Thesis Project Portfolio

Hypersonic Atmospheric Reentry Deceleration Experiment (HARD-E)

(Technical Report)

The Sociotechnical Implications of Space Debris: The Dilemma of Space Debris Production and Mitigation Legislation

(STS Research Paper)

An Undergraduate Thesis

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Sociotechnical Synthesis

This portfolio includes two projects: a technical capstone project and an STS research project. The technical project focuses on hypersonic atmospheric reentry research using a CubeSat, whereas the STS project focuses on space debris management. Despite the difference in focus, these projects are related. Space debris, which is defined as any nonfunctional human-made artifact that orbits about the Earth, exists as a consequence of space missions. Though pristine for billions of years, the last 60 years of space missions have left hundreds of millions of debris fragments in Earth's orbit. Much of the debris is concentrated in low Earth orbit (LEO), which is furthermore the most crowded with functional satellites of Earth's orbits. LEO is additionally expected to become more crowded in the near future, as spacecraft advancements reduce the cost of placing objects into orbit and large systems of satellites, which are called satellite constellations, become more common place. The decreasing cost of putting objects into orbit has additionally allowed for CubeSats to increase in use as a relatively inexpensive method of conducting research and as an opportunity for students to gain hands-on experience related to space mission planning. CubeSats are tied to space debris in that they typically inhabit LEO, which is increasingly congested with both debris and functional spacecraft. Once in space, mismanaged CubeSat projects could contribute to the worsening space debris issue. Additionally, CubeSat projects are at risk of being destroyed by space debris in the event of an even minor collision event.

The technical project seeks to assess the feasibility of using a CubeSat, which is a relatively inexpensive miniature satellite that is typically used for research purposes, for decelerating hypersonic research. The project's CubeSat, which will be of the 3U size variant, is planned to be launched into extreme low Earth orbit (ELEO) with a Northrop Grumman Antares launch vehicle, where the CubeSat will separate from the launch vehicle and orbit for approximately five days. After the CubeSat's orbit decays and the CubeSat begins to reenter the Earth's atmosphere, sensors on the CubeSat will collect data as the CubeSat undergoes hypersonic deceleration. More specifically, temperature, pressure, and orientation will be recorded during the CubeSat's decent. The collected data will then be transmitted to what will most likely be another orbiting satellite. The CubeSat is intended to completely burn up before making contact with the Earth's surface. The mission's success will largely depend on the collection and interpretation of intelligible data that provides insight into hypersonic deceleration, which is highly valuable for applications such as the development of reentry vehicles.

The STS project seeks to investigate the sociotechnical aspects of space debris and the management of space debris. Space debris is a pressing issue worth investigating due to its prevalence in the highly congested LEO, as previously stated. Due to the speed at which space debris travels, even relatively small fragments of debris are capable of catastrophically damaging spacecraft or fatally wounding any human that is involved in a collision event. Additionally, the propagation of space debris is governed by an exponential cascading effect, known as Kessler Syndrome, where collision events generate clouds of fragments that encircle the Earth and intensify the risk of future collisions. Proper space debris management largely consists of the responsible disposal of defunct spacecraft, such as dissipating any internal energy stores such that the debris will not explode and altering the spacecraft's orbit at the end of its operational life to either reenter the atmosphere or to remain in a distant graveyard orbit. Outlines for proper space debris management have been outlined by organizations such as the United Nations and NASA. However, these guidelines are not legally binding, and spacefaring entities voluntarily submit to them. In order to properly manage space debris and mitigate the future risks concerning space debris propagation, the international community must overhaul how space law currently works and impel all that would use space to behave responsibly. The STS project views space debris management through the wicked problems framework given the complexity inherent to space debris management. Through this framework, space debris is not an issue to be solved but rather one to be continuously managed through great effort and with global cooperation.

By concurrently conducting research on the technical project, which concerns hypersonic deceleration through a CubeSat platform, and the STS project, which investigates the issue of space debris management, great emphasis has been put on the responsibilities of an engineer and the role that engineering ethics has in the design process. Proper space debris management is essential in order to ensure a future in which research in space can be conducted fairly and with equal access to all spacefaring nations. Though primarily accomplished at a larger scale and through great cooperation between the entire spacefaring community, space debris management also ties into the individual design processes of smaller teams of engineers. By working on both projects concurrently, greater context is additionally added to all in place guidelines as adopted by NASA.