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UNCERTAINTY REDUCTION FOR SPACE OBJECTS COLLISION ANALYSIS BY PRECISE ORBIT: A CASE STUDY OF SPACE DEBRIS APPROACHING Q-SAT

Abstract

On January 18, 2022, it is reported that Tsinghua Gravity and Atmosphere Science Satellite (NORAD ID: 46026), also known as Q-Sat, would have a dangerously close distance with space debris (NORAD ID 49863). Due to limitation of observation and orbit prediction, whether the space debris will bump into the Q-Sat remains uncertain. Accurate and reasonable collision risk needs to be evaluated by a precise orbit and error variances. The accuracy of orbit prediction for Q-Sat and space debris has become a key issue in determining the degree of danger for this rendezvous event. Q-Sat is a spherical satellite which launched on August 6, 2020. It is currently operating in an orbit at an altitude of 490 kilometers and an inclination angle of 97.42 degrees. Orbit data from Q-Sat has a centimeter-level accuracy after precise orbit determination (POD). Because of its unique configuration, the drag coefficient and surface-to-mass ratio of the Q-Sat satellite can be accurately estimated. Drag coefficient is 1.5 and surface value ratio is $0.2043 m^2/kg$. For present paper, firstly, the Jacchia-Roberts atmospheric density model is optimized using high-precision Q-Sat orbit data and a dynamic inversion method. The influences by environmental parameters on prediction accuracy is therefore reduced. By using a repeated arc calculation method, the position standard deviation was statistically analyzed at the same time. The results show that the accuracy of the 24-hour orbit prediction does not exceed 150 meters. Secondly, for orbit determination and position standard deviation estimation, the Q-Sat historical accurate orbit data and the two-line elements of space debris are used. Finally, a refined error processing method is employed to perform a collision analysis for the two objects. Through calculation by methods introduced above, it is indicated that the Q-Sat and space debris have not yet reached the level of collision warning. As human space activities become increasingly packed, the possibility of a collision increased. It is crucial to reduce uncertainties in space debris collision analysis which can be improved by obtaining a more precise orbit and by conducting the refined error processing method.