Paper ID: 21798
oral

SPACE DEBRIS SYMPOSIUM (A6)
Modelling and Orbit Determination (9)

Author: Dr. David Finkleman
SkySentry, LLC, United States

Dr. Kenneth Chan
United States

ANALYSIS OF ASSUMPTIONS IN DEBRIS ENVIRONMENT EVOLUTION MODELS

Abstract

This paper examines the assumptions incorporated in major simulations of the evolution of the space debris environment. It extends and amplifies past reports, adding new and alternative insights. The 1999 COPUOS Report partitions models as discrete or engineering approximation and long term or short term. There has been no comprehensive assessment since. There are several independent approximations to initial populations, fragments created by collisions and explosions, and propagating fragments. Some are highly aggregated for synoptic behavior. Some are extremely detailed. We consider the fundamental physical assumptions in each class. The most pervasive assumption is particle behavior according to analysis of gas kinetics. Collision rates are generally taken proportional to the product of particle density, area, and relative velocity between objects. This kinetic theory result is based on: uniformly distributed particle velocity vectors, a sufficient sample of objects to define a statistical mean density, and random thermal motion among an aggregation moving at a uniform velocity. None of these is valid for the population of satellites and debris. There are only a few tens of thousands in a volume on the order of 1012 cubic kilometers. Relative velocities can vary deterministically from fractions of a meter per second to ten of kilometers per second. The relevant area of contact can also vary by orders of magnitude. The alternative is to propagate each member of the cohort and trace each collision and its consequences. This will probably be infeasible computationally. Often, the centers of mass of collections of fragments are propagated, and collisions inferred for these collections. Since orbits are uncertain, there is also uncertainty in the collision location and frequency as well as the number of fragments that might be created. Since the fragments are statistical entities, subsequent collisions they might have are even more deeply random and statistical. Monte Carlo realizations of possible collisions are compounded by Monte Carlo fragment distributions and exponentially compounded further collisions and random processes. Most keep track of fragments only above a certain size. Many models strive to conserve mass and energy. Some mass must disappear through reentry and leakage out of the volume. Energy is dissipated and transformed from kinetic energy to thermal energy and fragment dynamics. Nonetheless, some introduce additional large fragments whose mass accounts numerically for that lost. This is feedback that can drive instability. We will comment on and illustrate the effect of several other assumptions and their effect on outcomes.