SGAC Space Safety and Sustainability Project Group
- Reflecting the Views of the Next Generation for Five Years

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Abstract – One of the main threats facing the future of space exploration and utilization is a reduction in safety and sustainable use of space. The increasing number of space debris and their potential impact with space systems is a major threat for space missions. A disaster in space can lead to a reduced public support for space missions and stop continued space exploration.

In recognition of the importance of this topic, the Space Generation Advisory Council started a project group in 2009 to focus on the area of Space Safety and Sustainability, with the aim of reflecting the view of the young generation in this area.

This paper summarizes some of the activities and findings of the aforementioned project group in its fifth anniversary. It also provides an overview of new projects being initiated within the project group for the year 2015.

Keywords—Space Safety and Sustainability – Space Debris – Space Situational Awareness

I. Introduction

Space safety refers to the safeguard of valuable facilities on ground, on orbit, humans on-board, as well as the safeguard of the space and ground environment.

Space activities have created an orbital debris environment that poses increasing collision risks to existing space systems, including human spaceflight and robotic missions. Studies have shown that without the removal of large orbital debris from orbit, cascade collisions will lead to an exponential increase in the number of debris and a higher risk for space missions [1, 2, 3].

The proliferation of space debris and the increased possibilities of collision and interference raise concerns about the long-term sustainability of space activities, particularly in the Low Earth orbit (LEO) and Geostationary Orbit (GEO) environments. It is vital that we act now to keep space clean, safe and useable for future generations.

The space environment is an international domain and requires collaborative efforts from all space-faring nations to ensure the safety and sustainability of this environment. It is therefore essential that there is a wider awareness of an international culture of space safety and sustainability among the space community.

II. The SGAC Space Safety and Sustainability Project Group

The Space Generation Advisory Council (SGAC) is a global non-governmental organisation which aims to represent university students and young space professionals active in the space sector. The SGAC works closely with the United Nations, space agencies, industry, and academia and connects the younger generation with the more experiences members of the space community.

In 2009, following the interest of the younger generation to explore the topic of Space Safety and Sustainability (SSS), SGAC started a project group focusing on this topic. The aim of the project group was to:

- Identify key issues and areas of space safety and sustainability relating to current and proposed space operations.
- Examine the safety and long-term sustainability of outer space activities in all aspects, taking into account the interests of all countries.
- Create an international space forum to showcase the youth's perspective on the safety of space activities, and the sustainability of the space environment for future generations.

Above all, the project group aim is to voice the youth's perspective on issues relating to the safety of space activities, and the sustainability of the space environment.

III. Highlights of Recent Projects

Since 2009, various projects have been pursued at the SSS project group focusing on technical, legal and policy aspects of space safety and sustainability. Project usually focused on four subtopics:

- Space situational awareness
- Space debris
- Space safety
- Space weather effects

This section will summarize some of the findings of the projects ran in previous years.

A. Prioritizing Objects for Active space Debris Removal (ADR)

A study was conducted in 2013 to identify the top conjuncting objects in 2012 based on deterministic data from daily conjunction alerts received. The identified objects serve as high priority debris targets for active debris removal missions [4].

We would like to thank the International Association for the Advancement of Space Safety (IAASS) and Analytical Graphics (AGI) for supporting the SGAC SSS Project group.

This project was initiated as no published report was available on top risk space objects. Moreover, statistical debris models are mostly adapted for analysis based on the sub-millimeter population and are not suited for such a study.

Analysis based on the collision probability calculated just before the predicted conjunction, combined with object mass, volume, altitude, inclination and number of objects of the same type in orbit were used to provide an accurate representation of the most dangerous objects and regions in space.

Using all satellite conjunctions of 2012, top conjunctions of different months and years were identified. This information was used to identify regions with high collision risk, in which the most dangerous debris were identified using a scorecard method. The analysis identified altitudes between 800 and 1000 km with an inclination of 80 to 100 degrees as the highest risk regions. Moreover, the Russian-made Kosmos 3M upper stages were identified as the highest priority target for future active debris removal activities.

B. Using Launch Vehicle Upper Stages for ADR

Building on the identified priority objects for space debris removal, the SSS team developed a solution based on modifying a launch vehicle upper stage for active debris removal (ADR) [5, 6, 7, 8]. Fig. 1 shows the mission profile for this solution. The feasibility of using different space launch systems was analyzed based on relying on chemical or electrodynamic tether propulsion. Moreover, an analysis on how safe the reentry of such systems will be was conducted using the European Space Agency's DRAMA software.

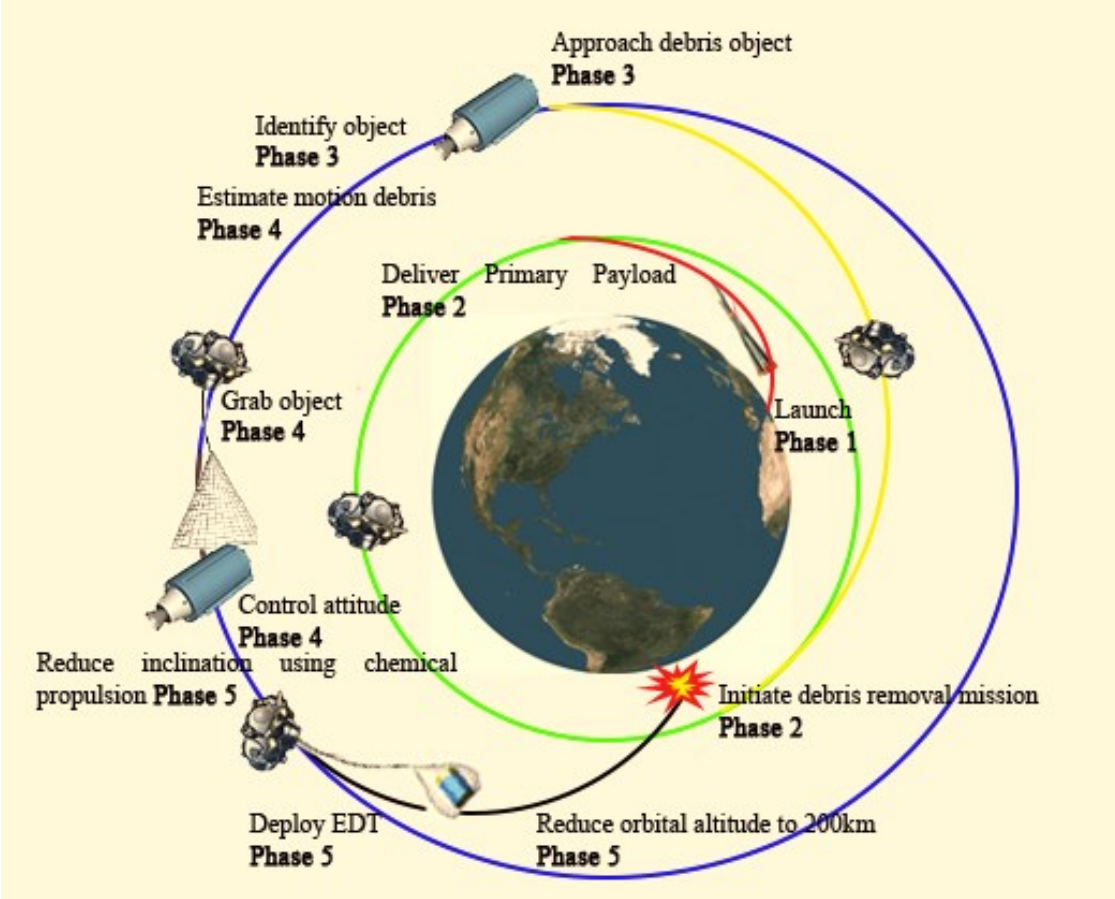

Fig. 1. Mission profile of the proposed active debris removal system based on a modified launch vehicle upper stage

C. Using Vortices for ADR

Another solution for ADR was proposed by SSS members based on two possible implementations of an air burst mechanism to place air molecules in the path of space debris, inducing a drag force which lowers orbital trajectory until intersection with the atmosphere [9].

The first implementation uses a ground-based system to generate air vortex rings that propagate to LEO while the second one relies on an air burst mechanism as a payload on a rocket which travels straight to an intersection point and never attempts to reach orbit.

The core goal of this solution is to use debris momentum against itself without investing additional energy in the deorbiting mechanism. Such a system is highly unlikely to generate more space debris in a failure condition, enhancing long-term sustainability and reducing risks of further LEO pollution. Simulations carried out with the WACCM-X and GITM models provided insight into system behavior, while experiments provided a means to test simple simulation cases

and demonstrate feasibility of the core concept. A thorough cost-benefit analysis was also conducted. Even if the concept is not the least expensive means for debris management available, the risk minimization of debris generation within a mission failure scenario may justify the additional expense.

D. Performance Mapping of ADR Solutions

Many different methods have been proposed in recent years for mitigation and removal of space debris. 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.

As such, SSS developed a project to identify major performance measures for space debris removal systems based on current rules and regulations, and to map the performance of the ADR technologies based on several criteria [10]. The performance map can help prioritize removal concepts and required technologies in order to better meet current needs. Fig. 2 shows the first draft of the performance chart, qualitatively developed. The next steps include quantifying different limits within this chart.

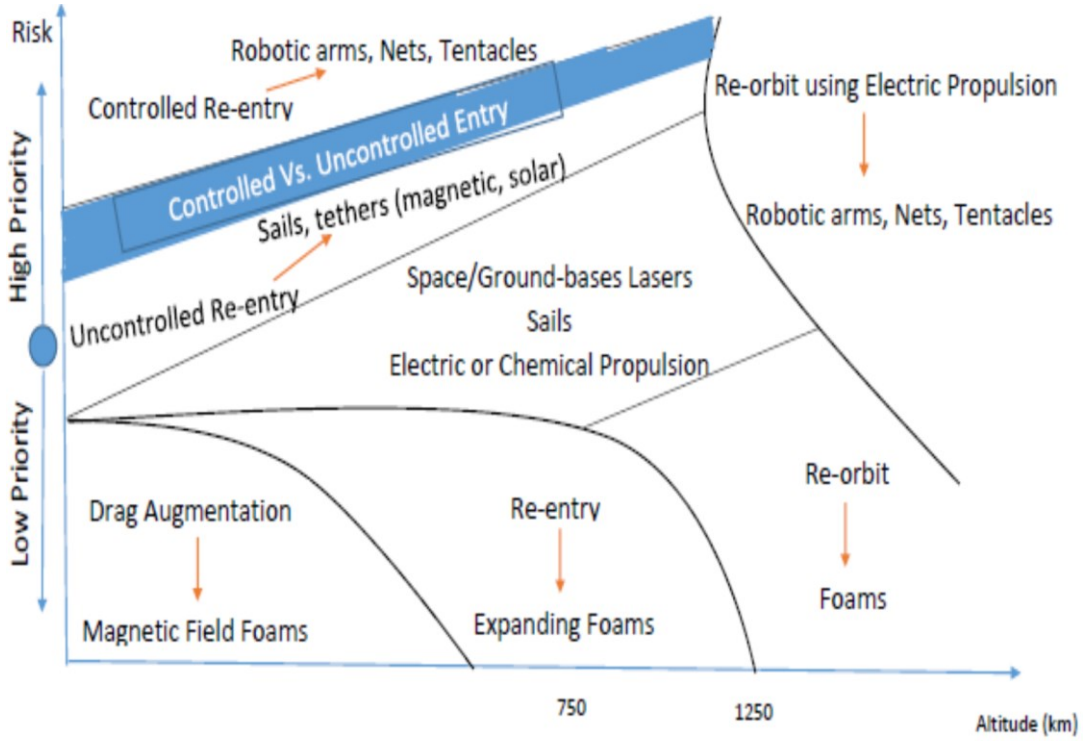

Fig. 2. First draft of the proposed ADR performance chart

E. Policy of ADR

Despite the many unanswered legal, political, and economic questions surrounding ADR, it is an endeavor worth pursuing if we are to continue relying on space activities for a variety of critical daily needs and services.

As such, a project was initiated in 2013 to explore some of the challenges in the area of ADR and propose an economically, politically, and legally viable ADR option [11]. Much like waste management on Earth, cleaning up space junk will likely lie somewhere between a public good and a private sector service. An international, cooperative, public-private partnership concept can address many of these issues and be economically sustainable, while also driving the creation of a proper set of regulations, standards and best practices. The project proposed a method of evaluation for ADR efforts based on a scorecard with criteria in each of the non-technical areas and applied it to the Clean Space project as a case study.

F. Space Situational Awareness (SSA) Policy

In order to fully comprehend the extent of the space debris issue, help avoid collisions, and to eventually manage ADR, a comprehensive SSA network is required.

Such networks already exist; the largest of these, however, belong to the United States and Russia and are run unilaterally as part of defense networks. Thus, the sharing of information obtained via these networks becomes difficult as it risks revealing strategic capabilities.

Alternative means must be found in order to encourage the sharing of SSA data. This project proposed a possible approach through the creation of a neutral international organization and network that exists solely to facilitate the collection and sharing of SSA data [12]. This network would

utilize the capabilities of already existing SSA infrastructure that are not restricted by being part of a defensive network.

IV. Future Activities

In the year 2015, the SGAC SSS project group initiated several new projects based on suggestions and proposals by our members. These activities will be outlined in this sections.

A. SGAC SSS Educational Series

Since its inception, the SSS has tried to develop educational content to raise awareness on the topics relating to space safety and sustainability. In this end, two literature reviews have been developed on the topics of Space Situational Awareness (SSA) [13] and Space Weather Effects on Space Missions [14]. Two other volumes focusing on Space Debris and Space Safety are currently in development and will be released in the year 2015.

B. Safety Analysis of a One-way Human Mission to Mars

This project focuses on the safety analysis of a one way human Mars mission. Different hazards associated with this type of mission are identified and analyzed. Special attention will be given to the hazards associated with life on Mars (habitat safety, resources gathering, radiation protection, etc.). The main goal of the project is to assess whether such a mission would be feasible (or not) from a human safety point of view.

C. Nuclear Powered Spacecraft Safety Analysis

In continuation of a recent report by the SSS project group to be presented at the UN COPUOS [15], this project will analyze the different types of nuclear power systems that could be used to power a future mission, and what hazards are associated with their use. Particular attention will be given to nuclear powered spacecraft during operations in the vicinity of Earth, particularly launch, Earth orbit operations and end-of-life disposal. Consideration will also be given to the impact that any faults could have on the space environment when the spacecraft is not in the vicinity of Earth. The anticipated output of the proposed report will be a set of recommendations that recognize the safety issues associated with nuclear-powered spacecraft and provides means towards addressing these issues.

D. Attitude Dynamics of active Debris Removal

In the last few years, many methods have been proposed for the de-spinning and grabbing of space debris during active debris removal missions. This project will evaluate the concepts already covered in literature and will select the most promising ones in terms of efficiency and feasibility.

E. Economics of rocket first stage recovery

This projects aims to investigate the costs and the operations of worldwide launch operators when dealing with the ballistic return of rocket first stages in comparison with current and future technologies that would be adopted by Russia. The overview will provide a justification for future improvement of the Russian technology for first-stage re-entry of launch systems. Moreover, the team will also explore the feasibility of installing an active onboard descent system for other family of international launchers.

F. International spacecraft design policies for orbital servicing

The purpose of this project is to address general guidelines for the design of "reparable/accessible/modular" spacecraft. This translates into preliminary system requirements and legal issues inherently related to the interaction of a servicing spacecraft with the serviced spacecraft. The scope of the project might range from technical and engineering matters to economic and political factors to be addressed in order to show the short-term feasibility and long-term gain of such missions.

G. Technical and Policy Related Aspects of Commercial Small Satellite Industry towards Space Safety and Sustainability

This project will conduct a literature review on the current de-orbiting systems for small satellites in nano- and micro-classes (<100kg). This will include assessing their developmental cycle, costs, heritage in space and ease of implementation. A questionnaire will be used to assess the technical, policy and the scope of implementation of deorbiting systems in the space segment and the launch segment by commercial satellite and launch vehicle developers. The overall aim of the project is to assess how seriously the commercial space industry is taking up the issues of space safety and sustainability, provided the non-binding nature of space debris guidelines in the present situation. Based on the literature review and interviews, an outlook for space safety and sustainability shall be drawn with respect to the commercial space and launch segment.

V. Conclusion

Five years after its inception, the SGAC SSS project group has successfully implemented several projects covering all aspects of space debris. These project have not only led to knowledge generation and publication, but they have also raised awareness about topics of space safety and sustainability within the student and young professional community working in the space sector.

Acknowledgment

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We also wish to thank our advisory board members for their guidance throughout the year.

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