High Resolution Satellite Imaging of Nitrogen Dioxide from Low Earth Orbit

(Technical Paper)

Positively Influencing Space Junk Policy by Utilizing Negative Emotions Toward 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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Introduction

More than 95% of the world's population lives in areas where air pollution exceeds standards designated to protect human health (University of Virginia, 2018, p. 2). Nitrogen dioxide is an important air pollutant because it contributes to smog, which can have significant influences on human health. Breathing in high amounts of nitrogen dioxide leaves individuals more prone to lung infections and respiratory problems such as asthma (Australian Government Department of the Environment and Energy, 2005, p. 1). While air quality in U.S. cities has improved over the last few decades, there is still evidence of large pollution distributions in major cities and drastic differences in health and life expectancy as a result. Accurately measuring the distribution of air pollutants that impact human health remains a key challenge in atmospheric chemistry and health sciences.

The increasing uses of remote sensing imagery and satellite global positioning systems are contributing to a greater surveillance of the environment and better understanding of the relationship between the environment and human health (Broome, Croner & Sperling, 1996, p. 1962). The air concentrations previously recorded are average concentrations that may lead to inaccurate conclusions of how intensely air pollution affects human health (Burnett, Jerett, Krewski, Ma, Newbold & Pope, 2005, p. 732). Chronic health effects associated within city gradients may be even more serious than previously reported in metropolitan areas.

In order to offer a solution to the currently inaccurate pollution data available, my technical project will develop a small 3U CubeSat capable of taking high quality geospatial images of NO2 concentrations over major cities. The data collected will serve as a means of more accurately understanding the amount of pollution present over major cities and may help the public more accurately understand the impact that they have on the environment and their health. My STS research will discuss the problem of space junk and the consequences that can emerge when launching another satellite into space. My technical and STS research topics will together explain the importance of identifying the many stakeholders that contribute to the implementation of a new technology into society.

Technical Topic: Developing a CubeSat for Capture of High Quality Images of NO2 Pollution

Geographic information systems (GIS) and digital computer technology are aiding the missions of the Centers for Disease Control and Prevention and the Agency for Toxic Substances and Disease Registry in protecting human public health (Broome et al., 1996, p. 1962). More frequently than ever, CubeSats are being used in order to obtain data pertaining to human public health. NASA plays a major role in the development and production of CubeSats. NASA has enabled educational institutions, universities, and non-profit organizations to launch CubeSats through the CubeSat Launch Initiative (CSLI) for Educational Launch of Nanosatellite (ELaNa) missions (Crusan & Galica, 2019, p. 51). When NASA funds CubeSat missions, both the organization being funded and the government benefit from a stronger public-private partnership that provides both educational value and useful scientific data. The use of Cubesats as an educational tool and a cheap way to obtain scientific information has exploded on a global scale. Cubesats offer low construction and launch costs which positively affect the stakeholders (Ehrenfreund, Hertzfeld, Ricco & Woellert, 2011, p. 664). The University of Virginia is being funded to develop a 3 unit CubeSat. To emphasize the small size of the satellite, the CubeSat structure will have a maximum volume of 12 x 12 x 34.065cm^2 and a maximum weight of 4.8 kilograms. The goal of the mission is to capture high quality images of NO2 distributions over major international cities.

Current measurements from CubeSats and other missions have not been able to capture the NO2 spatial distribution at precise enough scales that can be used to inform the public about air quality. Satellite data provides spatially continuous NO2 column maps over periodic time periods, but the current models of sensors lack the spatial resolution required to capture the fine-scale variability needed to accurately map urban NO2 distributions (University of Virginia, 2018, p. 3). Inaccurate data retrieved from blurry geospatial images may not be able to inform the public of the true dangers that exist. As pictured below in Figure 1, the goal of the mission is to develop a 3U CubeSat bus capable of measuring NO2 columns at a spatial resolution better than 1 km^2 (200 m x 800 m) and to use this data to improve the understanding of NO2 emissions and concentrations in urban landscapes (University of Virginia, 2018, p. 3).

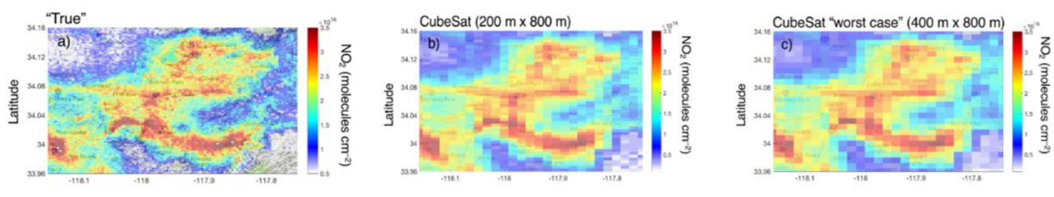

Figure 1: NO2 distributions over a small area in the Los Angeles, CA air basin. From left to right, the images demonstrate the scale of resolution that could result from a satellite imaging. The quality of image is highest on the left and is impaired further to the right. Image received from 3U CubeSat proposal, 2018, p. 3.

The CubeSat mission is divided into subject component teams that include program management, communications, software and avionics, thermal environment analysis, attitude determination, and structures and integration. I am a member of the attitude determination team. Working off of the progress that has been completed in previous years, the goal by the end of the school year is to use orbital mechanics in order to maximize the pointing accuracy of the 3U satellite towards Earth. This should improve the resolution of the images and provide more accurate data of NO2 distributions.

STS Topic: Establishing International Policy for the Increasing Quantity of Space Junk that Surrounds Earth

While the proposed 3U CubeSat offers great solutions to improve global public health, it is important to recognize the tradeoffs that introducing a new satellite into space presents. More than 4,600 satellites are currently orbiting the Earth along with over 14,000 old rocket parts and pieces of space junk that are no longer in use. The pieces of debris that are moving in space are accelerating at speeds far greater than a speeding bullet. If a collision were to occur, the result would be more pieces of debris flying around at extremely high uncontrolled velocities. In addition to collisions in outer space, the high density of space debris surrounding Earth could soon make it too dangerous for missions to leave Earth (Kiersz & Mosher, 2017, p. 1). The figure below offers a visual representation of the dense amount of junk that currently surrounds Earth.

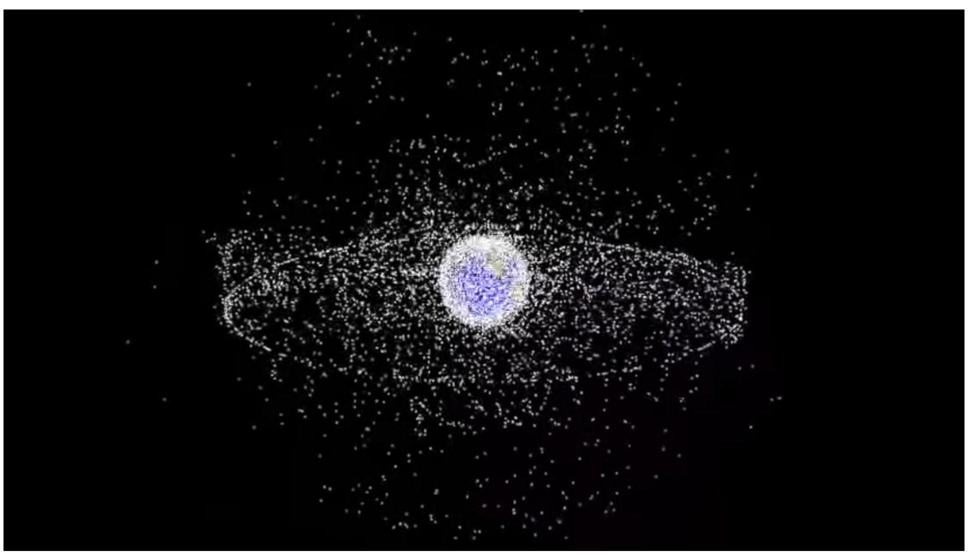

Figure 2: A visual representation of the amount of space junk that currently surrounds Earth. Overpopulation of space is a major issue closer to Earth in low Earth orbit, but extends into orbits that are further from Earth. Space junk is categorized as satellites that are currently in use and old rocket parts that are no longer in use. Image received from Wenz & Rand, 2015, p.1.

The expansion of human presence in space involves new stakeholders and new countries leading to an internationalization in space exploration. Identifying international countries as an indirect stakeholder in the issue of space junk is important to consider before introducing more satellite technology into space. Debris presents the same risk to a country's own systems as it does to everyone else. This could lead to international dispute and frustration over the introduction of new missions into surrounding Earth space.

The United States is currently the most responsible for the amount of debris in space, followed by Russia and China. Ailor from the Aerospace Corporation stated, "No other nation has permission to touch a US satellite. And if we went after a satellite, it could even be deemed an act of war." (Kiersz & Mosher, 2017, p.1). Space exploration between the Earth, Moon, and Mars only continues to increase as the aerospace industry continues to grow in success on a global spectrum. The governance that currently exists between nations in terms of space exploration is slim to none. Plans for space exploration and the consequences of evolving exploration must be considered especially in the effects that they may have in cross-cultural differences between nations.

Nations may need to start having international conferences to discuss safety issues regarding new missions. These discussions may need to address whether certain missions are even necessary to execute when space is becoming so scarce. Instead of nations planning projects individually, countries may need to start working together with less secrecy in order to collaboratively prevent collisions and international problems in the future.

In an effort to introduce more collaborate work efforts toward space exploration, the private sector will begin to play a much more major role than it did in the past as socio-economic motives may soon begin to drive the new era of space racing (Ehrenfreund, Peter, Schrogl & Logsdon, 2010, p. 250). There are currently few solutions, but as of 2011, the Committee on Space Research Panel of Exploration (COSPAR) was chartered to provide advice on how to support the development of space exploration programs. COSPAR is formed by the United States National Research Council, the International Academy of Astronautics, the International Astronautical Federation, the International Lunar Exploration Working Group, the European Space Science Committee, the Lunar Exploration Analysis Group, and the Mars Exploration Analysis Group. Their hope is that an international cooperation will lead to a global space exploration program. This will rise above cultural differences which could lead to healthy international relationships with public and private sectors. The program will increase knowledge obtained from space exploration on a global spectrum without becoming too conflicted with national economic gain and credibility. The overarching goal is to engage developing countries and emerging space nations in an international space exploration program to create a bottom-up support structure to support the continuity of the program's growth (Andsel, Billings, Enrenfreund, Foing, Mackwell, Mankins, McKay, Neal, Peter, Perino, Rummel, Zarnecki & Zwaan, 2012, p. 6). Creating new necessary political, economic, and legal frameworks will be difficult but necessary as nations begin to work together to design objects that go into space (Ehrenfreund, 2009, p. 244).

Evaluating the reasons to execute a space mission will become increasingly significant in the future. With a more specific application to my technical project, it is important to understand what the user feedback will be before introducing more junk into space. Of course the public wants to be healthy, but to it is essential to consider the extent to which the public will change their lifestyles in order to improve upon the amount of pollution currently present in their cities.

The issue of space junk introduces international countries as an indirect stakeholder in the network of actors involved in the problem. According to Downey, "In the PDS model, engineers have to make difficult trade-offs among alternative stakeholders, alternative definitions of the problem, and alternative perspectives about what is taking place, including their own." (Downey, 2005, p. 591). Beyond the people that will be affected in specific cities by the improvements that the 3U CubeSat can make, there are stakeholders in other countries that may be affected by the space junk that is accumulating around Earth. Properly identifying the relationships between each stakeholder may mitigate the risks that present themselves when more satellite technology is introduced into space.

Conclusion

My technical project applies an engineering solution to a scientific problem. By using more precise global positioning technology, the CubeSat mission will improve the quality of geospatial images of NO2 concentrations over major cities. The information obtained from the project will help the public become more aware about how much NO2 they are contributing to the environment and how these concentrations are negatively affecting their health.

The increased usage of remote sensing imagery and global positioning systems are aiding atmospheric and health science understand the effects of air pollutants on global public health. While the satellites that execute these missions have good intentions, it is important to keep in mind how many missions are being put into space. Space junk is becoming a major issue and there is small regulation amongst nations of who can claim space. Specifically for my technical project, while the intentions of collecting the data are great, it is important to consider whether or not the public will even care about the results presented. How the public will react can influence whether or not the mission is even necessary to execute. Introducing excessive and unnecessary amounts of satellites into space can create tensions between nations. As a result, the NO2 CubeSat mission that was originally intended to aid those being affected by air pollution in major cities may lead to unintended conflict between other nations if the amount of space junk becomes too dense.

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