Space Debris Tracking CubeSat

(Technical Paper)

Halting Orbital Pollution: A Study on Air Pollution Regulation as a Means for Regulating Orbital Pollution

(STS Paper)

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By
Owen Martin

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Technical Team Members:

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.

ADVISORS

Haibo Dong, Department of Mechanical and Aerospace Engineering

Tomonari Furukawa, Department of Mechanical and Aerospace Engineering

Bryn E. Seabrook, Department of Engineering and Society

Introduction

The space industry is arguably one of the fastest growing industries in the world today, demonstrated by the introduction of reusable rockets, mega-constellations for satellite internet, commercialized space-travel, and other examples not dreamt possible just fifty years ago. More organizations and institutions, space agencies and private companies have their hand in the space technology innovation game than have ever existed. The rate at which new technologies orbit the skies is ever growing, and has skyrocketed particularly in the last decade. With the introduction of so many satellites into orbit, the chance for in-orbit collisions of these satellites is growing as well. As of right now there exist over 170 million pieces of orbital debris in Earth's orbit larger than 1 mm in size (*ESA - How Many Space Debris Objects Are Currently in Orbit?*, n.d.). Without proper methods of halting this increase in debris accumulation, there is real potential for this issue to grow catastrophic, and to make Earth's orbit borderline unusable.

The research this paper will propose to do looks to investigate and attempt to make strides to halting the increase of orbital debris. My research will be split into two parts, a technical part, where my team and I will look to develop an in-situ sensor, to offer improvement or alternative on current detection methods used today. The goal of this project is to prove the efficacy of small-scale debris detection sensor, that could prove its use in small-compact size and weight configuration, to hopefully be implemented into commercial satellites, and ultimately granting a better ability to survey the entirety of low-Earth orbit (LEO). My STS research topic investigates the issue from an organizational standpoint, and will attempt to gain some information on how a future space-cleanup protocol should be organized and implemented across the responsible parties around the globe. It will attempt to do so through a comparison case study, the United Nations' signed Paris agreement – an agreement regarding climate change mitigation across most of the world's nations.

Technical Topic

Today, information on space-debris with size greater than around 10 cm is well-known with the methods currently employed. The currently relied on methods are mainly ground based, utilizing ground radar systems and optical methods, and all of these methods struggle to detect and provide useful data on objects less than 10 cm in size (Matney, n.d.). One of the factors that causes this difficulty in detecting small debris from the ground is atmospheric interference. The atmosphere can hinder the distance that a signal is able to travel and also dissipate and weaken the signal, making it either irretrievable or unreadable. Also, the sheer distance a ground observatory is from an object the size of a golf ball in orbit is large, and objects are detected via a reflected wave, which is weaker than the signal emitted from the ground observatory, so these weaker reflected waves struggle to be received across such large distances through the atmosphere. A method of avoiding these problems altogether is to use a radar detection system in orbit, and my research is setting the groundwork to accomplish this.

The implementation of an in-situ, small-scale debris tracking instrument would prove the efficacy of this type of device in providing more accurate data on small-scale space debris. To accomplish this task, my research will be to develop a sensor that can detect small-scale orbital debris, with the goal of implementation into a CubeSat. The sensor would be able to successfully detect small debris from a distance and approximate its size, though this distance will be much less than that required from a ground station, and the optimal distance will be determined through further research. Integration into a CubeSat is the target goal for this project. A CubeSat is a nanosatellite that meets a specific size and weight constraint that is universal to all CubeSats, for ease of implementation into the payload of a contracted rocket, to deliver into LEO. The CubeSat configuration is cost-effective, the structural requirements are simple to follow and provide guidance, and most CubeSats are deployed in LEO by default, where most orbital debris is accumulated already (*Space Debris - NASA*, n.d.). The ultimate goal for this project is to demonstrate the effectiveness of a small sensor that could be implemented into satellites from other space agencies and companies, without demanding a large power consumption and imbuing a size or weight imbalance. This would mean that no added satellites need to be added into orbit to survey the entire orbit, to avoid contributing to the issue.

Conducting trade studies is the plan of action for developing a design for the debris sensor. Some options that are being considered are transmitting a radar signal and receiving the reflected signal via an antenna, utilizing passive radar detection meaning picking up on scattered, reflected radar signals from third-party emissions, such as the Starlink constellation, and others. The sensor design faces many constraints, which prevent my team and I from spending too much time developing the perfect sensor with excessive power draw and complexities. One of the key constraints we face is the range of detection and resolution of the received signal. To transmit higher frequency radar waves required a larger power source, however the range of the sensor is dependent on this frequency, and dropping the transmitted frequency too low would yield too weak of a return signal to detect, thus there is a trade off between power draw and effective range of detection. This is just one example of many variables that are interdependent on each other, so optimizing these variables in a time-efficient manner will be paramount to the project's success.

STS Topic

The problem of accumulating orbital debris is becoming a more prevalent one year-by-year, with the advent of satellite-internet *'mega-constellations'* launching several thousand nanosatellites every year, increasing the likelihood of in-orbit collisions and thus the rate of debris production (*Annual Number of Objects Launched into Space*, n.d.). A need for a globally-organized cleanup effort is a necessity in the foreseeable future, as without intervention, debris accumulation will become increasingly uncontrollable, and detrimental to the ability to utilize space in general, be it through satellite usage, or astronomical observation.

A need for space-debris cleanup then begs the question of how should this cleanup effort be organized, and who should the responsibility be delegated to, if not delegated to all parties? My research will attempt to answer this question by investigating the use of a comparative case-study with the Paris Agreement established by the United Nations Framework Convention on Climate Change (UNFCCC), as a means of providing a comparison to be made with the orbital debris issue, to determine factors of the Paris Agreement that can be implemented in solving the orbital debris issue. The Paris Agreement was chosen specifically due to the closely related nature of the two issues being compared, as they both pertain to pollution on a global scale. Using a closely related issue is key for comparative purposes, contrary to any arbitrary successful international agreement. For example, the International Space Station (ISS) is an ongoing example of a very successful international space cooperation achievement, an "international partnership of five space agencies from fifteen countries" (*International Space Station Facts and Figures - NASA*, n.d.). However, there were no pressing and time-sensitive issues, like that of space pollution, that influenced the need for competing nations to come together on its invention. This is a different case for the issue of space-debris cleanup. Debris accumulation is contributed to by space agencies in their utilization of Earth's orbit, and those contributors have furthered the issue unequally. Russia's national space agency, Roscosmos, may be less willing to cooperate with United States's NASA (National Aeronautics and Space Administration) on a cleanup effort, because space pollution is an existing issue seen negatively in the public and industrial eye, and this can cause fingers to be pointed when either party is called up to provide resources for this issue.

It is notable that some nations contribute more than others to global warming, particularly the developed versus undeveloped nations. The same principle applies to the orbital pollution problem, where nations with developed space agencies produce more satellites, thus the bulk of the issue can be attributed to these nations. One of the most important controversies that drove the UNFCCC to create the Paris Agreement was this issue of developed versus developing nations contribution argument. The Kyoto Protocol, ratified in 2005 though negotiated and adopted by 1997, set the principle that only developed nations, titled Annex I parties, meet binding obligations to reduce their CO_2 emissions, where developing nations had no binding targets to meet. The Paris Agreement responds to this issue of differentiation and removes any notion of Annex I parties, and reestablishes the agreement around the idea that "developed country Parties should continue taking the lead by undertaking economy-wide absolute emission reduction targets" (United Nations Framework Convention on Climate Change, 2015, p. 4), but also holding that developing ones are responsible as well (Vogler, 2018). The transition from a developed-nations-only approach to a more lenient all-nations-responsible approach, is an example of a key precedent established by the Paris Agreement that can be applied to a similar issue regarding the orbital debris accumulation problem.

The argument still lies, however, on how relatable the climate crisis issue and orbital pollution are. At first glance these two have many similarities that could elicit similar responses and allow for parallels to be drawn. Though to rely on an analysis of the Paris agreement and its usefulness to provide insight on organizing the debris cleanup issue, would require a more in-depth comparison of the two. To accomplish this, my research will aim to use Latour's Actor-Network Theory on an analysis of the technological systems that contribute to both the climate crisis and orbital pollution.

Actor-Network Theory cannot be applied just to the issues themselves, as the framework is used to gauge the network of relationships between technologies and humans. Therefore, to utilize Actor-Network Theory in a comparison between climate change and orbital pollution, the technologies that contribute to these issues must be analyzed. The actors that are a part of the networks that surround either of these two issues are vast and intertwined, and thus to only analyze technologies that contribute the most to these issues respectively will be essential to making my research feasible. The goal of using Actor-Network Theory then is to research and analyze the technological systems chosen (i.e. fossil fuel power plants & starlink), then draw parallels across the two technological systems, regarding the relationships that technologies have with their actors, human or non-human. To then draw effective principles set by the Paris Agreement is to research how these principles have affected the relationship between the actors in the technological system pertaining to climate change contribution, and how these principles could similarly affect the relationship between the actors in the technological system pertaining to the orbital debris issue. This approach would allow for principles of the Paris Agreement to be drawn that could have positive effects on the orbital debris issue, in areas where the relationship between actors and technologies across both issues are similar.

Conclusion

Space debris mitigation is a global issue that has rapidly-growing effects that may easily spiral out of control without human intervention. The end goal of my research is to develop and perform a successful ground test of a small debris tracker that meets desired range, power, size, weight, and resolution criteria, amongst other things. The next step is to leave it to future classes to improve upon and implement into a CubeSat and deploy into LEO, at some point in the near future. My STS research seeks to find some guidance on how to effectively organize a global effort to clean-up space debris and remove it from orbit. The responsible parties all have contributed to the issue in varying amounts, and so to break down a method of assigning responsibility, or imbuing a sense of responsibility in these nations, is a crucial part of keeping the skies clean.

Sources

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