Understanding the History of Anti-Satellite Weapons and Assessing the Threats They Pose to Society

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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

For the past century, the world has viewed space as 'the final frontier'. Many nations have expanded their capabilities in this frontier, launching networks of satellites that have both commercial and strategic applications (Brinksman, 2009). Unfortunately, many competing nations seeking to utilize a shared space can lead to increased tensions and the threat of armed conflict (Gruenwald, 2023). It is this threat that has led many global superpowers to focus research on developing anti-satellite weapons, known as ASATs, with the hopes of securing their place in the space domain by remaining technologically competent in military space operations (Saunders & Lutes, 2007).

This Science, Technology, and Society (STS) thesis investigates the rise of ASATs around the globe, determines how they threaten to disrupt society, explores the legislature surrounding their use, and evaluates options for how the world should approach ASAT use in the future. I accomplished this through the implementation of a policy and risk analysis, which assisted me in both evaluating the development of ASATs and determining their social implications. This included summarizing the history of ASATs since their inception and looking at potential consequences of frequent ASAT use. Finally, I identified laws and treaties created due to ASAT use and considered recommended courses of action for future ASAT policy.

STS Framework

I chose to use a policy and risk analysis framework for this paper because ASATs are an advanced military technology, meaning their use is ruled by government policy and international treaties. Additionally, their destructive power presents a substantial risk to national security and the use of space in general, a topic that is fully explored later in this paper. Throughout the paper, I draw from ideas found in Deborah Lupton's *Risk* (2023) and an article titled *Emerging*

Challenges For Science, Technology and Innovation Policy Research: A Reflexive Overview by Piera Morlacchi and Ben Martin (2009). In *Risk*, Lupton outlines multiple methods describing how risk can be perceived and addressed. The method most applicable to this paper is social constructionism, which is, "advocated by those who are predominantly interested in the social and cultural aspects of risk" (Lupton, 2023, Page 25). Under the social constructionist approach, societies create risk assessments based on observations, prior knowledge, and experiences. Therefore, it is possible for two different social groups to view the same problem and develop dramatically different risk assessments. The social constructionist approach also posits that risk is never a constant value. Instead, the level of risk something has been assigned is always fluctuating based on the practices of the actors responsible for the risk. This means it is possible for a risk to disappear and reappear as new knowledge is gained or new developments surrounding the risk occur (Lupton, 2023).

A major point brought forward by Morlacchi and Martin is that regarding policy, the past, present, and future are all interlinked. They state that, "...the past shapes and informs the present and the future, while those active in the present interpret the past, constructing a specific version of history, and in so doing they also help to shape the future" (Morlacchi and Martin, 2009, Page 571). I needed to understand this connection between the past, present, and future to conduct a thorough analysis of ASAT legislature. I used this connection by first investigating past attempts to introduce ASAT policies and then synthesizing lessons learned to provide commentary on policies that may be adopted in the future. The other main idea I considered is that when theorizing about policies concerning technology, assumptions should be drawn empirically (Morlacchi and Martin, 2009). For example, when discussing policies for the future, I supported my arguments by referencing other policies that appeared in my research.

Methods

I gathered the information presented in this thesis from military, government, and civilian sources to provide a comprehensive view of issues surrounding ASATs. Military sources primarily consisted of declassified reports addressed to Congress or officers recounting their experiences working on weapons tests, which were able to provide a partial history of ASAT development and insight into the gravity of ASAT use. Due to the sensitive nature of military intelligence, the reports were unable to contain information from the present day and only focused on specific events. Therefore, they were unable to provide a holistic view of ASATs and I needed to fill in the gaps with information gathered from NASA, research articles from various universities, and journals written by scientific organizations. I also used these sources to assess how society is reliant on services provided by satellites and how ASATs threaten to disrupt such services. Finally, I developed suggestions for how ASATs should be treated in the future by utilizing articles detailing the United States' current policies on satellite protection and articles that proposed plausible treaties concerning ASATs.

History of ASAT Development

Whenever a brilliant scientific discovery is made or new technology is invented, one of the first things to happen is that militaries try to weaponize it. This is undoubtedly the case with space, considering the United States has gone so far as to create a new branch of the military that specializes in space operations (*About Space Force*, n.d.). Since the first satellite was launched into space by the USSR in 1957, many nations around the world have sought to utilize satellite technology for military purposes. This also means they looked for ways to limit enemy use of space, and therefore began developing ASATs to destroy enemy satellites if necessary (Johnson-Freese, 2016). To accomplish such feats, a nation must have a robust and well funded space program capable of sustaining such projects. This narrows the list of relevant countries from 195 down to just four that have successfully destroyed satellites using ASATs. These countries are the United States, Russia, China, and India, which are the primary countries of interest for the remainder of this paper (Grego, 2012).

United States

While the USSR was the first country to successfully launch a satellite into orbit with the debut of Sputnik I in 1957, the United States was the first to begin the development of an ASAT program (Grego, 2012). The very first ASAT was a ballistic missile known as the WS-199, and it had three primary variants that saw testing between 1957 and 1959. The United States Air Force gave contracts to the Martin Company for the WS-199B Bold Orion, Convair and Lockheed for the WS-199C High Virgo, and McConnell for the WS-199D Alpha Draco. The Bold Orion and High Virgo were air-launched systems while the Alpha Draco was a more traditional ground-launched system. Despite not destroying any satellites, all three variants reached hypersonic speeds and altitudes high enough to target satellites, so they served as proof of concept for future projects featuring more advanced ASAT models (Parsch, 2003).

After the initial ASAT tests using conventional ballistic missiles, the United States began experiments determining if other weapons systems could effectively serve as ASATs. During a nuclear weapons test over the Pacific Ocean in 1958 called Hardtack Teak, researchers observed that the blast produced a powerful electromagnetic pulse (EMP) capable of damaging electrical and communication systems (Vance & Vance, 2021). Four years later in 1962, during Operation Starfish, the military detonated a 1.4 megaton thermonuclear warhead over the Pacific to further observe the effect of EMPs caused by nuclear weapons. The pulse formed a radiation belt in the upper atmosphere, damaged at least seven satellites, and proved that nuclear weapons in space could be used as ASATs (NASA, 2022). The focus then shifted back to using missiles as ASATs when the Army's Nike-Zeus missile was modified to intercept Soviet satellites, but this program was abandoned in favor of the Air Force's cheaper, more effective Program 437. Program 437 operated from 1963 to 1975, and was advantageous because it utilized components the Air Force mostly already had on hand. The design combined the ballistic interceptor approach with the nuclear explosion approach by placing a warhead on a ballistic missile, intercepting enemy satellites, and then destroying the satellites with either the nuclear blast or the resulting EMP wave (Chun, 2000).

The next phase of missile-based ASAT systems came in the form of the ASM-135, an air-launched missile developed by Vought that could be mounted to an F-15. The ASM-135 used an infrared targeting system, was able to strike targets in a low earth orbit (LEO), had a range of about 350 miles, and could reach speeds of up to 15,000 miles per hour. Development of this missile system began in the 1970s as Program 437 was being phased out, with the first test occurring in 1982. In 1985 the ASM-135 ASAT became the first ASAT missile to successfully destroy an operational satellite when it hit the US Solwind P78-1, but the program was discontinued shortly after in 1988 (Museum of the Air Force, n.d.). During the 1990s, the United States once again began experimenting with unorthodox weapons systems. The Navy began tests on its Mid-Infrared Advanced Chemical Laser (MIRACL), a directed electromagnetic energy weapon capable of blinding a satellite orbiting at an altitude of 400 km. In the early 2000s, the military continued developing new ASAT systems such as satellite jammers, maneuverable satellites that can intercept and latch onto other satellites, and ground-based directed energy weapons that can interfere with or disable satellites. The final major milestones of the United States' ASAT development came in 2008 and 2009 when the Navy used sea-launched Aegis

SM-3 missiles to destroy two more satellites in orbit (Grego, 2012). Very few public developments have been made since that time.

Soviet Union/Russia

The United States' primary competitor during the space race, the USSR, also has a robust history of ASAT programs. Nikita Khrushchev, the leader of the Soviet Union, approved the first official Soviet ASAT program in 1960 which was titled the Istrebitel Sputnikov, meaning satellite destroyer. This program featured a highly maneuverable spacecraft rigged with explosives that could approach and destroy an enemy satellite (Zak, 2013). The first test of a Soviet ASAT system occurred in 1963 with the launch of Polyot-1, and a second test with a similar spacecraft occurred in 1964 when the Polyot-2 was launched (NASA, 2022). The Soviet Union continued to develop its Istrebitel Sputnikov system throughout the 1960s until it was declared fully operational in 1973. The Soviet program remained relatively dormant until 1976 when the United States introduced the space shuttle. While the shuttle was not intended for military use, the Soviets were concerned that the shuttle's ability to intercept and recover a satellite meant that it had potential for use as an ASAT (Grego, 2012). By 1978, the Soviets had introduced an improved version of the Istrebitel Sputnikov interceptor by placing it on top of an R-36 ICBM and claiming that it could be launched in just 90 minutes. However, just five years later the program went dormant again and the Soviets halted all tests (Zak, 2013).

The next major development in Soviet ASAT research was an attempt to replicate the United States ASM-135 missile that could be air-launched from an F-15. The Soviets attempted to load a missile capable of targeting LEO satellites just two weeks after the second American test, but the program ultimately failed and was never fully tested (Podvig, 2016). The Soviets once again tried to follow the American lead by deciding to develop a directed energy weapon.

Reports stated that the Soviets succeeded and possessed a system threatening both ballistic missiles and satellites, which caused great concern to the United States. A delegate sent to the Soviet testing facility by the United States in 1989 determined that the reported capabilities of the Soviet laser were grossly exaggerated and no dangerous system existed (Grego, 2012). Since that time, Russia has continued to develop ASAT missiles with both ground-launched and air-launched variations. The United States confirmed the most recent test occurred in late 2021 and was successful (Sankaran, 2022). Very little information has been made public about new Russian ASATs, but in February of 2024 American intelligence agencies reported that Russia is developing a nuclear based ASAT that can destroy satellites with a powerful EMP wave (Lillis et al., 2024).

China

The histories of China's and India's ASAT development programs are neither as storied nor as well documented as their Western counterparts. While China now possesses ASAT systems to rival those of the United States and Russia, its first semblance of an ASAT program did not begin until almost a decade after its rivals began theirs. Fearing a preemptive nuclear strike from either the United States or Russia, China decided that it needed defensive measures against this threat and created Program 640 in 1964. The initial purpose of Program 640 was to defend against ballistic and nuclear missiles, but it led to the development of technologies similar to those used in satellite interceptors (Kania, 2019). In 1983 the leader of China, Deng Xiaoping, canceled the program because he felt the resources dedicated to Program 640 should be utilized for different purposes, such as improving China's economic development (MacDonald & Ferguson, 2015). The Chinese ASAT initiative lay fairly dormant until 2007 when it successfully used a ballistic missile to destroy a weather satellite in LEO (Kan, 2007). Since then, China has continued efforts to develop a variety of ASATs such as additional missiles, directed energy weapons, jammers, and orbiting robots (Erwin, 2020).

<u>India</u>

India is the most recent country to become involved in ASAT development and did not become a major player until the 21st century. India made its first public statement regarding ASAT development in 2010 when it announced it was working on an ASAT missile system originally designed to defend against ballistic missiles, similar to the Chinese Program 640 (Grego, 2012). During March of 2019, the Indian initiative saw its first successful test, titled Mission Shakti, in which a ballistic missile defense interceptor destroyed a MicroSat with an area of about two square meters. Mission Shakti made India just the fourth country in history to successfully destroy a satellite with an ASAT (Tellis, 2019). Since the test, no evidence has suggested India is working on other ASAT variants such as directed energy weapons or jammers.

Risks of ASAT Use

The history of ASAT development appears to be entirely composed of secret military projects and tests that the public is not made aware of until decades after the fact. The question then becomes why should anyone care about ASATs more than other military operations? This can be answered by applying a social constructionism risk analysis, which involves taking the knowledge and experience gained during years of ASAT development and determining how ASATs may affect modern society and culture. At the start of 2024, over 8,300 satellites were orbiting Earth with 84%, or about 7,000, residing in LEO (Ieva, 2023). According to the United States International Trade Administration, “The services provided by satellites are indispensable to daily life, underpinning global economic activity and critical functions of national security.”(International Trade Administration, n.d.) The four primary categories of satellite services are telecommunications, remote sensing, space science, and national security. The telecommunications category is the most apparent service in everyday life since it includes satellite television, mobile phone data, and the GPS technology needed for almost all modes of transportation (International Trade Administration, n.d.). If a catastrophic event caused all satellites to suddenly go offline, the global effect it would have is incalculable.

Unfortunately, the continued use of ASATs threatens to cause an event exactly like the one described above. Since kinetic ASAT missiles destroy a target by physically striking it and breaking it apart, they naturally create a large amount of debris in space. For example, the recent Indian Mission Shakti test produced over 3,000 pieces of debris large enough to be tracked (Tellis, 2019) and the Chinese test produced over 15,000 pieces (Kan, 2007). For a piece of space debris to be tracked, it must be at least 3 mm in diameter. The pieces that remain in orbit travel at speeds similar to the satellite they were originally a part of, which is typically between 7-8 km/s. However, if the debris strikes another satellite traveling at a similar velocity the relative velocity of the debris can approach 15 km/s (NASA, n.d.). For reference, a 9mm bullet fired from a handgun has a muzzle velocity of about 1190 ft/s, which converts to 0.363 km/s (Winchester, n.d.). This means that a piece of space debris the size of a 9mm bullet with a relative velocity of 15 km/s will have over 1700 times more kinetic energy than a bullet immediately after it is fired. This poses a serious threat to all satellites orbiting at altitudes where debris is common.

If kinetic ASAT tests became commonplace or a country uses ASATs to cripple another nation’s infrastructure, the amount of dangerous space debris would increase exponentially. In 2009, an American satellite from the company Iridium accidentally collided with a Russian satellite called Cosmos-2251. The two satellites were destroyed as a result and produced a large cloud of debris. This collision combined with the Chinese ASAT test in 2007 caused over a

150% increase in the amount of cataloged space debris and still accounts for one-third of all debris tracked today. The destruction of only three satellites caused this massive percentage of debris, so if ASATs were used to take out tens or even hundreds of additional satellites the amount of debris ejected into space would be immense (NASA, n.d.).

Collisions between large objects in orbit are unlikely due to the sheer size of space, but as the amount of debris increases the likelihood of collisions also increases. Debris from an ASAT test may unintentionally strike a satellite, breaking the satellite into more pieces of debris which may go on to strike another satellite (Schwartz et al., 2021). This is known as the Kessler Syndrome, which is a model developed by a NASA scientist named Don Kessler to describe the "phenomenon of debris producing self-sustaining and increasing debris through collisions" (Schwartz et al., 2021). The occurrence of the Kessler Syndrome would render affected regions of space inhospitable to satellites due to the concentration of debris at specific altitudes. If a method of removing space debris is not found, the areas affected by the Kessler Syndrome would remain unusable until a significant portion of the debris naturally de-orbits, which could take decades. Some scientists believe the Kessler Syndrome is already occurring, but due to the current frequency of collisions it will be years or decades until dramatic effects can be seen. However, the continued use of ASATs and the increased number of satellite constellations being launched will accelerate the Kessler Syndromes' development (Schwartz et al., 2021).

Satellite technology is critical for modern societies to function, so decision-makers have an ethical responsibility to preserve the safety of space and avoid causing the Kessler Syndrome. Reckless action in this domain can jeopardize the comfort, safety, and even lives of innocent civilians across the globe (Raitt et al., 2005). It is clear that the development of satellites has drastically improved society by "providing communication and education services in remote areas, bringing information and entertainment to the masses, creating new materials for stronger and more durable structures, providing meteorological data so ships can be safer at sea, monitoring the threat of pollution, enhancing medical instruments for better health-care, enabling hikers and skiers to be located when lost, and many more" (Raitt et al., 2005). If humanity no longer could use space as a resource, all of these positive impacts would be lost. Additionally, current military technology heavily relies on satellite communication to properly function, and militaries themselves use satellites for the coordination of global operations. A loss of satellite resources would leave many countries with compromised national security, rendering them vulnerable to attack and putting their citizens at risk (Jones, 1998).

The threat of compromised national security brings with it a far more sinister threat, one that has plagued the world for the better part of a century: nuclear war. Nuclear weapons are always a delicate subject due to their unrivaled destructive power, and the involvement of satellites in nuclear networks means they too must be handled with care (Blatt, 2020). Military satellites are used as early warning devices, alerting a country when a nuclear strike has been ordered against them and providing time to mobilize defenses and plan a counterattack (*Defense Support Program Satellites*, n.d.). They serve as a vital part of nuclear deterrence by ensuring a country will have time to launch its own nuclear weapons, therefore guaranteeing mutual destruction. The existence of ASATs means that if an early warning satellite goes offline, there are two possibilities: a country has attacked it with an ASAT to clear the way for a nuclear strike, or the satellite malfunctioned due to debris or some other technical issue. A country will not know the reason for the satellite going offline, so it might choose to mobilize nuclear forces as a precaution. Additionally, if a Kessler Syndrome occurs due to the overuse of ASATs, rogue nations with nuclear capabilities such as North Korea might view it as an opportunity to use nuclear weapons without the guarantee of retaliation (Blatt, 2020). It is imperative that all early warning satellites be kept online to avoid such events unfolding, but ASATs might make this an impossible task.

Past Efforts to Enact ASAT Legislature

The sensitive nature of ASATs due to their involvement in matters of national security, civilian safety, and the preservation of space has led to the cooperation, and lack thereof, of countries that possess ASAT technology. Many treaties and policies arose in response to weapons tests and intelligence reports between the 1950s and the present day to both further national interests and reduce the amount of debris being created. The first weapons test ban of this nature was the Limited Test Ban Treaty of 1963, which outlawed the use of nuclear weapons in space and was signed by the United States, United Kingdom, and USSR (Office of the Historian, n.d.). Although this treaty did not specifically mention ASATs, nuclear weapons having the potential to damage satellites with an EMP blast meant this treaty set the precedent for future space preservation policies. Shortly afterward, the same countries signed a similar treaty known as the Outer Space Treaty in 1967. This treaty improved upon the Limited Test Ban Treaty by stipulating that, ‘States shall avoid harmful contamination of space and celestial bodies’ (Office of Outer Space Affairs, n.d.). It can be argued that the use of kinetic ASATs violates the Outer Space Treaty because they contaminate space with debris.

Once the Soviets began performing frequent ASAT tests during the 1970s, the United States launched an initiative to create an arms control agreement for ASATs. This consisted of three meetings between 1978 and 1979, but the United States and USSR abandoned the talks and no arms control agreement was established because the American/Soviet relationship began to break down. At this point in time, the United States and the Soviets were not implementing policies to preserve space, but rather to gain a strategic advantage over one another. In the case of the 1978-1979 talks, the Soviets had an operational system while the Americans had yet to test their new system. A complete test ban in this case would have been a large step forward for space preservation but would have potentially kept the American system inferior to the Soviet one, so an agreement was difficult to reach (Princeton, 1986). This theme continued in 1981 and 1983 when the Soviets proposed new treaties, which called for the complete ban of all active ASAT systems and forbade systems from being developed in the future. However,they also contained language that would prohibit the American's use of the Space Shuttle, so no treaties were adopted (Durch, 1984). After their treaty proposal failed, the Soviets created a 'self-imposed moratorium on ASAT testing' (Princeton, 1986). However, this did not last long as in 1985 the USSR stated that if the United States completed a test of its F-15 launched ASAT, it would 'consider itself free of its unilateral commitment not to place anti-satellite weapons in space' (Princeton, 1986).

Very few developments regarding ASAT treaties were made until 2008 when Russia and China collaborated to produce the Treaty on Prevention of the Placement of Weapons in Outer Space and of the Threat or Use of Force Against Outer Space Objects (PPWT) (Blatt, 2020). This proposal used language similar to the Soviet proposal in 1983, claiming that part of its purpose was to, "keep outer space as a sphere where no weapon of any kind is placed" (Loshchinin & Qun, 2008). Once again, the United States rejected this proposal. The proposal only banned the placing of weapons in space but did nothing to prevent the use of the ground-launched ASATs, known as direct-ascent ASATS (DA-ASATS), that could produce extreme amounts of debris. It also did nothing to limit the number of DA-ASATs a country could produce, meaning it would be unsuccessful in deterring an arms race (Blatt, 2020).

The four ASAT-capable nations have since been unable to collectively agree on an international ASAT treaty, but progress was made in 2022 when the United States adopted a self-imposed moratorium on the use of DA-ASATs. The United States cited the dangerous amount of debris produced by recent tests as the reason for this action, indicating that it has begun to treat space preservation as a serious issue (Silverstein & Panda, 2020). Russia, China, and India have yet to follow suit, meaning the dangers posed by ASATs are still far from being resolved. Looking at this situation through the lens of social constructionism sheds some light on one possible reason that no agreement has been reached. Each country may have performed individual risk analyses, and all except the United States determined that the risk posed by the Kessler Syndrome is outweighed by the strategic benefits of possessing DA-ASATs. If a collective ban on DA-ASATs is to be reached, each country would need to fully recognize the risks their ASATs programs incur and enact policies to mitigate that risk.

Looking Towards the Future

The risk and policy analyses conducted earlier in this paper show that the question of how to proceed with ASATs is one that affects all members of society. The analyses also provide guidance for policies that should be implemented in the future. The risk analysis offers insight into what the primary objectives of the policies should be, and the policy analysis shows what can be done to increase the odds that new policies will be widely accepted. Because the Kessler Syndrome would have a ruinous fallout, it should be the policy-makers' main focus and needs to be addressed by placing some form of sanction or ban on ASAT use. This is a responsibility that ultimately lies with the governments of ASAT-capable countries since they have an obligation to protect the citizens within their borders. Failing to restrict ASAT use and allowing the Kessler

Syndrome to occur would inevitably bring harm to innocent civilians, meaning the governments failed in one of their most basic purposes (Schwartz et al., 2021).

The most ideal solution would be the creation of an international treaty signed by all countries that possess space programs stating that they will not conduct any offensive military operations in space, including the use of ground-launched, air-launched, and space-launched ASATs. However, treaties of a similar nature such as the treaty proposed by the Soviets in 1983 have been rejected because they were too restrictive and a general lack of trust existed between the signing parties (Princeton, 1986). Despite failures in the past, a viable solution may exist in the form of a limited ASAT ban. Since the primary concern is the amount of debris being expelled into orbit and DA-ASATs are the primary culprits of this, a treaty banning all DA-ASATs would be almost as effective as a treaty banning ASATs altogether (Blatt, 2020). Such a treaty is more likely to be universally accepted than previous attempts for a few reasons. First, all countries should be united in the common goal of preserving space since they all have satellites at risk. Secondly, treaties such as the Limited Test Ban Treaty of 1963 and the Outer Space Treaty have already set the precedent for banning specific types of weapons in space, so a ban on DA-ASATs is not a novel idea (Blatt, 2020). Finally, countries would still be free to operate programs for ASATs that do not generate debris such as directed energy weapons and satellite jammers.

Despite governments being the actors who must pass legislation, the onus does not entirely lie at the state level. Civilians and their governments are intricately linked, and in most cases citizens have considerable sway over the decisions politicians make, especially in democratic countries. Two ways for citizens to enact change in America are by voting for politicians who will develop ASAT-related legislation and by protesting against the continued use of ASATs. These are two rights afforded to American citizens by the U.S. Constitution, but citizens of countries with similar rights can do the same. This can only be effective if those who know of the dangers posed by ASATs work to raise awareness among their peers. Historically speaking the largest changes come through collective effort, so increasing the number of people fighting for change also increases the odds of a universal ASAT ban being created (Ashoka, 2019).

Conclusion

ASATs are technologies that are not always in the headlines but have been very prevalent in the development of space and will continue to be influential in the future. They pose serious threats to the networks of satellites currently orbiting the earth, might render the space domain uninhabitable, and may even be the catalyst to start a nuclear war. It is the responsibility of all concerned parties including governments, militaries, and ordinary citizens to handle the delicate issue of ASATs with care to preserve space so that all of mankind can continue to benefit from the technology that resides within it.

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