Impact of the time span selected to calibrate the ballistic parameter on spacecraft re-entry predictions

C. Pardini and L. Anselmo

Space Flight Dynamics Laboratory, ISTI/CNR, Via G. Moruzzi 1, 56124 Pisa, Italy

(Carmen.Pardini@isti.cnr.it / Fax: +39-050-3153016 / Phone: +39-050-3152987)

The trajectory modelling of satellites which are re-entering the Earth's atmosphere, as a result of the natural orbital decay, has always been a challenging task. Residual lifetime estimations and re-entry predictions are affected by substantial uncertainties, associated with the atmospheric density models, with the forecasts of the relevant solar and geomagnetic activity indices and with the tracking data, which for uncontrolled re-entries are usually sparse and not particularly accurate. Furthermore, modelling the aerodynamic forces acting on low altitude satellites is a formidable task, especially for objects with a complex shape and unknown attitude evolution.

The ballistic parameter, defined as $B = C_D A/M$, where C_D is the drag coefficient, A the effective cross-sectional area and M the mass, incorporates the uncertainties related to the physical characteristics and attitude of the satellite, as well as to the complicated interaction between air molecules and satellite surface. Eventually, as the uncertainties affecting the drag force computation are driven mainly by the product of air density and ballistic parameter, the latter may be adjusted as to force the atmospheric density model to agree with the air drag revealed by the tracking data. Then, the value of B giving the best numerical fit between the estimated and the observed orbit, in a given time/data span, may be used to propagate the last available state vector, so as to calculate the satellite's residual lifetime.

However, the value of B may fluctuate from one data fit span to another, depending both on how the true density differs from the modelled one and on possible changes of the satellite's attitude. Of course, different values of B reflect in different estimations of the satellite's lifetime and re-entry epoch. Therefore, the choice of the suitable, if any, time/data span to calibrate the ballistic parameter is a very tricky problem during a re-entry campaign.

Trying to assess the impact of the aforementioned time/data span on satellites re-entry predictions, the past seven Inter-Agency Space Debris (IADC) re-entry test campaigns, covering a substantial fraction of a solar activity cycle, from 1998 to 2005, were reconsidered in a post-event analysis. For each satellite, atmospheric density model and observed solar and geomagnetic activity, various time/data spans were investigated to find the ballistic parameter best suited for re-entry predictions, as a function of the residual lifetime.