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Author: Mr. Priyank Dubey
Indian Institute of Technology, India

Ms. Bonthu Soumya
Indian Institute of Technology, India
Mr. Arya Das
Indian Institute of Technology Kanpur, India
Dr. Dipak Kumar Giri
Indian Institute of Technology Kanpur, India

MITIGATION OF NUCLEAR SPACE DEBRIS USING ADVANCED VITRIFICATION AND POT CALCINATION PROCESS: MISSION DESIGN AND FEASIBILITY STUDY

Abstract

In order to realize the dream of becoming an interplanetary species and deep space travel, nuclear power sources will be needed for both for the journey and to sustain human activities on the surface of the planets. Nuclear powered space missions have become an active research area, as such spacecrafts can operate for a long time in space without the need to be refuelled, which makes it a desirable technology for deep space exploration. There have been several nuclear-powered space missions launched by various space agencies till now. The increase in the number of nuclear-powered spacecrafts poses the threat of hazardous radioactive release into the Earth's atmosphere during end-of-service or re-entry. The existing space debris mitigation technique fails to tackle with Nuclear Space Debris (NSD) as they will expose the nuclear power source to extreme physical conditions during re-entry leading to a radioactive release. Hence, there is a great requirement of NSD mitigation technique. The current paper presents a complete mission design with new approach of orbital NSD mitigation utilizing the advanced vitrification and pot calcination process. This allows the hazardous nuclear waste to remain in a corrosive environment for thousands or even millions of years without the emission of harmful radiation. The process involves the mixing of the radioactive substance with a chemical compound (CC) that will crystallize (e.g., sugar, sand) when heated and, is then calcined. This calcinated material is mixed with fragmented glass in a very hot environment. Upon mixing, the radioactive substance will be bonded with glass material. The melted product is subsequently encapsulated and sealed in disposal repositories. The mission involves a base chaser spacecraft, which will be equipped with CC and De-Orbiting Kit Thrusters (DKT). It will fly in between the NSD targets, rendezvous in orbit, dock or capture the target, initiate vitrification by injecting the materials using hydraulics, and then will finally de-orbit it for re-entry. The high temperature generated during the re-entry will be utilized for final pot-calcination process. The feasibility study of entire mission design, NSD mitigation method will be done and they will be optimized according to orbits (LEO and GEO). This research will provide the recommendations for effective NSD mitigation system along with the control algorithms employed during the mission design, the design challenges, strategies adopted to cope with the challenges, and simulation result obtained during the implementations.