Paper ID: 99462
oral
student

23rd IAA SYMPOSIUM ON SPACE DEBRIS (A6)
Interactive Presentations - 23rd IAA SYMPOSIUM ON SPACE DEBRIS (IP)

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MIXED-FIDELITY LIGHT CURVE SIMULATION FOR CHARACTERIZATION OF RESIDENT SPACE OBJECTS

Abstract

The proliferation of resident space objects (RSOs) in Earth's orbital environment poses significant challenges for space situational awareness. Accurately characterizing these objects through light curve analysis remains complex due to the diverse geometries, surface properties, and dynamic behaviors of satellites and space debris. This research develops a mixed-fidelity simulation framework that integrates complementary light curve modeling approaches to enhance parameter estimation for RSOs.

Our methodology combines two distinct simulation techniques: a low-resolution facet-based Bidirectional Reflectance Distribution Function model and a high-fidelity Blender-based rendering approach. The framework employs a novel two-stage exploration strategy designed to overcome the computational limitations inherent in current characterization methods. Initially, a computationally efficient facet model rapidly explores the parameter space, identifying regions of potential interest through broad parametric sampling. Subsequently, a detailed Blender-based simulation performs high-resolution refinement of the most promising candidates, capturing intricate geometric and optical characteristics with high detail.

The research demonstrates the framework's capabilities using the Intelsat 901 satellite as a case study. By reproducing complex light curve signatures and estimating solar panel maneuver profiles, we illustrate the methodology's potential for advanced space object characterization. A key innovative component is the development of a machine learning-based surrogate model that approximates the high-fidelity Blender simulation. This approach aims to create a computationally efficient alternative for light curve generation while maintaining acceptable fidelity to the original high-resolution simulation.

Critical challenges in current light curve inversion methods include the difficulty of exploring complex parameter spaces while preserving detailed physical modelling. Our proposed framework addresses these limitations by integrating low and high-fidelity simulation approaches. The research contributes to the field by offering a more comprehensive method for characterizing the increasingly diverse population of orbital objects, with potential applications in space surveillance, debris tracking, and satellite mission planning.