Designing an Amateur Radio CubeSat
(Technical Paper)

Anti-Satellite Weapons and the Trend of Militarization: How to Combat Aggressive Militaristic Policies in Socially and Politically Unstable Nations
(STS Paper)

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Introduction

New space technologies have the potential to either foster human curiosity or further ground mankind in vice and competition. Space exploration can lead to a greater understanding of the universe and its workings, a result that would be beneficial to all societies. However, as new technologies increase access to outer space, the ability for nations to dominate each other also increases. The dual potential for space technologies to either promote understanding or destruction has been present since the beginning of space exploration during the Cold War. The United States began testing of anti-satellite (ASAT) weapons just two years after the Soviet Union launched *Sputnik,* the first satellite placed into Earth's orbit, in 1957 (Oppenheim, 2013). These tests motivated the Soviet Union to begin ASAT missile research in 1960 (Oppenheim, 2013). Today, this dual nature of space technology is exemplified by the competing goals of the NASA CubeSat Launch Initiative and the continuing development of anti-satellite missiles.

The NASA CubeSat Launch Initiative provides an affordable path for educational and non-profit organizations to launch small satellites for research purposes (Jackson, 2017). On the other hand, the creation of anti-satellite missiles promotes the dangerous belief that international disputes cannot or should not be solved by diplomatic means. Further, the creation of ASAT missiles is the latest symptom of a widespread pattern of militarization in socially and politically unstable nations. These rogue nations "pursue their [own] interests with violent methods contrary to accepted international behavior and contrary to international law" (Pillar, 2018). In order to ensure that current and future space technologies are used for the benefit of all communities, it is critical to address this pattern of militarization that has promoted the development of ASAT missiles. The STS Research Paper will discuss the reasons for the militarization of rogue nations and propose a solution to this problem. The Technical Report will detail the design and

construction of a CubeSat by a team of four year mechanical and aerospace engineers at the University of Virginia.

Technical Topic

The 1U VCC Libertas is a CubeSat developed by fourth year mechanical and aerospace engineering students at the University of Virginia through the NASA CubeSat Launch Initiative. A CubeSat is a nanosatellite (mass between 1-10 kilograms) that is comprised of small cube-shaped units each having a volume of 10 cubic centimeters (cm^3). For example, the 1U VCC Libertas consists of only one of these 10x10x10 cubic units, while a 3U cubesat would consist of three 10x10x10 cubic units. This concept is illustrated in Figure 1, which shows the most common CubeSat sizes.

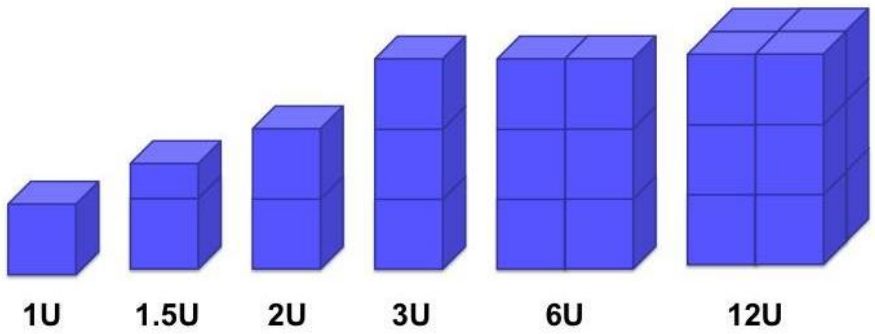

Figure 1. Standard CubeSat sizes where each cubic unit is 10 cm^3. From *Standard CubeSat Sizes,* by E. Mabrouk, 2017, https://www.nasa.gov/content/what-are-smallsats-and-cubesats.

The Libertas is currently in Low Earth Orbit at an altitude of approximately 250 miles along with CubeSats developed by Old Dominion University and Virginia Polytechnic Institute and State University. The joint mission of the three satellites is to "obtain measurements of atmospheric properties and quantify atmospheric density with respect to [the] orbital decay" of the satellites (Sandy, 2019). However, communication was never established between the

Libertas and the UVA Ground Station that transmits and receives information to and from the satellite. In order to demonstrate that the University of Virginia has the ability to design, build, and launch a functioning satellite, it was determined that a new CubeSat be developed.

The 1U Amateur Radio CubeSat will be designed and built by a team of fourth year mechanical and aerospace engineering students at the University of Virginia as a successor to the 1U VCC Libertas. The primary objective of this technical project is to establish reliable communication between the UVA Ground Station and the satellite. Communication with the satellite will be established over frequencies dedicated to those with amateur radio licenses. Anyone with an amateur radio license will be able to communicate with the satellite because "all [amateur radio] frequencies are shared," and "no frequency is assigned for the exclusive use of any amateur station" (Federal Communications Commission, 2017). Thus, the project will not only provide engineering students at the University of Virginia with experience in program management and spacecraft design, but will also promote interest in STEM and space exploration within other communities.

The 1U Amateur Radio CubeSat will be designed using the 1U VCC Libertas as a model. Four designs are being considered for the Amateur Radio CubeSat, all of which possess several key structural similarities with the Libertas. The first proposed Amateur Radio CubeSat design is identical to the Libertas, but it will be able to communicate along a wider frequency range due to the amateur radio license. A computer-generated model of the Libertas can be seen in Figure 2.

Figure 2. Conceptual image of the Libertas depicting key structural components. From *VCC B (Libertas) [UVA]* by G. D. Krebs, 2019, https://space.skyrocket.de/doc_sdat/vcc.htm

The second design option would incorporate a second experimental radio for use by the amateur radio community. While the primary radio would only allow for communication with the 1U Amateur Radio CubeSat, the secondary radio would allow the amateur radio community to conduct their own experiments. The third possible design would include a programmable camera that would allow engineering students at the University of Virginia and radio enthusiasts to take a picture of a selected location on the Earth's surface. The fourth design option would include both a secondary experimental radio and a camera for use by the amateur radio community. Thus, the fourth design option is a combination of both the second and third options. Preservation of the successfully engineered components of the Libertas will allow the Amateur Radio CubeSat team to devote the time and resources necessary to ensure that the new satellite is able to communicate reliably and promote interest in STEM by granting experimental access to the amateur radio community.

STS Topic

The 21st century has been marked by the militarization of nations that are hostile to the United States and its allies, causing widespread concern for the possibility of another global conflict. For example, North Korea and Iran continue to develop intercontinental ballistic missiles despite sanctions, while Russia seeks to regain the sphere of influence it held before the collapse of the Soviet Union (Sang-Hun, 2019; Gordon, 2019; Cooley, 2017). Further east, China has been expanding its control of the South China Sea through the construction of weaponized military bases on territorially disputed reefs and islands (Weiss, 2019). Diplomacy, sanctions, and even military intervention by the United States and its allies have not halted these activities. In 2007, China conducted a successful ASAT missile test, raising new concerns that this militarization is now expanding into outer space (Oppenheim, 2013). The Chinese ASAT test and the efforts to develop anti-satellite missiles in other nations suggest that space is no longer reserved for exploration and the acquisition of knowledge.

ASAT weapons are a unique threat because they can inflict damage to military and social infrastructures on a scale that no other current technology can match. The destruction of certain American military satellites would "instantly [paralyze] American troops, planes and ships around the world," leaving the United States vulnerable to attack (Myers, 2008). Further, the elimination of commercial satellites could cripple the navigational, communication, and economic infrastructures that have become crucial to the everyday functioning of Western societies (Myers, 2008). In order to prevent the usage and further proliferation of these weapons, it is critical to understand why they have been developed thus far. In particular, it is important to determine why socially and politically unstable nations have chosen to devote resources towards militarization and ASAT weapons instead of internal stability and national well-being.

An analysis of data collected by The World Bank and Central Intelligence Agency reveals that several nations with low Gross Domestic Products (GDP) per capita have high military expenditures and struggle with social and political unrest. GDP per capita indicates how much each citizen profits from the total output of goods and services within a particular country (Amadeo, 2019). GDP per capita is often used to quantify the standard of living within a country (Amadeo, 2019). Syria is a pertinent example of the aforementioned relationship between GDP per capita, high military expenditures, and internal instability. 13.6% of Syria's government expenditures are directed towards the military, yet the Syrian GDP per capita is ranked 194th in the world at 2,900 USD (The World Bank, 2018; Central Intelligence Agency, 2019). Moreover, Syria was ranked as the second least peaceful country in the world due to the civil war between the al-Assad regime, ISIS, and several tribal factions (Ioanes, 2019). A similar trend is observed for other nations like China, Russia, and Iran. Despite the turmoil within these nations, their governments have decided to invest in militarization rather than improving quality of life for their citizens.

The militarization of socially and politically unstable nations will be addressed according to the Technological Fix theory. The notion of a technological fix was first conceived by Alvin M. Weinberg, a 20th century atomic physicist. According to Weinberg, a technological fix is the "use of technology to respond to certain types of human social problems that are more traditionally addressed via political, legal, organizational, or other social processes" (Newberry, 2005). The technology only provides a temporary or superficial solution that fails to address the underlying cause of the problem. For example, Weinberg wrote that nuclear weapons served as a technological fix during the Cold War through their instillation of the notion of mutually assured destruction (Newberry, 2005). I argue that military expansion and the development of anti-

satellite missiles in unstable nations are also technological fixes. However, while nuclear weapons are a technological fix for war, militarization and anti-satellite missiles are a technological fix for a perceived power imbalance between Westernized and non-Westernized nations, and between autocratic regimes and their citizens.

Research Question and Methods

The STS Research Paper will address the following question: Why do socially and politically unstable nations prioritize the ability to wage war above internal stability and national well-being? This question is important because countries that aggressively pursue militaristic ambitions also tend to struggle with poverty and civil unrest. The presence of this correlation will be evidenced quantitatively with data from The World Bank and Central Intelligence Agency (see STS Topic above), which suggests that unstable nations with low standards of living tend to invest heavily in the military. This correlation will be further evidenced by literature reviews of newspaper and journal articles that discuss recent military expenditures made – and actions taken by – these nations. The development of anti-satellite missiles is the latest example of this trend, and therefore an appropriate case for analysis. In order to address the pressing social and political issues within these nations, it is critical to understand why their leaders prioritize warfighting capacity.

The militarization of unstable nations is a complex and dynamic problem without a clear solution. Therefore, a solution to the research question will be proposed with Wicked Problem Framing, which is most applicable to such problems. According to Rittel and Webber, wicked problems are governmental, societal, or policy planning problems that are “ill-defined and rely upon elusive political judgment for resolution” (Rittel & Webber, 1973). There are 10 defining

characteristics of wicked problems, but the most relevant to the research question is that wicked problems are symptoms of other problems (Rittel & Webber, 1973). The purpose of the STS Paper is to propose a solution to the wicked problem of militarization in unstable nations, which is a symptom of another problem – the desire to wield and maintain power. A solution to this wicked problem will be proposed by conducting literature reviews of journal articles that discuss the psychology of autocratic leaders, the relationship between political leaders and the military in autocratic countries, and the balance of power between all nations. These sources will elucidate what drives autocratic regimes to attain power, how they maintain that power, and how they demonstrate it to their citizens and other nations. This understanding will better position the United States and its allies to negotiate with these regimes, improve quality of life for their citizens, and end the trend of militarization that prevents world leaders from reaching diplomatic solutions to international disputes.

Conclusion

Space technology has the potential to be used in two competing ways. It can further human understanding of the universe and lead to discoveries that will benefit every society, or it can weaken the ability of nations to pursue or reach diplomatic solutions. The development of the 1U Amateur Radio CubeSat, which will be discussed in the Technical Report, is an example of the former case. The ability of the nanosatellite to communicate on amateur radio frequencies will promote interest in STEM and spacecraft design amongst mechanical and aerospace engineering students at the University of Virginia and amateur radio enthusiasts around the world. The inclusion of a secondary experimental radio or camera will further promote this interest. However, the development of anti-satellite missiles discourages the use of diplomacy to

solve international disputes, and is the latest example of militarization in unstable nations. The STS Research Paper seeks to determine the cause of aggressive militarization in these nations and proposes a solution to that problem.

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