Thesis Project Portfolio

CubeSat-Integrated Sensor System for Tracking Small Space Debris in Low Earth Orbit

(Technical Report)

Dual-Use Satellites: National Security Implications in Public-Private Partnerships

(STS Research Paper)

An Undergraduate Thesis

Presented to the Faculty of the School of Engineering and Applied Science

University of Virginia • Charlottesville, Virginia

In Fulfillment of the Requirements for the Degree

Bachelor of Science, School of Engineering

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Spring, 2025

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Table of Contents

Executive Summary

As momentum for space exploration continues, innovative solutions to both space debris and security challenges posed by satellite technologies are more interconnected than ever. There is a need for both technical advancements and thoughtful policy frameworks. My Capstone report focuses on the design and prototype of a CubeSat aimed at detecting small space debris less than 10 cm that are not currently tracked in low Earth orbit.

My STS research paper is focused on national security implications of public-private partnerships in satellite technologies, specifically remote sensing and Earth observation. This paper examines the blending of commercial and military satellite operations and their potential impact on data security and strategic interests. Alongside both the STS paper and Capstone project focusing on satellite technologies, they both address general space security. While the CubeSat project focuses on a technical solution for threats posed by space debris, the STS research looks at broader societal threats.

The space debris tracking CubeSat directly contributes to addressing space debris concerns and threats. There are currently no space models that track debris under 10 cm, causing problems for any type of space mission. As the number of entities going into space increases, so does the amount of debris, creating an exponential curve of threats that make detection and mitigation crucial for space sustainability.

My Capstone team is developing a CubeSat system equipped with a 30 gigahertz continuous wave radar system as the ideal model. The progress so far has been creating an integrated software-defined radar that can determine the size and trajectory of debris, which can then be integrated into a debris detection model. Preliminary model designs theorize that within one sidereal day or one orbit around the Earth in our current flight plan, the CubeSat will be able

to detect 30 debris objects. The data collected over the satellite's lifetime will significantly contribute to collision avoidance strategies for other satellite missions. These results not only highlight the technical viability but also stress the importance of using radar to track small debris specifically in low Earth orbit. However, challenges still remain in the implementation of hardware to finalize the radio rather than a software-defined prototype. This project represents a promising solution to a critical problem facing the space industry today, and further testing and refinement are suggested.

My STS research paper explores how public-private partnerships in the satellite industry blur the lines between military and commercial operations. This research question highlights the security implications especially concerning data handling. This research specifically uses the social construction of technology framework to analyze how societal factors influence these partnerships and how the partnerships are constructed.

My research found that most evidence suggests that these partnerships could introduce national security risks, particularly through the diffusion of advanced data analysis techniques and the increasing amount of satellite imagery available. Once collected, remote sensing data becomes incredibly difficult to contain, exposing sensitive US economic, military, and strategic vulnerabilities to adversaries. The final analysis revealed that dual-use satellite technologies blur the lines between civilian and military uses creating significant dead zones for policymakers. The rapid commercialization of remote sensing has eroded traditional tools that the government once had over these technologies. While the partnerships between the government and commercial satellite industries promote significant innovation and economic growth, the study concludes that they do pose serious risks. Policy recommendations in the future need to maintain flexibility and transparency while also regulating the use and sharing of satellite data.