Drag and O-atom Exposure Modeling for Satellites in Very Low Earth Orbit

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Abstract

Operating satellites in very low earth orbit (VLEO), approximately between 100-300km altitude, has numerous advantages. One advantage is close proximity to earth, which can enable accurate sensing with significantly lower SWaP+C (size, weight, and power + cost). Another advantage is that VLEO is effectively a "self-cleaning-orbit" where unpowered spacecraft will quickly re-enter the atmosphere and burn up; thereby reducing or avoiding the space debris problem. However, operating in VLEO comes with significant challenges compared to conventional LEO satellites. Major challenges include atmospheric drag in the rarefied (and highly variable) upper atmosphere and material degradation due to atomic oxygen impacts at orbital velocity. Future VLEO spacecraft will require drag-reduction strategies such as maintaining a ram-facing orientation that minimizes cross-sectional area and advanced materials/coatings that are both O atom resistant and low-drag. For these reasons, the scattering dynamics of high energy atoms and molecules on various materials becomes important to characterize. In this presentation, a new gas-surface scattering model, that is able to reproduce a wide range of molecular beam surface scattering data on various satellite materials, is summarized. This scattering model is implemented within a three-dimensional direct simulation Monte Carlo (DSMC) code and simulations are performed to understand how an accurate scattering model influences the drag coefficient for various satellite-relevant geometries and the resulting influence on expected satellite lifetime in VLEO. Furthermore, the simulations predict local forces on all satellite surfaces and therefore moments about the center of mass. Combinations of surface orientation and local scattering dynamics can lead to either 'aerodynamic' stability or instability, which is important when trying to maintain a ram-facing orientation to minimize drag. Finally, the DSMC simulations are able to capture O atom buildup within open cavities and some exemplary results will be presented to quantify potential O atom damage on internal satellite components.

Keywords: Very low Earth orbit, Atomic oxygen, Molecular beam, surface scattering, Satellite drag, Numerical simulation

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