Paper ID: 94082
student

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

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LEVERAGING BLOCKCHAIN TECHNOLOGY FOR TRACKING, MONITORING, AND MITIGATING SPACE DEBRIS: A LEGAL AND TECHNICAL FRAMEWORK FOR ACCIDENT PREVENTION

Abstract

The proliferation of space debris poses escalating risks to operational satellites, human spaceflight, and the long-term sustainability of outer space activities. Despite the efforts of international frameworks such as the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS) guidelines and the Inter-Agency Space Debris Coordination Committee (IADC) recommendations, challenges persist in achieving effective, transparent, and cooperative space debris management. This paper introduces a blockchain-based framework designed to complement existing guidelines by enhancing the tracking, monitoring, and mitigation of space debris while addressing regulatory and liability concerns under international space law.

Blockchain technology's decentralized and immutable architecture offers unique advantages for recording and sharing debris data. By integrating this technology with space situational awareness (SSA) networks and predictive analytics, the proposed framework creates a tamper-proof, globally accessible "Space Debris Ledger." This ledger supports real-time recording of debris orbits, automated collision alerts through smart contracts, and enhanced transparency among space actors.

From a legal perspective, the framework aligns with the principles of the Outer Space Treaty (OST), particularly the provisions on international cooperation (Article I) and liability (Article VII). It addresses the need for enhanced compliance with the IADC and UNCOPUOS guidelines by providing a decentralized mechanism for data sharing and collision prevention. Furthermore, blockchain's transparency can aid in attributing debris sources and assessing liability, crucial for mitigating disputes under the Liability Convention and fostering trust among spacefaring nations.

The paper also explores how blockchain can support compliance verification for active debris removal (ADR) and post-mission disposal (PMD) strategies, ensuring adherence to internationally accepted norms. Additionally, the policy implications of implementing this framework are discussed, emphasizing its role in bridging gaps between technological innovation and legal accountability.

By integrating blockchain with international legal standards and technical guidelines, this study presents a comprehensive solution for space debris management, paving the way for sustainable and secure space operations. The presentation will detail the technical architecture, legal considerations, and implementation challenges, offering a roadmap for stakeholders to collaboratively address the growing space debris crisis.