the spacecraft and wires. While there are no major changes, there are subtle changes that are worth examining.

The Van Allen Probes have been operational for over a year and a half. During this time, both spacecraft have been subjected to many maneuvers and have flown through many perigees and eclipses. The spacecraft carry a set of sun sensors and a magnetometer. The sun sensors provide a sun pulse (and thus a spin period) and a sun aspect angle when not in eclipse. The magnetometer provides a measurement of the earth's magnetic field. The magnetometer data can be used to estimate spacecraft spin rates—but only when the magnetic field is not rapidly changing. This paper examines the telemetry data to validate the dynamics predictions.