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PRACTICAL ORIGIN IDENTIFICATION OF ON-ORBIT SATELLITE FRAGMENTATION FROM IN-SITU SUB-MILLIMETER-SIZED DEBRIS MEASUREMENTS

Abstract

This paper verifies an origin identification in a more realistic environment considering collision probability. To enhance the modeling of tiny space debris with a size of 0.1 and 2 mm (sub-millimeter-sized debris), which cannot be observed from the ground, the origin identification has been initiated at Kyushu University. This effort involves estimating some orbital parameters of a broken-up object by in-situ debris measurements of the sub-millimeter-sized debris from a breakup. The in-situ Debris Environmental Awareness (IDEA) project is a suitable example. A measurement satellite developed by this project has debris impact detectors mounted on its surface. They record position and time data when the sub-millimeter-sized debris collides with the measurement satellite. The origin identification can be performed using these data. Although the IDEA project has ended, a similar measurement satellite remains essential. In previous studies, a close approach analysis between the measurement satellite and the sub-millimeter-sized debris was conducted for the origin identification. The measurement satellite was assumed to detect the sub-millimeter-sized debris when the relative distance is small. However, not all the sub-millimeter-sized debris in the small relative distance would be detected. Therefore, this paper verifies the origin identification in the more realistic environment considering collision probability.

This paper uses the collision flux to calculate the collision probability. In the close approach analysis, a cell that contains both the measurement satellite and the sub-millimeter-sized debris is created when the relative distance is small. The collision flux is calculated in the cell. A sampling based on the collision probability calculated by the collision flux yields realistic detected position and time data. The estimated values are derived by the origin identification by applying the Monte Carlo method. In addition, two origin identification methods using a constraint equation derived from the sharing of the geocentric position vector between the sub-millimeter-sized debris and the measurement satellite and using the geocentric declination of the sub-millimeter-sized debris are compared. The estimated results indicate that the orbital parameters of the broken-up object can be estimated. It is noted that the origin identification method using the constraint equation has a better solution than that using the geocentric declination because it has two global solutions, although using the geocentric declination has only one global solution. However, a subset of the estimated values exhibits a deviation depending on the random number. Therefore, an improvement strategy of the origin identification method is also outlined to avoid convergence to local solutions.