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SUSTAINABLE SPACE DEBRIS MANAGEMENT THROUGH REUSABLE ROCKET AND ROBOTIC CAPSULE SYSTEMS FOR LONG-TERM ORBITAL CLEAN-UP.

Abstract

With the rapid advancement of space exploration by nations such as India, the United States, Russia, China, Japan, and Europe, the need for sustainable space debris management has become paramount. Space activities across domains like scientific research, military applications, global communication, navigation, and weather forecasting contribute to orbital congestion. This abstract presents an innovative mission architecture aimed at mitigating artificial space debris, focusing on non-functional and traceable satellites in Earth's orbit. The proposed solution employs a reusable rocket, equipped with a detachable capsule, engineered to transport decommissioned satellites into a "graveyard orbit" — a designated area beyond the operational altitude to reduce congestion and collision risks. After deploying the capsule in this orbit, the reusable rocket safely returns to Earth using a precision landing system. The capsule, now in graveyard orbit, continues its mission by targeting non-operational satellites for retrieval. Central to this mission is the capsule's advanced robotic arm, capable of precision-based satellite capture. Upon approaching a target satellite, the arm extends from the capsule's nosecone to engage, secure, and carefully stow the satellite within a protective compartment. Once the satellite is captured, the nosecone reseals, safeguarding the satellite during the return phase. The capsule then initiates its deorbiting procedure and re-enters Earth's atmosphere. At a predetermined altitude, parachutes deploy to control the descent, allowing for a soft landing on either land or water. This mission structure not only minimizes further debris generation but also enables the potential recovery and repurposing of valuable satellite components. This concept integrates reusable launch systems, robotics, and orbital mechanics for a sustainable approach to space debris mitigation, ensuring responsible space exploration and enhancing orbital safety for future missions.