22nd IAA SYMPOSIUM ON SPACE DEBRIS (A6)
Post Mission Disposal and Space Debris Removal 2 - SEM (6)

Author: Mr. Christopher Tuttle
ClearSpace, Inc., United States, chris.tuttle@clearspace.today

Mr. Joe Cassady
Aerojet Rocketdyne, United States, joe.cassady@rocket.com
Dr. Darren McKnight
LeoLabs, United States, darren@leolabs.space
Dr. Timothy Maclay
ClearSpace, Inc., United States, tim@clearspace.today

# THE IMPLICATIONS FOR ROCKET BODY REMOVAL WHEN RESIDUAL FUEL IS ON BOARD: SPACE JUNK MIGHT BITE BACK!

**Abstract**

By several measures, derelict rocket bodies are the most dangerous space debris objects in low Earth orbit. Their sizes make them likely collision candidates, their masses possess enormous potential to generate lethal, non-trackable debris, and they are often left in populated orbits. In addition, they are not always – or completely – passivated, and residual hypergolic fuels can represent an explosive hazard. In fact, explosions of spent rocket upper stages are one of the leading contributors to the debris population.

It is these dangers that makes derelict rocket bodies good candidates for environmental remediation efforts, and it also these dangers that make removing these objects from orbit so challenging. In past studies, we have examined the major technical and economic aspects that must be considered in any practical program to remove large derelict objects from orbit. In this paper, we now focus on the particular challenge of removing objects that are potentially, explosively unstable, because of the presence of residual hypergolic fuels, the disturbance of which could trigger explosive breakup.

We begin with a survey of some of the most dangerous rocket bodies left in orbit and a characterization of the risks they pose to current and future satellite operators. We identify what fuels might remain on board and discuss the effects of aging and exposure in the harsh conditions of space, with an emphasis on fuel stability and volatility. Strategies for mitigating explosive volatility in the context of an active debris removal mission are then proposed, along with the possible operational techniques and the implications residual hypergolic fuels have on the cost and complexity of removal missions.