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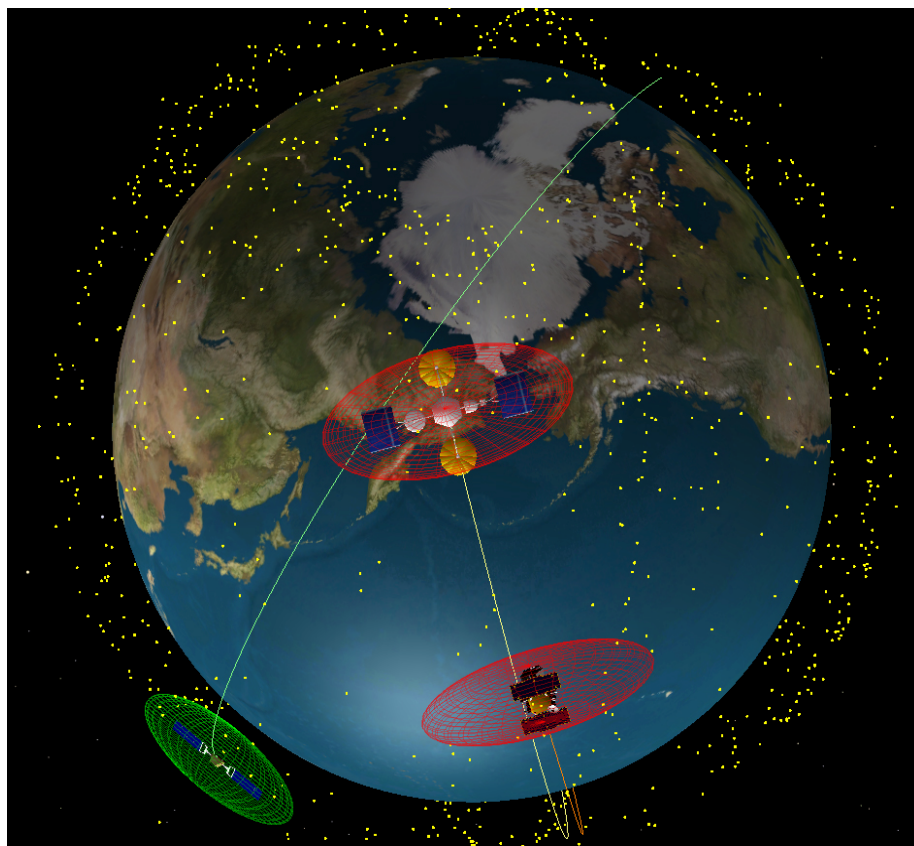
Collision Risk Assessment Analysis & Operations Space Situational Awareness for Space Assets

Orbital debris poses a significant threat to spacecraft health and safety. The current estimate of 'tracked' objects larger than 10 cm is greater than 18,000. This number increases by several hundred objects per year. Most of these tracked objects are characterized as orbital debris. Satellites are routinely hit by small particles that cause little or no damage. However, if a large particle were to hit an operational satellite, the impact could result in the end of the mission. A full blown collision, such as the February 2009 Iridium-Cosmos event, not only destroyed an operational satellite, but also increased the debris field significantly.

Because of the threat posed by orbiting objects, government agencies such as the Department of Defense (DoD), National Reconnaissance Office (NRO) and the National Aeronautics & Space Administration (NASA) have established risk assessment and risk mitigation strategies for many of their operational spacecraft. Greater situational awareness and concern in the satellite community has arisen due to large-scale break-up events such as the Iridium-Cosmos collision, China's anti-satellite (ASAT) test and the Breeze-M rocket explosion. These events demonstrate the necessity for an operations concept that includes monitoring, computing and mitigating collision risks.

a.i. solutions provides operational **collision risk assessment** for nearly **100** DoD, NASA and NOAA satellite programs spanning low earth orbit to geosynchronous regimes. The a.i. solutions **Risk Assessment Team** works with the Joint Space Operations Center (JSpOC) to provide daily analysis and operation support. This support consists of:

- **Modeling & Simulation - Regime Characterization**
- **Operations Concept Development**
- **Collision Risk Assessment Analysis**
- **Avoidance Maneuver Planning Strategy & Execution**



FreeFlyer® simulation showing orbital debris in low earth orbit (LEO) and spacecraft proximity zones, which define the 'safe' area around a spacecraft. A large part of the debris population resides in LEO, where the density distribution of cataloged objects is concentrated (near mean equatorial altitudes of 700 – 1100 km) with a peak at 800 km.



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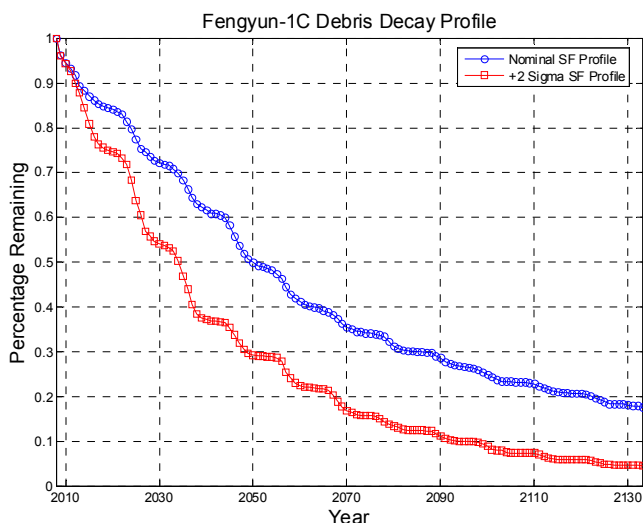
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I. Modeling & Simulation – Regime

Characterization. One question that both current and new missions often ask is: how often are ‘high-interest’ close approach events expected to occur over a typical mission lifetime? Characterization of the expected collision risk is performed in two different ways:

- **High Powered Computing using Cluster Technology**
- **Statistical Estimation Using Extreme Value Theory**

To determine how a given orbital regime or mission set is going to be affected by a specified set of debris, we perform long-term high fidelity state propagation. The evolution of the debris is easily characterized for decades by making use of Microsoft® Windows® Compute Cluster Server and FreeFlyer® COTS mission analysis software.

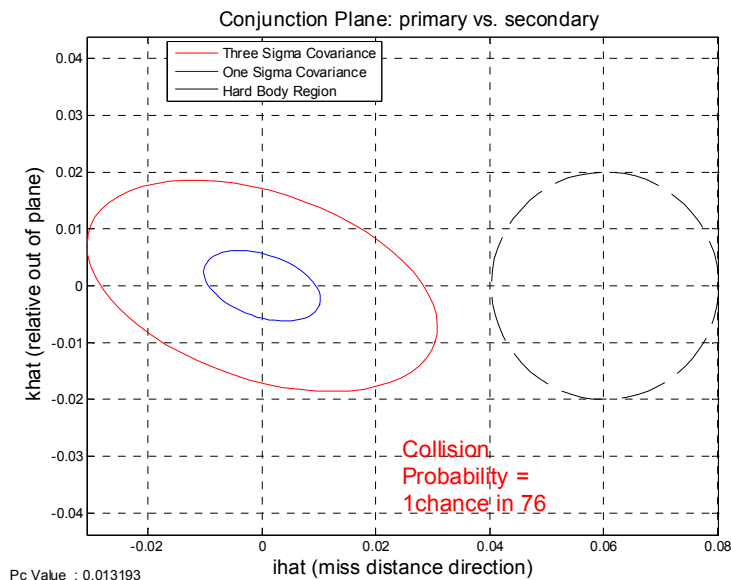


The Extreme Value Theory method of risk estimation is used to predict when high interest events will occur; based on historical data and an assumption of the distribution characteristics.

II. Operations Concept Development. The collision risk assessment operations concept documents and defines the roles and responsibilities of all major participants. The a.i. solutions Risk Assessment Team works with mission stakeholders to create a mission unique operations concept.

III. Collision Risk Assessment Analysis.

Operational collision risk assessment consists of receiving daily close approach predictions from the Air Force, quantifying the collision risk, and developing risk mitigation strategies as necessary. The a.i. solutions Risk Assessment Team performs **probabilistic collision risk** assessment based on the high-accuracy data provided by the JSpOC.



Additional risk assessment analysis includes: performing sensitivity analysis to see how changes to the initial conditions affect the probability values, and estimating how the collision probability calculation will evolve as future updates are made. Qualitative assessment of the JSpOC orbit determination solution is also performed.

IV. Avoidance Maneuver Planning Strategy & Execution.

If a collision threat has been validated, and/or deemed to be sufficiently high, the a.i. solutions Risk Assessment Team works with the mission operations team and mission management to generate an avoidance maneuver. The Risk Assessment Team will evaluate the maneuver trade space and help construct an optimal maneuver strategy.

For more information, contact:

David P. McKinley, Operations Engineering Manager, Mission Services Division,
david.mckinley@ai-solutions.com

Daryl Carrington, Director of Operations, Mission Services Division; 301-306-1756 x103
daryl.carrington@ai-solutions.com