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SPACE DEBRIS SYMPOSIUM (A6)
Mitigation and Standards (4)

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NEW INSIGHTS INTO THE STABILITY OF THE SPACE DEBRIS ENVIRONMENT

Abstract

This paper describes the evolution of the space debris environment by partitioning debris fragments into classes based on size (cross section) and mass. It extends the aggregated nonlinear analyses that demonstrate that the debris environment is unconditionally stable but chaotic and unpredictable. Collisions of each class with active satellites or other classes produces objects of lesser mass or size until the last class is so light or small that collisions among fragments of that class annihilate the objects. For example, collision of a large object with a smaller object produces fragments of the next smallest class from each object. The process is governed by a set of coupled, nonlinear ordinary differential equation. These can be cast in canonical form and linearized about equilibrium states when such exist. The characteristics of the eigenvalues and eigenvectors of controlling matrices determine stability. This is a relatively classical predator-prey problem such as when bears prey on foxes that prey on small rodents until the lowest class might be an herbivore that preys on no other animals. When predators exhaust the prey, they prey on each other until the species is extinguished. However, depending on the resources available for reproduction, prey populations are usually refreshed. There is a rich literature in population dynamics and epidemiology. In this paradigm there is almost always a stable equilibrium that balances predators and prey, generally with a preponderance of prey and a minority of predators. We will show that the debris evolution is unconditionally stable at any degree of disaggregation. As has been demonstrated, the equilibrium populations and the rate of approach to equilibrium can be adjusted by controlling satellite deployment rates, satellite sizes, and orbit velocities. Previous analyses considered only two classes: active satellites and debris. When more classes are considered, control parameters also influence the size distribution of the debris population. We also consider size classes of active satellites, which obviously do not create more, smaller satellites when they collide. We hope to examine the tradeoff between satellite size and the accompanying need for more satellites. One decreases collision frequency while the other increases it. Mankind's presence in near Earth space must contaminate the environment with debris. Our goal is a sustainable presence despite debris.