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Active Debris Removal Mapping Project

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Introduction

Space debris discussions initiated with the start of the space age 55 years ago and have seen special interest in current years. This is due to the large increase in the number of space debris which has led to an increased threat of collision with operational space systems and of unsafe re-entry.

According to various studies relating to the space debris population, it would be mandatory to deorbit at least 5 heavy debris per year from the low Earth orbits to stabilize their evolution [1].

Many different methods have been proposed in recent years for mitigation and space debris removal. These include ground based lasers and space based systems which use electro-dynamic tethers, solar sails or inflatable components.

It seems crucial to assess and categorize the different ADR methods in order to help policy makers make better decision regarding the focus of research.

Aim and Objectives

This project aims to identify major performance measures for space debris removal systems based on current rules and regulations and map the performance of the ADR technologies based on several criteria. The performance map can help prioritize removal concepts and required technologies in order to better meet current needs.

Method

In order to precisely place such methods on the chart , it would be useful to compare and rate them on the basis of several weighted factors (calculated for different size-altitudes couples).

Factors used to assess ADR methods include:

- Mass & volume at launch
- Material properties
- De-orbiting time
- Orbital altitude
- Hazardousness
- Affordability
- Reliability
- Approach maneuver complexity
- Link quality and control complexity
- Versatility with respect to different targets with comparable size and different shape
- Impact on power budget
- Sensitivity to target tumbling
- Technology readiness
- Representativeness of on-ground qualification
- Debris creation
- Reusability

References

[1] J.C. Liou, N.L. Johnson, N.M. Hill, "*Controlling the growth of future LEO debris population with Active Debris Removal*", Acta Astronautica, 66, 648-653, 2010

[2] C. Bonnal, "*Active Debris Removal*", P^{2}ROTEC Workshop, Ankara, 2010

[3] B. Weeden, "*Overview of Active Debris Removal*", Active Debris Removal Symposium, Secure World Foundation, 2012

[4] M. Andrenucci, P. Pergola, and A. Ruggiero , «Active Removal of Space Debris Expanding foam application for active debris removal", Final Report, 21-02-2011

Performance Chart Ideas

The proposed domain of the performance chart is outlined on the *altitude – risk* plane. The risk factor is obtained by multiplying the *debris mass* and the debris *probability of collision*. The higher the risk, the higher the priority of removal, thus "quick" capture and de-orbiting methods shall be preferred. Possibly, methods in this range shall also allow for a multi-target operability. Low risks are associated with a low probability of collision, and low debris mass and size. In this case, time shall not be considered a strict constraint and different solutions can be explored. For instance, a drag augmentation method can act effectively on a wide range of masses from 1 kg up to several tons [4]. However, such methods can be effective only at lower altitudes where the drag perturbation is enough. At higher orbits, where drag assistance cannot be exploited, space debris can be processed by means of expanding foams both for re-entry missions and re-orbit operations.

Two important boundary lines can be identified in the graph: the controlled vs. uncontrolled re-entry boundary, and the chemical vs. electrical propulsion. It is extremely difficult to precisely define where on solution is more effective than the other w.r.t. to different removal techniques and different classes of objects. The controlled re-entry band is associated to a high priority of removal, and chemical propulsion is therefore preferred. Such a band domain is associated with both a high probability of collision and a high debris mass (e.g. upper stages and inactive satellites). Robotic arms and similar mechanical methods are the only techniques that ensure a good control of the coupled dynamic of the debris and the capturing kit/vehicle, as well as a good control over the re-entry phase (mandatory for this class of objects).

On the other hand, random re-entry can be performed only if on-ground risk is negligible the debris is small enough to be destroyed by the atmosphere. Since precise control is not required for this class of objects, alternative methods can be explored (e.g. sails, magnetic tethers, solar tethers, etc).

Finally, one of major factors discriminating between chemical and electrical propulsion is the mission duration. Therefore, electrical propulsion becomes a competitive solution only for either high-altitude re-orbits and low-priority random re-entries.

Next Steps

The ADR Mapping team is currently focusing on the analysis of several active debris removal methods to quantify the performance map boundaries. Methods and technologies being analysed include:

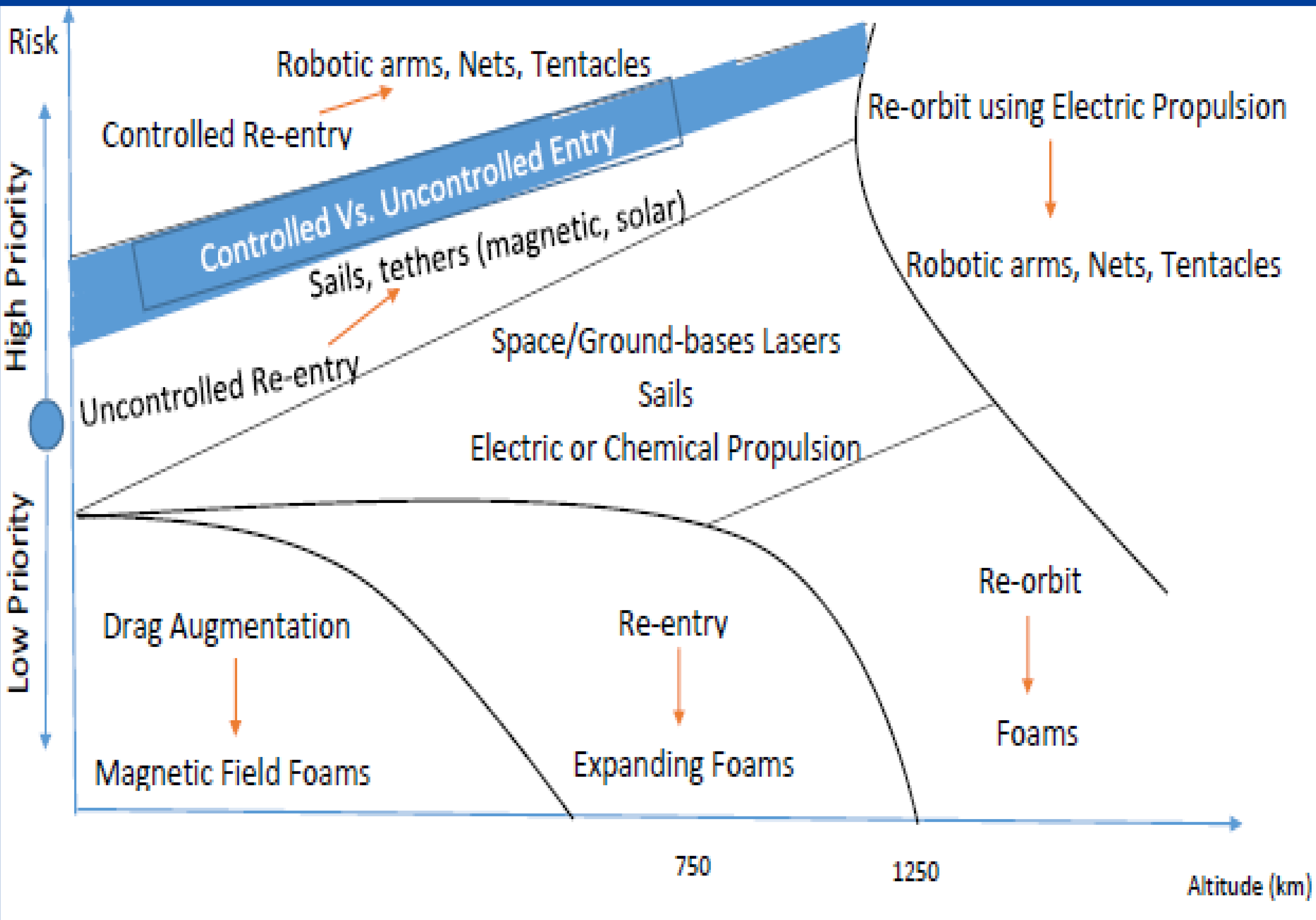
- Tethers
- Harpoons
- Debris sweeper
- Expanding foams
- Deploying clouds of frozen gas
- Chasing and grasping the debris
- Attaching deorbiting kits like thrusters
- Propulsion technique by ground or space based lasers
- Capturing techniques like deploying webs/nets to capture space debris

A continuation of this project may also categorize passive space debris mitigation techniques, collision avoidance maneuvers, and different type of shielding.

Conclusion

This paper provided the framework being used by the ADR project group to assess active space debris removal techniques and categorize them.

A complete analysis of the debris removal techniques introduced in this poster will be done to assess the characteristics their efficiency and link them with relevant areas of application. The performance charts developed help both policy makers and engineers in making decisions on space debris removal techniques.



First Draft of the proposed ADR Performance Chart