SEDS-USA-SSPI 2018-19 Chapter Competition

Taking Out the Trash

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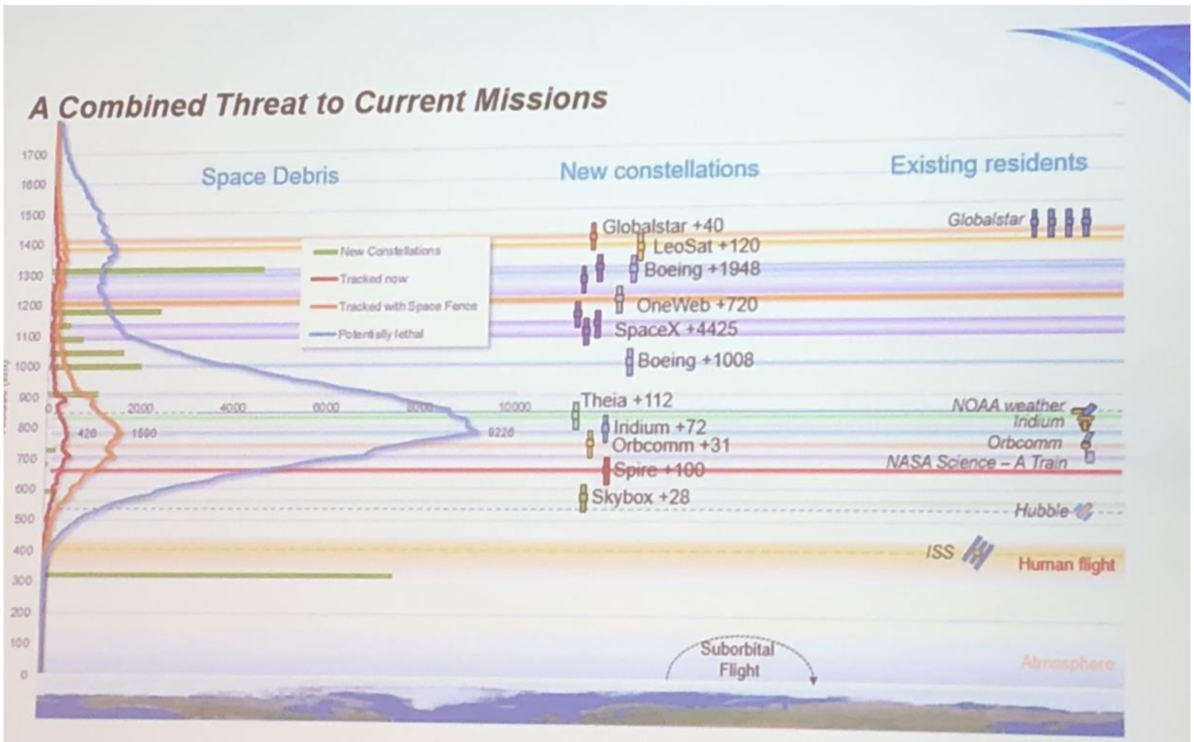
Space debris is an issue of growing concern, with the potential to block access to space, as dramatically illustrated in the film *Gravity*. The Kessler Syndrome shown in the film was proposed by NASA scientist Donald Kessler in 1978: a scenario in which the density of objects in low earth orbit is high enough that collisions between objects could cause a cascade, where each collision generates space debris that increases the likelihood of further collisions. The distribution of the resulting debris could render space activities and the use of satellites unfeasible for many generations.



The challenges to cleaning up low earth orbit are part regulatory, part technical but very much about business model. What are the sources of space debris: yesterday, today and tomorrow – including the larger number of proposed mega-constellations orbiting the earth with no onboard propulsion? Who pays to protect the “orbital commons?” How can the costs and responsibilities be equitably shared and that cost-and-responsibility sharing best enforced? What bright ideas exist for clearing it out? What combination of space law and policy, new technology and economic motivators will be required to reduce the existing cloud of space debris and to prevent additional space debris from being created?

Project Specifications

Research the problem of space debris:

- Its causes, current situation and future potential for interference in space activities, with specific focus on the different satellite orbits (LEO, MEO and GEO) most affected
- The treaties, regulations and insurance contracts that currently government responsibility for debris management, and their shortfalls that have led to the current situation
- Technologies proposed and undergoing testing for clean-up of space debris already in orbit

Following this survey of existing knowledge, propose a comprehensive solution to preventing future space debris and reducing the current density of debris in order. The solution will include:

- Changes to treaties and regulations that motivate launch companies, governments and spacecraft operators to prevent future space debris.
- Proper practices for launch companies and satellite operators in LEO, MEO and GEO for preventing space debris during launch and at end-of-life for orbiting assets.
- Introduction and expansion of technology with the greatest potential to remove space debris at the lowest total cost, based on existing proposals and solutions proposed by the team. The technology plan should include:
    - Engineering design and technology requirements.
    - Technology sourcing from existing technologies as well as technology innovation required to accomplish the mission.
    - Manufacturing, launch and operation of the technology.
    - High-level cost estimates to develop the technology and place it into orbit, and running costs for a mission.

Team Specifications

Teams must be comprised entirely of students at one university. Teams will be limited to one per university, and team candidacy must be submitted through that university's SEDS chapter. We recommend between 3 and 10 members per team, but we encourage team leadership to include as many interested chapter members as possible. Individual team members must maintain student status at the university naming the team and may only contribute to one project at a time.

Since this is a student project, SSPI and SEDS expect student team members to do the vast majority of the work. Mentors are assigned to assist teams with overcoming the learning curve, but should not do substantial work on the project, except when necessity dictates (driven by, e.g., proprietary software). All contributing team members should be credited on the team roster, which is submitted with the project.

Recommended Reading

We recommend a book titled *Space Mission Engineering: The New SMAD* edited by James R Wertz for guidance in mission design beginning with a blank sheet of paper and creating a cost-effective space mission. This book is a staple in the space and satellite industry and provides a very good overview of space mission design. It may be available from your university bookstore or can be purchased from Amazon.com.

Background Information

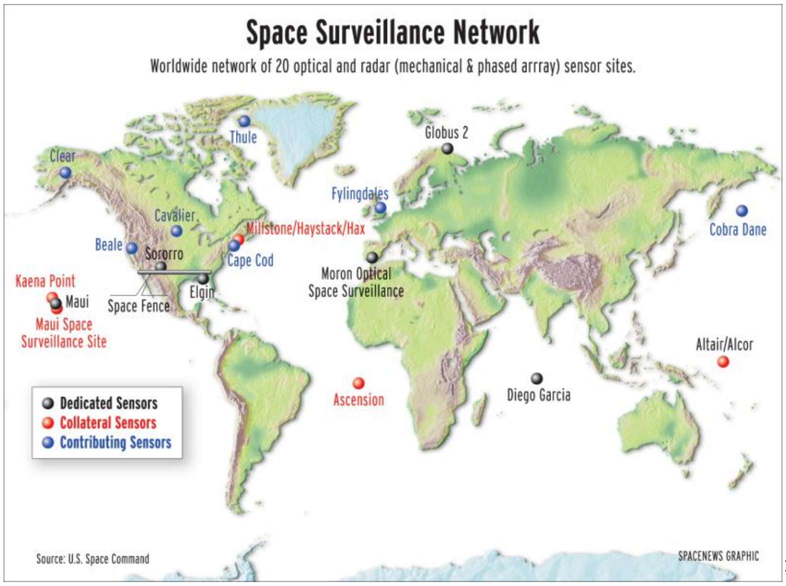
The following offer a starting point for research:

- https://orbitaldebris.jsc.nasa.gov/
- https://aerospace.org/story/space-debris-and-space-traffic-management
- https://aerospace.org/story/danger-orbital-debris
- https://spacenews.com/will-megaconstellations-cause-a-dangerous-spike-in-orbital-debris/
- http://interactive.satellitetoday.com/via/march-2019/the-gravity-of-space-debris/

Status Quo of Orbital Debris and Space Situational Awareness

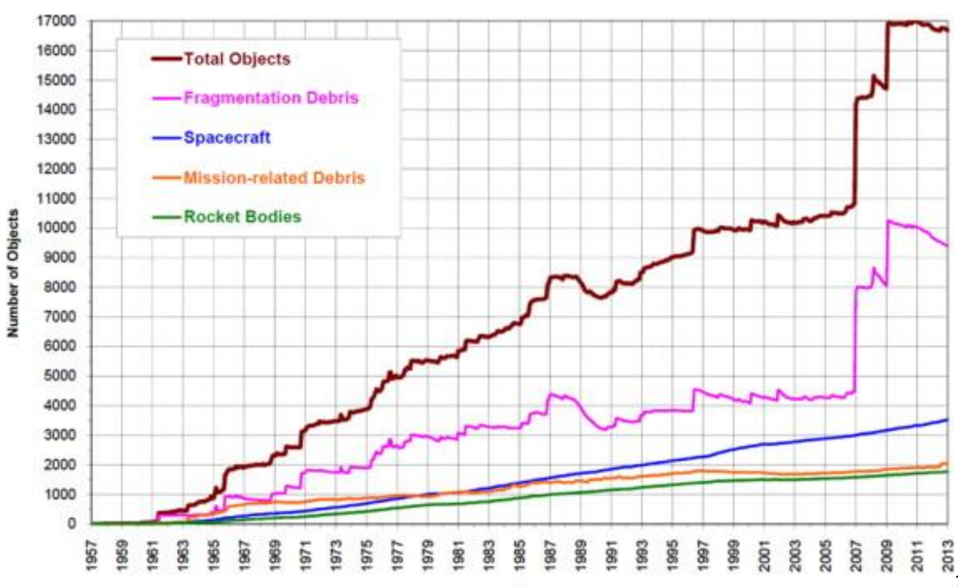
All objects in orbit are tracked by the U.S. Space Surveillance Network (SSN), and the data is published on online by the Joint Space Operations Center at Vandenburg Air Force Base. This same office provides warning notices to satellite operators when a close pass between two objects occurs. This office tracks and publishes data about around 20,000 objects greater than 10cm in diameter, however the number of untracked smaller objects is orders of magnitude larger.

The SSN is made up of many ground-based optical and radar sites as well as a small number of space-based sensors, although the published trajectory information is an aggregation of multiple measurements and cannot be tied back to any one specific sensor.



[1]

Even small pieces of debris can cause potential harm to spacecraft due to the high velocities of objects in orbit, while large rocket bodies could cause catastrophic collisions and hinder future access to commonly used orbits. For objects in Low Earth Orbit (LEO), drag is an ever-present force that continuously "cleans" the regime. However, based on the orbital altitude and physical properties of the object, this is a process that may take decades, and for higher objects, it is a common assumption that they will remain in space permanently.



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[1] U.S. Air Force Envisions Sharing Space Surveillance Data with Scientists: https://spacenews.com/u-s-air-force-envisions-sharing-space-surveillance-data-with-scientists/

[2] "Optical Orbital Debris Spotter" Englert, C., Et al.

International Obligations Related to Space Debris
To attempt to mitigate the rising issue of debris in space, many states, including the major space operators, have independently developed guidelines for debris mitigation. Most of these guidelines are heavily based on a 2007 UN Report: Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space.

This set of guidelines, while not legally binding, established many of the norms that have been adopted worldwide regarding orbital debris. Some of these guidelines include:

- Objects in GEO should be moved to a "graveyard" orbit above the GEO belt at end of life.
- If an object cannot be removed from orbit, it should have any onboard fuel depleted before operations cease.
- Objects in orbit should not release debris as a part of regular operations.

A later UN report has recommended that any spacecraft operating in LEO should have a debris mitigation plan that will result in the spacecraft deorbiting with 25 years of end of life. This 25-year rule is particularly relevant to CubeSats and small satellites, which may only deorbit due to drag, can could provide challenges to future proposals for mega-constellations.

Current Technologies Relevant to Space Debris
In addition to strategies for mitigations, some governments and commercial entities have considered the possibility for active debris removal. Many of these proposals have coincided with recent efforts to develop technology for satellite servicing as some of the fundamental technology and engineering challenges overlap (rendezvous, proximity operations, capture).

Other organizations have proposed electrodynamic tethers, nets, harpoons, and lasers as technology development opportunities for capturing and eventually de-orbiting space debris.

Timeline for Submissions

Discussions with SEDS-USA leadership have yielded the following schedule for the project.

Activity	Responsible	Target Date
ANNOUNCEMENT AND DECISION		
First project announcement to chapters	SEDS	15 March 2019
Second project announcement to chapters	SEDS	25 March 2019
Teams indicate interest in participating	SEDS	19 April 2019
Conference call/hangout to review requirements	Teams, SEDS	20 April 2019
PROJECT START		
Final deadline for team commitment to project	Teams	10 May 2019
Mentor assignment deadline	SSPI	15 May 2019
First online meeting with mentor	Teams	1 June 2019
Complete outline and project plan	Teams	15 June 2019
PROJECT WORK AND SUBMISSION		
First conference call on progress & problems	Teams, SEDS	~1 July 2019
Second conference call on progress & problems	Teams, SEDS	~15 August 2019
Reports due to SEDS and SSPI for review	Teams	1 October 2019
Completion of judging, announcement of awards	SSPI	15 October 2019
Presentation of awards	SEDS, SSPI	November 2019

Submission Details

Teams are expected to thoroughly document their progress through their project:

First Meeting

Team leadership should meet with their assigned mentor and submit brief documentation by the deadlines above. The documentation should include the following:

- Project overview (round-number estimates of basic engineering goals)
- Team roster
- How you will address each bullet point under "Project Specifications" (above), which you expect to be expect to be most challenging (and why), and a couple of scope reduction options.
- Brief timeline for project completion
- "Wish List" from SSPI/SEDS-USA

These items should all be discussed among team leadership before the mentor meeting.

Final Submission

The final submission should address each bullet point under "Project Specifications" (above), including brief descriptions where appropriate of why items were not treated in the project as a whole. Your submission should "tell a story," more or less. The overall submission should be built around a Project Overview document, which should reference documents like:

- Technical Drawings
- Case-studies
- Orbit scenarios
- Launch simulations

Final submission should reference modern scientific literature, much like a research paper. Additionally, the project must include a team roster, preferably with each team member credited with general areas of contribution. Teams are encouraged to assist and seek assistance from one another during that session.

How to Structure the Report

Use the following outline as a template for your report. You need not follow this exact order or include every item, but an effective report will use this outline as a guideline.

1. The problem of space debris
   a. Description of risks to current and future satellite operations posed by space debris
   b. Identification of specific orbital regimes most impacted by debris
   c. Current regulations governing space debris
2. The future evolution of space debris
   a. The impact of proposed mega-constellations on space debris
   b. How future legislation or regulation could mitigate the current and future-developing problems
   c. Potential future business cases for space debris removal
3. Proposed solutions
   a. A summary of proposed technologies to remove space debris, or mitigate the problem
   b. An analysis of what the team believes to be the most viable solution
4. Design and technology requirements, sourcing
   a. Engineering design and technology requirements for the removal technique including power and communications network
   b. High-level design for the spacecraft
5. Manufacturing, launch and operations
   a. Sourcing of technology (existing and proposed new) and spacecraft manufacturing
   b. Identification of appropriate launch provider
   c. Cost analysis for spacecraft development, launch and annual running costs for in-orbit operation
6. Conclusions

Awards

SSPI is making available up to three cash prizes payable to the top-scoring teams in the competition. The first prize is $750, second prize is $500 and third prize is $250.