 Paper ID: 13348
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SPACE DEBRIS SYMPOSIUM (A6)
Modelling and Risk Analysis (2)

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A PROPOSED MODEL FOR PREDICTIONS OF RE-ENTRY TIME AND IMPACT LOCATIONS OF RISK OBJECTS AND ASSESSMENT OF ATMOSPHERIC DENSITY MODELS

Abstract

The uncontrolled re-entry of space objects as the result of the natural decay of the orbits due to atmospheric drag is the main sink mechanism for the reduction in the number of space debris objects that progressively accumulate in the space prohibiting space utilization in its full potential. The uncontrolled re-entry of space object can pose great risks of impact on the Earth. Uncontrolled re-entry trajectory modelling of space objects is still a challenging task. As satellite orbits decay, the orbital altitude decreases so that aerodynamic drag becomes an increasingly dominant factor in perturbing the orbit. Accurate estimates of atmospheric density, drag coefficient, solar flux and geomagnetic index are very important to model the orbital evolution. Modelling uncertainties in atmospheric density can result in significant variations in prediction of orbital lifetime. Residual lifetime estimation, re-entry time and impact location prediction are affected by uncertainties in atmospheric density models, solar flux and geomagnetic indices and other initial conditions.

This paper represents a model for the re-entry time and impact location prediction using the concept of minimizing the dispersions on the re-entry time and the impact locations from various Two Line Elements (TLEs). This is achieved by estimating an optimal ballistic coefficient which gives the minimum dispersions in re-entry time and impact locations. Parameters for multi objective function taking into account the re-entry time, latitude and longitude are estimated from a set of TLEs and propagating the orbit until perigee altitude of becomes negative. Software Satellite Tool Kit (STK) is used for the analysis.

The effectiveness of the model is checked against the known recent re-entries of risk objects namely ROSAT and PHOBOS GRUNT. Comparisons of the results using various atmospheric density models, namely Jacchia-Roberts (JR), Mass Spectrometer Incoherent Scatter Extended Model 1990 (MSISE-90) and Naval Research Laboratory's Mass Spectrometer and Incoherent Scatter Radar Empirical Model (NRLMSISE2000), are also carried out. These atmospheric density models required two different environmental inputs, geomagnetic index (Kp) and solar flux index (F10.7), to represent the effects on the atmosphere of the solar-terrestrial interactions. Daily observed values along with forecasts of these indices are used.

Apart from presenting the robust model for the prediction of re-entry time and impact location, the present study gives a good insight into the behaviour of various atmospheric density models used in the estimation process of re-entry and impact location of satellite.