Orbit Processing and Analysis of a GEO Class of High Area-to-Mass Debris Objects

Tom Kelecy
Boeing LTS / AMOS, Kihei, HI and Colorado Springs, CO
Tim Payne
Air Force Space Command / A9AC, Colorado Springs, CO
Robin Thurston
1st Space Control Squadron / DOMA, Colorado Springs, CO
Gene Stansbery
NASA JSC-KX, Houston, TX

ABSTRACT

A population of recently discovered deep space objects is thought to be debris having origins from sources in the geosynchronous orbit (GEO) belt. Observations have been presented indicating that these objects have area-to-mass ratios (AMR's) of anywhere from 1's to 10's of m^2/kg, and thus would explain the observed migration of eccentricity (0.1-0.6) and inclination that distinguishes their orbital characteristics. The solar radiation perturbations on orbital period, inclination and eccentricity over a 20 year period for AMR's of 0.01, 1, 10 and 20 m^2/kg, are shown in the Figures 1.a-c. There is a heightened interest in the international community due to the large number and small size of these objects, as they pose a hazard to active satellites operating in the vicinity of the GEO belt.

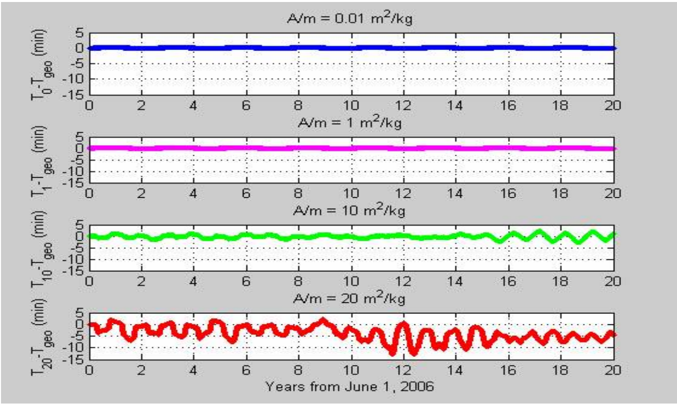

Fig. 1.a. Deviation from GEO Period 20-year Histories for A/m = .01, 1, 10 and 20 m^2/kg

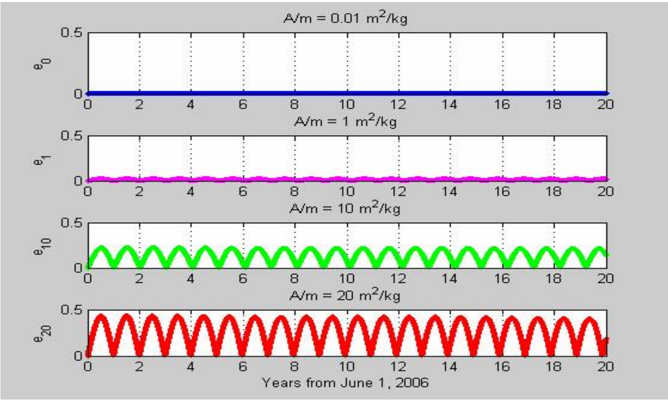

Fig. 1.b. Eccentricity 20-year Histories for A/m = .01, 1, 10 and 20 m^2/kg

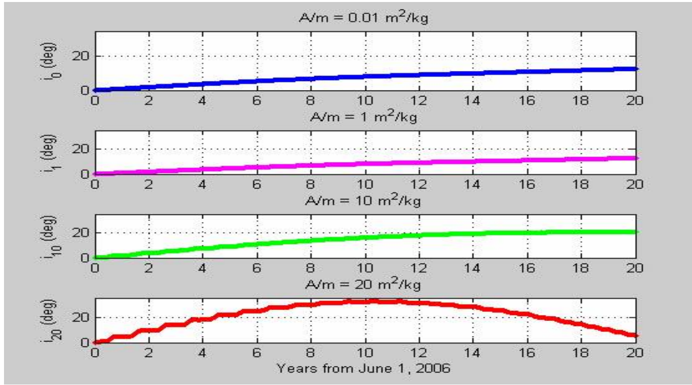

Fig. 1.c. Inclination 20-year Histories for A/m = .01, 1, 10 and 20 m^2/kg

It has been hypothesized that this class of debris originated from thermal insulation (e.g. MLI), or similar materials. Observational coverage of these objects has been limited by the orbital phasing and the locations of the tracking sites. Boeing, NASA and the U.S. Air Force Space Command have embarked on a collaborative effort with the Inter-Agency Space Debris Coordination Committee (IADC) to track selected high AMR of this population to more accurately characterize their orbits and orbit histories. Space Command tracking assets were tasked to provide angles measurements for representative set of high AMR debris objects, and the data were used to update the orbits, including estimation of AMR, and to provide a source for predictions to support follow-up observations.

Thus, one of the chief problems is that of the migration of the orbital elements resulting from solar perturbations. The longitudinal migration, along with the dimness and variability of the visual magnitudes make them a challenge to track consistently. The ground traces of 6 example debris objects is shown in Figure 2, where the ground traces represent one cycle. The other chief problem addressed is that of the AMR estimates. A Kalman filter process (the Orbit Determination Tool Kit) provides the capability to effectively estimate time variations of the AMR, as shown in Figure 3. The estimation corrections are seen to vary about a nominal value, as would be expected for a "tumbling" piece of debris, though the AMR signature for each object is somewhat unique.

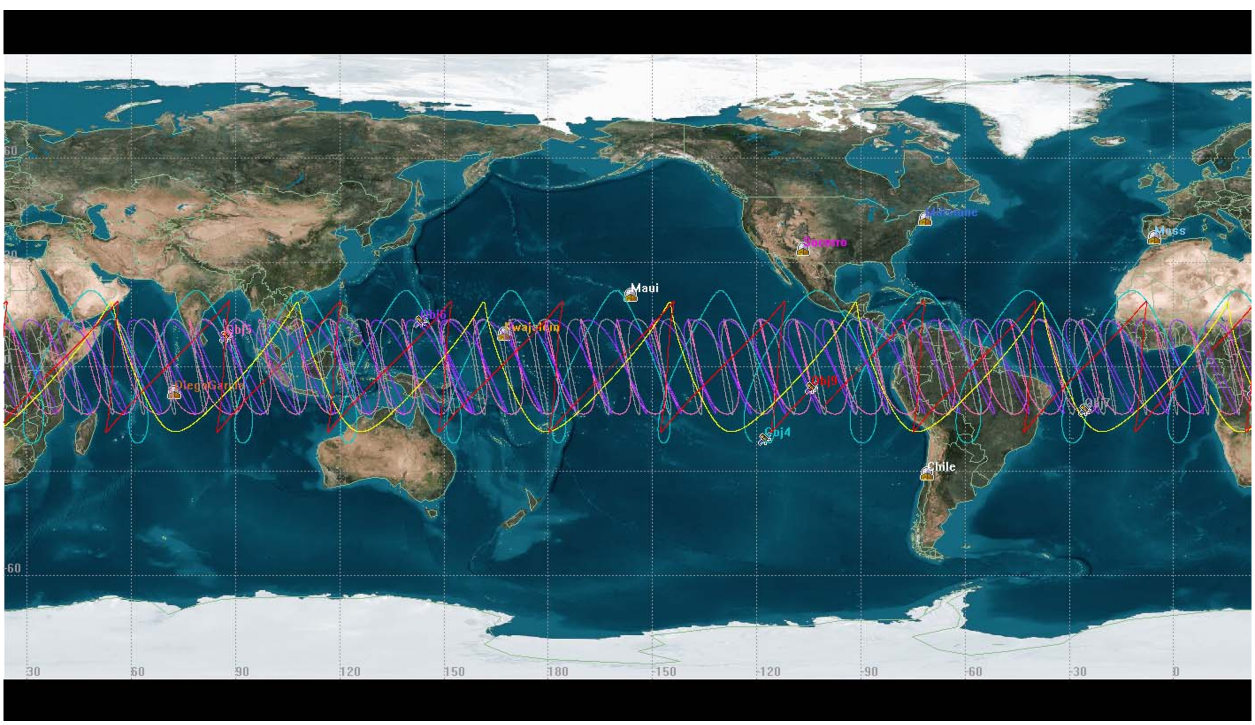

Fig. 2. 2-Dimensional Ground Trace Visualization for Six Example High AMR Debris Objects

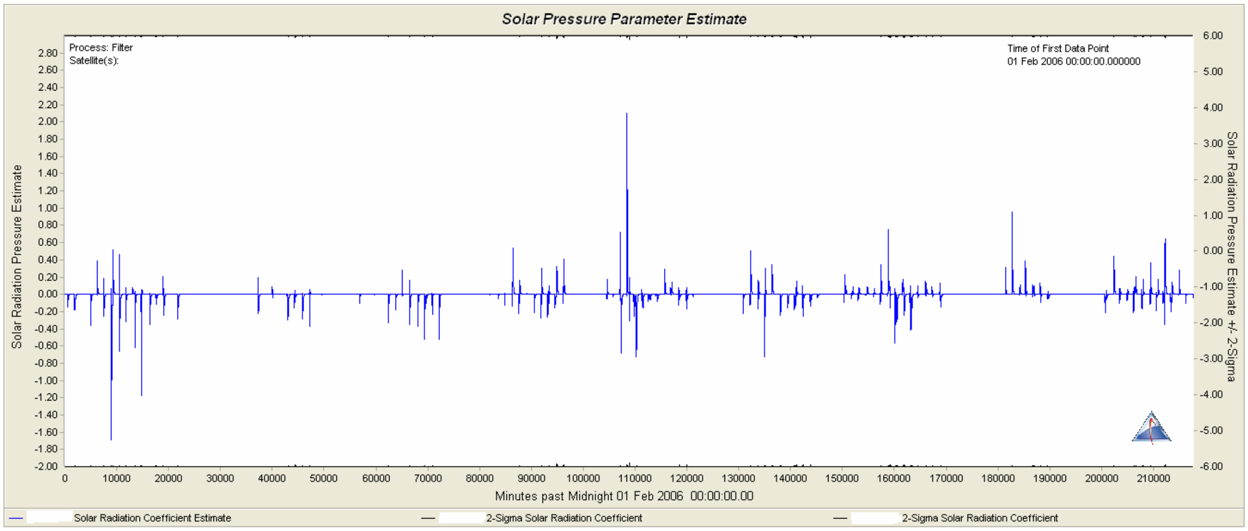

Fig 3. ODTK AMR Correction Estimates for Obj#6 (152 day span)

The orbit determination analysis indicates that the AMR variations are not always regular, and can have significant "spikes" over certain periods, likely orientation dependent. The best results were achieved when process noise was added to the AMR, not only along the sun line, but in directions orthogonal to the sun line (ecliptic plane and ecliptic north directions). Appropriate bounding of the AMR via the a priori sigma for that parameter accommodates the "nominal" variations, and translates into more realistic state covariance values for the estimated position/velocity state. If periodic behavior is noted in the AMR estimates, the parameter can be modeled to produce more accurate predictions. Along-track error growth rate for given object is correlated to the magnitude of the variability of that object's AMR.