A Novel Lifecycle Extension Plan for the Efficient Usage of On-Orbit Post-Consumer Assets

Jaclyn R. Wiley, Henry S. Neiberlein, Olivia R. Kirk, Andrew P. Bronsheyt

Abstract

Asteroid mining is a potential form of commercial space industry, and significant amounts of research have gone into the feasibility of that activity. Less research has been done on what happens to the asteroid post-mining; the two primary end-of-life scenarios for the remains of a mined asteroid are not ideal. The remains could be deorbited, which entails complex technical and legal challenges, or they could remain in orbit, which could lead to collisions and a general increase in space debris. This proposal outlines a solution for the post-consumer asteroid issue which avoids creating more space debris and the risky business of deorbiting. This solution is to use the post-consumer asteroid shell as a shelter for delicate equipment or as a "garbage can in space," which would hold the remains of defunct satellites until the time they could be more safely deorbited. The shell of the asteroid would provide protection from space debris impacts and some radiation. This proposal also discusses some of the major technical and legal challenges that this solution would face, and how stakeholders could potentially address them. More research is required to gain a better understanding of the challenges and opportunities that this proposal faces, which can be conducted during the long-term development of commercial asteroid mining technologies.

Theory

Asteroid assets post resource mining operation can be utilized for further scientific research and storage after their useful life for resource extraction has been exhausted. The Artificial Cavities or Depressions (ACD) created by mining operations can then be used for storage or as a protective vessel for future missions. The ACDs can be inexpensively prefabricated capsules that would act as a natural shield against space debris and offer shielding against radiation due to the material composition of the asteroid. The thickness of the material surrounding the ACDs would determine the passive shielding potential of the ACDs. A space object can be struck at any point on its surface by space debris and micrometeoroids. Collisions between objects in space take place at high velocities, and are often quite destructive and costly. Placing an object within an ACD would reduce the risk of an impact with a space object. Being able to have access to a low cost protective shell provided by a previous space mission and with no overhead launch cost could become very advantageous in the crowded space environment in the future.

Space objects interact with multiple types of radiation while orbiting the Earth. Passive radiation shielding is advantageous because it is simpler than active shielding and can block high-energy radiation if thick enough. Asteroid material used as passive shielding could be used to protect objects from potentially harmful radiation. ACDs created as a result of future mining operations have enormous potential for future utilization in the space environment for a wide variety of missions due to the unique advantages they provide.

Calculations

Bilham et al. found that a column density of 0.5 g/cm² of passive shielding material is required to simulate radiation levels of 0.5 rem/year, and the radiation exposure from a solar flare is attenuated to below 20 rem [17]. In order to calculate the thickness of the walls needed to simulate radiation levels on Earth, the density of the asteroid asset is needed. Carry carried out the average bulk density of Bus-Demo taxonomic classes of asteroids in 2012 [19].

To calculate the Te, the constant for column density was divided by the pa of common types of asteroids.

\[ Te = \frac{C}{\rho a} \]  
\[ \sigma T_e = (\mu \rho a)(Te) \]  
\[ Te = \frac{C}{\rho a} \]  

The authors recommend multiple areas of further study, which are concentrated into two main areas: Pre-Mission and Mission-Specific. The Pre-Mission recommendations are:

- *To conduct comprehensive study of asteroid assets returned to Earth orbit*
- *To experiment to determine the effectiveness of the mission design with a coherent non-coherent asteroids.*
- *To research atmospheric effects on the asteroid asset*

The Mission-Specific recommendations are:

- *To research different designs for ACD covers*
- *To research the potential implementation of inflatable habitats within assets*
- *To determine the space debris impact of such a mission*
- *To compare the space debris creation vs. mitigation potential of the mission*

Finally, the authors of this paper recommend a full-scale feasibility study for this concept. If it is found to be feasible in some or all conditions, then it should be pursued further.

Conclusions and Recommendations

**Conclusions**

1. Comprehensive study of asteroid assets considered for the implementation of this proposal is required.
2. The placement of space debris into the asteroid asset will be technically challenging, though they might become less so as related technologies develop.
3. Asteroid material could provide adequate passive shielding material against radiation if utilized on orbit.

**Recommendations**

The authors recommend multiple areas of further study, which are concentrated into two main areas: Pre-Mission and Mission-Specific.

The Pre-Mission recommendations are:

- *To conduct comprehensive study of asteroid assets returned to Earth orbit*
- *To experiment to determine the effectiveness of the mission design with a coherent non-coherent asteroids.*
- *To research atmospheric effects on the asteroid asset*

The Mission-Specific recommendations are:

- *To research different designs for ACD covers*
- *To research the potential implementation of inflatable habitats within assets*
- *To determine the space debris impact of such a mission*
- *To compare the space debris creation vs. mitigation potential of the mission*

Finally, the authors of this paper recommend a full-scale feasibility study for this concept. If it is found to be feasible in some or all conditions, then it should be pursued further.