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# Space Debris Mitigation: A Unified Policy Framework

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This is to certify that the doctoral dissertation by

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2023

Abstract

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MPhil, Walden University, 2022

MA, Forest Institute of Professional Psychology, 2013

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Proposal Submitted in Partial Fulfillment

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## Abstract

Space debris is a growing problem that impacts the ability to maneuver and conduct space missions, creates hazards for people on Earth, and has the potential for severe environmental damage. Clean-up efforts are not viable in the modern era due to a lack of viable, affordable, and safe technology conducive to such lines of effort. This leaves mitigative and preventative policy measures as the most effective way to proffer a solution to the problem. Public policy has largely failed to address space debris mitigation effectively due to the fragmentation of policies standards and a lack of horizontal integration of policies across levels of governance and multi-sector discoordination. As such, a unified policy framework that addresses space debris mitigation is extremely needed. The purpose of this study was to find the foundational elements of a unified policy, asking what are the shared standards, how are concepts operationalized, and who are the legitimized stakeholders. In this exploratory embedded single case study, stakeholder theory was used in conjunction with comparative analysis, descriptive coding, and emergent coding. In the analysis there were 17 total policies used from a variety of sources within eight participant entities. The key results included a unified framework for space debris mitigation through fine detail in response to the research questions. It was also concluded that spacecraft operators and the general public were not legitimized in present policies. Recommendations were made to create a more beneficial and inclusive policy framework for stakeholders. Impacts to positive social change are multiple, including the provision of a utilizable framework for future policy design.

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Dedication

Throughout my time in the U.S. Navy, I have encountered some of the most incredible shipmates that have significantly impacted my life:

Aboard destroyers with the toughest, most down-to-earth bo'suns;

In submarines with the smartest, most intellectually capable bubbleheads;

On intelligence platforms with the most ingenious, innovative cryptos;

At arid deserts with the most tenacious, resilient Seabees and infantrymen;

In aeronautics with the most attentive, systematically-minded air-dales.

I look to your example—to be as tireless as the boatswain, growing daily in knowledge and imagination like the submariners and cryptologists, doggedly pursuing my goals like the battle-hardened Seabees, with the singular focus of the aviators.  From each, I've learnt to be a better citizen, a better mentor, and a better man.  Thank you.

## Acknowledgments

I would sincerely like to thank my Committee Chair, Dr. Gregory Campbell, for being a bulwark of guidance and support throughout this process. Additionally, I would like to thank Dr. Lori Demeter, my Second Committee Member, for her erudite and timely insights.

Finally, to my family who raised me to "aim small, miss small" in everything I do and "work now, play later" when the task is at hand— "the easy road now is the hard road later, and the hard road now is the easy road later."

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# Chapter 1: Introduction to the Study

## Introduction

Advancements in space science have compounded over the last series of decades, exploding into an important field of study at the forefront of international, national, military, corporate, and technological interest (Johnson-Freese, 2017). These advancements have created great boons for humanity, but have come with side-effects that have been somewhat ignored until relatively recently: space debris. As more humans venture beyond the Earth's atmosphere by proxy or in person, more and more space junk has begun to clutter the vacuum immediately beyond the planet (Damjanov, 2017). This causes myriad issues including barriers to space flight, danger to astronauts, danger due to falling debris, increased financial strain associated with space science, and even atmospheric changes (Bernhard et al., 2022; Miller, 2021; Ross & Jones, 2022). While there are nonbinding policies at the institution, national, and international level, few binding policies have been put in place to preserve the space commons (Dodge, 2021; Hosseini et al., 2021; Nevala, 2017; Ribeiro et al., 2018; Svarovska, 2021).

The topic of this dissertation is the binding and nonbinding policies that presently exist, their legitimized stakeholders, accepted standards, and operationalized concepts. This study is important because the levels of technogenic contamination in the space commons has begun to reach a critical impasse. The continued injection of space debris remains largely unmitigated, the industry is being vitally affected, and a cascade effect of self-perpetuating debris called the "Kessler Syndrome" has begun to unravel (Bernhard et al., 2022). Whereas active debris removal (ADR) is not a viable objective at this time, binding mitigative and preventative policies are crucial to address the problem (Ribeiro et al., 2018; Svarovska, 2021).

In this study, I identified commonality, especially where stakeholders are concerned, between multiple policy frameworks through multiple avenues in order to assist in creating foundational concepts that can be used in an inclusive unified framework. By using foresight and strategic planning enshrined in governing mandates, it is possible to mitigate at least some of these concerns by stopping a problem before it becomes unmanageable.

To this end, the social implications of this study included the ability to strategically identify key shared components of cross-sector policies, allowing for policy development to proceed with as few obstacles as possible. This would impact the space science community (eventually removing some of the barriers to space travel), astronauts on mission (removing part of the dangers of remaining in orbit), and the global population (due to debris' impact on environmental change; Ross & Jones, 2022). Another social implication of this study was the identification of stakeholders in current policies, as well as stakeholders that have been largely overlooked in policy formation. In other words, those populations which have been disregarded in the formation of policies to date have been identified, in a consciousness-raising effort to bring a more inclusionary policy framework forward.

In this chapter, I will discuss the basics of the space debris problem, its current policy web, and the key foundations that the study will rest upon. This will include a brief history of some major events related to space debris, what makes the problem so pernicious, and why space debris continues to proliferate. I will also discuss obstacles to binding policy formation that directly address the prevention and mitigation of space debris. The stated core foundations of the study addressed in this chapter will include a problem statement, purpose, research questions, framework, assumptions, scope, limitations and delimitations, and significance in detail.

## Background

The problem and history of policy formation regarding space debris is quite complex, involving many evolving variables. This includes questions of who creates and is affected by space debris, what causes space debris, why clean-up efforts are not being utilized, and what makes it so dangerous. These questions directly affect the formation of mitigative and preventative policy, otherwise it would be unclear why policy is needed to address the problem at all. In the following sections, a background of the problem of space debris and the problem with policy formation are discussed shortly in order to systematically answer such questions in turn.

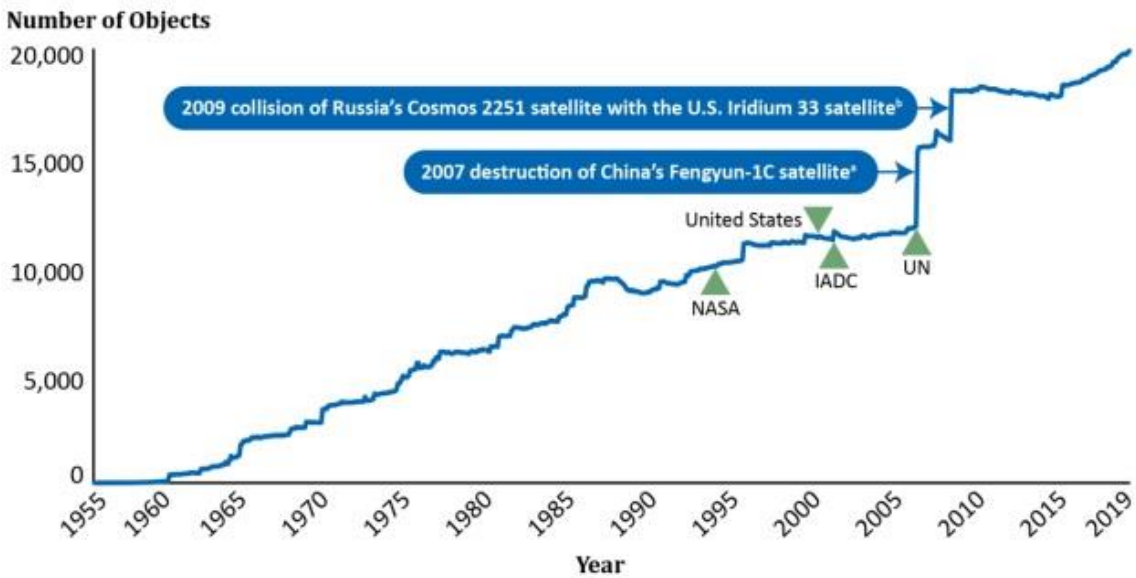
### The Problem with Space Debris

On February 13, 2009, loud sonic booms were heard over the skies of Kentucky (Byrne, 2009). The National Weather Service issued warnings regarding the loud series of explosions, while bright streaks pocked the skies from Kentucky to New Mexico (Byrne, 2009; National Oceanic and Atmospheric Association, 2009). The Federal Aviation Administration (FAA) gave notice to pilots to steer clear of falling objects, and shortly thereafter the astronauts at the International Space Station (ISS) were huddled together in a make-shift lifeboat due to impending danger (Harwood, 2009; National

Aeronautics and Space Administration [NASA], 2012). This was due to the collision of two satellites from competing nations travelling at 26,170 mph: Iridium-33 (an active U.S. communications orbiter) and Kosmos-2251 (a defunct Russian military communications craft; Marks, 2009). The impact spread debris far and wide, some reaching Earth after orbital decay and some ejected into low-earth orbit (LEO) as hazards to be avoided. Figure 1 is a graphical representation of the "Growth of the Population of Catalogued Objects in Orbit" from page 15 of NASA Office of Inspector General (2021). Green arrows indicate times when voluntary debris mitigation guidelines were issued by various organizations (notably, without significant effect).

**Figure 1**

*Growth of the Population of Catalogued Objects in Orbit*




*Note.* From "NASA's Efforts to Mitigate the Risks Posed by Orbital Debris," by NASA Office of the Inspector General, 2021, p. 15 (https://oig.nasa.gov/docs/IG-21-011.pdf). Authorized for unrestricted public use under 17 U.S.C. §105 (more information can be found at https://sti.nasa.gov/disclaimers/). Reprinted with permission.

As is visible in Figure 1, in 2007 China launched an anti-satellite missile to test its effectiveness against a defunct weather satellite. This singular event cause more than 3,500 pieces of large debris to be ejaculated into LEO (Garcia, 2021). Less than 15 years later, in July 2022, a 23-ton rocket was launched into space carrying large modules for a Chinese national space station (Chang, 2022). The rocket expelled four of its heavy-lift boosters back to Earth in an uncontrolled re-entry, placing populated areas at risk across the globe (Etkind & McGuinness, 2022). This prompted the NASA Administrator, Bill

Nelson, to release a statement directly chiding China for failing, at minimum, to share trajectory information of the falling debris (Etkind & McGuinness, 2022). While none were harmed during this evolution, China’s two other times using the same methods raised similar concerns, once causing major damage off Africa’s Ivory Coast (Chang, 2022). With situations such as these increasing in number, such incidents have become typical of life in the New Space Age.

***Orbital Debris***

While megaton explosions and falling rockets are an example of the problem in extremis, a different type of danger to humanity’s future is presented by the debris that stays aloft in LEO. Scientific advancement in space relies on the ability to travel to and around space. As of 2021, there were more than 27,000 tracked pieces of space junk orbiting Earth, including over 23,000 pieces larger than a softball (Garcia, 2021). Accounting for untracked pieces of debris, the numbers are estimated to be well over 100 million, with pieces as small as 3 mm able to cause catastrophic damage to equipment and personnel (Dawson, 2018; NASA Office of the Inspector General, 2021). As the debris field continues to broaden and cover larger swathes of the globe, scientific research organizations are burdened with the task of tracking that debris in order to ensure catastrophic collisions or damages do not occur to the (often tax-payer funded) equipment (Bernhard et al., 2022; Garcia, 2021). Additionally, even the smallest pieces of debris can cause life threatening consequences to astronauts or space tourists, not only due to bodily harm, but via danger to life-support and navigation systems including radiation shielding, oxygen tanks, air scrubbers, water reservoirs, gyroscopes, and the like (Garcia, 2021; NASA Office of Inspector General, 2021).

Even the smallest casualty on manned or unmanned spacecraft may cost millions of dollars to fix, if it is recoverable at all (European Space Agency [ESA], 2020; Garcia, 2021). Naturally, then, it behooves any spacefaring group to track debris early and remain flexible in finding new deconflicted flight plans, should heretofore unknown debris come into a collision path with spacecrafts in orbit (Bernhard et al., 2022; Klima et al., 2016). Space exploration, research, and technology has always been considered a natural monopoly due to the enormous costs associated with creating a business of this kind (U.S. Congress, Office of Technology Assessment, 1985).

***Entrenchment of Natural Monopolies***

The most well-known space travel industries are Virgin Galactic (Richard Branson), Blue Origin (Jeff Bezos), and SpaceX (Elon Musk). These businesses were built off the extreme wealth of other enterprises (Virgin, Amazon, and Tesla/PayPal, respectively)—wealth that the vast majority of people could never hope to achieve. Other well-known space-related companies are known for their coordination with government entities to gain contracts, including the Jet Propulsion Laboratory (JPL), Northup-Grumman, and Boeing. Often these companies make military weapons and equipment or have other money-making enterprises alongside their space engineering efforts. As a result, the space industry is controlled by those with large cash-flows alongside the few slow projects that are undertaken by public organizations (which are, themselves, influenced by the self-same private companies; U.S. Congress, Office of

Technology Assessment, 1985). The fiscal burden of tracking space debris is itself massive over time, including man-hours from highly educated engineers, and technology that can track debris which is ever-colliding and creating new hazards (ESA, 2020). This is to say nothing of the added costs of professionals and technology used to rapidly adjust satellites in orbit when catastrophe looms. Adding these burdens further entrench the entire space industry into the status of a natural monopoly, restricting the number of scientists and space enthusiasts who can leap forward into space.

### *Environmental Change*

Another major concern surrounding space debris has more recently taken hold as scientists have become more aware of and attuned to long-term changes in the environment. Spacefaring pursuits are now known to puncture holes in the Earth's ionosphere upon initial launch and eventual return to the planet's surface (Ross & Jones, 2022). Additionally, when technological waste reaches orbital decay and is eventually burned-up in Earth's atmosphere, the remnants resulting from the component parts of that waste are released into the atmosphere at all levels (Ross & Jones, 2022). This injects harmful chemicals such as heavy metals into the atmosphere at rates far above the natural balance, furthering atmospheric contamination caused by humans. These issues are believed to cause changes in upper-atmospheric conditions at rates other types of pollution do not (Ross & Jones, 2022). With climate change becoming ever-more concerning, space pollution should be viewed not just as extraplanetary litter, but as a presently contributing threat to environmental change.

***Active Debris Removal***

One suggestion to mitigate the continued proliferation of space waste is the advent of ADR devices. Such devices would work to collect or destroy waste before it is able to cause continued damage. While this may seem like a logical solution, there are many barriers to its implementation. The most prominent issue with ADR is the cost of production (Klima et al., 2016; Migaud, 2020; Ribeiro et al., 2018). The associated costs of ADR are extravagantly high, which provides a very low incentive for production among non-public entities operating on a capitalistic principle and public entities constantly seeking to earn their stipend through public appeal (NASA Office of Inspector General, 2021). Additionally, many if not most types of ADR would include systems that can double as kinetic weapons; that is to say, literal space lasers and weapons of mass destruction hovering over the planet (Miller, 2021; Weeden, 2011). Despite the obvious concerns of a single sovereignty/company owning equipment that can double as weapons in space, there is actual ratified international law forbidding such devices propagated by the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS; Miller, 2021). The problem of ADR is effectively moot in the present era due to a lack of incentive, pecuniary despondency, and concerns over wartime potentialities. As a result, the most reasonable method to deal with the problem of space debris is through legislation that prevents and mitigates at its outset, frames parameters on who is responsible for clean-up efforts, and defines very clearly the concepts related to the topic (Migaud, 2020; Miller, 2021; Ribeiro et al., 2018). Any notion to the contrary is nothing more than high-minded badinage until technology becomes advanced enough for cheap, safe, and legal clean-up efforts (NASA Office of Inspector General, 2021).

**The Problem with Policy Formation**

The propensity for technology to move faster than policy is logical in scope: technologists are well-equipped in the modern era to innovate quickly from multiple points of origin, while policy is a slow-moving process burdened by the responsibilities of safety, constituent desires, and single points of failure such as legislative bodies. Due to this implicit cycle, policies, especially in modern times, have become reactive and are seldom equipped to engage a problem before its apogee. Additionally, it is likely that politicians are reluctant to slow the pace of technological progress through mandates because technological advancements are often viewed as a societal boon. Indeed, there is a specific incentive to encourage technological growth to ensure a country does not fall behind that of competing countries on the world stage. Such may very well be the reasons why, in the examples given above, Russia refused to identify that Kosmos-2251 had been decommissioned and left to die in LEO, or why China is currently racing to add new components to their space station with little concern over where their space junk falls.

Adding to the reluctance many legislative bodies express in passing mandates are the diametrically opposed positions of civil liberty and public safety mandates (Puzio, 2003). While liberty is an expressed desire in most Western cultures, it must be tempered with hard laws that protect the public from harm. Liberty is, by definition, restricted when public health and safety mandates are codified by legislated bodies (Puzio, 2003).

For example, highway speeding laws restrict the public from the liberty of driving as fast as they may wish; however, this is justified in order to protect others from careless and inexperienced motorists. When a public safety measure (such as space debris mitigation law) is created which restricts the unlimited liberty enjoyed by the public, policymakers must conduct heavy research into the scope of restriction on liberties and balance these forces with delegated authority and informed decision-making (Erickson et al., 2002). Failure to do so could mean heavy backlash from constituents, an unwelcomed impetus of burden on the public, or policy enactment being dead on arrival (Erickson et al., 2002; Puzio, 2003). As a result, restrictive laws can be controversial at best and highly work-intensive to formulate.

While hard law may move slowly due to political reluctance, soft law seems to be largely ineffectual. Soft law, or nonbinding policy, lacks the ability to truly be reinforced through policing and punitive action (Cappellini et al., 2022). Nonbinding “laws” from the United Nations (UN) serve as a prime example, where the laws themselves are only reinforced through a tribunal system that is agreed to by all offending/offended parties (Permanent Court of Arbitration, 2012). The internationally-used Permanent Court of Arbitration ("The Hague") serves to meet the needs of national governments where damages are concerned, but even here there is no reinforcement power outside the threat of war and sanctions. For example, a country may simply dismiss the UN’s arbitration attempts as illegitimate or may refuse the terms reached. Additionally, this international court is largely available only to national powers, not to private entities (Permanent Court of Arbitration, 2012; Permanent Court of Arbitration, 2022; Shaw, 2003). This is problematic in an age where space developments are regularly led by private corporate entities. Thus, nonbinding soft law amounts to nothing more than recommendation that can be wielded for grandstanding and saber-rattling. This is further evidenced by the fact that the extant soft laws regarding space debris have failed to "…dramatically halt the growing trend of space debris in outer space" (Hosseini et al., 2021, p.399). This is also illustrated in Figure 1, where green arrows indicate when soft law guidelines were introduced, having little-to-no effect on space debris population growth. As a result, it would seem that hard law is the most appropriate way to create a preventative and mitigative policy stance toward an issue as important as space debris.

It is not hard to understand, then, that space debris holds back humanity as a whole from being able to advance itself into the final frontier. Space debris remains dangerous and costly to endeavors of expansionism, research, and scientific undertaking, while also presenting a danger to terrestrial life. Binding policy in the form of reinforced mandates move slowly due to political reticence, and nonbinding policy has historically fallen flat in this area for a multiplicity of reasons. Binding policy, which seeks to stop the problem effectively (i.e., mitigative and preventative), is the most obvious answer to be enacted by states to ensure the safety and efficacy of future space endeavors.

**Literature Gap and Study Necessity**

Whereas there have been multiple studies identifying the impact of space debris (see Bernhard et al., 2022; Ross & Jones, 2022), the need for mitigative and preventative policies (see Migaud, 2020; Miller, 2021; Ross & Jones, 2022), short-comings of extant policies (see Dodge, 2021; Hosseini et al., 2021; Percy & Landrum, 2014), and a ways to apply similar policies (see Garber & Rand, 2022; Muñoz-Patchen, 2018; Nevala, 2017), there have been no studies exploring common standards among extant multi-sector space policies, and few studies exploring operationalized concepts or legitimized stakeholders within those policies.

While there is much literature reviewing policies and their implications to the subject of space debris, no study has sought to provide the foundational elements for a unified framework. I attempted to fill that gap in the literature by exploring the key foundations of a unified policy framework, as explicitly mentioned is needed in the extant literature: accepted policy standards (see Kaiser, 2015; McCormick, 2013; Migaud, 2020; Ribeiro et al., 2018), operationalized concepts (see Svarovska, 2021; Weeden, 2011), and legitimized stakeholders (see Damjanov, 2017; Remisko & Zielonka, 2018).

The issues surrounding space debris are complex and multifaceted, ranging from outright danger to impediments to advancements in space science (Dawson, 2018). The literature strongly suggests that the next step to address this problem is the formation of an enforceable mitigative/preventative policy framework that coordinates agreed-upon standards with clearly defined concepts (Ribeiro et al., 2018; Svarovska, 2021). In this study, I broke down some of the obstacles facing policy formation by preempting accepted standards and operationalized concepts such that policy formation meets as few obstructions as possible for implementation. I used the information from my study to illustrate inequalities/biases in policy planning by exploring which stakeholders have been legitimized in extant policies. The time to act on space debris is now, and my goal was to remove barriers to inclusionary policy implementation by addressing the need for core unified policy framework constructs.

## Problem Statement

The situation or issue that prompted a search of the literature was the lack of legally-binding policy addressing space debris. As the military, public, and private sectors continue to pursue technological and scientific developments in space, there has been a serious concern about debris caused by human endeavors in LEO (Damjanov, 2017; Ross & Jones, 2022). This is extremely dangerous for astronauts on mission, has historically caused costly damage to valuable equipment, proliferates new debris (via the Kessler Syndrome), has a real environmental impact, and creates an arduous requirement for debris tracking (Bernhard et al., 2022; Miller, 2021; Ross & Jones, 2022). Contributing to the problem is the nonviability of en masse ADR due to a lack of technological advancement sufficiently able to conduct debris removal safely and without extreme financial burden (Ribeiro et al., 2018). Any viable removal technologies that do exist can also play a dual role as kinetic weapons (e.g., explosive ordnance and destructive lasers), and are effectively prohibited due to a ban on the militarization of the space commons under the UN Outer Space Treaty (OST; Miller, 2021). Additionally, due to UN Resolutions 1721(XVI) and 1962(XVIII), there is a prohibition on the sovereign appropriation of space and extraterrestrial territories; as a result, the burden of responsibility for active clean-up efforts is unclear due to a lack of outer space territorial boundaries (Damjanov, 2017).

Thus, the primary problem that I addressed in this study was as follows: while some public organizations have committed policy structures to the mitigation and prevention of space debris (such as NASA), there has been no legally-binding policy created at the state, national, or international level that addresses the responsibilities of spacefaring groups (see Ribeiro et al., 2018; Svarovska, 2021). At present there are a number of organizational policies intended to reduce space debris, primarily through preventative measures; however, these do not bear the weight of legal repercussions or demands (Dodge, 2021; Hosseini et al., 2021; Nevala, 2017). With a lack of enforceable policy, no incentive is given to ensure nations, organizations, or corporate entities are held accountable for viable space debris clean-up efforts (Svarovska, 2021). As the space industry continues to become a major market, it becomes increasingly important to address the problem of space debris legally (Migaud, 2020; Ross & Jones, 2022). Thus, it is evident that an enforceable policy of prevention and mitigation is desperately needed, however before such a policy web can be placed into action legislatively, a generally accepted, unified framework of space debris policy must first be identified (Ribeiro et al., 2018).

The core foundations of any unified policy framework are many, but one foundational pillar in particular stands out: the legitimization of stakeholders in a policy framework in which, by its nature, must include stakeholders of vast diversity in missions (e.g., science, warfighting, capitalistic gain), intent (e.g., protection, exploitation), and concern (e.g., public safety, status quo). Thus far, I have mentioned multiple stakeholders of space debris policy including military, public, and private sectors, as well as astronauts, scientists, national entities, and human-kind generally. In this study, I explored the identification of stakeholders in extant space debris policies, alongside shared policy standards and operationalized concepts.

## Purpose Statement

The purpose of this qualitative case study was to compare the space debris policies/regulations of national and international public organizations within member countries of North Atlantic Treaty Organization (NATO) to identify the foundational structures of an inclusive unified policy framework: legitimized stakeholders, accepted standards for space debris policy, and operationalized policy concepts. The policies and regulations that were explored in this study were those which specifically addressed space debris mitigation at the level of the national institution (e.g., NASA/Federal Communications Commission [FCC]/ESA regulations), national government (i.e., ratified public policy), or multinational institution/government, provided the multinational entity was primarily composed of, or significantly influenced by, NATO member countries (e.g., UN soft law). The research paradigm was interpretivist (including a relativist ontology and subjective epistemology), which aligned with the qualitative nature of the study. The concept or phenomenon of interest was the implicit identification of stakeholders as enshrined in policy, especially space debris mitigation policy.

## Research Questions

The problem and purpose of this study led to three research questions:

Research Question 1: Who do current space debris policies within member countries of NATO define and legitimize as stakeholders?

Identifying the population most space policies are written to appease furthers the ability to create a coherent policy that incorporates that population as well as point towards the inclusion of other stakeholders that may not be represented sufficiently (see Clormann & Klimburg-Witjes, 2022; Freeman, 2004; Freeman, et al., 2010).

Research Question 2: What are the foundationally accepted standards of space debris policy within member countries of NATO?

By using a comparative analysis strategy, this question was intended to elucidate on what aspects of space policies are emphasized in multiple sectors, giving rise to information that allowed for the analysis of legitimized stakeholders across the sample.

Research Question 3: How are these space debris policy concepts operationalized by member countries of NATO?

Without understanding what constitutes the key factors (alongside exacting language) of a policy, it is impossible to conduct analysis; that is, if the definition of term, phrase, or set of phrases is not understood it cannot be analyzed more deeply.

## Theoretical Framework

The theoretical framework that was used to answer the research questions is R. Edward Freeman's (1984/2010) stakeholder theory. The logical connections between this framework and the nature of my study included the fact that Freeman’s theoretical work has been used extensively in public policy analysis to describe the duties of an organization toward both internal hierarchies and external stakeholders within a given community (Freeman et al., 2010; Mintrom & Luetjens, 2017; Oliver et al., 2019;

Remisko & Zielonka, 2018). This connects to the field of space policy when creating restrictive mandates through binding policy in order to protect stakeholders (constituents, scientists, etc.); however, this must balance with the continuation of scientific advancement (internal hierarchies). Further, Freeman's stakeholder theory has been used in other studies to specifically analyze issues surrounding space debris, and was especially suited to this topic as it places an impetus of importance on the balance of organizational performance (e.g., scientific advancement) and the legitimization of stakeholder concerns as an ethical process to discover public policy structures (Freeman, 2004; Remisko & Zielonka, 2018). Freeman himself stated "this line of research is particularly relevant in areas such as the environment" (Freeman, 2004, p. 236). As noted previously, the issue of space debris is especially notable due to environmental concerns.

Researchers using stakeholder theory postulate that the most basic unit of analysis for organizational policy is the stakeholder (Freeman, 2004). Freeman's theory disregards the technical lines between "legitimate" and "illegitimate" stakeholders by instead identifying what the policy development team has perceived as the intended audience or consumer (Freeman, 2004). This group of people/businesses/entities is the de facto legitimized stakeholder group, independent of what more traditional methods of stakeholder identification pronounce. The philosophical backing behind this portion of the theory was the clear motivation for the research question "who do current space debris policies within member countries of NATO define and legitimize as stakeholders?"

Additionally, within stakeholder theory, there are multiple approaches to various ideals, most notably the stakeholder approach to social responsibility. Stakeholder theory's position views social responsibility as a natural extension of caring for the stakeholders in policy planning (Fooks et al., 2012; Freeman et al., 2010). This is done via various methods, most germane to this study is that of ethical leadership and the working environment. Ethical leadership is identified by stakeholder theory as the foundation to accomplishing organizational duties; without it, there is no way to manage the product (policy) effectively for the consumer (stakeholders; Freeman et al., 2010). Ethical leadership is achieved by ensuring the stakeholders of any entity are sufficiently considered in the strategic planning of policy development (Buchholz & Rosenthal, 2004; Freeman, 1984/2010). The stakeholder approach to social responsibility identifies unrealized stakeholders during the strategic planning process by dichotomizing the working environment into the operating environment and the broader environment (Buchholz & Rosenthal, 2004; Freeman, 2004; Freeman et al., 2010). In policy planning, this would mean looking at who is directly affected by policy mandates as well as individuals who are indirectly affected (Buchholz & Rosenthal, 2004; Remisko & Zielonka, 2018). By understanding the stakeholders within a working environment using stakeholder theory, policies are more equipped to create public value and trust thereby making policies attuned more toward the public they are intended to serve and garnering audience support (Braun & Busuioc, 2020; Mintrom & Luetjens, 2017).

By first defining who is already being attributed as a stakeholder in existing space debris mitigation policy, an operating environment of de facto legitimized stakeholders is established.  From there, an inclusive, socially responsible policy framework can be built using ethical leadership principles that establish stakeholder communities into the policy structures from both the operating environment and the broader environment.  This type of policy planning assists policymakers in create public policy that allows for balanced functionality alongside constituent concerns.  This theoretical framework will be explored in more detail, including its past applications to the field of public policy and administration, in Chapter 2.

## Nature of the Study

To address the research questions in this qualitative study, I used an exploratory embedded single case study design (Yin, 2018) including policy documents (artifacts and records) related to the prevention and mitigation of space debris.  The theoretical framework literature indicated the usage of archival policy documents in order to analyze extant legitimized stakeholders (via direct observation or artifacts) while formulating new policy foundations for specific populations (a bounded unit); as such, the theoretical framework aligned most appropriately with the embedded case study approach (Freeman, 2004; Freeman et al., 2010).  The bounded unit was national and multinational space entities from member states of the NATO.  The bounded unit of NATO member countries was chosen due to the nature of the alliance, which provides enforcement power via the structures of civil and military cooperation to address international crises (Zaborowski, 2017).

The methods of this qualitative study included the usage of analytical comparison to identify and connect standards of policy formation across organization boundaries, descriptive coding to describe concept operationalization, and emergent coding to process stakeholder identification/legitimization. Data were collected directly from the entities under study via a public records query. This prominently included organizational/ national websites which make such policies consumable online for the general populous. This type of archival material is classified by Ravitch and Carl (2021) as official documents (i.e., public records) and naturally-occurring documents (which exist without any interaction between the researcher and the organization or group). These naturally-occurring documents were analyzed using an iterative coding approach (described above) conducted without the aid of computer-assisted programming (see: Chapter 3, Methodology, Instrumentation).

The exploratory case study mode of inquiry was chosen as appropriate to this study, as case studies are often best suited for identifying how a bounded unit subject works or interacts within its environment and context (Harling, 2012; Houghton et al., 2013; Yin, 2018). The type of case study was exploratory; as Yin (2018) noted, the types of studies best suited for exploratory case studies involve who and what questions and are often defined by archival data. In this study, the first research question was a who question (who are the legitimized stakeholders), while the second and third questions were both what questions (what are the accepted standards; what are the operationalized concepts). Similarly, Chopard and Przybylski (2021) noted that exploratory case studies are best used for "studies which form an initial understanding" (p. 1) of a phenomenon, "guided by a specific purpose" (p. 2). The purpose of this study was to form an initial understanding of legitimized stakeholders, accepted standards, and operationalized concepts where such research has not been previously conducted, guided by the purpose of identifying the foundational structures of an inclusive unified framework.

Case studies are often conducted using direct observation and artifacts (e.g., archival material) to evaluate within a bounded unit (consisting of a single network, person, or organization; Harling, 2012, Yin, 2018). This particularly lends case study methodology to a study of policy, because policy research often involves the analysis of bounded units of artifacts (i.e., policy documents of a single entity). This research proposed to study policy documents as related to a singular organizational entity, though it contained multiple "subjects" within that entity. Thus, while the bounded unit was singular (NATO member countries), there were actually multiple separate entities with artifacts (policies) for analysis. Whereas other qualitative approaches focus on the culture and environment that impacts a phenomenon, the case study mode of inquiry was the most aptly suited for this type of policy study due to the nature of its bounded unit approach and readiness to use artifacts (Burkholder et al., 2021; Patton, 2015).

## Definitions and Key Terms

*Active Debris Removal (ADR):* This refers to the removal of space debris through active measures as opposed to passive measures. In this instance, passive measures would include preventative and mitigating policies, pulling space debris into orbital decay (an orbit low enough that it slowly succumbs to gravity and falls back to the Earth's surface in a quasi-controlled re-entry), or expelling the debris into deep space. Active measures would consist of technology that goes into space to physically collect space debris (Miller, 2021; Weeden, 2011).

*Astropolitics:* A fairly nebulous term, generally defined by geopolitical theoretical ideals applied to outer space. This may include concepts such as state or national interaction, cooperation, competition, or warfare as related to extraplanetary operations (Wang, 2009). More broadly, astropolitics may also include the actions of private entities within a specific nation and their effect on international relations.

*Environment:* Conventionally, environment may refer to one's natural surroundings, with scientific papers regularly referring to natural surroundings that have direct bearing on a phenomenon, individual, group, or humanity in general. In this study, I defined "environment" to include the terrestrial surface of Earth as well as its atmosphere and orbital space. This is in accordance with sustainable development studies which identify the Earth and space environments as a natural continuum which are greatly interconnected (Paulino & Pulsiri, 2022; Remisko & Zielonka, 2018).

*European Space Agency (ESA):* The ESA is a pan-European fully-launch capable space agency that significantly overlaps with NATO member countries (ESA, 2022).

*Kessler Syndrome:* Also known as the Kessler Effect, Kessler Syndrome can be defined as the proliferation of space debris without the direct injection of further debris. Essentially, as space debris orbits at extreme speeds, it collides with other space debris causing fractures and breakages that create new pieces of debris (Bernhard et al., 2022). This cycle is repeated ad infinitum, causing a complex web of high-velocity space debris to emerge.

*Kinetic Weapons:* Weapons with the ability to destroy or damage with explosive or precise force are considered kinetic weapons. In the context of this study, kinetic weapons in space are those which are able to create controlled damage or destruction to either a spacecraft or to the planet's surface. These would include explosive and laser weapons, and are the prime example of ADR technologies that become politically problematic in practice (Miller, 2021).

*Low-Earth Orbit (LEO):* This includes the spatial quality of being in low-Earth orbit as opposed to the farther reaches of outer space. Technically, this includes any orbital area within 2,000 km of Earth's surface (Dutta et al., 2022).

*National Aeronautics and Space Administration (NASA):* NASA is the chief public space agency in the United States that is fully-launch capable to reach outer space and beyond (NASA, 2022).

*Nonbinding/Binding Policy:* Alternatively termed soft law (nonbinding) and hard law (binding), binding policies are recognized as ratified law which has the backing of force (e.g., violence, arrest, fines) to produce a desired effect (Cappellina et al., 2022). Nonbinding policies can be seen as mere recommendation or guidelines of conduct, with the weight of national pressure, but lacking a legally enforceable standard. This is not to say a failure to recognize nonbinding policy cannot create a practical effect (i.e., withdrawal of cooperation between entities), but the nature of such effects would be passive in nature (Cappellina et al., 2022).

*Outer Space Treaty (OST):* Ratified by the UN in 1967, this first treaty (of five) includes a number of articles pertinent to this study (Tronchetti, 2013). Article I describes the right to use outer space for exploration and general usage unimpeded, so long as the goals are for the good of all humanity. Article II forbids the appropriation of any part of outer space including planetary bodies; there is some debate on how this is interpreted in terms of private entities (Tronchetti, 2013). Article III, especially when read in context of Article I, identifies that actions taken in space shall not violate extant international law (Tronchetti, 2013). Article IV precludes the militarization of space through the usage of orbital weapons systems and weapons systems or military activities on celestial bodies (e.g., planets or comets); it does not preclude the usage of anti-satellite weaponry, only weapons of mass destruction (Tronchetti, 2013). Article V regulates assistance to be given to astronauts in distress both in orbit and on Earth (i.e., after crash landing in the ocean). Article VI establishes the responsibilities of nation-states to regulate their national space activities, regardless if carried out by public or private entities (Tronchetti, 2013). Articles VII and VIII both contain guidance on liability for damage, jurisdiction, and control of space objects, but is primarily centered on control and jurisdiction within one's own spacecraft (Tronchetti, 2013). Article IX addresses environmental issues using vague language regarding contamination (Tronchetti, 2013). All other articles regard international cooperation and information sharing (Tronchetti, 2013).

*Space Debris:* While currently seen as a poorly defined construct both practically and operationally (Percy & Landrum, 2014; Weeden, 2011), broadly speaking this would likely include any material in orbit of the Earth that is man-made (technogenic/anthropogenic) without an active direct usage and without the ability to actively maneuver or avoid obstacles. This might include whole defunct satellites, pieces broken off of spacecraft that remain in orbit, and parts of space equipment that have been relinquished without removal from orbit.

*United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS):* This is a suborganization under the UN Office for Outer Space Affairs (UNOOSA), which focuses on space treaties. UNOOSA has historically brokered a number of important treaties and agreements including the OST (see below) and the Moon Agreement (UNOOSA, 2022a; UNOOSA, 2022b).

## Assumptions

Key assumptions for this study can be broken down as follows: terminological agreement, permissiveness, stakeholder bias, and researcher bias(es). Terminological agreement was assumed for this study vis-à-vis conceptual terms such as space junk, space waste, space debris, and the like. Whereas the technical definitions of these terms are operationally irregular, the practical definitions were assumed to mean any form of technogenic litter in the space commons. Permissiveness to use policy documents shared online for open public consumption was also assumed. If an organization placed their policies or policy archives in view of the public on an open forum (i.e., an unrestricted webpage), and given the organization was a public organization which may not copyright its materials (i.e., they are "public domain"), the documents were considered useable under the fair use doctrine without equivocation or reservation.

Lastly, there were two assumptions regarding bias in the research data. First, there was an assumption related to one of the research questions, namely that the policy documents were biased toward stakeholders. While there was no assumption as to how the stakeholders would be defined (e.g., private entities, the general public, militaries), there was an implicit assumption that policies were written in order to assuage a particular group of stakeholders that were directly or indirectly lobbying for such policies (Victor, 2007; Yu, 2005). Second is researcher bias: it was assumed that I, as the researcher, retained some level of bias while analyzing and coding the data. At the time of the study, I was an active member of the U.S. military and a public administrator; thus, bias based on experiences within the military-industrial complex were assumed and palliated via dialogic engagement, reflexive journaling, and the use of thick description throughout the findings.

## Scope and Delimitations

The focus of this study was on NATO member countries that have policy explicitly aimed towards space debris mitigation and prevention. As described above, NATO was considered the bounded unit due to the nature and effectiveness of the alliance in addressing significant threats through unilateral action across borders. Additionally, space debris policies from private organizations were not considered appropriate for usage, as this study sought to establish a policy framework for use in public governance, and corporate interests may have unduly influenced the ultimate findings. Policy documents from organizations which included other allied partnerships were also considered, insomuch as the non-NATO allied partnership was significantly comprised of, and influenced by, NATO member countries. This explicitly included the European Union (EU), ESA, and the UN.

One major delimiting factor was the existence of policy documents in the English language. Due to restrictions of funding, time, and interpreter's bias, if a country's policy documents were not readily available in the English language, they were not considered useable. Additionally, if a translation was available, but the translation was not explicitly endorsed by the issuing organization, the policy documents were likewise considered unusable for examination. This was due to potential reliability issues related to translation work from outside entities that were not endorsed by the governing organization's policymaking body.

## Limitations of the Study

There were limitations to this study, which can be broken down into the four major categories of qualitative research validity: credibility, transferability, confirmability, and dependability (Ravitch & Carl, 2021). Credibility and dependability were addressed through detailed and customed-tailored coding strategies depending on the question being addressed (i.e., analytic comparison, descriptive coding, and emergent coding). Alongside accepted practices in exploratory case studies, these actions were intended to assuage most potential criticisms related to dependability given the relative stability of the data acquired. Additionally, credibility was addressed through thick description of the data and findings and the usage of all available archival documents, given the scope and delimiting criteria, in a total population sampling design.

Confirmability of the data may be criticized due to the potential for researcher bias; however, this was moderated by ensuring the data collected would be available for review by future researchers seeking to reproduce the results. While researchers do not claim to be unbiased for the majority of work in qualitative research, structured transparency was used in this study to aid the consumer in understanding any potential qualms with confirmability (Ravitch & Carl, 2021). Additionally, isolation in analysis, reflexive journaling, and dialogic engagement were used to moderate bias concerns. Another bias related to confirmability involved the limits of my knowledge when acting as the instrument of research. This bias was addressed through naïve readings of the datasets within the sample, using research tools to understand the propagated topics, terms, and concepts.

Lastly, transferability constituted a significant concern for this study. Due to the nature of case study research, only documents within the bounded unit were used; additionally, some policy documents were not useable due to linguistic inaccessibility. For example, space debris policies in French or Bulgarian were not useable due to funding, time, concerns over reliability of interpretation, and interpreter bias. Due to this limitation, transferability may be limited in broad application. Case studies usually are not intended to be widely transferable, however one way in which this problem was addressed was by seeking policies from non-NATO alliances that published their ratified policies in English, such as the UN and ESA, which included countries that were not included in the sample.

## Significance

The significance of this study was centered on filling a gap in understanding by focusing specifically on key categorical notions between various organizations, the operationalization of policy concepts, and stakeholder identification. The results of this study should assist in the formation of formal, legal policies that can be executed in the private, public, and military sectors.  This binding policy formation may decrease the burden of danger, environmental impact, cost, and effort in continued space research and exploration over time.  This study has the potential to contribute to social change at the professional, community, individual, and national levels.  At the professional level, the field of space policy is provided with data regarding inclusivity that creates opportunities to grow new policies and expand extant policies to tackle the hard problem of inequality in policy formation.  The scientific community also benefits from this study, as current policy concepts were specifically elucidated, giving scientists and technologists the opportunity to clarify, based on scientific evidence, what constitutes the highest priorities at present.  This study provides an opportunity to critically re-affirm the need for policies that address environmental disruption in terms of community stakeholders (world citizenry).  Lastly, the provision of an inclusive enforceable policy framework may lead to a decrease in national budgetary strains as governments work to tackle climate change; a binding preventative and mitigative policy web will ultimately reduce the cost of later clean-up efforts as the issue becomes more prescient.

Today, space debris has already contributed to environmental disruption by puncturing holes in the ionosphere, changing upper-atmospheric conditions, and the injection of significantly harmful chemicals into the atmosphere as space debris re-enters and burns away in Earth's gravity (Ross & Jones, 2022).  As new space debris proliferates via the Kessler Syndrome and spacefaring entities continue to eject/abandon castoffs in low-Earth orbit unabated, this need becomes a dire emergency; indeed, some have already described the situation of technogenic contamination as “catastrophic” (Svarovska, 2021). The provision of inclusive framework foundations that embrace agreed-upon standards and concepts, and specifically includes community stakeholders as a part of the policy formation process, assists in the creation of formalized national policies that contribute to the year-over-year reduction of debris, grant the state an avenue of recourse/enforcement over the private sector, and ensure outer space remains an unobstructed part of the “common heritage of mankind”. In this way, this study is a direct praxis for social change by giving tools to policymakers for further advocacy of stable growth in the field of space science while balancing constituency inclusion, environmental concerns, and public safety.

In short, social change implications of this study included the ability to strategically identify key shared components of cross-sector policies, allowing for policy development to proceed with as few obstacles as possible. Standing to benefit is the space science community (eventually removing some of the barriers to space travel), astronauts on mission (removing part of the dangers of remaining in orbit), and the global population (due to debris' impact on climate change; see Ross & Jones, 2022). Another social change implication was the recognition of stakeholders in current policies, as well as stakeholders that were largely overlooked in policy formation. Those populations which were disregarded in the formation of policies were identified, in a consciousness-raising effort to bring forth a more inclusionary policy framework. That is to say, this study affects social change by assisting in working toward a safer, more sustainable environment for people of all social strata, instead of benefitting those who solely have the means to influence policy.

## Summary

Space debris is a rapidly evolving problem that threatens humanity's ability to use the space commons, and simultaneously creates concerning environmental impacts. The mitigation and prevention of space debris must be addressed through public policy, as ADR is not presently a realistic avenue of development. This is no mean feat due to the blockade that restrictive policies can sometimes create for heads of state. Although there are some public policies that aid in the mitigation and prevention of space debris, these policies are nonbinding and amount to mere recommendation that has been largely ineffective at quelling the problem. In this study, I sought to evaluate such policies within an established socio-political military alliance (NATO) using a case study methodology alongside stakeholder theory to answer salient questions about existing nonbinding space debris policies. The results of this study outline key factors of space debris mitigation across organizational and national borders, creating data that can ultimately be used to build a unified policy. In the following chapter, the problem of space debris is explored in detail alongside exemplars of attempts at mitigative and preventative policies. The chapter concludes with a look into unified policy frameworks and a synthesis of the literature.

Chapter 2: Literature Review

## Introduction

The situation that prompted me to search the literature was the lack of legally-binding policy addressing space debris. As the military, public, and private sectors continue to pursue technological and scientific developments in space, there has been a serious concern about debris caused by human endeavors in LEO (Damjanov, 2017; Ross & Jones, 2022). This is extremely dangerous for astronauts on mission, has historically caused costly damage to valuable equipment, proliferates new debris (via the Kessler Syndrome), has a real environmental impact, and creates an arduous requirement for debris tracking (Bernhard et al., 2022; Miller, 2021; Ross & Jones, 2022). Contributing to the problem is the non-viability of en masse ADR due to a lack of technological advancement sufficiently able to conduct debris removal safely and without extreme financial burden (Ribeiro et al., 2018). Any viable removal technologies that do exist can also play a dual role as kinetic weapons (e.g., explosive ordnance and destructive lasers), and are effectively prohibited due to a ban on the militarization of the space commons under the UN OST (Miller, 2021). Additionally, due to UN Resolutions 1721(XVI) and 1962(XVIII), there is a prohibition on the sovereign appropriation of space and extraterrestrial territories; as a result, the burden of responsibility for active clean-up efforts is unclear due to a lack of outer space territorial boundaries (Damjanov, 2017).

The primary problem for this study was as follows: while some public organizations have committed policy structures to the mitigation and prevention of space debris (such as NASA), there has been no legally-binding policy created at the state, national, or international level that addresses the responsibilities of spacefaring groups (Ribeiro et al., 2018; Svarovska, 2021). At present there are a number of organizational policies the purpose of which are to reduce space debris, primarily through preventative measures; however, these do not bear the weight of legal repercussions or demands (Dodge, 2021; Hosseini et al., 2021; Nevala, 2017). With a lack of enforceable policy, no incentive is given to ensure nations, organizations, or corporate entities are held accountable for viable space debris clean-up efforts (Svarovska, 2021). As the space industry continues to become a major market, it becomes increasingly important to address the problem of space debris legally (Migaud, 2020; Ross & Jones, 2022). Thus, it is evident that an enforceable policy of prevention and mitigation is desperately needed, however before such a policy web can be placed into action legislatively, a generally accepted, unified framework of space debris policy must first be identified (Ribeiro et al., 2018).

The core foundations of any unified policy framework are many, but one foundational pillar in particular stands out: the legitimization of stakeholders in a policy framework in which, by its nature, must include stakeholders of vast diversity in missions (e.g., science, warfighting, capitalistic gain), intent (e.g., protection, exploitation), and concern (e.g., public safety, status quo). I have mentioned multiple stakeholders connected to space debris policy including military, public, and private sectors, and astronauts, scientists, national entities, and human-kind generally. To address the problem statement, I intended to explore the identification of stakeholders in extant space debris policies, alongside shared policy standards and operationalized concepts.

The purpose of this qualitative case study was to compare the space debris policies/regulations of national and international public organizations within member countries of NATO to identify the foundational structures of an inclusive unified policy framework: legitimized stakeholders, accepted standards for space debris policy, and operationalized policy concepts. In this study I explored the policies and regulations which specifically addressed space debris mitigation at the level of the national institution (e.g., NASA/FCC/ESA regulations), national government (i.e., ratified public policy), or multinational institution/government, provided the multinational entity was primarily composed of, or significantly influenced by, NATO member countries (e.g., UN soft law). The research paradigm was interpretivist (including a relativist ontology and subjective epistemology), which aligned with the qualitative nature of the study. The concept or phenomenon of interest was the implicit identification of stakeholders as enshrined in policy, especially space debris mitigation policy.

The field of space policy was first created with the UN Outer Space Treaties, which became seminal documents that laid a foundation for future cooperation (Tronchetti, 2013). As the industry grew in national, corporate, and military fixtures, the hope of future treaties became untenable for multiple reasons. The result has been a fragmented system of policies at nearly every level of government that have failed to address problems dictated by the original UN Outer Space Treaties at a worldwide scale (Percy & Landrum, 2014). Any other policies created internationally have lacked the consequence of enforcement, further entrenching this problem (Svarovska, 2021). This impasse at the international level has caused for space policies to become incredibly important at the national and institutional levels, wherein self-regulation creates an impetus for change.

The history of technogenic contamination in space runs concurrent to the history of humanity's extraterrestrial endeavors (Hall, 2014). There are many ways in which space debris has been created, proliferated, and excused, with little viable notion toward its elimination (Miller, 2021; Ribeiro et al., 2018). The effects of space debris are catastrophic in nature, ranging from simple safety hazards to passing satellites and space stations, to danger at a massive scale for terrestrial life due to falling debris (sometimes including nuclear radiation) and climate change (Dawson, 2018; Jakhu et al., 2011; Ross & Jones, 2022). As the debris field continues to grow, other challenges have also arisen, including the need to track debris remotely (requiring immense resources), maneuverable satellites able to deconflict flight paths with debris, and a general risk to clear the debris field once in orbit (ESA, 2020).

Due to the failure of horizontal integration, the fragmentary nature of space policy in the modern era has caused for many attempts to be made at controlling the development of space debris across multiple sectors. These include alternate interpretations of the original UN treaties and the creation of a policy web in the EU (EUSST, 2022; Muñoz-Patchen, 2018; Nevala, 2017; Svarovska, 2021). The UN's treaties have proved unable to make meaningful difference where space debris is concerned, and the lack of enforceability on the international stage allows for a degree of insouciance (Muñoz-Patchen, 2018; Svarovska, 2021). The EU's space policies focus nearly entirely on ADR and are contradictory in places, making the policies ambiguous and ineffective for prevention and mitigation. Using the United States as an exemplar of national space laws, the issue of space debris is nearly entirely glossed over for more cultural fare, such as space insurance. Institutional policies for space-faring organizations (such as NASA) seem to represent a much more effective approach in that they are able to control their own levers of restrictive power in the arena of space science and technology. Other institutions, however, either lack governance at all, such as the Inter-Agency Space Debris Coordination Committee (IADC), or must rely on government overreach or flimsy assertions of authority to attempt to accomplish their goals, such as the FCC.

Creating democratic policy to mandate preventative and mitigative actions presents a number of salient challenges. Among these include the need to balance risk with reward; that is, a cost-benefit analysis of how restrictive a policy should reasonably be enacted (Puzio, 2003). In this case, it means weighing the costs of public safety, the denigration of personal liberties, and continued scientific innovation. Additionally, the potential to stifle a free market always exists alongside restrictive mandates, but this is particularly true for a natural monopoly such as space-related enterprises (Bauwens, 2017; Gould, 2010). The manner in which a policymaker is able to effectively navigate these hurdles is through operationalizing concepts effectively (in order to assuage vagueness in enforcement), stakeholder evaluation and policy field analysis (identifying who the policies are written for and how they may influence trends in the field), and multiple party amenability (using diverse perspectives to ensure equitable laws through quasi-dialogical engagement).

I used stakeholder theory as a theoretical framework to identify key features needed to build a unified policy framework. The core tenet of stakeholder theory holds that stakeholders are implicitly legitimized in the contextual writing of a policy document (Freeman, 1984/2010; Freeman, 2004). This extends into the postulation that a policy must both uphold the functions of internal hierarchies and stakeholder desires (Buchholz & Rosenthal, 2004; Remisko & Zielonka, 2018). Given the necessity of upholding the functions of internal hierarchies (i.e., space science, advancement, and technology) and stakeholder desires (public safety), it was obvious that this theoretical framework was ideal for the study of space debris mitigation and prevention policy (see Remisko & Zielonka, 2018). Within this framework is an ideology of particular importance for this study: the stakeholder approach to social responsibility. This ideological standard within stakeholder theory identifies the need to represent a wide swathe of stakeholders for inclusion and equity purposes (Buchholz & Rosenthal, 2004; Fooks et al., 2012; Freeman et al., 2010). In space debris policy, this would mean the insistent usage of shared language in policy design, accepted and shared standards across multiple stakeholder environments, and the overt identification of legitimized stakeholders in order to better incorporate a larger stakeholder environment.

Thus, the stakeholder approach to social responsibility provides a framework to identify why multiple perspectives must be applied in policy formation (inclusion of multiple stakeholders), and responds well to showcasing accepted standards of space debris policy across international, national, and institutional boundaries. In a similar vein, stakeholder theory upholds the need to operationalize concepts in such a way that extant stakeholders can be mutually intelligible in the communication of stakeholder needs/desires. Lastly, the stakeholder approach to social responsibility asks the question of who is a legitimized stakeholder enshrined in extant policy for the purpose of tailoring new policy to become more inclusive of a larger stakeholder environment.

Extraplanetary development is an exciting field which captures the imagination of scientists and laymen alike. It is the subject of countless television, radio, and literary works which have, themselves, shaped many of the hopes and expectations of society in the West. Naturally, then, the scientific body of literature related to humans and their relationship with space is prolific and expansive as a result.

In the following chapter, I shall review works related to the theoretical framework, the relevant milestones and research related to space science, salient international and national space policies, space debris and its effects, and efforts to address the issue. This chapter will conclude with an overview of salient research related to the creation of effective unified policy frameworks, and a short synthesis of reviewed literature.

## Literature Search Strategy

The literature for this review was searched systematically until saturation was met; a graphical representation of research chronology is depicted in Appendix A. According to Yin (2018), best practices for a literature review in case study methodologies involve identifying key citations and giving them thorough analysis, rather than meandering through countless citations which provide essentially similar data. As such, in this literature review I attempted to portray the most exhaustive works established in this subject matter area, placing prime importance on works that present new data through the lenses of various research methodologies in order to depict a complete representation of the subject matter's context. In order to gain a general understanding of the policy web related to astropolitics and space science, I reviewed general histories to identify context through books, research articles, and organizational websites related to national and international space policy development. From here, I conducted research into the problem of space debris and its real-world effects. A narrower approach to space debris literature was taken to identify how the problem has been previous addressed, if at all. Finally, research into policy framework development and theoretical structures led to a discovery of a theoretical framework that best fits the subject matter at hand.

The literature search consisted of searching online databases such as the SAGE Journals, Thoreau multi-database search (including EbscoHost and the Walden University Library), and Google Scholar. Online search terms included: *space debris, environment, orbital debris, space junk, climate change, law, public policy, policy, space policy, history, stakeholder theory, United Nations, Outer Space Treaty, effective(ness), efficacious(ness), public safety, mandate(s), Active Debris Removal, policy framework(s), civil, liberty, public health, natural monopoly, policy incentive(s), free market, innovation, strategic planning, social responsibility, corporate social responsibility,* and *NATO.* In addition, more general information resources were sought in public libraries and book stores, this included searches for seminal or omnibus literature in the history of space policy, human advancements in space science, stakeholder theory, and case study methodology. While I used a general search strategy for libraries and book stores, there were occasions where particular books of interest were sought based on their common citation within the multiple pieces of literature found online.

The most basic and germane search terms such as *space debris*, s*takeholder theory*, or *public policy* returned hundreds and often thousands of works. Boolean tools, such as the usage of the word "AND" were used to return more specific works. Additionally, I narrowed the works to peer-reviewed journals (as well as books in some cases) published within the last 5, 7, 10, 15, or 20 years until the strata of literature was broadened or narrowed to include the most comprehensive (and timely) works. As I identified literature presenting information that was novel, comprehensive, particular, timely, or justifiably notable in other arenas, they were added to the research corpus.

In addition to online literature and physical literature search strategies, I used a compendium of websites that address space debris, space science and technology. This included websites from NASA, ESA, UN, The Planetary Society, and the National Space Society. These websites are cited sparingly, if at all, throughout the literature review, but provided important information that assisted in guiding the flow of questions that arose in the logical analysis of the research.

Appendix A depicts the logical flow of the research, starting with a broad set of interests and continually narrowing as questions from the literature would arise. As is depicted, when a new problem or question would arise, preeminent articles or literature were sought that addressed that question. If the literature sufficiently answered that question, it was followed by the next question raised in a logical progression. This was continued until a refined research problem and gap was revealed in the literature.

## Theoretical Framework

A study's theoretical framework can be seen as the blueprint for the study's design; that is, it guides the literature review, methodology selection, and ultimate analysis of the results (Grant & Osanloo, 2014). It acts as a schema by which the researcher can perceive the data, steeped in an established and accepted research model (Grant & Osanloo, 2014). I selected Stakeholder theory for this study as it was appropriately aligned to the research problem, purpose, significance, and questions. As the following sections will detail, stakeholder theory literature suggests qualitative designs and case study methodology as a study's prime mover. It has also been used in similar studies which have investigated similar concepts, samples of which are described below.

### Stakeholder Theory

The theoretical framework that fits most appropriately with the subject matter is stakeholder theory. This theory directly contends the research question, and is particularly suited for directing research pertaining to stakeholders in policy analysis (Freeman et al., 2010). As discussed in the section Creating an Effective Policy Framework (below), the analysis and identification of the stakeholder is a key factor in the creation of public value for inclusive policies and policy frameworks. Stakeholder theory positionally holds that the most foundational unit of analysis for policy in general, and social responsibility specifically, is the stakeholder (Freeman, 2004; Freeman et al., 2010).

By asking the research question "who do current space debris policies define and legitimize as stakeholders?", I was able to generate a key factor in the development of an inclusive policy framework. In other words, by utilizing stakeholder theory to extrapolate the stakeholders enshrined in policy, context was given to the culture, influences, and concerns of the policymakers, while also pointing towards a more inclusive approach (Braun & Busuioc, 2020). In a real way, stakeholders are treated as the absolute foundational unit of policy design; thus, using stakeholder theory to delineate extant stakeholders whose interests have been addressed in current policy created a powerful tactic for building knowledge that can be used to address inequalities in policy formation.

Stakeholder theory contains many subsumed approaches to policy analysis and strategic management. One of the most effectively used in environmental research is that of social responsibility. Alternatively termed corporate social responsibility, sustainability, triple bottom line, and corporate citizenship, this theoretical structure stands alone in placing social responsibility as a prime mover for stakeholder fulfillment (Freeman et al., 2010). Freeman (2004) identified succinctly that any researcher utilizing stakeholder theory correctly will recognize the approach to social responsibility as superfluous, because stakeholder theory inherently subsumes social responsibility concepts as core tenets. The impetus of concern for the wellbeing of the stakeholder is expressed in policy planning via ethical leadership in the working environment. Ethical leadership is described as unifying marginalized stakeholders with those who have been legitimized through iterative strategic planning; this is accomplished by artificially dividing the working environment into the operational environment and broader environment (Freeman 2004; Freeman et al., 2010). Such an approach is driven by what Davis (1973) called the iron law of responsibility: those who are granted power in a society must use it to go beyond economic, technical, and legal imperatives by engaging social obligation, or risk losing everything.

Growing out of the iron law of responsibility and ethical leadership practices are policy outcomes that are responsive to social needs (Freeman et al., 2010). In other words, the policymaker first acknowledges the need to create policies that go beyond rudimentary economic or technical necessities and into the realm of social responsiveness. Then the extant environment is analyzed to extract who is currently attributed as a legitimate stakeholder (operational environment) and a strategic planning approach to stakeholder analysis is used to identify the marginalized (broader environment). Finally, a policy framework is reasserted that incorporates the needs of those who are directly and indirectly affected by the relevant subject matter. Thus, a unified policy framework is created that is functional in addressing prescient issues, while also responsive to a social contract formed by the nature of the power given to the policymaker. In this way, the stakeholder approach to social responsibility is especially impactful for policy design where the environment or social commons is concerned (Freeman, 2004).

**History of Stakeholder Theory**

The term "stakeholder" first appeared at the Stanford Research Institute in 1963, giving rise to the underpinnings of this theoretical structure (Freeman, 1984). This term was built from strategic management and organizational theory research, specifically in relation to capitalistic enterprises, but was narrow in scope as it only described shareholders and those who could fiscally benefit from corporate action (Freeman, 1984). In the late seventies, R. Edward Freeman worked to construct a theoretical model that centralized stakeholders broadly at Wharton University and went on to practically engage this theory at AT&T in 1977 (Freeman, 2004). In 1984, Freeman wrote his seminal text, *Strategic Management: A Stakeholder Approach*, which propagated stakeholder theory into areas of philosophy and business management (Buchholz & Rosenthal, 2004; Freeman, 2004). Freeman's intention in centralizing and expanding the definition of stakeholder was to tear-down and rebuild capitalistic models, such that a more wholistic, inclusive perspective of stakeholders would become the norm within enterprises (Buchholz & Rosenthal, 2004). The purpose of stakeholder theory was to showcase a new model of business in free markets that would allow for social welfare and responsibility generally, instead of careless gain (Freeman, 2004). As the theory began to take hold shortly after, it began to be used in multiple arenas including vertical integration, public policy, public administration, and environmental regulation (Freeman et al., 2010). Much to the surprise of Freeman, who never intended to create an academic framework, this theory became a strong force in the realm of strategic planning and its related fields in policy, health care, and law (Freeman, 2004). Today, Freeman's stakeholder theory is a standard theoretical model that has informed the works of thousands of scholars.

**Major Propositions and Assumptions**

Freeman's 1984 text can be distilled to a few significant philosophical points (Freeman, 2004):

- One must account for how their actions can affect others and how the actions of others may take an effect on them.
- Maintaining an understanding of stakeholder values and contexts is an absolute must.
- An understanding of the stakeholder must occur at three levels:
    - Rational: one's organization in its entirety.
    - Process: the policies which dictate how actions are performed.
    - Transactional: bargaining within the daily milieu.
- The ideas which come from the previous three steps should be applied into new strategic planning models.
- The interests and desires of stakeholders must be balanced at every level.

In many ways, stakeholder theory has not strayed far from these original precepts, as the theory has maintained most of the philosophical assumptions which assert these points. One assumption is the existence in any organization of actors with specific interests, and that those interests play out in policy (Freeman et al., 2010; Remisko & Zielonka, 2018). Another assumption that has maintained its significance over time is that social responsibility is a natural extension of caring for stakeholders in policy and strategic planning (Fooks et al, 2012; Freeman et al., 2010). From these, basic propositions have also held true: stakeholder theory is useful to describe and analyze an organization's relation to society (Buchholz & Rosenthal, 2004; Freeman et al., 2010), and the purpose of any organization is to serve the stakeholders' interests with a moral impetus on striking a balance between those interests (Buchholz & Rosenthal, 2004).

***Key Concepts***

As the theory grew, so did the definition of stakeholder. Carrol (1996) defined stakeholders as "any individual or group can affect or is affected by the actions, decision, policies, practices, or goals of the organization" (p. 74). This encompassing definition serves stakeholder theory well, as it identifies a larger set of stakeholders and allows for application outside of the corporate world. Stakeholder theory has also grown to include multiple other propositions, such as the roles of social performance, the iron law of responsibility, public value, stakeholder legitimization, and a whole school of thought within public policy.

Social performance can operationally be defined as stakeholder engagement. All organizations must engage in social performance (i.e., engage the public) in order to create a viable product with public value (Freeman et al., 2010). A failure to do so means the organization has not first understood the interests of stakeholders external to the organization. Thus, a lack of policy or planning for public interests indicates a lack of social performance, and therefore a lack of public value (Freeman et al., 2010).

The iron law of responsibility asserts that any entity which is granted power by the public (stakeholders) will inevitably lose that power if it is not used in a way that is socially responsible (Freeman et al. 2010). This works alongside the need for social performance in that public value is again centralized. In order to wield power in a socially responsible manner, the entity must engage in social performance in order to create public value. If that entity does not create public value, the power given to them will be lost.

Public value is of utmost importance in stakeholder theory because it is the driving purpose behind any organization or government's mission. In the field of public policy, Buchholz and Rosenthal (2004) stated that policy is intended to serve the social good by holding corporate or government entities accountable through a means outside of market forces. While policy cannot replace corporate moral accountability entirely, it does provide levers to ensure the power given to that entity remains within public values (outside of public detriment; Buchholz & Rosenthal, 2004). In some ways, public policy is intended to be the enshrinement of public value in the societal plane in that "...it is a social decision-making process" (Buchholz & Rosenthal, 2004, p. 148).

Stakeholder theory in the field of public policy has propositions which are particular to this field. For example, a large corpus of research in stakeholder theory has rested on the identification of legitimized stakeholders in policies in order to create public value, especially where environment, e-Government, and strategic management are concerned (Freeman et al., 2010). The underlying assumption herein is that policymakers inherently legitimize stakeholders by incorporating variable interests for appeasement and planning in policy (Remisko & Zielonka, 2018; Victor, 2007; Yu, 2005). As such, stakeholder engagement in the policy planning process can both legitimize and delegitimize stakeholders by placing interests outside of policy schemes (Harrison & St. John, 1996). Thus, in engaging with policy, it is important to divide the working environment into operational and broader environments for stakeholder contextualization (Freeman, 2004; Freeman et al., 2010; Harrison & St. John, 1996). This allows for a thorough analysis of stakeholders and their vested interests, creating a policy framework which contributes to higher public value and public trust (Mintrom & Luetjens, 2017).

**Application in the Literature**

Stakeholder theory is rooted in the case study methodology, and was developed directly from case study analyses (Freeman, 2004). The primary method by which the concepts within this theoretical framework evolve has also persisted to be case studies (Freeman et al., 2010). This makes rational sense, as stakeholder theory researchers evaluate closed systems of policy and how they interact with the public through operating and broader environments. Examples include Fooks et al. (2012) which used the framework to test ideals of neutralization, or cognitive schemas, to justify societally abhorrent behavior in a tobacco company. Similarly, Kochan and Rubenstein (2000) used stakeholder theory to evaluate the stakeholders in a partnership of auto makers. In environmental literature, De Lopez (2001) used stakeholder theory to understand public value for environmental conservation in a national park. Multiple examples of stakeholder theory being used for case study research (with various submethodological underpinnings) abound in every field for which it has been used.

Existing literature also includes stakeholder theory extensively as a theoretical backing to identify extant stakeholders which have been legitimized and delegitimized.

Mitchell, Agle, and Wood (1997) used stakeholder theory to create a framework for stakeholder identification that later became a powerful tool for environmental activism (Freeman, 2004). This tool frames stakeholders in distinct categories of power, legitimacy, and urgency, but has limited academic backing (Parent & Deephouse, 2007; Tiew et al., 2022). Alternatively, Bryson (2018) noted a significant number of tools used to identify stakeholders based on stakeholder theory and its incorporation into the wider strategic planning model for public policy. One such application is explored further in Creating an Effective Policy Framework below (Figure 2). An extensive search of the literature revealed only two studies which directly dealt with the problem of space debris through the lens of stakeholder theory (both using a case study methodology); the following is a short analysis of both studies.

### *Sustainable Development and Stakeholder Theory*

Of particular interest, Remisko and Zielonka (2018) used stakeholder theory in combination with sustainable development principles to identify stakeholders related to space debris in a qualitative case study format. Notably, these stakeholders are those which have an active vested interest in space debris, not those which have been legitimized in extant policy. Remisko and Zielonka (2018) found that that the following are the entities which form the basis for stakeholders in space debris: governments, national agencies, international institutions, insurance companies, research laboratories, operators with final customers, launch operators, equipment manufacturers, and satellite manufacturers.

Remisko and Zielonka (2018) stated that governments are said to incorporate military defense and hold the largest stake in the space sector due to being the largest customer of space technology. National agencies, numbering 71 in total, have significant cross-over to national interests in the realms of economics and politics, as well as scientific goals. Similarly, international institutions are often comprised of national agencies which gather together for important missions. Insurance companies are stated to be stakeholders of crucial importance due to the risk and cost of damage due to space debris. Research laboratories, like international institutions, are often arms of national agencies, but may deviate from this rule on occasion. Operators with final customers is defined as "entities that actually make economic use out of launched satellites" (p. 14). Launch operators, which may rely on government funding, are non-governmental organizations such as SpaceX. Equipment manufacturers are companies which produce spacecraft parts and technology. Lastly, satellite manufacturers are those companies of enormous power and resources that deliver finalized products for the exploitation of space resources. Remisko and Zielonka (2018) noted significant dependencies between these stakeholders and, to this end, a need arises for policy to reflect converging interests via stakeholder engagement.

While the study by Remisko and Zielonka (2018) gives valuable insight into the field of space debris as related to extant stakeholders, it is notable that their focus was solely on public-private partnerships. As such, broader stakeholders such as humanity generally were not considered. While this is understandable given the nature of the study, the next study does take into account a broader stakeholder environment.

***The Space Debris Environment and Satellite Manufacturing***

Tam (2015) conducted a doctoral study at Walden University using a qualitative exploratory case study methodology, which sought to analyze stakeholders' ongoing concerns and the facilitation of risk management. Tam used stakeholder theory in a conceptual framework to support analysis of interviews with 12 leaders that work in satellite manufacturing. This study identified that all of humanity falls into the category of a stakeholder regarding the usage of the space commons; however, this was differentiated multiple times from key stakeholders, such as satellite manufacturers and others which have been described by Remisko and Zielonka (2018).

Tam found that the primary driver of space debris mitigation in manufacturing included meeting the requirements of governmental and regulatory policy (e.g., NASA's institution-level policies or the UN's OST). Additionally, debris damage mitigation (survivability) was a primary driver in manufacturing concerns. This played out through multiple themes of construction design and structural considerations to decrease the impact of space debris. Tam concludes with the finding that space debris prevention is the best method of space debris mitigation, and noted many of the participants looked to policy at multiple levels for an understanding of what rules to follow in preventing space debris.

This study related to the present study in that Tam expressed some of the interests of one of the key stakeholder groups, satellite manufacturers. From this study, it would seem satellite manufacturers are naturally concerned with the fabrication of satellites that can withstand damages from space debris. Additionally, this group of stakeholders is interested in policies which outline specific manufacturing principles that prevent space debris.

**Rationale and Relation to this Study**

According to stakeholder theory, policies must create public value, which inherently creates a need to engage with stakeholders in both operating and broader environments (Buchholz & Rosenthal, 2004; Freeman, 2004; Mintrom & Leutjens, 2017). Stakeholder engagement has the potential to delegitimize stakeholders as well as legitimize stakeholders (Harrison & St. John, 1996). This is because policies legitimize stakeholders implicitly given the inclusion and exclusion of variable stakeholder interests (Remisko & Zielonka, 2018; Victor, 2007; Yu, 2005). Delegitimization has the potential to create an underclass for which policies are not written, have no public value, and may even possibly create negative effects (Freeman et al., 2010). It is the responsibility of policymakers to uphold social good while keeping corporate and government entities in check (Buchholz & Rosenthal, 2004). Thus, stakeholders' interests must be balanced in public policy formation to ensure as many stakeholder interests are assuaged and delegitimization does not occur; this is the explicit purpose for stakeholder theory (Freeman, 2004).

In space debris mitigation and prevention policies, there is a common theme in the literature that a unified policy framework is needed (Ribeiro et al., 2018; Svarovska, 2021). This policy framework should be a composition of existing soft policies at multiple levels of governance and institutions in order to create an amenable policy web (Ribeiro et al., 2018). A unified policy framework will bring a needed parsimony to a policy field which suffers from issues in horizontal integration and fragmentation (Percy & Landrum, 2014). This need creates a question of who current stakeholders are in the existing policies from which this unified framework will be forged. Stakeholder theory is a logical conclusion for a theoretical framework that can address this question due to its philosophical readiness to identify legitimized stakeholders in policy works, as well as delegitimized stakeholders whose interests are not implicit to written policies.

## Context of the Broader Environment

In order to gain a more meaningful understanding of space policies generally and space debris policies specifically, context of the environment in which those policies are grow, adapted, and acted upon is necessary. This is reflected in the theoretical framework's recognition of need to explore the operational environment as well as the broader environment as they coalesce into the working environment (Buchholz & Rosenthal, 2004; Freeman, 2004; Freeman et al., 2010). By using the literature review to identify the context of the operational and broader environments, I was better equipped to understand the orientation of policies as they stand in the present. The following is an exploration of the broader environment: a historical context of space activity and international policy.

### A Short History of Multi-Sector Expansion into Outer Space

Prior to the space race of the 1950's and 1960's, the race for advanced weapons of war dominated the landscape of what eventually became space exploration, especially in the form of rockets. During World Wars I and II, multiple nations were forced to identify increasingly deadlier weapons for usage in full-scale war at an international level.

Progressively sophisticated, deadly rockets were an ominous byproduct of this race to the bottom. The technology fueling these weapons of mass warfare would eventually become what lifted the first technogenic satellites into outer orbit, starting in 1944 with the German Wehrmacht V-2 rocket created by Dr. Wernher von Braun (Moltz, 2019; Scharmen, 2021). Dr. von Braun's V-2 was the first to reach outer space—technology that was eventually stolen by the Allied Forces (notably including the USA and USSR) and improved upon to create Inter-Continental Ballistic Missiles (Moltz, 2019). In other words, technology created by Germany's fascist forces fell into the laps of two allied opponent forces, which, in turn, became outright ideological competitors (i.e., communism vs. capitalism) on the world stage.

This technology now shared by two competing nations led to the USSR's successful launch and orbit of Sputnik 1 in 1957 and the USA's Explorer 1 in 1958 (Dawson, 2018). During this phase of the space race, the focus became the interjection of space capable science and technology into LEO and was inevitably followed by the Moon race. Whereas the USSR beat the USA to nearly every technological leap in the space race, the USA was able to be the first to place human feet on the surface of Luna with Apollo 11 in 1969 (Crumpler, 2021). In just 25 short years, humanity went from an entirely terrestrial creature to one capable of interplanetary travel. These leaps of scientific achievement became the crux of numerous debates regarding the ethicality and legality of space-related topics at a national and international level.

***International Reaction to the Space Race***

As a consequence of the space races, numerous national and international space science organizations emerged, especially as related to military or national allegiances (e.g., NASA, the Soviet Space Program, ESA). Outside of the strictly national interests at play, the UN also took heed of the space race, and, in 1958, formed the first international working group to address such issues called the UN Committee on the Peaceful Uses of Outer Space (UNCOPUOS; UNOOSA, 2022a). In 1959, UNCOPUOS met formally for the first time, and by the end of that year the committee was no longer considered ad hoc, but rather a permanent fixture of the UN's mission (UNOOSA, 2022a).

Only 2 years later in 1961, UNCOPUOS had already established the need for, and ratification of, the UN Register of Objects Launched into Outer Space (UNOOSA, 2022a). By 1963, the body had established its first international policies related to space science and exploration: *The Declaration of Legal Principles Governing the Activities of States in the Exploration and Uses of Outer Space*, the first ever body of space law (Tronchetti, 2013). Following this breakthrough in international policy, a stream of other policy works were developed by UNCOPUOS including *The Outer Space Treaty* of 1967, *The Rescue Agreement* of 1968, *The Liability Convention* of 1972, *The Registration Convention* of 1976, and *The Moon Agreement* of 1984 (Tronchetti, 2013; UNOOSA, 2022a). These will be explored below in greater detail.

***Civilian, Military, and National Reactions to the Space Race***

Alongside the international scramble for a governing body, various civilian groups also began to form as direct and indirect lobbying entities for scientific engagement, education, advocacy, and humanitarian concern. Among these include The Planetary Society, founded in 1980 by the well-known scientist and educator Dr. Carl Sagan and succeeded by Bill Nye, of "science guy" fame. The Planetary Society was formed under the explicit purpose to conduct both direct and indirect lobbying efforts to increase funding for general space science, and especially science at NASA (The Planetary Society, 2022a). Additionally, the National Space Institute founded by Dr. Wernher von Braun (later becoming the National Space Society) was formed in 1974. Dr. von Braun's institute contributed greatly to an indirect lobby effort aimed at space advocacy (Michaud, 1986). Likewise, numerous other organizations formed after the initial space races to bring awareness to space science including the Space Foundation, Space Frontier Foundation, Space Studies Institute, L5 Society, and others. Many, if not all, of these mentioned organizations played a role in fomenting a policy web around the space industry for the purposes of national, scientific, military, and capitalistic advancement.

The widespread awakening to the possibilities realized in the exploitation of space resources were felt in multiple sectors; national militaries around the globe most certainly took notice as well. The dubious nature of intelligence agencies make it impossible to know just how many national endeavors, if any, have been coopted for more nefarious purposes, but the possibility to utilize space as a method to more efficiently identify intelligence opportunities is undeniable (Dawson, 2018; Johnson-Freese, 2017; Moltz, 2019). Outside of intelligence, more efficient Global Positioning System (GPS) technologies greatly enhanced militaries capabilities to wage war around the world (Dawson, 2018). Naturally, the early usage of satellite technology to enhance global communications also contributed significantly to military readiness worldwide (Dawson, 2018).

National and corporate infrastructure also began to emerge at a global scale during and following the first space age. Communications and entertainment could rightly be pointed out as the most revolutionary for modernized societies, with satellite capabilities ranging from general telephonic usage to transactional banking and internet services (Johnson-Freese, 2017). Other important infrastructure changes for both governmental and corporate entities included GPS navigation for travel, mapping, and search and rescue services (Dawson, 2018; Johnson-Freese, 2017). Weather and climate satellites revolutionized the tracking of major storm systems as well as global climate trends. Advancements in technology for space purposes were also found to be useable to the corporate market, leading to a number of general-purpose inventions: water filtration, athletic shoes, medical imaging technology, small device photography, and multiple-use microtechnology such as are found in modern smart phones and portable computers (Jet Propulsion Laboratory, 2016).

In short, it is competition between ideologies which has spurred the advancement of space science, and has continued to be driven by competition in any number of spheres. Today, space science is a modality used to make corporations more marketable for various purposes, is absolutely essential to military capability, and continues to be an ideological sticking-point between competing world powers. Massive undertakings are now conducted by national, transnational, international, and intranational competitors alike, with the scope of civil and governmental involvement continuing to grow concurrently. Public policies safeguarding the general population and future generations, however, have not kept apace of the rapid advancement of space endeavors.

**International Space Policy History Overview**

As the UN created its own branch dedicated to international cooperation in space, multiple policy tools were attempted by means of agreement and ratification. Among these include *The Outer Space Treaty* of 1967, *The Rescue Agreement* of 1968, *The Liability Convention* of 1972, *The Registration Convention* of 1976, and *The Moon Agreement* of 1984. By and large, these treaties have been the only instances of international space policy measures that have carried support by a majority of nations at the gross international level. In addition to these five treaties, five declarations of principles have also been propagated by the UNCOPUOS: *The Declaration of Legal Principles* of 1963, *The Broadcasting Principles* of 1982, *The Remote Sensing Principles* of 1986, *The Nuclear Power Sources Principles* of 1992, and *The Benefits Declaration* of 1996 (UNOOSA, 2022c). Notably, these principles are declarations adopted by the general assembly, not ratified soft policy (Tronchetti, 2013). As technological advancements in space science boomed and more space-related organizations unrelated to governmental bodies emerged, it would seem the ability or motivation to ratify soft policy on the international stage dwindled. An in-depth exploration of these policies can be found below in the section Space Debris Mitigation Policies to Date.

Moving into the 21st century, most legal and policy developments began to take hold at the national or organizational level. States with full launch capabilities (i.e., the ability to launch and recover spacecraft) began to form their own laws on spacefaring as they related to the problems they faced within that time. For example, the U.S. FAA began to put forth mandates for commercial launch and reentry activity, experimental activity permits, and licensing of spaceports (Jakhu et al., 2011). Such laws also began to form in China, Japan, India, Russia, and member-states of the ESA such as France, Belgium, and the Netherlands (Tronchetti, 2013). In addition to these independent bodies of space law, individual public organizations dedicated to space science also created internal working policies for myriad issues concerning safety and public interest. These organizations included the ESA, NASA, Roscosmos (Russian Space Agency), Japan Aerospace Exploration Agency (JAXA), India Space Research Organization (ISRO), and the Chinese National Space Administration (CNSA).

At every level of policy development, the primary purpose of policy has been to identify safety standards for space development, but rarely, if ever, focused on interaction and cooperation. The rare exception to this consisted of a loose set of agreements related to the ISS, called the ISS Intergovernmental Agreement (IGA). The IGA was signed by NASA, CSA, JAXA, Roscosmos, and the ESA to identify roles and responsibilities within the ISS as well as identify utilization protocols and property rights (ISS IGA, 1998). Even this rare cooperative agreement focused almost entirely on the principles of ownership as opposed to actual cooperation.

To say nothing of the enforceability of these policies, it is clear the history of international space policy is fraught with at least four easily identifiable issues: it is fragmentary in nature, it lacks ideological and literal scope, it is reactionary at best, and it lacks horizontal integration (Hosseini et al., 2021; Migaud, 2020; Percy & Landrum, 2014; Tronchetti, 2013). The fragmentary nature of space law is exhibited in the sheer number of organizations which create policy at every level without coalescence or coordination, creating an arcane network of disjointed policy documents. The scope of each policy is relevant only to the matters at hand and rarely extend beyond what present circumstances dictate. Additionally, the scope of such policies rarely proceeds past the physical space of LEO into geosynchronous equatorial orbit, deep space, or exoplanetary engagement. The reactionary nature of space policies has become a hallmark of government in the 21st century, allowing issues related to scientific advancement to come forth as threatening before advancing a mitigative solution. Lastly, the lack of horizontal integration is implied through every other issue, as there is lack of a singular regulatory body which can dictate, enforce, or measurably track such policies.

These issues are on display in an interesting way through the activistic and experimental Asgardian Space Nation project. The Space Kingdom of Asgardia is a self-referential space nation that seeks international recognition as a digital state (Asgardia, 2022). Asgardia has its own national [digital] currency (the Solar), constitution, parliament, and, importantly, its own sovereign territory in the satellite Asgardia-1 (launched in 2017; Asgardia, 2022). The limited scope of international law is ill-equipped to deal with an issue such as this, wherein the [now-former] citizens of terrestrial nations consider themselves visitors to Earth while declaring their actual home as Asgardia-1. As silly as the situation seems, the fragmented nature of the present policy stops NASA, for example, from declaring sovereignty over Asgardia-1; the lack of horizontal integration also keeps international authority from asserting itself over the unruly citizens of Asgardia. With a reactive and limited scope of law presently asserted in the realm of spacefaring peoples, many questions are raised over the history of space policy at an international level to date.

## An Analysis of Core International Space Policies

A history of space policy as a response to its contextual environment was given in the section International Space Policy History Overview; this section will build on the background of the current environment of space policy by analyzing key space policy documents. In doing so, policies have been chosen for analysis that have particular bearing for this study, including multiple UN treaties and NATO's lack of space policy. This section will conclude with a short synthesis of themes, a rudimentary analysis of stakeholders mentioned explicitly or implicitly to the policies, and the policies in context of the current literature.

The operational and broader environments related to space debris mitigation policy cannot be properly understood without a deeper understanding of the corpus of policy which constitute the foundations of space policy: the UN OST, Liability Convention, and Registration Convention (Tronchetti, 2013). These policies have formed the initial framework for all space policies and are generally respected by UN members, except where interpretations of the policies are not shared (Tronchetti, 2013). Each of the following policies has an impact on the field of space debris mitigation in variable ways, and have been evaluated in multiple studies related to space debris (see Hosseini et al., 2021; Muñoz-Patchen, 2018; Svarovska, 2021).

The influence of the UN on the development of space policy cannot be understated.  Since the inception of UNCOPUOS, the first ever body of space laws, international or domestic, were formed in the halls of the UN.  Other multinational measures have been taken at strategically allied levels of coordination between groups such as the EU or the IADC.  However, policies at the multinational level only apply to their own member states in the cases of the EU, and in the case of the IADC only act as a forum for informational sharing.  No organization can be said to have the same breadth and reach as the UN, though the policies remain soft and mostly unenforceable.  Given the UN's status in this discussion, it is quintessential to understand these foundational space policies—particularly the OST, the Liability Convention, and the Registration Convention—in order to fully grasp space debris mitigation policies at present.

### *The Outer Space Treaty*

The OST consists of a series of 18 articles which band together to form a kind of basic structure that can govern the space commons.  The articles of this treaty that apply directly or indirectly to the discussion of space debris are Articles I-IV (dealing with the unimpeded usage of space without appropriation in any way), Articles VI-IX (dealing with responsibility and liability), and Articles XI, XIII (dealing with multinational cooperation). The following summaries of the articles are taken from the source document (UN Treaty on the Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, 1966) in conjunction with a basic analysis taken from the seminal text *Fundamental of Space Law and Policy* by Tronchetti (2013). All other items of in-line analysis shall be cited as appropriate.

The first article of the OST details the rights of states to conduct space science within the space commons. Conspicuously missing in this language is the right of organizations or individuals to use the space commons, only states are given this luxury. Additionally, Article I identifies that this freedom is restricted to endeavors that benefit the totality of extant countries; the usage of the word "countries" is used here in conjunction with the phrase "...the province of all mankind [*sic*]" (p. 13). Contextually regarding stakeholders, the article names only states as the able progenitors of action, while counting all of humankind as the benefactors. In essence, this article excludes the general population from space exploration, enabling national authorities alone to be the lever of power while simultaneously acknowledging the potential impact outside of national interest.

The second article deals with the appropriation of space as a territory, stating that no state shall claim sovereignty over any part of space or celestial body (e.g., the Moon or Mars). Tronchetti (2013) stated that this extends to non-state entities such as corporations or unsponsored scientific organizations, however there is significant debate on whether such entities would be held to the same standard (Pop, 2001).

Article III regards space activities as needing to continue to fall within the bounds of extant international law.  For the sake of space debris mitigation, there is much debate on whether aspects of non-space related international law should be applied. Specifically, there is debate on the applicability of international agreements regarding pollution in maritime law (Svarovska, 2021), ozone depletion a la the Montreal Protocols (Garber & Rand, 2022), and doctrines of abandonment (Nevala, 2017).

Article IV is the only article specifically mentioning the potentiality of the militarization of the space commons.  This article rebuffs any attempts to place nuclear weapons or weapons of mass destruction in orbit around the planet.  In the context of space debris, this is an important article particularly due to the potential for ADR technology to double as weapons of mass destruction (i.e., kinetic weapons).  There have been many comparisons between ADR and kinetic weapons in scientific literature, generally warning of the dangers of allowing ADR unabated (Dawson, 2018; Miller, 2021; Weeden, 2011).  Additionally, debris itself can be utilized as an indirect weapon, such as "malfunctioning" orbiting nuclear reactors or the "accidental" crashes of two satellites from competing enemy territories.

Article VI lays out the responsibility of nations to regulate space activities carried out within their borders.  This article states that the country must authorize and supervise space-related activities, giving rise to licensing and permits as a part of the legal system in most spacefaring nations.  In essence, the UN has placed the power to regulate space solely in the hands of national power structures (Tronchetti, 2013).

Article VII outlines responsibility for damages during launch, recovery, or while on mission in space. This article mentions that a party (nation) is responsible for damages both on Earth's surface and while in space or on a celestial body. Article VII clarifies that any damages by an object launched in space are the responsibility of the party who sponsored the spacecraft and the country who launched it. For example, Canada often uses the USA's spaceports to launch satellites; in this case, both Canada and the USA are liable for potential damages to other countries' orbiters. Notably, Svarovska (2021) stated that this article likely does not apply to space debris mitigation, as such a problem was not recognized at the time of its writing.

Article VIII regards the sovereignty of spacecraft; that is to say, any country which sponsors a vessel of any kind retains jurisdiction over that craft at all times. This article mentions that the craft remains the possession of the sponsoring state even after reentry, meaning that a receiving state must return the possession to the sponsor. A question that this article fails to answer is in the case of abandoned property; in other international policies, there are doctrines of abandonment which could also be applied in similar nature to abandoned satellites (Nevala, 2017). Furthermore, this article creates legal pitfalls for ADR efforts, where one country may not have the "jurisdiction" to remove another's space debris from orbit (Hosseini et al., 2021).

Article IX is of particular interest due its vague verbiage prohibiting the contamination of the environment or space commons. The only mandate mentioned here is that missions shall seek to avoid "harmful contamination and also adverse changes in the environment of the Earth" (UN Treaty on the Principles Governing the Activities of

States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, 1966, p.14). Some scholars are content with this language for the prosecution of countries which create debris, especially through defunct satellites (Muñoz-Patchen, 2018). Additionally, there is debate on whether this article can be enforced for sustainable development initiatives in space (Svarovska, 2021). However, poorly defined concepts in the verbiage of this article (e.g., "harmful", "contamination", "adverse", "changes", "environment") have caused it to be effectively moot where space debris is concerned (Tronchetti, 2013).

Article XI simply states that any projects in the space commons must be communicated to the Secretary-General of the UN and the general space science community, including the nature, location, and results of the project. This applies to the issue of space debris, because it furthers entrenches the necessity to communicate locations and issues related to spacecraft, defunct or active.

Finally, Article XIII identifies that any international/multinational efforts in space should be dealt with at the international or multinational level if problems or conflicts arise. In the context of the responsibility and jurisdiction articles (VII and VIII), this article is an essential release of responsibility by the UNCOPUOS to identify who must take action in an issue involving multinational entities such as the ESA.

### ***The Liability Convention***

The Liability Convention clarifies the concepts of "space object", "damage", "launching state", and "liability" (Tronchetti, 2013). The definition of "space object" is important as it provides the first agreed-upon definition of space debris: "component parts of a space object as well as its launch vehicle and parts thereof" (Svarovska, 2021, p. 4). This convention creates a divide between damage caused on the Earth's surface/atmosphere and damage caused anywhere else. The concept of absolute liability designed in the verbiage of this convention has created issues in the efforts of ADR; that is to say, if one country's debris damages another country's property while a third country is conducting ADR missions, the fault still rests with the first country's vessel. In other words, if Japan is using ADR to clear U.S. space debris and accidently damages a Russian spacecraft with the U.S.'s debris, the U.S. remains responsible. According to this agreement, any collisions in space create an equal liability between all parties involved; in other words, both parties involved in the crash must take equal fault. Additionally, any person seeking redress for damage must do so at the national level (i.e., a corporation cannot seek compensation without the tacit appeal of the host country; UN Convention on International Liability for Damage Caused by Space Objects, 1971).

***The Registration Convention***

As the name suggests, the Registration Convention was created in order to insist upon a registration system for technogenic objects in space. The registration may occur at the publicly available international register or with a privately-held national register. There are two primary factors which many countries find objectionable in this convention: the nature of the space science mission or craft, and the time span required to report said mission. The terminology in the Convention's article specifying time span simply says "as soon as practicable" (p. 17) making the requirement so vague as to be meaningfully opaque. As to the other issue, many countries will wish to conceal the nature of their space missions, particularly where military matters are concerned (Tronchetti, 2013). The result has been an increasing reticence to abide by this agreement in the years after its passing (Tronchetti, 2013). Importantly, this convention has adopted the same definition of "space object" as the Liability Convention.

***NATO Space Policies***

The space policies propagated by NATO are significantly more truncated than that of the UN. This is most likely due to its explicit stance that "The Alliance is not aiming to develop space capabilities of its own and will continue to rely on national space assets. NATO's approach to space will remain fully in line with international law" (NATO, 2022a, paragraph 7). Regardless, the organization has identified some key structures regarding space-related activities for the benefit of monitoring, communication, and surveillance efforts. The following is a review of the NATO Overarching Space Policy (2022b).

The primary matter which dominates the NATO Overarching Space Policy is that of information sharing and voluntary coordination. The policy document only breaks from this rhetoric in order to acknowledge that kinetic weapons in space would be a hazard to accessibility of space routes or damage to vessels due to space debris. In addition, the organization mirrors the UN's OST by declaring space a global environment free of sovereignty, which NATO intends to uphold by empowering nations instead of creating autonomous ventures themselves. The only actionable items stated in the policy document is that NATO intends to serve allied nations by utilizing functional space situational awareness (SSA) tools (orbital tracking and path prediction), and by considering ways to exploit scientific advancements to meet this end.

**Core Space Policies in the Literature, and a Localized Synthesis**

This short review of the main international policies prescient to this study revealed a series of shortcomings in the literature. Policies propagated by NATO can be almost completely discarded by concluding that the policies are largely irrelevant and inoperative. At present, NATO regularly uses members' space capabilities to procure "...positioning and navigation; integrated tactical warning and threat assessment; environmental monitoring for mission planning; command and control communications; and [intelligence surveillance, and reconnaissance] capabilities" (Sari & Nasu, 2021). Thus, despite their own statements, NATO does not simply rely on the good will of member states, but actively pursues militarization of the space commons (Sari & Nasu, 2021). Given the acknowledgement that NATO does, in fact, use the space capabilities of its members, their policies can be viewed as self-servingly disinterested at best. Whereas, at the time of writing, NATO is an effective alliance in addressing international crises, and the alliance is already involved in the space commons to a high degree, the timing is appropriate (and needed) for a policy update that includes the type of unified framework Svarovska (2021) described. Because of the wide number of cultures in the NATO alliance and the nature of implicit civilian/military cooperation, it is of particular importance that an inclusive policy structure is created which allots room for scientific and civilian engagement alongside national and militaristic interests.

In the span of core UN space policies, there are a number of failures due to either a failure of imagination, a failure of inclusive language, or a failure of specificity. Muñoz-Patchen (2018) identified that the OST has the possibility of being utilized for space debris mitigation based on free access principles, however this would require harsher regulation of clean-up costs at the international level. Similarly, the language of the OST commits other international laws as applicable to the space commons. In terms of space debris, this has caused wide speculation on what kinds of international laws would be included. Svarovska (2021) showed how international maritime laws regarding pollution may apply to space debris, comparing masses of floating litter to space debris and the ISS to auxiliary ships that service oil rigs at sea. Garber and Rand (2022) argued the atmospheric issues caused by space debris might be covered under the Montreal Protocols, which have successfully addressed ozone depletion. International doctrines of abandonment have also gained backing as applicable to space debris under the OST's commitment to standing international law (Nevala, 2017). All of these solutions, however, support mitigation in a piecemeal fashion: litter on the high seas, ozone depletion, and abandonment doctrines, respectively. As Svarovska (2021) noted, a unified framework is desperately needed in order to pull these policy frameworks together.

Another issue is the vague language and lack of operationalized definitions used to describe environmental impact and cooperation, making it impossible to create meaningful influence (Svarovska, 2021; Weeden, 2011). This occurs consistently throughout the UN's space policy documents, as Svarovska (2021) denoted, likely due to the fact that they were created at a time in which the earliest space pioneers were not aware of the impacts of future endeavors. Regarding the lack of specificity, UN space policies also lack verbiage to address abandonment and statutes of limitation for ownership or liability, creating significant issues in the development of ADR solutions (Miller, 2021). With the assertion by Ribeiro et al. (2018) that nations are focusing primarily on ADR instead of mitigation and prevention, alongside assertions by Miller (2021) that ADR has the significant potential to rapidly militarize space, it becomes of utmost importance to delineate language which outlines prevention and mitigation in no uncertain terms (Weeden, 2011).

Finally, the UN fails to incorporate stakeholders outside of a seemingly nationalistic state supremacy. Space resources, as the UN claims, are a common resource for all humankind, however the UN fails to identify any individuals in the space industry outside of the state with a vested interest in the same. Trochetti (2013) noted that the original OST articles may be broadened to include non-state actors, but this is a subject of contention among international legal scholars (Pop, 2001). Who, then, is the space commons for, according to the UN? All stakeholders described explicitly are national entities (e.g., OST Article VI explicitly gives states sovereignty over the space domain), to the direct exclusion of militaries and citizens. This is an interesting feature in spite of high-minded verbiage regarding benefits to all human-kind. Thus, it could be argued that the UN's primary goal in the OST, Liability, and Registration Conventions is to ensure national entities hold strict control over the populace's ability to use space resources by granting extra powers to states via allied corroboration. Enshrining such a thing in international policy would have the added benefit of disempowering component constituents from challenging stated laws.

## Context of the Operating Environment

Just as the previous section described the broader environment surrounding space debris policy, the following sections are a description of the operational environment of space debris policy. In discussing stakeholder theory as it relates to public policy and administration, Freeman et al. (2010) stated an understanding of both is necessary in order to properly ascertain the de facto legitimized stakeholders of any policy. The following section describes the history of space debris through the context of notable events, how space debris is created, proliferated, and eliminated (theoretically or otherwise), and the effects of space debris.

### Space Debris Creation, Proliferation, and Death

There are many notable events which represent the current state of space debris. These events illustrate the disinterest many stakeholders in the space commons have toward space pollution and litter, as well as illuminate the multitude of ways in which space debris can be created, proliferated, and potentially eliminated. To this end, the following is a short history and description of how space debris has been created, proliferated, and the ways in which it may be eliminated.

#### *History of Space Debris Notable Events*

The history of space debris is as long as humanity's history with spacefaring. The first ever satellite in space, Sputnik 1, was itself space debris after becoming defunct, but was burned up in the atmosphere shortly after its ejaculation into space (Hall, 2014). The first instance of space debris as it is known today was the USA's Vanguard 1 satellite, launched in March of 1958 (Hall, 2014). Vanguard 1 is still in medium Earth orbit and will continue to be for another 200 years (Hall, 2014). Even during the early years of humanity's venture into the space commons, multiple events can be noted as astronaut oversight including the losses of gear such as gloves, equipment such as cameras, and tools such as in 2008 when an astronaut lost an open tool bag causing multiple objects to lock in orbit (Hall, 2014).

Lost satellites and equipment, however, do not contribute to the bulk of the problem. The ESA's Ariane 1 was a rocket used on multiple trips to place communication satellites in orbit; however, in 1986 Ariane 1 broke up in LEO creating the largest cloud of orbital debris ever seen at that time (Anz-Meador, 2019). This record would not last for long, as in 1997 when Northup-Grumman's Pegasus Hydrazine Auxiliary Propulsion System broke up in similar fashion creating a new record mass of space debris (Matney & Settecerri, 1997). This mishap was especially notable at the time due to the risk it placed on the Hubble Space Telescope (Matney & Settecerri, 1997). Such events have occurred many times over in LEO, medium Earth orbit, and geosynchronous equatorial orbit. In 2005, it was estimated that 73% of space debris was due to rocket fragmentation in LEO (Hall, 2014).

The unintentional break-up of multiple satellites and rockets represent the unforeseen consequences of space travel; however, the next instances represent the intentional creation of space debris. Perhaps the most egregious example is in 2007, when China intentionally tested a missile by launching it into space to destroy its own defunct state weather satellite. The explosive event caused over 3,500 new pieces of debris to be ejected into LEO (NASA Office of Inspector General, 2021). This malfeasance was echoed in 2019 by India's ISRO, when an anti-satellite test missile was launched to destroy its own obsolete satellite, placing multiple assets in danger, especially the ISS (NASA Office of Inspector General, 2021).

The most memorable event in recent history is likely the collision between Iridium-33 and Kosmos-2251 in 2009, as mentioned in Chapter 1. Iridium-33 was a commercial communications satellite in active use at the time of the collision, while Kosmos-2251 was a reportedly-inactive military communications satellite (Hall, 2014). The event caused mass chaos on the ground as large streaks of debris fell to Earth, visible to the naked eye across the United States. This collision also created a massive debris cloud in every orbital sector around the planet.

Two events in 2020 were cause for concern related to discarded Chinese rocket boosters launching modules to its newly formed space station. The first was a narrow miss between an inoperative Soviet-era satellite, which would have caused devastating effects to the magnitude of thousands of orbital debris pieces (NASA Office of Inspector General, 2021). The second event occurred when one of the rocket boosters fell to Earth in an uncontrolled reentry, causing damage to a small village off the African Ivory Coast (Browne, 2021).

The reach of humankind to space endeavors started with unmanned national satellites, leading to manned spaceflights, and has reached its current apogee with corporate and civilian satellites. Telecommunications satellites have dominated the space industry for a number of years; these capabilities have grown significantly since the first space age. Small, easily launched satellites (often referred to as "CubeSats") are now launched by the thousands. These are mostly used for communications purposes, just as their forebears before them. However, CubeSats are much more technically advanced and provide communications services of a different order, such as the internet provider Starlink. Communication enterprises are not the sole progenitors of small satellites, however: The Planetary Society launched two (now safely de-orbited) nanosatellites called LightSail 1 and LightSail 2 (The Planetary Society, 2022b). Both were scientific projects intended to test the operational capability of miniaturized solar sailing which included using "sails" to catch photons from the Sun, similar to how a boat catches wind.

With the steadily increasing number of people and organizations able to take part in space operations via satellites, CubeSats, and nanosatellites, the possibility for catastrophe looms large. Incidents in orbit such as general negligence, unintentional or intentional fragmentation, collisions, and malfeasance create new problems daily with little remedy. In the following two subsections, a more in-depth view of space debris proliferation will be explored, along with the practical and proposed elimination solutions.

***Space Debris Proliferation***

As highlighted above, there are many ways in which space debris is created and proliferated in LEO. These range from clutter due to mismanagement or accidental release, to outright malfeasance. The initial production of debris can be the result of forgotten, lost, or broken items from active satellites, space stations, or space-walking astronauts. This is highlighted in the stories of the missing glove or the tool bag lost adrift. Abandoned satellites themselves become debris once decommissioned, if not properly disposed. This is exemplified in the story of Vanguard 1, or the numerous CubeSats and nanosatellites that are essentially left derelict. Despite the problematic or neglectful behavior associated with these actions, they tend to be relatively understandable in terms of how they come to be. There will be accidental release of items in the space environment; humans make mistakes and astronautical explorers are no different (Damjanov, 2017). Derelict satellites may be distasteful, but a simple solution has not always been feasible. Other causes of debris, however, require a further explanation.

Rocket fragmentation has historically contributed to the bulk of the problem of space debris, especially in the early days of the space age with Soviet era rockets (Anz-Meador, 2019). The break-up of rockets is notably different from the discarding of booster rockets, which will be discussed later. Rockets breaking up upon leaving or re-entry of Earth's atmosphere tend to be accidental in nature and unplanned. The primary cause of rocket fragmentation can be attributed to propulsion-related explosions pre- or post-apogee (Anz-Meador, 2019). In other words, there is a structural failure due to stress on the hull that causes the pressure differential to become unstable during an acceleration or deceleration event. This can cause the combustion of pressurized compartments or the ignition of fuel outside a "clean" control apparatus.

Discarded rocket boosters, while hardly excusable, are relatively low contributors to the problem. While much has been made in recent years over China's insouciance toward uncontrolled reentry of the CNSA's rocket boosters, every country which is space capable has engaged in the same or similar activity. The true danger related to discarded rocket boosters lies in planned placement of the freefall alongside information sharing efforts (Etkind & McGuinness, 2022). As shuttles or modules are lifted into space, a large amount of fuel is needed to propel the vessels past Earth's gravity well. This is why accessory boosters are attached to the sides of the ascending spacecraft in order to provide extra thrust (Wilson, 2006). When the booster rocket has expended its payload, it becomes dead weight and a bulky hazard; as such the boosters are released as the freight is able to continue its journey on its own. Historically, these booster releases have been parachuted down over wide swathes of ocean to ensure safety for the surrounding area (Wilson, 2006). These are also generally concurrent with a robust information sharing scheme which ensures all countries and citizens in the area may make way during the event (Etkind & McGuinness, 2022). The reason such space debris has become hazardous in recent years has been due to a notable disregard for these norms.

Full collisions in space are rare, but do happen with catastrophic effects. There are two primary reasons why a full collision in space is likely to occur: bad tracking data and/or an inability to maneuver (Dawson, 2018). Ineffective tracking data may mean that dead satellites, fallen into disuse, are no longer being tracked by another government, group, or organization with assets in orbit. This is the case with the exemplar of the crash between Iridium-33 and Kosmos-2251. Kosmos-2251 was an inactive military satellite that was not being tracked at the time of impact with Iridium-33. Other instances have also occurred with less severe impact, such as the glancing crash between the Russian space station Mir and Soyuz TM-17 in 1994 (Portree, 1995). A cause for increasing concern is the exponentially growing usage of CubeSats, nanosatellites, or ChipSats. These very small satellites may remain in active orbit conducting missions of various purpose with effective plans for disposal, but may also lack the ability to maneuver once placed in orbit (Dawson, 2018; Hall, 2014). If a piece of space debris contacts a non-maneuverable satellite, the satellite may break apart into multiple pieces of space debris thrown into multiple other orbits at high speed. Alternatively, the satellite may simply be knocked off its current track into a new path that does not allow for orbital decay on the schedule previously planned. This can increase the risk for future collisions or disjointed re-entry plans. In short, a satellite which cannot maneuver from the path of space debris is in danger of becoming space debris itself.

The intentional destruction of satellites while in orbit is far-and-away the most scandalous of space debris creation events. Two premier examples include anti-satellite missile tests conducted by China in 2007 and India in 2019. In both cases, the country had a dead satellite and a desire to "test" anti-satellite missiles (politically named "missile defense tests"), leading to a decision to destroy their satellite in orbit (Moltz, 2019). Both of these eyebrow-raising decisions caused massive clouds of debris in and around the orbital paths of other active satellites and space stations. Other instances of intentional satellite destruction include the previously routine self-destruct functions of defunct Soviet military spacecraft before the 1990s (Anz-Meador, 2019). There are many reasons why a country would desire to conduct such actions. The most obvious is that of power projection—the usage or placement of technology in a quasi-threatening manner for the purposes of displaying national or military might. Alternative reasoning, however, implies something much more insidious. In the book *War in Space* (2018), Senior Lecturer Emeritus of the University of Washington, Dr. Linda Dawson, argued that space debris can itself become a weapon:

> A small 1-mm object does very little damage, but if that object increases to 3 mm, it produces energy similar to that of a bullet. As the debris size and mass increases, so does the kinetic energy. For objects that are 5 cm in size, the resulting collision is similar to being hit by a bus. At 10 cm, the force would be equivalent to a large bomb. (Dawson, 2018, p. 49)

The possibilities are many, as space debris may act as a method of power projection in-and-of itself, may create a deterrent for other nations seeking to launch military satellites, act as surreptitious space weapons, and give a country credibility in the argument to launch space weapons as "clean-up" efforts.

Another form of space debris injection consists of solid fuel exhaust. Solid fuel is used in the upper-stages of launches and has the capability of introducing particles into space for extended periods of time. Aluminum oxide, for example, can be released in small quantities and remain in orbit for approximately two weeks (Hall, 2014). Larger aluminum oxide chunks stay in the same orbital track as the launched satellite or shuttle for much longer, even years, dependent on velocity and atmospheric drag (National Research Council, 1995). These solid fuel spheres exist in swarms alongside paint, dust, and other castoffs during launch (National Research Council, 1995).

An important topic to discuss regarding space debris creation is the Kessler Effect or Kessler Syndrome. While this does not include the direct injection of debris into space, it does describe the manner in which space debris multiplies exponentially. As space debris orbits around the planet and collides with other pieces of space debris, the impact of such collisions causes breakages of the existing space garbage into smaller chunks of junk (Dawson, 2018). This creates a cascading effect or chain reaction of exponentially increasing space debris that becomes harder to track as time goes on. Between 1980 and 2010, the risk of collision in space multiplied by 4.5; as the risk continues to soar, specific orbital paths in LEO and beyond become literally unusable due to the risk of collision and further space debris creation (Bernhard et al., 2022).

### *Space Debris Elimination*

There are numerous ways in which space debris has been proposed to be eliminated throughout the years, some are successful in practice while others remain theoretical in nature. Some of the successful ventures have included orbital decay and planned crashes; theoretical ventures include ADR tools, deep space deorbiting, and kinetic weapons. Orbital decay is the primary method of dealing with space debris and defunct satellites when not left to die in space. This method allows for the craft to succumb to Earth's gravity, slowly decaying the orbit until atmospheric drag pulls the vessel into Earth's atmosphere. From here, the debris is generally incinerated by the friction caused by high velocity re-entry against the upper atmosphere.

Planned crashes, outside of controlled and uncontrolled re-entries on Earth's surface, are the intentional destruction of a satellite on the surface on another celestial body. One pertinent example is NASA's Lunar Orbiter 1. This exploratory satellite orbited the Moon 576 times before becoming obsolete, and was intentionally crashed onto the surface of the Moon on its 577th orbit in order to prevent the obfuscation of other vessels' orbit or transmissions (NASA, 2019). This exemplifies the usage of natural surroundings to ensure a vessel is safely removed from the potential debris field it may cause via other means of destruction.

Another established method, though less used, is the deorbiting of spacecraft by pushing it into deep space. Remaining a mostly theoretical method for orbiting satellites, this method would use propulsion to send the aircraft out of the Earth's gravity well into deep space. This has been proposed via various methods, such as using the battery of the craft for final propulsion or simply using a small fuel reserve normally used for minor adjustments (Aerospace, 2021). An example of pushing a craft into deep space, used for non-orbital craft, is NASA's famous Voyager missions; after its primary mission was completed, it was allowed to continue to the deepest reaches of interstellar space outside of the solar system. This prospect certainly seems more realistic than other proposed methods, such as collecting large debris objects in space in order to cobble together a makeshift space station (Dawson, 2018).

Lastly, ADR is the intentional removal of space debris using tools of various types. This may include the JAXA-proposed magnetic electrified space net, which would capture the space debris to slow it down and allow it to burn up in Earth's atmosphere as in the conventional orbital decay method (Dawson, 2018). Another alternative includes the usage of a space shuttle to collect debris as a make-shift space garbage truck

(Dawson, 2018). These solutions, however efficient, are classified as exorbitantly expensive projects with little pay-off for organizations which must justify their expenditures to a constituency (Migaud, 2020).

Most other alternatives in ADR are inherently problematic because they involve solutions that could double as kinetic weapons. This would especially include the commonly proposed space laser (Dawson, 2018). In this proposal, the laser would be fired at space debris to breakdown the chemical bonds within the target, effectively destroying it. Legality aside, it is not hard to imagine why most countries would be wary of an opponent launching something with this destructive power into space, given the dangers it may pose to adversarial craft or the Earth itself. Subsumed into this level of concern would include explosive propulsion proposals that would create pocket explosions to push debris into deep space or toward the Earth's atmosphere, such as through plasma rockets (Miller, 2021). Lastly, the Russian proposal to launch a nuclear-powered craft dedicated to debris collection is likewise viewed with skepticism due to the dangers of placing something as volatile as nuclear power in space. Miller (2021) and Weeden (2011) identified that these types of ADR would inevitably lead to the militarization of the space commons and should be approached with extreme caution.

Any ADR efforts taken would require extreme transparency between countries, to include open and honest communication facilitated at the highest levels of state. This need for transparency is tied to the lack of clear legal definitions in property laws and jurisdiction for clean-up efforts (Weeden, 2011). Nearly all modes of ADR have other more nefarious potential uses, which could lead to a break-down in terrestrial diplomacy

(Dawson, 2018; Miller, 2021). Additionally, all created space debris belongs to a country, some of which, though defunct, may contain equipment vital to that country's national security. While the debris may have no practical usage, the country may still wish to claim jurisdiction over the item, preventing salvage by others (Dawson, 2018). The jump to ADR may seem like a tempting prospect, but it is rife with issues related to financing, as well as questions such as who is authorized to conduct salvage efforts, where jurisdictional boundaries lie, what types of ADR equipment are agreeable, and what exactly constitutes space debris.

## Effects of Space Debris

Maintaining a more contextual understanding of the history of space debris and space advancement, here it is elucidated as to what the effects of space debris are. As previously stated, stakeholder theory calls for a detailed understanding of the operational environment (Buchholz & Rosenthal, 2004; Freeman, 2004; Freeman et al., 2010). This section is a continuation of the previous section by adding extra context to the myriad reasons why space debris is a problem, and the stakeholders potentially affected by it.

### *Space Debris as a Safety Hazard*

One of the most obvious safety hazards related to space debris is the danger it poses to astronauts and cosmonauts on mission. The slowest pieces of space debris can travel upwards of 7 or 8 km per second or 17,500 miles per hour (NASA Office of the Inspector General, 2021). As of 2021, the NASA Office of the Inspector General (2021) estimated there were over 100 million pieces of space debris over 1 mm in size in LEO. Dawson (2018) asserted space debris measuring just 3 mm in size can exert the equivalent force of a bullet. This information should be held in the context that currently NASA is unable to track space debris under 100 mm (10 cm; NASA Office of the Inspector General, 2021).

A direct hit of space debris to a person's body could spell immediate death, but the likelihood is that an indirect hit poses the higher risk. On too many occasions to recount, space station personnel have been evacuated to "life boat" like pods or modules in order to protect from passing debris that are relatively small in size. The number of life support systems that are needed to in order to survive in space include things such as fuel cells, air scrubbers, compressed air, hydraulic systems, radiation shielding, thermal protection, water, and food—to say nothing of windows, pressurized compartments, and space suits. The penetration of any of these by even a small hazard could be so calamitous it would cause a mission abort due to safety concerns (NASA Office of the Inspector General, 2021). In 1994, it was estimated that the windows on the Space Shuttle were replaced about every 11 days, amounting to approximately 40 windows, at $30,000 to $50,000 per window (Edelstein, 1994). By 2001, that number had increased to 80 windows, due to submillimeter impacts alone (ESA, 2005). The danger of orbital debris to manned spaceflight is so pervasive, it comprises 11 of the 20 likely causes of loss to shuttle and crew (Jakhu et al., 2011).

Related to these concerns are the dangers to non-manned craft. Given the amount of money, time, and effort put into space craft of various size, it is in the best interest of any spacefaring organization to ensure the safety of their unmanned vessels. There is obviously risk of puncture to the satellite if it comes into contact with debris of any size larger than the graphite tip of a pencil (3 mm). However, even if contact with small debris does not puncture a vital system, the mere contact itself can cause significant erosion to the satellite's surface (NASA Office of the Inspector General, 2021). Over time, these render the satellite's walled defenses useless and open to disastrous failure.

Lastly, there is a danger for larger pieces of space junk to fall back to Earth as its orbit decays and it succumbs to Earth's gravity. If planned, the debris from objects such as spent boosters may fall immediately to Earth after usage; however, most space debris takes anywhere from tens to thousands of years before re-entry is expected (Jakhu et al., 2011). It is expected that the friction of Earth's atmosphere will cause most large pieces of debris to be 60-90% eliminated in the re-entry burn alone; the remaining 10-40% of the debris are heavy items such as steel, titanium, and glass (Jakhu et al., 2011). As of 2011 there were 32 defunct nuclear reactors in orbit; at least one incident has occurred of a nuclear core falling to Earth, contaminating a 124,000 $km^2$ swathe of Canada—only 1% of the core was recovered (Jakhu et al., 2021). The risk of falling debris not only exists to land-based people and property, but also to air traffic and maritime operations (Jakhu et al., 2011). In 2008, a U.S. spy satellite carrying poisonous hydrazine fuel malfunctioned causing it to fall to Earth. The risk was so great to the general populous that then-President George W. Bush had to personally order its destruction via a SM-3 intercept warhead (Jakhu et al., 2011).

### *Space Debris as an Environmental Hazard*

Environmental impacts of space debris include the above-mentioned story of the nuclear reactor which fell to Earth. With nuclear space capabilities only likely to increase, the dangers of space debris become more immediately impactful. In 2011, there was approximately 1,000 kg of unspent nuclear fuel in LEO (Jakhu, 2011). The longer debris remains in orbit, the higher the likelihood of catastrophic collision and the sooner the debris is expected to decay in its orbit towards Earth. There are, however, less obvious environmental impacts related to space debris.

The risk of smoke from the re-entry of space debris is understated. This exhaust causes direct injection of harmful chemicals into the middle stratosphere and mesosphere.

> Reentering space debris injects a chemical zoo of particles into the mesosphere as it "burns up." These particles drift downward into the stratosphere to join the rocket particles accumulating in to the different layers. These particle layers, too thin to see with the naked eye, scatter or absorb a small fraction of sunlight, warming the stratosphere and causing ozone depletion. (Ross & Jones, 2022, p. 9)

Such chemicals include dangerous heavy metals such as aluminum oxide (commonly called "alumina"), previously mentioned as the expended solid fuel left in LEO as small chunks from expended booster rockets (Dawson, 2018; Ross & Jones, 2022). This would also include the aforementioned hydrazine fuel, considered highly toxic to humans (Jakhu, 2011). Generally, any component falling to Earth which contains chemicals or metals with low melting temperatures, such as aluminum and lead, can be expected to burn up in Earth's atmosphere, causing further contamination (Jakhu, 2011; Ross & Jones, 2022). In 2011, it was estimated that one piece of debris re-enters the atmosphere daily (Jakhu, 2011).

Given the information reviewed, it is possible the discussion of environmental hazards inherently assumes a definition of "environment" that should be re-assessed when regarding the topic of space. The Webster's New World College Dictionary (2014) defined environment as "all the conditions, circumstances, and influences surrounding, and affecting the development of, an organism or group of organisms" (p. 486). In light of humanity's reach for what is beyond its cradle, it is reasonable to suggest that humanity is no longer a singularly planetary species. While not quite multi-planetary, humanity uses space to the extent that it is now necessary to survive for many due to reliance on the resource of space. If this is truly the case, space itself, especially LEO, has become a part of the feasible environment. Any space junk in that environment can be said to be litter pollution by nature of its existence, causing the same effects of litter pollution that clogs a stream of fresh water vital for the survival of a village. In essence, no second order effects are needed in order to define space debris as an environmental hazard requiring present need for actionable clean-up efforts.

***Space Debris as a Challenge to Future Endeavors***

In order to continue to conduct missions in space that are vital for scientific advancement, exploration, and societal welfare, each organization setting out to conduct such missions must make extraordinary efforts in order to ensure catastrophic failure is not assured. As described above in terms of cost to equipment and lives, the effects of space debris are cause for concern by any spacefaring group. The efforts needed to ensure collision or disaster are abated include the need to identify a deconflicted orbital path, the need to constantly track space debris and its formation, and work hours from qualified professionals, among other requirements. At present, the costs of attending to the most basic parts of these requirements constitute upwards of 5-10% of mission funding, amounting to hundreds of millions of dollars (ESA, 2020). This does not include the need for advanced technology allowing for the rapid maneuverability of spacecraft to avoid danger while in orbit. As discussed in Chapter 1, the space industry has been considered a natural monopoly due to start-up and maintenance costs associated with space science nearly since its inception (U.S. Congress, Office of Technology Assessment, 1985). With the compiled costs associated with space debris avoidance, this further entrenches the field into the status of natural monopoly.

The dangers of the continuously cascading Kessler effect have arguably already begun to compound, creating an operational environment that is rife with looming disaster (Dawson, 2018). The associated costs of mission requirements will most likely be overshadowed in the near future, if not already, by the associated costs of clean-up efforts (ESA, 2020). Given that most amenable ADR plans are out of reach for even the most affluent investors, it can be said that as the extant space debris proliferates into a chain reaction of new debris, the costs will only continue to rise. The result of this effect is the inhibition of space science by any individual who is not financially capable of the extraordinary associated costs.

## Foundational Considerations of Effective Policy Frameworks

The creation, implementation, and execution of policy as law exists within the realms of both the broader environment (e.g., UN space policies) and the operating environment (e.g., specific space debris policy). In order to gain a better perspective on the considerations which play into policy framework creation (and, therefore, stakeholder legitimization), this section will describe the multitude of philosophical and legal constructs which dictate policy formation. Policy will be viewed through philosophical challenges to public safety mandates in a democratic society, the importance of operationalize concepts, and strategic planning focused on stakeholder evaluation and field policy analysis.

Creating an effective policy requires a policymaker to overcome many challenges to the policymaking process. This is especially true of a unified policy framework that can be used by governmental systems more broadly. Policy frameworks set an ideological standard and starting point for subsequent enforceable regulation formation. Naturally, then, a unified policy framework represents an attempt to amalgamate extant fragmented policy documents into an amenable ideological standard that can then be used to coordinate policy more efficiently and effectively.

This is especially prescient to the topic of space policies related to debris mitigation and prevention. Cooperation and coordination between spacefaring agencies are a lynchpin for the successful multilateral regulation of space debris in the space commons (Kaiser, 2015). As such, binding international policy is needed to address the debris problem at a reasonable scale (Migaud, 2020). At present, all international space debris policies are nonbinding soft-law, and require a unified body of enforcement capability (McCormick, 2013). Soft law may provide a basis for cooperation, but is regularly disregarded when inconvenient and is generally viewed as mostly ineffective (Cappellini et al., 2022). This is evidenced in the fact that extant international space debris policies have failed to "…dramatically halt the growing trend of space debris in outer space" (Hosseini et al., 2021, p.399). NATO, being an established example of an international enforcement alliance with the means to address international crises through civil and military cooperation, provides a unique population of policy webs from which to draw (Zaborowski, 2017).

## Challenges to Creating Public Safety Mandates

Space debris mitigation and prevention policies are essentially public safety mandates. In the same way environmental protection laws are created to protect the public from the ruin of infrastructure or public necessities, so does space debris mitigation aim to protect the public from potential disaster. Public safety mandates run a thin line between inhibiting personal freedoms and assuring public health. As mentioned in Chapter 1, speeding laws restrict the freedom to drive as fast as one may wish on the highway, but protect the public from dangerous situations that may cause serious injury or death. Smoking laws restrict the freedom to smoke in any setting one may wish, but also protect non-smokers from the dangers of second-hand smoke. This balance between public safety and civil liberties must be asserted in Western culture especially (Puzio, 2003). Likewise, space debris mitigation policies must strike a balance between stakeholder desires, innovation, fiscal equity, punitive action, and free market principles.

### *Multiple Party Amenability*

One of the most influential political theorists in history, John Stuart Mill, established in his theory of liberal democracy that the definition of "good life" would need to remain neutral in the eyes of government (Brink, 2007). In other words, it is essential that policy and law do not dictate to a constituency how to define a "good life" by creating laws that assume the "common good" from a singular perspective. This has the potential to create incredible inequalities and the stifling of personal freedoms. As such, Mill idealized the ideas of diversity of thought and culture in policy formation in order to create a stable policy field that does not dictate to constituents monocultural values (Brink, 2007). This protects the common person from overbearing cultural supremacy in the governance of the masses.

The same principle applies in creating a unified policy framework and stakeholder legitimization; it is important that a variety of differing perspectives are used to create an amenable unified theory, as opposed to the unilateral usage of one country or organization as an exemplar. While not perfect in scope, this multi-level diversity of thought creates a simulacrum of a dialogical discourse between more powerful majority voices with less powerful minority voices. Such a dialogical engagement is an essential component to the democratic process, foundationally underpinning the human right of free speech, creating equity in the public square (Chambers, 2009).

Similarly, it is essential that a policy framework be flexible enough for changes at local levels to meet the needs of the constituency. Overly inflexible policy mandates at the highest levels shut down the ability for free speech to exact its toll on the democratic process, essentially shunning the disenfranchised from having a voice (Post, 2006). Therefore, just as it is important for multiple levels of policy to be included in a unified policy framework formation, it is equally important that the framework is flexible enough to be altered at the local level without disrupting coordinated efforts toward the ultimate policy goal. To this end, the question of who is legitimized and delegitimized in extant space debris policies becomes a question of utmost importance for policymakers seeking to create a unified policy framework: to ensure a monocultural/homogeneous standard is not imposed unilaterally.

***Potential to Stifle Innovation and a Free Market Economy***

Space debris is often seen as a necessary byproduct of space travel; any ventures into space will inevitably create some level of debris at variable measurement (Damjanov, 2017). As such, mitigation procedures have the potential to limit practical operations due to the inability to use some established procedures. Additionally, financial strain caused by mandates forcing developers to create new (possibly expensive) ways to mitigate issues before, during, and after launch may stifle the ability to launch at all. This also applies to regulations that require insurance or proof of financial viability. All these types of policy tools inherently limit the ability to participate in the space commons to those with the financial or technological means to do so. Efforts to deter space debris are already hampered by economic and technological capability, which is the likely reason so many policies focus on ADR methods instead of mitigation (Migaud, 2020; Ribeiro et al., 2018). A policy framework to this end would need to ensure, within reason, that innovation is not stifled by overbearing financial burden. This is reflected in the descriptions of stakeholders by Remisko and Zielonka (2018), specifically naming insurance companies as a key stakeholder.

Again, the balance of the levers of government used for public safety mandates must also create an environment wherein a free-market economy can still continue to flourish. Thus, the question of what constitutes "acceptable risk" arises. The overregulation of space flight has the potentiality to contribute to the already entrenched natural monopoly of space science. As a result, space debris policies have the possibility of contributing to a runaway market, giving established economic powers a distinctive advantage to project the narrow interests of an elect few (Gould, 2010).

This effect is not solely financial. Bauwens (2017) succinctly described: "As to how it affects individuals, sweeping overhauls... do not promote consumer participation because the sheer amount of new rules and regulations alone likely overwhelm those with minimal knowledge of the industry" (Bauwens, 2017, p. 12). In other words, the innovative scientific and market leaders of tomorrow may be discouraged by the overregulation of the market today. It is essential that safety policies do not stifle the hope of a better future by creating a bureaucratic mesh of disjointed policy doctrines. Some of this is assuaged by a horizontal integration and defragmentation of the policy web, effectively ensuring enforcement and implementation of policy is the responsibility of a singular entity (Percy & Landrum, 2014). Policies which create a stronger or overwhelming burden to financially challenged start-ups, ventures, or enterprises, thus create the delegitimized underclass spoken to by Freeman et al. (2010).

### *The Creation of Natural Monopolies*

Related to the concerns described above is the creation of an entrenched natural monopoly. A natural monopoly is a market wherein high fixed start-up costs create barriers for entry, followed by lowered costs for production and the potential for market needs to be met without competition (Wells, 2016). For example, the space travel industry requires an incredible amount of financial and other resources to be able to participate in any meaningful way; once these resources are secured, operational costs drop dramatically (U.S. Congress, Office of Technology Assessment, 1985; Wells, 2016). Start-up expenses include machinery, advanced production tools, fuels, ports in areas conducive to launch, etc. A critical part of these costs is the need for highly trained personnel from a variety of fields such as astrophysics, engineering, chemistry, and, critically, legal experts. The need for such experts is a result of the complicated legal mandates one must meet to qualify for space flight. The extension of mandates through space debris mitigation policies has the potential to further entrench this field into the status of a natural monopoly by requiring extra costs in legal fees and technological/engineering considerations. In such a case, competition, such as is found in a normal free market, is not a sufficient regulatory measure (Posner, 1999).

The result is the interests of a few stakeholders projected into that which is often described as the common heritage of all humankind. Individuals with this type of power are not only able to decide what constitutes viability in the space commons, but will also have undue influence on future policy measures via direct and indirect lobbying. By having the capital to invest in election engineering, direct lobbying for one's own interests is possible (Victor, 2007). Through the influence of power on the greater masses, the scope of what is considered the best course of action is fed through indirect lobbying (Victor, 2007). Therefore, the further entrenchment of a natural monopoly through policy demands has the potential to single out the interests of specific stakeholders to be addressed, leaving other stakeholders behind.

### *Incentivizing Policy Appropriately*

There is a dearth of research concerning the effectiveness of leveraging fines and negative incentives against rule breakers in the field of space science. However, it stands to reason that the creation of enforceable policy does not necessarily mean the policies will be followed by all parties. There are many tools which can be used to enforce mitigative policies including fines, penalties, or property seizure. In some cases, it is conceivable that if a market power has enough fiscal stamina, that power may simply choose to pay a fine and continue as they were (Barrett et al., 2018). Fines and penalties can be used to enforce policy by way of incentivizing strict licensure laws or the failure to stay below a debris threshold after launch. The same would apply to the improper disposal of equipment, fuels, or dangerous substances. However, there is sufficient research to suggest that fines and penalties in environmental policy may not ultimately have a long-term effect on the compliance practices of a corporate entity (Barrett et al., 2018). In fact, excessive fines may increase the likelihood of non-compliance with environmental mandates (Barrett et al., 2018). As such, caution in devising such monetary policies should be taken to ensure stakeholder interests are connected to the desired outcome.

## Operationalizing Concepts

A key issue when creating public policy is clarifying the language used to convey the intent. As Cooper (2012) identified, the implementation of policy concepts at the level of the public administrator can be variable based on interpretation and political paradigm. The more room is left in a law or policy document for interpretation, the more an administrator must rely on professional judgement, potentially misinterpreting or misrepresenting the intended legislation. As such, it is extremely important that concepts in policymaking are clarified, using exacting language in order to remove as much vagueness as possible. This is an issue of administrative ethics; whereas a public administrator attempts to remain politically neutral, the judgement of the public administrator in the execution of laws and policies remains inherently political (Cooper, 2012). Thus, distinct and clear verbiage in policy writing assists administrations in the execution of the law as intended, leaving little room for the administrator to waiver on interpretation. Given this necessity, and specific literature identifying a lack of solid operationalized concepts in the space debris policy field, a necessary question arises in attempts to identify legitimized stakeholders (Percy & Landrum, 2014; Svarovska, 2021; Weeden, 2011). This question asks what the policy concepts actually mean in an actionable (operationalized) arena, such that the stakeholders who would be held accountable for those actionable definitions can be more readily identified.

**Strategic Planning**

Using a strategic planning model can assist in the creation, analysis, revision, and implementation of policy frameworks. There are two intertwined aspects of this that will be focused on for the purpose of this literature review: stakeholder evaluation and policy field analysis. Stakeholder evaluation is a process whereby a policymaking body or other group of individuals assess the audience for a set product(/policy), who is invested in the outcomes, may be affected by its production/creation, and will profit from the implementation. Policy field analysis is the identification of the environmental factors that shape the way a policy is formed. Where the policy field is the circumstances by which public services are enacted, analysis lends to an understanding of the principal players who enacted them, the processes they may use, and their relationships to the stakeholders (Bryson, 2018).

***Stakeholder Evaluation***

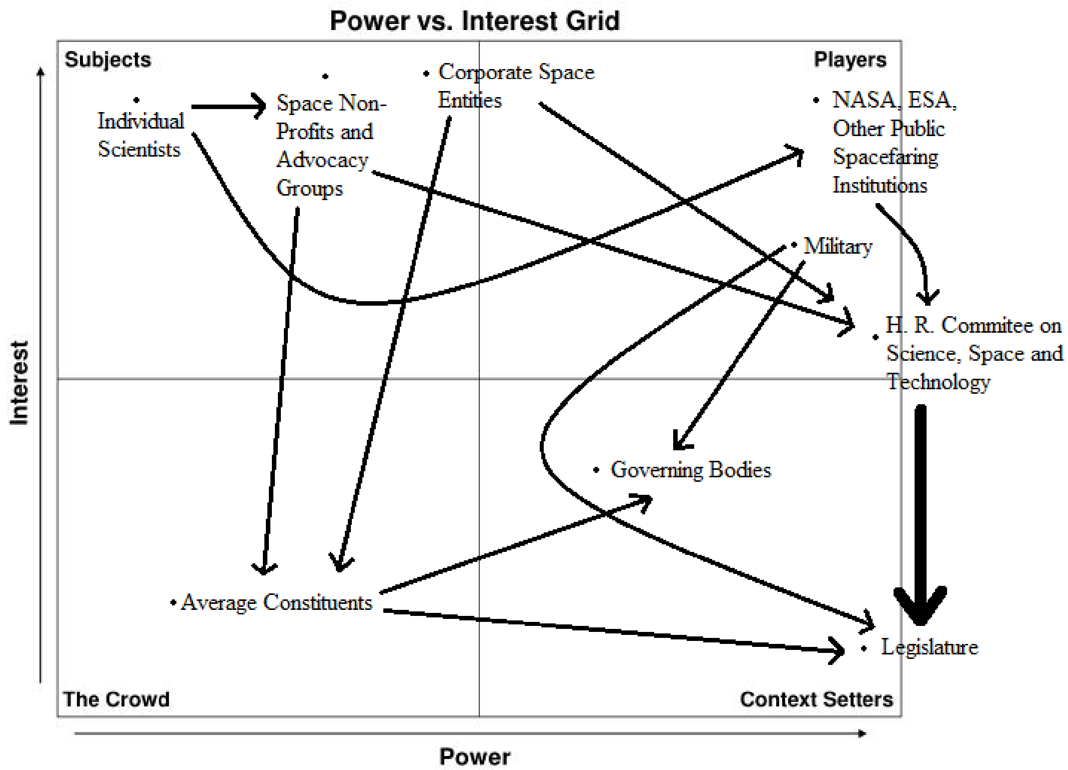
The three most effective ways to "map" stakeholders for policy development are basic analysis, power versus interest grids, and stakeholder influence diagrams (Bryson, 2018, p. 129). In basic analysis, stakeholders are identified by a researcher, followed by a description of how those stakeholders define success; then the products (policy outcomes) are judged against those criteria. This allows for a policymaking group to understand the overall mission of the policies they are setting out to create (Bryson, 2018). Additionally, policymakers can use this analysis to discuss the amount of influence presupposed onto the policy field, as well as needed buy-in from constituents.

From here, a power versus interest grid can be used to recognize who requires the most attention in these policies. The power versus interest grid allows policymakers to visually identify who hold the highest and lowest stakes in the formulated policies. Stakeholders with a high power and high interest are players who assert great influence on policy decisions. High power, low interest stakeholders are context setters who establish the environment the policies must operate within, but may not have desire to participate in the subject matter area. Individuals who are low power with high interest are the subjects of the higher-powered individuals, being wont to the vicissitudes of the players and context setters. Finally, those with low power and low interest are the crowd who may not factor into the decision-making process (Bryson, 2018).

The stakeholder influence diagram is built off the power versus interest grid and elucidates by drawing arrows to identify which stakeholders influence one-another (Bryson, 2018). In other words, how do stakeholders in one sector influence the stakeholders of another? These are important steps in policy formation because the stakeholders are an integral part of the policy formation and design. This is especially true of public safety policies which inherently limit the freedoms of some in order to protect others. A sample analysis of the power vs. interest grid and stakeholder influence diagram are mapped in Figure 2. This extends directly into stakeholder theory's stated need to identify those within the broader and operating environments as a whole in order to extend an inclusive policy framework. Looking at Figure 2, if the interests of stakeholders in the players and context setters quadrant are the only needs addressed in policy, then the policy is inherently exclusionary, delegitimizing those in the subjects and crowd quadrants. This visual mapping representation will be further discussed in Chapter 3.

**Figure 2**

*Sample Space Policy Power vs Interest Grid and Stakeholder Influence Diagram*




*Note*. A non-exhaustive hypothetical sample of potential stakeholders in space policy with arrows indicating potential lines of influence. H. R. Committee on Science, Space and Technology has a direct effect on the Legislature as indicated by a bolder line, and the Legislature is understood to influence all other stakeholders.

### *Policy Field Analysis*

In a policy field analysis, the policymaking body is asked to imagine different possible futures in the environment, produced by various policy alignments. Variable forces and trends are explored as a consequence of policy decisions. These trends are analyzed to identify how consequential the trends will be to the desired outcomes, and subsequent reports on these trends are used to identify policy planning maneuvers (Bryson, 2018, p. 47). This grants the governing body a window into how variable stakeholders may influence those trends, who holds the most power over those consequential trends, and how to mitigate or empower those stakeholders in future decision-making (Bryson, 2018).

Utilizing the power versus interest grid in Figure 2: if a policymaking body wants to drop debris emissions to 10% of its current figures, it must imagine this future playing out with policy enactments. This may include the market forces which influence space science, and the key stakeholders which influence those market forces (i.e., corporate space entities and the military industrial complex). National space entities such as NASA and the ESA may not be an issue in this analysis despite being players, as they are predisposed to follow policy using extensive internal controls. Thus, policymakers may choose to focus more intensely on the regulation of the corporate and military sectors in order to bolster policy development, subsuming the interests of other stakeholders.

## Synthesis

The following is a synthesis of the information described in this literature review. Synthesis has been categorized through the scope of the theoretical framework; that is to say, this synthesis begins with cohesive stakeholder theory principals, their application to policy formation and space debris mitigation policy specifically, expands to the broader environment, and narrows to the operational environment. (The reader will note a localized synthesis was conducted in the section An Analysis of Core International Space

Policies for the sake of readability; the following will include a more complete synthesis.) This section concludes with a short synthesis of how stakeholder theory has been used methodologically in the literature.

**Overall Synthesis**

Stakeholder theory postulates the purpose of any organization, to include government institutions, is to serve stakeholder interests (Buchholz & Rosenthal, 2004). The iron law of responsibility dictates that the power granted to an organization is inherently granted by the public and the organization will lose this power if it is not used in a socially responsible manner (Freeman et al., 2010). The usage of power in a socially responsible manner is done through the creation of inclusive policies that create public value by legitimizing as many stakeholder interests as possible (Buchholz & Rosenthal, 2004). In order to achieve this goal, stakeholder interests must be understood through the scope of both the operating and broader environment (Freeman, 2004; Freeman et al., 2010; Harrison and St. John, 1996; Mintrom and Leutjens, 2017).

At present, there is no unified space debris mitigation policy framework available for governance (Ribeiro et al., 2018; Svarovska, 2021), however one is desperately needed (Migaud, 2020; Ross & Jones, 2022). There are many concerns when formulating a policy framework, nearly all relating to stakeholder theory's assertions of stakeholder inclusivity to create public value. Policy must include diverse interests a la the operating and broader environment to prevent monocultural systemic inequality (Brink, 2007; Chambers, 2009). Additionally, policies must not over-burden the economically underprivileged; specifically related to space debris, this error in judgement runs the risk of stifling innovation in space science and technology (Bauwens, 2017; Gould, 2010; Migaud, 2020; Ribeiro et al., 2018). Space as a corporate venture is already couched in a natural monopoly, pushing out economically underprivileged potential stakeholders (U.S. Congress, Office of Technology Advancement, 1985; Wells, 2016). This leads to some stakeholders having the ability to influence policy more readily, covertly and overtly (Victor, 2007). Additionally, policy incentives such as fines and penalties may contribute to the problem by entrenching the natural monopoly and entrenching undue influence on policy formation by few stakeholder interests (Barrett et al., 2018).

Stakeholders are inherently legitimized (and delegitimized) through stakeholder interests being enshrined in policy (Freeman et al., 2010; Remisko & Zielonka, 2018; Victor, 2007; Yu, 2005). In order to create an effective unified policy (i.e., a composite of extant soft policies), stakeholders need to be identified in extant policies so delegitimization can be addressed to ensure public value via inclusionary policies (Buchholz & Rosenthal, 2004; Damjanov, 2017). If the field of space science is already dominated by a natural monopoly, it is likely the interests of the economically privileged are more heavily represented.

### ***Broader Environment***

A review of the broader environment shows national and military interests are deeply involved in space endeavors, which has caused reactive interests for scientific engagement by civilian groups and interests for consumer-market exploitation by corporate interests (Dawson, 2018; Johnson-Freese, 2017; Michaud, 1986). Another reaction to national and military interests in space endeavors has included international protectionism (Tronchetti, 2013). The scope of international protectionism in foundational space policy documents has shown a focus mainly on ensuring state supremacy under the guise of general human interests (Pop, 2021; Tronchetti, 2013). This has caused a high number of fragmentary policies to emerge at every level of governance, including the institutional (national agencies), national, quasi-national (military), multi-national (EU and joint agencies), and quasi-international (interest groups; Percy & Landrum, 2014).

### *Operating Environment*

A review of the operating environment reveals many of the stakeholders in the broader environment have the same interests within this sphere of influence, although primarily for fiscal reasons (Anz-Meador, 2019; Edelstein, 1994; Moltz, 2019). The web of stakeholders is expanded in the operating environment to include individual astronauts, scientists, manufacturers, taxpayers, and [critically] all of humanity for the reasons of safety and environmental decline (Dawson, 2018; Edelstein, 1994; Jakhu et al., 2011; NASA Office of the Inspector General, 2021; Ross & Jones, 2022). This is due to the actual safety and environmental effects of space debris, not just the nuisance it may cause to an overarching mission.

### *Literature Agreement and Sample Identification*

These findings align with the literature, specifically that of Remisko and Zielonka (2018) and Tam (2015), which identified space debris stakeholders thusly: governments, national agencies, international institutions, insurance companies, research laboratories, operators with final customers, launch operators, equipment manufacturers, satellite manufacturers, and all of humanity. Each of these stakeholders have multiple lines of converging interests (Remisko & Zielonka, 2018). One of the few institutions that has included the majority of these stakeholders at multiple levels is the NATO alliance (Zaborowski, 2017). NATO is notable for its ability to coalesce national, agency, and military interests alongside civilian expert engagement to address international crises (Zaborowski, 2017). Given that NATO does not have a space debris policy, but actively pursues space-related objectives, with its member countries accounting for approximately 93% of global space flights, it may represent a significant exemplar for study using an embedded design (Center for Strategic & International Studies, 2022; NATO, 2022b; Sari & Nasu, 2021).

**Methodological Synthesis**

Methods used in studies which were aided by stakeholder theory as a framework are overwhelmingly qualitative in nature, with the case study approach being most commonly used. Case studies were used to build the foundations of stakeholder theory, and continues to be well-suited as the theory calls for analysis of policy in the context of a bounded unit (Freeman, 2004). Stakeholder theory has been primary used to identify stakeholders in a bounded unit (Bryson, 2018; Kochan & Rubenstein, 2000; Mitchell, et al., 1997; Parent & Deephouse, 2007; Tiew et al., 2022), as well as reveal knowledge about stakeholder engagement (Fooks et al., 2012; Mintrom & Luetjens, 2017; Remisko & Zielonka, 2018), and assist in identifying stakeholder interests which create public value (De Lopez, 2001; Mintrom & Luetjens, 2017; Tam, 2015). Finally, literature which identifies stakeholder theory as a primary framework make prolific usage of archival documents or artifacts in the research to answer research questions (Fooks et al., 2012; Parent and Deephouse, 2007; Tam, 2015; Tiew et al., 2022).

In order to identify legitimized and delegitimized stakeholders in existing policies, clear operational definitions need to be delineated clearly in order to identify who is responsible for actionable policies and whose interests are represented that policy (Cooper, 2012). This is particularly true for space debris policies, as the literature shows much of the current policy web uses vague language with poor operational definitions (Percy & Landrum, 2014; Svarovska, 2021; Weeden, 2011). Seeking amenable policy standards across national, institutional, and international boundaries will assist in defining those operational definitions.

Additionally, the strategic planning literature reveals three tools which assisted in analyzing the findings of this study: power versus interest models, stakeholder influence diagrams, and policy field analysis (Bryson, 2018). These tools assisted by mapping the field of stakeholders, their range of influence, and elucidated how policy enactments related to stakeholders may meet the goals of policymakers (Bryson, 2018).

## Summary and Conclusions

In this chapter, an exhaustive literature review revealed the importance of space debris relative to space science and environmental dangers. The literature revealed that in a very short time in human history, the Space Race, Space Age, and New Space Age have created growing pains related to an explosion (sometimes literally) of a dangerous space debris field. This problem is largely unmitigated due to a number of issues including the nonviability of ADR in the present era and a lack of space debris policies that address the issues of space debris with enforcement at an international scale. In this chapter I reviewed the theoretical framework in detail, then explored the broader and operating environments in order to better understand stakeholders outside of policy, and why policy that is inclusive to diverse stakeholders is important. Literature findings included a vast web of knowledge related to space debris and the dangers it poses, but a lack of binding unified policy addressing the issue, as well as potential barriers to creating such a policy. One of those barriers is the dearth of understanding as to who is legitimized in extant policy works; this was found to be an important question to ensure an inclusive policy framework is created for the sake of governance. This study represented an attempt to fill that gap. Finally, models of stakeholder analysis in strategic management literature were reviewed as pertinent to this study for analysis of findings. In the next chapter, research methods, designs, and concerns will be addressed in detail.

# Chapter 3: Research Method

## Introduction

The purpose of this qualitative case study was to compare the space debris policies/regulations of national and international public organizations within member countries of NATO to identify the foundational structures of an inclusive unified policy framework: legitimized stakeholders, accepted standards for space debris policy, and operationalized policy concepts. I used a case study methodology to approach the analysis of policies related to space debris within NATO member countries. In this analysis, I used three types of coding to understand who is legitimized and delegitimized as a stakeholder in extant policy by merging shared principles of each policy reviewed, identifying the operational definitions of crucial concepts within those policies, and subsequently identifying key stakeholders. The three types of coding were used in a stepwise, iterative process, and were conducted through three stages of analysis as follows: analytic comparison (to draw out similarities in policy documents), descriptive coding (to operationally define concepts), and emergent coding (to describe stakeholders for whom the extant policies are written). The following chapter is an elucidation on the research design, rationale, role of the researcher, methods, and potential pitfalls in trustworthiness and ethics.

## Research Design and Rationale

### Research Questions

To restate the primary research questions posed in Chapter 1, the following is what I sought to illuminate in the case of NATO member countries:

Research Question 1: Who do current space debris policies within member countries of NATO define and legitimize as stakeholders?

Research Question 2: What are the foundationally accepted standards of space debris policy within member countries of NATO?

Research Question 3: How are these space debris policy concepts operationalized by member countries of NATO?

## Central Concepts and Phenomenon of Interest

The central concepts of this study were related to strategic planning in policy design, namely the need for inclusive policy design, environmental protection, public safety, and space debris. Informed by stakeholder theory, I sought to identify legitimized and delegitimized stakeholders through analysis of the extant policy web in this study. Stakeholder theory asserts that policies inherently legitimize stakeholders in policy by including (or excluding) the interests of specific stakeholders (Freeman et al., 2010; Harrison & St. John, 1996; Remisko & Zielonka, 2018; Victor, 2007; Yu, 2005). In order to create public value in public policy, an inclusionary framework is needed via stakeholder analysis and engagement (Buchholz & Rosenthal, 2004; Freeman et al., 2010). Through this study, I sought to identify which stakeholder interests have been legitimized in policy via thorough analysis and interpretation.

## Research Tradition

I used a qualitative methodology for this study. Ravitch and Carl (2021), Burkholder et al. (2020), and Patton (2015) stated that qualitative methods are considered appropriate when a researcher is attempting to provide thick, rich, and detailed descriptions of the data. Additionally, qualitative research is appropriate for research that requires a degree of systematic interpretation with an awareness of the context wherein the data are harvested (Ravitch & Carl, 2021). At its core, qualitative research is used to describe and make meaning of phenomena via exploratory measures that create an understanding of that phenomena through analysis (Burkholder et al., 2020). Qualitative research is idiopathic (exhaustive and contextual), whereas quantitative research is nomothetic (causal and narrower in scope; Babbie, 2017). This study fit qualitative methods well because it was exploratory, provided rich detail in context, provided interpretation of the data, defined concepts based on contextual analysis, and exhaustively reviewed the data. Additionally, as indicated in Chapter 2, the theoretical framework significantly lent itself to qualitative methods, as this theory is inherently couched in case study research.

**Research Design**

Within the qualitative paradigm, there were multiple research designs which could be employed for this study; however, the ultimate decision was to use an exploratory embedded single case study approach. The qualitative designs initially considered included basic qualitative design, case study, and grounded theory. Other qualitative designs were discarded due to poor fit with the problem, purpose, and questions this study presented. That is, through this study, I did not seek to test theory (realism), describe lived experiences (phenomenology and heuristic models), identify findings through/with a social lens (social constructivism, ethnographies, and interactive/participatory applications), use narrative discourse (narrative inquiry), or describe the system with which the phenomenon interacts (systems theory). From here, the choices for research design were pared down from basic qualitative design, case study, or grounded theory.

Basic or generic qualitative designs are often used to delineate meaning for individuals or describe practical knowledge garnered from an analysis of the data (Saldaña, 2016). While I did seek to describe meaning in terms of operationalized concepts, I did not seek to ascribe meaning for any particular group of individuals or social system. This study certainly represents an attempt to garner practical knowledge; however, the scope of the data was that of a bounded unit (NATO), which lent itself more readily to the case study methodology.

Grounded theory is often used to build theory around a phenomenon and is well-equipped for exploratory research in particular (Charmaz, 2014). However, grounded theory generally is used to explain the phenomenon through theory building, where this study sought to describe without inference towards explanatory factors (Charmaz, 2014). Essentially, this is the difference between "why?" (explanation) and "what?" "who?" or "how?" (description). This left case study designs to contend with, which I used to conduct the research with a bounded unit and thick description of the phenomenon without gesturing toward explanation (Yin, 2018).

Within the case study design, there are multiple subgenres of research including exploratory, explanatory, single/multiple, and embedded/holistic case studies. Explanatory case studies, as the name implies, attempt to explain a phenomenon using questions which are causal in nature (Yin, 2018). As described above, I did not seek to explain the phenomenon, but rather describe it. Alternatively, exploratory case studies are used to "...develop the conceptual framework" (Yin, 2018, p. 67) which contributes to an ultimate goal. This was the explicit purpose of the current study: to create foundational bulwarks of knowledge that can be used in the goal of a legislative framework. Additionally, Yin (2018) identified that exploratory case studies are most appropriate for research questions which ask "who," "how," and "what" questions. Explanatory case studies are more suited for "how" and "why" questions. This study's research questions aligned perfectly with this description of exploratory case studies, including "who are legitimized stakeholders," "what are foundationally accepted standards," and "how are concepts operationalized." Thus, an exploratory design was most appropriate.

A multiple case study is a case study with multiple bounded units and contexts. Multiple case studies are used for work in comparing or contrasting contexts through what Yin (2018) called replication (i.e., seeking sufficiently similar or different cases). Alternatively, a single case study is used for a single bounded unit and context for study. Cases most appropriate for the single case study design are chosen based on five rationales: critical cases, rare or extreme cases, common cases, cases which are particularly revelatory, and longitudinal cases (Yin, 2018). The case of NATO member countries fell into two categories within these rationales. It was a critical case because it had the potential to provide a significant contribution to the field by refocusing future research and building upon extant space debris theory. Additionally, due to the fact that NATO member countries contribute greatly to the body of space policy and space flight, it represented a common case able to illuminate the structures of policy as they stand. Because I sought to explore a critical and common single case, the single case study was most appropriate.

Most narrow in this description of the case study design is that of the embedded versus holistic single case study. A holistic case study seeks to identify one global source of data. An embedded single case study seeks to identify multiple subunit sources of data within a bounded unit (Yin, 2018). This differs from the multiple case study in that it still uses a single bounded unit, but there are multiple subunits within that one case. By the descriptions laid out in this section, an exploratory embedded single case study was the most appropriate design for this study's research problem, purpose, and questions. The context/bounded unit was NATO, the case was space debris policy, and the embedded subunits of analysis were member countries and/or their alliances.

## Role of the Researcher

When discussing the role of the researcher, two primary concerns are prominent: interaction with data sources and interpretation of the data. Both of these have much to do with the bias of the researcher and ensuring that consumers of the research are able to either identify the bias of the researcher (via transparency and critical reflexivity) or have confidence that the research remains unbiased (to the degree possible). The role of the researcher in interacting with the data generally describes the literal role the researcher must take when discussing phenomena with participants or subjects in order to reduce reflexivity. These might include the role of student, novice, or expert (Rubin & Rubin, 2012). Given that no living sources of data were used, instead only using archival sources, this did not directly apply. Instead, the role of the researcher was focused on the researcher as an instrument for analysis.

My role as primary instrument had significant implications throughout the research process, in that my positionality with the data may have unduly influenced the findings in an unwanted manner due to social identities and personal proclivities toward meaning-making (see Ravitch & Carl, 2021). I needed to be aware of positionality with the bounded unit and potential stakeholders: I was an active member of the U.S. military and United States Citizen. As such, there was potential to more readily interpret military influence in the data, percieve the military as stakeholders in coding, and read American influence in non-American policy documents.

I attempted to mitigate this potential for bias by reflexive journaling and dialogic engagement. Reflexive journaling is the regular journaling any researcher may conduct throughout the research process. This was a way to document presuppositions regarding the data, as well as assumptions, values, or culture through a narrative format. This was seen as a way to bracket my own bias through exposed revelations (see Burkholder et al., 2020). Dialogic engagement, also known as peer debriefing, is comprised of structured engagements with strategically-selected individuals in order to ensure undue bias is not negatively affecting the interpretation of the data (Ravitch & Carl, 2021). Ultimately, any qualitative study requires the researcher to take a role as the respectful observer while recognizing how personal biases may influence interpretation; this study was no different in that regard (Rubin & Rubin, 2012).

In summary, my role in this study was to collect data from multiple sources, interrogate the data using various coding strategies, and formulate a unified policy framework. As such, one could succinctly describe my role as the primary instrument of the research. This required strategies to reduce bias and inform any research consumers of potential bias. This was done using reflexive journaling, dialogic engagement, and transparency in writing.

## Methodology

In the following section, I will discuss data selection, sampling strategy, selection criteria, instrumentation, procedures for data collection, data analysis, and relationship between saturation and sample size. Information detailed in this section generally relates to processes related to human participants in the dissertation study; however, I did not use human participants in this study. As such, the discerning reader will note that headings have deviated slightly from the prescribed in order to adjust to the present study.

### Participant Selection Logic

As an exploratory embedded single case study, the data selection process was fairly rudimentary. The bounded unit was already chosen well before the data was harvested; thus, the only data selection which needed to occur existed at the level of the embedded subunit. From here, I used multiple limiting and delimiting factors to identify appropriate data for usage.

#### *Bounded Unit Justification*

The usage of NATO member countries as a case for this case study was based on multiple factors. The enforcement power of NATO to engage international crises alongside civilian experts in various fields was the prime factor (see Zaborowski, 2017). Stakeholders that exist within the realm of space policy and space debris were extrapolated in detail in Chapter 2 (i.e., governments, national agencies, international institutions, insurance companies, research laboratories, operators with final customers, launch operators, equipment manufacturers, satellite manufacturers, and all of humanity; Remisko & Zielonka, 2018; Tam, 2015). Given this information, it was clear that NATO was a critical example of an alliance which was able to include nearly all of these stakeholders (with the exception of "all of humanity"), because of its specific engagement with national, agency, and governmental interests alongside civilian expert engagement.

Additionally, NATO does not proport to have a detailed space policy itself; however, the alliance does actively pursue space-related objectives (NATO, 2022b). NATO member countries accounted for over 93% of global space flights in 2021 (Center for Strategic & International Studies, 2022). Given NATO's overt description of using allied nation's space-faring capabilities to attend to its international objectives, it represented an exemplar for a study with an embedded design (see Sari & Nasu, 2021). Finally, given the wide range of cultures and perspectives in NATO's 30 member countries, it NATO represents a sufficiently wide diversity of thought and approach to the space debris problem. While no study, and no case study in particular, can create perfect transferability or external validity (i.e., generalizability to the wider population), thick descriptions of the data from multiple diverse sources can assuaging this concern to a degree. As such, NATO represented a critical and common case for usage in the study of space debris when using an embedded design.

***Population and Sampling within the Bounded Unit***

The population for study was NATO member countries, including their institutions and multinational alliances in which they played a significant role (provided those alliances maintain a policy standard on space debris). To identify a sample, a purposive, total population sampling strategy was used. A purposive sampling strategy is indicated as the best practice for case study research, as it allows researchers to seek rich and specific information (Burkholder et al., 2020; Yin, 2018). The total population sampling strategy is a type of purposive sampling that indicates the usage of all samples within the population, so long as those samples fit the characteristics/criteria for selection. This was feasible given the already small population and strenuous limiting/delimiting criteria (described below). The policy field of space debris was already somewhat narrowed within the bounded unit, as not all NATO member countries are concerned with space interloping or travel, and did not have a pressing need to create a space debris policy web. Using limiting and delimiting criteria, the field of useable policies available were further restricted. That is to say, the utilizable space debris policies from within the bounded unit were narrow enough that all policy documents which fit the limiting and delimiting criteria were able to be used in a total population sample.

Ravitch and Carl (2021) identified three types of archival data used for qualitative studies: personal, official, and pop culture documents (p. 152). Personal documents are created by individuals and act as a way to peer into the lives of those individuals. Pop culture documents provide societal context for a person or group via things such as magazines or films. Official documents are documents which are developed by an organization specifically for public consumption. Space debris policies would fit into the official documents category and can be further classified as naturally occurring documents—that is, documents which already exist without any interaction between the researcher and the organization or group (Ravitch & Carl, 2021). Thus, data within the bounded unit included all naturally occurring documents (i.e., policies) within the bounded unit that fit the limiting and delimiting factors. A more detailed look at procedures for dataset selection is detailed in the section Procedures for Data Collection (below) and Appendix B.

***Limiting and Delimiting Factors: Criteria for Selection***

The focus of this case study was NATO member countries that have policy explicitly crafted to mitigate or prevent space debris. With the population of NATO member countries representing the case of study, private or corporate organizations were not considered appropriate for usage. This was because the goal of the study was to provide data that could be used for public policy, and private/corporate interests may have influenced the findings toward more capitalistic interests. Outside of public, national, and institutional policies, this study also included allied partnerships under the auspices that that partnership was significantly comprised of and influenced by NATO member countries. Such partnerships included a number of multi-national and international organizations, as outlined in Appendix B.

The primary criterion for sample selection was that the potential participant's naturally occurring policy documents must be in the English language. This was because of research restrictions placed on funding, time, and interpreter's bias. If the documents of the national, institutional, multi-national, or appendant body were not readily available in English, they were considered unusable. Translations available pro forma via third party actors that were not officially and expressly endorsed by the issuing organization were likewise unusable. This was primarily due to reliability issues related to translations from outside entities due to poor translation or interjected bias.

Additionally, the participant's policy documents must have been readily available via physical or online sources that could be navigable in the English language. This was mostly for practical purposes; I did not anticipate "ready availability" would constitute a considerable concern, and indeed it did not. Thus, participant selection was considered viable if (1) the sample was from the population within the bounded unit (NATO member country, member country's space agency, or an organization or institution that is significantly comprised of, and influenced primarily by, NATO member countries), (2) had official policies related to space debris, (3) that were offered in an official capacity via online or physical methods, (4) in the English language.

***Participant Identification, Numbers, and Saturation***

To summarize the preceding statements, the bounded unit was NATO, the population was NATO member countries, and a purposive, total population sampling strategy was employed alongside rigorous criteria. The sampling criteria were: (1) must be a NATO member country, member country's institution, or a multinational organization that is significantly influenced by NATO member countries; (2) must have space debris policies; (3) policies must be offered via official channels for open access for public consumption; and (4) the policies must be offered in an official capacity in English. Appendix B provides an outline of the selection logic in detail, which assisted in the data selection process. In total, eight participants met the criteria, with 17 datasets provided within those eight participants. Datasets were pulled directly from the official channel used to propagate those policies for public consumption (i.e., official websites); this is further explained in Procedures for Data Collection (below). Numbers of participants or datasets in qualitative research are dependent on the aim of the study, phenomenon of study, and the degree of thick, rich descriptions given by each participant/dataset (Dibley et al., 2020). The end goal for number of participants is a saturation of information; that is, when new information is no longer being provided in the information gathering process (Houghton et al., 2013).

This aims of this study were to identify key information in a bounded unit, with the phenomenon of interest being legitimized stakeholders in space debris mitigation policies. Saturation was met well within the bounds of eight participants with 17 datasets, as the stakeholders within this specific topic were deeply intertwined (see Remisko and Zielonka, 2018), met the goal of analyzing diverse datasets within the bounded unit due to the variable sources listed in Appendix B, and the policies were fully formed, meaning there was significant overlap providing thick descriptions, leading to rapid saturation. Converging lines of evidence via triangulation was achieved by the inclusion of policies from organizations which were significantly comprised of, and influenced by NATO member states. That is to say, multiple sources of evidence were given by each member state via national and/or agency policy, as well as other alliances of significance. As such, for the research aims, saturation was met with the review of all data that met the limiting and delimiting factors.

**Instrumentation**

No instruments were used in this study, as the nature of the study required me, the researcher, to be the instrument of analysis. As this was an exploratory embedded single case study using only organizational naturally-occurring archival documents, there was no need for an instrument to interrogate the data. Specifically, there was no need for a case study protocol in order to formulate a structured, semi-structured, or extemporaneous question guide for an interview process. Instead, the information was already present in the form of fully-fledged policy documents, which I coded without additional input. The sources of the data were government/institutional websites; that is to say, the data were pulled directly from the participant's own website. The preservation of the presented policies as original to their ratification was assumed. I identified the websites as legitimate via the usage of the Google Safe Browsing Tool (to identify scam websites presenting as government pages) and by following the root uniform resource locator (URL) to identify that it was an official webpage.

The usage of Computer Assisted Qualitative Data Analysis Software (CAQDAS) was not considered. Qualitative designs and case studies in particular require the researcher to be close to the data and provide creative solutions to pattern creation and interpretation (Patton, 2015; Yin, 2018). CAQDAS can create distance between the data and the researcher, and may subvert the creative and analytic processes that identify thematic patterns, frame the data, and use interpretive coding methods (Patton, 2015).

This does not align with a core tenant of the case studies methodology: to provide context-rich pattern discovery with concerted conceptual scaffolding.

In the analysis of the findings, there were three models used to organize the data for consumption: a power versus interest grid, stakeholder influence model, and policy field analysis. Great detail is given in how to deploy these measures for analysis in the seminal strategic management text by Bryson (2018). The power versus interests and stakeholder influence models were developed by Bryson et al. (2002) and have been specifically used in conjunction with stakeholder theory for work in public policy and administration. Bryson (2018) showed that power versus interest grids are most effective when used in tandem with stakeholder influence diagrams. Both of these instruments greatly assisted in the production of a thorough analysis of the findings, because they related directly to the subject matter (legitimized and delegitimized stakeholders in policy works) by identifying the power and influence dynamics between those extrapolated from the datasets.

The policy field analysis tool was originally developed by Stone and Sandfort (2009) for usage in public policy related to nonprofit organizations. While public governance is notably different from the nonprofit cradle from which this tool grew, Bryson (2018) identified it as a powerful tool particularly for governmental agencies. The policy field analysis tool assisted in analyzing the findings of this study by informing the discussion on actual and potential collaborators, as well as competition and obstructions to collaboration (Bryson, 2018).

**Procedures for Data Collection**

A detailed flow chart for the sample selection process is provided in Appendix B. First, all nations which were members of NATO were identified through official NATO correspondence (i.e., their website). From here, policy archives were searched within those component countries' government websites and data collection centers, assuming they were navigable in English without the use of translation software or web applications. Outside of government websites, component organizational websites such as national space agency websites were also searched using the same methods and criteria. For multinational organizations (e.g., EU, ESA, or the UN) space debris policies were again sought through official websites. This search method proved sufficiently exhaustive.

Any policy documents that were provided as ratified by policymakers in an official capacity were collected by me personally and recorded/stored via computer in multiple locations (for redundancy purposes) as PDF documents to preserve the data at the time of finding and preserved for a minimum of 5 years. Data collection occurred in a singular event, with the date of collection recorded for each dataset. As such, the frequency of collection was only once. The problem of too few participants did not manifest during data collection, Appendix B provides a list of participants and datasets. However, I was prepared to alter the sampling criteria to broaden the search appropriately if there were too few participants (i.e., seeking official interpretations from the entities or seeking policies not readily available for public consumption). This option did not prove necessary.

## Data Analysis Plan

In qualitative designs, a researcher is primarily concerned with thematic formation via an iterative process known as coding. In this process, there are multiple methods of conducting systematic coding, largely dependent on the types of questions being asked and the methods of the study itself. For this study, there were three questions, which required an iterative, stepwise coding process. Each question was asked in a systematic manner, building on one another until the primary research question was answered. Thus, the question concerning the similarities between policies used analytic comparison coding. The question concerning operationalized definitions used descriptive coding. The primary question, which sought to describe implicit stakeholders, built upon the two previous questions and used emergent coding. This flow of coding followed the interpretive coding model, whereby a researcher uses different types of coding subsequently (comparative, descriptive, emergent) to bring the data from the purely descriptive into a theoretical coding stage (Ravitch & Carl, 2021).

### *Analytic Comparison*

Also called comparative analysis or constant comparative analysis, analytic comparison coding is very common in qualitative research (Burkholder et al., 2020, p. 253). This involves making simple thematic or theoretical comparisons across units or subunits of data while staying close to the text (Burkholder et al., 2020; Patton, 2015). The process is context-rich and sensitive, using systematic in-depth explanations of similarities and differences between units of data (Patton, 2015, p. 590). For the purpose of identifying foundationally accepted standards across space debris policies, this approach assisted in the identification of contextually similar themes and categories.

***Descriptive Coding***

Descriptive coding is a method that is mostly emic (though some of the researcher's understanding is used) and stays close to the texts being analyzed (Ravitch & Carl, 2021). Using this methodology, the researcher uses open coding methods to denote categorical structures and analyzes those categories to find the most parsimonious codes used to describe a phenomenon (Ravitch & Carl, 2021). As the name suggests, descriptive coding is used to describe data as it is written without overt attempts by the researcher to interpret the text any further, often using who, what, when, and where as guideposts (Burkholder et al., 2020). This style of coding assisted in identifying operational definitions of key words or phrases found throughout the documents, staying mostly descriptive in order to ensure the intent of a policy's authors were preserved absolutely.

***Emergent Coding***

Commonly known as inductive coding, emergent coding requires the researcher to interpret the data using a theoretical framework (Burkholder et al., 2020; Ravitch & Carl, 2021). This type of coding can use discursive strategies for identifying primacy, negation, emphasis, and repetition in a text (Burkholder et al., 2020, p. 102). Emergent coding was useful in identifying legitimized and delegitimized stakeholders in policy through the analysis of linguistic elements of the text alongside analysis of stakeholder interests enshrined or negated from the text. Using this approach, I was able to pull information from the text that directly or indirectly described stakeholders and stakeholder interests, identified which interests were left out of the texts, which interests were repetitive or matters of prime advocacy, and gaps of the same nature. The theoretical framework (stakeholder theory) informed the utilization of this process to interpret themes and create categorical notions of the data as they related to (legitimized and delegitimized) stakeholders.

## Issues of Trustworthiness

There are four primary domains of trustworthiness (validity) in qualitative research. These domains are generally referred to as credibility, transferability, dependability, and confirmability. Credibility is defined by whether another researcher can presumably reproduce the results of a study using the methods put forth (Dibley et al., 2020). Credibility can also be seen as the research method's ability to contribute to a complex and credible result in answering the research question(s) (Ravitch & Carl, 2021). Transferability refers to the ability of the researcher to generalize results to a broader population or broader phenomenon. Transferability is not necessarily sought after in qualitative designs because qualitative studies tend to seek more rich descriptive data as opposed to specific data points (Ravitch & Carl, 2021). This is especially true for case studies, which specifically seek to understand only that case or cases (Patton, 2015). Dependability is the determination of whether the results from a given study align with the body of literature already extant within a field, and also refers to the stability of that data over time (Dibley et al., 2020; Ravitch & Carl, 2021). Lastly, confirmability is a measure of whether a study's conclusions are the result of the presented data or the result of researcher bias (Ravitch & Carl, 2021). This is essentially a measure of relative objectivity in the study's results and conclusions (Ravitch & Carl, 2021)

Alternatively, Yin (2018) framed issues of validity for qualitative studies in terms of language used more often for quantitative designs. Yin (2018, pp. 42-47) stated that the four most primary concerns for validity include construct validity, internal validity, external validity, and reliability. Construct validity deals with the operational measures related to the concepts being studied. Internal validity is generally used only for studies which seek to identify a causal relationship and is not generally used for exploratory studies. External validity shows the generalizability of the data and is related to the concept of transferability described above. Lastly, reliability is the demonstrable methods of data collection and analysis, which should be repeatable with the same or similar results.

**Trustworthiness in the Present Study**

In this study, there were a number of controls in place to address the above issues. Firstly, utilizing multiple sources of data in an embedded design allowed for the case study to have convergent lines of data coinciding across a spectrum of instances (Yin, 2018). This assisted in assuaging some of my concerns regarding construct validity as well as credibility; by presenting multiple sources of evidence, constructs were integrated from multiple perspectives and meaningful inference was presented from a variety of sources (see Ravitch & Carl, 2021; Yin, 2018). Secondly, the incorporation of a theoretical framework supporting the research questions and analysis moderated concerns of external validity/transferability and confirmability (Yin, 2018). By using a theoretical framework, a basis was provided to ground interpretive results as a structure which eased relative objectivity related to researcher bias (see Ravitch & Carl, 2021; Yin, 2018).

Thirdly, thick context-rich descriptions of the data, research plan, and methods used have been provided, which aid in creating reliability, transferability/external validity, and dependability. By providing thick descriptions of the data related to the phenomenon from multiple diverse sources, the results were contextualized allowing for greater transferability/external validity (where relevant; Ravitch & Carl, 2021; Yin, 2018). Additionally, by providing transparent, context-rich descriptions of the research plan and methods used, other researchers are able to reproduce this study with similar or same results, forming reliability and dependability (Ravitch & Carl, 2021; Yin, 2018).

Finally, in this study I incorporated reflexive journaling and dialogic engagement in order to curb issues related to confirmability and construct validity. Reflexive journaling is a tool used by qualitative researchers to bring out researcher biases and weaken relative objectivity through consciousness raising efforts; as such, this method is effective to build confirmability (Ravitch & Carl, 2021). While qualitative researchers do not seek absolute objectivity insomuch as the researcher does not claim to be truly objective (i.e., the researcher is subjective to the world because they live within in and cannot be separate from it), efforts to mitigate subjectivity through reflexive journaling assisted in acknowledging and exploring potential interpretive biases (see Dibley et al., 2020; Ravitch & Carl, 2021). Dialogic engagement provided me with structured challenges to data analysis through communication with a trusted field expert. This scrutiny allowed for the analysis and mitigation of subjectivity as appropriate, while ensuring constructs were not simply the built manifestations of my own prejudices (see Ravitch & Carl, 2021; Yin, 2018).

**Ethical Considerations**

Due to the nature of this study, there were no human or living subjects requiring special consideration for research purposes. As a result, there were no issues involving personal privacy, harm due to participation, or negative effects on a vulnerable population due to misinterpretation of the data. Additionally, I declare no conflicting loyalties or conflicts of interest, as the research was funded solely by myself. Informed consent was not needed to conduct this research using naturally occurring official archival data, and no evaluation of policy effectiveness was being assessed through the scope of this research (thus leaving the component organizations at scant risk of external backlash). No incentives to participate were offered, and no vulnerable or at-risk populations were targeted for research in any way.

The ethical considerations involved in this study focused primarily on the potential effects to the policy field and the fair use of public documents. This study may have an impact on the policy field by having created useable data for future space debris policies. It was important to ensure that the research was conducted with strict controls and reviews on bias, because of the possibility of manifesting public law regarding space debris. These were essentially ethical considerations for the sake of research bystanders or constituents which may be subject to such policies. One such consideration is a shift in concentration of risk if this study is used in public policy (Vong & Levinson, 2020). If risk or the burden of responsibility is shifted in any way to broader society or creates an inequitable risk on those for whom the policy does not grant benefit, this could be considered a significant ethical consideration. For example, if policy created as a result of this study places fiscal or bureaucratic burden on scientists or citizens who intend to conduct space science, this could not only hamper those efforts, but also hamper the advancement of space science more broadly. The usage of stakeholder theory in analysis to identify who was considered a delegitimized stakeholder in existing policies was hoped to assuage this problem by creating a groundwork for a more inclusive policy framework.

The fair use of public documents was a secondary concern to the effects of policy implementation, but still notable. Pressman (2008, p. 93) identified four tenets of the fair use doctrine: the character of the usage, the nature of the work used, the amount of the work used, and the pecuniary effects of use on the author(s). In this study, the character of usage was for research and education, the works were not copyrighted and were available for public consumption, the whole policy document was used, and there were no foreseeable pecuniary effects. As a result, concerns regarding fair use and copyright were not be considered to be a significant ethical threat.

In legal terms, the definition of minimal risk for ethical consideration provided by U.S. federal regulation (45 CFR 46.102(j)) is as follows:

> *Minimal risk* means that the probability and magnitude of harm or discomfort anticipated in the research are not greater in and of themselves than those ordinarily encountered in daily life or during the performance of routine physical or psychological examinations or tests. (Office of Human Research Protections,

2018, §46.102(j))

Given the scope and nature of this study, to use archival public use documents without the usage of living or human participants, it is unlikely that ethical considerations for this study ever met or rose above "minimal risk" to any person, even by the most rigorous standards.  All data collected was stored, without efforts gesturing toward confidentiality, and will continue to be stored for a minimum of 5 years following the study.

## Summary

Chapter 3 detailed the methodology used in this study, including research design and rationale, role of the researcher, intended methodology, issues of trustworthiness, and ethical considerations.  A detailed description of hand-coding procedures was provided alongside the detailed plan to build credibility, dependability, confirmability, transferability/external validity, reliability, and construct validity.  The intended case study methodology was analyzed and was found to be within the ethical guidelines of the Walden University Internal Review Board and federal mandates.  In the following chapter, results from the study will be reported.

# Chapter 4: Results

## Introduction

The purpose of this qualitative case study was to compare the space debris policies/regulations of national and international public organizations within member countries of NATO to identify the foundational structures of an inclusive unified policy framework: legitimized stakeholders, accepted standards for space debris policy, and operationalized policy concepts. The first research question was: Who do current space debris policies within member countries of NATO define and legitimize as stakeholders? The second research question was: What are the foundationally accepted standards of space debris policy within member countries of NATO? The third research question was: How are these space debris policy concepts operationalized by member countries of NATO? In the following chapter, I will examinesample's contextual and demographical context/genre, explore how the data collection and analysis proceeded, and center discussions on emergent issues related to trustworthiness. Finally, the results of the study are presented in this chapter in Figure 3, Table 1, Table 2, Table 3, Table 4, and Figure 4.

## Setting

Upon approval by the Institutional Review Board on May 15, 2023 (Walden IRB approval no. 05-15-23-1020629), I collected all policy documents in a single instance on May 17, 2023, via official governmental, institutional, or organizational online websites, as stated in Chapter 3. The data were gathered via personal computer and then professionally printed and bound for annotation and tabulation during the coding process. Coding and analysis were conducted in a home environment over approximately 13 days.

With the knowledge that there was to be a major spaceflight event during the timeframe of the research—SpaceX and Axiom Space sent noted American astronaut Peggy Whitson and the first Saudi Arabian woman astronaut, Rayyanah Barnawi, to the orbital laboratory on May 21, 2023—I sought to minimize the potential for outside influence of the coding process. To accomplish this, I maintained media-silence to the extent possible regarding space science and technology. This was done by the temporary deletion of social media accounts and the intentional avoidance of any space-related news and current events. Additionally, I remained socially unavailable for the duration of the research and analysis period, including taking time off from work, refusing phone calls, and avoidance of other social scenarios in order to avoid discussion of current events and the research itself. The only exceptions were daily mental health and wellbeing checks with a trusted colleague via text message, and dialogic engagement.

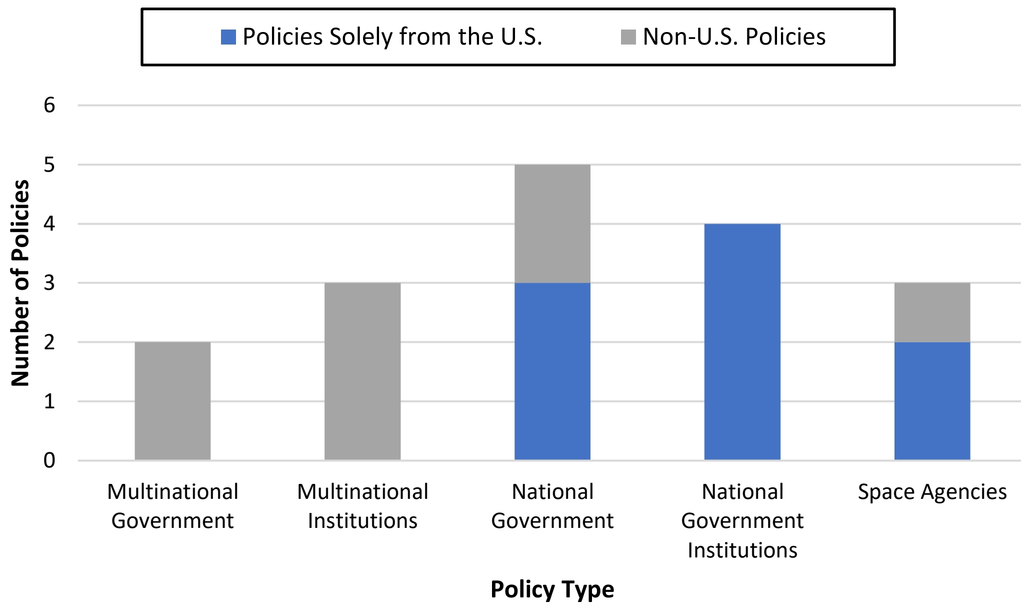
## Demographics

In sum, there were 17 policy datasets used from eight participants. As depicted in Figure 3, of the 17 policies, two were from multinational governance organizations, five were from national governments, three were from space agencies, three were from multinational institutions, and four were from component government institutions. Additionally, nine of the 17 policies were from the United States government or one of its appendant institutions or agencies. The United States significantly outpaces the rest of the world in terms of space activities by a large margin (Center for Strategic & International Studies, 2002). Therefore, this seeming imbalance was not perceived as overtly problematic. A full description of the source of each policy can be found in

Appendix B. Figure 3, below, graphically represents the datasets categorically and highlights the influence of United States policies on the total sample.

**Figure 3**

*Demographic Information of Sample Policies*




*Note*. In total, there were 17 total policies used from a variety of sources within eight participant entities. United States policies constituted a significant number of the sample policies.

## Data Collection

There were ultimately eight participants in this study which provided a total of 17 datasets in the form of fully-fledged and codified policies. I collected the data in a single instance on May 17, 2023, from official governmental/organizational/institutional online websites available to the public; the total time for data collection was approximately 4 hours (not including background research for limiting/delimiting factors). Notably, some policy documents had been updated quite recently: as early as April 2023 in the United Kingdom (UK), March 2023 in Canada, and September 2022 for the U.S. FCC. In gathering the policy documents, I took special care to ensure they were the most fully up-to-date and were provided officially from that entity. The data were gathered via personal computer and saved locally, as well as on three separate electronic storage devices and cloud-based storage on Google Drive for redundancy purposes. The datasets were then individually printed and bound for usage in the coding process. There were no anomalous circumstances or variations in the data collection plan presented in Chapter 3.

## Data Analysis

The coding process followed an interpretive coding model by using stepwise, iterative coding cycles and phases to produce discreet codes that brought the data from the purely descriptive to the theoretical coding final stages (see Ravitch & Carl, 2021). I used comparative analysis in the first phase, descriptive coding the second phase, and emergent coding in the third phase, moving from contextually stiff descriptive codes to more interpretive codes with each phase. Notably, because I sought to answer three research questions, one question was answered at every phase of coding. The first iterative phase of coding was used for the second research question identifying shared standards across policies in the sample. The second iterative phase of coding was used for the third research question identifying operationalized concepts in the sample. Lastly, the third phase of coding was used to answer the first research question regarding the legitimization of stakeholders within the sampled policies.

The code moved from conceptually very close to the text with extreme fine detail paid to ensure completeness in the first phase, slightly farther from the text using a degree of interpretation in the second phase, and finally moving in the mostly theoretical in the third phase. Each phase was iterative, meaning coding would occur in multiple cycles. Additionally, as notions, themes, and categorical structures were discovered throughout the coding process, previous phases were revisited. In this way, the coding process was meta-iterative, or containing cycles within cycles.

Before the coding process began, I conducted a basic read-through of the sample policies in order to ensure comprehension of the material in detail. This naïve reading was required in order to deeply understand the presented technical data regarding the physics of orbital mechanics, spacecraft design features, actuarial mathematics, and structures of multiple governance organizations (with research tools at-hand to clarify unknowns). I found through this initial reading that multiple policies regularly referred to the same concepts, but by extremely inconsistent verbiage. This was noted for the later coding phases. After I completed the naïve reading, I conducted the first phase alongside detailed notetaking, followed by actual coding in a cycle. In total the first phase of coding consisted of eight cycles. Due to the extreme detail required for this phase of coding alongside detailed notetaking, the second phase was considerably shorter due to familiarity with the sample, totaling only three cycles. I completed the third phase of coding in three cycles.

My tools for research consisted of multiple notebooks of annotations, color-coded highlighters, color and shape-coded folder tabs, reference keys to track codes as they formed, and in-text marginal notations. The outcomes were structured and restructured multiple times until the most parsimonious and true-to-form structures were revealed. The following is a short description of the coded categories and themes that emerged.

**Research Question Two: Shared and Accepted Standards**

Throughout the first coding cycle it became obvious that the intent of the various policies varied widely. By the third cycle, it had become clear that intent tended to be dependent on the type of issuing organization. Government policies tended to focus solely on levers of power and structural/organizational establishment, including political cooperation between nations. Some made recommendations or mandates to these ends, but the mandates tended to align with the research of Ribeiro et al. (2018), who found that the focus of present policy is ADR. Otherwise, recommendations centered on licensing and the needed documentation to apply for a license. An interesting note was that national governments (and the EU) also focused on SSA, a type of surveillance and tracking, which will be discussed at length in Chapter 5.

Multinational institutions and space agencies, however, took a much more technical approach. Without any mention of levers of power and (except for NASA) scant discussion of organizational structure, the policies focused entirely on recommendations for design and planning, specifically. Planning was further broken up into premission/launch, on-mission, passivation procedures, and end of mission disposal. Disposal was further detailed into multiple avenues for the discarding of spacecraft. The following is the thematic and categorical overview with short explanations that are described more in-depth in Table 3.

***Category 1: Levers of Power***

Levers of power were generally composed of two elements: licensing and oversight. These levers would sometimes have full state backing, including criminal indictment if the mandates of the license were not met, property seizure, or exorbitant fines. Many of these policies also provided insight into the application of waivers for non-compliance.

***Category 2: Structural/Organizational***

The structural and organization themes merged often with levers of power and oversight, as the primary goal was to establish a chain of command or accountability structure. Otherwise, a great amount of focus was placed on formal documentation of every design and plan during premission, on-mission, and end-of-mission phases.

***Category 3: Recommendations/Mandates***

Recommendations and mandates have been grouped together for this code, as they were functionally described in the same manner throughout the sample. Recommendations amounted to best practices, while mandates tended to be centered on the necessitates of documented actions required for mission approval. Regardless of this difference, they were practically conjoined in terms of actual data. The following are the subcodes within this category:

- Subcategory 1: Design: materials, construction, and schematic specifications.

- Subcategory 2: Planning: detailed strategic preparation for all phases of the mission, including "failure mode" or various spacecraft malfunction operating procedures.
    - Subcategory 2-1: Launch: planning for the phase of the mission that starts when the space vehicle is no longer touching the ground until its departure from Earth's atmosphere.
    - Subcategory 2-2: On-Mission: planning for the phase of the mission in which the spacecraft actually performs its intended function.
    - Subcategory 2-3: Passivation: not technically a mission "phase", this was a procedure described in depth in multiple documents as procedures taken after the spacecraft has performed its mission but before disposal in order to decrease the possibility of accidental explosion. This concept will be explored in detail in the section Operationalized Concepts.
    - Subcategory 2-4: End of Mission Disposal: planning for the disposition of the spacecraft after the performance of its mission has been completed.
        - Subcategory 2-4-1: Atmospheric and Direct Reentry: planning for the spacecraft to reenter Earth's atmosphere safely with minimal surviving debris and minimization of harm to the terrestrial populous and environment.
        - Subcategory 2-4-2: Retrieval: the actual retrieval of the spacecraft from space.

  - Subcategory 2-4-3: Storage/Graveyard Orbits: detailed descriptions of appropriate orbital graves. This concept will be explored in detail in the section Operationalized Concepts.

**Research Question Three: Operationalized Concepts**

Despite assertions from Percy and Landrum (2014), and Weeden (2011) it was found that space debris was extremely well defined across most of the sample, with the exception of national government policies. There were a number of repeating concepts that were either poorly defined, multiply defined, inferentially defined, or described in wide inconsistence throughout the sample. These were categorized under three themes: technical concepts, actions needed, and compliance metrics and parameters. A more detailed description can be found in Table 4.

- Theme 1: Technical Concepts: concepts which did not require action, but merely described the physical state or situatedness of a person, place, thing, or idea within the context of the document.
- Theme 2: Actions Needed: these were concepts that required action from the mission team, national entity, or operators in detail.
- Theme 3: Compliance Metrics and Parameters: these concepts tended to vary widely across the sample and dealt with specific parameters defining what was acceptable, meeting the general standards of the spacefaring community.

**Research Question One: Legitimized Stakeholders**

The final phase of coding dealt with the first and primary research question, concerning who was legitimized as a stakeholder within the sample policies. I began by using the list of stakeholders provided in the literature review by Remisko and Zielonka (2018) and Tam (2015) for initial guidance. These stakeholders were defined as: governments, national agencies, international institutions, insurance companies, research laboratories, operators with final customers, launch operators, equipment manufacturers, satellite manufacturers, and general humanity. Notably, these groups were considered stakeholders for space debris generally, not for the mitigation thereof enshrined in policy. As such, from the first two phases of coding it appeared necessary to re-structure the stakeholders more succinctly/relevantly, based on the sample policies' intent and authorship. Thus, stakeholders were consolidated in the first cycle of coding, as displayed in Table 1. During the second and third cycles of coding, the level of legitimization was noted and scaled from most legitimized to least legitimized, as found in Table 2.

**Table 1**

*Recategorized Stakeholders*

| Initial Stakeholder Codes | Consolidated Stakeholder Codes |
|---|---|
| Governments<br>International Institutions | State Powers |
| National Agencies | Space Agencies |
| Insurance Companies | Insurance Companies |
| Research Laboratories<br>Operators with Final Customers | Operators |
| Launch Operators | Launch Services |
| Equipment Manufacturers<br>Satellite Manufacturers | Manufacturers |
| Humanity in General | Public |

*Note*. Three of the stakeholders on the initial list given by Remisko and Zielonka (2018) and Tam (2015) have been merged, while three others have changed to more descriptively appropriate names.

**Table 2**

*Policy Stakeholders Ranked by Legitimization*

| Category | Stakeholder | Description |
|---|---|---|
| Legitimized | State Powers | Governing bodies and government institutions. |
| | Insurance Companies | Private corporations that provide liability insurance to spacefaring groups or individuals. |
| | Space Agencies | Empowered by the state(s) to conduct spacefaring missions with tax-payer funds. |
| | Launch Services | Private entities which can be chartered to bring people or spacecraft to space; only responsible for the flight to space and the safe return of the launch vessel. |
| | Manufacturers | Private entities that factor into design and construction of spacecraft and rockets used for operators, launch services, and space agencies. |
| Neutral | Public | Humanity generally. |
| Delegitimized | Operators | Any company, researcher, scientist, laboratory, or enterprise that seeks to use the space commons, excluding space agencies and launch services. |

*Note.* The stakeholders listed here are in rank order of most legitimized in the sample, to least legitimized in the sample. A short description of the stakeholder is provided for clarity purposes; descriptions are based on insight from contextual and/or inferential analysis of the sample.

## Evidence of Trustworthiness

In order to mitigate issues of trustworthiness, a number of controls were implemented. There were no variations from the trustworthiness controls discussed in Chapter 3, except the addition of self-isolation due to my role as the instrument of research, which will be described in the following paragraphs. Credibility was achieved by the usage of multiple, diverse sets of data/evidence from across multiple sources in an embedded design (see Yin, 2018). Due to this feature of the research design, multiple perspectives were used to make meaningful inference (see Ravitch & Carl, 2021; Yin, 2018).

Transferability was achieved through the usage of a theoretical framework, which supported the research questions and analysis process. By using a theoretical framework to ground the coding process and interpretive results, transferability was gained through the moderation of relative objectivity from the research (see Ravitch & Carl, 2021; Yin, 2018). Transferability was also supported by thick, context-rich descriptions of the data, research plan, and methods used. In these thick descriptions, diverse datasets also assisted in creating a web of results that supports transferability with deep contextualization (see Ravitch & Carl, 2021; Yin, 2018).

Dependability was achieved, again, via the usage of thick context-rich descriptions of the results, research plan, and methods used. The transparency used to describe the data in this study allow for reproducibility that would produce similar or the same results, supporting dependability (see Ravitch & Carl, 2021; Yin, 2018). The level of detail provided in the results, to include specific references to the sample, supports independent confirmation of the results to this end.

Finally, confirmability was achieved via multiple methods. Due to the fact that my role in this study was as the instrument of research, strong concerns were noted over this area of trustworthiness in particular. Isolation from discussion of the research and current events (outside of dialogic engagement) was used in order to mitigate any outside contamination or interference with the interpretation process. While no researcher can claim to be totally objective in any qualitative study, ensuring the results are not tainted by outside influence can assist greatly in pacifying biases that may arise from outside interactions about the research (Dibley et al., 2020). Secondly, the usage of the theoretical framework also assisted in quelling issues related to confirmability by grounding the research to principled analysis (Yin; 2018). Thirdly, dialogic engagement was used to curb subjectivity by providing structured challenges to the codes developed during the analysis process with a trusted field expert (see Ravitch & Carl, 2021; Yin, 2018). Finally, the usage of reflexive journaling proved to be very productive in identifying and bracketing bias throughout the research process (see Ravitch & Carl, 2021). Reflexive journal provided a medium for consciousness-raising data regarding bias, that I then bracketed by acknowledgement and exploration of how those biases may have affected the interpretive results. These combined efforts allowed for confidence that confirmability was met and any prejudices were identified and bracketed (see Ravitch & Carl, 2021; Yin, 2018).

## Results

In the following section, the results will be presented in great detail. The results are laid out in the same sequence as the coding process, as opposed to the sequence of the research questions, for the most logical readability. The reader should note some annotations within this document to assist in understanding references and technical vernacular related to space science. In the sections Shared and Accepted Standards and Operationalized Concepts, due to the sheer volume of information coded and a desire to provide the highest degree of transparency, each code has been given a reference letter as a superscript. These letters correspond to the Reference Key found in Appendix C. For example, "Redundant Systems[MQ]" means the code "Redundant Systems" was specifically referenced in the policies NPR 8715.6B and NS 8719.14C, which correspond with the letters "M" and "Q" respectively in Appendix C.

Letters were chosen for the references superscript, because there are codes related to actuarial mathematics that use numerical superscript to describe scientific notation. For those more familiar with social sciences than mathematics: in order to put these numbers into layman's terms, take the number in the superscript and add that number of zeros to the end of "1". For example, $10^{-4}$ means a probability of 1 in 10,000. Note that the number "4" is in the superscript and "10,000" has four zeros. All other formulas have been given detailed explanations directly after their usage.

### Shared and Accepted Standards

Shared and accepted standards have been laid out in a table with nested results in Table 3. This information has also been presented in Appendix D in a different format, should Table 3 prove difficult for some readers. Each of these codes has been pulled directly from the sample with little-to-no interpretation, except to apply universal language to multiply described concepts. In an effort to stay as close to the text as possible for this comparative analysis phase, the results are stiff and direct, however they represent the most parsimonious culmination of agreement between the 17 datasets in the sample with strict adherence. Please note, any standard in Table 3 with an asterisk (*) will be elucidated upon in the section Operationalized Concepts and can be defined using Table 4. Each level of code is nested and directly relates to the code to its nested parent; code levels should be read from left to right.

**Table 3**

*Shared and Accepted Standards*

| Level One Code | Level Two Code | Level Three Code | Level Four Code |
|---|---|---|---|
| Levers of Power | Establish a chain of command or accountability structure (CDEGIJLMNOQ) | Ensure responsibilities of all personnel in the chain of command have clearly outlined responsibilities (CDELM) | |
| | Fiscal accountability required via proof of insurance or financial viability for any damages(FJL) | In case of a 3rd party loss(FL)<br><br>To the amount specified by law or license(FJL) | |

| Level One Code | Level Two Code | Level Three Code | Level Four Code |
|---|---|---|---|
| | Licensing required for sanctioned activities:(FJLNOP) | For Launch(LN)<br>For Operations(FJLO)<br>*For Disposal(FNO) | Licenses may be revoked, suspended, or modified by the licensing body(FJLNO) |
| | The force of the state may be used to ensure compliance with these standards(FJNO) | | |
| | Non-compliance may lead to indictment and/or criminal proceedings(EFLNOP) | | |
| | Non-compliance may lead to seizure of property(FL) | | |
| | Non-compliance may lead to fines and penalties(FLNOP) | | |
| Structural/ Organizational | Oversight is a part of the accountability structure(CDEFM) | | |
| | Documentation is required at every phase of mission planning: | Premission (BCDEFJLMNOQ) | Space debris mitigation plan(BCDJMNQ)<br>*Risk and probability analysis(BCDJMNQ) |

| Level One Code | Level Two Code | Level Three Code | Level Four Code |
| --- | --- | --- | --- |
| | | | Measures mitigating hazards due to malfunction/failure mode(BDJMNOQ) |
| | | | Design specifications (BCDJMNOQ) |
| | | | Design testing reports(DQ) |
| | | | *Disposal plan(BCJMQ) |
| | | | Justification for disposal plan(BCDH) |
| | | | Plan to alert the authorities in case of malfunction or failure mode(DN) |
| | | | Basic contact information, launch site, and date of launch(NOQ) |
| | | | Special organizational standardized forms(BCJMQ) |
| | | | *Approvals or verification of compliance (CDJLMNOQ) |

| Level One Code | Level Two Code | Level Three Code | Level Four Code |
|---|---|---|---|
| | | On-Mission(CDFJMQ) | Justification of any non-compliant actions(CM) |
| | | | Any actions taken that were not in the premission plan(CFJMNO) |
| | | | Periodic compliance verification(DJM) |
| | | | Ephemeris (orbital trajectory and position) data(JMNOQ) |
| | | Verification of disposal(FMQ) | |
| | | Statements agreeing to abide by national and international standards(FIO) | |
| | | Waivers for non-compliance (DGJM,P[for NASA only]) | Justifications for non-compliance(DJM) |
| Recommendations and/or Mandates | Design and Planning | Ensure fuel retention is sufficient for end-of-mission disposal(CMO) | |
| | | Any parts that are released in orbit should be retained(CQ) | |

| Level One Code | Level Two Code | Level Three Code | Level Four Code |
|---|---|---|---|
| | | Limit any objects released in orbit(BCQ) | |
| | | *Design and operational plan should meet the acceptable risk standards for potential break-up(BM) | |
| | | *Design and operational plan should allow for passivation to avoid accidental explosions (ABCEHIJKMNOQ) | *Passivation plan must meet the acceptable risk standard for successful passivation(CHOQ) |
| | | Intentional destruction, including self-destruct mechanisms during operations or launch should be absolutely avoided(ABCJ) | |
| | | Limit the use of tethered systems to ensure breakage or loss of control does not occur(BEHQ) | |
| | | Use the most cost-effective methods available to meet all requirements(DEP) | |

| Level One Code | Level Two Code | Level Three Code | Level Four Code |
|---|---|---|---|
| | Design Only | Optimize break-up prevention in the design of the spacecraft(ABHJM) | Use impact testing in the design phase(ACQ) |
| | | | Use scenario testing for failure modes and malfunctions(ANQ) |
| | | | Ensure any fragments resulting from break-up remain less than 10 cm (NQ) |
| | | *Ensure design independently meets the acceptable risk standard for accidental explosions(CEHMOQ) | |
| | | Ensure the maneuverability of the spacecraft stays viable in order to avoid collisions and attain disposal objectives(ABEQ) | |
| | | Use redundant systems to avoid loss of control and maneuverability(MQ) | |

| Level One Code | Level Two Code | Level Three Code | Level Four Code |
|---|---|---|---|
| | | Avoid the usage of pyrotechnics, or ensure pyrotechnics do not create space debris larger than 10 microns(CQ) | |
| | | Use "design for demise" materials to ensure materials do not create surviving debris at launch and reentry(CHKOQ) | |
| | | *Ensure the probability of small space debris or micrometeoroid (less than 1 cm) causing loss of control due to impact meets acceptable risk standards(EHOQ) | |
| | | Ensure conversion of energy sources into energy does not generate space debris(NO) | |
| | | Employ venting measures in the design(BQ) | Leak-before-burst designs are beneficial but insufficient(BQ) |
| | | Continue seeking designs for ADR(GHILM) | |

| Level One Code | Level Two Code | Level Three Code | Level Four Code |
|---|---|---|---|
| | Planning: General | If intentional destruction becomes necessary, do so at a low enough altitude that rapid atmospheric reentry may occur[(AB)] | |
| | | Coordination between agencies and international partners is of utmost importance:[(BEGIMO)] | For avoidance of space craft and space debris during launch[(BMN)] |
| | | | For deciding on an orbital pathway[(MO)] |
| | | | For the purpose of warning about failure modes and malfunctions with the details of time and trajectory[(BM)] |
| | | *Use of Space Situational Awareness and Space Surveillance Tracking is of utmost importance:[(BGIMOQ)] | *To track and identify irresponsible behavior in the space commons[(GIMOQ)] |
| | | | *To track space debris and spacecraft[(BGIMO)] |
| | | | *To coordinate launch windows without the risk of collision[(BQ)] |

| Level One Code | Level Two Code | Level Three Code | Level Four Code |
| --- | --- | --- | --- |
| | | *All disposal plans must meet the acceptable risk standards of success(HOQ) | |
| | | *After end-of-mission, all spacecraft should meet the acceptable timeframe standard(HJQ) | *Remaining outside of the protected regions(HJQ)<br><br>*Staying in orbit no longer than the accepted timeframe standard(HJQ) |
| | Planning: Launch | *Probability of collision with other spacecraft upon launch and initial injection into orbit should meet the acceptable risk standard or remain a distance of 200 km from the nearest spacecraft(NQ) | Coordination with other agencies and international partners is key to assure avoidance of spacecraft and space debris during launch(BMN) |
| | | *Probability of collision with small debris upon launch and initial injection into orbit should meet acceptable risk standards (when space debris is known to exist)(NQ) | |

| Level One Code | Level Two Code | Level Three Code | Level Four Code |
|---|---|---|---|
| | Planning: On-Mission | Ensure maneuverability stays viable, with no loss of control, in order to avoid collisions with spacecraft and space debris(ABCHMOQ) | |
| | | *Avoid collisions with known and tracked small debris, large debris, and other spacecraft(ACHMOQ) | *Large debris and other spacecraft impacts constitute a risk of catastrophic collision(HOQ) |
| | Planning: Passivation | *To prevent accidental explosion, spacecraft should be passivated at the end-of-mission or when stored energy is not required for post-mission disposal, in order to prevent accidental explosion or break-up(ABCEIJKMNQ) | *See *Operationalized Concepts* for a full description of passivation measures. |
| | | *Passivation must occur as soon as end-of-mission phase is reached (unless stored energy is needed for disposal)(EH) | |

| Level One Code | Level Two Code | Level Three Code | Level Four Code |
|---|---|---|---|
| | Planning: Atmospheric and Direct Reentry | *Risk of human casualty from surviving objects upon reentry into Earth's atmosphere must meet acceptable risk standards (ABCDEHNOQ) | |
| | | Environmental changes due to debris must be protected against through whatever means available(ABC) | |
| | | *Impact zones should be planned for uninhabited areas, such as large swathes of ocean, if human casualty risk rises above the acceptable risk standard(BEHO) | |
| | | *Direct Reentry | *Direct reentry is the preferred method of disposal, especially controlled direct reentry(AHQ) |
| | | | Ensure the spacecraft is at a low-enough orbit before reentry that break-up does not occur(BQ) |

| Level One Code | Level Two Code | Level Three Code | Level Four Code |
|---|---|---|---|
| | | | Uncontrolled direct reentry is satisfactory with the proper safety, planning, coordination, and execution(I) (NASA requires only controlled reentries)(Q) |
| | | *Atmospheric Reentry | *Limit time in orbit before reentry to the acceptable timeframe standard(MQ) |
| | | | Come to a low-enough altitude for atmospheric reentry (i.e., de-orbit) to avoid interference with other objects in LEO(BQ) |
| | Planning: Retrieval | *Retrieval is an option for disposal(BCEHQ) | *Retrieval must occur within the acceptable timeframe standard(HQ) |
| | Planning: Storage/Graveyard Orbit | *Storage/Graveyard /Alternative orbits are acceptable options for disposal, provided they do not interfere with common orbital traffic routes(ABEHKQ) | |

| Level One Code | Level Two Code | Level Three Code | Level Four Code |
|---|---|---|---|
| | | *Protected regions must be avoided[BCJM] | *Lower-Earth Orbit[BCEHMPQ] |
| | | | *Geosynchronous Equatorial Orbit[BCKMQ] |
| | | | *Sun-Earth and Earth-Moon Lagrange points[BCMQ] |
| | | *Once in a storage/graveyard orbit, the spacecraft should not breach the protected regions for the acceptable timeframe standard[HQ] | |
| | | *While transiting protected regions, as well as during Geosynchronous Transfer Orbit (GTO), time spent in protected regions should be limited[HKQ] | |
| | | *Acceptable disposal orbits include:[EHQ] | *Heliocentric Earth-Escape[EHQ] |
| | | | *Between LEO and GEO (i.e., MEO)[EHQ] |
| | | | *Above GEO[ABEHQ] |

| Level One Code | Level Two Code | Level Three Code | Level Four Code |
|---|---|---|---|
| | | *Long-term reentry in MEO, Tundra, or highly-inclined GEO orbits must meet acceptable timeline and acceptable risk standards[(HQ)] | |

*Note.* Superscript letters indicate references in Appendix C. Each level of code is nested within the other levels of code and should be read from left to right.

* Concepts which are explained in more detail in *Operationalized Concepts*, Table 4.

From this table, a few things become noticeable. Firstly, no single policy includes all standards, and most policies appear to focus on particular categories of standards. This alludes to the research by Percy and Landrum (2014) which identified that existing space debris policies are highly fragmented (contain only part of the standards needed for mitigation) and lack horizontal integration (recommendations and mandates are scattered throughout multiple levels of governance). Some of the difficulty with the data provided is highlighted by the large proportion of U.S. policies represented in the sample. For example, there are two datasets in the sample which are solely from different departments of NASA ("MQ" in Appendix C). Where these policies are the only ones that agree, the standard listed is provided from a singular cultural/organizational perspective.

Throughout the shared standards, it is notable that when a standard was listed in the sample, its details were almost always in agreement wherever it was discussed. Referring again to Percy and Landrum (2014), the primary difficulty was finding which datasets in which the standard was actually identified. Otherwise, when a standard was discussed in multiple datasets it was nearly always in agreement in detail (although possibly using differing verbiage to describe the same concept). One notable exception was in the standard regarding direct reentry. One policy (issued by the EU) stated that uncontrolled direct reentry was an acceptable practice, so long as multiple safety protocols were observed; another policy (issued by NASA) specifically forbade uncontrolled reentry. Such disagreements were extremely rare in the sample.

In this, the second research question ("what are the foundationally accepted standards of space debris policy within member countries of NATO?") was answered in depth. The structure of the code formed the answer to the question with refined detail by implicitly describing shared standards. These standards fell into natural subcategories, mostly described by the datasets themselves. The only interpretive aspect I added during this first phase was the categorical notions of levers, structural/organization, and recommendations/mandates for clarity. In sum, the findings show shared standards are many, but their fragmented nature has disallowed them from being implemented as a unified framework. Appendix D is provided in an alternative format for consumption of the shared standards.

**Operationalized Concepts**

In the coding of operationalized concepts, I had become highly familiar with the sample policies from the previous phase of coding. During this second phase of coding, in the second cycle a full re-phase was triggered due to the addition of "operator" in the technical concepts, which I noted as needed further in-depth understanding. At this point, phase one (shared and accepted standards) was rephased for one cycle before returning to operationalized concepts. This iterative rephase assisted in fleshing out the three categories and addition of two new codes (launch services and compliance). Concepts which were well defined throughout the sample were not included in this list; instead, only the only concepts included in this list are those which were actively operationalized in the sample policies, or implicitly described without overt notion.

The results are presented in Table 4, and integrated into Appendix D in a different format for readership purposes. In places, references are again keyed using lettered superscript as in Table 3; these correspond to the Reference Key found in Appendix C. Like the comparative analysis of the last phase, this phase used descriptive coding, where I endeavored to stay close to the text, but with some interpretation assisting in the formation of concepts. As such, the reader will note that where references are not listed, the operationalized definitions were inferred from the text using more interpretive coding methods. For assistance in understanding probability calculations, refer to the Results introduction. All other formulas are explained in detail via asterisks and crosses indicating footnotes at the bottom of Table 4.

**Table 4**

*Operationalized Concepts*

| Level One Code | Level Two Code | Level Three Code | Level Four Code |
|---|---|---|---|
| Technical Concepts | Operators | Responsible for mitigation on-mission, as differentiated from launch services. This includes all actions taken during the lifetime and disposal of the spacecraft, and on-mission licensing and renewals. | |
| | Launch Services | Responsible from the time of lift-off until injection into orbit. This includes stage (rocket booster) separation, launch site, and launch licensing. | |
| | *Small Debris | Debris less than 10 cm in size | |
| | *Large Debris | Debris over 10 cm in size(HOQ) | |
| | Large Constellations | Satellites or spacecraft that function in conjunction with one-another in groups of 100 or more.(HQ) | |
| | Small Satellites | No larger than 10 cm x 10 cm x 10 cm in | |

| Level One Code | Level Two Code | Level Three Code | Level Four Code |
|---|---|---|---|
| | | size when fully deployed.(HQ) | |
| | Storage/Graveyard Orbits | Heliocentric Earth-Escape(EHQ) | Departing Earth's gravity well to a Sun-based orbital path |
| | | Middle Earth Orbit (MEO) | 2,000 km – 35,586 km in a near-circular orbit(HQ) |
| | | | 2,000 km – 19,700 km; 20,700 km - 35,300 km (avoiding 20,182 ± 300 km) in an eccentric orbit(EHQ) |
| | | Above GEO | Above 36,100 km(EHQ) |
| | | | **Use the following formula to calculate initial disposal orbit: $\Delta H > h + (1{,}000 \cdot C_R \cdot A/M)$, with eccentricity <.003 (ABEHQ) |
| | Protected Regions | Lower-Earth Orbit | Below 2,000 km altitude(BCEHMPQ) |
| | | Geosynchronous Equatorial Orbit (GEO) | 35,786 km ± 200 km, at ±15° from Latitude 0° (Earth's equator) (BCKMQ) |
| | | Lagrange Points(BCMQ) | So-called "parking spots" for spacecraft; due to gravitational force from two celestial bodies that equal the centripetal force of the object in |

| Level One Code | Level Two Code | Level Three Code | Level Four Code |
|---|---|---|---|
| | | | orbit, the spacecraft may remain in a Lagrange point with minimum fuel consumption for extended periods of time. |
| | Accidental Explosion | Chemical/hypergolic fuel reaction(ABCEHOQ) | Fuels which spontaneously ignite when mixed |
| | | Explosive decompression(BEHOQ) | When internally pressurized atmosphere/gas or fluids within a spacecraft decompresses with explosive force |
| | | Swollen/burst batteries or electrical storage units(ABOQ) | Due to high temperatures, impact, etc. |
| Actions Needed | Disposal | Atmospheric Reentry | Bring the spacecraft into a low enough altitude that it eventually succumbs to atmospheric drag and reenters Earth's atmosphere over time |
| | | Direct Reentry | The intentional, targeted reentry of Earth's atmosphere |
| | | Retrieval | (Unclear how this meaningfully differs from ADR) |

| Level One Code | Level Two Code | Level Three Code | Level Four Code |
|---|---|---|---|
| | | Storage Orbit | (See *Storage/Graveyard Orbits*, above) |
| | Space Situational Awareness/Space Surveillance Tracking(BGIMOQ) | The use of ground-based or space-based sensors to track and monitor actions, debris, and spacecraft in space. | Can be used for collision risk assessments, and cataloguing space objects. |
| | Passivation | Deplete residual propellants and pressurants (compressed fluids such as hydraulics) by venting (including tanks and lines) and/or burn-off (ABCEHOQ) | |
| | | All electrical storage devices should be depleted(ABOQ) | Completely deplete any batteries(BOQ)<br><br>Disconnect all electronic device charging lines(BQ) |
| | | Depressurize any pressurized spaces by venting(BEHOQ) | This especially applies to pressurize compartments that contain gas/atmosphere. |
| | | Secure all flywheels, momentum wheels, or gyroscopes(BQ) | Flywheels/momentum wheels/gyroscopes assist in propelling the spacecraft. |

| Level One Code | Level Two Code | Level Three Code | Level Four Code |
|---|---|---|---|
| Compliance Metrics and Parameters | Compliance | Technical Compliance | Design and Planning |
| | | Cooperative Compliance | Warning appropriate authorities in case of emergency, utilizing the accountability structures, working with partners and international agencies as appropriate |
| | | Documentary Compliance | Proper paperwork is filed in a timely manner |
| | Acceptable Timeframes | After end-of-mission, the spacecraft shall not remain in orbit for over 25 years.[HJMQ] | †Total object-time must not exceed 100 years[HJQ] |
| | | If the object is being retrieved for disposal, retrieval must be conducted in 5 years or less.[HQ] | |
| | | If spacecraft is disposed in a storage/graveyard orbit, it may not reenter the protected regions for 100 years[HQ] | If using a long-term reentry plan, the spacecraft must not reenter the protected regions for 200 years[HQ] |
| | Acceptable Risk | Probability of successful disposal | $\geq 0.9$ with a goal of $\geq 0.99$ [HOQ] |
| | | Probability of break-up | $< 10^{-3}$ [BM] |

| Level One Code | Level Two Code | Level Three Code | Level Four Code |
|---|---|---|---|
| | | Probability of accidental explosion | $< 10^{-3}$ (CEHMOQ) |
| | | Probability of small debris impacts causing a loss of control | $< 10^{-2}$ (EHOQ) |
| | | Probability of general collision with large space debris or other spacecraft | $< 10^{-3}$ (HOQ) |
| | | Probability of collision with another spacecraft during the launch phase | $< 10^{-6}$ (NQ) |
| | | Probability of collision with known space debris during the launch phase | $< 10^{-5}$ (NQ) |
| | | ‡Probability of human casualty | $< 10^{-4}$, if the surviving debris has a force of over 15 joules (11 ft-lbs) (ABCDEHNOQ) |

*Note.* Superscript letters indicate references in Appendix C. Each level of code is nested within the other levels of code and should be read from left to right.

* Debris <10 cm cannot be tracked by methods currently available (NASA OIG, 2021). It is therefore likely that the distinction between small and large debris is based on trackability.

** $\Delta H$ = height of initial disposal orbit, $h$ = height of maximum altitude of GEO, $C_R$ = Solar Radiation Pressure Coefficient (typically between 1.2-1.5), $A$ = area of the spacecraft in $m^2$, $M$ = mass of the spacecraft in kilograms.

† Object-time is the total amount of time for all spacecraft within a constellation.

‡ Human casualty risk is calculated as $E = D_A \cdot P_D$, where $E$ = expected casualties, $D_A$ = the debris casualty area, and $P_D$ = the total average population density.

Like shared and accepted standards, there was much agreement on the operationalization of the terms in Table 4, when those concepts were mentioned. However, there was much more disagreement in the sample on how to characterize the terms. An example is the accepted timeframe for atmospheric reentry: whereas nearly all of the policies that mentioned this concept identified a blanket 25 year maximum, the FCC recently changed the maximum time to 5 years before reentry. This change was made despite NASA reporting that the change would only cause a 10% reduction in debris over the next 200 years, characterizing the change as "not a statistically significant benefit" (FCC, Mitigation of Orbital Debris in the New Space Age, p. 6).

Another example of disagreement in the sample is the technical definition of "small debris". In most instructions, small debris was not defined at all, instead only choosing to mention small debris and define large debris as being larger than 10 cm. Alternatively, some policies did define small debris as being smaller than 1 cm, however this definition was often in the context of micrometeoroids producing damage that would cause loss of control. From here, the policy would go on to use modifying language such as "...debris *smaller than* [emphasis added] 1 cm" (USG Orbital Debris Mitigation Standard Practices, p. 4). During the literature review, it was uncovered that debris smaller than 10 cm is not able to be tracked by any methods currently available, lending credence to the dichotomy of large/small being centered on the 10 cm mark. Because of this, it was understood that small debris meant anything less than large debris, with emphasis added to debris smaller than 1 cm in the context of loss of control scenarios for the specific purpose of probability calculation.

Due to uncovered bias in reflexive journaling and dialogic engagement, one concept was removed from this phase: ephemeris. I originally included the term for operational definition solely because it was an uncommon word to me. This implicit bias was bracketed and the concept was removed, as ephemeris was well-defined outside the sample and did not require additional analysis. One area of uncertainty, which may represent the limits of my knowledge in this study, was the retrieval disposal method. Retrieval was mentioned as an end-of-mission disposal option in multiple datasets within sample, but it remained unclear how the retrieval of a spacecraft was meaningfully different from ADR. Again, this may reflect my own failure of knowledge or imagination and not an actual failure of description from the sample policies.

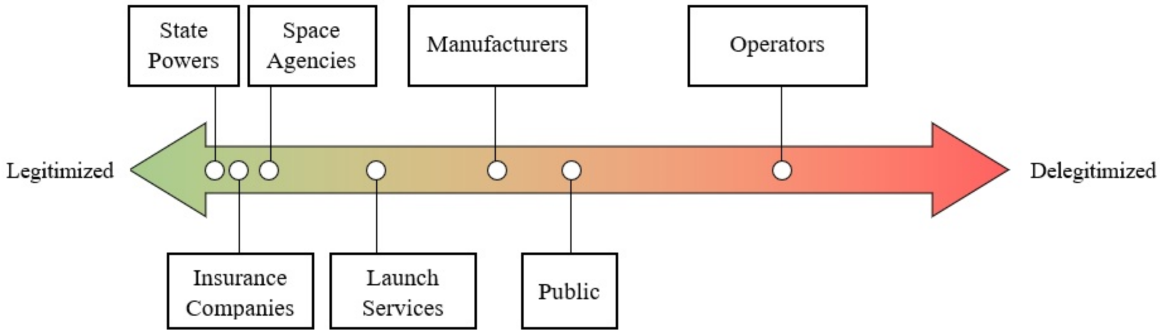
In this phase the third research question ("how are these space debris policy concepts operationalized by member countries of NATO?") was answered in depth. The descriptive coding method was effective in allowing me to elucidate concepts while staying close to the sample's text and provide for more meaningful interpretation. While some of the concepts fell into themes naturally (such as acceptable risk), I used interpretive analysis to differentiate the concepts into three overarching themes: technical concepts, actions needed, and compliance metrics and parameters. These themes were inexact, but functional for the purpose of a structured approach. In total, the findings of this phase helped identify numerous concepts that were defined using verbatim representation, background knowledge, inference, and other descriptive coding methods.

**Legitimized Stakeholders**

In Table 1, the stakeholders are presented from the initial stages of coding. In Table 2, the findings of this phase were presented with a short definition of the stakeholders that were included in this category. In this section, the results will be considered in depth to identify the logic used to support the findings. At the outset of this section, it is important to note that the legitimization of stakeholders was perceived as a continuum, not as a binary of "legitimate" and "delegitimate". This was necessary in order to ensure the research question did not create an implied requirement that delegitimized stakeholders must exist (thus leading to confirmation bias). Despite this, it was found that at least one group of stakeholders was delegitimized in the sample policies, with one group presented as "neutral" to legitimization, leaning toward delegitimized. Figure 4 represents an inexact ranking of the stakeholders on a continuum.

**Figure 4**

*Continuum of Legitimized Stakeholders*




*Note*. This figure shows an estimation as to how stakeholders fall into the continuum of legitimization within the sample.

As displayed in Figure 4, state powers and insurance companies rank very close together on the continuum, followed closely by space agencies. Farther back is launch services, manufacturers, and the public. Farther still is operators, who rest on the continuum toward delegitimized. In the following sections, these results will be explained in detail alongside contextual evidence.

***Legitimized Stakeholders***

First among the legitimized stakeholders is state powers. State powers included multinational and national governments, government institutions, and their appendant bodies, namely the EU, UK, Canada, U.S., FCC, FAA, U.S. Department of Defense (DOD), and variable figureheads within each of these entities (such as Secretaries of State). This followed what was expected from the literature review, regarding the fact that the UN space policy web exclusively empowers states to conduct operations in the space commons (UN Treaty on the Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, 1966, Article I). Adding to this established stakeholder group, most of the sample policies were directly written by the same states, even if in a multinational setting. Other evidence of legitimization of state power interests included the overt mandate to cooperate between other international state powers. The EU goes so far as to specifically mention that the United States must be cooperated with in the realm of space activities by law.

The most obvious state power interests in the sample, however, were communicated through the power of the state to levy fine, penalties, seizure of property, criminal indictment, and ultimately the force of the state (i.e., sanctioned violence) in order to procure compliance with the state's mandates. These were delegated through the scope of licensing protocols with the option for open revocation, suspension, or modification at the whim of the state or its appendant bodies. However, this is rational given that the UN Liability Convention creates an impetus for the state to answer for any damages due to space activities of itself or its citizens (UN Convention on International Liability for Damage Caused by Space Objects, 1971). In Chapter 5, arguments will be made that SSA also constitutes the interests of the state for more odious purposes from textual analysis.

Insurance companies were imbricated with the state powers as functionally synonymous. While few datasets mentioned insurance (and none specifically named "insurance companies"), in the places where insurance was mentioned, it was as a requirement to comply with state mandates for licensure. In effect, insurance companies may, without restriction in policy, impugn whatever requirements they like upon spacefaring entities in order to comply with insurance policies and therefore licensure, making them a secondary arm of the state. It is notable that insurance was not required per se, as each time insurance was mentioned the option to provide proof of cash on hand was also given. However, the amount of fiscal need was exorbitant, such that even the most successful companies may bristle. In U.S. Code Title 51, §50914.(a)(3)(A), the amount of cash on hand needed to obtain a license, if insurance is not used, is a combined total of $600,000,000, with the option for a higher amount should potential liability warrant—up to $1,500,000,000 [§50915.(a)(1)(A)]. In effect, insurance companies were deputized by the state, placing this group of stakeholders firmly in the category of the legitimized.

Space agencies were legitimized in much the same way as state powers. Space agencies are, after all, the state's practical representative to all things space related at the luxury of the tax payer. Space agencies were granted a large swathe of power to self-regulate and were referenced with regularity outside of their own policies as cooperative partners. This appears to be for a good reason; the single-most referenced dataset within the sample was the 77-page NASA Technical Standard 8719.14A. In this document were a majority of the technical standards elsewhere mentioned across the sample, with special attention given to define complex concepts. For space agencies, the severe risk of penalty was absent in cases of non-compliance. For example, NASA was the only group specifically allowed to request waivers for non-compliance in the FCC's Mitigation of Orbital Debris in the New Space Age. This dynamic will be revisited in Chapter 5.

The legitimization of launch services was not as explicit, but still very clear in the analysis of the sample. This group is comprised of private entities that can be chartered/contracted to bring people or spacecraft into space (or back from space). The responsibilities of launch services during the mission's phases start at lift-off and end upon the return of the vehicle after dropping its payload into orbit. Thus, the responsibilities of launch services are only applicable during the premission and launch phases. Policies across every category made particular mention that governments (i.e., state powers) should seek out and procure services from launch services (as differentiated from space agencies). This was usually coupled with an intent from the policy author(s) to provide reciprocal services to these private entities in order to ensure the capability of launch services to perform to mission standards. In particular, the FAA in U.S. Code Title 14, mentioned on multiple occasions that generous inspections would be conducted in order to ensure the viability of licensing for launch, with leeway given for the usage of outside inspectors (i.e., from space agencies). Unsurprisingly, the policies that mentioned launch services naturally favored high-income corporations (which is virtually all of them in the present day). The FCC's Mitigation of Orbital Debris the New Space Age even mentioned SpaceX by name as a direct contributor to the propagated policy (p. 5).

Manufacturers were defined as private entities that secure contracts with space agencies, launch services, and operators to produce materials, designs, and final products. Once the service is rendered to the contracted entity and the final product is delivered, manufacturers are essentially held harmless for follow-on actions, taking no effective blame in malfunctions that cause space debris. This was more noticed by the negation of assumed risk by manufacturers than overt statements to the same effect. This meant that manufacturers were only responsible during the premission planning phase. manufacturers were also specifically addressed by multiple policies to procure services to space agencies and private spacefaring ventures. In the U.S. National Space Policy (a Presidential Policy Directive), then-President Barak Obama writes "United States Government payloads shall be launched on vehicles manufactured in the United States" while encouraging an "...innovative and entrepreneurial commercial space sector" (p.5). Similar sentiments were echoed throughout many of the datasets, with a particular emphasis placed on manufacturers developing viable technologies and designs for ADR.

***Neutral Stakeholders***

Neutral stakeholders are here defined as those stakeholders whose interests are questionably represented. In this category is the public, or humanity in general with the exception of astronauts on mission (i.e., in space). Overall, nearly every policy mentioned the public, but these references were scarcely mentioned in comparison to other stakeholders. When referenced, there were a few comments that regarded the purpose of the space sector as to vaguely benefit the public. Most references were notions toward safety to the public, although this was often weakly, briefly, or inferentially stated at best. When mentioned, the safety aspects were almost always laid out as a human casualty acceptable risk of $10^{-4}$ (i.e., 1 in 10,000) of space debris surviving reentry with over 15 joules of force and killing or harming a person on the ground. Notably, 15 joules of force is given as enough blunt force to kill, in some cases accompanied with complex mathematics regarding the likelihood that person is lying down or standing up at any given moment. This did not inspire a strong sense that the safety of the public was a prime mover of the policies, especially considering stronger acceptable risk mandates existed for collision with another spacecraft ($10^{-6}$) and collision with known space debris ($10^{-5}$). However, public safety was mentioned and there were statements affecting the benefits to the public that could be stifled should space debris make the space commons untenable for continued operations.

Tangentially related, operators were delegitimized in policy, which will be discussed in the following section. It is notable that the primary manner in which the public benefits from space operations is through operators for services such as telecommunications, internet, banking, etc. Given the status of operators, it can be surmised that the public's safety may be considered legitimized, but the practical interests of the public may not be.

### ***Delegitimized Stakeholders***

Delegitimized stakeholders are those whose interests are specifically not represented in the datasets. Operators have been categorized thusly due to being disproportionately affected by the potential for fines and criminal actions such as seizure and indictment. It is noteworthy that many of those who fall under the operators category are not large multi-billion-dollar corporations, as in launch services. This group of stakeholders represents large and small corporations, research laboratories, scientists, and others who actively use the space commons with a spacecraft of some kind. This may include small satellites, CubeSats, or nano-satellites, which are relatively cheap to create. Because of this, it is common for operators to use launch services as "ride shares" due to limited funding and the limited space needed to put their spacecraft in orbit.

It is precisely because of this that operators are the most at-risk in case of a malfunction. The liability of space debris creation stops at premission for manufacturers and the launch phase for launch services; however operators maintain liability throughout the life of the spacecraft. The FCC's Mitigation of Orbital Debris in the New Space Age made clear that if a spacecraft malfunctioned in orbit, waivers for non-compliance would not be automatically granted if space debris was created as a result—even if the operator was not at fault and had no ability to change the fate of the spacecraft after malfunction. In effect, this puts the operator at a risk of fines over a series of decades, depending on the decay trajectory of the spacecraft, should this state power be inclined to levy such a penalty. In the same document, it was stated that waivers would be considered based on "the level of government funding, coordination, and oversight..." (pp. 11-12), but that a mission of general education and practical experience would be "unlikely to make a mission sufficiently unique to warrant a waiver" (p. 12). All the while, it was made clear that waivers would be granted for space agency missions. The FCC's policy document, written at the hand of the FCC Secretary, is typical of other policies (although possibly more pointed in tone). Few policies mention operators as anything other than entities that must follow the rules. Unlike other stakeholders, operators were not seen as potential collaborators, cooperative partners, or frankly valuable parts of the space science sector.

In addition to the potential for recourse, the licensing process for operators is just as arduous as it is for launch services, but without the supportive organizational culture of the FAA to assist in licensing. The FCC and Canadian Ministry of Innovation, Science and Industry claimed to have jurisdiction over basically all space activities because space activities require transmissions to communicate with a satellite for maneuvering and operational purposes. Given that these two state powers hold control of the telecommunications sector in their respective countries, they presume it logical that they have the right to license and mandate compliance with their policies, even if the spacecraft has little or nothing to do with telecommunications. This applies to everything in regards to design and full mission planning, not just the distribution of radio frequency bands. Operators are pitted against these state power for arduous, costly licensing processes and costly periodic licensing renewals for a single mission. In this way, operators are stakeholders that have been principally delegitimized in the sample.

**Summary**

In this section, the research questions have been answered and analyzed in great detail. Shared and accepted standards for space debris mitigation are many and tend to fall in the categories of levers of power, structural/organizational, and recommendations/mandates, with multiple subcategories. Operationalized concepts were explored in depth and fell into themes of technical concepts, actions needed, and compliance metrics and parameters. Finally, legitimized stakeholders were found to be state powers, insurance companies, space agencies, launch services, and manufacturers. Neutral stakeholders were the public and delegitimized stakeholders were operators.

In the next chapter, the results will be discussed using a power versus interest grid, stakeholder influence diagram, and policy field analysis. The outcomes will be interpreted with an eye toward extant social and governmental systems that have supported the findings. Lastly, limitations of the study, recommendations, and implications will also be discussed.

# Chapter 5: Discussion, Conclusions, and Recommendations

## Introduction

The purpose of this study was to identify the foundational structures of a unified policy framework addressing space debris mitigation and prevention. An exploratory embedded single case study methodology was used, with NATO member countries as the bounded unit, naturally-occurring policy documents as the subjects for analysis, and stakeholder theory as a theoretical framework. I hoped to recognize shared standards across the sample, discover operationalized concepts throughout the datasets, and identify legitimized stakeholders in extant policy. The reason I conducted this study was because space debris is a growing problem and mitigative policy to date has done little to quell the tide of debris being injected in the space commons.

The findings of this study included a wide range of shared standards that were categorized in terms of levers of power, structural/organizational, and recommendation/mandate standards. These were further divided into multiple subcategories, including documentation, design, and planning. In addition to these shared standards, I found a multitude of operationalized concepts which fell into themes of technical concepts, actions needed, and compliance metrics and parameters. Operationalized concepts represented how concepts within the sample were being functionally represented and used. Finally, in this study I identified implicitly legitimized stakeholders in extant policy as state powers, insurance companies, space agencies, launch services, and manufacturers. Stakeholders identified as neutral or delegitimized in policy were the public and operators, respectively.

# Interpretation of the Findings

In this chapter, I will interpret the findings through the scope of analysis. In Chapter 2, I split the working environment of space debris policy into the broader environment and operating environment (see Buchholz & Rosenthal, 2004; Freeman, 2004; Freeman et al., 2010). Here, the split halves will be brought together into the working environment in order to make sense of the findings in detail. In this section I will discuss how the findings confirmed and disconfirmed the data presented in the Literature Review. The findings will then be extended in discussion based on a power versus interest grid, stakeholder influence modeling, and a policy field analysis to assist in directing policy moving toward an achievable goal.

## Confirmation or Affirmation

The findings confirmed or affirmed the information presented in the literature review in a number of ways. Most obvious among them was the legitimization of state powers. As discussed the literature review, the basis of the space sector was founded on ideological competition at the beginning of the Space Race, and most space activities around this time were centered on alternatives to military conflict, or an extension of military conflict (i.e., the development of rockets and other technology). The legitimization of state powers as the supreme arbiter of the space commons could very well be a vestige of this period of initial growth. Additionally, the space treaties of the UN were discussed as having only legitimized the supremacy of the state in all affairs related to space. This was reflected in the legitimization of state powers, even though state powers are the prime drivers of space debris (Anz-Meador, 2019; Browne, 2021;

Hall, 2014; NASA Office of the Inspector General, 2021). It was also reflected in the shared standards of cooperation among international partners, namely state powers or their actors, the space agencies.

The levers of power found in shared standards within the sample also reflect the legitimization of state powers. Licensing and permits are represented in international space policy as in Article VI of the UN OST. In a similar vein, the UN's Liability Convention holds states accountable for actions conducted in space, making the deputization of insurance companies seem like a logical option to ensure the state is not held accountable for third-party damages.

Specific shared standards also affirmed much of the information uncovered in the literature review. Many of the shared standards used fine detail to describe the evacuation of high-traffic routes, addressing the problem described in the literature review of clutter in primary orbital pathways. Additionally, the most attention paid in the shared standards was related to fragmentation (i.e., accidental explosion, break-up, disposal, and passivation). This affirmed the data suggesting fragmentation has been the leading cause of space debris (Anz-Meador, 2019). The operationalized concept of SSA and shared mandate of providing a design or spacecraft with options toward maneuverability addressed stated concerns about collisions in space, both with other spacecraft and with large debris (Dawson, 2018).

Submillimeter impacts from extremely small pieces of debris were stated to cause continued erosion to the spacecraft and the potential for catastrophic loss (NASA Office of the Inspector General, 2021). This concern was affirmed in the findings through the scope of design features and acceptable risk measures that would prevent a loss of control in case of such impacts. The findings of Tam (2015), that satellite manufacturers would be concerned with space debris for the express purpose of meeting requirements defined in regulatory policy, was also confirmed in the delegitimization of manufacturers. Finally, the risk of surviving debris reentering Earth's atmosphere with the potential for death or bodily harm was likewise affirmed in the operationalized concept of acceptable risk, as well as a multitude of shared standards related to design and planning atmospheric/direct reentry.

**Disconfirmation or Negation**

The findings of this study disconfirm some of the data presented in the literature review. Most of what could be considered disconfirmation, might be better considered as negation. It was found that space debris was robustly defined in the datasets, which disconfirmed the findings of Percy and Landrum (2014) and Weeden (2011) regarding this topic (possibly due to the age of those studies). One of the major concerns discussed in the literature review was the potential for ADR methods to double as actual weapons in space (Miller, 2021; Weeden, 2011). This information was negated in the sample, not only by a failure to mention the possibility, but by also continually calling for ADR development. The possibility for space debris itself to be used as a weapon went likewise unmentioned except for the forbidding of intentional destruction of spacecraft (Dawson, 2018). In the literature review, the disposal method given by NASA (2019) of intentional destruction by essentially crashing a spacecraft into another celestial body, such as NASA did with Lunar Orbiter 1, was not mentioned in any sample policy. Finally, environmental impacts were mentioned in the shared standards, however these mentions were rare in comparison to some other shared standards. The concerns raised by Ross and Jones (2022) regarding atmospheric contamination due to reentering debris or spacecraft was never mentioned.

**Extension**

In the findings, I saw that the extant literature was insufficient in describing the stakeholders of space debris, at least where present policy is concerned. The stakeholder list provided by Remisko and Zielonka (2018) and Tam (2015) were consolidated with minor nominal changes to better reflect how space debris policies defined the stakeholders (as described in Table 1). In addition, the information provided through the findings could, themselves, represent a fully utilizable space debris mitigation unified policy framework. While I sought to discover the foundational aspects of such a framework, the transparent detail provided has significant impact for policymakers. This will be discussed more in depth in the Implications section below.

In the course of analysis, I made some noted observations not directly related to the findings of the study. SSA and space surveillance tracking (SSA/SST) is a common method of tracking debris over 10 cm and spacecraft currently in orbit through the use of land-based and space-based sensors. It was odd, then, that the National Space Policy of the United States placed a great amount of concern on the Director of National Intelligence and Secretary of Defense being significant stakeholders in SSA/SST to "...support national and homeland security" (National Space Policy of the United States, p.13). The Director of National Intelligence was specifically called upon to "integrate all source intelligence of foreign space capabilities and intentions with space surveillance information to produce enhanced intelligence products that support SSA" (National Space Policy of the United States, p.14). This seemed to imply that SSA/SST is being used as a euphemism, but for the purposes of forming a more expansive operationalized definition, the data were lacking.

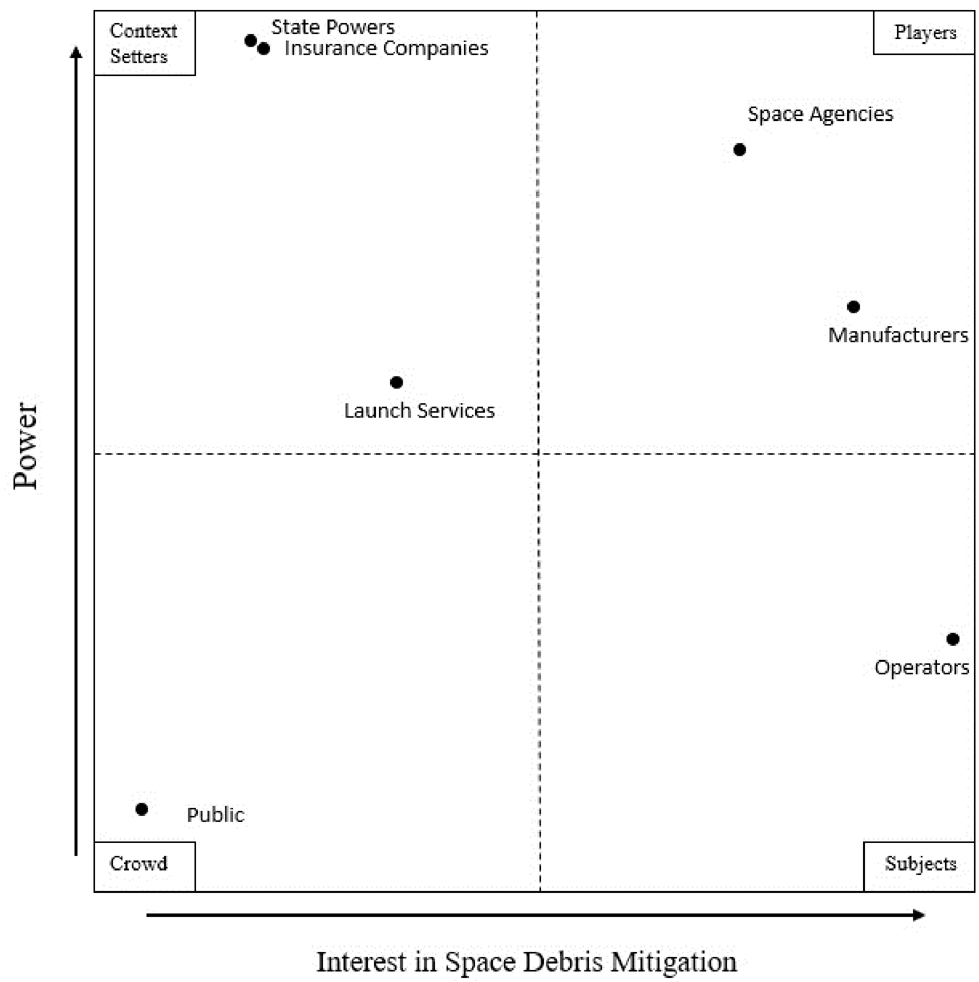
It was also noted that the FCC's Mitigation of Orbital Debris in the New Space Age was markedly different in tone than most other datasets in the sample. The front matter of the policy went to painstaking lengths to delegitimize criticisms from NASA regarding the policy. Given that the FCC's role in government is to dictate radio frequency and telecommunications usage, it seemed out of place for the FCC to provide mandates on spacecraft design and planning not related to telecommunications. Out of general curiosity, I was able to identify that there were other significant objections from members of Congress regarding the FCC's role as operating outside of its jurisdiction and causing a further dis-integrated policy web (specifically related to the policy in the sample). The secretary of the organization wrote off these concerns stating "Of course, the Commission's authority to adopt these rules for commercial satellites has been well established for more than 20 years", then cited the FCC's own policy to support this claim (Rosenworcel, 2022, p. 2). Despite the FCC secretary's assertion that the FCC is a part of the solution, it would seem there is significant dissent. It is notable that the FCC is funded at least in part by regulatory fees (FCC, 2021), supporting the conclusion that the FCC is highly biased in the creation of self-preferential policies that uphold structures of systematic de-democratization.

### *Power Versus Interest Grid*

In order to extend the discussion of the findings, I created a power versus interest grid using evidence from the literature review and the study's results. The product is presented in Figure 5, below. Note that each quadrant contains a characteristic label: players (high power, high interest), context setters (high power, low interest), subjects (low power, high interest), and crowd (low power, low interest). Those who hold high power and high interest are called players because they can effectively play the field and have great interest in doing so. The players are here defined as space agencies and manufacturers. Those with high power and low interest are called context setters because, though they lack the interest to control the field, the power they wield contributes to the contextual environment (Bryson, 2018). Context setters are state powers, insurance companies, and launch services. Those with high interest and low power are called subjects because they have a need to participate within the field, but lack the power of impact; they are subjected to the whims of players and context setters (Bryson, 2018). The subjects are operators, and the crowd (everyone else) consists of the public. Please note that the interest axis of Figure 5 is specifically “Interest in Space Debris Mitigation.” It is notable in Figure 5 that, except for manufacturers and launch services being reversed, the level of power corresponds to the ranking of legitimization in the sample.

**Figure 5**

*Power versus Interest Grid*




State powers were placed at the highest tier of power with low-moderate interest in space debris mitigation. This is because the legitimization of state powers was robust throughout the datasets as the ultimate authority to dictate mandates. However, state powers do not have an apparent interest in space debris mitigation, except to ensure against liability in case of third-party damage. To this end, insurance companies are similarly situated. The datasets provide strong legitimization of insurance companies, effectively deputized by the state as described in the results section. Insurance companies have a slightly higher interest in space debris mitigation because of the potential costs that would arise should damages occur. However, this is not a great interest, as the likelihood of third-party damages is low with the extant mandates and recommendations put into place across the policy field, and rare history of such occurrences.

Space agencies are placed as having high power due to their enmeshment with state powers. Interest is likewise ranked highly, as the space agencies vie for orbital lanes of traffic available to conduct space activities. However, interest in space debris mitigation is not ranked higher due to practicality: a loss of a spacecraft due to space debris impact will not cause the space agency to go bankrupt, for example. The tax-payer is the de facto customer, regardless of the amount of support proffered. Additionally, space agencies are not beholden to many of the licensing mandates required for space activities, or their associated penalties for noncompliance.

Manufacturers are ranked as mid-high in power due to the sway they have over the market of available design for spacecraft. However, manufacturers rely on securing contracts with numerous other entities to gain funding; thus, their interest in procuring designs which mitigate space debris are high. While manufacturers are private entities, there is relative surety that other stakeholders will be required to contract with them in order to fabricate and plan spacecraft and launch vehicles, leaving them in the mid-high power tier with high interest in space debris mitigation.

Launch services are rated with mid-power, due to a relative few owning a near-monopoly on actual space travel and transportation. Their interests in space debris are much lower due to the fact that buy-in to private launch services is literally mandated by law. In other words, space debris created by them is a concern, but only during the time of launch and with potentially limited consequences for future business. The primary debris concern of launch services is break-up before departing Earth's atmosphere, which can be better defined as launch debris rather than space debris. Space debris policies do have some bearing on launch services, however the design and planning of launch services missions do not tend to change significantly over time, only in the premission phases of identifying viable routes to orbit.

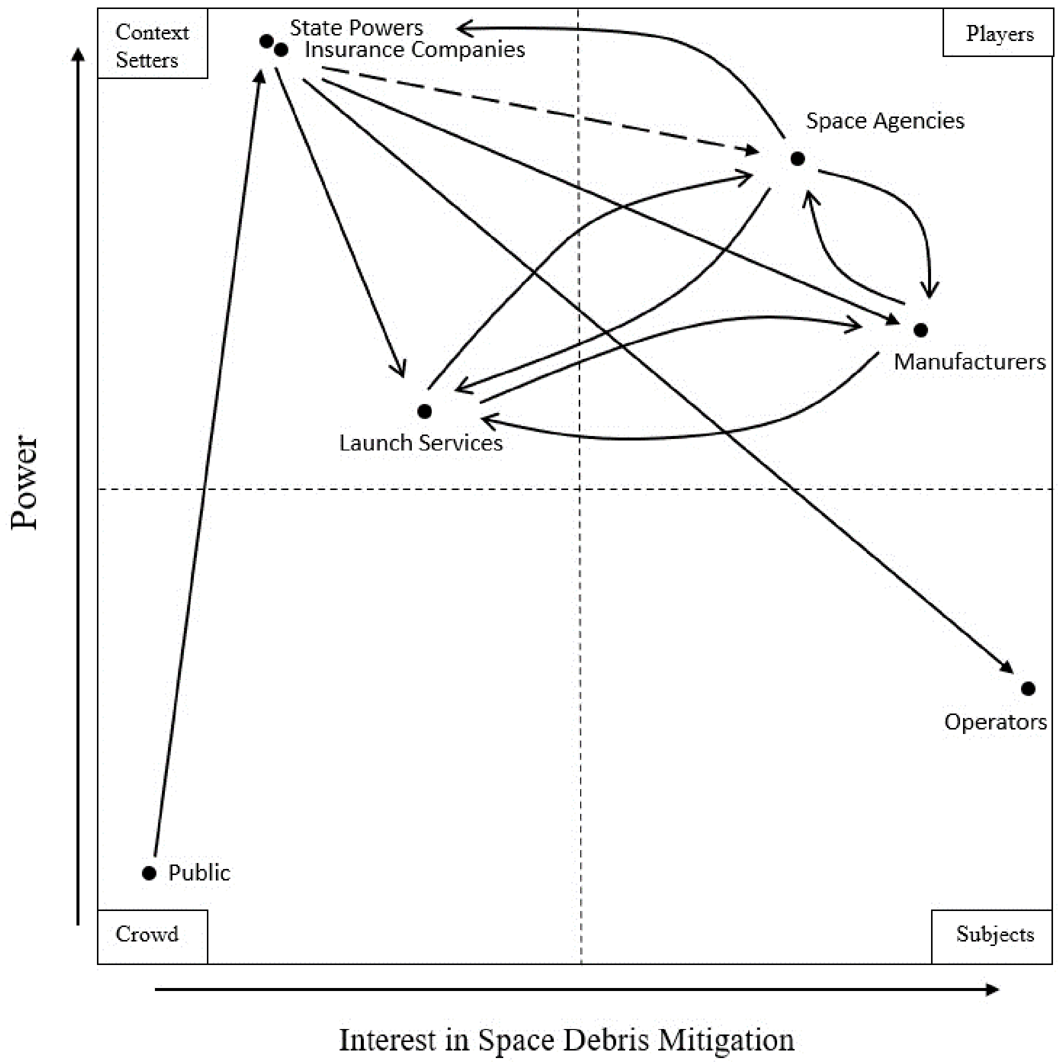
Operators are ranked as high in interest to mitigate space debris due to the penalties of non-compliance and safety of the spacecraft. Again, this aligns with research conducted by Tam (2015) showing the primary reason for a high interest in space debris mitigation for satellite manufacturers was to follow requirements in regulatory policy. Unlike space agencies, operators may have significant fiduciary consequences should space debris be generated by or impact the spacecraft while in orbit. Operators have relatively little power in this context, as described by the findings in Results. Finally, the public is listed as having low interest and low power in this grid. While the public has high interest in the services rendered by operators, interest in space debris remains low. Similarly, no single member of the public has significant power in this arena.

***Stakeholder Influence Diagram***

The stakeholder influence diagram presented in Figure 6 and Figure 7 displays the influence of various stakeholders on other stakeholders within the diagram. Influence is represented using an arrow, meaning one stakeholder directly influences another stakeholder, with the point of the arrow displaying the direction of influence. This diagram allows for a clearer depiction of how policies and structures of legitimization have been organized.

**Figure 6**

*Stakeholder Influence Diagram*




*Note*. Arrows depict influence and direction of influence. The dotted arrow indicates insurance companies do not assert significant influence on space agencies.

There is a significant amount of influence being directed at the higher echelons of power. This is reflected in the manner in which stakeholders are legitimized in policy.

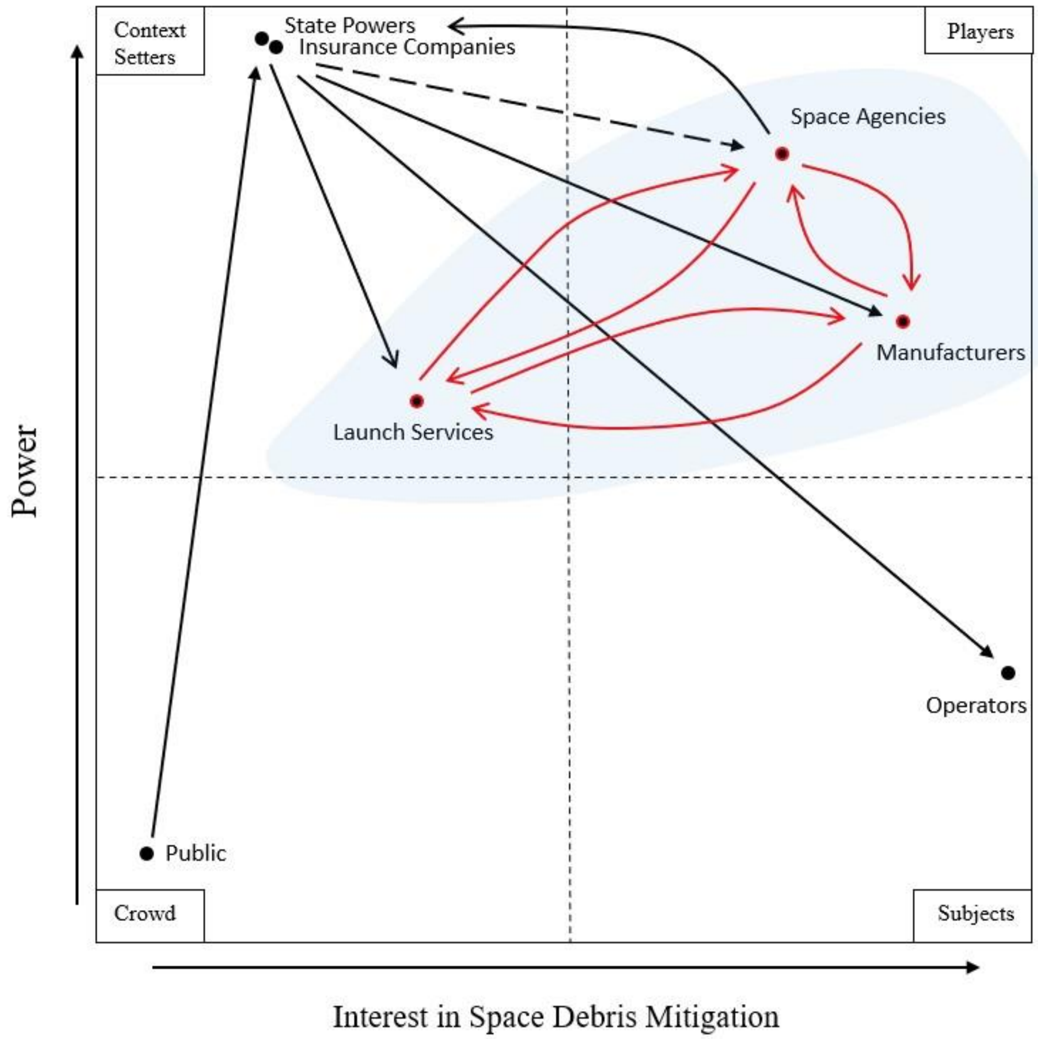
As many of the policies are issued by state powers and space agencies, naturally the legitimized stakeholders within those policies tend to be direct influencers. This does not indicate a causal direction however, as the legitimization may be due to power, or the power may be due to legitimization. The same is likely for influence; whereas legitimization in policy appears to be highly correlated to influence, causation could be bi-directional or monodirectional as with many intertwined systems. In Figure 6, it is notable that state powers and insurance companies work in tandem to assert influence over all stakeholders, except space agencies. Space agencies are influence by state powers, but not directly by insurance companies (hence the dotted arrow indicating a partial influence).

When analyzing Figure 6, it becomes remarkably clear that state power is granted prime legitimacy. Despite not having significant interest in space debris mitigation, state powers influence all aspects of the space sector. The only entities that have the overt ability to influence state powers are the public and space agencies. However, by comparison these influences are weak; the public influences state powers through democratic levers which normally have little or nothing to do with actual space activity, and space agencies are more likely to influence specific missions that are established by state powers. The weak influence of the public over the state powers align with their status as neutral stakeholders. Yet, operators do not hold influence on any other stakeholders in this diagram, which assists in understanding their delegitimized status in the policy sample. Whereas other stakeholders may have their interests represented in policy to some degree through influences with one-another, operators are not influencers, but rather the influenced. It could be argued that the public influences operators, but (as with most forms of technology) it is more likely the services rendered to the public will create interest, not the other way around. There is also an argument that manufacturers may be influenced by operators as they vie for contracts. However, operators are many; the larger corporations are more likely to be able to provide their own manufacturers and the smaller operators are more likely to be at the whim of services provided by manufacturers.

Figure 7 (below) highlights an interesting power/influence dynamic within this diagram. A power, interest, and influence triad has emerged that shows how space agencies, launch services, and manufacturers hold sway over one-another in a cyclical fashion. State powers mandate that space agencies seek launch services for transportation to space, and the same launch services must compete to gain contracts with the space agencies. Due to this dynamic, launch services influence space agencies and vice versa. The same scenario plays out between space agencies and manufacturers; space agencies are required to have their spacecraft furnished by manufacturers and manufacturers rely on the steady tax-payer funding provided by space agencies. Finally, manufacturers must also compete for contracts with launch services to produce spacefaring vehicles, while launch services must work with manufacturers to produce technology that allows for more economical and technologically advanced products. This highly intertwined triad, along with the connection between space agencies and state powers may be partially responsible for the implicit legitimization of manufacturers and launch services in the sample's datasets.

**Figure 7**

*Power, Interest, and Influence Triad Highlighted*




*Note.* This figure highlights the intertwined nature of influence between three legitimized stakeholders: space agencies, manufacturers, and launch services.

## Putting it Together: A Policy Field Analysis

Having already identified the elements, structures, stakeholders, and relationships within the policy field, this policy field analysis is a simple construction of a hypothetical scenario of a best-case future. Having established in the literature review that space debris will be inevitable as long as humans have technogenic objects in the space commons, a significant reduction is the best possible outcome. In terms of space debris mitigation policy, the best result would be a policy framework that addresses the problem, includes multiple party amenability, does not stifle innovation, reduces the effects of natural monopolies, and applies incentives effectively.

With the data provided in the working environment via the literature review and results of this study, multi-party amenability appears to be attainable. Shared standards exist, and commonality between operationalized definitions exist with only minor discrepancies in verbiage. This type of multi-party amenability addresses multiple cultures and interests, at least within NATO member countries. Multi-party amenability among stakeholders also appears possible: to ensure the public and operators are more included into policy provisions, little effort would be needed. Policymakers might start by implementing language that openly identifies operators as partners in the provision of services to the constituency. Additionally, language that clarifies the public good as the prime mover of activities in the space commons would be beneficial, in conjunction with adjusting human casualty risks in such a way that prove human casualty prevention is the highest importance.

Regarding the stifling of innovation as discussed in the literature review, there are options that exist to ensure entrepreneurships and start-ups are not snuffed-out by policies which have high fees or insurance costs. Policymakers could create a caveat for financial waivers applied to missions which advance the public good, defined in a multitude of ways. For example, a nano-satellite that is used for educational purposes may not pose a great threat if it is stipulated to stay in a near atmospheric drag suborbit with all the same robust controls in the application for licensure, and could be greatly beneficial to the next generation of college students budding in the field. The same could be said of generating interest in space science among high school, middle school, or elementary aged children. Making fiscal allowances for these types of meaningful endeavors with continued oversight and planning from the state could be markedly beneficial to society as a whole and the space sector in particular.

Natural monopolies are a harder issue to tackle. As discussed in the literature review, space science is a natural monopoly due to high fixed start-up costs which drop dramatically upon establishment (Wells, 2016). Licensing that volunteers funding for potential third-party damage risks may be warranted in order to ensure fair competition within the space sector and could have the added benefit of driving down costs for contracted work with space agencies through a more diverse marketplace. This could be achieved by taking on proposals from potential start-ups and reallocating (or reappropriating) funds such as licensing fees toward those start-ups. For a more conservative approach, the reallocated funds could be used to cover the costs of insurance, thereby appeasing a major stakeholder. This would be, in essence, a Robin Hood scheme that would only create additional funds in the long run. For example, licensing fees from an established launch service are used to cover the insurance costs for a start-up which was chosen based on a promising proposal. Once that new start-up has established itself in the industry, its costs to provide services significantly drop, thereby allowing it to starting paying its own licensing fees.  Now there are two companies paying licensing fees.  Ideally this would work on a timescale that continues until the fixed cost barriers to market entry are reduced through sufficient competition and technological advancement.

Finally, an idealized scenario would ensure a balance of incentives; that to say exorbitant fines may actually increase the likelihood of non-compliant behavior (Barrett et al., 2018).  While the force of the state may remain in place for actions such as seizure of property or inspections, it may be feasible to reward good behavior as well.  Good behavior may be simply identified as a willingness to cooperate with other operators, launch services, manufacturers, space agencies, and state powers to produce meaningfully beneficial products that benefit the public and, critically, a cleaner space commons (i.e., ADR).  This might be achieved operationally by an agreement to openly share technology or designs.  This could lead to a merit-type system that gives preference for government contracts, or reduces liabilities for a company based on good behavior. These "good citizen" policies could be implemented with little effort.

In sum, utilizing a unified framework of space debris mitigation policies that already exist in this study could accomplish the ideal future for space debris mitigation with few inexpensive changes that have the potential for the generation of significant public value.  These suggestions alone would create stronger stakeholder legitimization in the policy framework, create opportunities for public and private involvement in the space commons, build competition in the space sector that would drive down costs associated with space science, generate revenue for the state in the long run, and create a more cooperative network of actors in the space sector.

**Final Analysis**

The theoretical framework was used liberally throughout this study to formulate the research questions, identify the methodology, conduct the coding process, and analyze the findings. Here, I will extend this analysis through three pillars within stakeholder theory: social performance, the iron law of responsibility, and public value (Buchholz & Rosenthal, 2004; Freeman et al., 2010).

Social performance is essentially stakeholder engagement. Engagement with stakeholders in the operating and broader environments is necessary in order to create public value (Freeman et al., 2010). That is to say, if the policies to not perform to serve the stakeholder, then the policies do not hold value for the audience for which they are intended. The findings of this study produce mixed results to this end. Many of the policies are self-referential, legitimizing the entity that authors the policy. National governments and international governments (of which national governments are voting members—not the public) tend to produce policies that legitimize state powers as the supreme authority. Space agencies and governmental institutions, by comparison, do similarly by reenforcing the structures that uphold the legitimacy of that agency's existence. In total, however, the policies do a poor job of social performance for the public good by neutralizing the public interest in services rendered by operators and reducing human casualty risk to a probability point. It should be stated that the probability risk standards for human casualty are quite strong; however, the appearance can seem otherwise given stronger probability risk standards for incidents such as collisions. Somewhat ironically, only one policy in the sample mandated a probability of zero for human casualty: the U.S. DOD, the only group in the sample with the state-backed authority to kill.

The iron law of responsibility asserts that any entity which is granted power by the public (i.e., stakeholders) will inevitably lose that power if it is not used in a way that is socially responsible. This theoretical construct is met throughout the policy documents in the sample. It is clear that each of the policies analyzed (except, perhaps, for the FCC's self-aggrandizement) had the best intent for the space commons and the future of space activities, albeit communicated in ways that were most natural to that entity. NASA produced a 77-page technical specification policy on space debris mitigation, then-President Barak Obama formed a policy lauding cooperative engagement, and the UK issued law that outlined the levers of power used by the state to ensure a cleaner space commons. In other words: NASA focused on technicality, the UK government focused on government actions, and the diplomatic head of the U.S. focused on diplomacy. These are all actions which manifest naturally within the organizations who authored their respective documents with the common intent of mitigating space debris.

Lastly, public value is likely the most important aspect of any public organization, and can only be attained through the scope of social performance and the iron law of responsibility (Buchholz & Rosenthal, 2004; Freeman et al., 2010). The question of whether or not these policies create public value is dependent on the stakeholder concerned. I would argue, based on the evidence provided, that most do create public value, even if the public and operators are left out of the list of legitimized stakeholders. The policies themselves, while not overly effective to-date, are expressions of constituent interest (including individuals who work in the space sector). While the policies can and should do better to decrease regulatory fragmentation, increase horizontal integration, and increase stakeholder inclusion, the policies within the dataset are reaching for a goal that is laudable on the whole and within the public interest, thereby creating public value.

## Limitations of the Study

There were some limitations to this study that were bracketed via various means. Transferability was limited by the nature of the methodology, as case studies do not tend to be transferable or generalizable to a wider population. In this case, however the issue was moderated by the usage of total population sampling in an embedded design, which allowed for extensive diverse perspectives to contribute to the results. However, samples were not viable if the dataset was not offered in English in an official capacity. This limited the findings to what is essentially solely Anglophone cultures (with the weak exception of Canada). Except in the samples of international institutions and organizations, no non-Anglophone cultural participants were used as a stand-alone dataset without such influences. Additionally, the bounded unit was NATO, to the dereliction of non-Western countries. Again, this was partially moderated by the inclusion of international institutions and organizations, but no non-Western country perspective was used as a stand-alone dataset.

Another issue related to transferability was that some of the shared standard findings found in multiple datasets were referenced in datasets provided by the same organization. For example, there were some shared standards that were only supported by two policies, both issued by NASA. In this example, the transferability of those shared standards to a wider cultural perspective is limited. As such, the consumer of this study should apply caution in generalizing the results, especially to groups outside of the Western Anglophone cultural sphere.

Confirmability was an area of particular concern, due to the fact that my role as researcher was also as the instrument of research. This created a higher chance of researcher bias influencing the results. Multiple actions were taken to mitigate bias, including the usage of a theoretical framework to ground the analysis, isolation in analysis, reflexive journaling, and dialogic engagement. Four researcher biases were noted and bracketed in the implementation of these controls. The first was that I had an unconscious assumption that governments would likely delegitimize corporations such as SpaceX due to the controversial nature of their figureheads; this was bracketed and the results proved to be in opposition to the bias. Additionally, researcher bias was found against any legitimization of operations in space by military entities due to assumptions about the militarization of the space commons; this was also bracketed and the results proved to be in relative opposition to the bias. Thirdly, I noted a tendency to code operationalized concepts due to the novelty of the concept to myself; this was bracketed and I reviewed operationalized concepts through dialogic engagement with a trusted field expert to identify essential concepts only. Finally, one bias that was not bracketed due to the nature of the bias is limits of knowledge. While I attempted to gain a full understanding of the concepts in the sample, it is unknown if there were any missing pieces.  This is evident in the shared disposal standard "retrieval" where I am unaware if the standard is meaningfully different from ADR.

In my judgement, the results were assessed as credible: large, diverse and convergent lines of data were provided, custom and established coding strategies were used, and thick, rich, transparent findings were communicated with fine detail. Combined, this assisted in results that can be reproduced and independently verified. Dependability was also assessed as sufficiently met due to the relative stability of the data acquired, strategies employed to preserve the data, and detailed descriptions of the research methods and processes were communicated with fine detail.  The data were in alignment with the corpus of literature extant within the field, and is inherently stable over time.

## Recommendations

Future studies that may address stakeholder legitimization are recommended, especially where space debris mitigation is concerned.  The focus of this study was NATO member countries and lacked in broad applicability outside Anglophone culture, however future studies could focus on non-NATO countries and/or NATO opponents on the world stage, such as BRICS (Brazil, Russia, India, China, South Africa).  Leaders in space science that were not mentioned in this study, such as Russia, China, Japan, and India, are highly recommended for future study.  Due to the potential for researcher bias in a study that uses the researcher as the instrument of research, independent replication studies are also recommended.  Another limitation of this study, is that stakeholders were marked discreetly, or in a singular category.  A future study that seeks to understand the power dynamics and relationships of combined stakeholders (such as launch services which also act as operators and/or manufacturers) could strengthen this body of knowledge.

The strengths of this study include robust data regarding shared standards and operationalized concepts in fine detail.  This may be furthered by studies identifying the effectiveness of fines and penalties, as they are currently enacted, to stem the production of space debris; this would prove to be a productive and fertile area of research. Additionally, further examination of transparency in space debris generation would be a warranted area of investigation.  Finally, it is my assessment that, though arduous, the hand-coding process enriched the findings a great deal.  Future replication studies using CAQDAS may assist in supporting or disconfirming the findings of this study.

## Implications

The implications for significance and positive social change provided by this study are numerous.  I set out to conduct a study to identify key foundational components of a unified policy framework.  However, due to the high fidelity across shared standards and concepts, despite being fragmentary, and due to the high diversity of the sample across different levels of intent, culture, and types of entities, the information described in the results (and more succinctly in Appendix D) may well constitute the best practices for future policy planning.  Additionally, the analysis in the discussion and interpretation provided in this chapter could provide policymakers with tools and ideas for engaging a more inclusive and stakeholder-center policy web.  The impact of these two potentialities is expansive across multiple levels.

At the national level, the social change implications include the development of cross-sector policies with few obstacles to implementation. This study is by its very nature a praxis toward stakeholder inclusivity by recognizing stakeholders, identifying their interests in policy across multiple sectors, and legitimization through repeated attempts to legitimize their needs. By underwriting a dialogue of inclusion and stakeholder engagement, this study contributes to social change by way of consciousness-raising efforts. The utilization of any part of this study by policymakers can assist individuals, corporations, space agencies, and international working groups within the space sector by creating a policy web more equipped to handle the growing space debris problem, and thereby creating a more sustainable environment.

The empirical implications are interwoven with the selfsame concept. This study contributes to the field by creating a unified policy that addresses space debris through serendipity. Other implications include the furtherance of stakeholder theory as a model utilizable in practical research for policy design. Finally, practical recommendations for practice in the field of public policy and administration, and space policy in particular, are described in this study through the methods described for stakeholder engagement across sectors.

## Conclusion

It is vitally important that humanity continues in its endeavors to produce fecund scientific, engineering, and exploration endeavors in the space commons. This must mean the stewardship of the space commons around our own planet, and maybe one day around other celestial bodies as well. It seems humanity's growth is endless when applied in a measured and coordinated fashion. While not yet an interplanetary species, in the modern era humanity cannot truly be said to be a mono-planetary species due to the reliance we have on space-based proxies. As we look to the stars in excitement for the next stages of human capacity, a new opportunity arises to start this approaching age of development with an ethic of sustainability that will take us much farther than our present dreams have ever considered.

> We are star stuff which has taken its destiny into its own hands.
>
> —Carl Sagan, *Cosmos*

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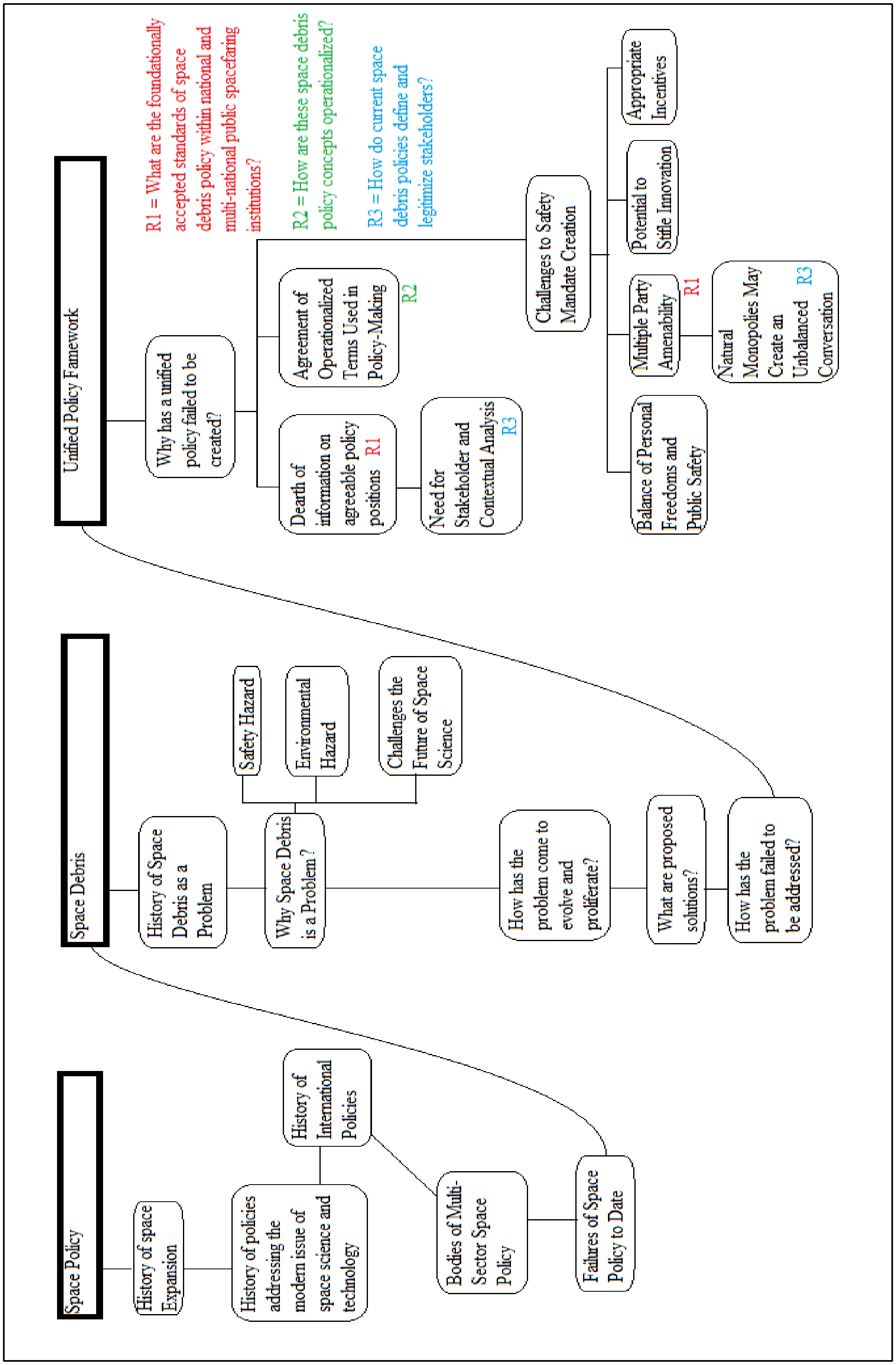
# Appendix A: Literature Review Search Sequence



## Appendix B: Sample Selection Guide

Step 1: Identify a full listing of all NATO member countries.

Step 2: Identify international organizations that maintain orbital debris mitigation and prevention policies.

Step 3: Pare this list down to international organizations comprised of, or significantly influenced by, NATO member countries.

| International Entities → | |
|---|---|
| International Organizations with Orbital Debris Policies | Comprised of, or significantly influenced by, NATO member countries |
| UNCOPUOS | UNCOPUOS |
| EU | EU |
| ESA | ESA |
| IADC | IADC |
| International Organization for Standardization | European Code of Conduct for Space Debris Mitigation |
| International Telecommunications Union | |
| European Code of Conduct for Space Debris Mitigation | |

Step 4: Set this list aside as samples from an international policy level.

Step 5: Identify all NATO member countries that have national space policies.

Step 6: Ascertain which policies are original to that country and which policies are adoptions of international policies as listed in Steps 2 and 3.

Step 7: Pare down the list of remaining policies to those who have official and approved English versions available. Set this list aside as samples from a national policy level.

| National Entities | | | |
|---|---|---|---|
| NATO Member Countries | Having Space Policies | That have not been directly adopted from International Policies | With approved translations in English |
| Albania | Canada | Canada | United Kingdom |
| Belgium | Denmark | Denmark | Canada |
| Bulgaria | Finland | Finland | United States |
| Canada | France | France | |
| Croatia | Germany | Germany | *Finnish policy provided in English, but only legally-binding in Finnish and Swedish |
| Czech Republic | Greece | Greece | |
| Denmark | Italy | United Kingdom | |
| Estonia | Netherlands | United States | |
| Finland | United Kingdom | | |
| France | United States | | |
| Germany | | | |
| Greece | | | |
| Hungary | | | |
| Iceland | | | |
| Italy | | | |
| Latvia | | | |
| Lithuania | | | |
| Luxembourg | | | |
| Montenegro | | | |
| Netherlands | | | |
| North Macedonia | | | |
| Norway | | | |
| Poland | | | |
| Portugal | | | |
| Romania | | | |
| Slovakia | | | |
| Spain | | | |
| Turkey | | | |
| United Kingdom | | | |
| United States | | | |

Step 8: Identify all space debris policies within each sample's policy web and list them according to that entity. In countries that delegate powers, list the delegated institution and concordant policies.

<table>
<tr><td colspan="3">Total Policy Sample Set</td></tr>
<tr><td colspan="3">→</td></tr>
<tr><th>Policymaking Entity</th><th colspan="2">Policies, Treaties, or Agreements</th></tr>
<tr><td>UNCOPUOS</td><td colspan="2">Space Debris Mitigation Guidelines</td></tr>
<tr><td>EU</td><td colspan="2">REGULATION (EU) 2021/696 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 28 April 2021 establishing the Union Space Programme and the European Union Agency for the Space Programme and repealing Regulations (EU) No 912/2010, (EU) No 1285/2013 and (EU) No 377/2014 and Decision No 541/2014/EU</td></tr>
<tr><td>ESA</td><td colspan="2">ESA/ADMIN/IPOL(2014)2: Space Debris Mitigation Policy for Agency Projects</td></tr>
<tr><td>IADC</td><td colspan="2">IADC Space Debris Mitigation Guidelines</td></tr>
<tr><td>European Code of Conduct for Space Debris Mitigation</td><td colspan="2">European Code of Conduct for Space Debris Mitigation</td></tr>
<tr><td>United Kingdom</td><td colspan="2">Outer Space Act of 1986</td></tr>
<tr><td rowspan="2">Canada</td><td colspan="2">Canadian Client Procedures Circular (CPC) 2-6-02 Procedure for the submission of Applications for Spectrum Licenses for Space Stations</td></tr>
<tr><td colspan="2">ITU-R S.1003-2 (Ratified as part of CPC-2-6-02, above)</td></tr>
<tr><td rowspan="11">United States</td><td colspan="2">Title 51 U.S. Code</td></tr>
<tr><td colspan="2">U.S. National Space Policy, Presidential Policy Directive</td></tr>
<tr><td colspan="2">USG Orbital Debris Mitigation Standard Practices, 2019</td></tr>
<tr><td rowspan="2">NASA</td><td>NASA Procedural Requirements for Limiting Orbital Debris, NPR 8715.6B, 2007; Revised 2017</td></tr>
<tr><td>NASA Process for Limiting Orbital Debris, NS 8719.14A, 2007; Revised 2021</td></tr>
<tr><td>FAA</td><td>FAA Regulation, Title 14, CFR</td></tr>
<tr><td rowspan="2">FCC</td><td>FCC Regulations, Title 47, CFR</td></tr>
<tr><td>Mitigation of Orbital Debris in the New Space Age, 2022</td></tr>
<tr><td>DOD</td><td>DOD Instruction 3100.12 (Space Support)</td></tr>
</table>

# Appendix C: Reference Key

| Key | Policy Sample Referenced |
|---|---|
| A | UNCOPUOS Space Debris Mitigation Guidelines |
| B | IADC Space Debris Mitigation Guidelines |
| C | European Code of Conduct for Space Debris Mitigation |
| D | ESA/ADMIN/IPOL(2014)2: Space Debris Mitigation Policy for Agency Projects |
| E | Department of Defense Instruction 3100.12 (Space Support) |
| F | U.K. Outer Space Act of 1986 |
| G | U.S. National Space Policy, Presidential Policy Directive |
| H | U.S. Government Orbital Debris Mitigation Standard Practices, 2019 |
| I | Regulation (EU) 2021/696 of the European Parliament and of the Council of 28 April 2021 establishing the Union Space Programme and the European Union Agency for the Space Programme and repealing Regulation (EU) No 912/2010, (EU) No 1285/2013 and (EU) No 377/2014 and Decision No 541/2014/EU |
| J | Canadian Client Procedures Circular (CPC) 2-6-02 Procedure for the submission of Applications for Spectrum Licenses for Space Stations |
| K | ITU-R S.1003-2 (Ratified as a part of CPC-2-6-02) |
| L | Title 51 U.S. Code |
| M | NASA Procedural Requirements for Limiting Orbital Debris, NPR 8715.6B, 2007; Revised 2017 |
| N | FAA Regulation, Title 14, CFR |
| O | FCC Regulations, Title 47, CFR |
| P | Mitigation of Orbital Debris in the New Space Age, 2022 |
| Q | NASA Process for Limiting Orbital Debris, NS 8719.14A, 2007; Revised 2021 |

# Appendix D: Shared Standards and Operationalized Concepts

1. Levers of Power.

    (a) Establish a chain of command or accountability structure.

        (1) Ensure responsibilities of all personnel in the chain of command have clearly outlined responsibilities.

    (b) Fiscal accountability is required via proof of insurance or financial viability for any damages.

        (1) In case of 3rd party loss.

        (2) To the amount specified by law or license.

    (c) Licensing required for sanctioned activities.

        (1) For launch.

        (2) For operations.

        (3) For disposal.

        (4) Licenses may be revoked, suspended, or modified by the licensing body.

    (d) The force of the state may be used to ensure compliance with these standards.

    (e) Non-compliance may lead to indictment and/or criminal proceedings.

    (f) Non-compliance may lead to seizure of property.

    (g) Non-compliance may lead to fines and penalties.

2. Structural/Organizational.

    (a) Oversight shall be a part of the accountability structure.

    (b) Documentation is required at every phase of mission planning and execution.

        (1) Premission.

            (A) Space debris mitigation plan.

(B) Risk and probability analysis (including break-up, population affected, and geographical areas).

(C) Measures mitigating hazards due to malfunction/failure mode.

(D) Design specifications.

(1) Testing reports for design specifications.

(E) Disposal plan.

(1) Justification for disposal design.

(F) Plan to alert authorities in case of malfunction/failure mode.

(G) Basic contact information, launch site, and date.

(H) Special organizational standardized forms.

(I) Approvals or verification of compliance.

(2) Throughout the on-mission phase.

(A) Justification for non-compliant actions taken.

(B) Any actions taken that were not in the premission plan.

(C) Periodic compliance verification.

(D) Ephemeris (orbital trajectory and position) data.

(1) Especially around Mars, the Moon, and Lagrange points.

(3) Verification of disposal.

(4) Statements agreeing to national and international standards.

(5) Waivers for non-compliance, if applicable.

(A) Justification of waivered non-compliance.

3. Recommendations/Mandates.

(a) Design and Planning

(1) Ensure fuel retention is sufficient for end-of-mission disposal.

(2) Any parts that are released in orbit should be retained.

(3) Limit any objects released in orbit.

(4) Design and operational plan should make the probability of break-up less than $10^{-3}$.

(5) Design and operational plan should allow for passivation to avoid accidental explosions.

(A) Probability of successful passivation should be 0.9 or greater with a goal of 0.99 or greater.

(6) Intentional destruction, including self-destruct mechanisms during operations or launch, should be absolutely avoided.

(7) Limit the use of tethered system to ensure breakage or loss of control does not occur.

(8) Use the most cost-effective methods available to meet all requirements.

(b) Design Only.

(1) Optimize break-up prevention in the design of the spacecraft.

(A) Use impact testing in the design phase.

(B) Use scenario testing for failure modes and malfunctions.

(C) Ensure any fragments resulting from break-up remain less than 10 cm.

(2) Ensure design independently meets the acceptable risk probability of accidental explosion of less than $10^{-3}$.

(3) Ensure maneuverability of the spacecraft stays viable in order to avoid collisions and disposal objectives.

(4) Use redundant systems to avoid loss of control and maneuverability.

(5) Avoid the usage of pyrotechnics, or ensure pyrotechnics do not create space

debris no larger than 10 microns.

(6) Use "design for demise" materials to ensure materials do not create surviving debris at launch and reentry.

(7) Ensure the probability of small space debris or micrometeoroid (<1 cm) impact has a probability of less than $10^{-2}$ of causing loss of control or maneuverability.

(8) Ensure conversion of energy sources into energy does not generate space debris.

(9) Employ venting measures in the design; "leak-before-burst" designs are beneficial but not sufficient.

(10) Continue seeking designs for ADR.

(c) Planning: General.

(1) If intentional destruction becomes necessary, do so at a low enough altitude that rapid atmospheric reentry may occur.

(2) Coordination between agencies and international partners is of utmost importance.

(A) For avoidance of spacecraft and space debris during launch.

(B) For deciding on an orbital path.

(C) For the purpose of warning about failure mode and malfunctions with the details of time and trajectory.

(3) Use of space situational awareness is of utmost importance.

(A) To track and identify irresponsible behavior in the space commons.

(B) To track space debris and spacecraft.

(C) To coordinate launch windows without the risk of collision.

(4) All disposal plans must have a success probability of 0.9 or greater with a goal of 0.99 or greater.

(5) After end of mission, no spacecraft should remain in a protected region for

over 25 years before disposal (or less, depending on disposal method) with a total object-time of 100 years or less.

(6) Large constellations are defined as groups of functional satellites in numbers of 100 or more.

(7) Small satellites are defined as equal to or smaller than 10 cm x 10 cm x 10 cm when fully deployed.

(d) Planning: Launch.

(1) Probability of collision with other spacecraft upon launch and initial injection into orbit should be less than $10^{-6}$ or remain a distance of 200 km from the nearest spacecraft.

(A) Coordination with other agencies and international partners is key to assure avoidance of spacecraft and space debris on launch.

(2) Probability of collision with small debris upon launch and initial injection into orbit should be less than $10^{-5}$ when space debris is known to exist.

(e) Planning: On-Mission.

(1) Ensure maneuverability stays viable, with no loss of control, to avoid collisions with spacecraft and space debris.

(2) Avoid collisions with known and tracked small space debris, large space debris, and spacecraft.

(A) Large space debris and spacecraft are 10 cm or greater and pose the threat of catastrophic collision.

(B) Probability of collision with large space debris and spacecraft should be less than $10^{-3}$.

(f) Planning: Passivation.

(1) To prevent accidental explosion, spacecraft should be passivated at the end-of-mission or when stored energy is not required for post-mission disposal, in order to prevent accidental explosion or break-up.

(A) Deplete residual propellants and pressurants by venting (including tanks and lines) and/or burn-off residual propellant.

(B) All electrical storage devices should be depleted.

(1) Completely deplete batteries.

(2) Disconnect all charging lines.

(C) Depressurize any pressurized compartments, tanks, or lines.

(1) Leak before burst designs are beneficial but not sufficient.

(D) Secure all flywheels, momentum wheels, or gyroscopes.

(2) Passivation must occur as soon as end-of-mission phase is reached (unless stored energy is needed for disposal).

(g) Planning: Atmospheric and Direct Reentry.

(1) Risk of human casualty form surviving objects with an impact of greater than (or equal to) 15 joules must be less than $10^{-4}$.

(2) Environmental changes due to debris must be protected against through whatever means available.

(3) Impact zones should be planned for uninhabited areas, such as large swathes of ocean, if human casualty risk rises above $10^{-4}$.

(4) Direct Reentry Only.

(A) This is the preferred method of disposal, especially controlled direct reentry.

(B) Ensure the spacecraft is at a low-enough orbit that break-up does not occur.

(C) Uncontrolled direct reentry is satisfactory with proper safety, planning, execution, and coordination (NASA requires only controlled reentries).

(5) Atmospheric Reentry Only.

(A) Limit time in orbit before reentry to no more than 25 years.

(B) Come to a low-enough altitude for atmospheric reentry (i.e., deorbit) to avoid interference with other objects in LEO.

(h) Planning: Retrieval.

(1) Retrieval is an option for disposal in LEO.

(A) Retrieval must occur within 5 years of end-of-mission.

(i) Planning: Storage/Graveyard Orbit.

(1) Storage/Graveyard/Alternative orbits are acceptable options for disposal, provided they do not interfere with common orbital traffic routes or protected regions.

(A) Protected regions must be avoided, to include:

(1) LEO.

(a) LEO is altitudes up to 2,000 km.

(b) Maximum time in LEO after end-of-mission is 25 years.

(2) GEO.

(a) GEO is 35,786 ± 200 km, ±15° from Latitude 0°.

(b) Maximum time in GEO after end-of-mission is 25 years.

(3) Sun-Earth and Earth-Moon Lagrange Points.

(B) Once in a storage/graveyard orbit, the spacecraft should not breach the protected regions for at least 100 years.

(C) While transiting protected regions, as well as during Geosynchronous Transfer Orbit (GTO), time spent in protected regions should be limited.

(2) Acceptable disposal orbits include:

(A) Heliocentric Earth-escape.

(B) Between LEO and GEO (i.e., MEO):

(1) 2,000 km to 35,586 km altitude in a near-circular orbit.

(2) 2,000 km to 19,700 km; 20,700 km to 35,300 km (avoiding 20,182 ± 300 km) in an eccentric orbit.

(C) Above GEO.

(1) Perigee greater than 36,100 km.

(2) Calculate initial disposal orbit as follows (at minimum):

$$\Delta H > (GEO + 235 \text{ km}) + (1{,}000 \times C_R \times A/M)$$

with eccentricity of less than 0.003 (1,2,5,8,17)

(a) $C_R$ = Solar Radiation Pressure Coefficient, typically between 1.2-1.5

(b) A = Areas of spacecraft in $m^2$

(c) M = Mass of spacecraft in kg

(D) Long-Term Reentry in MEO, Tundra, or highly-inclined GEO orbits.

(1) Total post-mission lifetime must be less than 200 years.

(2) Probability of collision with large space debris or another spacecraft must remain below $10^{-3}$.