Attachment I

USA DUAL Project Proposal #PPRN:

ISS Debris Avoidance and Collision Probability Support

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Introduction

This project proposes to improve the quality of state error covariance matrices used in the ISS debris avoidance collision probability process. Covariance matrices obtained from the current orbit determination process do not contain the full effects of all error sources. In particular, the effects of atmospheric uncertainty and variability can lead to large errors in predicted states which are not accounted for by the currently available state error covariance matrices.

Background

To the present, collision probability and debris avoidance with tracked space objects have been dealt with through a system confidence approach. The process uses average system tracking performance (i.e., state vector uncertainty) expected by USSPACECOM, as an estimate for the threatening object. Similarly, NASA's average tracking accuracy is used for the STS vehicle at risk. These system averages were then used to determine the dimensions of an Orbiter centered box in which the closest point of approach of the threat object was not allowed to occur. In principle, the concept would not have allowed for a collision probability to exceed a predetermined value. This process, though simple in concept and execution, has several problems which could impact both the level of safety of an at risk vehicle and its likelihood of mission success.

One problem with the box method is that the closest point of approach criteria could actually allow for a box violation away from an external point of closest approach. In principle this does not have to be true. However if the implemented search criteria is for a point of closest approach within the box instead of a passage through the box then such an error could be made.

Another problem with this method is that it assumes that if the box is not violated then the collision probability will not be exceeded. In fact, this may not be true. Certain combinations of miss geometry and state uncertainty can lead to collision probabilities in excess of the expected limit. This is especially true if the at risk vehicle is large, as is the case for the ISS. A converse to this problem exists also in that box violations do not automatically result in an unacceptably high risk of a collision.

Besides the direct safety issue, the box method would also have unwelcome effects on the likelihood of ISS mission success. An appropriately sized box for the ISS would lead to a debris avoidance maneuver rate that would strain system capabilities and affect onboard science through disruption of sustained microgravity periods. Reducing the box size for the ISS would alleviate these two problems but would increase the lifetime collision risk of the ISS to unacceptable levels.

The risk assessment method to be used with the ISS, and to be applied to all manned flight, will be a method based on event by event evaluation of collision probability. This method requires relatively accurate knowledge of the state vector uncertainties of each object involved in a predicted close approach. The state error covariance matrices of the threat object and at risk vehicle will be used in an existing process to determine the expected probability of a collision between the two objects. The computed collision probability will then be compared against predetermined threshold values to determine the requirement for a debris avoidance maneuver.

Project Proposal

The process of accurate orbit determination and propagation requires high fidelity modeling of all significant forces affecting an orbiting object. Due to its variability and poor predictability, the atmosphere surrounding the Earth gives rise to one of the most uncertain forces acting on an orbiting object. The variability of this atmospheric effect increases the uncertainty of the state error covariance matrix obtained from the orbit determination process. In addition it also contributes significantly to the degradation of orbit prediction. This is of particular importance to the ISS. The predictions of state and state vector uncertainty will be used to compute the expected probability of a collision and of the need for a debris avoidance maneuver.

Through analysis and simulation, this project will seek to determine the effect of atmospheric errors on orbit determination and propagation. This will include any biasing of the orbit determination result as well as propagation errors of the state and state error covariance matrix. Based upon the results obtained, the investigators will make any appropriate recommendations concerning the method by which atmospheric uncertainty is dealt with during real time operations. These recommendations should specifically address orbit determination and the propagation of states and state error covariance matrices.

Additional Information

This proposal represents a continuation of an existing DUAL project for ISS debris avoidance support. The investigators have been students and faculty in the Aerospace Engineering Department at Texas A&M University. The faculty advisors have significant experience in the area of orbit determination and with various DOD organizations involved in space surveillance and orbit determination. Existing contacts within DOD have supplied analysis software and are expected to be able to supply tracking data to be used in the investigative process.