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SPACE DEBRIS SYMPOSIUM (A6)
Modelling and Risk Analysis (2)

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EXPLICIT EXPRESSION OF COLLISION PROBABILITY FOR SPACE OBJECTS IN ARBITRARY-SHAPE ORBIT

Abstract

The calculation of collision probability between space objects is the foundation of collision risk assessment and avoidance maneuver. The explicit expression of collision probability for space objects in arbitrary-shape orbits based on the analytical method is presented in this paper. The maximum collision probability and the corresponding position error covariance matrix are then analyzed by the means of the explicit expression, an analytical method for determining probability upper-bound for arbitrary shape and orientation of error covariance matrix is obtained. Collision probability analysis can be accomplished using a simple Gaussian probability model where the objects are assumed spherical. At the point of closest approach, each object's positional uncertainties are combined and their radii summed. The resultant is projected into a plane perpendicular to relative velocity where the collision probability is calculated as an integral of 2-dimensional Gaussian distributed probability density function (PDF) over a circular region. Through the space compression, the integral of anisotropic PDF over a circular region is transformed to the integral of isotropic PDF over an elliptical region. The elliptical region can be approximated by a circular region which occupies the same area. This integral can be expressed as infinite series whose recursion is known. The partial sum of the infinite series could be taken as the sufficient approximation of the integral. Based on the first term of the infinite series, an explicit expression of the collision probability is deduced under the assumption that the orbit's eccentricity is arbitrary; the collision probability is expressed as an explicit function of the encounter geometry and position error covariance in the satellite-based NTW coordinate system. With the help of the explicit expression, the influencing factors of the collision probability are analyzed, some significant conclusions are obtained. The explicit expression can used to analyze the maximum collision probability and the corresponding position error covariance as well. An analytical method for determining probability upper-bound for arbitrary shape and orientation of covariance matrix is obtained. In the end, the U.S. and Russian satellite collision event in February 2009 is analyzed using the collision probability analytical method presented previously. The results indicated that the explicit expression is accurate and efficient, and could be used in theory analysis and engineering practice.