Hypersonic ReEntry Deployable Glider Experiment
(Technical Paper)

Space Debris: How Technology as a Self-Determining Entity in Space Impacts Social, Economic, Political and Other Forms of Developing Technology
(STS Paper)

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Prospectus

Introduction

On February 10, 2009, two satellites collided in Low Earth Orbit resulting in nearly 2,000 pieces of space debris (Weeden, 2009). Space debris, a relatively new issue threatening space exploration and development, is divided into two main categories: naturally occurring and artificial, man-made (ESA, 2021). Naturally occurring debris presents itself in the form of meteoroids which have long been a concern to scientists especially with the growth of space assets since the 1970s. Additionally, advancements in hypersonic flight have raised concerns regarding the potential collisions between hypersonic crafts and space debris.

The incentive behind this hypersonic research stems from the seriousness of space debris, its potential impact on hypersonic vehicles, and the significance of hypersonic technology. Hypersonic technology presents opportunities for efficient travel methods, National defense, as well as scientific advancement through data collection. Space debris exists, quite literally, as a physical barrier to hypersonic flight given the additional planning that must go into circumnavigating hazardous debris mid-flight. Thus, it is worth investigating the relationship between space debris and hypersonic technology. The technical portion of this project will focus on developing a hypersonic vehicle to collect data in orbit which can then be used to further research in the field of hypersonics.

Society has seemingly lost control of the technology it has developed for space and as a result, future generations will encounter stricter barriers to entry. Additionally, society has been aware of the potential harm of artificial debris but technology is the driving factor behind the current space entanglement. The effect that space debris has on society must be examined from a broader perspective before being analyzed on a critical level. The question that will be explored

throughout the STS portion of this paper is how technology as a self-determining entity in space impacts social, economic, political and other forms of developing technology.

Technical Topic: Hypersonic Glider Flight Experiment

Hypersonic flight occurs at speeds exceeding five times the speed of sound and is an expanding research field in the aerospace industry with military and civil applications. Military applications include hypersonic missiles, both offensive and defensive, and high-speed aircraft. Civil applications include access to space and commercial air travel. A CubeSat is a small satellite flown in low earth orbit that is well suited for undergraduate education. As CubeSats orbit Earth, they fly at hypersonic speeds and re-enter the atmosphere in around five to seven days if launched into Extreme Low Earth Orbit (ELEO) (Panwar & Kennewell, 1999). Once objects re-enter the atmosphere, they can prolong hypersonic flight if measures are taken to reduce drag.

Some current United States Weapons systems being developed include the Air-Launched Rapid Response Weapon (ARRW), Intermediate Range Conventional Prompt Strike (IRCPS), Long-Range Hypersonic Weapon (LRHW) and unmanned hypersonic aircraft. However, conducting these large scale projects is expensive and time consuming (Bentle, 2021). By conducting this research experiment on a hypersonic glider utilizing a CubeSat, data collection will be cheaper, faster, and more accessible. Having undergraduate students conduct the research experiment will provide them with the knowledge base to directly enter the hypersonics workforce. Additionally, further understanding of hypersonic flight may lead to advancements in commercial aircraft and spacecraft. Hypersonic aircraft would greatly decrease travel time, while

hypersonic spacecraft would provide greater accessibility to space travel. Flight data collected from CubeSat research will provide hypersonics researchers and professionals with information to help advance hypersonic flight, ultimately making it more accessible to the world.

As previously described, the goal of this research is to perform a hypersonic experiment using a test article deployed from a CubeSat in Extreme Low Earth Orbit (ELEO). This goal has been discretized into three primary objectives, which are motivated by a combination of technical and educational considerations. These primary objectives have been further subdivided into supporting objectives (communications; software and analysis; power, thermal, and environment; attitude determination and control system (ADACS) and orbits; and structures and integration) intended to facilitate the completion of these larger goals. Upon project completion, the fulfillment of these objectives will be used to gauge mission success.

For the design and construction of the project, the team is provided with resources such as industry experts, sponsors, and available facilities. Team advisor, Chris Goyne, alongside additional faculty support from University of Virginia provides invaluable knowledge and guidance to the team during the conceptual design of the project. The Federal Communications Commission (FCC) will also be consulted for additional guidance on requirements and regulations on communication with the CubeSat. Two key sponsors for the team include the National Aeronautics and Space Administration (NASA) for funding of the fabrication and testing of the team design as well as providing the launch site, Wallops Flight Facility, and Northrop Grumman for providing the Antares launch vehicle (Clark, 2021). The final deliverable will be a hypersonic flight vehicle proposal outlining the technical and logistical goals of launching the vehicle into orbit, retrieving data, and distributing data to hypersonic research

teams. The proposal will be utilized by the succeeding spacecraft design team to assemble the cubesat vehicle and launch it into orbit.

STS Topic: Background and Theory on Space Debris

Artificial debris and its threat to space assets has become a topic of great concern due to the severity of the issue it poses for existing and future technologies in space. Currently the Department of Defense (DoD) tracks anywhere from 24,000 to 30,000 objects that can be classified as artificial debris (Garcia, 2015). Man-made debris originates from leftover space "junk" from launches, accidents, and obsolete space crafts. Much of this debris is not tracked on a regular basis by the DoD as its primary concern is any object exceeding 10 centimeters. Smaller objects under this dimension, such as paint flakes, can still cause significant damage to functional crafts but due to their size and dynamic patterns of orbit, existing technology is better suited monitoring debris with catastrophic mission effects.

The issue of space debris is far reaching--involving many elements and members of society. On a superficial level, there are scientists and government agencies monitoring space traffic maneuvering through the debris field. Policy makers and regulation enforcers are responsible for minimizing the accumulation of additional space debris with international laws that closely monitor new launches and their jettisoned components. At an economic and societal level, private industries and activists hold a wide range of interests in space. These interests vary from commercialized space flight to environmental activism. Scientific exploration in space faces a severe threat due to space debris because of the harmful interactions between the scientific technology in space and orbital projectiles. In turn, these harmful interactions indirectly affect future exploration technologies from being developed due to additional precautions that must be taken into consideration. Overall, the network of stakeholders, physical artifacts, and

non-physical artifacts mentioned do not have clearly defined relationships. There is no single source of the problem just as there is no single resolvent.

Artificial debris is one such limitation that has already raised political concerns regarding continued expansion. New agencies such as the United States Space Force are being tasked with monitoring this growing area of concern as it also threatens National security (Department of Defense, 2021). Additionally, the Federal Communications Commission (FCC) claims responsibility for new space systems integrating plans for mitigating orbital debris as a part of their respective mission sets (FCC, 2020). Concerns raised by opponents of the FCC are that regulations imposed do not align with national interests and that the authority given overlaps with similar regulatory agencies. Such regulations have filtered down into government agencies such as the National Aeronautics and Space Administration (NASA). NASA has been forced to implement several policies aligning with the demands of the FCC in order to mitigate space debris stemming from scientific oriented missions (Harrington, J. D).

Society is very much reliant on the technology that sits in orbit; from everyday applications such as networks, communication, security systems--nearly everything that can be considered a form of technology is and soon will be reliant on space technology to some degree. Economics is a very large factor in determining who and what gets to go into space. The Organisation for Economic Co-operation and Development of space (OECD) is responsible for stimulating economic progress and world trade. The OECD cites impact avoidance and debris mitigation as significant mission costs that mission planners must account for. Societal status and wealth have reignited a space race among the wealthy elite--Jeff Bezos and Elon Musk are notable figures worth mentioning. Fierce competition among their private corporations in space has led to lawsuits, trivial arguments, and bidding wars over federal funding (Cai, 2021). The

masses backing the billionaires and others alike generally support the idea of space exploration but the image of private industries' expansion in space is clearly clouded by underlying competition. Space debris has no limitations on the individuals and entities it impacts. Private industries and their economic backers must take into consideration the regulations and additional technological capabilities required to enter the domain of space.

Environmental concerns brought up by the threat of space debris have sparked innovations in debris mitigation technology. Several spacecraft that failed to burn up in the atmosphere upon reentry have caused environmental issues in several communities. Testimonies from locals in the vicinity of space debris impact sites report a disproportionate cancer rate which is likely due to the rocket fuel contained in the debris (Luke, 2021). Several technologies such as harpoons, lasers, and specialized satellites have been proposed to mitigate space debris (CTU, 2021).

The threat posed by space debris on society is best explained by the STS concept of Technological Determinism. This concept states that society is shaped by technology and not the other way around (Hallstrom, 2021). There are some opposing views in this piece of literature as the extent to which society is shaped by technology is questioned. Ultimately, it is determined that society does have some influence over technology's self-determining behaviour which is contrary to traditional arguments in Technological Determinism. For the purposes of this study, hard determinism is seen as technology, in the form of unintended artificial debris, has taken on a "life of its own" in space and is ultimately independent of the social concerns it raises (Smith, 1994). Capitalist societies, concerned with rapid growth, have seemingly lost control of the technology it has developed for space and as a result, future generations will face the consequences (Adler, 2006). Adler however does provide a counter-view in that he argues that

the self-determing aspect of technology may not be a negative feature. Technology driving itself in the direction it best sees fit may guide society in the areas of progress previously unexplored. Soft determinism is revealed in that society has been aware of the potential harm of artificial debris but technology is the driving factor behind the current space entanglement. To reiterate the significance of the technological determinism of space debris, space debris will continue to shape society with no regards to the social, political, economic, and technological impacts it causes. A better understanding of the relationship between technological determinism and space debris will enhance the understanding of the root causes and hopefully mitigate its impacts.

Methodologies

To reiterate, the question that will be explored throughout this discussion is how technology, in the form of space debris, as a self-determining entity in space impacts social, economic, political and other forms of developing technology. To investigate this question, several research methods will be used: wicked problem framing, policy analysis, and network analysis. Understanding the key issues at hand through wicked problem framing, the policy makeup of regulations regarding space debris mitigation, and the factors at play through network analysis will successfully accomplish research goals in this investigation. The scope and relevance of the topic will prove to be valuable in the availability of resources used to investigate the research question.

Some keywords that will aid in the research process are “machine learning”, “technology policies”, “space regulations”, “space politics”, and “technological determinism”. These keywords will aid in the research process because they are refined to the scope of the space regulations, policies, and the STS topic of Technological Determinism. The research will be

organized as such: providing a broad overview of the policies in place and those that are developing through the use of policy analysis, establishing the problem at hand through wicked problem framing, establishing the network of space debris through network analysis, and finally, relating these areas of research back to Technological Determinism through literature analysis.

Conclusion

Through demonstrating the feasibility of CubeSats as a platform for hypersonic glider flight, this project will introduce a new method for conducting low-cost hypersonics research in conditions unachievable on the ground. The project will rely on several events occurring: the successful deployment of the CubeSat and hypersonic glider, the stability of the glider during flight, and data being relayed during reentry. Ideally, the data will show a longer time in orbit than a typical CubeSat design due to the decreased drag on the test article with stable hypersonic flight conditions.

Research into the impact of space debris as a self-determining entity and its impact on society is expected to yield the following outcomes: more awareness of space debris as a issue affecting society, the connection between Technological Determinism and space debris, and incentives for further investigation into mitigating space pollution in the form of a research paper. Additionally, a wide range of data, technical research, and policies relating to space debris and STS concepts should result from the research conducted.

References

Adler, P. S. (2006, July 7). Technological Determinism. (Stewart Clegg & J. R. Bailey, Eds.) The International Encyclopedia of Organization Studies.

Advanced technology to remove space debris from orbit. Capitol Technology University. (2020, June 1). Retrieved October 15, 2021, from https://www.captechu.edu/blog/advanced-technology-remove-space-debris-orbit.

Bentle, R. (2021, September). Strategy at Mach 5: Hypersonic Weapons in Chinese Military Strategy. Retrieved from Air University: https://www.airuniversity.af.edu/Wild-Blue-Yonder/Article-Display/Article/2771133/strategy-at-mach-5-hypersonic-weapons-in-chinese-military-strategy/

Cai, K. (2021, September 29). Elon Musk, now world's richest person, told Forbes he's sending Jeff Bezos a silver medal. Forbes. Retrieved October 26, 2021, from https://www.forbes.com/sites/kenrickcai/2021/09/28/elon-musk-responds-to-replacing-jeff-bezos-richest-person-silver-medal/?sh=2b3a69c81cd4.

Clark, S. (2021, February 20). Antares launch timeline on the NG-15 mission. Spaceflight Now. Retrieved October 19, 2021, from https://spaceflightnow.com/2021/02/20/antares-launch-timeline-on-the-ng-15-mission/.

Department of Defense . (n.d.). About the United States Space Force. United States Space Force. Retrieved October 1, 2021, https://www.spaceforce.mil/About-Us/About-Space-Force/

Federal Communications Commission, 20, Mitigation of Orbital Debris in the New Space Age 1–137 (2020). Washington, D.C.

Garcia, M. (2015, April 14). Space Debris and Human Spacecraft. NASA. Retrieved October 1, 2021, from https://www.nasa.gov/mission_pages/station/news/orbital_debris.html.

Hallstrom, J. (2020, June 11). Embodying the past, designing the future: Technological determinism reconsidered in Technology Education. International Journal of Technology and Design Education. Retrieved October 17, 2021, from https://link.springer.com/article/10.1007/s10798-020-09600-2.

Harrington, J. D., & Ramji, N. (n.d.). Orbital Debris. Retrieved October 12, 2021.

Luke, C. (2021, September 6). What is space junk and how does it affect the environment? Earth.Org - Past | Present | Future. Retrieved October 14, 2021, from https://earth.org/space-junk-what-is-it-what-can-we-do-about-it/.

OECD Development Centre, & OECD Secretariat, 87, Space Sustainability: The Economics of Space Debris In Perspective1–63 (n.d.). Paris; OECD Science, Technology, and Industry.

Panwar, R., & Kennewell, J. (1999). Satellite Orbital Decay Calculations. Australian Government: Bureau of Meteorology. Retrieved October 19, 2021, from https://www.sws.bom.gov.au/Category/Educational/Space%20Weather/Space%20Weather%20Effects/guide-to-space-radiation.pdf.

The European Space Agency. (n.d.). About space debris. ESA. Retrieved October 1, 2021, from https://www.esa.int/Safety_Security/Space_Debris/About_space_debris.

Smith, M. R. (1994). Technological Determinism in American Culture (dissertation). MIT Press, Massachusetts, MA.

Weeden, B. (n.d.). 2009 Iridium-Cosmos Collision Fact Sheet. Publications by Brian Weeden | Secure World. Retrieved October 18, 2021, from https://swfound.org/about-us/staff-publications/publications-by-dr-brian-weeden/.